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**TWIN HILLS FEED - TAILINGS, SURFACE AND
GROUNDWATER WATER STUDIES
FRONT END ENGINEERING DESIGN
HYDROGEOLOGY SUMMARY REPORT**

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EXECUTIVE SUMMARY

The Hydrogeological FEED study addressed gaps identified during the Definitive Feasibility Study (DFS) stage of the Twin Hills Gold Mine study. This work aimed to increase the confidence of the numerical model predictions for the mine water supply and determine the feasibility of a Managed Aquifer Recharge scheme on the Okawayo River.

A long-term multi-well pump test was conducted on the Southern Limb Marble aquifer to determine the sustainable yield of the water supply wells. Concurrently, a tracer test from injection wells in the Okawayo riverbed was run to determine the connectivity and degree of karstification along the marble and flow across the schists. The test concluded that matrix flow dominates the marbles, with localised flow via dissolution channels in the marble, along structures, and across the marble-schist contact.

The results confirm a hydraulic connection between the proposed MAR area and the marble aquifer and that a MAR scheme will recharge the aquifer.

- The marble aquifer has localised flow in discrete dissolution channels along the anticline axis, and marble-schist contacts and recharges the downstream aquifer.
- The marble aquifer is matrix-dominated with localised fracture flow.
- There is connectivity along the NW-SE structures from the marble through the schist.

The hydrodynamic coefficients were calculated from the multi-well pump test data, and the numerical model was updated and calibrated accordingly. The recommended pumping rates to ensure sustainability of the groundwater resources were calculated using the Theis equation and are shown in Table 1, along with the recommended pumping rates on a 16-hour pumping cycle to fall within the permitted volumes (500'000m³/an) for the Southern Limb.

Table 1: Recommended pumping rates within the permit.

Cycle:		Total (pumping 24hr)		Permitted (pumping 16hr)	
Boreholes (Number)	Borehole IDs	Recommended pumping rate (m ³ /day)	Recommended pumping rate (m ³ /an)	Recommended pumping rate (m ³ /day)	Recommended pumping rate (m ³ /an)
WW 206662	OKP042	346	126,144	219	80,000
WW 206666	OKP049	1,123	409,968	712	260,000
WW 206665	OKP057	259	94,608	164	60,000
WW 206663	Quarry	432	157,680	274	100,000
Sum:		2,160	788,400	1370	500,000

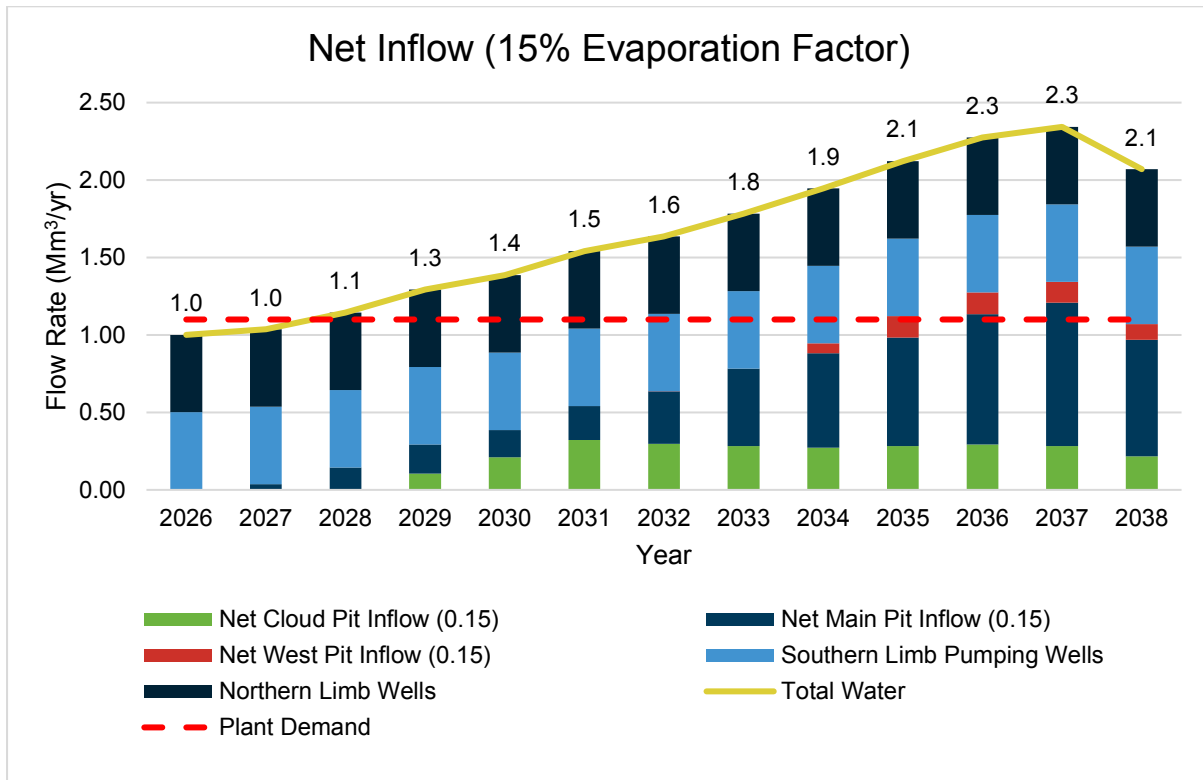


Figure 1: Stacked flow rate of the pumping boreholes and pit inflows with evaporation consideration (Northern and Southern Limb at 0.5Mm³/yr each).

Simulations for flow over the Life of Mine (LOM) were run, and the results show:

- There is no significant difference between the total flow rate of this model and the FEED Interim memo model.
- The pit lake volumes were estimated from a pit water balance considering groundwater seepage flows and general assumptions to estimate pit lake evaporation and losses along the seepage walls of the open pits.
 - Due to limited site-specific evaporation data, a sensitivity assessment was undertaken to show variability with the evaporation factor.
- The total groundwater flow rate into the pits is 0.60 Mm³/y in year 3, increasing to 2.5 Mm³/y in year 14. However, when compensating for evaporation (15% evaporation factor), this average has been reduced to 0.6 Mm³/y in the last six years of mining (Figure 1).
- A 16-hour pumping cycle will sustain the borehole abstraction rate of 500,000 m³/y from the southern limb.
- The extent of the COD around the pit is larger than in the previous model as it reaches the COD induced by the additional wells in the northern limb.
 - The COD is ellipsoid in shape along the SW-NE line of pits, and the total length is approximately 10 km, which is about 1.5 km SW of the West Pit and 2 km NE of the Cloud Pit.
 - Pumping along the northern limb has created a COD along strike and has overlapped with the COD around the pits. The COD does not extend significantly to the south or reach the adjacent Dobbelsberg Farm.

- The 5 m COD contour is simulated to be more than 5 km from Twinhills 3 and Dobblesberg boreholes.

The Managed Aquifer Recharge (MAR) simulations indicate that the hydraulic head in the marble aquifers can be improved. In addition, the simulated MAR does not significantly impact the pore pressures behind the southern pit walls, specifically near the Okawayo River.

The solute concentration of 100 mg/l surpasses the unsaturated zone and is 45 m below the Cloud WRD. Although the numerical simulation does not show considerable solute migration to the river (290 m in the unsaturated zone), the pumping wells (i.e. OKP042 and OKP049) could capture the solute due to the observed hydraulic connectivity through the NW-SE structures.

The study and results have increased the model's confidence and is suitable for the design phase. However, the following is recommended:

- Very little data is available for this area and the pit wall evaporation potential, and a pit lake model with calibration from site-monitored evaporation rates at depth is recommended during the life of mine.
- Tracer testing on the northern limb marbles to define the connectivity along the marble and to confirm the feasibility of a MAR scheme in the Khan River.
- Long-term multi-well pump testing at the northern limb water supply wells to calculate the matrix and fracture flow hydrodynamic coefficients, to determine the sustainable yields and required pumping cycles.
- Test pumping at OKP045 to determine the hydraulic coefficient of the NW-SE striking fault along the Okawayo River. In addition, further structural studies should be undertaken to better define the structure geometries.
- Feasibility design of a combined surface water flood mitigation structure/sub-surface sand dam in the Okawayo tributary upgradient of the mine area as a dual purpose to enhance recharge to the upper contact of the marble unit.
- Samples to be collected during the dry season from groundwater and surface water for stable isotopes and tritium to refine the recharge estimates to groundwater.
- Incorporate detailed pit designs with a monthly cutback to more accurately simulate groundwater inflow into the pit.
- Update the numerical model with the results.
- The observation wells close to the river (e.g. OKP045, OKP042 and OKP049) must be monitored seasonally during operation for any solute transport within the capture zone of the wells.
- Consider seepage capture to prevent solute from entering the Okawayo baseflow in case of a contamination leak from the Cloud WRD into the unsaturated zone.
- An optimised network of monitoring boreholes around the pits.
- Water balance study in the pits considering the evaporation impact and a pit lake model evaporation, with a sensitivity analysis.
- Pit Lake modelling to determine the water quality of the pit lake after mine-closure, including a detailed geochemistry assessment of the pit wall rocks.

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- Appendix A3 – Evaporation Factor of 45%
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ABBREVIATIONS

CDT	Constant Discharge Test
CHD	Constant Head Test
DFS	Definitive Feasibility Study
ECC	Environmental Compliance Consultancy
FEED	Front End Engineering Design
Osino	Osino Resources
T	Transmissivity
K	Hydraulic Conductivity
KP	Knight Piésold
L	Litres
mm	Millimetres
m/day	Metres per day
m/s	Metres per second
m ² /day	Metres squared per day
m ³ /hr	Cubic metres per hour
mbc	Metres below the collar
mbgl	Metres below ground level
OW	Observation Well
PW	Pumping Well

1.0 INTRODUCTION

Osino Resources (Pty) Ltd appointed Knight Piésold Consulting (Pty) Ltd to conduct a Front-End Engineering Design (FEED) phase study to address gaps and mitigate risks identified in the Definitive Feasibility Study (DFS) for Twin Hills Gold Mine.

This study included additional fieldwork of a multi-well pump test of four identified boreholes and a tracer assessment in the Okawayo River. This document contains details of the fieldwork activities undertaken and discusses the findings. The phase also includes updating the FEFLOW numerical model by incorporating the findings from the fieldwork and updated site infrastructure.

1.1 OBJECTIVES

The main objective of the FEED phase is to close gaps and risks identified during the DFS (KP, 2023) and the third-party review from Palaris (Palaris, 2023) and SLR (SLR, 2023).

Key objectives for the Twin Hills FEED program can be summarised as follows:

- Reduce risks to the groundwater model water calculated supply volumes related to the karstic environment by obtaining more field-based information from tracer tests and long-term multi-well pumping tests.
- Determine the feasibility of a combined surface water flood mitigation structure/sub-surface sand dam in the Okawayo tributary upgradient of the mine area as a dual purpose to enhance recharge to the marble aquifer.
- Determine the hydraulic connectivity between the marble and schist units.
- Include additional information about the northern marble aquifer since the completion of the DFS.

1.2 SCOPE OF WORK

The following tasks were completed to advance the hydrogeological study for the Twin Hills project and to reduce identified risks:

- A long-term multi-well pump test of water supply boreholes to evaluate the sustainable yield and determine whether overlapping drawdown cones could occur.
- Tracer Testing and interpretation to assess the degree of karstification and connectivity
- To determine whether the unsaturated zone connects the MAR area to the downstream planned pits.
- Characterise the karst units and connectivity along the southern limb.
 - Flow across the schists and determine the connectivity of the northern and southern marble limbs beyond Okawayo.
- VWT data extraction and interpretation.
- Numerical model update and re-calibration with fieldwork data.
- Numerical model simulations for updated pit inflows and extent of impact due to the lowering of the groundwater.
- Semi-saturated contaminant transport model in the vadose zone.

2.0 MULTI-WELL PUMPING TEST

A multi-well pumping test was conducted on the southern Karibib Marble limb at the Twin Hills Gold Mine. This test aimed to determine the long-term pumping impacts on the marble aquifer and the sustainable yields for water abstraction for the mine's needs.

A tracer test was conducted concurrently, taking advantage of the stresses the pumping test induced on the marble aquifer. The setup and results of this test are described in Section 3.0.

