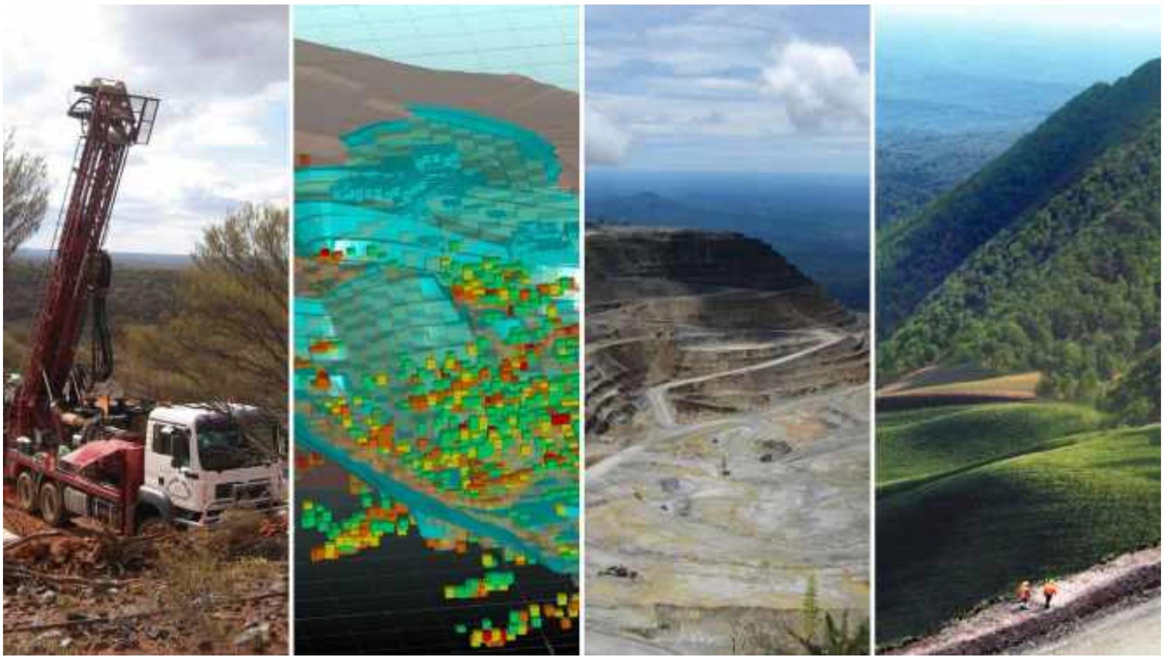
Final

Sunrise Dam Gold Mine – Tailings Dam Stage 12 Embankment Raise Numerical Modelling

Sunrise Dam Groundwater Study, Western Australia

AngloGold Ashanti Australia Limited



SRK Consulting (Australasia) Pty Ltd ▪ AGA028 ▪ February 2025

srk consulting

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Useful definitions

This list contains definitions of symbols, units, abbreviations, and terminology that may be unfamiliar to the reader.

AGAA	AngloGold Ashanti Australia Limited
CTD	Centrally Thickened Discharge
DEM	digital elevation model
DEMIRS	Department of Energy, Mines, Industry Regulation and Safety
EVT	evapotranspiration
GIS	geographic information system
kL/d	kilolitres per day
km	kilometres
L/s	litres per second
LiDAR	light detection and ranging
m	metres
m/d	metres per day
m^3/d	cubic metres per day
mAHD	metres (Australian Height Datum)
mbgl	metres below ground level
mm	millimetres
RCP	Representative Conservation Pathway(s)
RMS	Residual Mean Square
SRK	SRK Consulting (Australasia) Pty Ltd
SRMS	Scaled Residual Mean Square
TDS	total dissolved solids
TSF	tailings storage facility

1 Introduction

AngloGold Ashanti Australia Limited (AGAA) has approached SRK Consulting (Australasia) Pty Ltd (SRK) to undertake numerical groundwater modelling to assess potential seepage impacts from future embankment raises of the Centrally Thickened Discharge Tailings Storage Facility (CTD TSF), located ~3 km southeast of the Cleo/Sunrise open pit at the Sunrise Dam Gold Mine (SDGM). The CTD TSF has been operational since 2000, with the footprint most recently increased by the Stage 10 expansion in 2017. AGAA is seeking to raise the height of the existing Stage 10 embankment, however, the overall maximum height of the CTD TSF will remain at the current elevation. The CTD TSF has existing seepage interception measures comprised of trenches and abstraction bores and a spatially extensive groundwater monitoring network with monthly observations.

The objectives of the numerical modelling are:

- to calibrate the model to the historical groundwater and abstraction data to simulate current and historical seepage rates from the CTD TSF and refine hydraulic conductivity of the hydrogeology underlying the CTD TSF
- simulate groundwater levels during the operation of the CTD TSF Stage 12 raise for three climate scenarios to assess for potential impacts
- simulate groundwater levels following closure of the CTD TSF.

Available data at the CTD TSF covered a long period (>14-years) of deposition, several storm and flooding events, and abstraction from the seepage interception trenches and bores. Groundwater responses in the observed data available for calibration is of the same magnitude as expected for future CTD TSF behaviour. The final calibration has achieved a good result to matching trends in the shallow bores; periods of increase, decrease and the magnitude of overall fluctuation are well represented.

All predictive scenarios simulated a continuation of the decline in water levels following the peak in early 2024 caused by flooding at the site after large rainfall events in January and March 2024. The modelled reduction in applied seepage infiltration in late 2025 due to covering of the foundation with tailings further increases the decline in groundwater levels, particularly in the south and southeast. The operation of the CTD TSF is managed by seepage mitigation measures and should have little impact on the maximum groundwater levels which are most sensitive to large rainfall and flooding events.

2 Data reviewed

Data reviewed for this project included:

- Groundwater levels from 75 piezometers and bores around the CTD TSF. Water levels further from the CTD TSF at AGAA's borefields and the Cleo/Sunrise pit were also provided for context. Groundwater levels were provided from 2009 until August 2024 and include the most recent large rainfall event in March 2024 that caused significant flooding on site.
- Abstraction from trenches and recovery bores.
- Rainfall data for the site.
- Discharge to the CTD TSF – available in the calibration phase of the provided GoldSim model and outputs.
- CTD TSF levels and geometry over time from elevation grids
- Regional numerical model files.

Studies/reports reviewed for conceptualisation included:

- August 2003 – URS – Final Summary Report Hydrogeological Investigation of CTD Tailings Storage Facility (has information of pumping tests and initial modelling)
- August 2005 – URS – Hydrogeological Review of CTD Expansion and Seepage Mitigation (further modelling, infiltration tests, and missing borelogs CTD26, 27)
- November 2013 – URS – Review of CTD TSF Seepage Management Strategies (good summary of modelling and conceptual hydrogeology)
- June 2018 – Groundwater Investigations for the Proposed CTD TSF Stage 10 Expansion (proposed works)
- 2018 – Sunrise Dam – CTD and Processing Plant Drilling and Monitoring Bore Installation (execution of works)
- 2019 – Sunrise Dam – CTD Upgrade Monitoring Bore Drilling and Installation Program (further execution of works)
- August 2021 – AECOM – Groundwater Monitoring Summary – Centrally Thickened Discharge Tailings Storage Facility, July 2018 to June 2021 (most recent triennial groundwater monitoring summary, previous triennial reports were also provided)
- June 2022 – Groundwater Consulting – Sunrise Dam Groundwater Modelling (regional scale modelling)
- May 2023 – Sunrise Dam Gold Mine Climatic Conditions and Design Parameters Report (briefly reviewed for range of predictions)
- September 2023 – Sunrise Dam Gold Mine Groundwater Operating Strategy
- January 2024 – WSP – Sunrise Dam – CTD and Processing Plant Drilling and Monitoring Bore Installation.

Overall, the geographical and temporal coverage of the TSF is very good, enabling a robust model calibration and scenario development for the expansion of the TSF.

There is a long record of water levels and recovery trench and bore abstraction rates during construction works for CTD TSF stages, with a good record of groundwater level responses from both tailings deposition (particularly in the expansion in the south) and climatic events (lower rainfall and subsequent water level declines) in bores further from the TSF (CTD16, CTD17). Where bores have been decommissioned, there is sufficient overlap with readings from replacement bores.

3 Conceptual model

3.1 Topography and setting

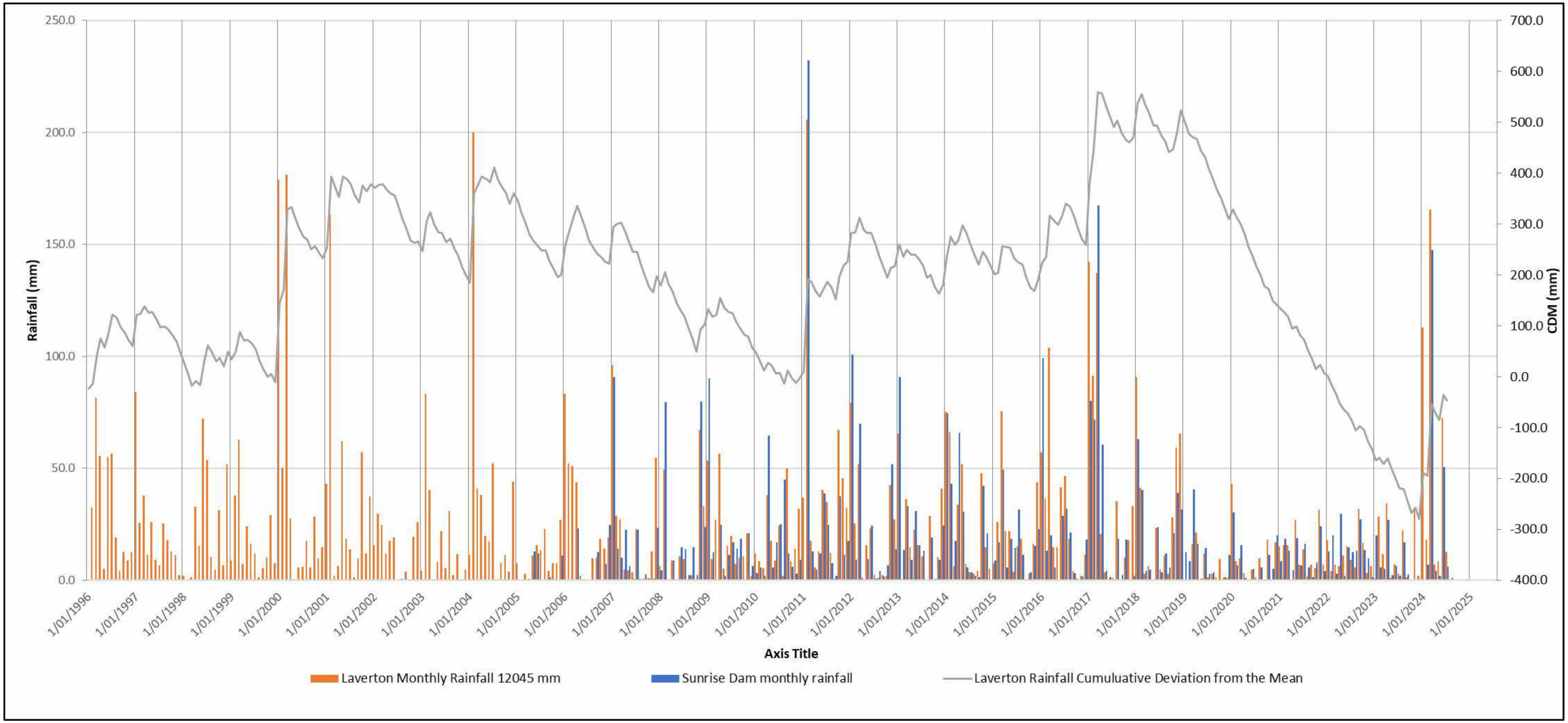
The Sunrise CTD TSF is located 3 km east of Lake Carey along an ephemeral drainage line. Topography is gently sloping from 500 mAHD 18 km to the east, to 395 mAHD at the edge of Lake Carey. East of the CTD TSF steeply sloping hills are formed by outcropping Archaean Basement rock. The elevation of the CTD TSF ranges from 401 mAHD on the west and 409 mAHD on the east. Aeolian dunes are located on the fringe of Lake Carey, within which are clay pans that frequently hold water following periods of high rainfall and/or recharge. The clay pans are located approximately halfway between Lake Carey and the CTD TSF.

3.2 Climate

The project area is located in a continental arid climatic region where annual evaporation (2,780 mm) greatly exceeds the average annual rainfall (233.7 mm – recorded at Laverton) (WSP, 2023). Approximately 60% of rainfall is between December and March during extreme rainfall events associated with cyclonic activity (URS, 2013) with low and infrequent daily rainfall totals (WSP, 2023). Annual rainfall recorded at the site since 2001 has an annual average of 236 mm with a range of 80–509 mm a year, similar to the Laverton long-term average. Available data is presented in Figure 3.1 as monthly rainfall totals and a cumulative deviation from the mean to represent overall rainfall trends.

There have been 6 years with very high rainfall events recorded at the site processing plant weather station since 2009 (the model calibration period), where rainfall exceeded 75 mm in a single month (February 2011, January 2012, January 2013, January 2016, January and March 2017, January 2024 and March 2024). These events led to significant (standing water on Lake Carey and fringing clay pans) and prolonged (over 1 month) flooding at the site (evidenced by available timelapse imagery on Google Earth engine and 2024 site observations). For the calibration period, the 2011, 2017, and 2024 events recorded over 110 mm in a single month.

Figure 3.1: Laverton and Sunrise Dam rainfall



Notes: Cumulative Deviation from the Mean (CDM) represents trends in overall rainfall over long periods of time, January 2024 rainfall recorded at Laverton missing from Sunrise Dam due to faulty gauge at the time of storm

3.3 CTD TSF operation and other abstraction

The CTD TSF has been operating since 2000, the original footprint foundation was covered by tailings by 2006. Footprint of the CTD TSF was expanded by the Stage 10 expansion on the southeast perimeter in 2017 (Figure 3.2) with deposition into this expansion occurring in 2020. The Stage 10 expansion is almost completely covered by tailings with only a small section of uncovered foundation remaining along the southeastern and eastern edge (Figure 3.2). Seepage interception measures have been progressively implemented as (URS, 2013):

- Northern trench in August 2003
- Southern trench in October 2003
- Eastern trench in January 2006 (decommissioned and covered by the Stage 10 expansion)
- CTDRB3 abstraction bore in March 2008
- CTDRB2 abstraction bore in October 2008
- CTRDB1 abstraction bore in April 2010
- Stage 10 trench in September 2019.

The Cleo/Sunrise open pit is located ~3 km to the northwest of the CTD TSF and has been operating since 1994. Dewatering rates for the Cleo/Sunrise open pit and underground range between 4,000 m^3/d and 10,000 m^3/d.

Bravo borefield is located ~2.5 km to the north-northwest of the CTD TSF. The borefield was commissioned in September 2022 and has been operating at an average rate of 1,590 m^3/d.

Figure 3.2: CTD TSF progression

2016 – original CTD TSF footprint: 2017 – Stage 10 expansion: 2024 – current tailings extent

Source: 2016, 2017 Google Earth Engine Timelapse, 2024 ESRI World Imagery

3.4 Geology

The site is located on Archaean Greenstone meta-sedimentary, meta-volcaniclastic and felsic to intermediate metavolcanic rocks overlain by surficial transported lateritic gravels, calcrete, alluvium and colluvium deposits. At the site, the Archaean Greenstone basement is highly weathered into a lateritic profile composed of saprock and saprolite.

The Tertiary period Lake Carey Palaeodrainage system, located on the western side of the site, is comprised of palaeochannel sands and lacustrine clay and reaches an average depth of 40 m (Groundwater Consulting, 2022).

3.5 Hydrogeology

The hydro-stratigraphy at the CTD TSF is comprised of a surficial aquifer made up of transported alluvium, ironstone, calcrete, and palaeochannel deposits, and a deeper Archaean bedrock aquifer. The weathered bedrock saprolite clay profile acts as an aquitard between the two aquifers. The hydro-stratigraphy adopted in the model is largely the same as that presented in the URS 2013 modelling exercise, with the exception of extending the extent of lake clays underlying the high hydraulic conductivity formations (alluvium, ironstone, and pisolitic palaeochannel) beneath the CTD TSF based on field drilling observations.

Table 3.1: Hydro-stratigraphy

Sequence	Lithological unit	Typical thickness (m)	Description
Transported	Alluvium	0.5–1.5	Gravelly, sandy silt, limited to the channel on the western side of the TSF.
	Ironstone	0.5–4	Iron cemented gravelly sand silt, with subordinate calcium and silica cemented beds.
	Pisolitic palaeochannel	1–10	Pisolitic gravels with minor sand and clay.
	Gravelly clay	5–20	Sandy and gravelly clay, probably lacustrine with minor ironstone and silcrete cemented inter-beds.
	Lake clay	1–20	Homogeneous highly plastic lacustrine clays. Previously suggested extent was limited in distribution to areas west of the CTD TSF. However, recent field investigations have logged on the south and southeast segment of the CTD TSF. Where gravelly and silty clay is logged, a higher hydraulic conductivity than the saprolite is expected.
Archaean Bedrock	Weathered bedrock	20–30	In-situ saprolite clay profile of weathered bedrock – considered an aquitard.
	Bedrock		Fresh bedrock.

Source: Adapted from (URS, 2013)

The pertinent aspects of the hydrogeology at the CTD TSF and Sunrise Dam Gold Mine are, in the context of numerical modelling:

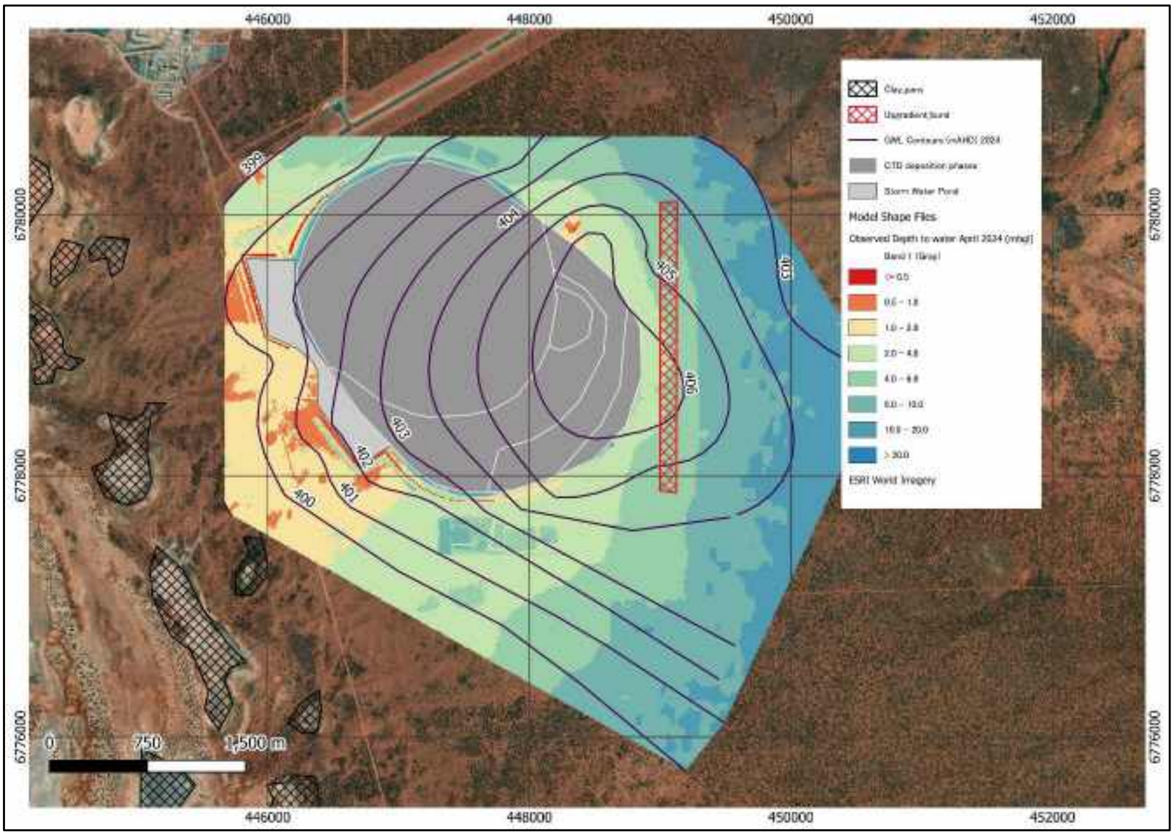
- Flooding events, particularly those caused by rainfall greater than 75–100 mm in a single month, have a significant impact on recharge to groundwater from ponding at Lake Carey, Fringing Clay Pans, and stormwater runoff captured in the stormwater storage pond, and ponding around the CTD TSF. This is observed in large (>2 m) responses in monitoring bores with a long observation record (CTDMB16, CTDMB2, CTDMB11).
- Surficial transported deposits overlie a weathered Archaean basement; these are variable under the CTD TSF with higher permeability pisolitic palaeochannel and calcrete, silcrete ironstone deposits in the north and centre of the CTD TSF and lower permeability lake clay deposits in the west. The depth of these materials is typically between 10 m and 30 m below ground level (mbgl) at the CTD TSF.
- Bedrock geology at the site is comprised of metasedimentary, metavolcaniclastic, and metafelsic to intermediate metavolcanic Archaean greenstone belt formations. Faulting inferred within the basement by 1:500,000 mapping (DEMIRS, 2024).
- A regolith profile of saprolite and saprock is present consistently across the site to a depth of up to 70–80 mbgl. The upper and lower saprolite clay layer is consistent within the regolith profile and will act as an aquitard separating the saprock and fresh bedrock from any superficial deposits that underlie the CTD TSF.
- A palaeochannel that underlies the Lake Carey salt lake is present to the west of the CTD TSF and Cleo/Sunrise pit. The palaeochannel is up to 85–100 m deep in areas and consists of sand, silts and clays. The upper part of the palaeochannel (to 40 mbgl) has a higher proportion of sands.

