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for a better
future /**

Genesis Minerals

**Gwalia TSF3 & TSF4
Groundwater
Management Plan**

wsp

May 2024

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Gwalia TSF3 & TSF4 Groundwater Management Plan Subtitle

Genesis Minerals

WSP

Lvl 3, Mia Yellagonga Tower 2, 5 Spring St

Perth WA 6000

PO Box 7181

Cloisters Square WA 6850

Tel: +61 8 9489 9700

Fax: +61 8 9489 9777

wsp.com

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Prepared by:		23 May 2024	
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WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Appendix A Groundwater level assessment

1 Introduction

WSP Pty Ltd (WSP) was contracted by Genesis Minerals (Leonora) Ltd (Genesis) to assist with the development of a Groundwater Management Plan for Gwalia tailings storage facilities, namely, TSF3 and TSF4. WSP has been involved with the on-going design of embankment raises at TSF3 and TSF4 and has previously provided advice related to the management of potential seepage from TSF4, including input on the construction of the TSF4 toe drain.

1.1 Background

Genesis had an amendment to prescribed premises licence L8337/2009/2 (The Licence) issued on 21 December 2023 which included authorisation for use of the Stage 2 embankment raise at TSF4 (RL 373.5 m) and final lift for TSF3 (RL 392.5 m). Potential issues have previously been noted relating to seepage with historic operations of the TSFs. As a result, DWER has introduced conditions in The Licence related to the management of this:

3.4.3 The licence holder must engage the services of a person qualified in the area of hydrogeology to develop a Groundwater Management Plan to manage groundwater mounding impacts around TSF3 and TSF4.

3.4.4 The Groundwater Management Plan required by condition 3.4.3 must, as a minimum include:

(a) An assessment of the existing groundwater monitoring bore network and whether it is adequate to monitor groundwater mounding and seepage impacts within the zone of influence of TSF3 and TSF4.

(b) If the monitoring bore network is found to be inadequate, propose additional groundwater monitoring locations and bore designs (i.e., bore depths, screen interval) with relevant justification.

(c) A suitable monitoring program that includes bore specific triggers for standing water levels for existing and new (if required) bores.

(d) Management actions to reduce groundwater mounding if those triggers are breached.

3.4.5 The licence holder must submit to the CEO the Groundwater Management Plan required by condition 3.4.3 no later than 31 March 2024. This deadline was extended, following discussions with the regulator to allow an appropriate assessment to be undertaken.

Genesis requested WSP provide a Groundwater Management Plan to address the above requirements. The plan needs to take into consideration the extra water in TSF3 requirements as indicated in email correspondence titled: *Request for quote – Groundwater Management Plan – Gwalia TSF3 and TSF4* dated: 29 November 2023.

1.2 Scope

The Groundwater Management Plan is required to address the following:

- Adequacy of existing groundwater monitoring locations within the zone of influence of TSF3 and TSF4
- Additional monitoring bore locations
- Assess and assign appropriate trigger levels
- Recommend potential management/remediation measures.

Numerical groundwater/seepage modelling to inform bore locations, numbers, design, and/or trench depths, and lengths is not included in the current scope.

1.3 TSF3 and TSF4 History

The TSF3 and TSF4 layout is shown in Figure 1.1 and a summary of the TSF3 and TSF 4 history is provided in Table 1.1.



Figure 1.1 Overview of the Gwalia Gold Mine TSF3 and TSF4 (image from Google Earth, 2023)

Table 1.1 Gwalia TSF3 and TSF4 history

Date/Year	TSF Development
1890s - 1965	Mining operations commenced at the Gwalia gold mine following discovery of gold during the 1890s. In the years prior to 1965, tailings from the treatment of ore were pumped as a conventional tailings slurry and deposited directly onto the natural ground surface without provisions for perimeter containment or return water operations (Soil and Rock Engineering Pty. Ltd., 1994).
1965 - 1994	Several TSFs have been previously referenced throughout the record of operations. However, specific design and construction details, as well as operational and monitoring conditions are often not documented.
1965 - 1994	Following 1965 and before 1994, the Sons of Gwalia Tailings Dam No. 1 was constructed (exact date of construction is not known).
1965 - 1994	Following 1965 and before 1994, the Grand/Grant's Patch TSF (also referred to as the GP TSF) was constructed. The exact date, and sequence of construction and operations, thereafter, is not known. The TSF was understood to have been operated as a multi-celled facility (Tailings Dam No. 1 and No. 2).
1986	Tailings that were previously deposited onto the natural ground surface (i.e., pre-1965) were excavated as part of a re-processing operation for the recovery of gold.
1988 - 1994	A third TSF (Tailings Dam No. 3) was constructed as part of the expansion of the GP TSF (not to be confused with the current TSF3 in operation).
1994	WAA was submitted by Soil and Rock Engineering Pty for the construction of a new TSF (TSF3), north of the existing Grant's Patch TSF. Based on interpretation of historic aerial and satellite imagery prior to construction of TSF3, it is apparent that the southern footprint of the TSF extends onto the basin of the legacy, Grant's Patch facility. The TSF3 starter embankment was constructed using mine waste rock to a crest elevation of RL 375 m, with subsequent capacity achieved via upstream raising of the facility.
-	Following introduction of TSF3, the Grant's Patch TSF was subsequently de-commissioned and rehabilitated (date of de-commissioning and rehabilitation works is not known).
1994 - 2003	Tailings deposition commenced at TSF3 in 1994 and continued until the facility was placed under care and maintenance in 2003.
2003 - 2008	TSF3 placed in care and maintenance for a period of 5-years.
2008	Tailings deposition resumed following re-commissioning of TSF3 in 2008 following a 5-year period in care and maintenance.
-	Following closure and rehabilitation of the Grant's Patch TSF, re-mining of the tailings beach for the application of paste backfill of underground mining voids. Upon review of historic satellite imagery, it can be inferred that the east cell of the Grant's Patch TSF was re-mined to near-foundation level.
2020	Construction of a new TSF (TSF4) commenced, utilising the previously de-commissioned and rehabilitated Grant's Patch TSF as the foundation for TSF4, re-activating the Grant's Patch TSF in the process. TSF4 combined the existing two-celled configuration of the Grant's Patch TSF into a single-cell facility and utilises the southern embankment of TSF3 to achieve containment (Stage 1). As with TSF3, TSF4 is raised via the upstream embankment raise construction method.
2020	Deposition was re-routed, following construction of the Stage 1 raise at TSF4 (formally the southern section of the Grant/Grand Patch TSF).

Date/Year	TSF Development
2020	TSF4 Stage 1 deposition commenced in 2020 following extensive remining of the Grant's Patch tailings beach. Tailings deposition backfilled these excavation voids (some extending to the natural ground level).
2020 - 2024	Following commencement of operations, observations of seepage were noted along the downstream toe of the TSF4 south embankment. Seepage can still be observed at the toe (following a ~ 1-year fallow period at TSF4). In 2022, the TSF4 toe drain was modified to intercept this surface seepage.
2020 – 2022	Deposition was on-going at TSF4 (Stage 1) from October 2020 to May 2022 (with reference to the 2021 and 2022 audit reports).
2022	Deposition at TSF4 was on-going until 18 May 2022 before being re-routed to TSF3 (West Cell).
2022	Deposition commenced at TSF3 (West Cell) on 18 May 2022 and was on-going until 29 March 2024.
2022	Following completion of a geophysical investigation to identify preferential drainage zones around the toe of TSF4 in 2021 (Golder 2021), a smaller scale seepage collection trench was modified around the south and western embankment of TSF4 Golder.
2022	TSF4 trench or toes drain construction activities started on 21 March 2022 and were completed on 2 May 2022. The intent of the toe drain is to intercept potential seepage from TSF4, control and contain it and return any potential seepage water back to the TSFs.
2024	Discharge to TSF4 re-commenced 29 March 2024.

2 Conceptual hydrogeology

2.1 Data reviewed

The data/documents reviewed as part of this assessment are summarised in Table 2.1.

Table 2.1 Data/documents reviewed

Data/Documents	Format	Date	Comments
Department of Water and Environmental Regulation (2023). L8337 – Gwalia Mine – Amendment Amalgamation and Transfer Licence DRFT V2.pdf. Licence number L8337/2009/2. Genesis Minerals (Leonora) Pty Ltd. 7/02/2014 to 8/2/2029	.PDF	2023	DWER licence amendments as per Section 1.1.
Golder (Sep 2020) St Barbara Limited. Groundwater Monitoring Bores and VWP Installation Report (report ref.: 20138708-001-R-Rev0)	.PDF	Sep. 2020	TSF4 Monitoring bore/VWP installation report.
Golder (18 Sep 2020) Review of Seepage along the Southern Flank of TSF4 (report ref.: 20447647-001-L-Rev0.	.PDF	Sep. 2020	TSF4 Southern embankment seepage review.
Golder (7 May 2021) 2021 Gwalia TSF 4 Geophysical Survey. (PowerPoint summary)	.PPT	May 2021	TSF4 geophysical survey to investigates southern embankment seepage review.
Golder (28 Sep 2021) Gwalia Gold Mine TSF4 Seepage Assessment (report ref.: 20447647-009-L-Rev0).	.PDF	Sep. 2021	TSF4 Southern embankment seepage review.
Golder (May 2021) Gwalia Gold Mine Tailings Storage Facilities. Operating Manual (report ref.: 1896746-001-R-Rev3).	.PDF	May 2021	Operating Manual
Golder (27 July 2021) Gwalia Seepage Trench Assessment Leapfrog Model (PowerPoint summary).	.PPT	Jul. 2021	Leapfrog geology model to support TSF4 seepage design.
Golder (May 2022) St Barabara TSF4 Seepage Trench Construction Completion Report (report ref.: 21489895-003-R-Rev).	.PDF	May 2022	TSF4 seepage trench construction report.
Tsf swl data.xls	Excel	Feb. 2004 – Aug. 2023	Groundwater chemistry data for TSF3/4 monitoring bores (Feb 2004 to Aug 2023)
ChemistryTable-SWL&Chem.xls	Excel	Jul. 2000 – Oct. 2023	Groundwater level data for TSF3/4 monitoring bores (July 2000 to Oct 2023)
TSF3 and 4 toe drain return flow.xls	Excel	Jan. 2022 – Dec. 2022	TSF3 and TSF4 toe drain abstraction rates

2.2 Groundwater level hydrographs

The existing groundwater monitoring bore locations are shown in Figure 2.1. There are 7 monitoring bores and 20 piezometers around TSF3, and 8 monitoring bores and 10 piezometers around TSF4. In each case, the piezometers are located within the embankment and the monitoring bores are mainly close to the foot of the embankment.