2.1 DESIGN AND EXECUTION

A team of specialists from Boegman Groundwater installed pumping systems into the selected boreholes (Table 2-1) and conducted the long-term multi-well pumping test under the supervision of KP hydrogeologists.

Boegman Groundwater provided Osino Resources with permanent installations for groundwater supply during the construction and operational phases. The permanent installations include a built-in monitoring system, flow control, and early detection systems to protect the pumping equipment from running dry.

The Multi-well Pumping Test began on January 16, 2024, at 12:00 p.m. and was set to run for approximately two weeks, depending on the drawdown achieved.

Table 2-1 and Figure 2-1 show the pumping boreholes selected for the multi-well pumping test. The discharge points for each pumping well was chosen to ensure that the discharge from the wells was far enough away to prevent recirculation as indicated in Figure 2-1.

Table 2-1: Pumping Boreholes Details

Borehole specifications								
Borehole Number	Pumping Borehole	X	Y	Z	BH Depth (mbgl)	Proposed Pump Inlet depth (mbgl)	Final Hole Diameter (mm)	Proposed rate (l/s)
WW 206662	OKP042	601302	7583900	1224	120	110	203	5.0
WW 206666	OKP049	599545	7582960	1233	130	110	203	15.0
WW 206665	OKP057	596545	7581477	1202	120	110*	203	18.0
WW 206663	Quarry BH	596467	7580421	1208	130	100	203	11.1

* Moved to 104 m during the test.

2.2 OBSERVATION NETWORK

Various observation methods and locations were utilised to monitor the multi-well pump test and the impact on the aquifers in the region. The monitoring network is shown in Figure 2-1, and details of the observation network can be found in the Field Summary Report in Appendix A. The following observation methods were used:

- At least one dedicated observation borehole was allocated for each pumping borehole where level loggers were placed. Table 2-2 and Figure 2-1 show the observation boreholes selected to monitor the aquifer/s during the multi-well pumping test.
- Additional boreholes were manually monitored throughout the test, including water supply boreholes on the surrounding farms.
- Data from VWTs installed in boreholes around the proposed pits were also assessed.

2.3 TEST DURATION AND TIMELINE

The pumping test was initiated on January 16, 2024, and ran for over two weeks. Details on the test duration can be found in Table 2-2. The observation network water levels were recorded throughout the active pumping and recovery of the borehole levels. Due to the slow recovery, monitoring was stopped once the recovery duration was equal to the pumping duration.

Table 2-2: Multi-well Pump Test duration summary per borehole.

Borehole Number	BH ID and Obs Boreholes	Pumping Start	Pumping End	Duration (Days)	Pumping Rate (m ³ /hour)	Max Drawdown (%)	Recovery reached at t/t ₀ (%)
WW 206662 OKRHH011	OKP042 OKP027	16/01/2024	12/02/2024	27	18	48.1	55.5
WW 206666 OKRHH022	OKP049 OKP026	16/01/2024	12/02/2024	27	54	70.5	41
WW 206665 OKRHH005	OKP057 OKP017	16/01/2024	30/01/2024	14	64.8	84.1	97
WW 206663 Mingjie 2	Quarry BH Mingjie 2	16/01/2024	28/01/2024	12	40	94.8	96

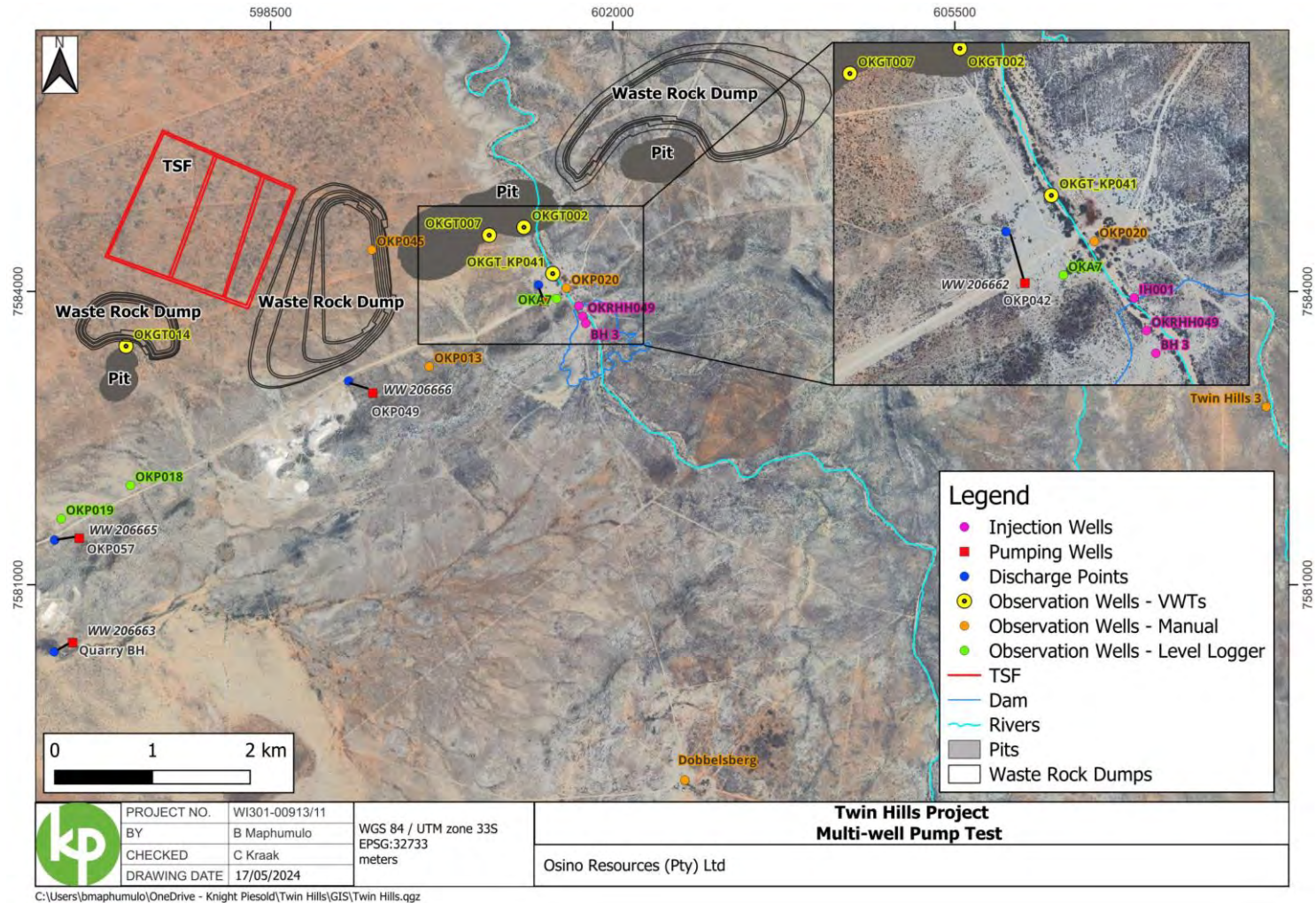


Figure 2-1: Multi-well Pumping Test Layout

2.4 DATA INTERPRETATION AND RESULTS

Multi-well pumping test data were assessed using a spherical model (Barker, 1988) to estimate the following parameters:

- K (fracture hydraulic conductivity)
- Ss (fracture specific storage)
- K' (matrix hydraulic conductivity)
- Ss' (matrix specific storage)
- n (flow dimension)
- b (extent of flow region)
- Sf (fracture skin factor)
- Sw (wellbore skin factor)

This approach is the most suitable for this aquifer, which has a double porosity fracture type. The storage coefficients computed from the pumping-phase data could be impacted by the compression induced in the aquifer during the pumping, possible pump flow rate variations, well loss, and extra drawdown. However, the recovery phase of the multi-well pumping tests is more reliable in calculating hydraulic conductivity because gravity is the only effective force on the aquifer.

2.4.1 BOREHOLE WW 206662 (OKP042)

The early drawdown and derivative data shown in Figure 2-2 is evidence of fissures or wellbore storage. The peak or hump shown on the derivative curve is also indicative of wellbore storage. At mid-time, the derivative curve shows a dip, which is the effect of fractured skin (restricted block to fissure flow), and it reaches a constant value that reflects radial flow. As drawdown reaches the boundaries, the aquifer exhibits matrix linear flow. Three assessments were done:

1. Figure 2-2: The hydrodynamic coefficients were computed using the pumping data only,
2. Figure 2-3: The pumping data and recovery in the pumping borehole and
3. Figure 2-4: The observation borehole.

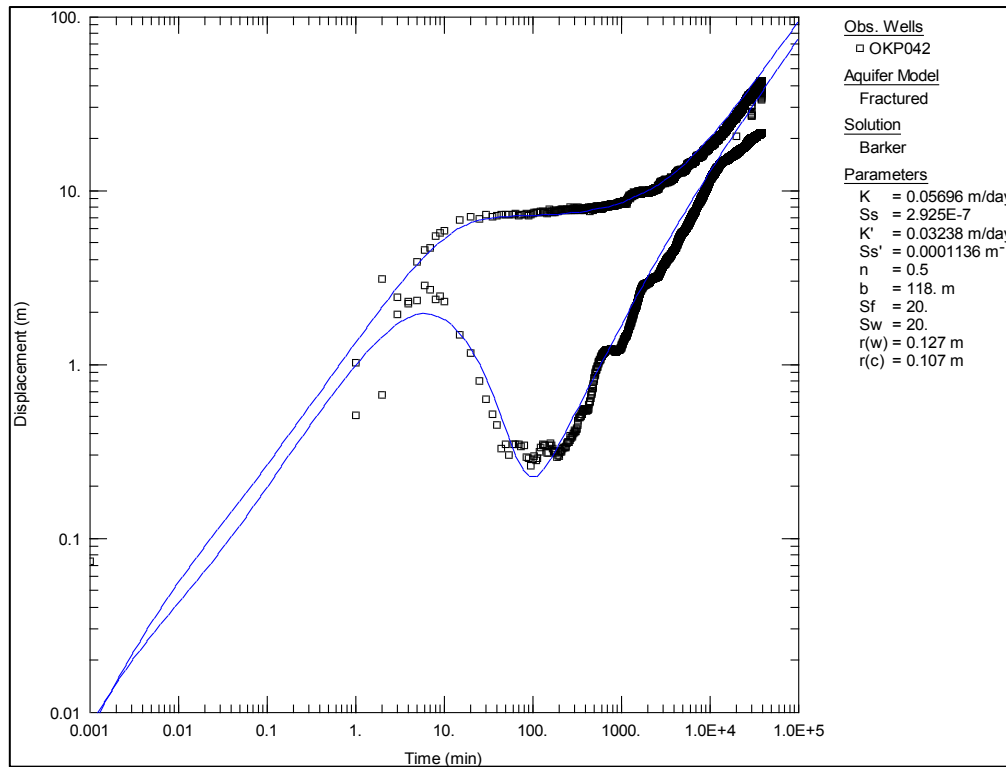


Figure 2-2: log-log displacement- time plot of WW 206662 (OKP042) without the recovery data with the Derivative-type curve.