- Groundwater has high salinity due to the arid low precipitation, high evaporation climate. Total dissolved solids (TDS) in groundwater ranges between 50,000 mg/L and 180,000 mg/L, with salinity increasing with depth and high (90,000–120,000 mg/L) TDS recorded at the periphery of Lake Carey. As the shallow aquifer is lower salinity than the deep aquifer and groundwater at Lake Carey is highly saline, salinity from the CTD TSF should not be increased by density driven flow towards Lake Carey. Density driven flow was not considered in the model.
- Local to the CTD TSF, site groundwater flows from higher topography in the southeast towards the salt lake in the west and northwest and is thought to discharge to the Lake Carey palaeochannel. There is a distinct downward head in the area with bores at the CTD TSF recording 0.5–1.0 m head differences between deep and shallow bores. Bores further from the CTD TSF (CTDMB37) record a lower (0.2 m) vertical gradient.
- A peak in groundwater levels is observed in April 2024 following large rainfall events in January and March and subsequent flooding. Subsequently depth to water decrease to a little as 0.4 m (at CTDMB7) in areas west of the CTD TSF; these high levels have since receded. A similar trend is observed in all bores at the CTD TSF.
- Low depth to groundwater is most acute in areas where the topography dips in the alluvial channel on the western side of the CTD TSF and is not due to local mounding in this area as the groundwater gradient is uniform and gentle (0.003 m/m). Mounding from the CTD TSF is more evident in the east as a result of ponding on the foundation, increased infiltration at the upstream bund/dam and distance from seepage mitigation abstraction. The peak April 2024 groundwater contours and depth to water is presented in Figure 3.3.
- Minimal information is available to inform pre-CTD TSF groundwater levels or responses to high rainfall events. Inferred pre-CTD TSF (September 1999) groundwater contours are presented in Figure 3.4; these are likely to represent a low (or at least not a peak following flooding) in groundwater levels as the groundwater level measurements were recorded six months following a moderate (62 mm in March 1999) rainfall event.
- The top of clay within the regolith profile undulates between Cleo/Sunrise pit and CTD TSF and likely limits the propagation of drawdown from the Cleo/Sunrise pit towards the CTD TSF. There are several areas where the interpreted top of clay forms ‘ridges’ between the pit and CTD TSF. Thus, flow from the CTD TSF to the Cleo/Sunrise pit will likely be limited to where the non-clay regolith and transported material is not interrupted by clay ‘ridge’. Historical data from shallow monitoring bores (PMB1–4, construction uncertain) between 2009 and 2023 suggest that there has been drawdown of 1–2 m in the area between the pit and CTD TSF since 2017; however, it is unclear if this is due to Cleo/Sunrise pit dewatering, or a natural decline from lower rainfall during this period. Calibration results suggest some connection between the Cleo/Sunrise pit as overall a better calibration could be achieved with the inclusion of the pit as a dewatering feature.
- Groundwater levels have been increasing steadily since mid-2021 in the southern and eastern section of the CTD TSF, despite declining water levels elsewhere. Increasing water levels in this area are a response to deposition in the Stage 10 expansion; seepage rates to groundwater will be higher in this area as the tailings are deposited on the exposed foundation, rather than a foundation completely covered by tailings in the original CTD TSF. A foundation covered by tailings will have lower seepage rates as the lower hydraulic conductivity tailings will slow vertical seepage migration, allowing for more time for slurry water to evaporate from the

partially saturated tailings. Seepage rates are therefore expected to decrease from the current rates, once the full Stage 10 footprint is covered with tailings.

- Abstraction from seepage interception trenches and bores is recycled back to the processing plant, then returned to the CTD TSF via slurry deposition; a proportion of water will be lost to evaporation and some seepage to groundwater that is not then intercepted by bores or trenches. The southeastern and eastern section of the CTD TSF does not have any seepage interception (the Stage 10 trench terminates approximately at the easting centreline of the CTD TSF, the same easting as the interception bores). Seepage abstraction and deposition of slurry water is recorded throughout the operation of the CTD TSF and used for model calibration.
- Recent drilling within the CTD TSF tailing material in 2024 (including downhole Nuclear Magnetic Resonance (NMR) testing, piezometer construction and core testing) observed that the tailings are largely unsaturated with only one bore in the centre of the CTD encountering a saturated column ~1 m above natural surface. This demonstrates that seepage rates are extremely low once a tailings beach has formed.
- Recent drilling in 2024 at the CTD TSF confirmed a shallow (~5 m thick) pisolite ironstone surficial aquifer in the south and gravelly alluvial deposits in the east.
- Additional to the recent drilling and testing works performed in the second half of 2024, all existing (and newly drilled) monitoring bores at the CTD TSF were slug tested to inform the initial hydraulic parameters for numerical modelling. Results of the slug testing analysis are summarised in Table 3.2.

Figure 3.3: Depth to water and groundwater contours April 2024 peak in groundwater levels



Notes: Low depths to water on the immediate fringe of the CTD TSF display groundwater levels in the seepage interception trenches.

Figure 3.4: Inferred pre-CTD TSF groundwater contours

Table 3.2: 2024 slug testing results

Bore ID	Easting	Northing	Screen from (mbgl)	Screen to (mbgl)	Date	Average slug test K (m/d)
CTDMB2	446692	6780438	8.2	9.2	06/01/2024	8.07
CTDMB2A	446699	6780438	14.0	20.0	06/01/2024	1.53
CTDMB3	447867	6780418	11.7	12.7	20/02/2024	0.30
CTDMB7	446080	6778888	5.0	6.0	06/02/2024	
CTDMB11A	445734	6779605	4.0	10.0	05/02/2024	4.31
CTDMB11B	445736	6779599	4.2	10.2	05/02/2024	2.10
CTDMB13	447274	6780504	5.2	17.2	07/01/2024	1.97
CTDMB16	444452	6779382	2.7	8.7	19/02/2024	4.99
CTDMB17A	450127	6779339	30.4	36.4	20/02/2024	11.83
CTDMB17B	450126	6779342	14.2	20.2	20/02/2024	1.79
CTDMB24A	446374	6778170	15.9	21.9	06/02/2024	1.75
CTDMB24B	446370	6778170	4.1	10.1	07/02/2024	3.19
CTDMB29A	448865	6779594	12.0	18.0	09/01/2024	4.76
CTDMB29B	448870	6779594	30.0	36.0	09/01/2024	0.29
CTDMB30A	447901	6780680	9.0	15.0	07/01/2024	13.03
CTDMB30B	447906	6780680	28.0	34.0	07/01/2024	7.75

Bore ID	Easting	Northing	Screen from (mbgl)	Screen to (mbgl)	Date	Average slug test K (m/d)
CTDMB31A	445487	6779279	5.0	8.0	06/02/2024	0.92
CTDMB31B	445487	6779280	15.0	20.0	06/02/2024	2.91
CTDMB31C	445475	6779288	25.0	28.0	06/02/2024	2.19
CTDMB32A	445808	6779288	6.0	10.0	05/02/2024	3.12
CTDMB32B	445795	6779302	11.0	17.0	05/02/2024	3.18
CTDMB32C	445808	6779311	25.0	30.0	05/02/2024	0.09
CTDMB33A	446383	6778326	5.0	9.0	07/02/2024	1.89
CTDMB33B	446357	6778332	14.0	20.0	19/02/2024	1.88
CTDMB33C	446384	6778346	24.5	28.5	07/02/2024	1.56
CTDMB34A	446822	6777970	4.0	10.0	17/02/2024	5.41
CTDMB34B	446822	6777975	17.0	21.0	17/02/2024	1.47
CTDMB34C	446811	6777980	24.0	29.0	17/02/2024	9.94
CTDMB35A	446284	6777958	6.0	8.0	17/02/2024	3.24
CTDMB35B	446285	6777963	12.0	14.0	17/02/2024	0.10
CTDMB35C	446285	6777969	19.0	25.0	17/02/2024	3.36
CTDMB36A	447216	6777593	5.0	8.0	19/02/2024	3.95
CTDMB36B	447216	6777598	9.0	12.0	19/02/2024	5.49
CTDMB36C	447215	6777604	24.0	28.0	19/02/2024	2.64
CTDMB37A	448211	6776587	6.0	11.0	21/02/2024	4.15
CTDMB37B	448211	6776593	16.0	18.0	21/02/2024	8.26
CTDMB37C	448211	6776599	22.0	24.0	21/02/2024	1.37
CTDMB38A	448160	6777802	6.0	8.0	18/02/2024	3.84
CTDMB38B	448160	6777807	12.0	14.0	18/02/2024	5.25
CTDMB38C	448160	6777813	23.0	28.0	18/02/2024	0.11
CTDMB39A	448948	6777984	0.0	6.0	18/02/2024	
CTDMB39B	448948	6777990	8.0	9.0	18/02/2024	7.02
CTDMB39C	448948	6777995	28.0	30.0	18/02/2024	0.07
CTDMB40A	448985	6778603	4.0	6.0	10/01/2024	8.97
CTDMB40B	448984	6778608	9.0	12.0	10/01/2024	2.49
CTDMB40C	448984	6778613	28.0	30.0	10/01/2024	0.51
CTDMB41A	448503	6779773	0.0	6.0	07/01/2024	1.85
CTDMB41B	448503	6779778	12.0	17.0	07/01/2024	7.74
CTDMB41C	448503	6779783	27.0	30.0	07/01/2024	0.81
CTDBH19	448871	6779216	0.0	30.0	16/09/2024	0.47
CTDBH15	448880	6778585	0.0	25.0	16/09/2024	0.62
CTDBH18	448391	6777982	0.0	15.0	16/09/2024	2.11
CTDBH14	447989	6777738	0.0	20.0	16/09/2024	0.93

4 Model build

The model was built in Groundwater Vistas and operated using the industry standard MODFLOW-USG code. Some pre-processing and post-processing was performed in Python to prepare abstraction and seepage inputs and read and graph heads files after each run.

4.1 Extent

The model extent was 26 km (from Lake Carey to the approximate top of the catchment) by 15 km (measured along the fringe of Lake Carey), with the CTD TSF on the centreline but to the western side (Figure 4.1). The extent was chosen to be large enough to allow up-gradient water flow to be applied as recharge and regulated by evapotranspiration (EVT) rather than assigning general head boundary conditions.

The Cleo/Sunrise pit and waste rock dumps were included in the model extent to allow calibration to include pit dewatering flows and levels; the intention was to exclude this area as no flow cells unless the inclusion of pit dewatering was found to be beneficial during calibration. However, these features were included after it was found that there is likely some influence from the pit and Bravo borefield (further discussed in Section 5). The level of detail (definition of waste rock dumps and regolith profile) was minimal in this area.

4.2 Grid

A uniform 100 m by 100 m cell size was initially developed in Leapfrog with a 10° rotation and was further refined into a quadtree grid with a minimum spacing of 25 m mostly refined around the perimeter of the CTD TSF to accommodate the high concentration of monitoring bores, trenches and abstraction wells. The grid refinement is presented in Figure 4.1.

Figure 4.1: Grid refinement

Notes: Left – entire model domain; Right – zoomed into the CTD TSF.

4.3 Layers

The model was constructed with seven layers to represent the shallow aquifer, aquitards (saprolite and lacustrine deposits) and deep fractured bedrock aquifer. The model layers are presented in Table 4.1.

The CTD TSF was represented in layers 1 and 2; these layers were pinched out and deactivated everywhere outside the CTD TSF. Layer 2 is to represent the CTD TSF up to the present day for calibration, while layer 1 is to allow the possibility of assigning seepage (assigned by the river boundary condition) during the Stage 12 raise.

All surficial deposits were grouped as transported in the Leapfrog model and created as two layers (3–4) to allow for zonation of hydraulic conductivity within GIS and Groundwater Vistas.

Saprolite, saprock and basement rock were assigned to layers 5, 6 and 7 respectively.

Table 4.1: Model layers

Layer	Represents	Comments
1	Stage 12 Raise TSF Material	Not utilised during calibration
2	Current TSF material	
3	Transported shallow	Predominantly high hydraulic conductivity
4	Transported deep	
5	Saprolite	
6	Saprock	
7	Archaean basement	

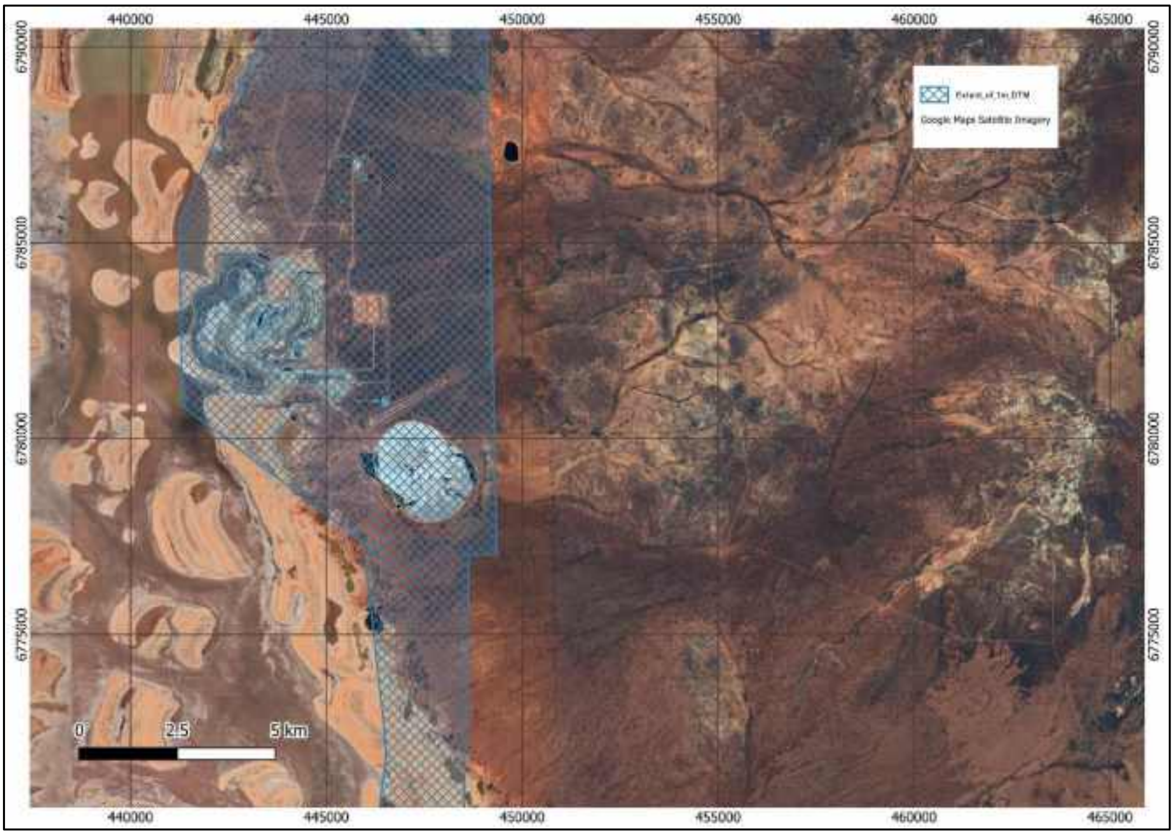
4.4 Layer elevations

The provided 1 m digital elevation model (DEM) was merged with the available government 1 second DEM for the model surface. The government DEM was assumed to be less accurate than the light detection and ranging (LiDAR) and was 3–7 m higher in the CTD TSF area than the LiDAR data. To account for this, the government DEM was lowered by 3 m to align the two DEMs at the lake edge prior to merging. The extent of LiDAR coverage covers the CTD TSF and the immediate area (500 m or more from the CTD TSF boundary); LiDAR coverage is show in Figure 4.2. Monitoring bores have been surveyed (top of casing and ground level) and groundwater elevations used for the calibration are measured from surveyed points and do not rely on LiDAR or DEM data.

The topography was elevated by approximately 8 m at the southern external perimeter embankment (the maximum height of the CTD TSF will remain the same) to incorporate the Stage 12 raise and a cover in the closure scenarios. The raise was extended out to the current TSF footprint with a steep sided ‘wall’ at the CTD TSF boundary (the design CTD TSF raise is presented in Figure 4.5). The surface is not intended to realistically represent the final CTD TSF landform at closure but rather to allow for representation of several prediction scenarios in the numerical model should they be required while also reducing the requirement for adjusting the model surface after calibration.

Remaining layer elevations were set to contacts between shallow aquifer, saprolite, saprock and basement rock in the provided Leapfrog project with minor adjustments based on hydrogeological holes and the provided WSP Leapfrog project. Additionally, the shallow aquifer was split into two layers to allow for placement of thicker high hydraulic conductivity layers into the lacustrine clays.

Figure 4.2: Extent of LiDAR available for topography elevation



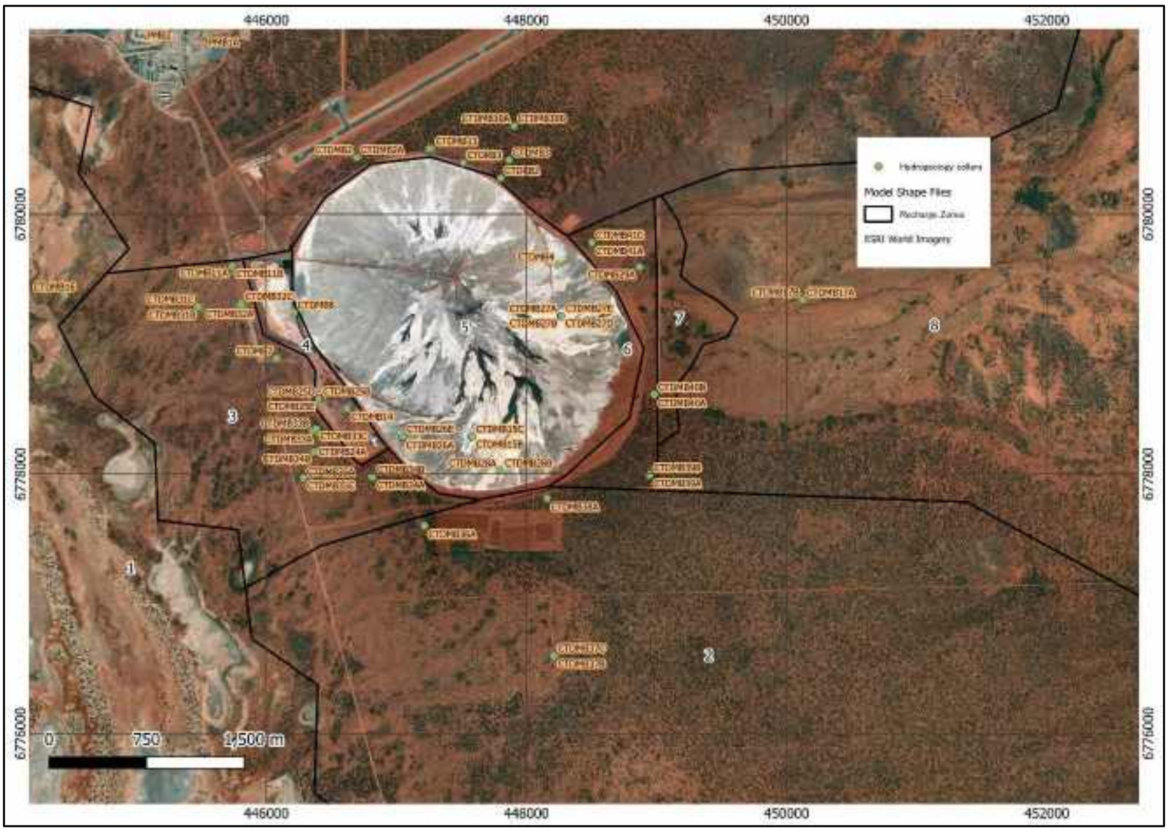
4.5 Boundary conditions

Boundary conditions used to represent the recharge, discharge, seepage and abstraction mechanisms in the model are presented and described in Table 4.2. The recharge zones are presented in Figure 4.3, and the location of other boundary conditions is presented in Figure 4.1. Starting values are included, however many of these were varied during the calibration.

Table 4.2: Boundary conditions

Boundary condition	Value	Unit	Description
Recharge	$1e^{-6}$ to $8e^{-5}$	m/d	Higher values for recharge were applied where flooding has been observed at Lake Carey, clay pans, the stormwater storage pond, and the dam/bund on the western side of the CTD TSF. Additionally recharge multipliers were increased during flooding events to account for higher infiltration during flooding events. Water levels in model cells in the high recharge areas at Lake Carey temporarily rose above surface during calibration during the higher rainfall events for one time step, this water was re-distributed in the model in the subsequent time step and was not removed – i.e. while the peaks are unrealistic the total volume of water that recharged over 1 month time step should be similar to that of recharge from ponding over a 2–3 month period.
EVT	0.003 to 0.006	m/d	EVT was set to the equivalent of between 1.0 m and 2.0 m per year across the site. Extinction depth was set at between 0.5 m and 3.5 m.
River package	RCond Head	m/d mAHD	Conductance values were calibrated for the different phases of deposition. Lower values were applied where the foundation was covered with tailings to account for the influence for the longer seepage times and thus higher potential for seepage to evaporate before seeping into the groundwater. The head was kept constant at different values within the TSF material and on the foundation. The layer where the boundary condition was applied was also varied; layer 2 for TSF material, and layer 3 for pooling on the foundation. The CTD TSF footprint was ~4.82 km^2 based on the original outline and Stage 10 expansion.
Constant head/drain	Pit – 336 Lake – 396	mAHD	A constant head boundary was placed at the northwestern edge of the model to simulate regional groundwater outflow. A low proportion (<1%) of inflow/outflow was associated with this condition (EVT, recharge, abstraction and seepage accounted for >99% of flows during calibration). The pit was represented by a constant head boundary initially and sometimes changed for a drain or well boundary condition to adjust scenarios.
Wells	Based on historical abstraction	m^3/d	Historical abstraction rates were applied at abstraction wells. Trenches were represented as wells with historical abstraction and the trench was assigned as an extremely high hydraulic conductivity feature in the model in layer 3 and 4, if appropriate. The hydraulic gradient in the trench would be essentially flat and will transmit any water to the abstraction point instantaneously.