Groundwater level hydrographs for monitor bores to the north, east, south, and, west of the TSFs are shown and discussed in Attachment A. Key dates (from Table 1.1) and hydrograph characteristic are summarised in Table 2.2 as follows:

- TSF3 2003-2008. The care and maintenance period effect on groundwater levels is visible in the TSF3 hydrographs.
- TSF4 2020-2022. The TSF4 deposition effects on groundwater levels is visible in the TSF4 hydrographs.
- The effectiveness of the 2022 TSF4 toe drain improvements cannot yet be discerned. More data is required.

Table 2.2 Key TSF activity and groundwater level hydrograph characteristics summary

Year	TSF Activity	Hydrographs
1994	1994 tailings deposition commenced in TSF3.	TSF3 hydrographs commence mid-2000. Hence no true baseline groundwater levels are available for TSF3.
2003 – 2008	2003 to 2008 TSF3 went into in care and maintenance.	TSF3 hydrographs (TSF3/1, TSF3/4, TSF3/6, and TSF3/7) show declining levels in response.
2020 – 2022	2020 to May 2022 tailings deposition to TSF4.	Mid-2020. Rising groundwater levels in TSF4 monitor bores (TSF4/1RD, TSF4/2, TSF4/3, TSF4/5, SF4/6, and TSF3/7).
2022 – 2024	May 2022 to March 2024 tailings re-routed to TSF3.	Early 2022 TSF4 groundwater levels start to decline.
2022	May 2022 TSF4 toe drain improvements.	Mid 2022 TSF4 groundwater declining at a reduced level. Toe drain improvement impact not yet clear. More data required.
2024	29 March 2024 deposition re-routed to TSF4.	Groundwater reading interval increased to weekly from monthly.

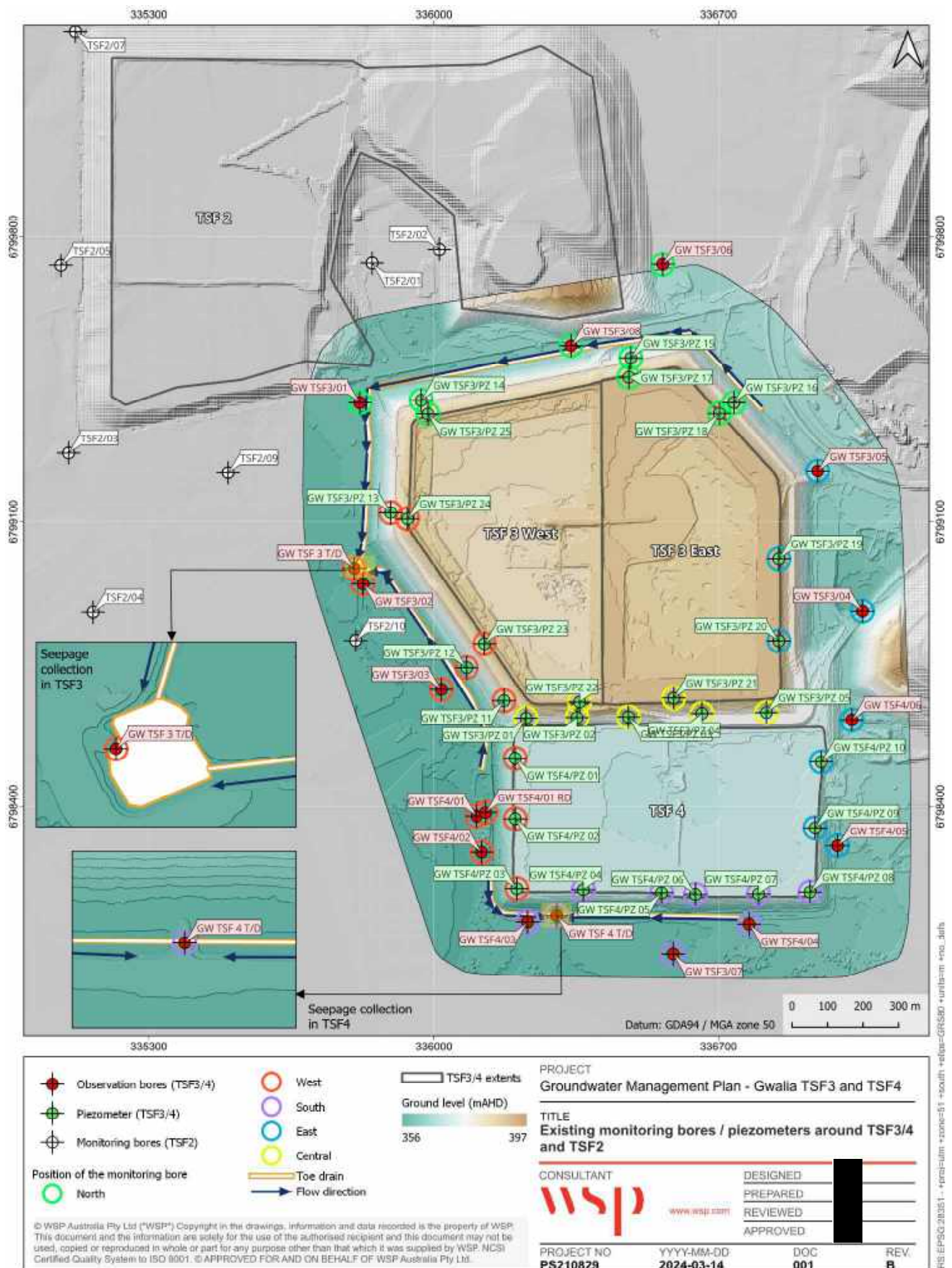


Figure 2.1 TSF3 and TSF4 existing monitoring bores and VVPs

2.3 Groundwater level contours

Recent groundwater elevation contours (Sep 2023) are shown in Figure 2.2 and are summarised as follows:

- The regional groundwater flow direction is likely to reflect the surface flow direction from north to the south – southeast. Figure 2.2 shows groundwater elevations at 359.4 m AHD to the north of TSF3 and 357.2 m AHD to the south of TSF4.
- The regional groundwater flow direction is likely to be impacted by:
 - The TSF seepage causing mounding
 - Mine dewatering causing a cone of depression to the north-east
 - More local seepage to/from Lake Raeside.
- Potential mounding occurs beneath TSF3 and TSF4 and the mound is higher beneath TSF3 than TSF4 (Figure 2.2).
- Figure 2.2 shows where the groundwater surface is predicted to intersect the trench (light blue shading) along the southern and western embankment of TSF4, and the south-western embankment of TSF3.
- The depth to groundwater is shown in Figure 2.3 which indicates the following:
 - Groundwater is shallowest (< 0.5 mbgl) beneath the TSFs, within the toe drain, in parts of the Lake Raeside, and to the west and south of TSF4, and mid-way along the northern TSF3 embankment.
 - Groundwater is deepest (> 6 mbgl) to the north of TSF3, and on the eastern side of TSF3 and TSF4 that is mainly due to the higher ground elevation to the north and east but may also be affected by the mine dewatering operation to the northeast.
 - The groundwater level is generally around 1 to 4 mbgl in the immediate vicinity of the TSFs.

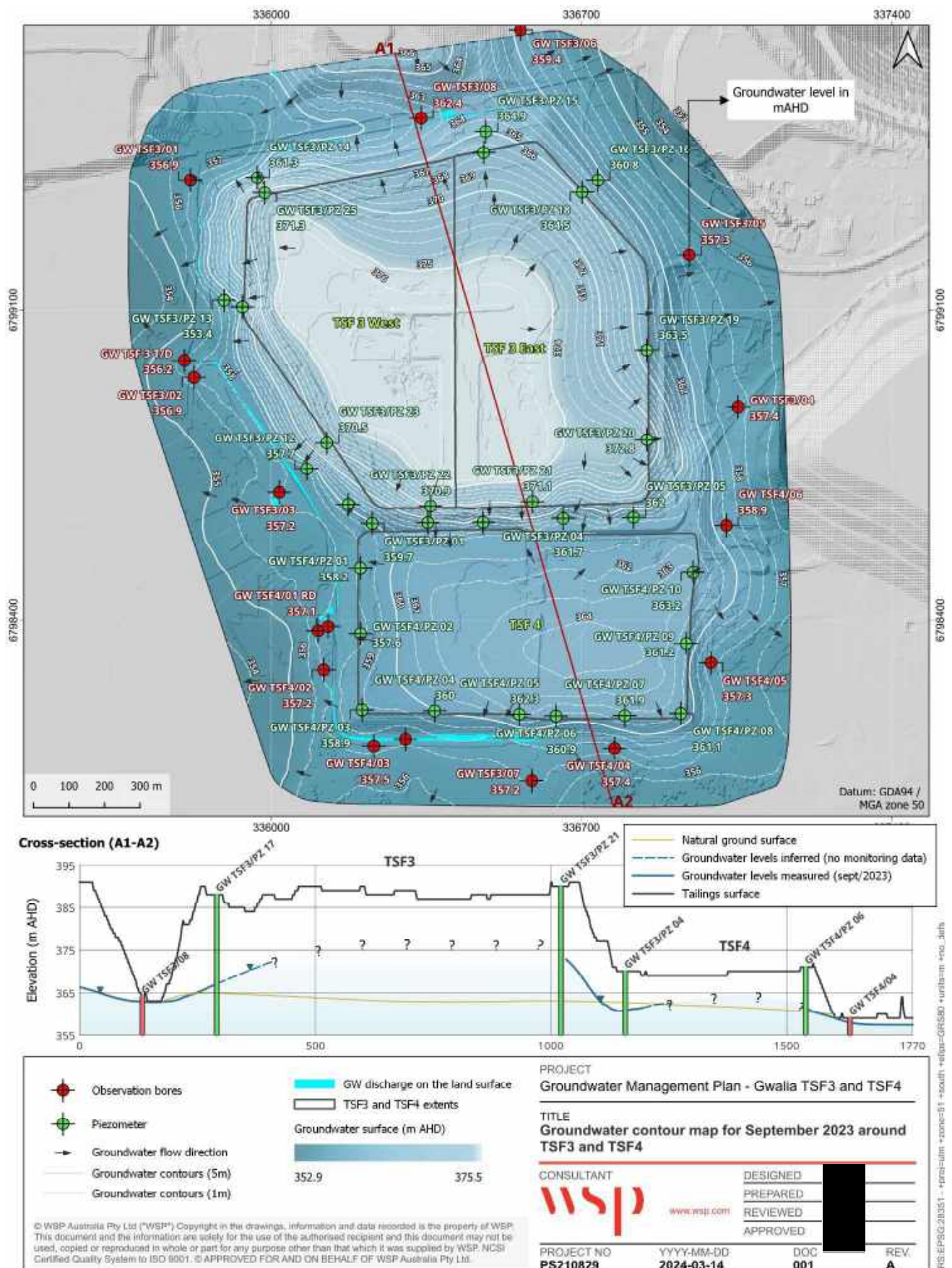


Figure 2.2 Groundwater elevation contour map (m AHD, Sep 2023)