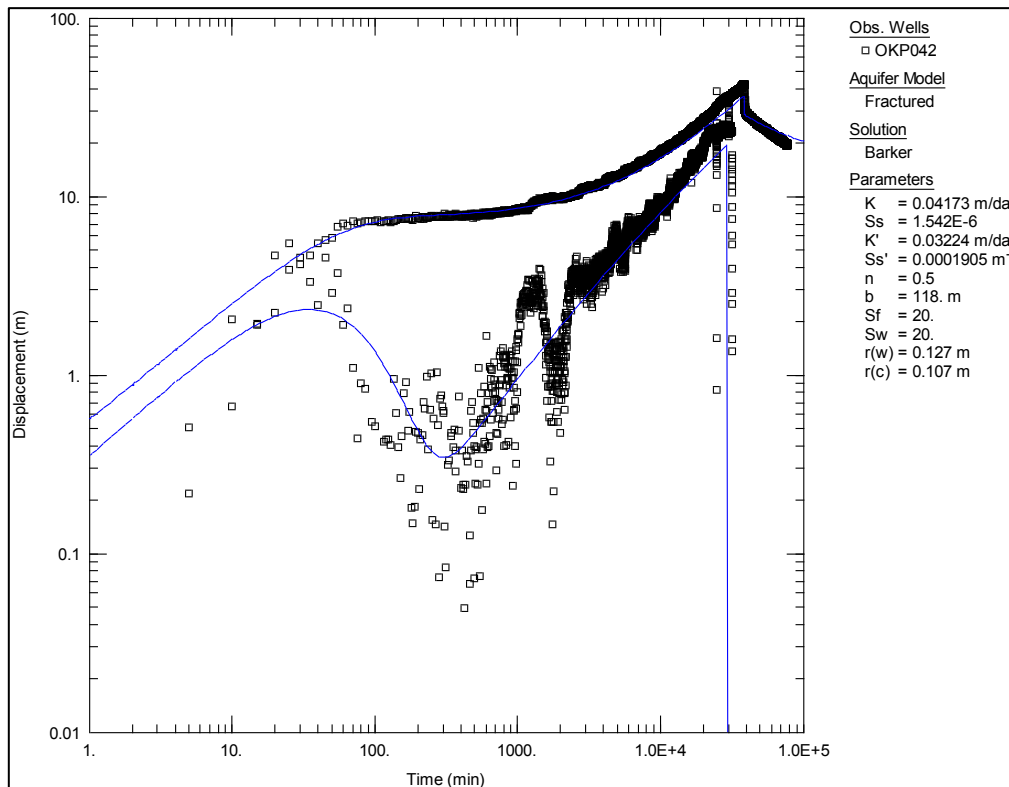


Figure 2-3: log-log displacement- time plot of WW 206662 (OKP042) with the recovery data with the Derivative-type curve.

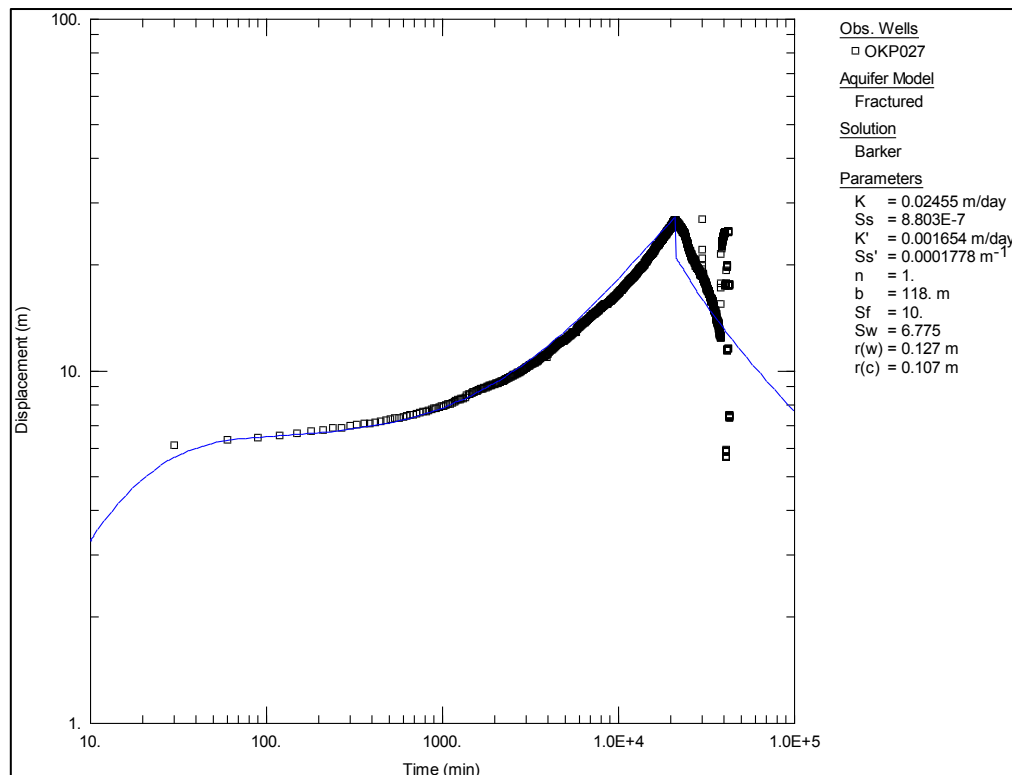


Figure 2-4: log-log displacement-time plot of OKRHH011 (OKP027) (OKP042 observation boreholes) with the recovery data.

2.4.2 BOREHOLE WW 206666 (OKP049)

The borehole and its observation borehole show the same hydraulic response. Wellbore storage and local fissures are evident in the data. The hydrodynamic coefficients were computed using the pumping data and recovery in the pumping and observation boreholes. The hydrodynamic coefficients from the recovery data are more reliable for K calculation.

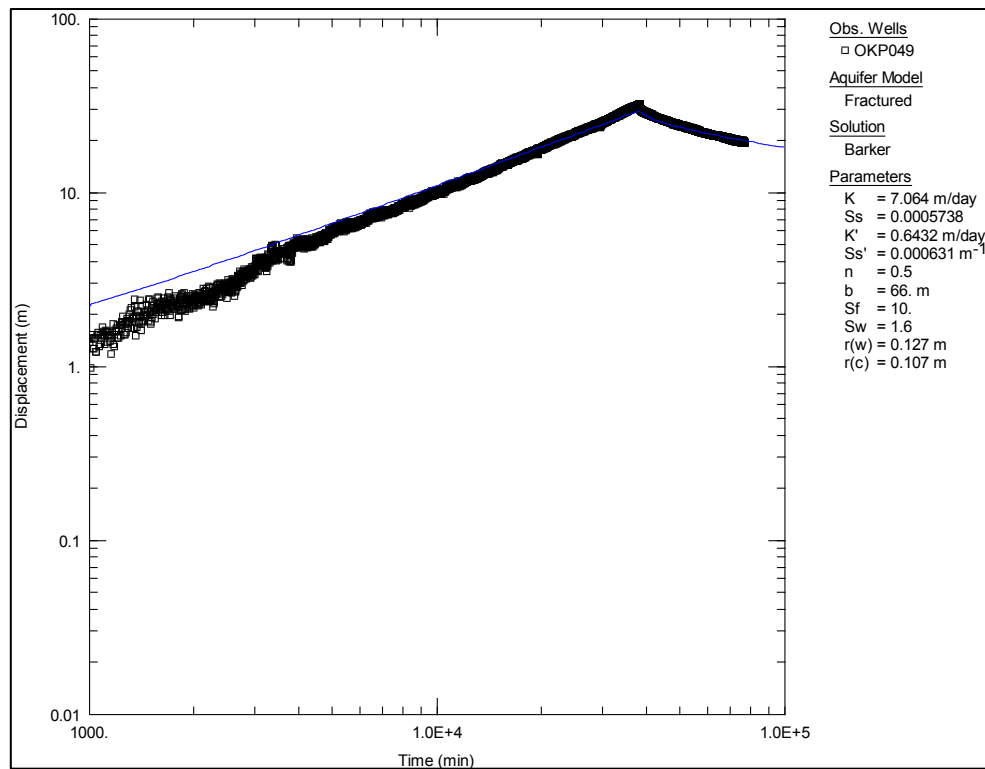


Figure 2-5: log-log displacement-time plot of WW 206666 (OKP049) with the recovery data.

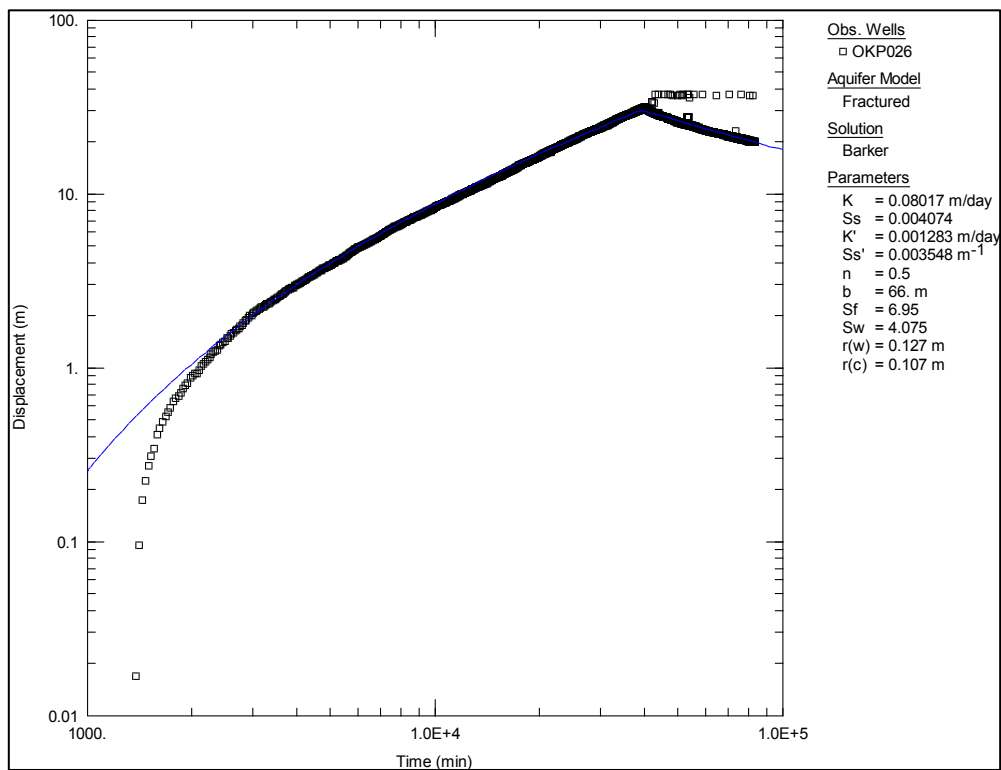


Figure 2-6: log-log displacement-time plot of OKRHH022 (OKP026) (OKP049 observation borehole) with the recovery data.

2.4.3 BOREHOLE WW 206665 (OKP057)

The log-log displacement plot for OKP057 shows a steady drawdown with a notable drop around 22 hours, indicated by the red circle in Figure 2-7. As the pump flow rate is constant, this shift suggests that the cone of drawdown has reached a low-flow boundary with lesser hydraulic conductivity or storage, leading to increased drawdown. The hydrodynamic coefficients were computed using three assessments:

1. Figure 2-7: The hydrodynamic coefficients were computed using the pumping data only,
2. Figure 2-8: The pumping data and recovery in the pumping borehole and
3. Figure 2-9: The observation borehole without recovery data
4. Figure 2-10: The observation borehole with recovery data.

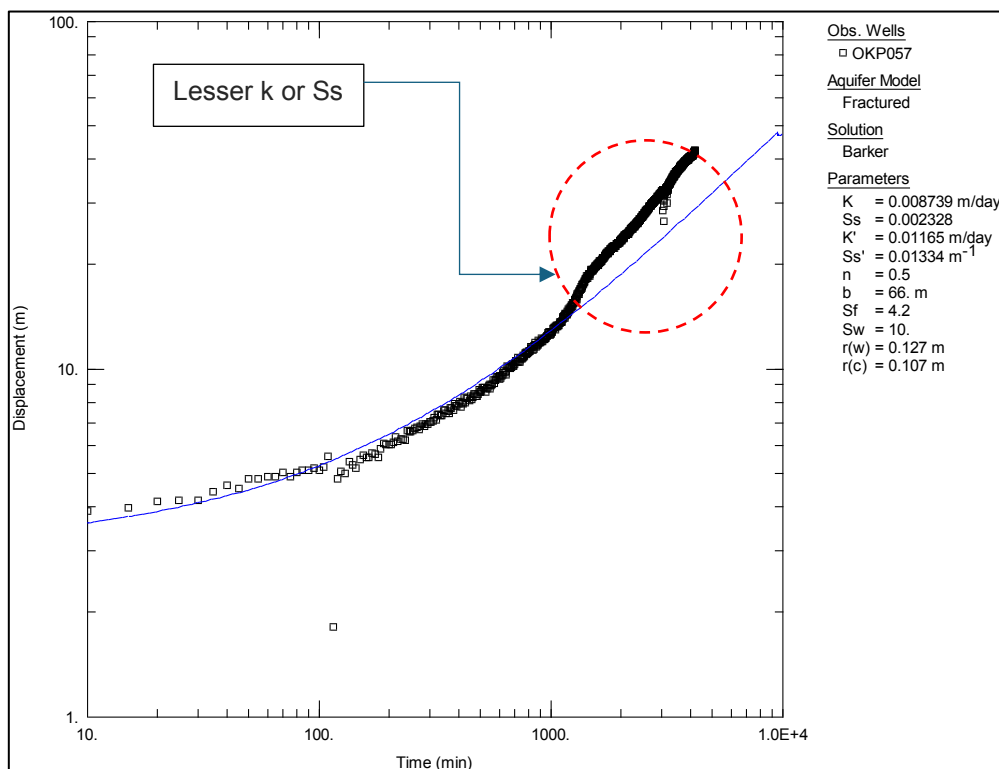


Figure 2-7: log-log displacement-time plot of WW 206665 (OKP057) without the recovery data.