Figure 4.3: Recharge boundary condition



4.6 Stress periods

Monthly stress periods were adopted for the calibration and prediction phases during and immediately after operation of the CTD TSF. The monthly stress period fits well with monthly groundwater observation and abstraction data and was sufficient to reproduce groundwater responses to rainfall events. The calibration period was from 2009 to late 2024 to incorporate available groundwater observation data around the CTD TSF and incorporates the most recent flooding from rainfall events in 2024.

4.7 Initial parameters

Hydraulic conductivity and storage parameter ranges were initially based on previous field investigations (AECOM, 2018), previous modelling work (URS, 2005; URS, 2013; Groundwater Consulting, 2022), and recent field investigations including slug testing, packer testing and laboratory sampling. Hydraulic zones were applied based on the provided WSP Leapfrog project, previous reporting, and field investigations. Zones are described in Table 4.3 and presented spatially in Figure 4.4.

Table 4.3: Hydraulic property zones

Hydro-stratigraphic unit	Zones	Initial hydraulic conductivity (m/d)	Comments
Tailings material	1	0.1–5	
Alluvium	8	0.2–4	
Ironstone/Laterite/ Pisolitic gravel	7, 8, 9, 10	1.5–20	
Gravelly clay and colluvium	2, 17	1.5–12	
Lake Carey palaeochannel	12	20	
Lake clay	11	0.01	
Saprolite	3	0.01	Exclusively layer 5, aquitard
Saprock	5	-	Exclusively layer 6
Bedrock	4	0.01–0.6	Exclusively layer 7
Faulted bedrock	16	NA	Added during calibration

Figure 4.4: Distribution of hydraulic property zones in layer 3

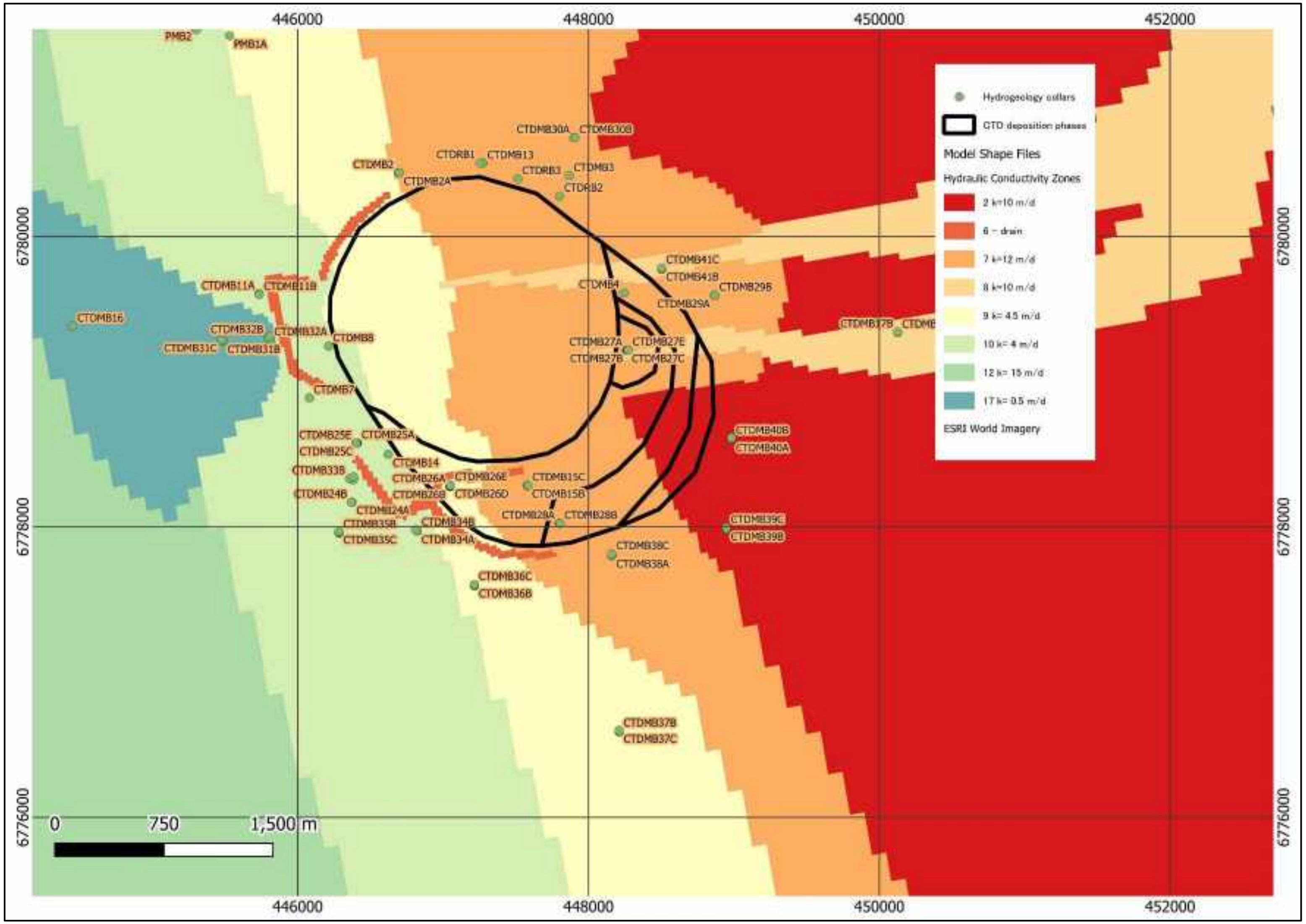


Figure 4.5: Topography with a future CTD TSF raise 12 incorporated

Notes: Looking north, assumed Stage 12 raise in blue, 3x vertical exaggeration.

5 Calibration

Hydraulic parameters, seepage (as a function of the river boundary condition conductance), recharge from rainfall and, to a lesser extent, EVT, were adjusted to calibrate the model to observation data. Abstraction from wells and trenches was prescribed as the metered abstraction rates. Observation wells were separated into the ‘sectors’ (Figure 5.2) to calibrate simulated water levels against observation data to assist with visualising the response of changes on different areas of the TSF.

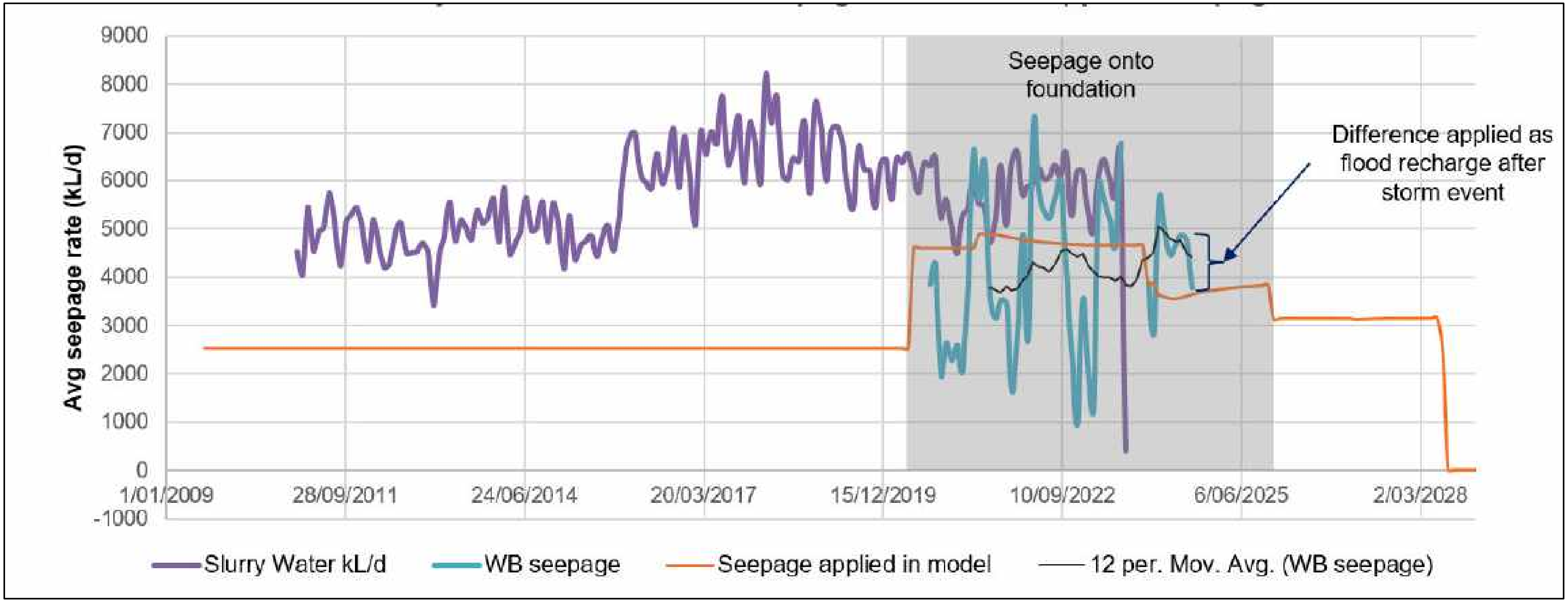
Effort was taken to replicate mounding of water levels as the CTD TSF expanded into the Stage 10 extension. The location of high seepage areas (conceptualised as where water ponded directly on the foundation without tailings retarding the flow) was adjusted several times in an attempt to match increases in water levels at various segments of the TSF. The adjustments of locations and timings were limited in number (Figure 5.3) where the TSF progression could be informed by LiDAR and historical satellite data, to avoid ‘overfitting’ observation data by adjusting inflow locations. As a result, it would not be possible to match simulated and observed levels exactly. Seepage through the tailings was also adjusted in matching trends.

Achieving a good match to trends in rates of decrease, rates of increase and magnitude of fluctuation in groundwater level change were prioritised over absolute groundwater elevations during the calibration.

Seepage rates were checked during each calibration run to compare to the water balance estimates for seepage to ensure that good matches to water level observations were not being achieved with seepage that were orders of magnitude higher or lower than those estimated by the water balance (and outside the range of possibility, i.e. greater than deposition rates). The water content (i.e. the maximum possible seepage from tailings) is measured daily and water balance estimates of seepage are derived from these rates, pond levels, and evaporation and rainfall rates. The slurry water, simulated water balance seepage rates and the applied seepage rates in the groundwater model during the final calibration (and extended out to predictive scenarios) are provided in Figure 5.1.

Similarly, simulated well abstraction was also checked to ensure that simulated abstraction was not being reduced from actual metered abstraction.

Figure 5.1: Slurry deposition, water balance inferred seepage, and groundwater model seepage



Notes: Increase in the applied seepage rate is due to a pond forming on the exposed foundation. Reduction in the applied seepage rate in 2026 is due TSF material covering the foundation.

Figure 5.2: Sectors used to group observed versus simulated hydrographs

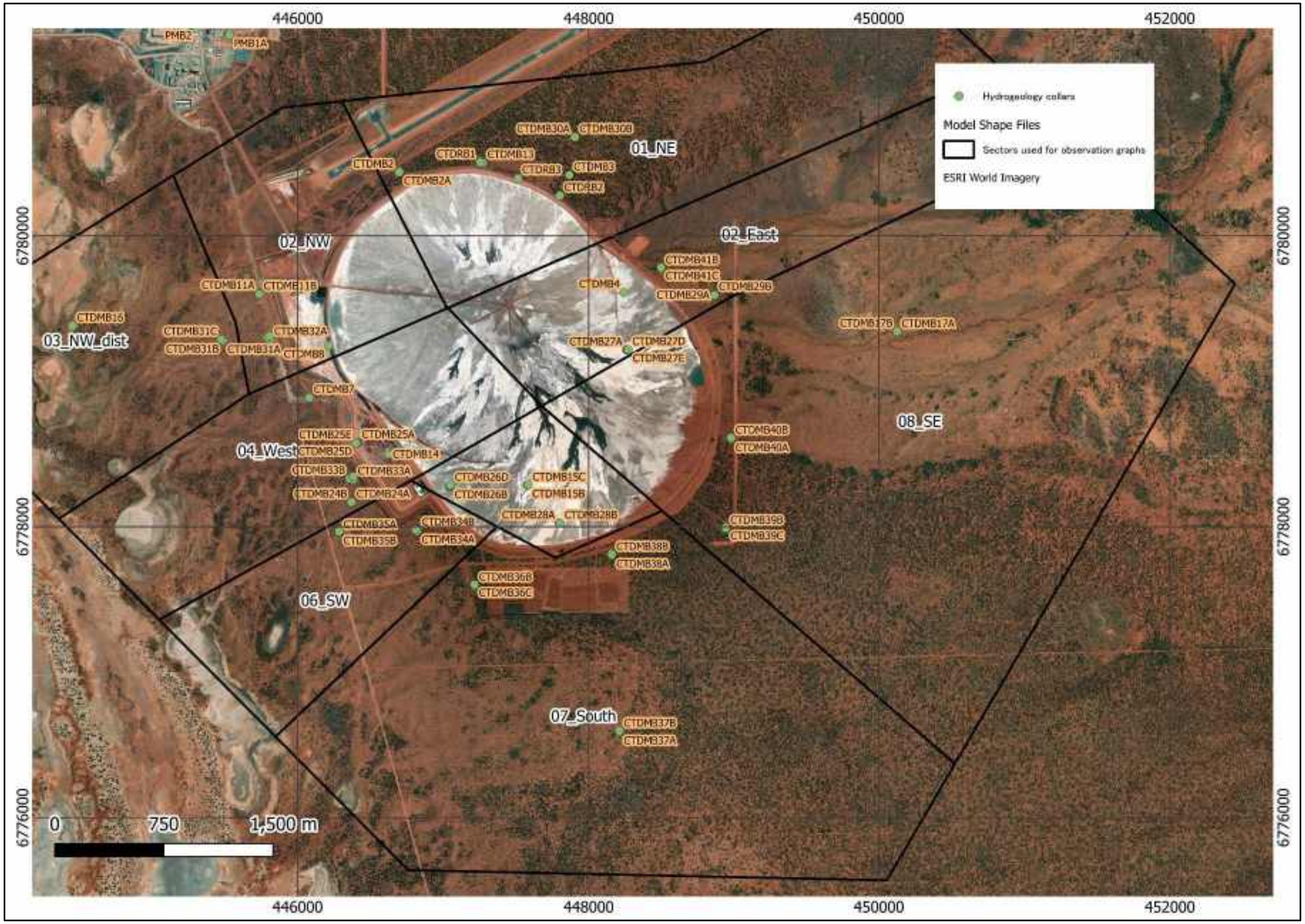
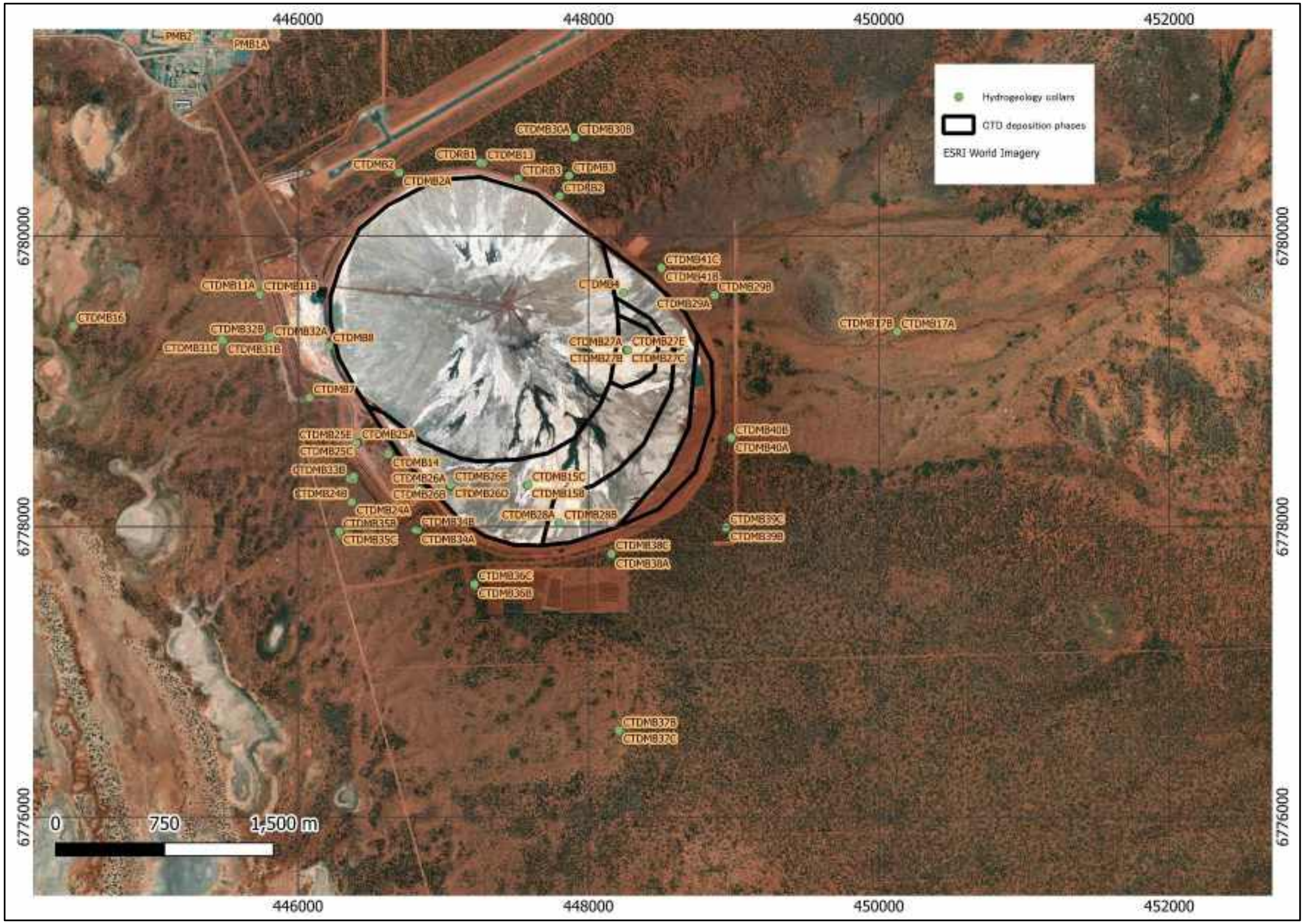


Figure 5.3: Stages of TSF deposition pond location on foundation



5.1 Discussion

Available data at the CTD TSF covered a long period (>14 years) of deposition, several storm and flooding events, and abstraction from the seepage interception trenches and bores. Groundwater responses in the observed data available for calibration is of the same magnitude as expected for future CTD TSF behaviour and is very relevant to model predictions. The final calibration has achieved a good result to matching trends in the shallow bores; periods of increase, decrease and the magnitude of overall fluctuation are well represented.

The influence of pit dewatering and, to a lesser extent, the Bravo borefield (in operation since September 2022), became evident during calibration; in general, better calibration results could be achieved with pit dewatering present. This was observed in the north section of the CTD TSF (as well as the constant drawdown in the Bravo borefield before operation); as such, Cleo/Sunrise pit was kept within the model. Pit dewatering would have a 1–2 m influence on groundwater levels and groundwater flow is likely to be impacted via vertical migration through the saprolite aquitard and some influence via surficial deposits over the operation of the CTD TSF. While the calibration did not focus on calibrating the response of the Bravo borefield and pit dewatering, simulated outflows of these conditions were checked against observed data (heads for Bravo borefield and dewatering rates for the Cleo/Sunrise pit) to ensure that the influence of these was realistic.

The best calibration results were achieved with higher-than-expected saprock (2 m/d) and basement rock (0.08 m/d) hydraulic conductivities particularly in-up gradient bore (CTDMB17A/B), possibly due to connection to pit or underground dewatering through fracturing. Higher hydraulic conductivities at depth are possible, as many of the near CTD TSF deep bores have slug test data that suggest hydraulic conductivities greater than 4 m/d are possible. Acceptable calibration could still be achieved with lower hydraulic conductivity for the saprock (0.5 m/d) and basement (0.01 m/d) by increasing the hydraulic conductivity of the transported material combined with some reduction of the seepage rate and increase in the EVT depth at the lake.