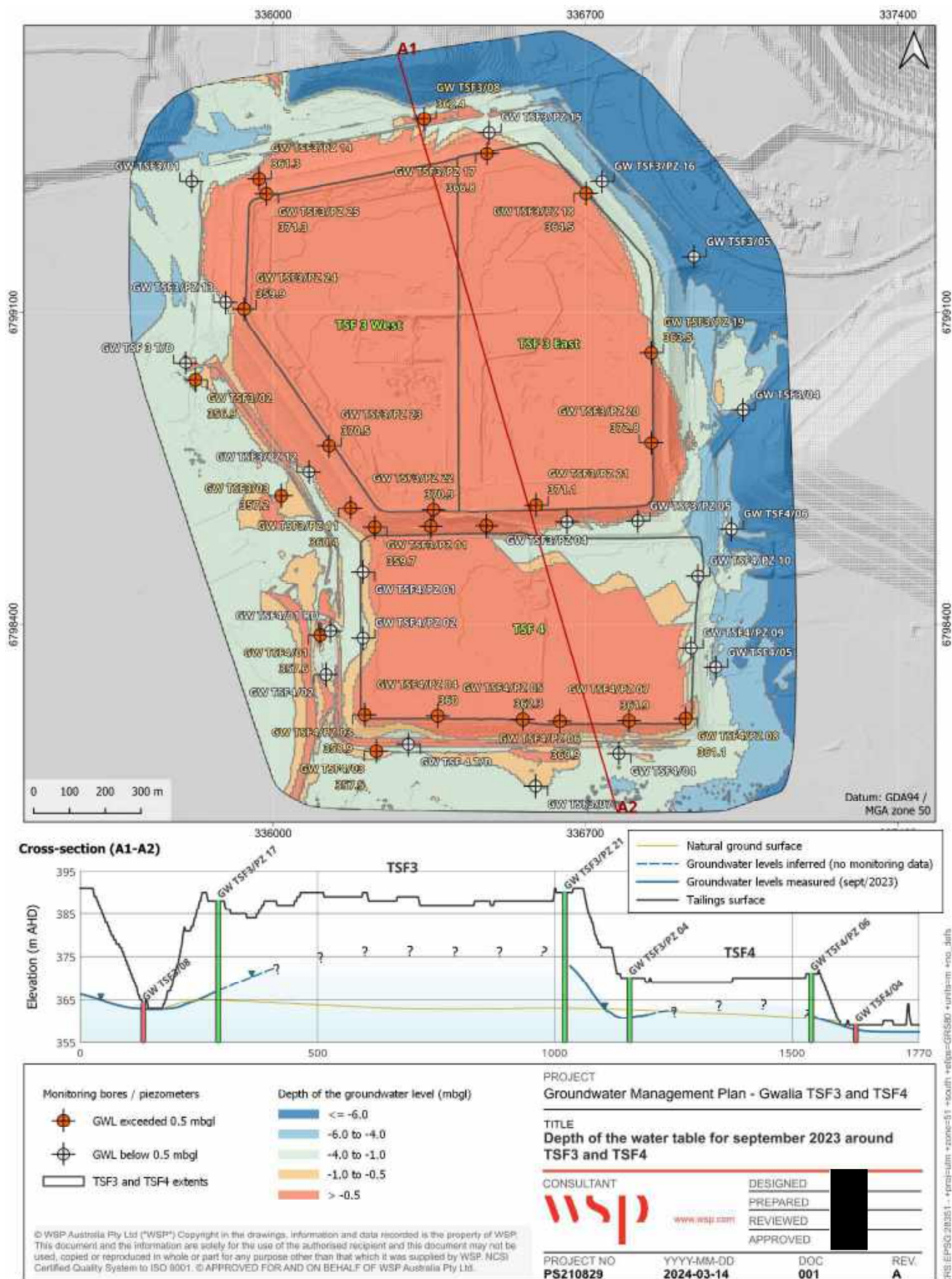


Figure 2.3 Groundwater depth map (m BGL, Sep 2023)

2.4 Groundwater flow estimate

A preliminary groundwater flow estimate (of north to south groundwater flow) from beneath the southern TSF4 embankment is presented below:

$$Q = Kia$$

Where:

- Q = Groundwater flow (m^3/d)
- I = hydraulic gradient (5m/120m, scaled with reference to Figure 2.2)
- A = Cross sectional area of sand (3m x 940 m scaled with reference to Figure 4.2)
- K = sand permeability (1 to 5 m/d (Kruseman and de Ridder (1994)))

Therefore, $Q = 118$ to $588 \text{ m}^3/\text{d}$ (1.4 to 6.8 L/s).

3 Toe drain

3.1 Toe drain design

Observation of seepage were made along the southern flank of TSF4 after it was commissioned in October 2020. The seepage zones were inferred to come from the foundation of the TSF. A TSF4 seepage collection trench was designed to intercept the seepage zones, collect seepage in a sump, and pump seepage water to the plant. It was recognised that extraction bores may be required to capture deeper seepage. However, a phased approach was selected (whereby, the effectiveness of the trench would be assessed before assessing whether extraction bores would be required).

The seepage trench or 'toe drain' was constructed from March to May 2022 and is located along the southern and western embankment toes of TSF4 to depths of between 2.0 and 3.0 mbgl. A toe drain is also in place around the northern and western embankment of TSF3. The toe drain locations can be seen in Figure 4.3.

3.2 Toe drain pumping rates

The TSF toe drain pumping rates are shown in Figure 3.1.

- The TSF3 toe drain pumping rates increase in response to rainfall.
 - The TSF3 toe drain pumping rates show a gradual increase from 2009 to 2017 and then show a declining rate to 2021. The rates increased again in 2022 which is consistent with the tailings deposition records.
 - The TSF3 toe drain pumping rates (5 to 28 m³/hr (1.4 to 7.8 L/s), average approximately 15 m³/hr (4.2 L/s) and are significantly higher than the TSF4 toe drain rates of 2 to 3 m³/hr (0.6 to 0.8 L/s).
 - The TSF4 pumping rates of 2 to 3 m³/hr (0.6 to 0.8 L/s) achieved to date may capture shallow seepage from TSF4 but are unlikely to have a controlling effect on groundwater levels in the general area to the south of TSF4.
-

3.3 Toe drain water quality

TSF3 and TSF4 toe drain water chemistry data are summarised as follows:

- TSF3: The TSF3 toe drain water has been sampled on numerous occasions from 1/3/04 to 21/01/24. WAD-CN is regularly above the detection limit but below Genesis' Department of Water and Environmental Regulation (DWER) Environmental Licence 0.5 mg/L trigger value (Section 3.4, DWER Environmental Licence L8337/2009/2) and total cyanide is recorded above detection limits, indicating that TSF seepage is being intersected.
- TSF4: The TSF toe drain water has been sampled on 7 (seven) occasions from 10/5/22 to 21/01/24 and on each occasion, the WAD-CN is below the detection limit, but total cyanide is recorded above detection limits (0.153 to 0.533 mg/L) on 6 occasions, indicating that TSF seepage is being intersected.

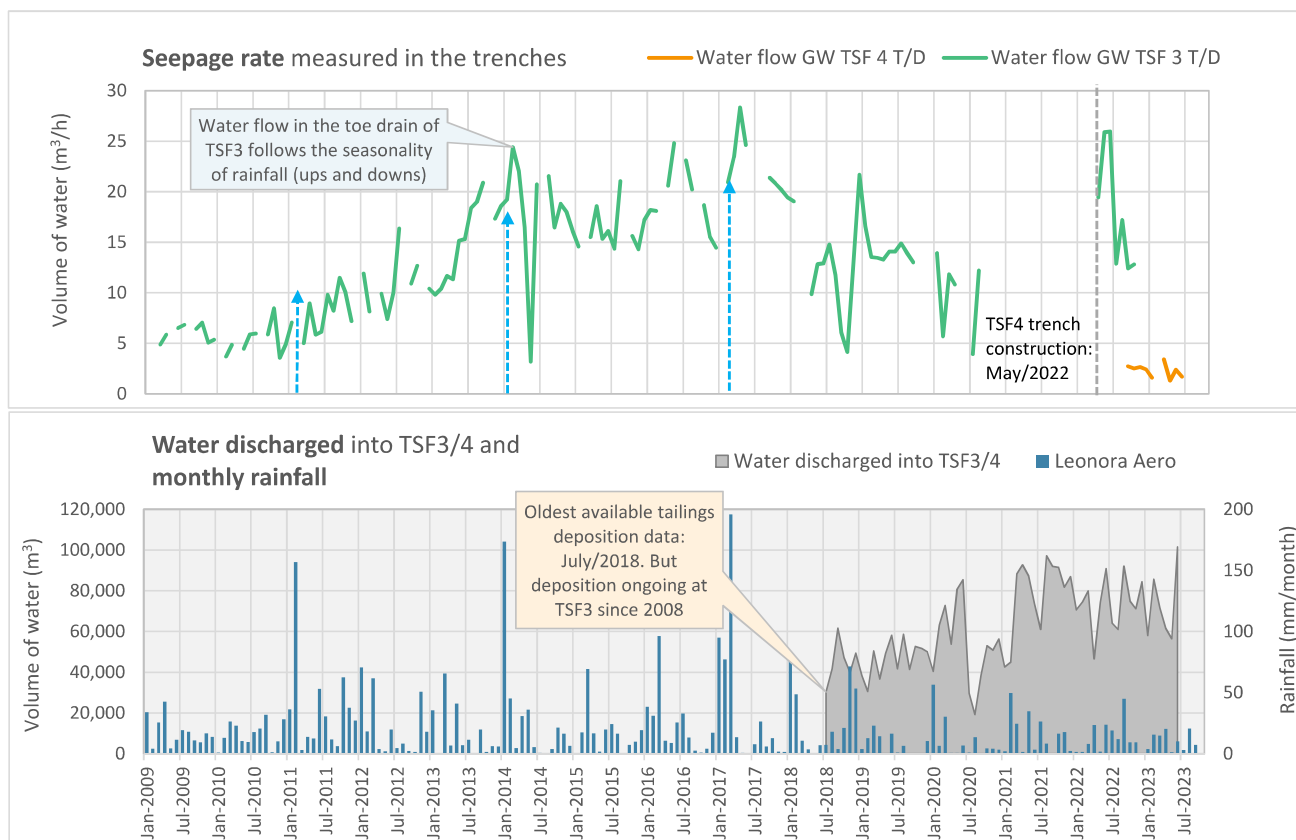


Figure 3.1 TSF toe drain pumping rates

4 Groundwater management plan

A groundwater management plan has been developed based on the conceptual hydrogeological model (CHM) and a source-path-receptor (SPR) model outlined in the section below.