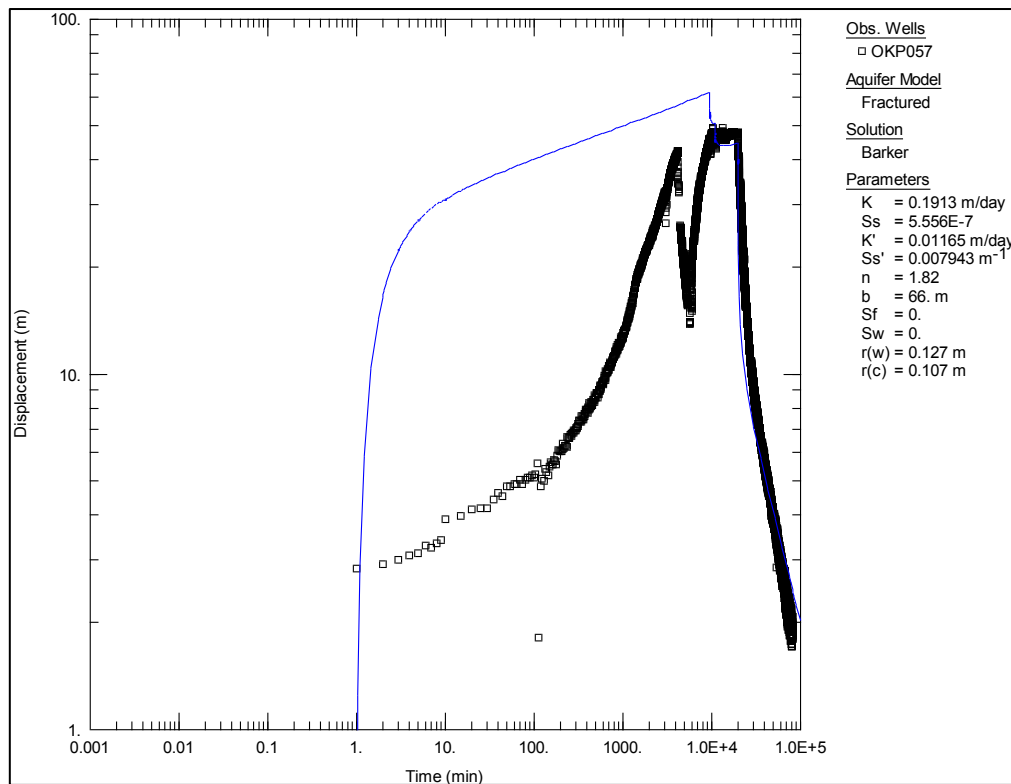


Figure 2-8: log-log displacement-time plot of WW 206665 (OKP057) with the recovery data.

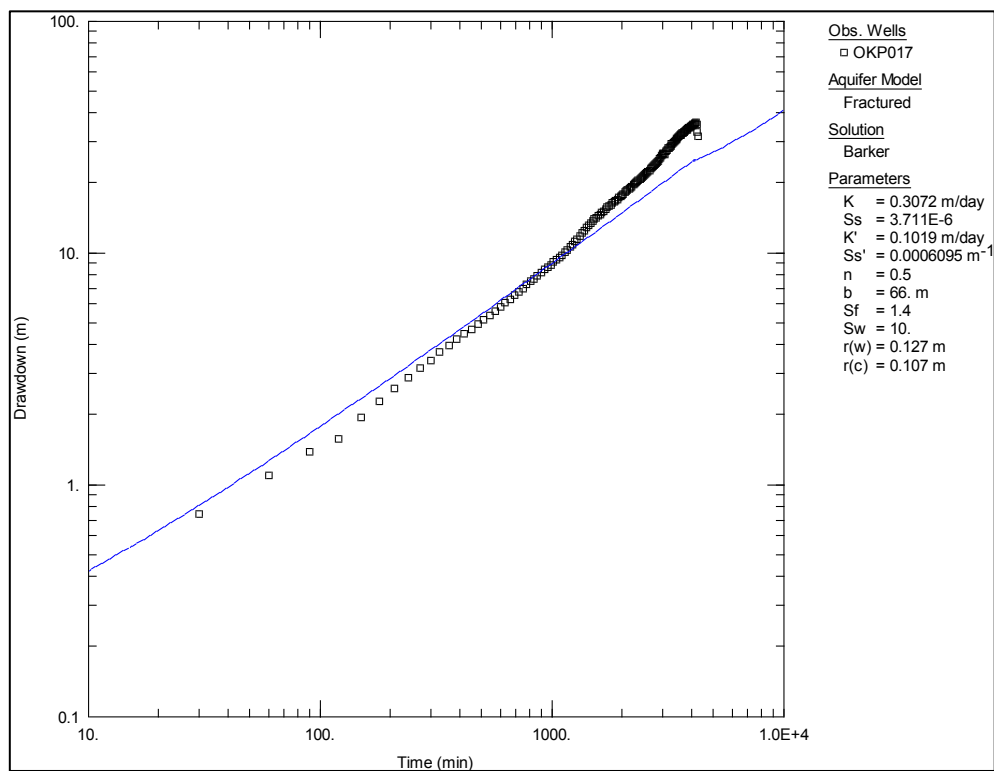


Figure 2-9: log-log displacement-time plot of OKRHH005 (OKP017) (OKP057 observation borehole) without the recovery data.

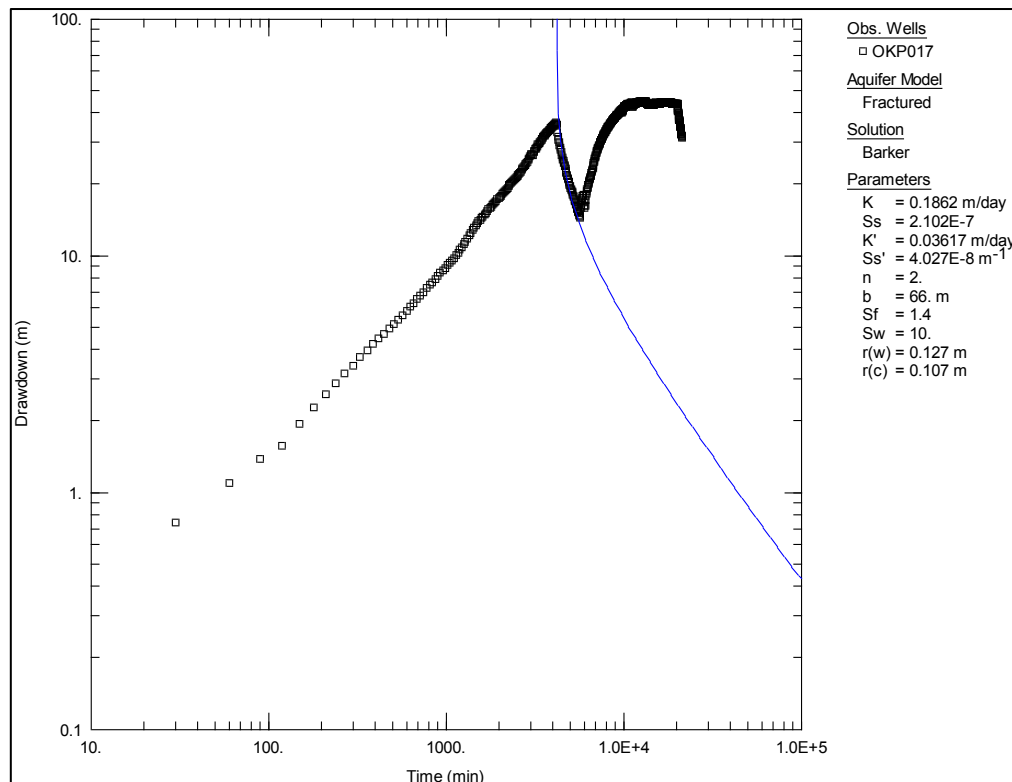


Figure 2-10: log-log displacement-time plot of OKRHH005 (OKP017) (OKP057 observation borehole) with the recovery data.

2.4.4 BOREHOLE WW 206663 (QUARRY BH)

Since the pumping test was conducted under a constant head test for the pumping portion, the constant head analysis with an average drawdown of 36 m was selected to compute the hydraulic coefficients. However, the constant flow rate analysis was chosen for the recovery data in the pumping and observation boreholes.

The hydrodynamic coefficients computed using the observation borehole correlate better with the calculations based on the constant head analysis than with the recovery data.

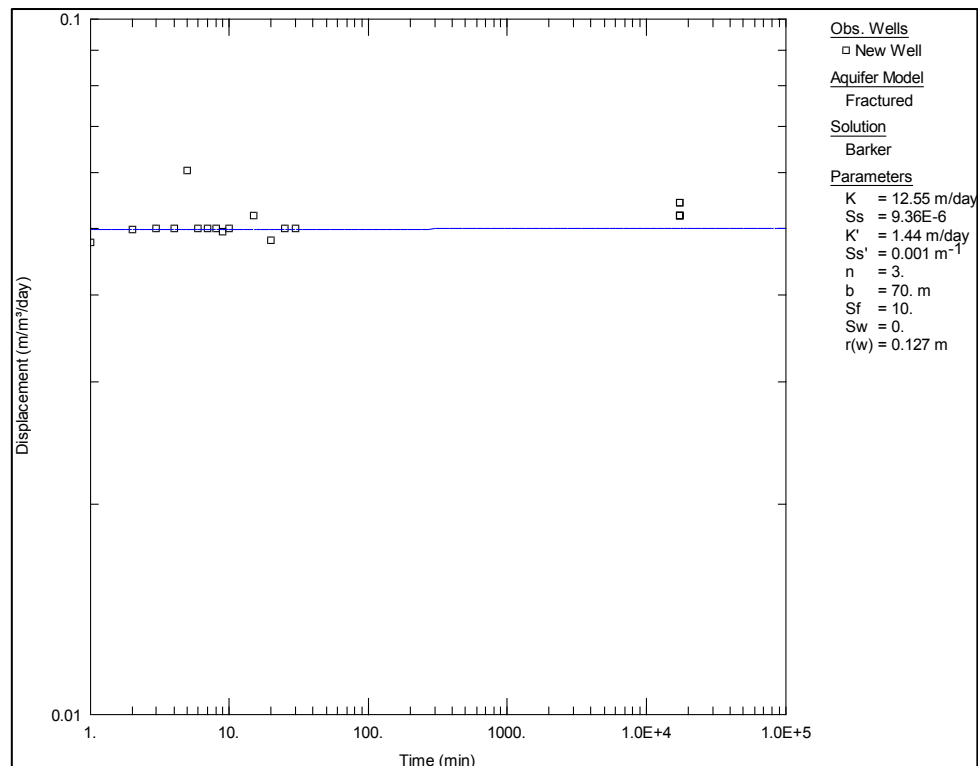


Figure 2-11: log-log displacement ($\text{m/m}^3/\text{day}$)- time plot of WW 206663 (Quarry BH) under the constant head (36 m) test only with the pumping data.