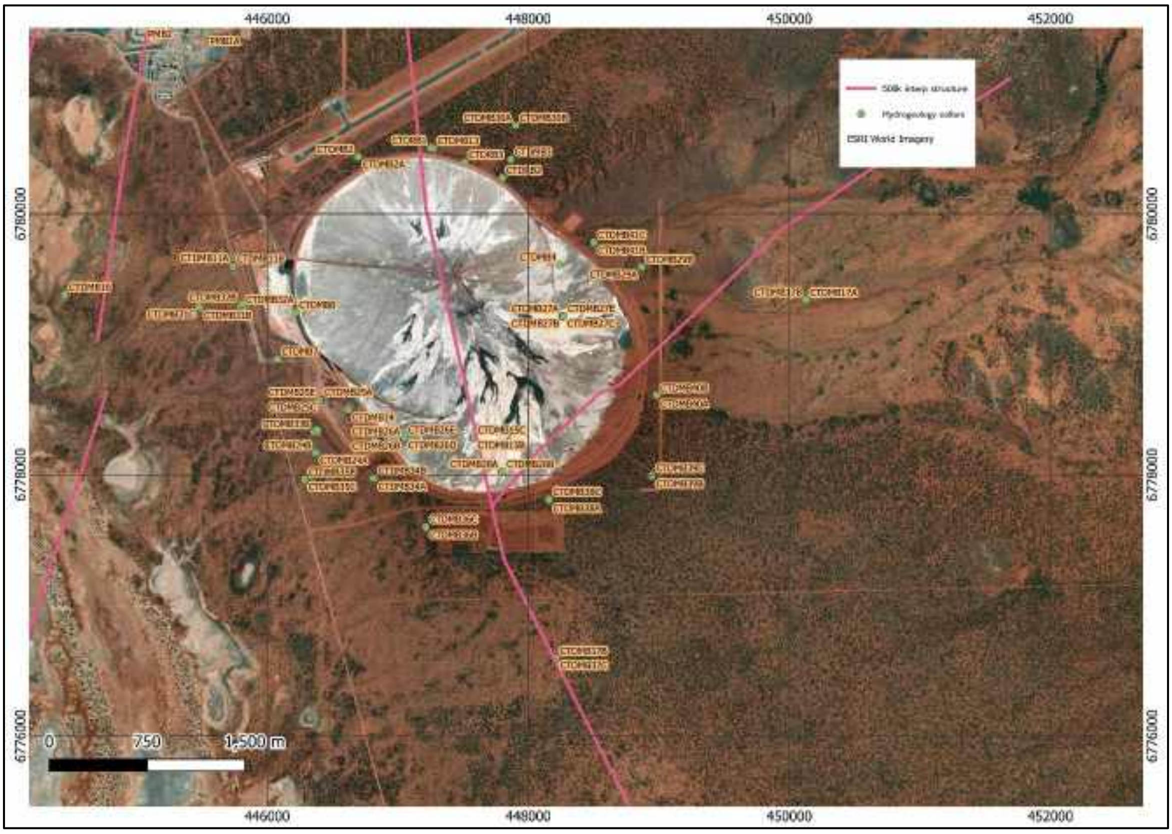
A fault zone was added in later calibration runs in the bedrock to connect CTDMB17A/B with a north–south running fault to connect to Bravo borefield and improve match to lower levels within CTDMB17A/B and some other deeper screened bores. The locations of placed fault zones were based on 1:500,000 geological mapping (DEMIRS, 2024) . While these may be justified conceptually from geological mapping and slug testing with depth, it is not certain if higher hydraulic conductivity is limited to discrete larger-scale faulting or if the bedrock is generally higher hydraulic conductivity through extensive fracturing.

Higher recharge multipliers were applied during periods of high rainfall (>75 mm per month) to account for influence of ponding and flooding at site. This over-simplification of the recharge multiplier during flooding events results in very high peaks in water levels near to high recharge areas (lake, claypans, east dam/bund and the stormwater storage pond). This is because the recharge that will occur over the course of 2–3 months of flooding is applied in the model over 1 month only (within the high rainfall event). The over-simplification was later adjusted to represent flooding by extending the recharge over a longer period of time, adjusting the recharge multipliers as required to maintain a similar rate of recharge into the model.

Differences between deep and shallow bores were difficult to reproduce in some areas. Fidelity to the highest water levels and greatest increase in water levels (normally in the shallower bores) was prioritised to ensure impacts of seepage are well represented in the model.

Water levels within the CTD TSF were up to 1–2 m above the natural surface (highest on the western side and below natural surface on the eastern side) for all calibration runs (original surface is estimated from recent CTD TSF drilling and cross-sections); this corresponds to the data collected in the most recent field investigation (all holes except BH04 were dry) and previous CTD TSF liquefaction assessments (ATC Williams, 2014).

Figure 5.4: Mapped linear features at CTD TSF



5.2 Sensitivity analysis

Sensitivity analysis was undertaken as both observations during calibration as to the sensitivity of parameters on calibration fit, and a single automated PEST run adjusting hydraulic conductivity, specific yield, recharge and river conductance (proxy for seepage rates).

The following observations from the calibrations were noted:

- Calibration was highly sensitive to the location of tailings deposition within the CTD TSF footprint.
- Higher recharge in areas that likely flood during high precipitation events (stormwater storage pond, clay pans near to the edge of Lake Carey) improved calibration in the west and at MB16 near to the clay pans. Clay pan recharge impacted groundwater levels at the west of the CTD TSF more than those on the eastern side.
- Higher bedrock conductivity had an impact on simulated deep bores with a flow on effect on surficial deposits. Higher bedrock hydraulic conductivity had to be compensated for with higher

CTD TSF seepage rates to achieve a good calibration in the surficial aquifer. Similarly, but to a lesser extent, hydraulic conductivity of the aquitard layer (layer 5) also had an impact on simulated level by increasing separation between deep and shallow aquifers, especially during periods of higher stresses (seepage onto the foundation and operation of Bravo borefield).

- The calibration is sensitive to pit dewatering and, to a lesser extent, the operation of Bravo borefield. Small responses to commissioning of the Bravo borefield in late 2022 are possible, e.g. CTDMB36C, 29A/B. The small dip in water levels could be attributed to noise in the data or response seepage interception; however, a connection to the Bravo borefield in the model made a dip more evident during the simulation.
- The EVT depth makes a difference to calibration results by lowering groundwater levels near Lake Carey and on the west side of the CTD TSF where water levels can reach 2 mbgl. However, the EVT rate has a smaller impact as the high evaporation environment removes all groundwater that recharges Lake Carey (the model was insensitive to rates that exceeded 1 m per year on the Lake Carey surface – pan evaporation is >2 m per year).

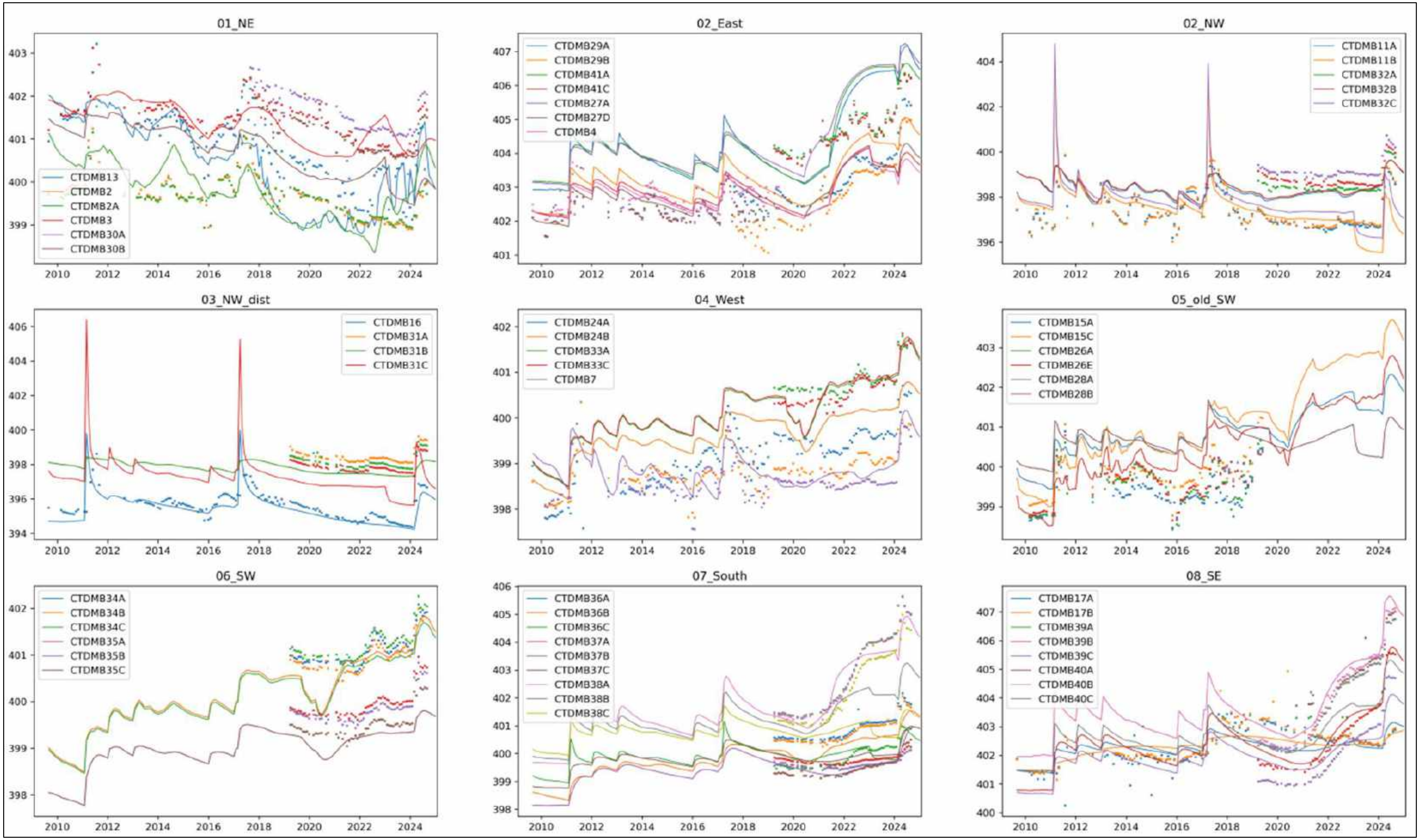
5.3 Final calibrated parameters

Final calibration (base) has achieved a good result to matching trends in the shallow bores; periods of increase, decrease and the magnitude of overall fluctuation are well represented. Final calibrated parameters are presented in Table 4.3. Simulated versus observed water levels for the calibrated model are presented in Figure 5.5 (in time series) and Figure 5.7 to Figure 5.9 (as 1:1 plots grouped by bore, layer, and location). Figure 5.6 presents the difference between observed water levels and simulated water levels at the April 2024 peak. The final calibrated Residual Mean Square (RMS) error was 2.93 and Scaled Residual Mean Square (SRMS) (which takes into account the difference in head measurement elevations) was 0.047. The RMS and SRMS were checked throughout the calibration, however, match of overall trends in critical areas was prioritised over reducing the overall errors.

Some misalignment between simulated and observed heads in periods of increases/decreases can be observed and is likely caused by simplification of tailings deposition and seepage placement on the foundation not matching tailings deposition locations and times; however, this is considered acceptable for impact on predictions (further discussed in Section 7). Additionally, the calibration on the eastern, northeastern, and southern side of the CTD TSF has some deviation to observed trends in water levels.   Specifically, for the period 2022–2024, water levels were over-simulated, which led to a (0.5 m) over-prediction in water levels in the northeast (CTDMB2A) and a under-prediction in the south (0.5 m) after the 2024 storm event. Generally, the calibration's deviation is greatest on the eastern side where the highest spread between observed versus simulated values occurs (Figure 5.9) and the model tends to underpredict water levels in the lower layers 5 and 6 (Figure 5.8).

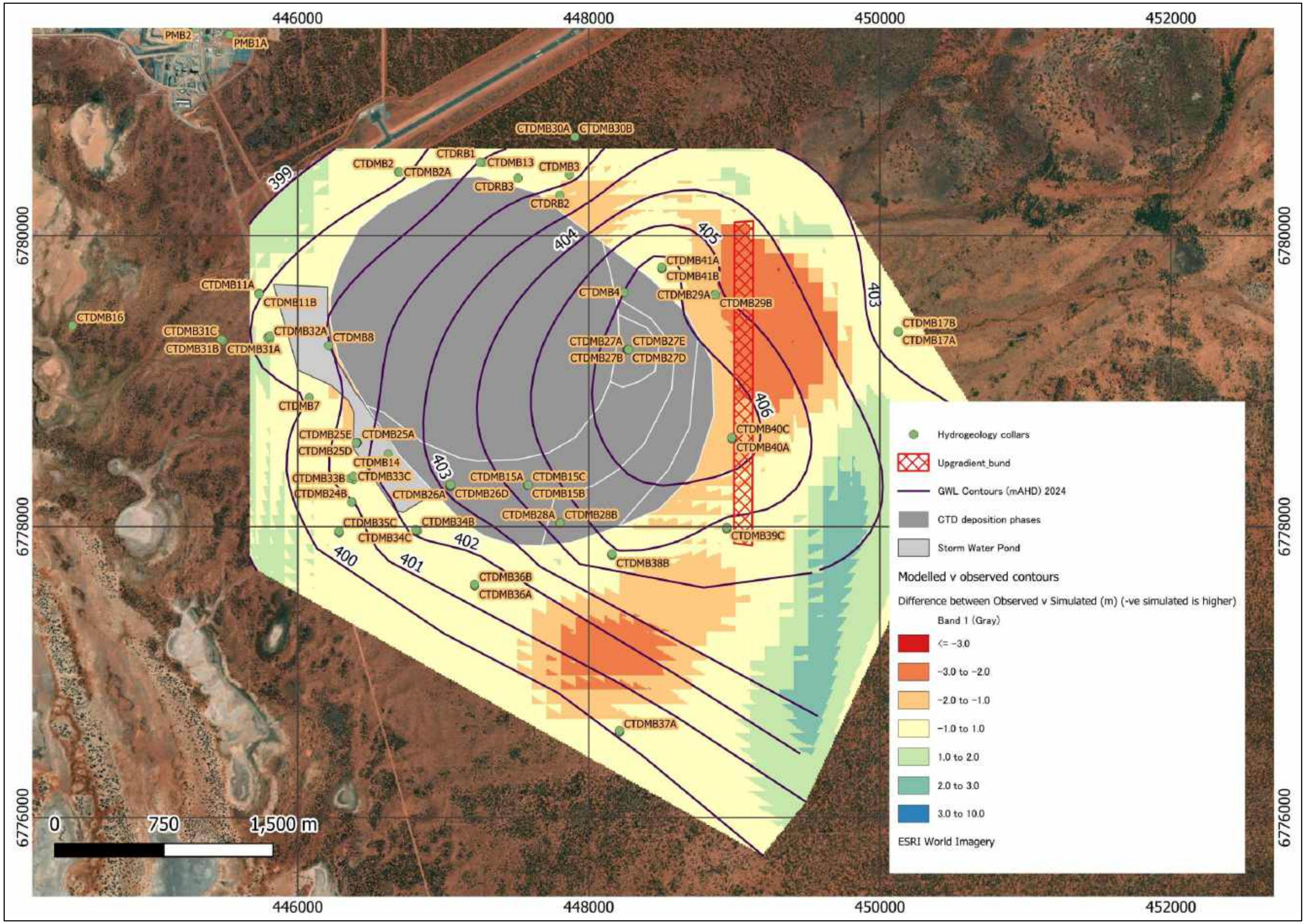
Finally, water levels in CTDMB40 have a good match except for the period after the 2024 storm events (January and March 2024) where simulated water levels recede faster than those observed. This is likely a function of the pond currently sitting right next to CTDMB40 (other bores have a good simulated match to the recession after the 2024 rain event).

Figure 5.5: Calibration graphs for calibrated model



Notes: Top figure is with selected bores for figure clarity, bottom figure has most bores. Lines represent modelled levels, dots represent observations.

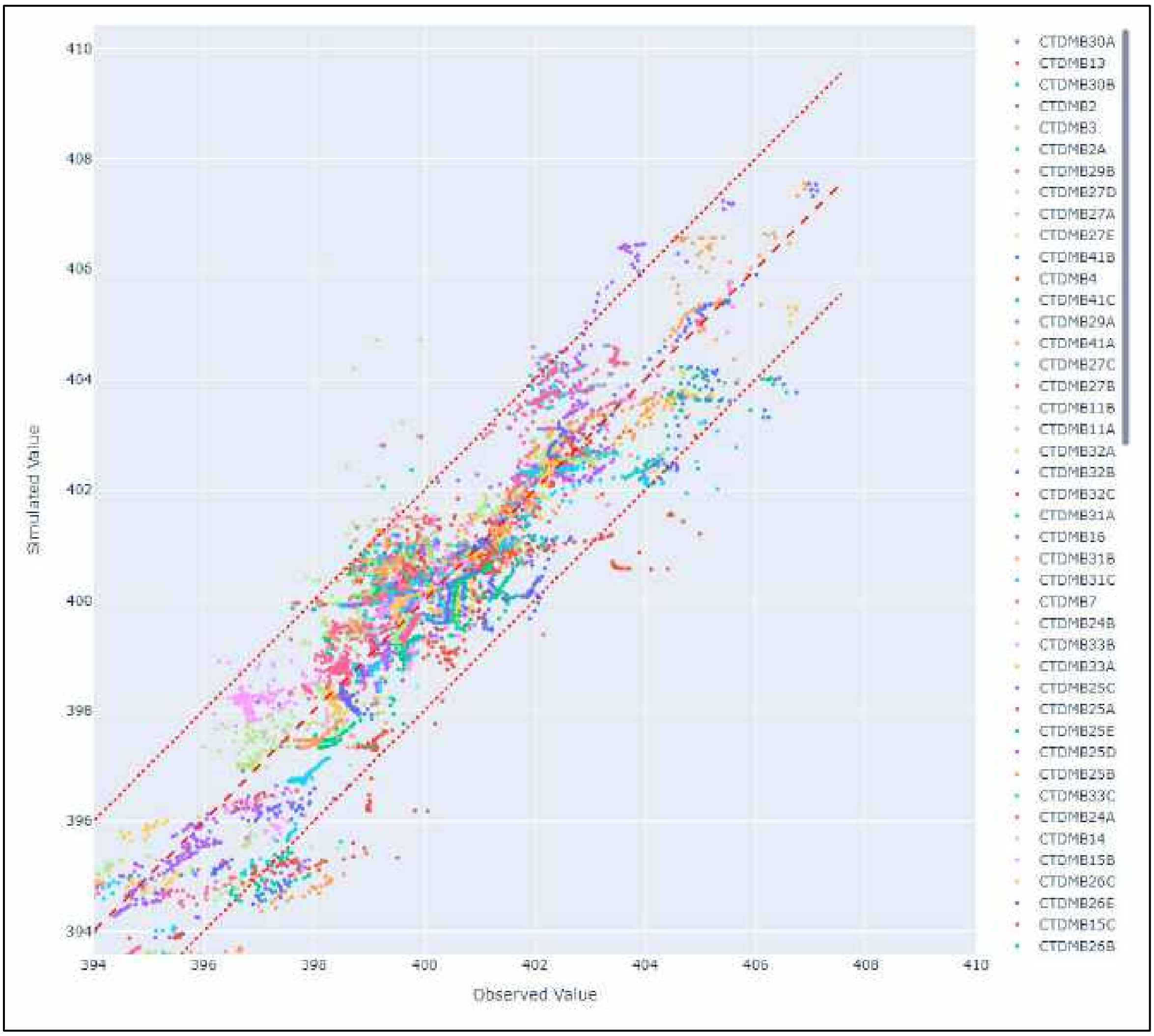
Figure 5.6: Difference between simulated and actual groundwater levels April 2024



Sources: Observed contours from 2024 groundwater monitoring review (Anglo Gold Ashanti, 2024)

Notes: Higher differences away from monitoring bores (east of CTDMB39A, south towards CTDMB37, and between CTDMB29 and CTDMB17 are not informed by observation data and are artefacts of drawn contours).

Figure 5.7: 1:1 observed versus simulated plot for final calibration



Notes: Dashed red line is the 1:1 modelled versus observed and dotted are offset 2 m from this line.