4.1 Conceptual hydrogeology model

The TSF3 and TSF4 conceptual hydrogeology model is summarised as follows:

- The TSF4 geology was assessed by Golder in 2021 (Golder 2021) and characterised by clay, with sand and clay, and sand overlying in the east (Figure 4.1 and Figure 4.2).
- The regional groundwater flow direction is likely to reflect the surface flow direction from north to the south. This regional pattern will be modified by:
 - The TSF seepage causing mounding (higher beneath TSF3 than TSF4)
 - Mine dewatering causing a cone of depression to the northeast
 - Seepage to/from Lake Raeside. There is potentially a vertically upwards hydraulic gradient associated with Lake Raeside.

Key points from the groundwater hydrographs are:

- The TSF3 2003-2008 care and maintenance period is visible in the TSF3 hydrographs. This includes the effect of TSF3 on TSF3/7 (located approximately 600 m south of TSF3).
- TSF3/07 is located 600m to the south of TSF3 which indicates that TSF3 may have possibly had a Zone of Influence (ZOI) of greater than 600m to the south, prior to the construction of TSF4. WAD-CN has also been detected in TSF3/7, albeit in low concentrations (although TSF2 to the north cannot be ruled out as a potential historical source of WAD-CN).
- TSF4 2020-2022 deposition is visible in the TSF4 hydrographs, which show a rapid rise in response to TSF4 deposition (taking the groundwater to, or close to ground level in TSF3/7, TSF4/2, and TSF4/3).

Toe drain:

- The TSF3 toe drain rates (5 to 28 m³/hr (1.4 to 7.8 L/s) average approximately 15 m³/hr (4.2 L/s) that is significantly higher than the TSF4 toe drain rates of 2 to 3 m³/hr (0.6 to 0.8 L/s).
- The TSF4 pumping rates of 2 to 3 m³/hr (0.6 to 0.8 L/s) achieved to date may capture shallow seepage from TSF4 but are unlikely to have a controlling effect on groundwater levels in the general area to the south of the TSF. By comparison, the seepage rate beneath TSF is estimated to be 118 to 588 m³/d (1.4 to 6.8 L/s).
- The effects of the TSF4 toe drain improvements on groundwater levels to the south of TSF4 cannot yet be assessed. More data is required.

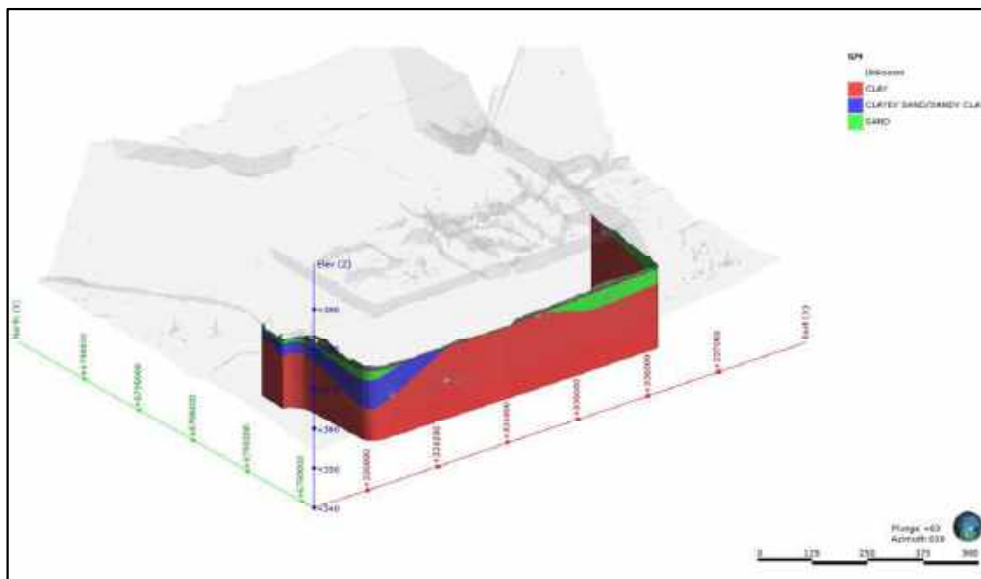


Figure 4.1 TSF4 seepage trench geology long section – 3D (Golder 2021)

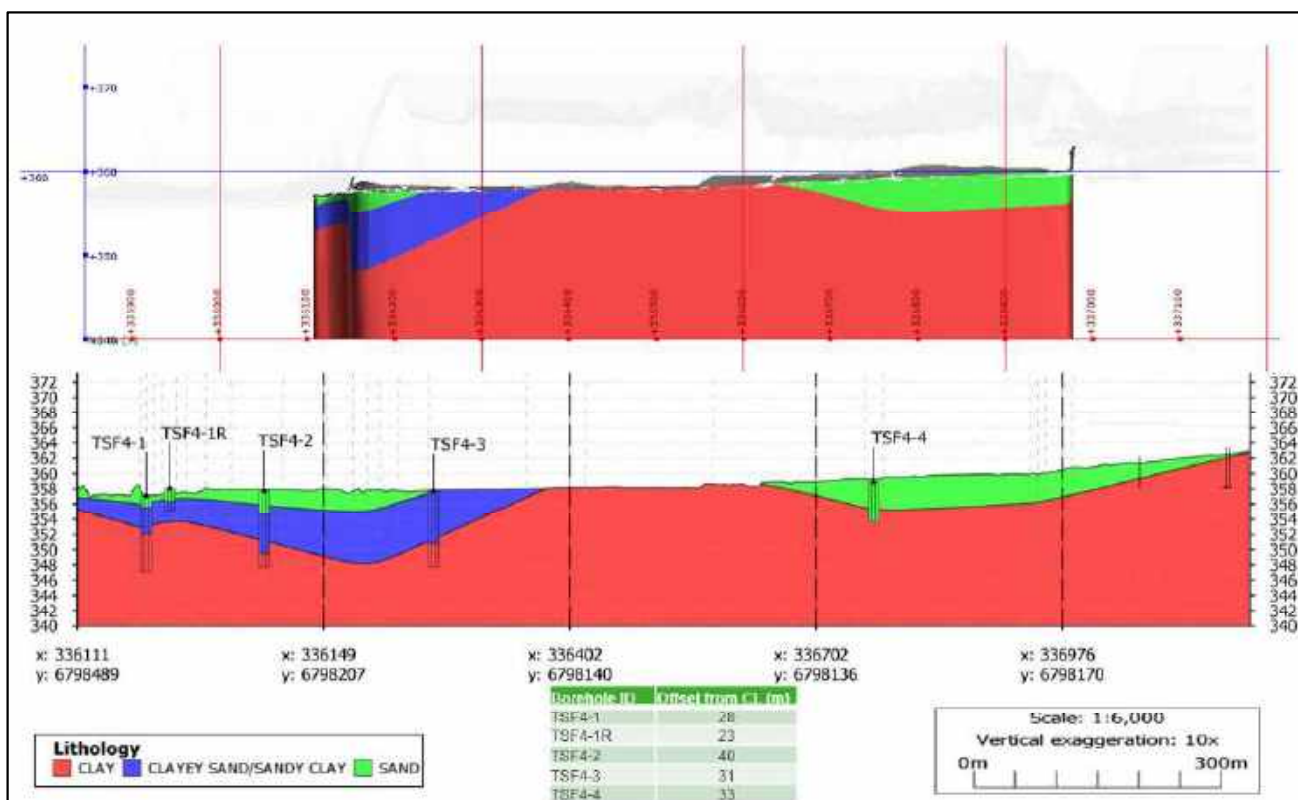


Figure 4.2 TSF4 seepage trench long section looking north (Golder 2021)

4.2 Sourcepathreceptor model

The monitoring bore plan outlined below is based on the conceptual hydrogeological model and a preliminary source-path-receptor (S-P-R) model summarised in Table 4.1.

Table 4.1 Sourcepathreceptor model

Component	Factors
Source	— TSF Seepage (water quality): Potentially impacted by mine related activities. — TSF Groundwater level impacts. These can result from: — Direct seepage that may be accompanied by a change in water quality. — Mass loading effect that pressurises the aquifer. Does not include a change in water quality. — The nature of the source may change with time depending on the tailings deposition rate, the presence of active/non active cells, the pond size, the pond location, the beach location and drainage, and the tailings permeability. — Stage 2 deposition at TSF4 uses a conventional beach profile, following the Stage 1 deposition. This is likely to result in a reduced hydraulic connection between TSF4 and the underlying groundwater system. Deposition previously took place within excavated areas that would have resulted in a high hydraulic connection between the tailings and the underlying groundwater. Stage 2 also has drainage installed in the beach to help facilitate water recovery and minimise seepage.
Path	— <u>Shallow perched aquifer</u>: Shallow sand at surface overlying clay. — <u>Deeper aquifer</u>: Deeper sands interbedded with clay.
Receptors	— <u>Vegetation</u>: Vegetation associated with the shallow sand aquifer may be affected by: — Water quality change (salinity or changes in quality). — By a rise in groundwater levels causing water logging of the roots. — <u>Lake Raeside</u>: May interact with the regional groundwater system, in parts draining to groundwater, and in other parts receiving groundwater. The lake may act as a groundwater sink and an upward hydraulic gradient may exist. — <u>Deeper aquifer</u>: No clear receptor as the aquifer is not being exploited by others in the area. — <u>Open pit</u>: Not an environmentally sensitive receptor.

4.3 Task 1: Groundwater monitoring bore network assessment

The existing groundwater monitoring bore network comprises 8 bores (TSF3/1 to TSF3/8) around TSF3, and 6 bores (TSF4/1RD to TSF4/6) around TSF4. The monitoring network provides adequate coverage of the groundwater conditions within the immediate vicinity of the TSF with the following exceptions:

- All the existing bores are close to the TSF3/4 embankments. Bores at greater distance in a southerly direction are required to define the TSF ZOI.
- The S-P-R analysis identifies the surrounding vegetation as a potential shallow seepage receptor. There is a lack of shallow groundwater monitoring bores in the vegetation zones.
- There is a gap in the monitoring bore network along the TSF4 southern embankment between TSF4/3 and TSF3/07. An additional bore should be considered at this location.