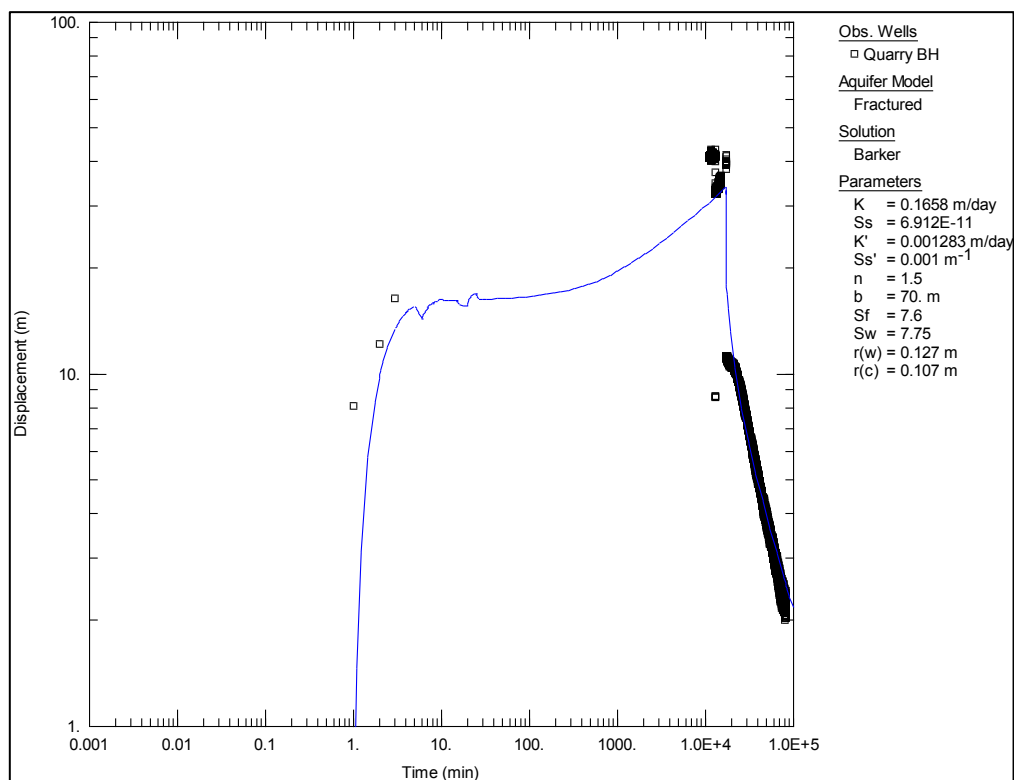


Figure 2-12: log-log displacement-time plot of WW 206663 (Quarry BH) with only the recovery data.

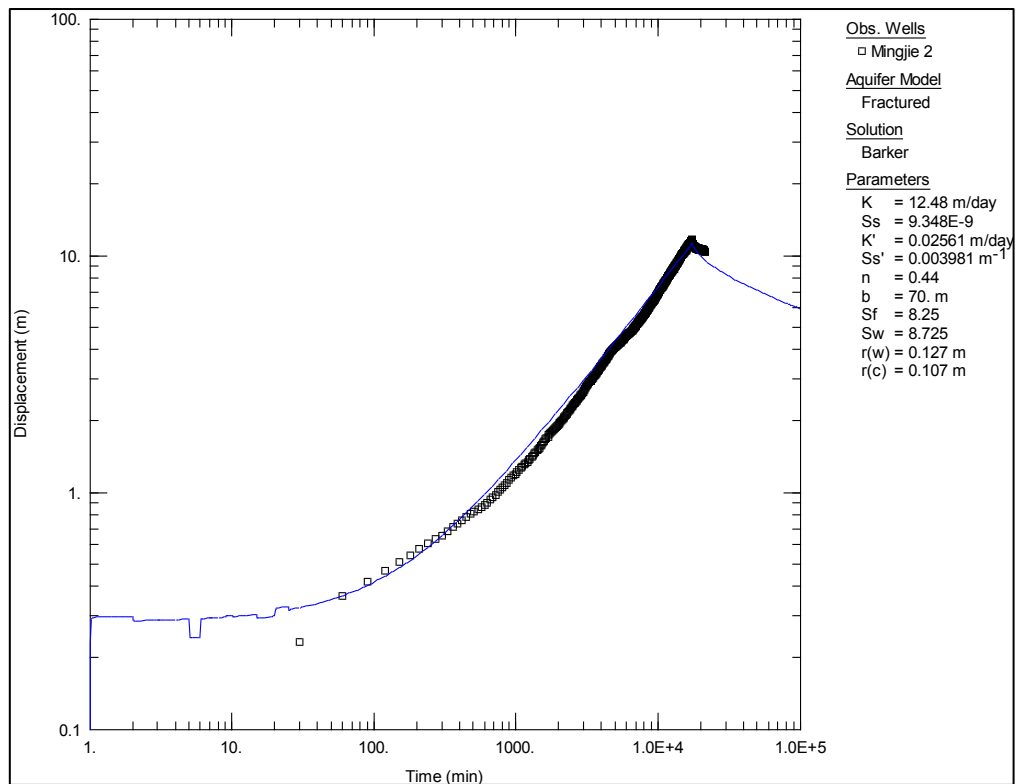


Figure 2-13: log-log displacement-time plot of Mingjie 2 (Quarry BH observation borehole) with the recovery data.

2.4.5 PUMPING TEST RESULTS SUMMARY

Table 2-3 shows the computed hydrodynamic coefficients derived from the multi-well pumping test. Acronyms D and R refer to the analysis for the coefficients using the drawdown (pumping) or the recovery data, respectively. The boreholes without the abbreviations were analysed using both the drawdown and the recovery data. T_{m+f} was calculated using the average hydraulic conductivity of the matrix and fracture.

Table 2-3: Hydrodynamic coefficients

Borehole Number	BH ID	(S_m)	K_m (m/day)	K_f (m/day)	S_f	b (m)	T_m (m ² /day)	T_{m+f} (m ² /day)
WW 206662	OKP042 (D)	1.14E-04	0.03	0.06	2.93E-07	118	3.82	5.27
	OKP042 (R)	1.91E-04	0.03	0.04	1.54E-06	118	3.80	4.36
OKRHH011	OKP027	1.78E-04	0.002	0.02	8.80E-07	118	0.20	1.55
WW 206666	OKP049	6.31E-04	0.64	7.06	5.74E-04	66	42.45	254.34
OKRHH022	OKP026	3.55E-03	0.001	0.08	4.07E-03	66	0.08	2.69
	OKP026 (R)	7.94E-04	0.64	6.09	3.91E-04	66	42.45	222.29
WW 206665	OKP057 (D)	1.33E-02	0.01	0.01	2.33E-03	66	0.58	0.67
	OKP057 (R)	1.33E-02	0.01	0.10	3.72E-04	66	0.77	3.72
OKRHH005	OKP017 (D)	6.10E-04	0.10	0.31	3.71E-06	66	6.73	13.50
	OKP017 (R)	4.03E-08	0.04	0.19	2.10E-07	66	2.39	7.34
WW 206663	Quarry (Constant H)	1.00E-03	1.44	12.55	9.36E-06	70	100.80	489.65
	Quarry (R)	1.00E-03	0.001	0.17	6.91E-11	70	0.09	5.85
Mingjie 2	Mingjie 2	3.98E-03	0.03	12.48	9.35E-09	70	1.79	437.70

R - Recovery
D - Drawdown
H - Head
m - Matrix
f - fracture

2.4.6 VWT DATA ASSESSMENT

Four geotechnical exploration boreholes near the pit were equipped with grouted-in multilevel vibrating wire transducers (VWT). At each borehole, three transducers were installed at various depths.

The VWTs data are used:

- To measure the hydraulic head in different lithologies (calcrete, marble, schist) and structures pre-mining and during operations
- To monitor the changes in pore pressures in response to passive dewatering as the pit develops
- To monitor the transient pore pressures following high rainfall events, particularly in calcrete

- To monitor the response to managed aquifer recharge upgradient in the Okawayo stream (OKGT041)
- To detect potential seepage from the WRDs (OKGT014).
- To update and calibrate the numerical model as mining progresses.

The data from the VWTs were assessed to determine the extent of the impact of the multi-well pumping.

- The data from July 2023 to February 2024 from the VWT piezometers were downloaded for analysis.
- Trends for OKGT002, OKGT0014 and OKGT041 were analysed, and the rate of change recorded does not show that the multi-well pumping test impacted the water levels in those areas.
- The trend for the shallow sensor in OKGT007 (Figure 2-14) does not show any impact from the multi-well pump testing. However, the mid and deep sensors show a drop in water levels during the test pumping. It must be noted that the shallow sensor (geology: schist fault under calcrete) is installed close to the water table and unsaturated zone; therefore, it cannot show the variations in the deeper aquifer hydraulic head as much as the two deeper sensors.
- The mid sensor has an approximate drop of 2m on January 28.
- The deep sensor shows two drops on January 28 and February 4, respectively, by 2 m and 0.70 m. This suggests connectivity via a structure between OKGT007 and the marble unit.

The graphs illustrate the VWT data before and after pumping, which are shown in Appendix 1.

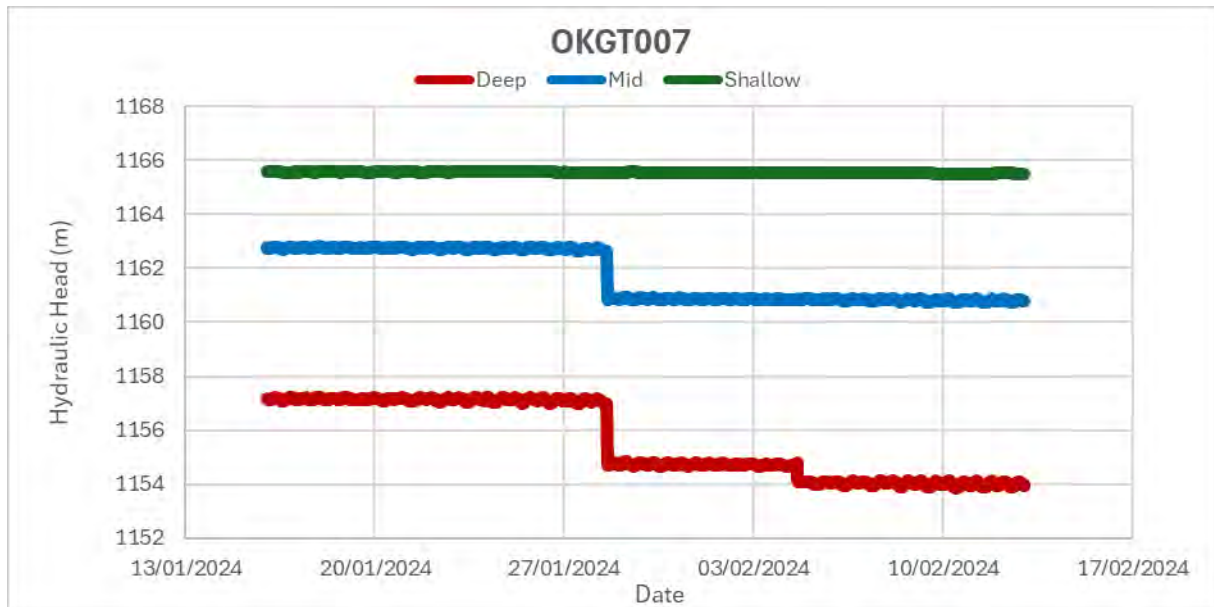


Figure 2-14: VWT hydraulic head plot for OKGT0070.

2.5 SUSTAINABLE YIELD

The Theis Solution (Time/Drawdown) was applied to calculate the sustainable yield for protecting the aquifer and pump equipment. The sustainable yields were calculated using the Theis equation and are shown in Table 2-4, along with the recommended pumping rates on a 16-hour cycle to fall within the permitted volumes (500'000m³/an) for the Southern Limb.

Figure 2-15 to Figure 2-18 show the sustainable yield curves using the Theis Solution for each pumping borehole.

Table 2-4: Calculated sustainable yield and proposed pumping rates within the permit.