Figure 5.8: 1:1 observed versus simulated plot for final calibration per layer

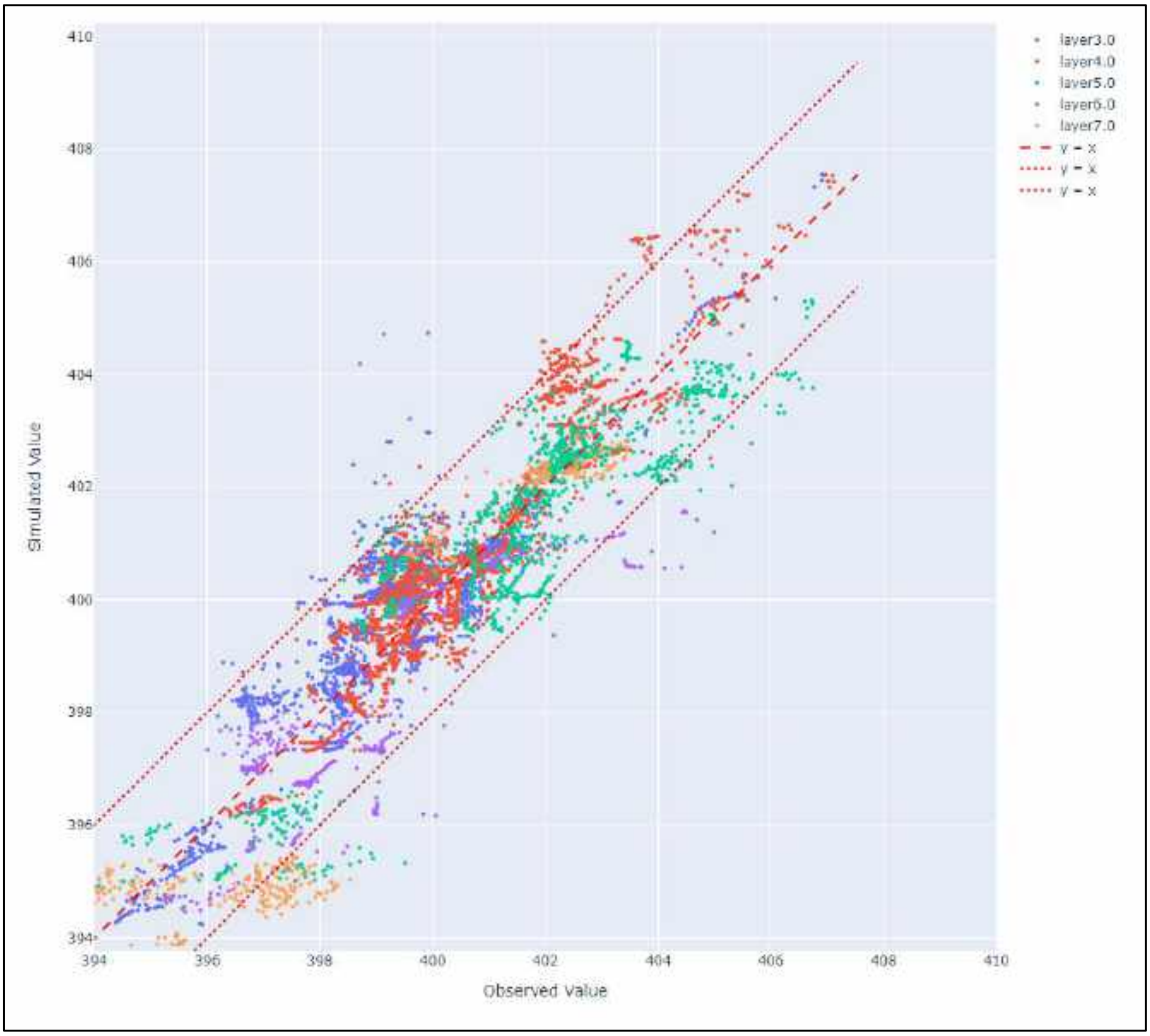


Figure 5.9: 1:1 observed versus simulated plot for final calibration per group

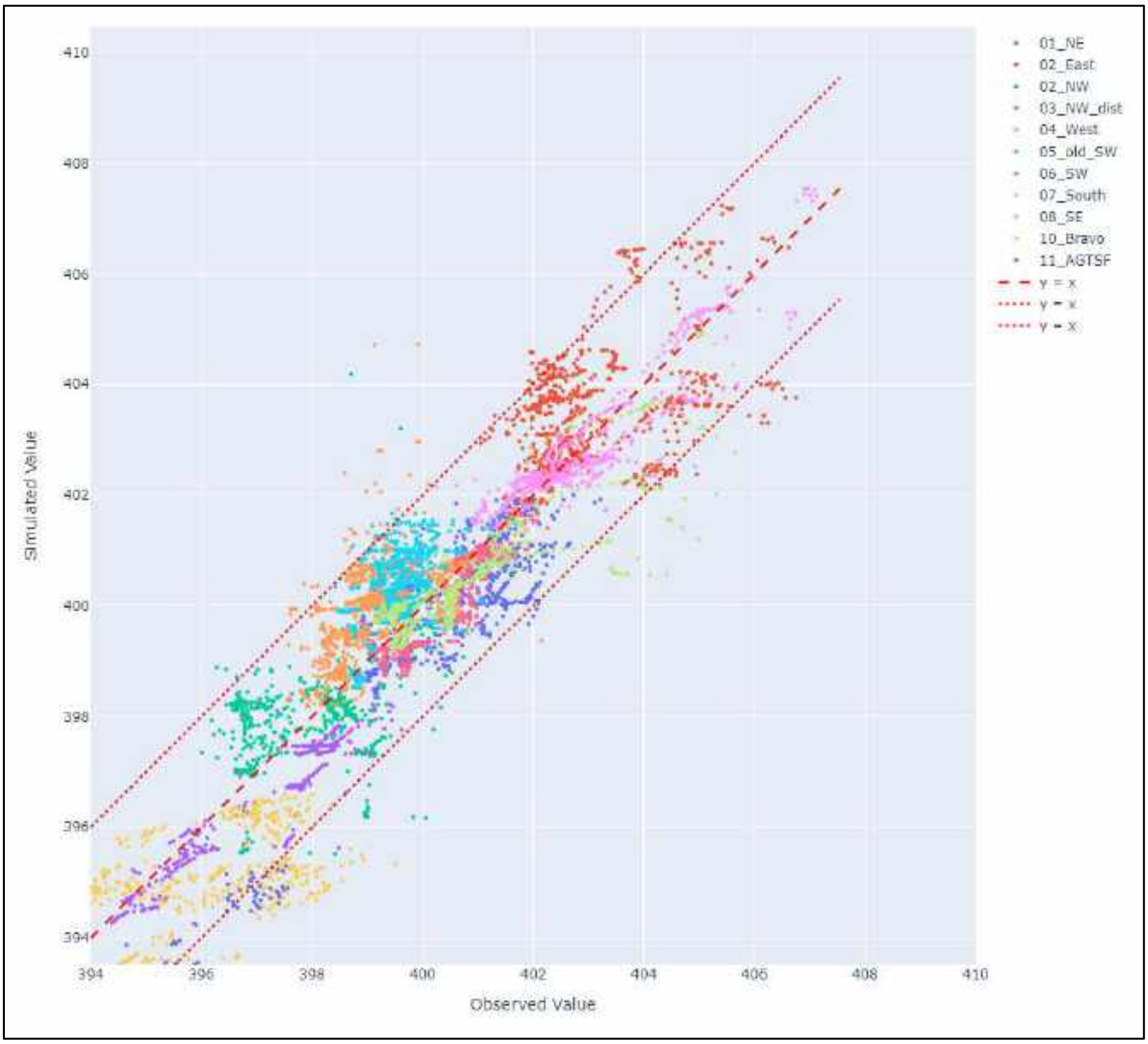


Table 5.1: Calibrated hydraulic parameters

Hydro-stratigraphic unit	Zones	Adopted hydraulic conductivity (m/d)	Adopted specific yield (-)	Comments
Tailings material	1	0.1	0.03	
Alluvium	8	10	0.08	
Ironstone/Laterite/ Pisolitic gravel	7, 8, 9, 10	2–15	0.04	
Gravelly clay and colluvium	2, 17	0.5–10	0.04	
Lake Carey palaeochannel	12	15	0.08	
Lake clay	11	0.15	0.04	
Saprolite	3	0.005	0.01	Exclusively layer 5, aquitard
Saprock	5	1.5	0.05	Exclusively layer 6
Bedrock	4	0.04	0.08	Exclusively layer 7
Faulted bedrock	15, 16	1–3	0.1	Added during calibration

5.3.1 Calibrated water balance

The calibrated water balance is presented for the 'base' calibration in Table 5.2. Interception wells, trenches and Bravo borefield are the applied historical abstraction, and storage in/out is representative of changes in water level as cells fill up and empty.

Table 5.2: Calibrated water balance

Boundary condition	Average rate during the calibration	
	In (kL/d)	Out (kL/d)
Storage	9,359	14,849
Constant head	580	
Pit abstraction	-	4,743
Interception bores and trenches and Bravo borefield	-	2,698
Seepage	3,108	-
EVT	-	10,584
Recharge	19,827	-
Total	**32,874**	**32,874**

6 Predictive scenarios

Predictive scenarios were performed to assesses the impact of continued CTD TSF operation of the Stage 12 Raise until the end of FY2032 (1 July 2032) as per the provided H3 business plan. The H3 business plan includes the throughput of the mill which is expected to remain constant at approximately 4,000,000 tonnes per annum with a decrease of 3,000,000 tonnes in FY2032. Calibrated seepage rates are considered applicable for predictive scenarios, as the throughput does not increase from the most recent deposition rates (calibrated seepage rates and total slurry water are discussed in Section 5). Three climate scenarios – low rainfall, current climate (2009 to 2024), and high rainfall – were performed during the operational phase of the CTD TSF with a short period (11 years) of recovery – 11 years was sufficient for groundwater levels to equilibrate to the predicted climate at the CTD TSF. Additionally, a closure scenario was performed for 350 years post closure of the CTD TSF until 2375.

The WSP (WSP, 2023) predictions for rainfall were used for the wet, dry and closure scenarios with historical data used for the current climate scenario. The cumulative rainfall deviation for each scenario from the mean of all scenarios is presented in Figure 6.1.

No additional mitigation measures, above those already implemented (trenches and bores), were simulated.

SC1 – High Rainfall (RCP 8.5 Wet Case)

The Representative Concentration Pathways (RCP) 8.5 Wet Case was utilised for the High Rainfall scenario. This is the most conservative operational scenario, as mounding is considered the most significant issue for the operation of the CTD TSF.

The wet scenario has a large rainfall event just before closure of the CTD TSF.

SC2 – Current climate

The climate period from 2009 to 2024 was repeated for the current climate scenario. The historical rainfall for this period is stable during the operational period, with a large rainfall event at closure followed by a period of drying climate. This scenario has a large rainfall event in 2026.

SC3 – Low Rainfall (RCP 8.5 Dry Case)

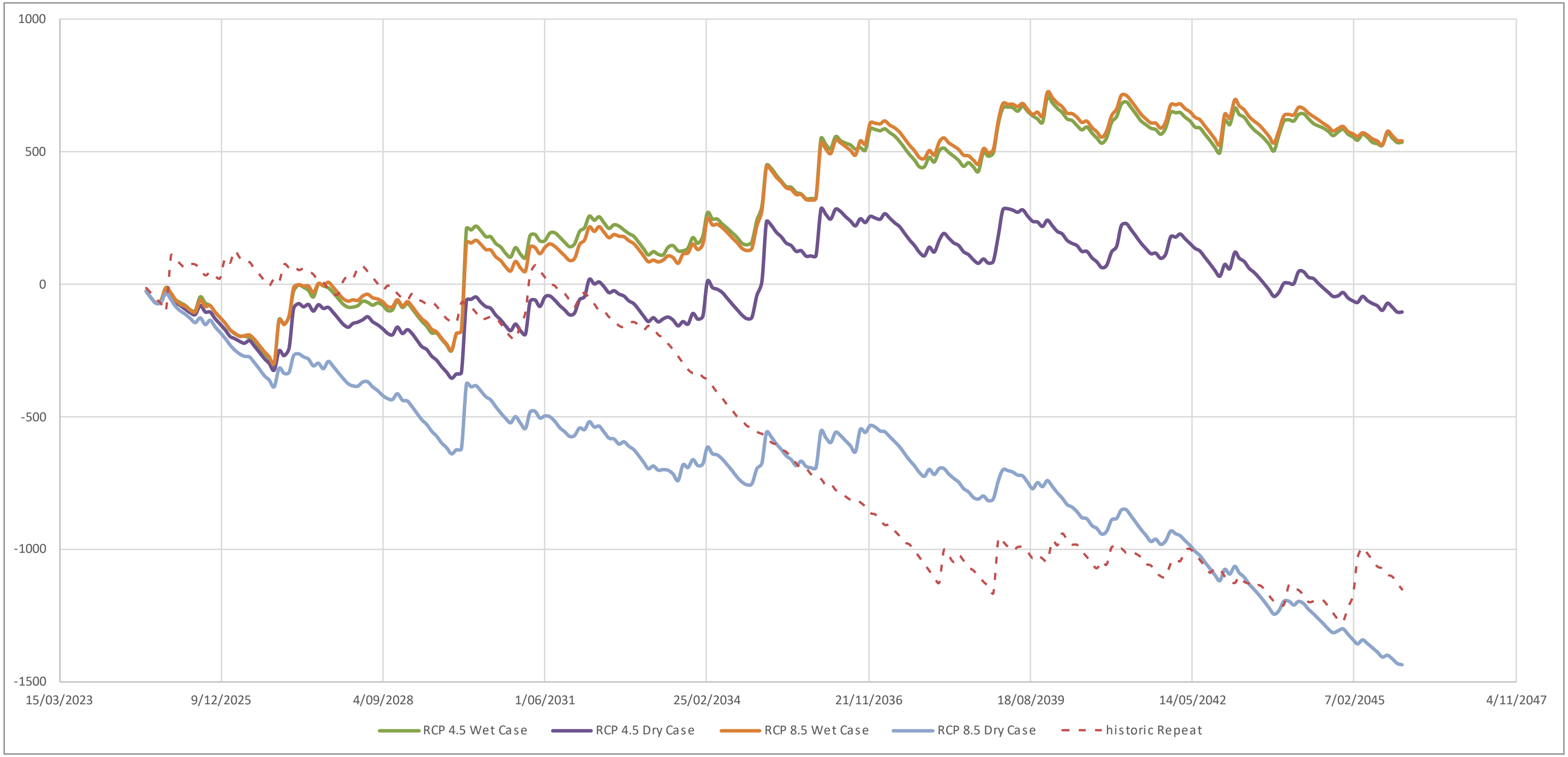
The RCP 8.5 Dry Case was utilised for the Low Rainfall scenario. This is the least conservative operational scenario.

The dry scenario has the same large rainfall event as the Wet Case scenario just before closure of the CTD TSF.

SC4 – Closure

The High Rainfall scenario was continued for 350 years to simulate conditions after closure time steps remained at monthly intervals. Rainfall was taken from the WSP predictions for the RCP 8.5 Wet Case (available until 2104). The gap in WSP rainfall predictions between 2045 and 2075 was filled by repeating the 2075 to 2104 data. Additionally, the 2075 to 2104 was repeated after 2104 to extend the closure scenario to 2375.

Figure 6.1: Cumulative deviation of rainfall from the mean for climate scenarios



6.2 Assumptions in future scenarios

6.2.1 Ongoing seepage interception, Cleo/Sunrise pit and Bravo borefield

The existing interceptions scheme (trenches and bores) were simulated as operating at 80–90% capacity (based on maximum historical abstractions) for future predictions. Bravo borefield was also included and the pit was represented as a drain or well boundary at 336 mAHD until the end of operations at the CTD TSF. All abstraction was turned off at the end of operations at the CTD TSF at the end of FY2032 (1 July 2032.

Seepage was represented by the continuation of the river boundary condition at the calibrated conductance values to represent the calibrated seepage rate when the foundation is covered by tailings. The higher conductance representing seepage onto the foundation was continued until the beginning of 2026. Seepage was simulated for the raise by placing the river condition by maintaining the calibrated seepage rate per square metre for the footprint of the tailings. The applied seepage is likely higher than what would be observed in reality, as the seepage rate is applied to the entire CTD TSF (now expanded) while deposition (and therefore seepage) will be rotated around the sectors of the CTD TSF. This is considered a conservative assumption from the perspective of predicting mounding impacts.

A higher rate of seepage was continued onto the foundation until January 2026 on the assumption that the CTD TSF foundation will be completely covered by this date. The lower rate was then applied within the tailings until the completion of deposition.

6.2.2 Climate as recharge and evapotranspiration

Recharge and evaporation rates were the main adjustments for the three scenarios. Recharge rates were taken from the RCP 8.5 Wet Case and Dry Case from the WSP climate predictions (WSP, 2023) as the two extreme scenarios. Recharge was applied as a recharge multiplier (calculated as a deviation from the mean) with an adjustment for flooding for rainfall events over 75 mm in the month. Flooding events were applied over a 2–3 month period to avoid unrealistically high peaks in groundwater levels and to represent observed conditions on site. Evaporation was applied as an annual mean for the corresponding Wet/Dry climate predictions.

Recharge and evaporation were repeated from the calibration phase for the base case scenario.

Additionally, the high recharge zones representing features that will be removed at closure (stormwater storage pond and the small dam [bund]) to the east on the CTD TSF were removed after FY2032 during all scenarios. Further to this, the CTD TSF area had the same recharge as surrounding areas applied under the assumption that a shedding cover with some infiltration will be constructed at closure. A small zone on the eastern side of the CTD TSF was left as higher recharge (similar to that of the calibrated value at the eastern dam/bund) to simulate some obstruction of the drainage line and subsequent ponding and increased recharge.

6.3 Scenario outputs

Scenario outputs are presented for the three operational scenarios and the closure scenarios as:

- hydrographs at selected points for operations (Figure 6.2 and Figure 6.5) and closure (Figure 6.6 to Figure 6.9). Hydrographs present the simulated groundwater level for the three scenarios at monitoring bores to show rates of groundwater decline between rainfall events and groundwater level increases after rainfall events. For simplicity only the applied recharge (rainfall) for Scenario 1 is presented on these graphs but peaks after rainfall events in other scenarios are annotated. The calibration period and observed groundwater levels are also presented as a reference for the goodness of fit at each bore during the calibration.
- groundwater level contours over laying a depth to water (DTW) grid for the water level for the current climate scenario at the time of closure of the CTD TSF in June 2032 (Figure 6.10) and 300 years after closure (Figure 6.11).
- cross section with the highest groundwater level through the CTD TSF (Figure 6.12).

The highest screened layer (usually layer 3) was used for outputs during the predictive scenarios due to the difficultly in reproducing vertical trends during the calibration. Layer 3 was used for contours and depth-to-water plots and is considered the most representative for predictions in the unconfined aquifer, as EVT is active within this layer.

6.3.1 Groundwater levels during operation

All predictive scenarios simulated a continuation of the decline in water levels following the peak in early 2024 caused by flooding at the site. The reduction in applied seepage infiltration in late 2025 due to covering of the foundation with tailings further increases the decline in groundwater levels, particularly in the south and southeast. Groundwater levels are simulated to decline sufficiently by 2027 so that, should another large storm event (with associated flooding) happen, then groundwater levels should not rise above the 2024 peak. The two modelled storm events during operation (2027 and 2030) do not raise groundwater levels above the 2024 peak. Another storm event prior to this (particularly in 2025) before groundwater levels have receded will likely raise groundwater levels to equal to or above the 2024 event (further discussed in Section 7).

There is a slight decline in rate of groundwater decrease in the north and west once both the CTD TSF seepage and abstraction are turned off. This suggests that seepage in this area is completely removed by abstraction, and mitigation measures will continue to be effective in controlling seepage in this area during the remainder of operation of the CTD TSF.

Predicted depth to groundwater is least on the western side of the CTD TSF in all scenarios as a combination of the sloping topography and recharge from the stormwater storage pond following large rainfall events. Water levels in the south and southeast can also remain high (due to the persistence of pooling of TSF water on the eastern edge on the foundation which should be alleviated when the foundation is covered in tailings by January 2026). The future groundwater levels presented for 2030 in the wet scenario (SC001), after an applied high rainfall event, is slightly less than the peak observed in April 2024, suggesting that if there is a gap of 2–3 years between large storm events, groundwater level will not exceed the highest observed levels, i.e. groundwater levels in simulations will not exceed those presently (April 2024) based on the applied rainfall events. Groundwater levels come to within 0.5 m of surface on the fringes of Lake Carey (within clay pans and topographic lows in alluvial channels and dunes) during an applied high rainfall event in 2030 (Figure 6.10); this is considered a natural variation caused by high rainfall recharge and is reflective of the existing hydrogeological regime adjacent to Lake Carey. Groundwater levels in all other scenarios are less than those presented in the SC1 peak.

The models may be over-predicting groundwater recession in CTDMB40, as the calibration had a higher rate of recession than observed (see Section 5.3). While groundwater in this area is still >3 mbgl, it is recommended that attention is paid to monitoring to ensure that groundwater recession rates are similar to those simulated both during deposition on the foundation and when the foundation is covered by tailings.

As the calibration aimed to be conservative, simulated groundwater levels were higher than observed in the west and northwest areas where depth to water is the least (within 1 m at some bores). The predictions should be similarly conservative in over-predicting responses to rainfall, and the depth-to-water grids presented in Figure 6.10 to Figure 6.11 will be over-simulating groundwater levels, particularly on the western side of the CTD TSF. Importantly, all future simulations have groundwater levels staying below the current peaks even when similarly large storm events as the early 2024 period were applied (several large rainfall events in the space of 3 months).