- TSF3/8 is sited within a trench and any water flow out of the bore is recovered in the toe-drain, so the actual reference to groundwater level relative to surface may be inaccurate. The TSF is bordered to the north by a Waste Rock Landform, and any mounding associated with the final lift of TSF3 is unlikely to result in environmental impact. Due to the non-representative groundwater levels being collected and their limited environmental value, TSF3/8 should be removed from the groundwater monitoring programme.
- Logs are available for the more recent TSF4 monitoring bores but not for the earlier TSF3 bores. Therefore, the stratigraphy in which the monitoring bores are installed is unknown.

4.4 Task 2: Additional bores

Additional monitoring bore locations are shown on Figure 4.3 and are summarised in Table 4.2.

4.4.1 *Additional monitoring bore types*

The existing monitoring bores could be expanded with the following specific aims:

- Expand the monitoring bore coverage to define the TSF ZOI.
- Bores to monitor groundwater levels within vegetation zones to monitor levels and quality, at the potentially sensitive receptor vegetation zones.

4.4.2 *Additional monitoring bores construction*

The bores should be constructed as follows:

- 50 mm Upvc, slotted in the lower 3 to 6 m depending upon bore depth (1 mm aperture slots)
- The annulus to be backfilled with gravel pack to 0.5 m above the slotted section
- A 0.5m bentonite seal to be installed above the gravel pack
- The annulus to be grout sealed to surface
- The monitoring bores should be completed at surface with a cement plinth and lockable headworks.

The bore depths and slotted intervals will be subject to revision, depending on ground conditions encountered during the drilling works, mainly the sand and clay layer depths.

Dual completions (shallow and deep bores at the same location) may be recommended.

The bores should be installed under the supervision of a suitable experienced hydrogeologist.

4.4.3 *TSF ZOI definition bores*

Install five (5) monitoring bores, two monitor bores 250 m, and three monitor bores 460 m to the south of TSF4 to better define/constrain the TSF ZOI. Preliminary ZOI monitoring bore locations are shown in Figure 4.3.

The installation of monitoring bores further to the south will also establish baseline conditions for a potential future TSF expansion to the south in a similar way that TSF3/7 provided a long-term record to the south of TSF4.

4.4.4 *Test vegetation zone monitor bores*

Vegetation zones within the TSF ZOI are potential groundwater level/quality change receptors. Therefore, it is proposed to install trial defensive shallow monitor bores within key vegetation areas.

4 trial shallow monitoring bores (depth estimate 3 to 6 mbgl) to monitor groundwater quality and levels at the key receptor locations near the TSF are shown in Figure 4.3.

The Vegetation zone monitoring bore locations should be informed by the vegetation studies that are understood to be ongoing.

The bores should be installed under the supervision of a suitable experienced hydrogeologist. These are test bores to identify if the vegetation is dependent upon a shallow water table the presence of which cannot be guaranteed.

Artesian flow, if encountered, could be managed by connecting black poly pipe to the headworks and running it back into the toe drain. A pressure gauge could be installed to check the hydrostatic head, but the line would be left open to allow flow in normal operations.

4.4.5 *Test recovery bores*

Test recovery bores are recommended along the southern embankment of TSF4.

Five (5) test recovery bore are proposed, the locations of are shown in Figure 4.3. The bore should be to an estimated depth of 18m, at 100m spacing intervals and be constructed with 150 mm Upvc for the installation of 4” submersible pumps, capable of achieving ~15 m³/hr (4.2 L/s). Each bore should be subjected to a step-rate test and 24-hour constant rate test, as part of the installation works.

The bores should be installed and tested under the supervision of a suitable experienced hydrogeologist. The viability of the test recovery bores is dependent upon the intersection of a sufficient thickness of permeable and saturated sand (to be verified as part of the drilling works) and cannot be guaranteed.



Figure 4.3 Recommended additional monitoring bores around TSF3/4

Table 4.2 Recommended additional monitoring bores

Monitoring Bores	Easting	Northing	Approx. Depth (mbgl)	Monitoring Rationale
MB01	335817	6798750	6	Vegetation zone monitoring
MB02	335931	6798566	6	Vegetation zone monitoring
MB03	336241	6797963	6	Vegetation zone monitoring
MB04	336780	6798019	6	Vegetation zone monitoring
MB05	336145	6797908	18	TSF ZOI definition
MB06	336582	6797903	18	TSF ZOI definition
MB07	336136	6797695	18	TSF ZOI definition
MB08	336579	6797702	18	TSF ZOI definition
MB09	336968	6797705	18	TSF ZOI definition
BH4	336487	6798114	3	Geotechnical programme monitoring
BH5	336117	6798239	6	Geotechnical programme monitoring
RB01	336404	6798081		Recovery bore
RB02	336504	6798081		Recovery bore
RB03	336604	6798081		Recovery bore
RB04	336705	6798081		Recovery bore
RB05	336805	6798081		Recovery bore

4.4.5.1 Geotechnical programme monitoring bores

At the time of writing, additional monitoring bores are being opportunistically installed as part of a geotechnical investigation through the conversion of HQ diamond holes to monitoring bores. The geotechnical hole locations BH4, BH5, and BH6 are shown in Figure 4.3 and the proposed monitoring construction details are outlined below.

- BH4: Install a shallow (~3.0 m deep) monitoring bore adjacent to existing monitoring bore TS4/2 to monitor water levels and quality in the shallow sandy aquifer. The bore would be constructed with 50 mm Upvc to a depth of 3 m, slotted from 1 to 3 mbgl. The anticipated profile (based on the TSF4-2) log is: 0-3m sand, 3-4.5m sandy clay. This bore is close to TSF4/2 that is slotted from 6.5 to 9.5 m and beneath a clay layer. The purpose of the proposed bore is to target the shallow sand aquifer in the Lake Raeside vicinity and identify the vertical head gradient direction by comparison of the absolute levels observed in TSF4/2.
- BH5: Install a shallow (6 m deep) monitoring bore in between existing bores TSF4/03, and TSF4/04, and to the north of TSF3/07 to monitor groundwater quality in the shallow sandy aquifer adjacent to the southern embankment and drain, and close to the seepage zone. The bore would be constructed with 50 mm Upvc to a depth of 6 mbgl, slotted from 3 to 6 mbgl. The profile here is not clear and could either be a sand (as per TSF4/04 to the east) or clay (as per TSF4/03 to the west).
- BH6: This location is very close to existing monitoring bore TS4/5 (slotted 3.5 to 6.5 m) and piezometers TSF4/PZ08 and TSF4/PZ09. An additional monitoring bore is not required at this location.

4.5 Task 3: Monitoring programme

4.5.1 Existing groundwater monitoring programme

The existing Environmental Licence (L8337/2009/02, Section 3.2) stipulates the following monitoring programme for monitoring bores TSF3/1 to 8 and TS4/ 1 to 6.

- Standing Water Levels (SWP): Monthly whilst the plant is operating and quarterly whilst the plant is in care and maintenance.
- Chemistry Suite (Ph, TDS, WAD-CN, Na, K, Ca, Mg, As, Pb, Ni, Fe, Cd, Cr, Cu, Hg, Se, Zn, Cl, CO₃, HCO₃, SO₄, and NO₃): Quarterly whilst the plant is operating and six monthly whilst the plant is in care and maintenance.

The only trigger level in the existing Genesis Environmental Licence (Licence number L8337/2009/2, Section 3.4.1) is a limit of 0.5 mg/L for WAD-CN.

4.5.2 Proposed groundwater monitoring programme

The Vegetation Zone bores, and Zone of Influence bores should be dipped and have field parameters (temp, Ph electrical conductivity) taken monthly on a monthly basis and WAD_CN readings taken on a quarterly basis. The proposed sample suite and schedule should be reviewed following the proposed one-year trial period.

4.6 Task 4: Management actions

4.6.1 Trigger Action Response Plan (TARP)

Appendix D of the Gwalia Gold Mine Tailings Storage Facilities Operating, Surveillance and Maintenance (OSM) Manual (Golder, 2021) presents a Trigger Action Response Plan (TARP) for the TSFs and includes a high-level trigger concerning the groundwater monitoring bores¹. The triggers and responses are a high-level and are developed further below.

Groundwater elevation trigger considerations vary by location:

- North and East: Groundwater levels are deeper in the northeast and east due to the higher ground elevation and may also be lowered by the open pit and its dewatering operation. Minimum depth to groundwater trigger levels could be applied but to little effect, as they are unlikely to be breached.
- West: Groundwater levels associated with Lake Raeside have historically been at or close to surface. Groundwater elevation trigger levels are not appropriate as the groundwater is naturally close to, or at, natural ground level.
- South: Groundwater levels are affected by mine operations and have previously approached ground levels in response to TSF3 and particularly TSF4 deposition rates (Table 2.3, Figure 2.4 TSF3/7, TSF4/3, and Figure 2.5 TSF4/2).
- Potential mitigating circumstances include:
 - Future tailings deposition at TSF4 will form a conventional beach profile (that includes internal seepage mitigation measures) that will promote effective return water operations; reducing the size and volume of water stored at TSF4 during operations. Previously, deposition was taking place in excavation voids, excavated to the natural ground and, as a result, the hydraulic connection between tailings and the groundwater would have been more direct than it will be in the future.

¹ WSP note that, at the time of writing, the latest version of the Gwalia OSM is being updated and is subject to review.

- The TSF4 toe drain improvements made in 2022 may start to take effect and begin to control groundwater levels.

Further potential management measures to control groundwater levels include:

- The TSF4 drain design could potentially be further modified/improved.
- Recovery bores could be installed and operated along the toe of the southern TSF4 embankment.

4.7 Trial groundwater monitoring period

A trial monitoring period is required to monitor groundwater conditions under the ongoing TSF4 conditions. A minimum one (1) year trial monitoring programme is recommended to establish background groundwater levels in the potential sensitive receptors, define the TSF ZoI, monitor the impact the TSF beach and drainage system, and assess the effectiveness of the TSF4 toe drain.

4.7.1 *Additional monitoring bores*

The monitoring network should be further developed to include:

- Vegetation area monitoring bores. The viability of the vegetation bores is dependent upon the intersection of a shallow (perched) water table which is not guaranteed and would need to be investigated.
- TSF ZoI definition monitoring bores.

4.7.2 *Trial recovery bores*

Trial recovery bores are recommended along the southern embankment of TSF4.