Cycle:		Total (pumping 24hr)		Permitted (pumping 16hr)	
Boreholes (Number)	Borehole IDs	Recommended pumping rate (m ³ /day)	Recommended pumping rate (m ³ /an)	Recommended pumping rate (m ³ /day)	Recommended pumping rate (m ³ /an)
WW 206662	OKP042	346	126,144	219	80,000
WW 206666	OKP049	1,123	409,968	712	260,000
WW 206665	OKP057	259	94,608	164	60,000
WW 206663	Quarry	432	157,680	274	100,000
Sum:		2,160	788,400	1370	500,000

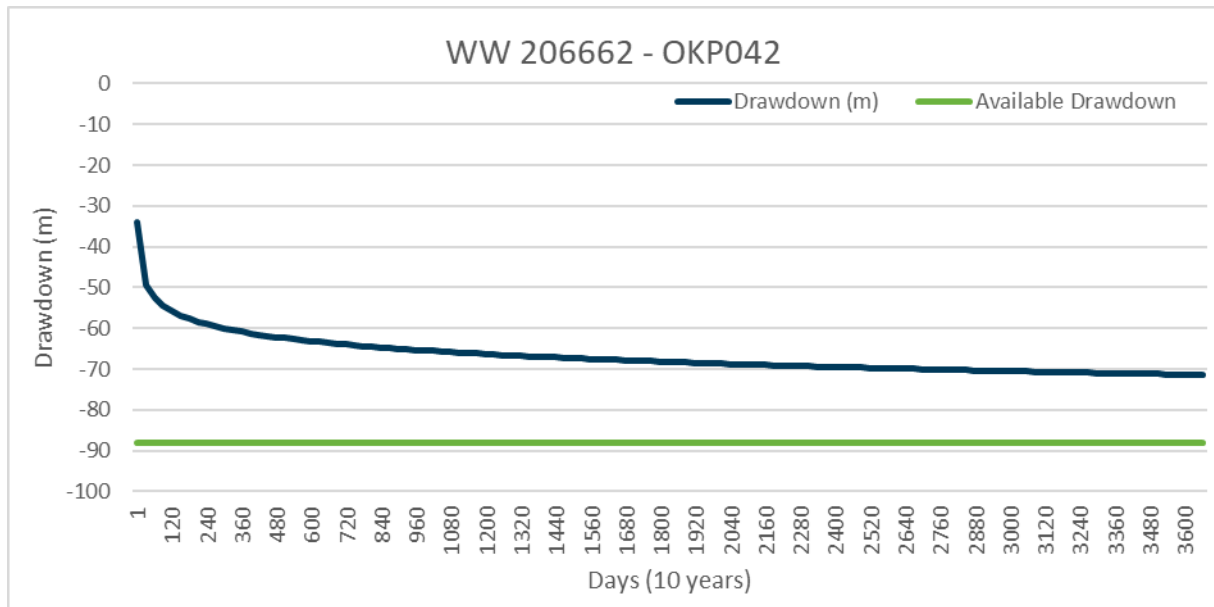


Figure 2-15: WW 206662 (OKP042) Theis Solution (Time/Drawdown) at 4 L/s over 10 years.

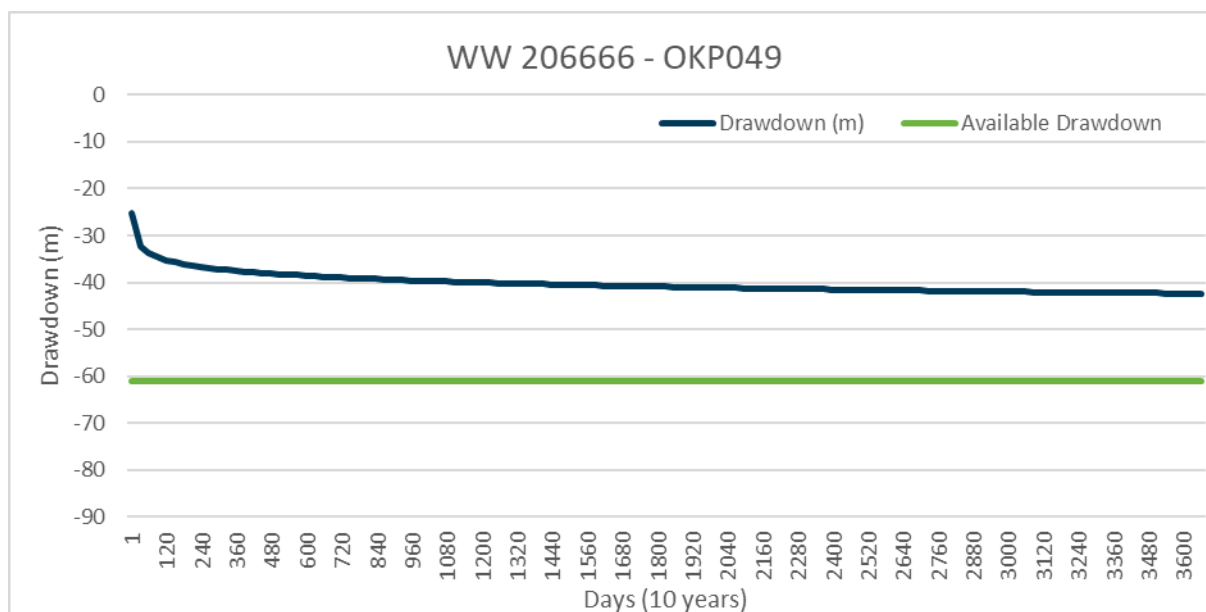


Figure 2-16: WW 206666 (OKP049) Theis Solution (Time/Drawdown) at 13 L/s over 10 years.

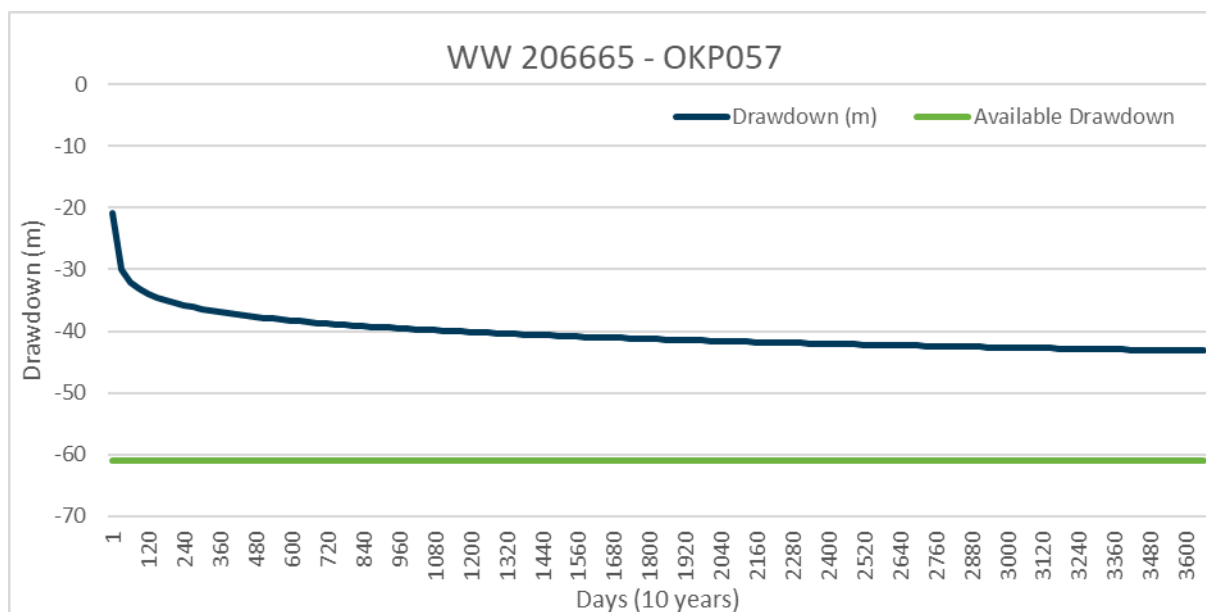


Figure 2-17: WW 206665 (OKP057) Theis Solution (Time/Drawdown) at 3 L/s over 10 years.

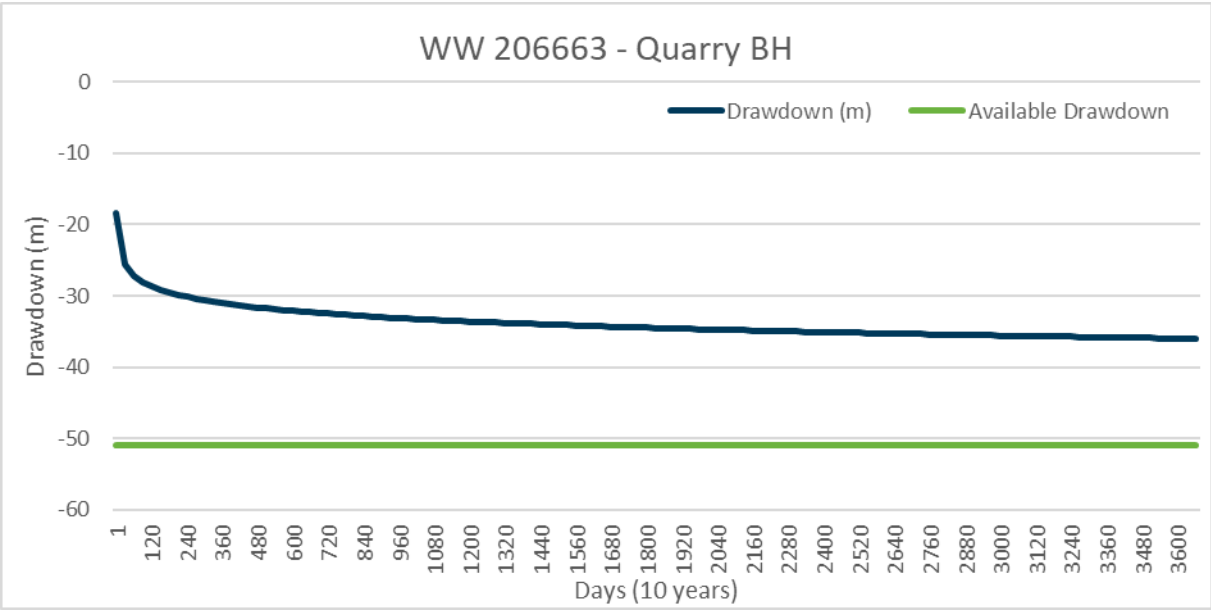


Figure 2-18: WW 206663 (Quarry BH) Theis Solution (Time/Drawdown) at 5 L/s over 10 years.

3.0 TRACER TESTING

3.1 INTRODUCTION

The dye tracing technique is one of the most efficient and well-known methods to assess karst aquifers. This method can estimate discharge conditions, flow direction, flow rate, residence time, transport, and dispersion. Fluorescent dye tracers are more applicable than other tracers, as they are detectable at low concentrations, and are easy to use.

The study aimed to assess the degree of karstification and connectivity by identifying karstic features such as conduits and identifying laminar or turbulent flow regimes. The tracing test was conducted simultaneously with the multi-well pumping test. Due to the complex and heterogenous aquifer, three dyes, including Uranine, Rhodamine WT and Tinopal, were used upstream of the southern marble formation.

The details of the three selected dye tracers are outlined in Table 3-1.

Table 3-1: Features of the three selected dye tracers (EPA, 1999)

Dye Name	Maximum Excitation λ (nm)	Maximum Emission λ (nm)	Fluorescence Intensity (%)	Detection Limit ($\mu\text{g/L}$ { -1 })	Sorption Tendency
Sodium fluorescein	492	513	100	0.002	Very low
Rhodamine WT	558	583	25	0.006	moderate
Tinopal CBS-X	355	435	60	0.01	moderate

3.2 INJECTION HOLE PREPARATION

The injection sites were selected upstream of the sampling points where there is a possible conduit for groundwater flow. The injection boreholes were placed in the Okawayo River, where there is potential hydraulic connection between the proposed MAR sand attenuation dam site and the downgradient mine water supply boreholes in the marble. Table 3-2 details the injection boreholes, targets and the associated dye.

Table 3-2: Table Injection boreholes with Specified dye

BH ID	X	Y	Target	Specified Dye
IH001	601654	7583852	Alluvial deposits are underlain by fresh marble	Rhodamine WT
OKRHH049	601694	7583747	Within a zone of marble dissolution and fracturing	Sodium Flurescein (Uranine)
BH3 (OKRHH033)	601724	7583647	A structure within the marble unit	Tinpaol CBS_X

3.3 Data interpretation and results

Samples were collected from the multi-well pumping boreholes and selected monitoring points at specific intervals, and the sampling intervals were adjusted based on the dye detection throughout the test.

Samples collected in 50ml plastic bottles were labelled according to their time, date, and whether they were obtained from pumping or monitoring boreholes. After collection, the samples were stored in a dark location away from sunlight. The samples were then analysed based on the results from the Fluorometer.

3.3.1 RECOVERY CALCULATIONS

The tracer recovery is quantified using:

$$M_R = \int_0^{\infty} C(t) Q(t) dt$$

M_R mass recovery, $C(t)$, and $Q(t)$ are the concentration and discharge in time, respectively, and t is time.