6.3.2 Groundwater levels post closure

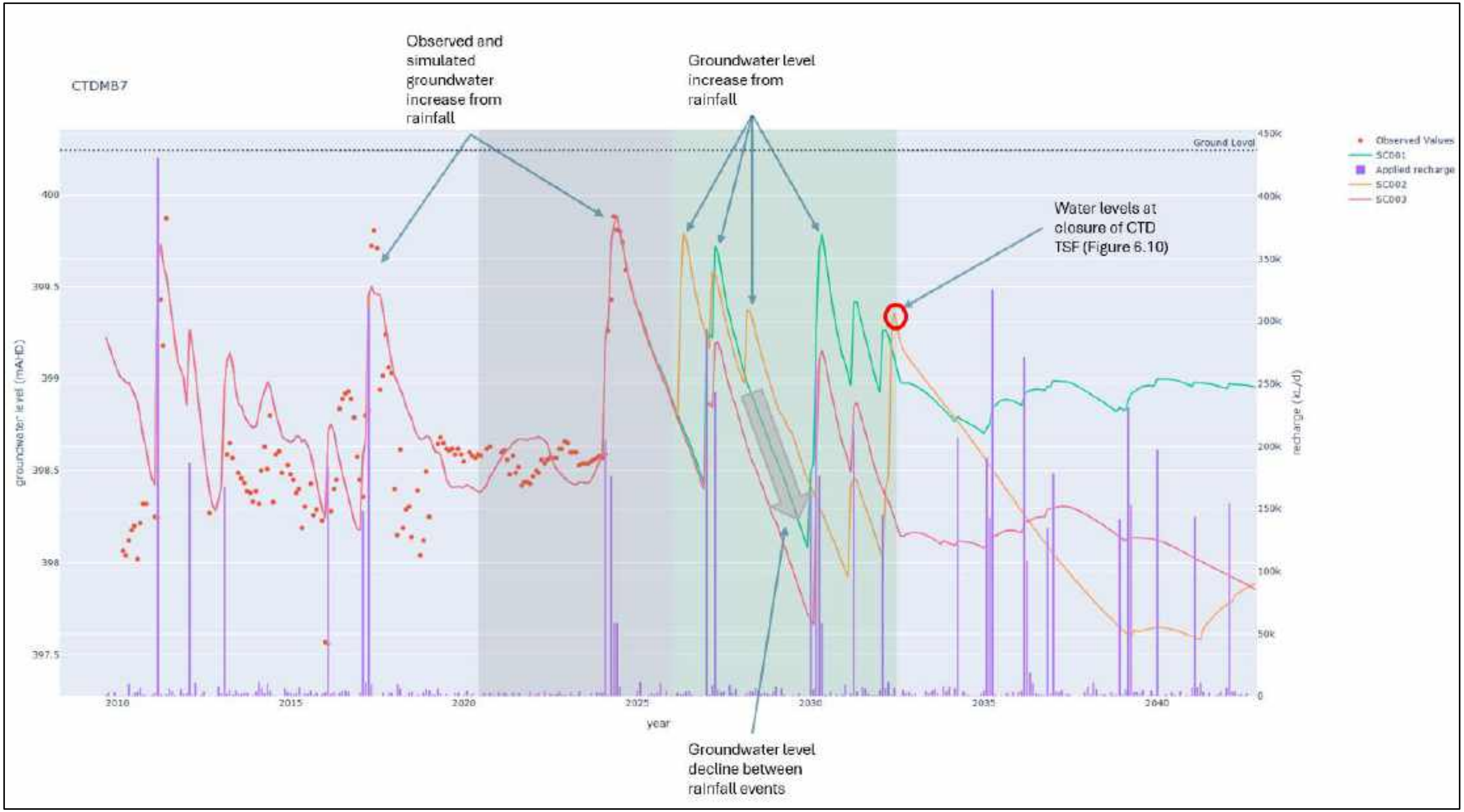
Groundwater levels simulated to recover (reduction of the mound under the CTD TSF to background levels) quickly (less than 10 years). By 2040, groundwater levels resume natural fluctuations. As the predictions for the wet scenarios are for a ‘wetting’ climate, groundwater levels are simulated to increase following closure and return to natural fluctuation post 2040 in response to higher rainfall in the wet climate scenario.

The western side of the CTD TSF is simulated to have groundwater levels within 2 m of the surface at closure; the low depth to groundwater water is due to the low topographic elevation on the western side of the CTD TSF. Increased recharge around the TSF (stormwater pond, up-gradient bund/dam) is switched off in the closure scenario; therefore groundwater level rise is solely the result of increased rainfall recharge in the wet climate scenario.

6.3.3 Particle tracking

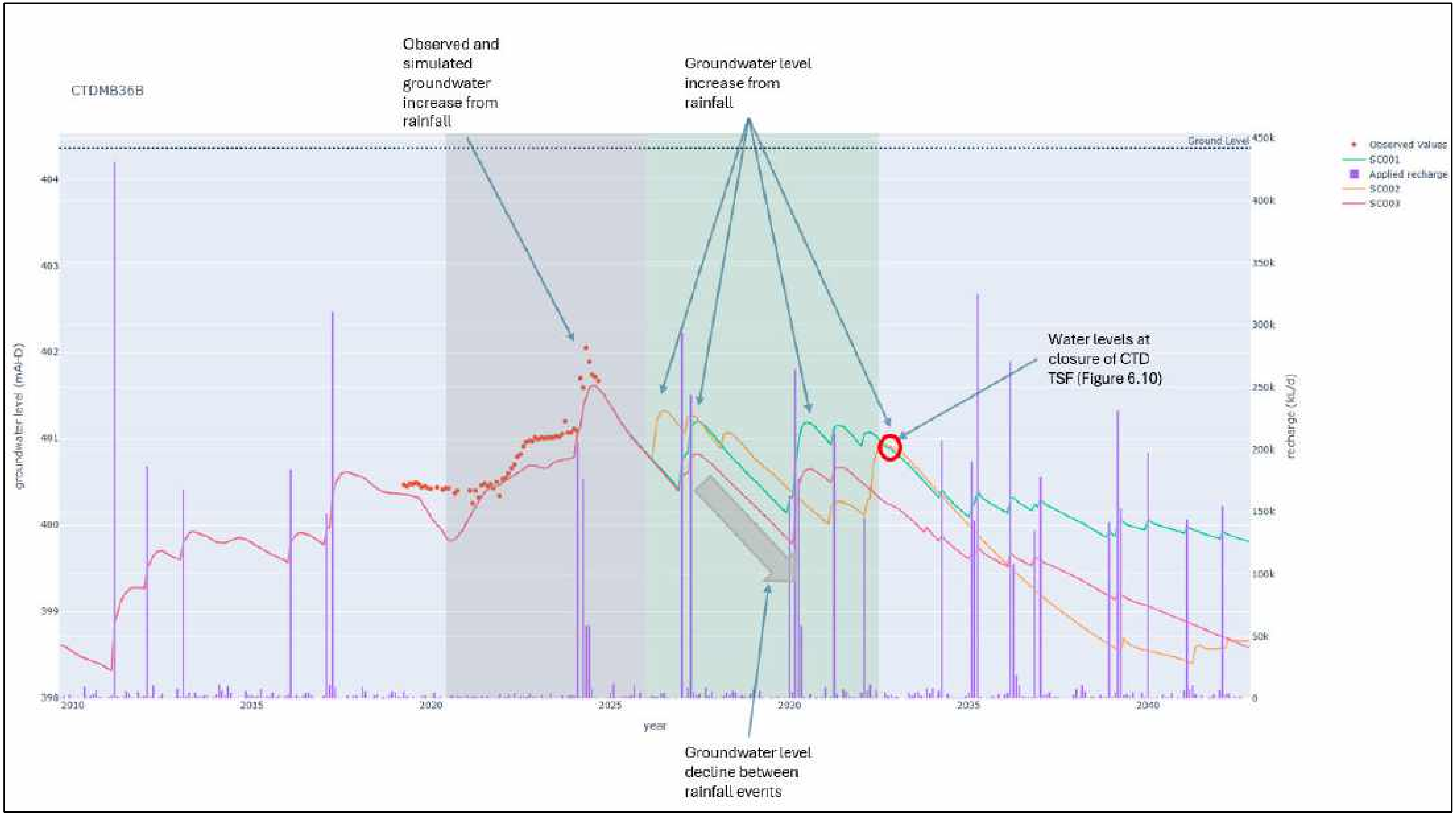
Particle tracking was performed on the Wet Case scenario (SC1) as an indication of travel times and direction from the CTD TSF during operation. The results are presented in Figure 6.13. Particles released from the TSF generally travel to interception infrastructure during operations, however, some particles do bypass the trenches en route to Lake Carey. Preliminary testing of travel times has particles from the CTD TSF arriving at the fringe of Lake Carey within 40 to 80 years. The range of travel times is influenced by adopted porosity values which were varied between calibrated specific yield (4% to 10% – most conservative) to as high as 20% (least conservative).

Figure 6.2: Hydrographs operations – west



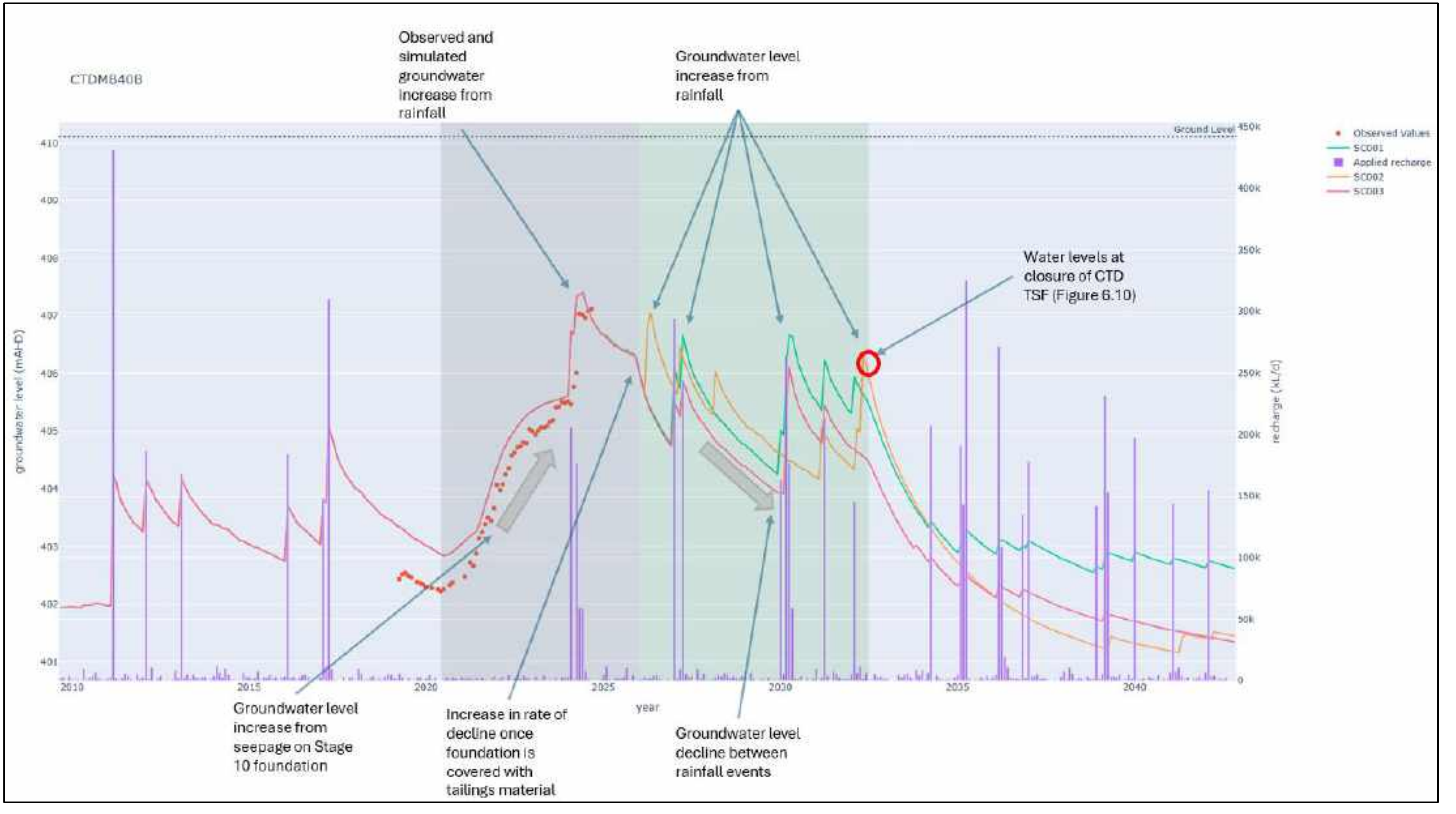
Notes: Calibration period is included with observed values, grey shading represents deposition onto foundation, green shading represents continued deposition after foundation is covered. Applied recharge for SC001 only

Figure 6.3: Hydrographs operations – southwest



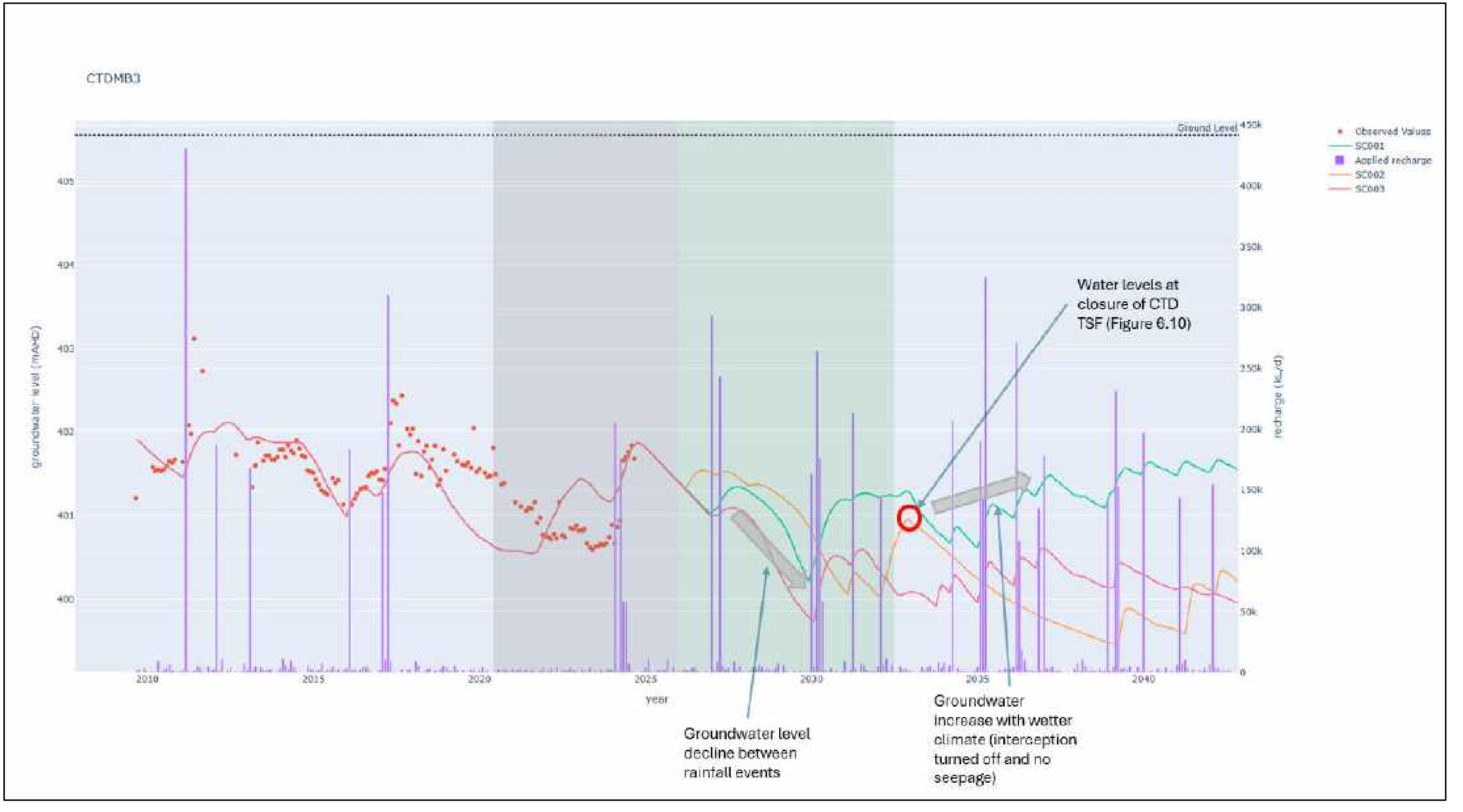
Notes: Calibration period is included with observed values, grey shading represents deposition onto foundation, green shading represents continued deposition after foundation is covered. Applied recharge for SC001 only

Figure 6.4: Hydrographs operations – southeast



Notes: Calibration period is included with observed values, grey shading represents deposition onto foundation, green shading represents continued deposition after foundation is covered. Applied recharge for SC001 only

Figure 6.5: Hydrographs operations – northeast



Notes: Calibration period is included with observed values, grey shading represents deposition onto foundation, green shading represents continued deposition after foundation is covered. Applied recharge for SC001 only