- Trial bores would need to be installed and tested to confirm their viability. Dewatering bores would be slotted against the shallow sand aquifer. The viability of the recovery bores is dependent upon the intersection of a productive sand layer (aquifer) which is not guaranteed and would need to be investigated.
- Five (5) tests recovery bore are proposed, the locations of are shown in Figure 4.3. The bores could be to an estimated depth of 18 m, at 100 m spacing intervals, and be constructed with 150 mm PVC for the installation of 4” submersible pumps capable of achieving 15 m³/hr (4.2 L/s). Each bore should be subjected to a step-rate test and 24-hour constant rate test, as part of the installation works

4.7.3 *Groundwater model*

- A 3D transient groundwater flow model (in FEFLOW) could be constructed to optimise the toe drain depth, recovery bore depth, and spacing to avoid well interference and drawdown gaps, predict groundwater levels and evaluate the management options.
- The model would require a 3D Leapfrog geology model, bore logs, and test results, slug tests on all monitoring bores, and TSF3/4 future operating scenarios.

If recovery bores or increased toe drain abstraction rates are required, the abstracted water will need to be directed to a suitable storage or discharge location.

4.7.4 *Trigger action response plan*

Trigger levels can potentially be set at the defensive bore locations which have identified receptors including vegetation zone bores.

The existing monitoring programme outlined in Section 4.5 would be expanded to include the additional bores.

A tentative trigger action response plan (TARP) that includes preliminary high-level management actions to reduce groundwater mounding if the site-specific trigger levels (SSTVs) are breached is shown in Table 4.2. Trigger levels should be set in bores that are in sensitive receptor areas.

As stated previously a minimum one (1) year trial monitoring programme is recommended to establish background groundwater levels in the potential sensitive receptors, define the TSF Zol, monitor the impact the TSF beach and the effectiveness of the TSF4 toe drain.

Table 4.3 Tentative trigger action response plan (TARP)

	Monitoring Bores	Early Trigger (mbgl)	Trigger (mbgl)	Trigger Level Comments	Response
TSF North	TSF3/01	1.0	0.5	Baseline groundwater level estimated to be 2 to 5 mbgl	Early Trigger Response — Notify Genesis Mine Management — Review recent monitoring results against historical data — Compare observation data with model predictions — Investigate the likely cause of any exceedance — Determine if there has been a specific incident or operational practice that has led to an exceedance — Report Incidents in accordance with Environmental Licence reporting obligations. Full Trigger Response — Review decants pond area and location. Manage the decant pond such that it is away from the trigger exceedance area and generally away from southern and western embankments. — Review the toe drain design and operation e.g. set the trench pump inlet to a lower level or deepen the trench and the pump inlet. — Recovery bores operation (if testing proves successful).
	TSF3/06	1.0	0.5		
	TSF3/08	-	-	Remove from programme due to spurious/erroneous results and limited environmental value	
TSF East	TSF3/04	1.0	0.5	Background groundwater level estimated to be 7.5 mbgl	
	TSF3/01	1.0	0.5		
	TSF4/05	1.0	0.5		
	TSF4/06	1.0	0.5		
TSF South	TSF3/07	N/a	TBC	Trigger levels to be informed by trial period.	
	TSF4/03	N/a	TBC		
	TSF4/04	N/a	TBC		
TSF West	TSF3/02	N/a	N/a	Baseline values are naturally at, or close to, ground level. Maximum groundwater level trigger levels not appropriate.	
	TSF3/03	N/a	N/a		
	TSF4/01	N/a	N/a		
	TSF4/01RD	N/a	N/a		
Vegetation zone monitoring	MB01	TBC	TBC	Bore locations and trigger levels to be informed by trial period.	— All the above measures apply, in addition: — Undertake vegetation surveys to assess impacts to potential receptors
	MB02	TBC	TBC		
	MB03	TBC	TBC		

	Monitoring Bores	Early Trigger (mbgl)	Trigger (mbgl)	Trigger Level Comments	Response
	MB04	TBC	TBC		— Incorporate groundwater level data and quality into the vegetation zone reporting. — Shallow recovery bores, potentially with low capacity (e.g., Airwell) pumps could be installed.
TSF ZOI definition	MB05	TBC	TBC	Trigger levels to be informed by trial period.	-
	MB06	TBC	TBC		-
	MB07	TBC	TBC		-
	MB08	TBC	TBC		-
	MB09	TBC	TBC		-
Geotechnical programme monitoring	BH4	TBC	TBC	Trigger levels to be informed by trial period.	-
	BH5	TBC	TBC		-

5 Conclusions

The following conclusions are made based on the above assessment:

- Groundwater levels to the north and east of the TSF tend not to come close to ground level. They are deeper because of the higher ground level to the northeast and east and possibly due to the open pit and its dewatering operation to the northeast. Minimum depth to groundwater trigger levels could be applied but to little effect as they are unlikely to be breached.
- Groundwater levels to the west have, since the year 2000, been consistently within 0.5 mbgl, and often close to, or at ground level. A groundwater trigger level stipulating a minimum depth to water would not be appropriate to the west of the TSF as the natural groundwater levels associated with Lake Raeside are close to, or at ground level.
- Groundwater levels to the south of TSF4 show a clear response to the TSF4 deposition that took place between 2020 and 2022. The TSF4 south hydrographs show a rapid rise in response to TSF4 deposition taking the groundwater to, or close to, ground level; for example, in TSF3/7, TSF4/2, and TSF4/3.
- TSF4 south groundwater levels can potentially be managed by recovery bores, deepening the TSF4 toe drain pump inlet, deepening the TSF4 toe drain, or reducing /redirecting deposition into/from TSF4.
- Vegetation zone monitoring and recovery bore viability needs to be tested. The viability of the vegetation monitoring bores is dependent upon the presence of a shallow water table aquifer. The viability of the recovery bores is dependent upon sufficient sand aquifer thickness. It would be better test the viability of these bores earlier in the trial period rather than finding out that they are not viable later. Another potential issue with recovery bores would be to find a balance between managing groundwater levels without drawing water in from Lake Raeside.
- The impact the TSF4 toe drain on groundwater levels and the viability of the vegetation monitoring and recovery bores is not clear. Groundwater level data needs to be collected during future operations to assess this, and a one-year trial period is recommended, during which the various groundwater monitoring and control measures can be assessed.

6 Recommendations

6.1 Trial monitoring period

A trial monitoring period is required to monitor groundwater levels and quality in an expanded monitoring network under the ongoing TSF4 conditions to assess groundwater level response, accounting for the conventional tailings beach profile and drainage system installed in TSF4, as well as the improvements made to the TSF4 toe drain.

6.2 Additional monitoring bores

The monitoring network should be further developed to include:

- Defensive bores at the potential drawdown-sensitive receptors identified as Vegetation Areas. The viability of the vegetation monitoring bore is dependent upon the presence of a shallow water aquifer that cannot be guaranteed. Therefore, it is advisable to install and test these bores early in the trial period to establish their viability.
 - Expansion of the TSF monitoring bore network to further define the TSF ZOI.
-

6.3 Test recovery bores

Test recovery bores are recommended along the southern embankment of TSF4. The proposed locations are shown in Figure 4.3.

- The viability of the test recovery bores is dependent upon the intersection of a sufficient thickness of permeable and saturated sand and cannot be guaranteed. Therefore, it is advisable to install and test these bores early in the trial period to establish their viability.
 - Monitoring and recovery bore installation and testing should take place under the supervision of a suitable experienced hydrogeologist.
 - Genesis may prefer to re-name any additional bores in line with existing site bore naming system.
-

6.4 Groundwater model

A groundwater model to predict groundwater levels and evaluate the management options (e.g., optimum bore locations and number, optimum trench design/depth under future TSF3 and TSF4 operation scenarios, could be constructed). The model would require the following inputs:

- The 3D Leapfrog geology model
 - Recovery bore logs and test results
 - Slug tests on all monitoring bores
 - TSF3 and TSF4 future operating scenarios.
-

6.5 Water storage/discharge

If recovery bores or increased toe drain abstraction rates are required, this water will need to be stored or discharged.

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8 References

- 1 Department of Water and Environmental Regulation (2023). L8337 – Gwalia Mine – Amendment Amalgamation and Transfer Licence DRFT V2.pdf. Licence number L8337/2009/2. Genesis Minerals (Leonora) Pty Ltd. 7/02/2014 to 8/2/2029.
- 2 Golder (Sep 2020) St Barbara Limited. Groundwater Monitoring Bores and VWP Installation Report. Ref 20138708-001-R-Rev0).
- 3 Golder (18 Sep 2020) Review of Seepage along the Southern Flank of TSF4. Ref 20447647-001-L-Rev0.
- 4 Golder (May 2021) Gwalia Gold Mine Tailings Storage Facilities. Operating Manual. Ref 1896746-001-R-Rev3.
- 5 Golder (7 May 2021) 2021 Gwalia TSF 4 Geophysical Survey. PowerPoint
- 6 Golder (27 July 2021) Gwalia Seepage Trench Assessment Leapfrog Model. PowerPoint.
- 7 Golder (28 Sep 2021) Gwalia gold Mine TSF4 Seepage Assessment. Ref 20447647-009-L-Rev0.
- 8 Golder (May 2022) St Barabara TSF4 Seepage Trench Construction Completion Report. Ref 21489895-003-R-RevA.
- 9 Kruseman and de Ridder (1994) Analysis and Evaluation of Pumping Test Data. 2nd Edition.

Appendix A

Groundwater level assessment



Table A.1 Groundwater level hydrographs summary

Sector	Description
North	Groundwater level hydrographs to the north of TSF3 are shown in Figure A.1. — The groundwater level record starts in 2000, 6-years after TSF3 commenced operation in 1994. The groundwater levels recorded in 2000. Therefore, the groundwater levels cannot be regarded as the baseline level. — The monitoring bore groundwater levels in general show a muted response to rainfall events. The exceptions are TSF3/1 and particularly TSF3/6 to the northeast that showed a distinct rise due to a storm event in 2017 (TSF3/6 rose by approximately 1.0 m). Smaller rises in groundwater levels can be seen in response to high rainfall events in 2001, 2005, 2010, and 2014. — The TSF3/6 response is similar in bores to the east of the TSF (TSF3/4 and TSF3/5) that may result from the more permeable sand profile on the northeast and eastern side of the TSF. The on-going dewatering operations at the open pit may also influence groundwater conditions in north-east. Genesis notes that TSF3/4 is linked to a borrow pit which captures all site surface water drainage that is likely to contribute to its responsiveness to rainfall events. — TSF3/1 and particularly TSF3/06 show a declining trend from 2003 to 2008 when the Gwalia gold mine was in care and maintenance. In this period, TSF3/01 declined to a level of about 2 mbgl and TSF3/06 declined to a level of 5 mbgl. These are ‘quasi’, or ‘best estimate’ baseline groundwater levels at these locations. Groundwater is deeper to the north and east of the TSF mainly due to the higher ground elevation to the east but may also be lowered by the open pit and its associated dewatering operation to the northeast. — TSF3/6 is located 270 m to the north of TSF3 and the recorded groundwater levels are influenced by the TSF3 deposition rates. The TSF zone of influence (ZOI) can, therefore, be said to be at least 270 m to the north of TSF3. — The longer-term gradual rise in TSF3/1 and particularly TSF3/06 from 2008 to 2017 together with an associated increase in toe drain flow rates are likely related to the TSF3 deposition that restarted in 2008. — Groundwater levels in TSF3/8 in the centre north of TSF3 show a more variable hydrograph that comes close to surface in years 2006, 2010, 2015, and 2022. Genesis notes that TSF3/8 is sited within a trench and any water flow out of the bore is recovered in the toe-drain, so the actual reference to groundwater level relative to surface may be inaccurate. The TSF is bordered to the north by a Waste Rock Landform, and any mounding associated with the final lift of TSF3 is unlikely to result in environmental impact. Due to the non-representative groundwater levels being collected and their limited environmental value TSF3/8 should be removed from the groundwater monitoring programme. — The piezometer measurements are relatively stable. Genesis note that piezometer measurements changed from dyps to loggers around 2020, which may explain the step change at this this time.
East/Central	Groundwater levels to the east of the TSF are shown in Figure A.2. — Groundwater levels (TSF3/4 and TSF3/5) show distinct peaks of up to 4 m in response to rainfall events. This may result from the occurrence of higher permeability sand to the east of the TSF, as opposed to the lower permeability clay interbedded with sand to the west. As noted above TSF3/4 groundwater level are likely to be impacted by surface water flows directed to an adjacent borrow pit.