Table 3-8 shows the recovery calculations of the pumping and observation boreholes.

Table 3-3: Recovery calculations of the pumping and observation boreholes.

Tracer	Recovery by 04/13/2024	Sampling site							Sum
		Pumping boreholes				Observations Boreholes			
		OKP042	OKP049	OKP057	Quarry	OKP013	OKP020	OKP045	
Tinopal	(kg)	0.04	0.04	0.01	0.00	0.08	0.00	0.30	0.5
	(%)	1.80	2.00	0.26	0.08	3.84	0.00	15.00	22.99
Uranine	(kg)	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.11
	(%)	5.60	0.00	0.00	0.00	0.00	0.00	0.00	5.60
Rhodamine WT	(kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Rhodamine was not recovered in any of the monitoring boreholes because it was injected in the alluvial, and there was no rainfall during the test period to mobilise the dye from the injection borehole. However, samples from the injection well showed dilution over time, suggesting some migration.

Uranine was only detected in OKP042. The pumping at OKP042 ceased 26 days from the injection time. The permanent pumping equipment prevented access for continued sampling. Therefore, OKP027, the closest observation borehole in the same structure as OKP042, was selected to continue the tracer sampling. The concentration over time for OKP042-OKP027 is shown in Figure 3-1 and indicates that the maximum concentration and a complete breakthrough curve were achieved for Uranine.

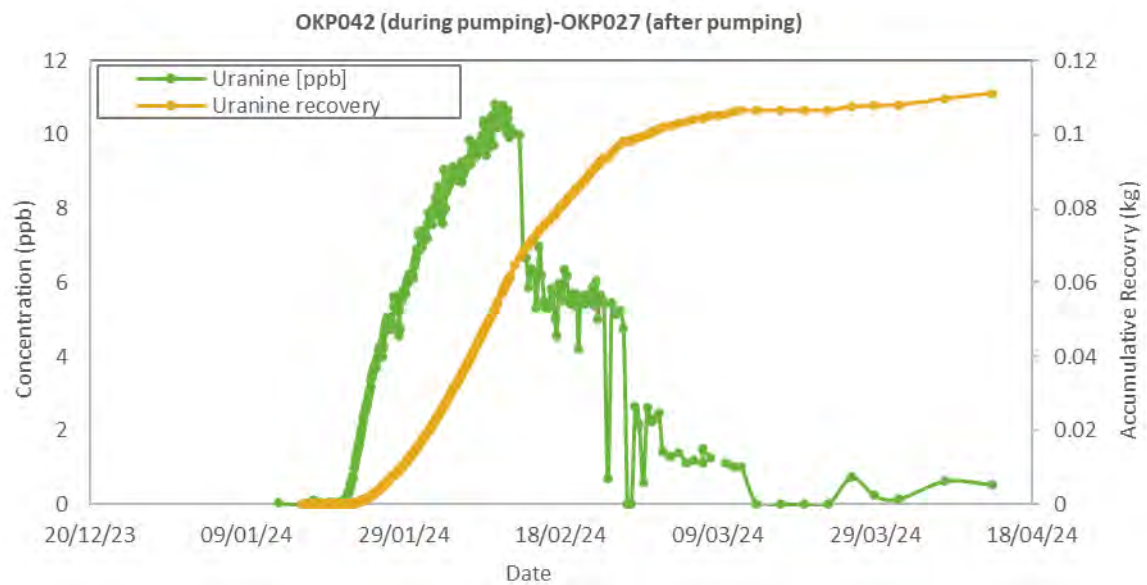


Figure 3-1: Uranine concentration and its accumulative recovery at OKP042-OKP027.

Figure 3-2 illustrates the Tinopal concentration curves for the pumping boreholes and samples collected manually with a bailer. Unfortunately, a complete breakthrough curve was not achieved during the sampling period.

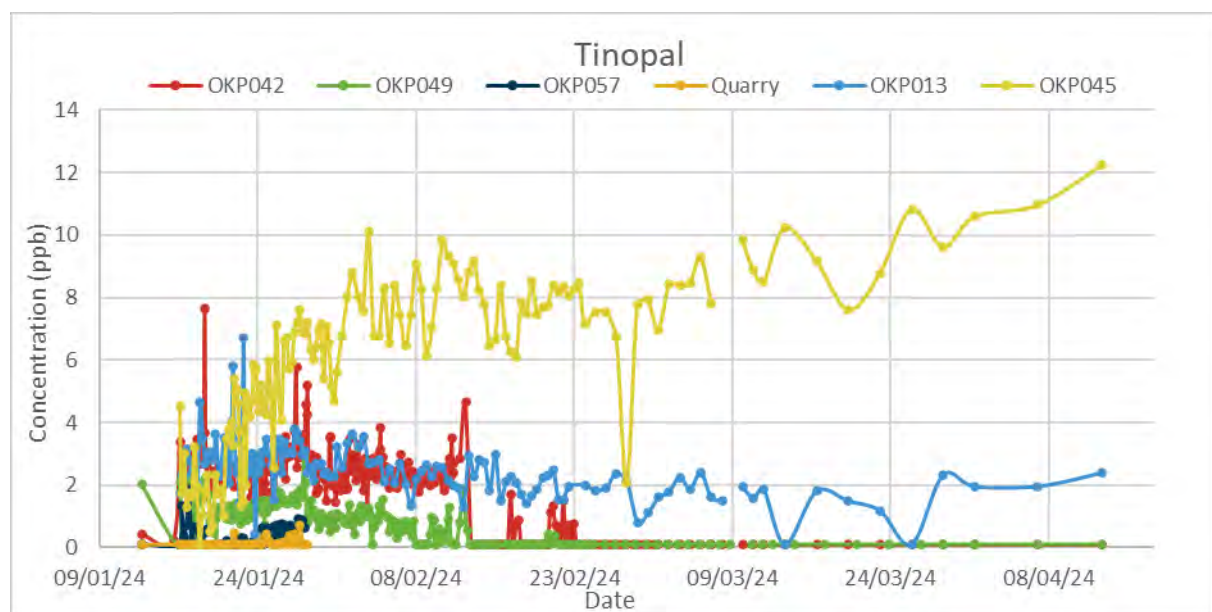


Figure 3-2: Tinopal concentration curves.

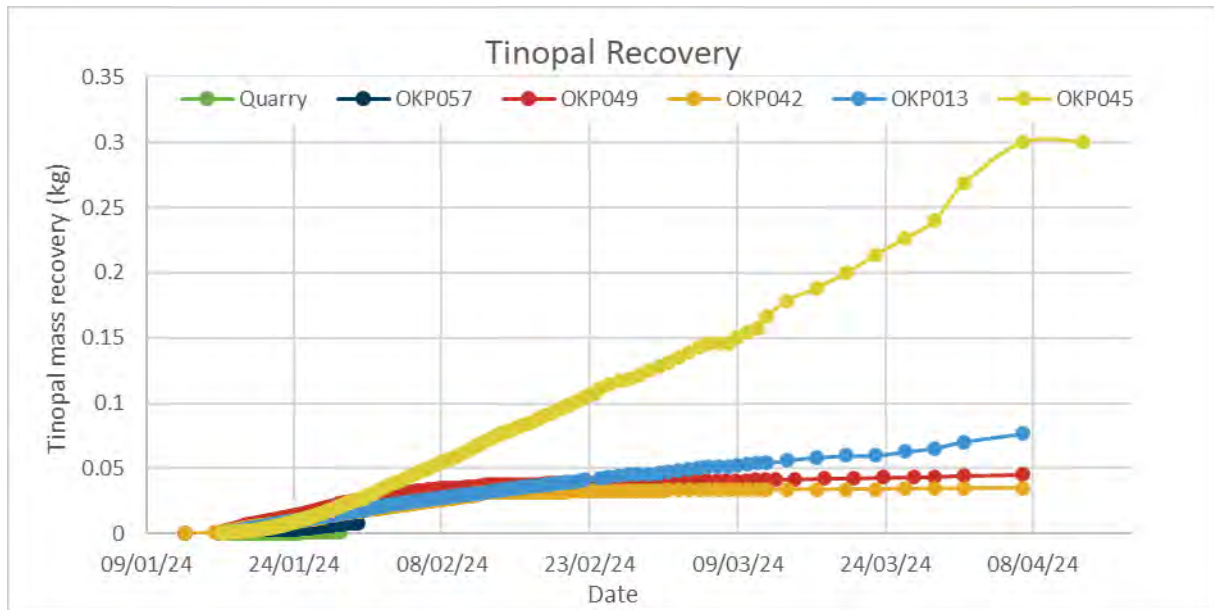


Figure 3-3: Tinopal Recovery Calculations curves.

3.3.2 ANALYTICAL SOLUTION

In general, the concentration variations of a solute over time can be affected by dispersion and advection without considering sorption and other chemical, biological, and radioactive disintegration. Therefore, the transport equation can be formulated in 1-Dimension as follows:

$$\frac{\partial c}{\partial t} = D_l \frac{\partial^2 c}{\partial x^2} - v_x \frac{\partial c}{\partial x}$$

Where c is concentration, t time, D_l is dispersion, and v_x is velocity. The analytical solution used in this project is based on the work of Kreft and Zuber (1978), assuming the monitoring point for the breakthrough curve (BTC) is fixed:

$$c(t) = \frac{M}{Qt_0 \sqrt{4\pi P_D \left(\frac{t}{t_0}\right)^3}} \exp\left(-\frac{\left(1 - \frac{t}{t_0}\right)^2}{4P_D \frac{t}{t_0}}\right)$$

Where c is concentration, M mass of injection, Q discharge of well, t time, t_0 mean transit time, and $P_D = D/vL$.

Based on the analytical solution for Uranine from OKP042, groundwater velocity and dispersion were determined as 0.95 m/h and 95 m²/h, respectively.

Figure 3-4 shows that the measured versus simulated concentration for Uranine recovered at OKP042 using the analytical solution has a good correlation.

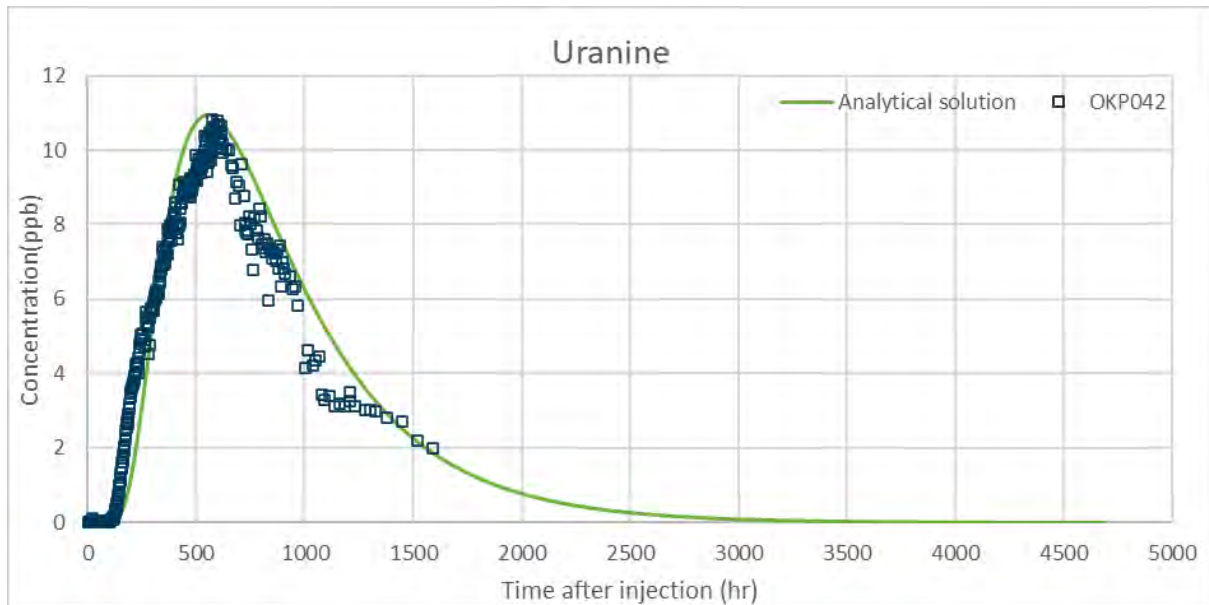


Figure 3-4: Tracer concentration observation and simulation based on the analytical solution.