Figure 6.6: Hydrographs closure – west

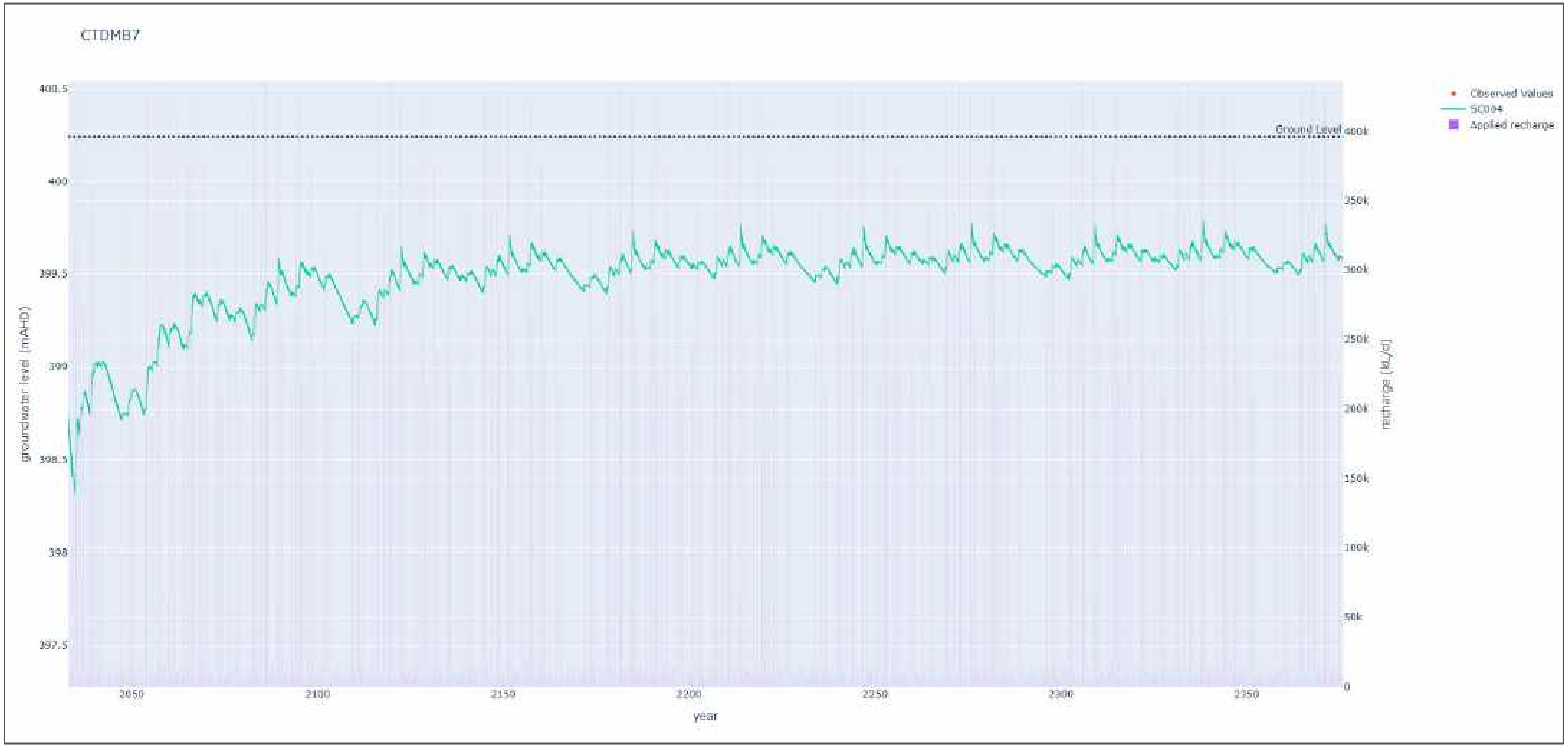


Figure 6.7: Hydrographs closure – southwest

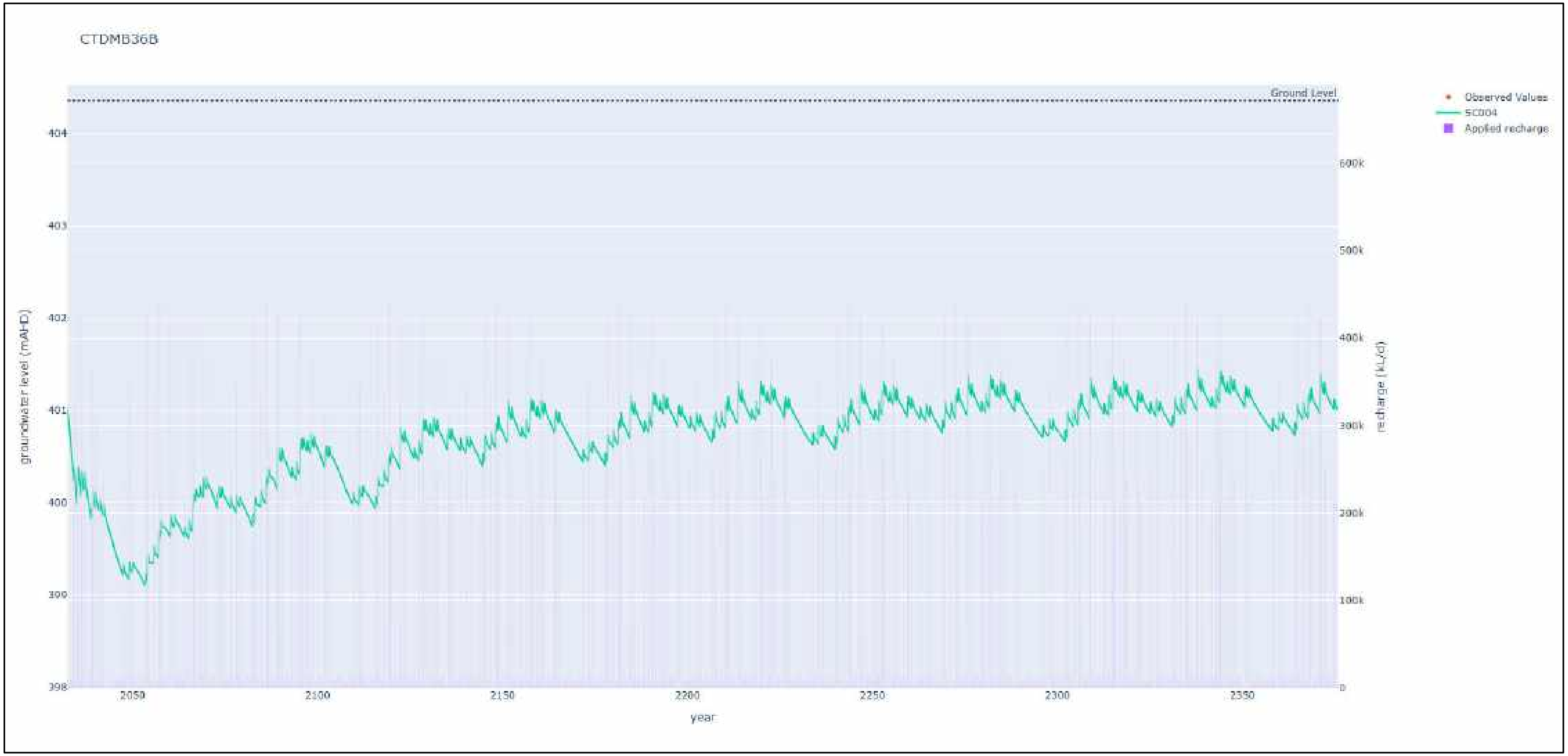


Figure 6.8: Hydrographs closure – southeast

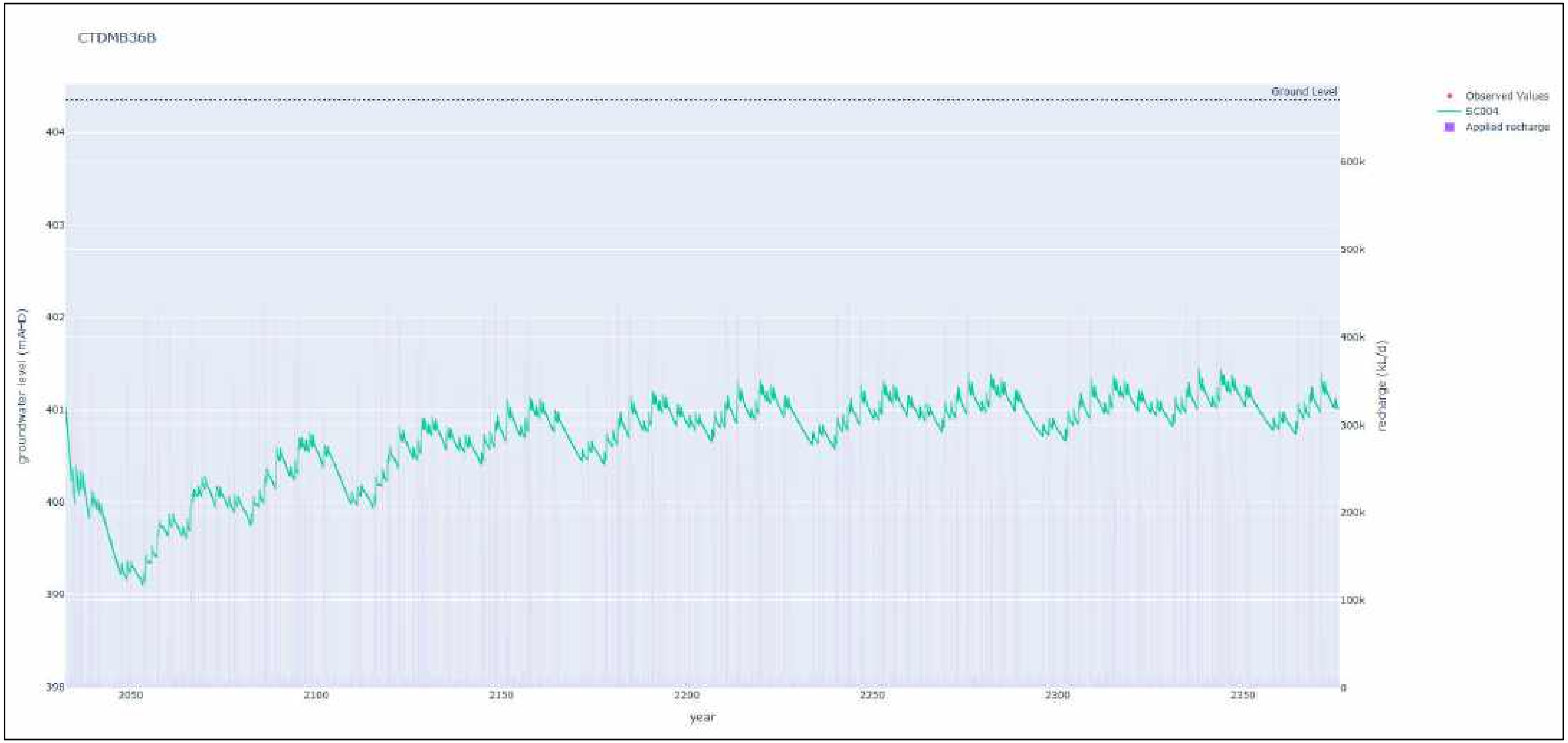


Figure 6.9: Hydrographs closure – northeast

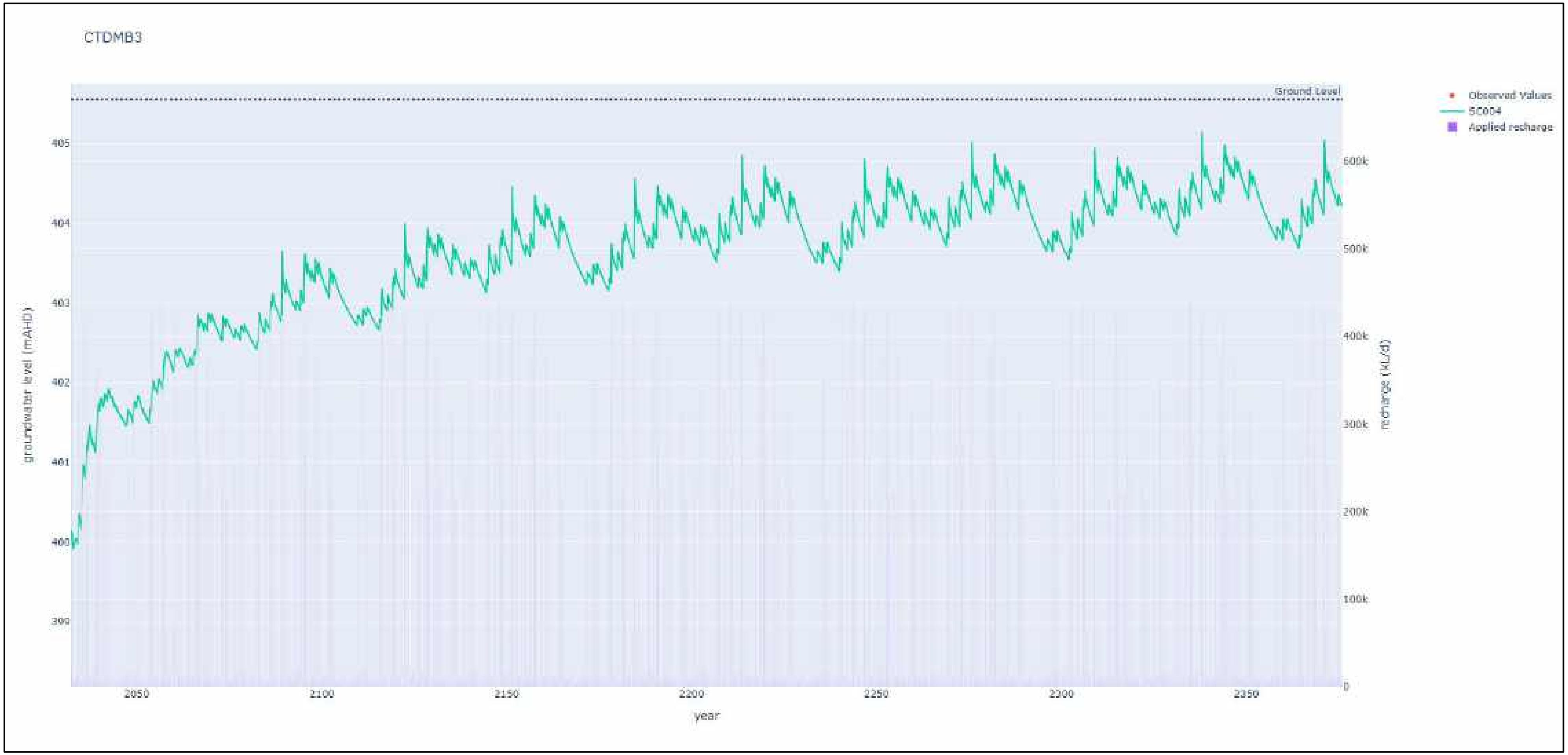
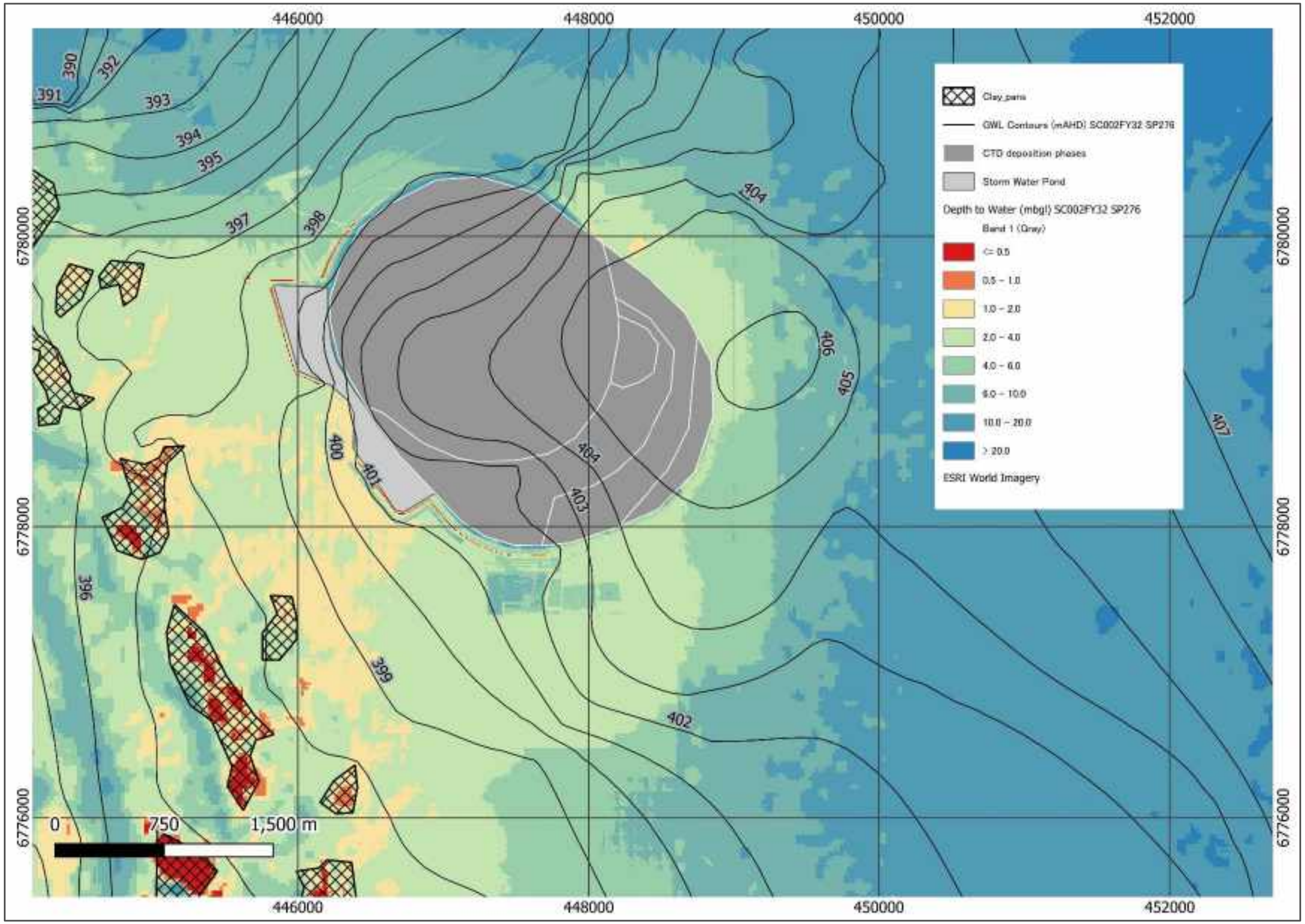
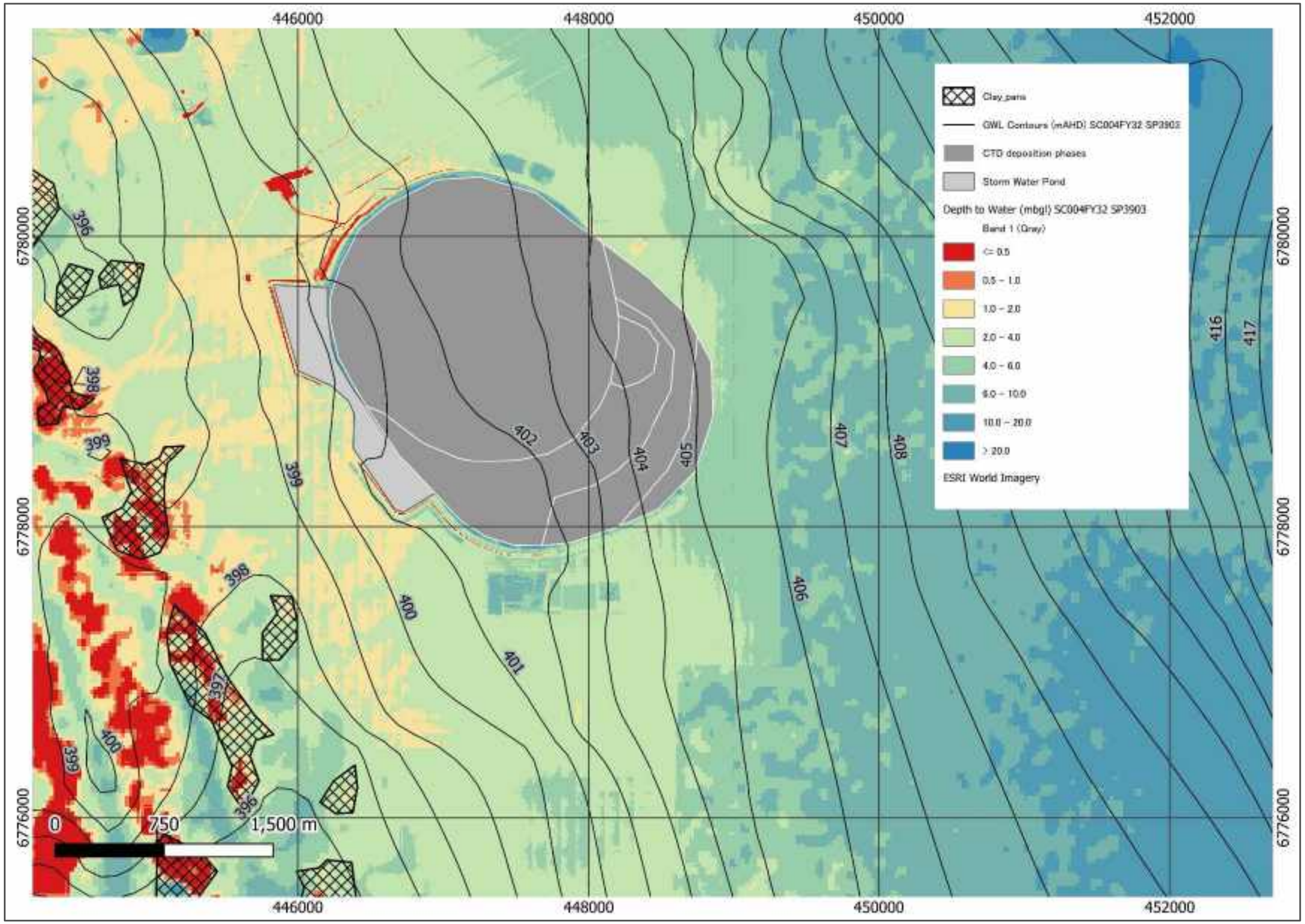


Figure 6.10: Depth-to-water at closure of CTD TSF (June 2032) – Current Climate Scenario



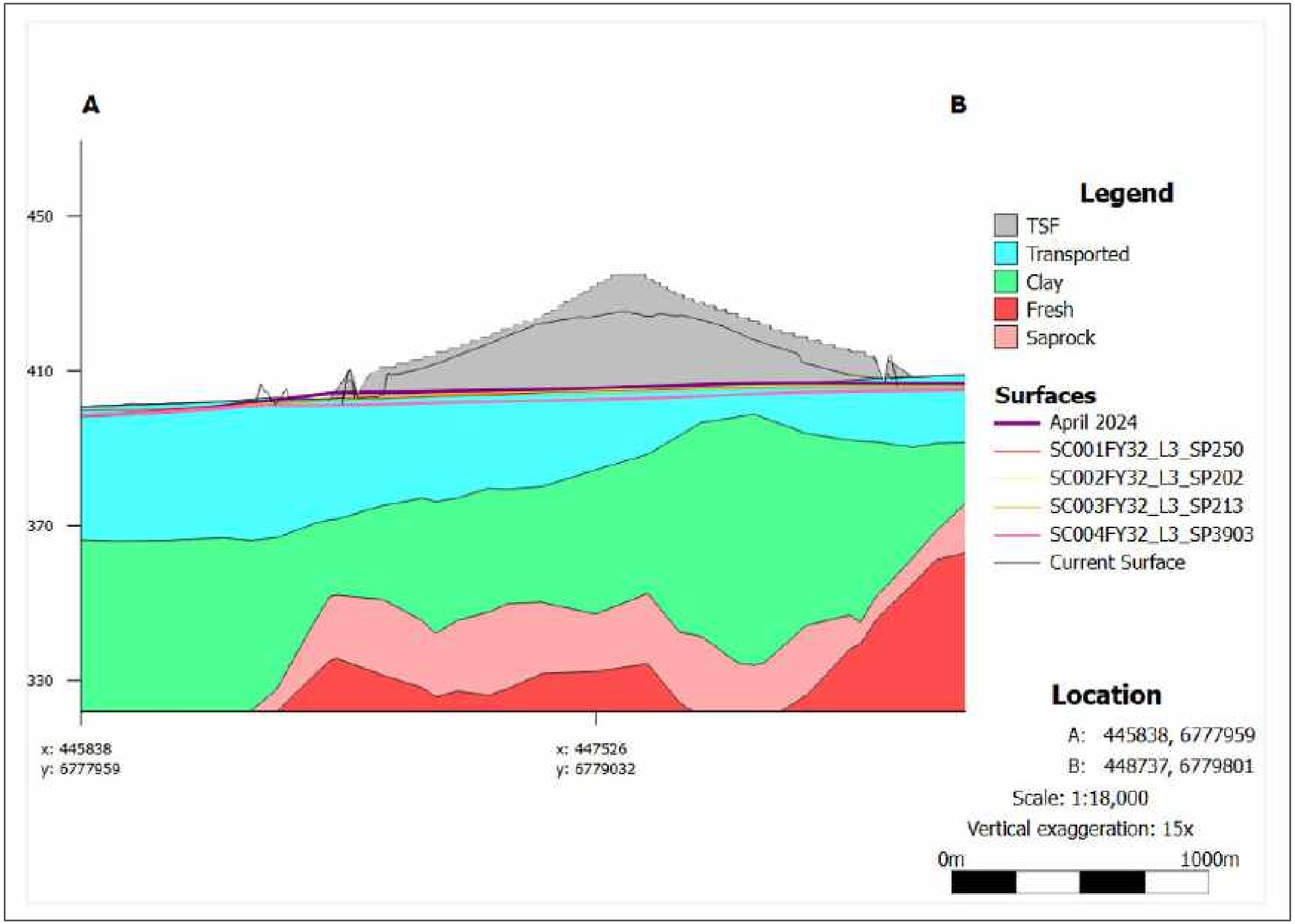
Notes: Low depths to water on the immediate fringe of the CTD TSF display groundwater levels in the seepage interception trenches. The low depth to water on the fringes of Lake Carey and clay pans caused by natural groundwater recharge.