Sector	Description
	— TSF3/4 and TSF3/5 show a declining trend during the 2003 to 2008 care and maintenance period, and a rising trend from 2008 onwards in response to the recommencement of tailings deposition at TSF3. — TSF3/4 and TSF3/5 each reduced to a depth of 7.5 mbgl during the 2003 to 2008 care and maintenance period. This level is a ‘best estimate’ of background groundwater levels at these locations although steady state conditions may not have been reached. These relatively deep levels (compared to those observed elsewhere around the TSF) have been termed ‘background’ rather than ‘baseline’, as they likely to be affected by the open pit dewatering operation to the northeast. — The TSF4/5, and TF4/6 levels show a rise from 2020 to 2021 and then a decline from 2021 to 2023. A similar response occurs in TSF4 monitoring bores to the south and to the east (see below). — The rise and decline are interpreted to be in response to TSF4 deposition rates rather than the TSF4 toe drain that was not improved until in 2022. In addition, there is no toe drain along the eastern side of TSF4 (yet groundwater declined from 2021). — Groundwater levels are generally deeper on the eastern side of TSF3 and TF4 mainly due to the high ground level to the east but may also be lowered by the open pit dewatering operation to the northeast.
South	Groundwater levels to the south of TSF4 are shown in Figure A.3. — The long-term TSF3/7 hydrograph declines to a level of about 1.5 mbgl from 2003 to 2008 when the Gwalia gold mine was in care and maintenance. This is the most representative baseline groundwater level at this location as steady state conditions appear to have been reached. — As at other locations TSF3/7 shows a declining trend during the 2003 to 2008 care and maintenance period and a rising trend from 2008 onwards in response to the tailing deposition history. — TSF3/7 is located 600m to the south of TSF3 which indicates that TSF3 had a ZOI of greater than 600m to the south, prior to the construction of TSF4. — The long-term TSF3/7 hydrograph shows a muted response to rainfall events and rapid rise in 2020, followed by a decline from 2021, related to TSF4 deposition. — TSF3/7 is located 100 m to the south of TSF4 and the recorded groundwater levels are influenced by the TSF4 deposition. The TSF zone of influence can, therefore, be said to be at least 150 m to the south of TSF4. — TSF3/7, TSF4/3, and TSF4/4 show a rise in levels from 2020 and a decline from 2021. The rise and the subsequent decline in water levels likely result from the TSF4 deposition rates but could also be controlled by the toe drain improvement in 2022. However, the reduction in levels started in 2021 when the tailing deposition rate started to reduce rather than in 2022 when the toe drain improvements were completed. — TSF3/7 and TSF4/4 are in sand and show a distinct response to TSF4 deposition compared to the more muted response in TS4/3 that is in sand and clay. TSF3/7 at 100 m is further from TSF4 and is, therefore, slower to respond than TSF4/4. — TSF4 2020-2022 deposition is visible in the TSF4 hydrographs which show a rapid rise in response to TSF4 deposition taking the groundwater to, or close to ground level in TSF3/7, TSF4/2, and TSF4/3.

Sector	Description
West	Groundwater levels to the west of the TSF are shown in Figure A.4. — The TSF3/4 west bore groundwater levels differ significantly from the other bores in that, since the year 2000, they are consistently within 0.5 mbgl, and often closer to, or at, the surface. — A minimum mbgl trigger level would not be appropriate for the TSF monitoring bore groundwater levels to the west of the TSF, as the natural condition is for the groundwater level to be close to, or at ground level. — The TSF4 west groundwater levels (TSF4/1RD and TSF4/2) show a similar trend to the south and east monitoring bores in that they show a rise from 2020 and a decline from 2021. The rise and the subsequent decline in water levels likely results from the TSF4 deposition history. — TSF4/1RD shows a muted response to the tailings deposition as it slotted against sand and clay. TSF4/2 is also slotted against sand and clay but has sand just above the slots and is therefore more responsive to the tailings deposition. — The TSF4 toe drain flows of 2 to 3 m³/hr (0.6 to 0.8 L/s) are much lower than the TSF3 to drain that have ranged between 5 and 28 m³/hr (1.4 to 7.8 L/s). As a comparison in 2022 the TSF4 toe drain flow was about 2.5 m³/hr whilst the TSF3 toe drain flow was 5 times higher at about 13 m³/hr.

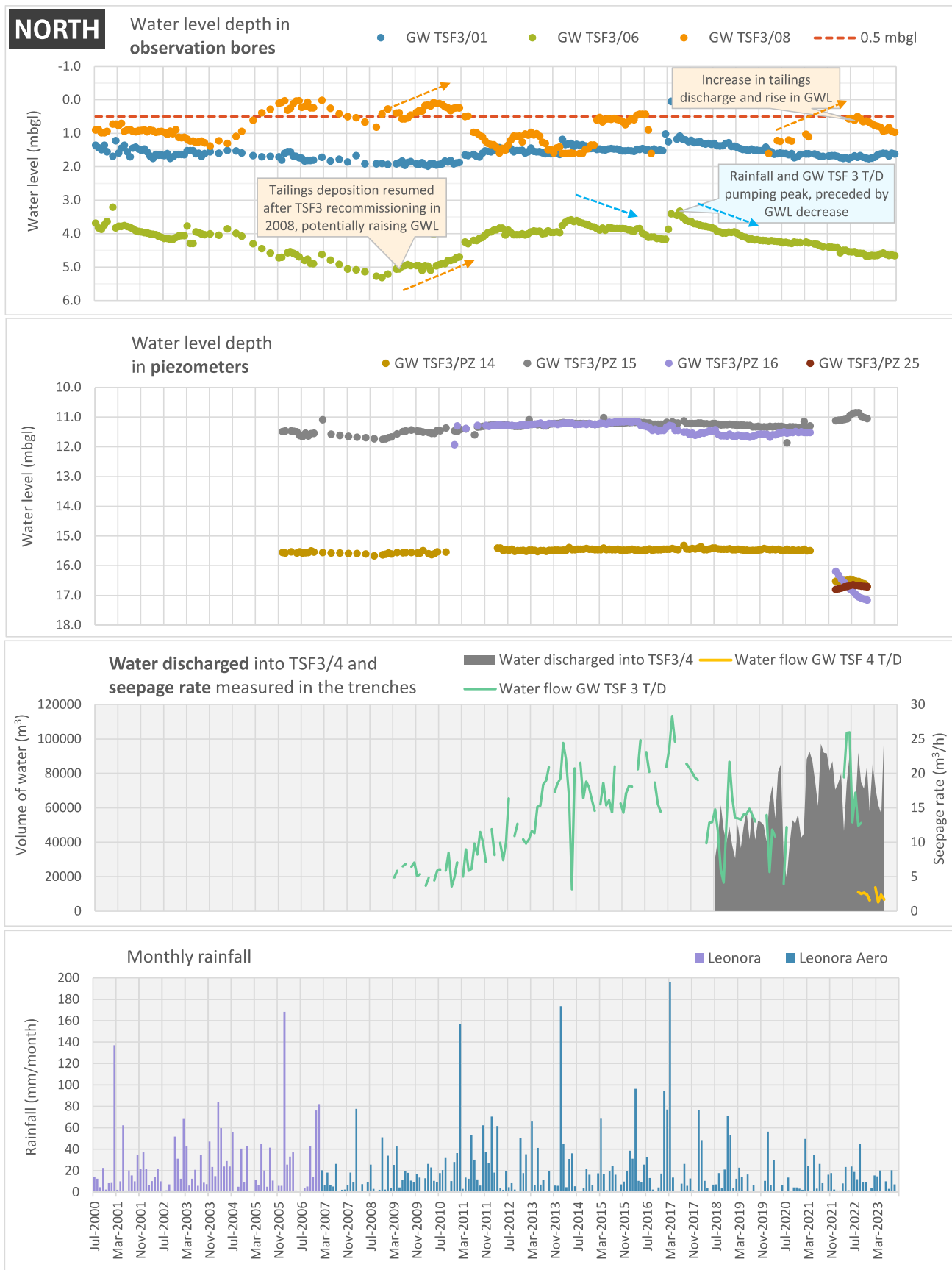


Figure A.1 Groundwater depth over time - North (2000 – 2023)

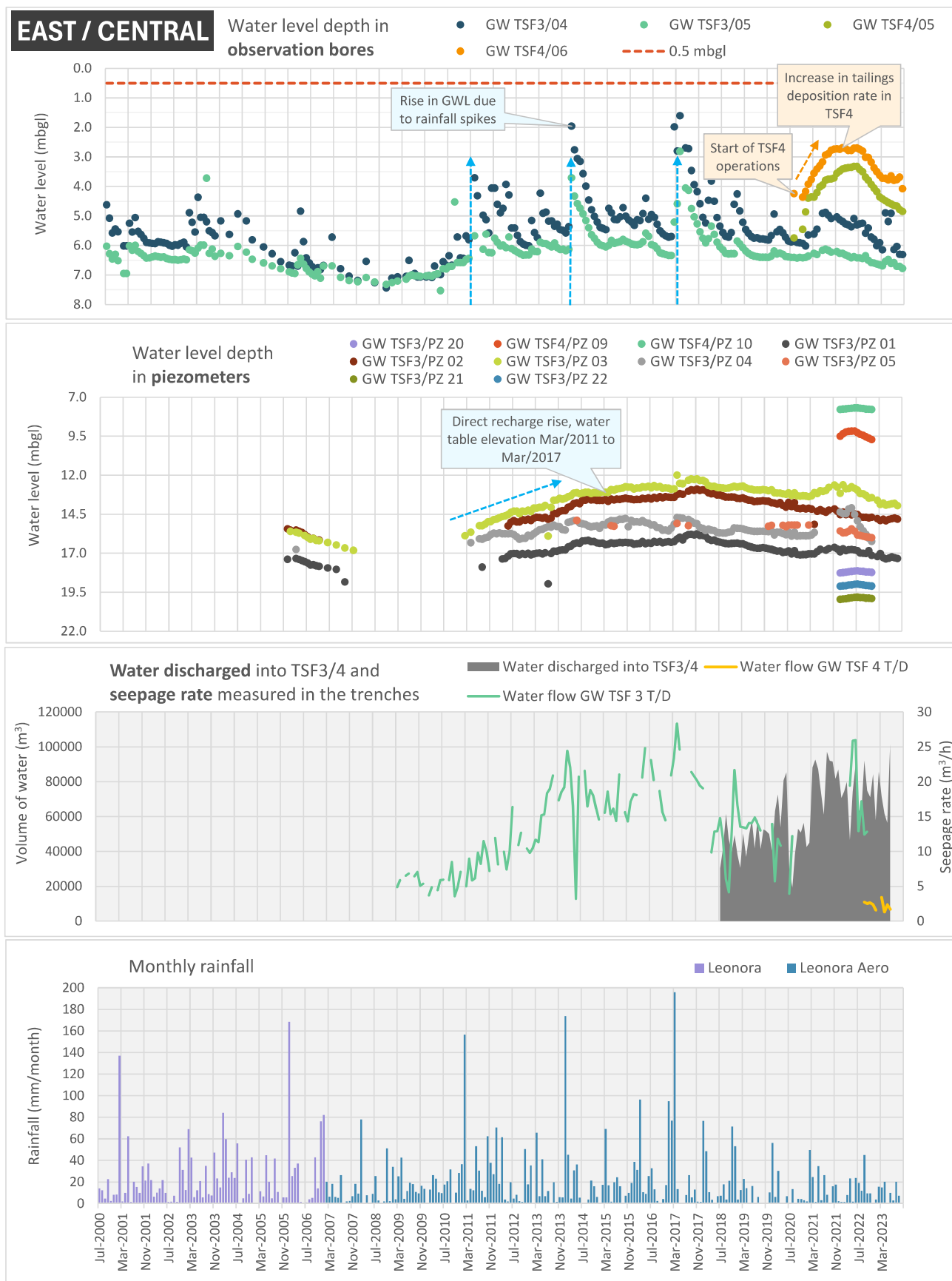


Figure A.2 Groundwater depth over time - East/Central (2000 – 2023)

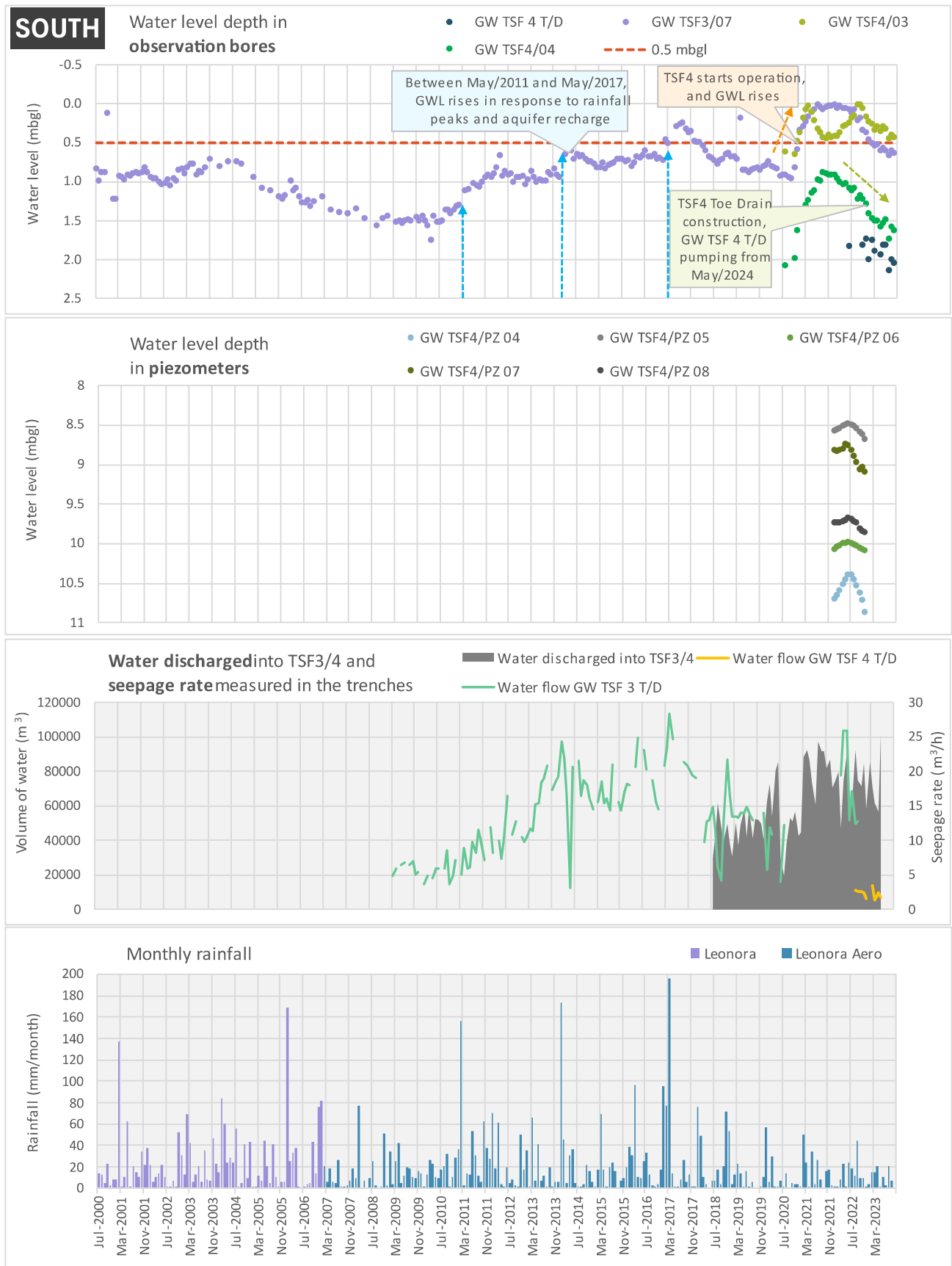


Figure A.3 Groundwater depth over time – South (2000 – 2023)

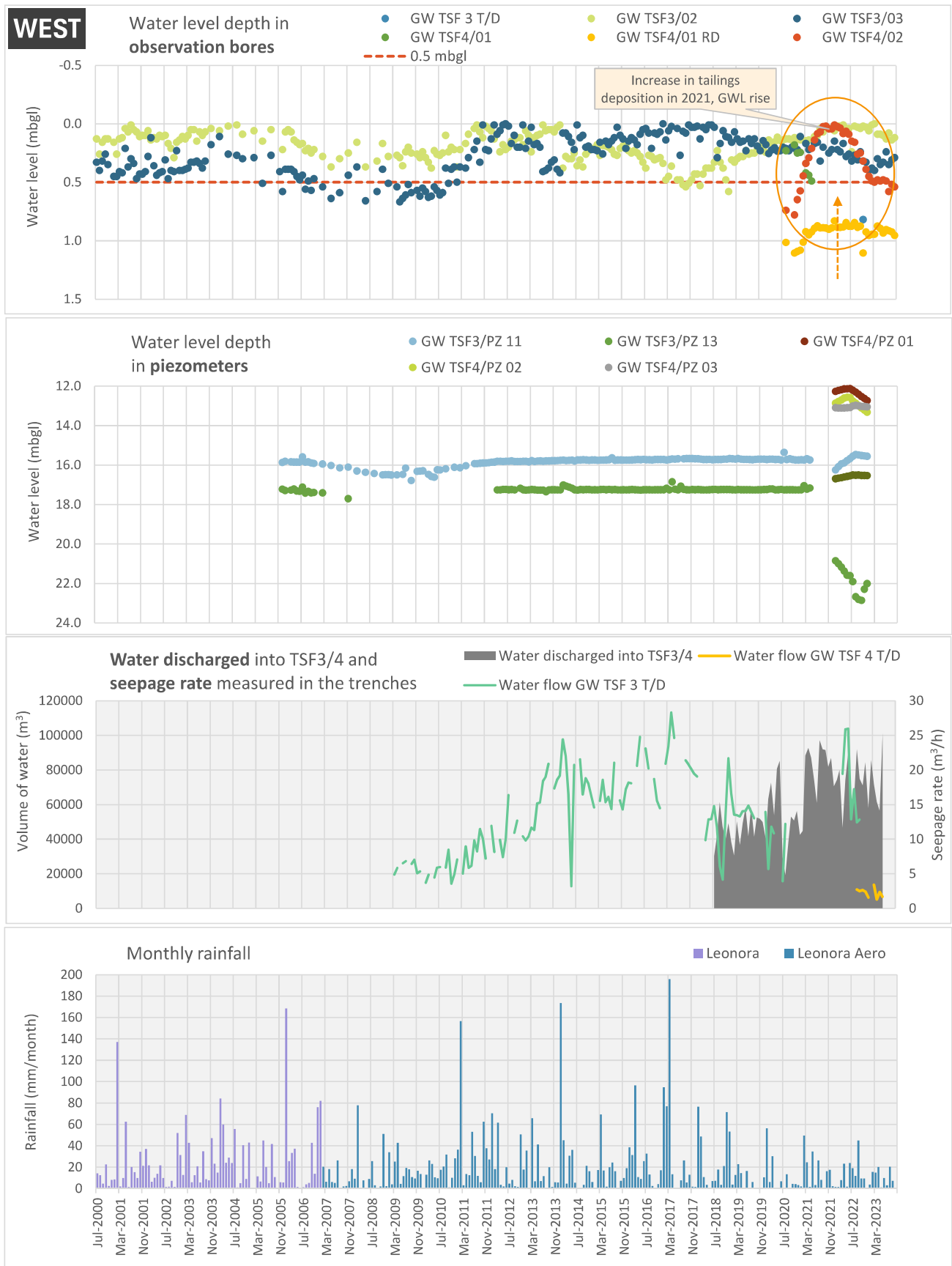


Figure A.4 Groundwater depth over time - West (2000 – 2023)

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