Figure 6.11: Depth to water – Closure scenario (2334)



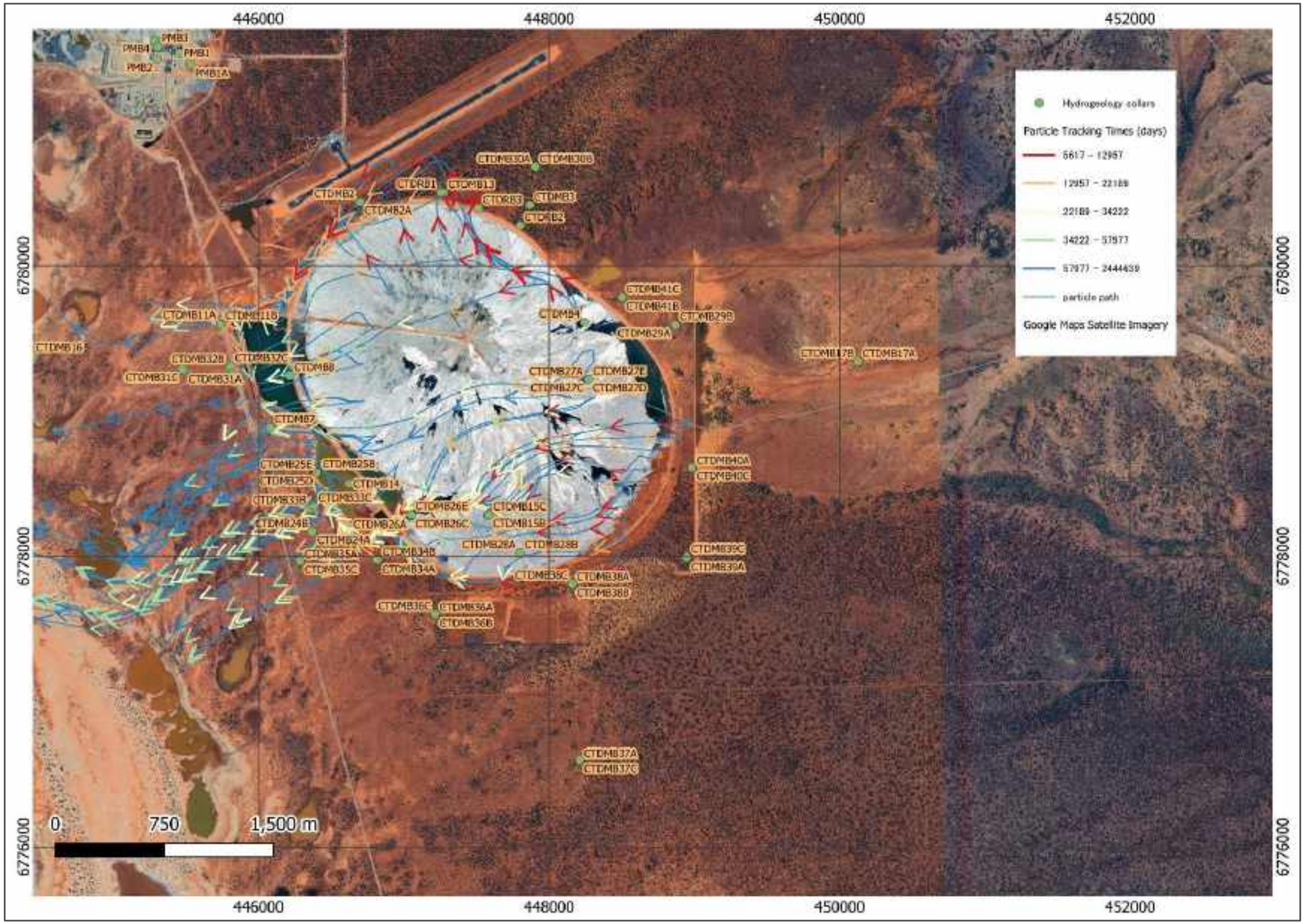
Notes: Arbitrary time period chosen during a peak in water levels in year 2334. Increases in rainfall in the Wet climate scenario lead to higher water levels across site.

Figure 6.12: Cross-section with groundwater level – all scenarios



Notes: Simplified materials is represented in the cross-section and not the model hydrogeological zones. Future maximum operational groundwater levels are less than the April 2024 peak.

Figure 6.13: Particle tracking as an indication of travel times and direction during operation



7 Uncertainty

Several calibration runs adjusted with different parameter and boundary condition values were run in the predictive phase to assess uncertainty in the model predictions. The major uncertainties that provided good calibration with observed values by adjusting multiple parameters in combination (non-uniqueness) included:

- Low saprock and bedrock hydraulic conductivity – led to applying lower CTD TSF seepage rates and increases to recharge and EVT rates at the lake boundary (better calibration on the western side and worse at the eastern side in CTD17A/B up-gradient of CTD TSF).
- High saprock and bedrock hydraulic conductivity – a good calibration could be achieved in most areas by increasing CTD TSF seepage and recharge in some areas; however, the western side of the CTD TSF had a worse calibration and there was difficulty matching the magnitude of response from seepage and recharge.
- Hydraulic conductivity of the saprolite reduces the influence of the Cleo/Sunrise pit on the CTD TSF which required a reduction in seepage or an increase in EVT. Reducing the saprolite hydraulic conductivity also led to more propagation of drawdown in deeper bores.
- Hydraulic conductivity of the surficial deposits affects the levels on the western side and, to a lesser extent, the eastern side of the CTD TSF. Lowering the hydraulic conductivity can improve the calibration between the CTD TSF and Lake Carey (at CTDMB31) while increasing water levels at the CTD TSF. This can be offset by decreasing the seepage and recharge rates at the CTD TSF.
- Location of higher recharge zone and the proportion of rainfall that recharges during flooding events.

The Wet Case scenario was run with combinations of the above parameters (as outlined in Table 7.1), to assess the potential impact of uncertainty on predictions.

The main uncertainty in predictions is the frequency and possibility of large storm events that lead to flooding. Two sequential large flooding events before groundwater level has had a chance to recede will lead to a rise in groundwater levels irrespective of deposition and interception activities at the CTD TSF.

Table 7.1: Uncertainty scenarios

Uncertainty scenario	Designed to test	Outputs/Comments
SC001A	High basement/saprock hydraulic conductivity. High superficial deposits. High seepage rates.	Lower overall groundwater levels and higher rates of groundwater decline. Less conservative predictions.
SC001FY32B	Base calibration.	
SC001B	Reduced well pumping rates.	Included to assess if over-predicting abstraction rates in the base case would miss impacts from seepage. Very little change in drawdown rates does not lead to higher water levels than the April 2024 peak.
SC001ET	Extra evaporation.	Evaporation rates are increased – small change to the calibration but prediction rates of decline are higher.

Uncertainty scenario	Designed to test	Outputs/Comments
SC005FY32B	Large rainfall event in 2025.	
SC005FY32C	Large rainfall event in 2025 – without CTD TSF seepage.	Seepage interception inactive to show impact of abstraction.

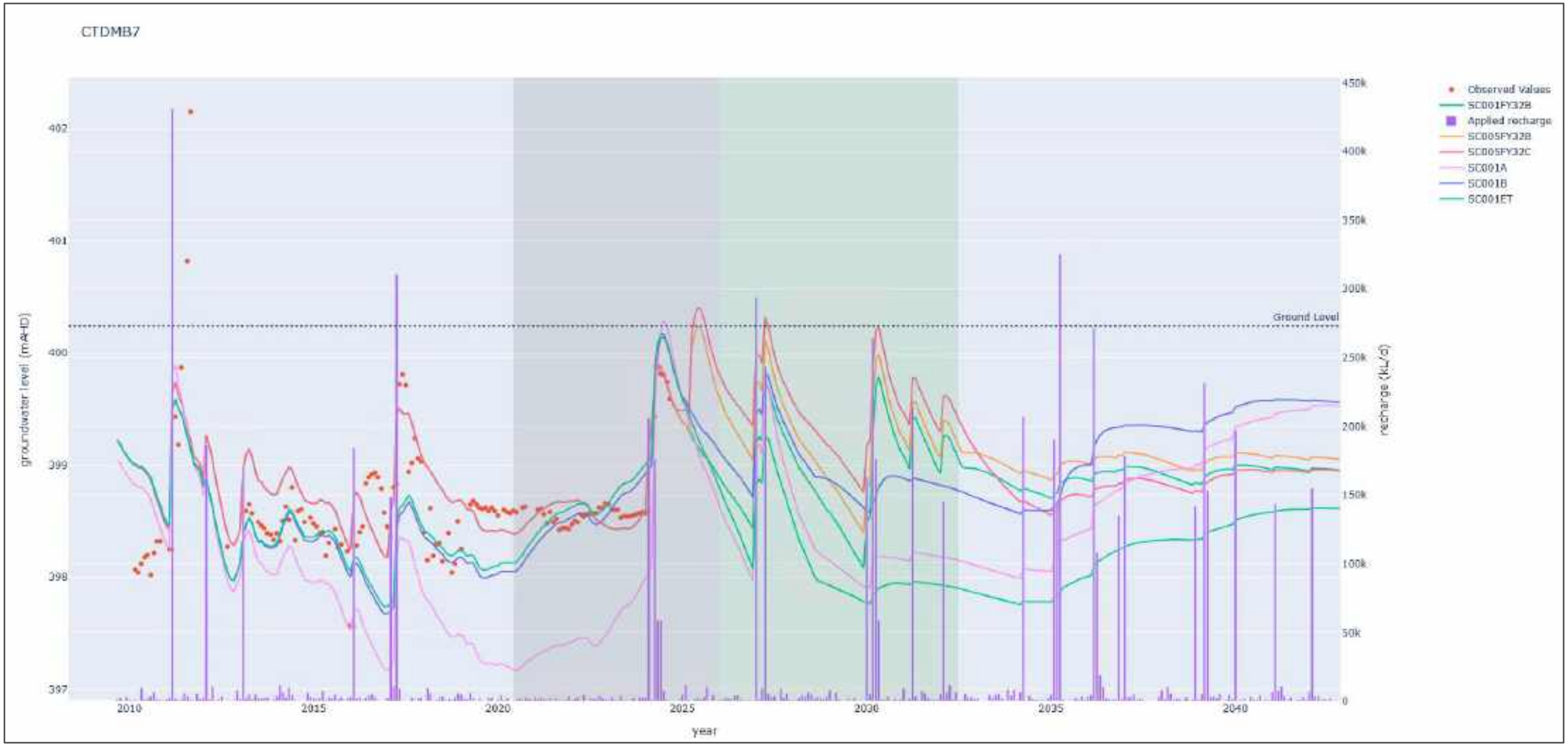
Uncertainty identified during the calibration has the following impacts on predictions:

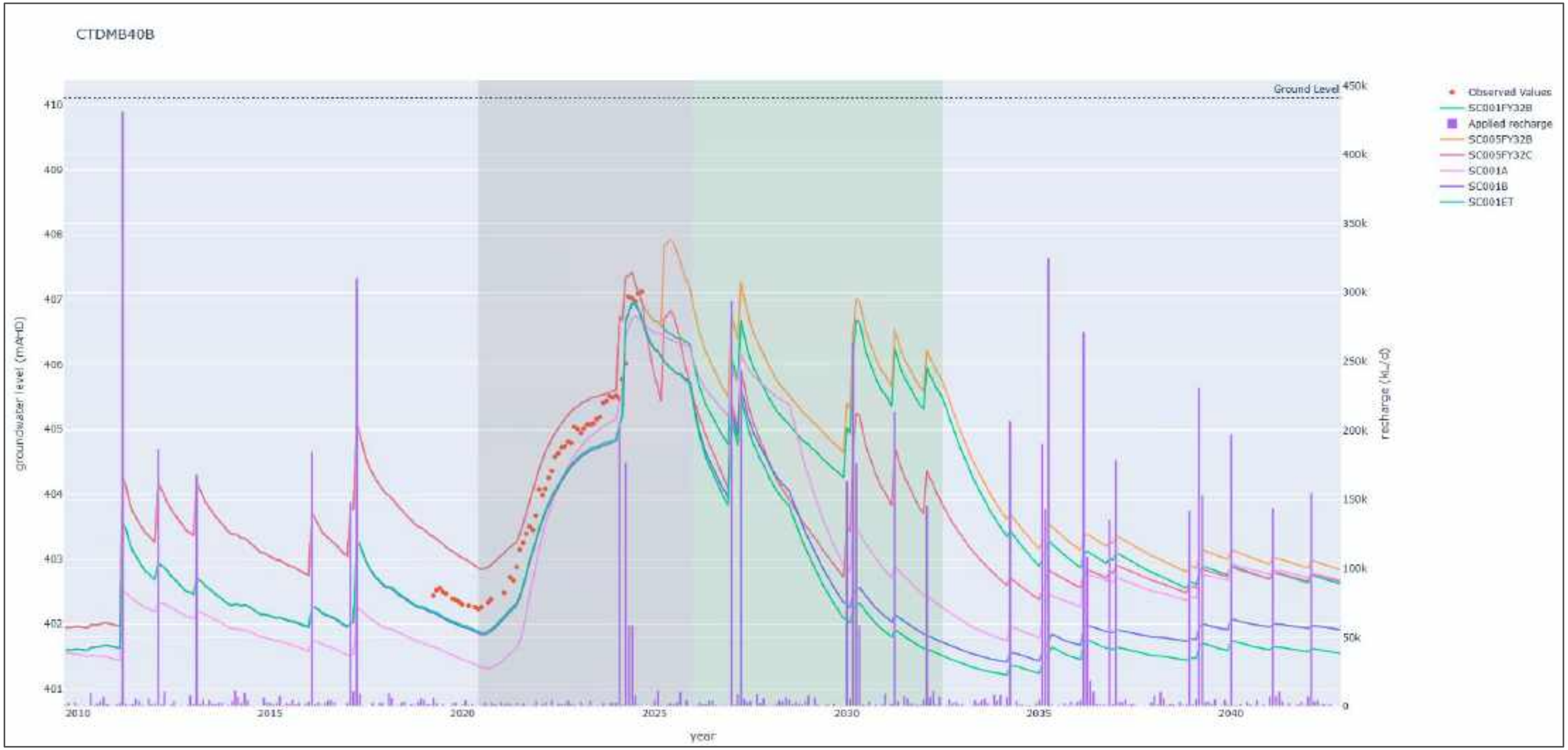
- Reducing the aquitard hydraulic conductivity had a negative impact on calibration in both the surficial aquifer (over-predicting water levels) and the deep aquifer (under-predicting water levels). The over-prediction in water levels in the surficial aquifer continued into the predictive phase, however, does not change the overall trend in groundwater level decline following the April 2024 peak and the cover of the foundation.
- An increased basement hydraulic conductivity led to higher groundwater declines during predictions but maintained similar trends to increasing the basement rock hydraulic conductivity with increased CTD TSF seepage rates leading to calibration under-predicting groundwater levels but maintaining a good response to rainfall events.
- The western side of the CTD TSF is the most sensitive to parameter changes and the adopted hydraulic parameters in the base case have the best calibration in this area while maintaining conservative predictions compared to the other scenarios.

Overall, the impact of the combination of uncertainties on predictions is considered acceptable due to the extensive operational record under abstraction, seepage and climatic stresses and the ability to calibrate to these stresses. In each instance where a parameter (hydraulic conductivity) was adjusted, an equal uncertainty (rate of seepage or proportion of rainfall as recharge) can be adjusted to fit the magnitude of responses; these adjustments lead to a corresponding similarity in magnitude of simulated responses to seepage and climate in the predictive scenarios of the model. This is observed in the similar forward predictions in the uncertainty scenarios, with any differences in rates of decline/increase in water levels leading to some difference of relative levels but the overall trend of receding water levels following the April 2024 peak and covering of the foundation by tailings material consistent between uncertainty scenarios.

Uncertainty in frequency of high rainfall events that lead to flooding was represented in SC005A (with operation of CTD TSF) and SC005B (without operation of CTD TSF) to show the potential impact of a second high rainfall event before groundwater receded to pre-storm levels. These simulations show that a large rainfall event in 2025 may cause water levels to return the highs of 2024, particularly in the west and southeast. However, the operation of the CTD TSF will have little impact on the maximum groundwater levels achieved in the western side and the groundwater level peak may even be higher without the operation of the seepage mitigation abstraction.

Figure 7.1: Hydrographs comparing predicted groundwater levels at selected points for the uncertainty scenarios





Notes: Calibration period is included with observed values, grey shading represents deposition onto foundation, green shading represents continued deposition after foundation is covered. Applied recharge for SC001 only, SC001A, SC001B, and SC001ET was performed with on older calibration and with deposition to 2028.

7.1 Limitations

The numerical model build and calibration focused specifically on the operation and impact of the CTD TSF. While the amount of information available to calibrate to is sufficient to make predictions on the operation of the CTD TSF, the numerical model has several limitations, specifically:

- Model predictions for the long-term conditions post closure of the CTD TSF are less certain than the operational predictions. As the Cleo/Sunrise pit is dewatered throughout the calibration period of the model, predictions without this dewatering influence are less certain once the water levels recover. Pit recovery and impact were not in the scope of this model.
- Deposition locations had to be assumed and seepage to the aquifer during the calibration and predictive phases are averages and not meant to represent actual seepage rates in the given time period. Actual seepage rates will be most sensitive to evaporation rates, direct rainfall onto the CTD TSF and stormwater pond, and the tailings deposition area (where foundation is exposed).
- If the model is utilised to assess the effectiveness of additional seepage infrastructure in the future, the actual rates achievable from trenches and/or bores may not be accurate. The model will be able to provide abstraction rates that would be required to achieve a water level response at an applied recharge and seepage rate, but the number of bores drilled or depth/length of trench required to achieve these rates will be determined hydrogeological conditions on site.

8 Conclusions

A numerical model was constructed to support predictions of the impact of ongoing deposition during the Stage 12 raise at the Sunrise CTD TSF. The model has been calibrated to spatially extensive groundwater monitoring data collected monthly since 2009. Importantly, the calibration period has included groundwater stresses that are of the same expected magnitude during deposition for the remainder of the life of the CTD TSF. Calibrated stresses include:

- Three extreme rainfall events that resulted in flooding and a large (up to 1.3 m) increase in water levels from the subsequent recharge (including the most recent flooding event in early to mid-2024).
- Seepage infiltration through a TSF foundation that is completely covered in tailings (pre-2019) and a higher seepage infiltration rate when the TSF pond is located directly on the foundation (post-2019). Total water content of deposited slurry was measured daily during this period.
- Abstraction data from seepage mitigation trenches and bores for the entire calibration period.

In addition to the historical record, AGAA has conducted field investigations in 2024, including drilling and testing in the CTD TSF material and the southeastern section of the CTD TSF where the Stage 10 CTD TSF expansion was built. All new and existing monitoring bores were slug tested in 2024 for additional hydraulic conductivity data of material underlying the CTD TSF.

Available data at the CTD TSF covered a long period (>14 years) of deposition, several storm and flooding events, and abstraction from the seepage interception trenches and bores. Groundwater responses in the observed data available for calibration is of the same magnitude as expected future CTD TSF behaviour and is very relevant to model predictions. The final calibration has achieved a good result to matching trends in the shallow bores; periods of increase, decrease and the magnitude of overall fluctuation are well represented.

Monitored groundwater levels should be assessed against model predictions at key locations, locations are provided in Table 8.1. Lower than simulated rates of recession of groundwater levels should be identified as early as possible to consider remedial actions. This is particularly true of the southeastern side where groundwater levels have been slower to recede than in other areas. If groundwater levels fail to recede as simulated (particularly in CTDMB40), the development of a trench (or the extension of the Stage 10 trench) may be required in the southeastern segment of the CTD TSF; interception bores in alluvium close to CTDMB40 and CTDMB29 may also be considered.

Table 8.1: Key locations for assessing groundwater level decline matches simulated levels

Bore to check against model predictions	Rationale
CTDMB7	To assess that groundwater levels are decreasing at the modelled rate so that subsequent rainfall events do not cause flooding.
CTDMB40	To assess that groundwater levels do start to decrease as simulated, particularly after the foundation is covered by tailings.
CTDMB39	Similar to CTDMB40 but with some decline already observed.
CTDMB29	Similar to CTDMB40 but with some decline already observed.

Seepage infiltration rates are anticipated to reduce once the foundation is fully covered by tailings (reliant on Stage 12 embankment raise and anticipated early 2026), having a lower hydraulic conductivity than the foundation material. Flooding due to high rainfall events in early 2024 has increased water levels, although these are currently receding following a groundwater level peak. Mounding is concentrated to the east of the dam where depth to groundwater is less of a concern due to higher topography. Lower depth to groundwater on the western side is likely due to lower topography in this area and the proximity to Lake Carey. Closure scenarios where CTD TSF influence on groundwater is minimal or nonexistent (due to a shedding cover), also had some bores equalise at less than 2 mbgl indicating that climate, topography and the local hydrogeological regime, are the overwhelming influences on depth to groundwater in the CTD TSF area.

Groundwater levels following Stage 12 of the CTD TSF are simulated to recede due to the reduction in seepage from the CTD TSF once the foundation is covered by tailings and a combination of natural recession from evaporation at Lake Carey, some pit dewatering influence, and ongoing abstraction of the seepage interception system. The seepage rate is not expected to increase through tailings despite the raise of embankment height and tailings thickness. This is due to unique deposition and facility arrangement with no permanent pool, thickened slurry discharge and thin layer deposition promoting evaporative drying and desiccation of the tailings mass. This was further demonstrated by the recent geotechnical and hydrogeological field investigation which observed that the tailings material is largely unsaturated. As such, groundwater levels in early 2024 are simulated to be the highest that the area around the CTD TSF will reach.

The operation of the CTD TSF will have little impact on the maximum groundwater levels and the groundwater level peak may even be higher without the operation of the seepage mitigation abstraction in certain scenarios. Groundwater levels are most sensitive to large rainfall and flooding events. A large rainfall event, similar to that of 2024, before groundwater has receded (i.e. during 2025), will likely return water levels to within 1 m surface on the western side of the CTD TSF regardless of the operation of the CTD TSF, as simulated in SC005A – with the CTD TSF seepage and SC005B without CTD TSF seepage. The low depth to water in the west is in part caused by topographic lows at CTDMB7 and not a particular high point in the CTD TSF mound (which is highest in the east of the CTD TSF where depth to groundwater is over 2 m), as the groundwater gradient is uniform and gently sloping (0.003 m/m) in the west.

Closure

This report, Sunrise Dam Gold Mine – Tailings Dam Stage 12 Embankment Raise Numerical Modelling, was prepared by

[redacted]

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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