3.4 RESULTS DISCUSSION

The following outcomes were observed from the conducted tracer test:

- Rhodamine WT was not observed in any of the detection sites.
- Rhodamine was injected into the alluvial deposits in the Okawayo River. There was limited rainfall during the test, so the movement downstream was insufficient to be picked up at the downgradient monitoring sites.
- However, measurements taken from the injection borehole indicated dilution, suggesting migration away from the injection borehole.
- Tinopal was detected at a higher concentration than the background on the 17th of January 2024, the first day after the injection for the 4 pumping boreholes (OKP042, OKP049, OKP057 and Quarry Hole)
- Minerals in the marble may mimic the wavelength of Tinopal, so it is unlikely that it was directly from the injection site on that date.
- Therefore, the exact start of the Tinopal tracer in the monitoring boreholes is challenging to pinpoint.
- A higher concentration of Tinopal was observed at the closest pumping borehole (OKP042) than at the farthest pumping borehole (Quarry), which could indicate some direct flow from the structure, but this can't be confirmed.
- Uranine and Tinopal were confirmed to be detected at OKP042 on January 21, 2024.
- OKP049 has a higher recovery of Tinopal than OKP042 despite having a lower solute concentration, likely due to the higher flow rate.
 - OKP045 is located downstream in the Okawayo River along the fault zone.
 - This suggests that OKP049 receives flow via fracture flow that may be controlled by the marble anticline axis and OKP042 through matrix flow from the injection site.
- The discharge point from OKP042 flowed into the Okawayo riverbed approximately 420 m upstream from OKP045.

- The shallow VWTs located in and close to the riverbed (OKGT002 and OKGT014) show no indication of increased water levels in the shallow aquifer, suggesting that flow from the OKP042 discharge point infiltrated directly into the deeper aquifer (via the structure).
- OKP045 sampling showed a marked increase in tracer concentrations, with the recovery calculations revealing that the structure has a considerable flow path (Figure 3-3).
- Considering the values derived from OKP042 compared to OKP045 (Figure 3-3), the latter received combined flow directly from the injection site and the OKP042 discharge site.

The results confirm a hydraulic connection between the proposed MAR area and the marble aquifer and that a MAR scheme will recharge the aquifer. The following conclusions can be made:

- The marble aquifer has localised flow in discrete dissolution channels along the anticline axis and the marble-schist contact, which recharges the downstream aquifer.
- The marble aquifer is matrix-dominated with localised fracture flow.
- There is connectivity along the NW-SE structures from the marble through the schist.

4.0 STABLE ISOTOPE ANALYSIS

The meteoric water line (MWL) is a slope that shows the composition of the stable isotopes of hydrogen and oxygen in precipitation in the local environment (Castañeda et al., 2012). Samples from surface and groundwater in that region are plotted against this line for assessment. Water entering the groundwater system from direct recharge, not being exposed to evaporation, plots along this line. In contrast, open surface water bodies undergo evaporation, resulting in the enrichment of the heavier isotopes of deuterium and oxygen as the lighter molecules evaporate. These samples plot below the MWL along an evaporative trend line, depending on the level of enrichment. Analysing stable isotopes can indicate whether there is surface water and groundwater interaction.

A total of six groundwater samples and one rainwater sample were analysed for stable isotopes of deuterium (δD) and oxygen ($\delta^{18}O$). The summary of the results of the stable isotope is shown below in Table 4-1; the $\delta^{18}O$ values range from -7.19 to 5.59‰, and the δD values range from -48.0 to 43.5‰.

The results for the stable isotopes are plotted on the δD vs $\delta^{18}O$ graph along with the Global Meteoric Water Line (GMWL) and the Local Meteoric Water Line (LMWL), as shown in Figure 4-1 below (Kaseke, et al., 2018). The groundwater samples plotted on the GMWL are directly above the LMWL, while the rain sample plots are above the LMWL and relatively far below the GMWL. The rainwater sample is highly enriched in both deuterium and oxygen and has a strong evaporative signature, which may be due to the dry semi-arid climate or more likely the sample collection methodology was unreliable.

The isotopes in the groundwater samples plot close to each other (including OKP020 and OKP045), suggesting the same source (Figure 4-1). The difference between the groundwater samples and the isotopes in the rainfall indicates that the marble aquifer may have been recharged under different climatic conditions or extreme rainfall events. Additional seasonal samples should be collected for site-specific meteoric data, as the rainfall can vary significantly from the start to the end of the season.

It is recommended that more than one rainfall event and groundwater samples from upstream and downstream of the marble aquifer in the south should be analysed for δD , oxygen $\delta^{18}O$ and tritium.

Table 4-1: Stable Isotope Results for Twin Hills Samples

Sample Identification	$\delta^{18}O$ (‰)	δD (‰)
Quarry	-7,03	-46,7
OKP013	-6,86	-44,0
OKP020	-6,66	-41,4
OKP042	-6,58	-40,9
OKP045	-7,42	-47,5
OKP049	-6,65	-43,4
OKP057	-7,19	-48,0
Twin Hills Rain	+5,59	+43,5

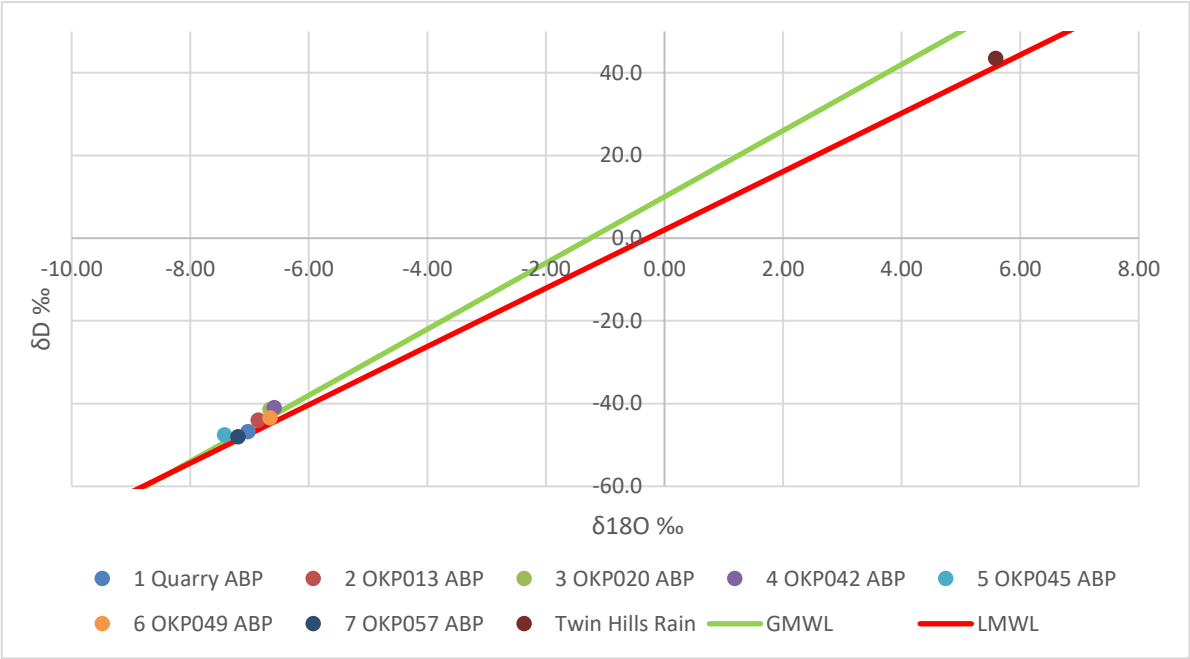


Figure 4-1: Stable Isotopes for Twin Hills Samples

5.0 NUMERICAL MODELLING

The following updates were made on the numerical model:

- Observation boreholes: the four VWTs were added to the previous observation boreholes to calibrate the model.
- Tracer test results: The conduit flow process model implemented a channelised flow path along the southern marble aquifer.
- Multi-well pumping test results: the hydraulic conductivities and specific storage computed from the multi-well pumping test were defined around the borehole.
- Northern limb data: the hydraulic conductivities and the recommended pumping rate were applied based on Report No.: 2024-WG-5 (SLR, 2024).
 - The northern limb boreholes have not been tested for long-term sustainable yields and the extent of overlapping pumping drawdown effects.
- Sustainable yield: the recommended sustainable yields in 16 h cyclic time series (Table 2-4) were assigned for the pumping multi-layer boreholes in the southern aquifer.
- Waste rock dumps and tailing facilities: the new design of the WRDs and TSF (KP design, 14 March 2024) was considered in the numerical model.

5.1 CONDUIT FLOW PROCESS MODEL

Karstic aquifers are usually dual porosity characterised by their conduit network and connection to the host matrix. Such characteristics were confirmed by applying multi-well pump tests and groundwater level time series in the case of interest. Therefore, a conduit flow process (CFP) coupled with a MODFLOW 2005 numerical model was built in Model Muse based on a 3D hydro-stratigraphical conceptual model. The model has 22 layers, with the ones across the mine depth of 15 m thick. No stresses were applied to the aquifers for this simulation.

Considering the results of the tracing test, a main conduit along the karstic aquifer was implemented in the model. Conduit features, including diameter, length, tortuosity, roughness height, lower and upper Reynolds number, direct conduit recharge and transfer coefficient between the conduit and the host matrix, were assigned and adjusted to the model for calibration (Figure 5-1).

MODPATH, a post-processing tool in Model Muse associated with MODFLOW, was run to show the pathlines (Figure 5-2). This modelling results show a temporal disconnect between the northern and the southern marble units, with travel times above 2.5×10^5 years. Conduit flow along the marble in the fold-axial cleavage is highest and directs flow from the MAR area and recharge zones south-westerly along the marble unit. Flow across the marble-schist contact is significantly reduced, and flow is actively diverted in a westerly direction along the strike before entering the schist. Movement through the schist is restricted due to the low hydraulic conductivities in this unit. However, flow paths have slightly increased rates through the NW-SE structures.

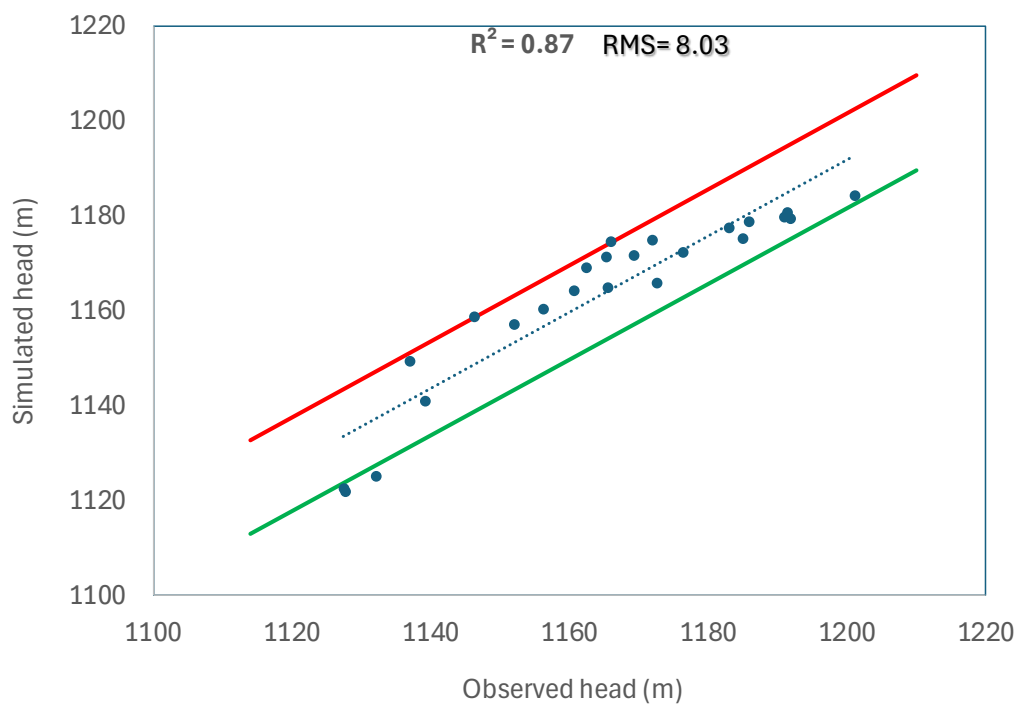


Figure 5-1: Simulated hydraulic head vs observed hydraulic head

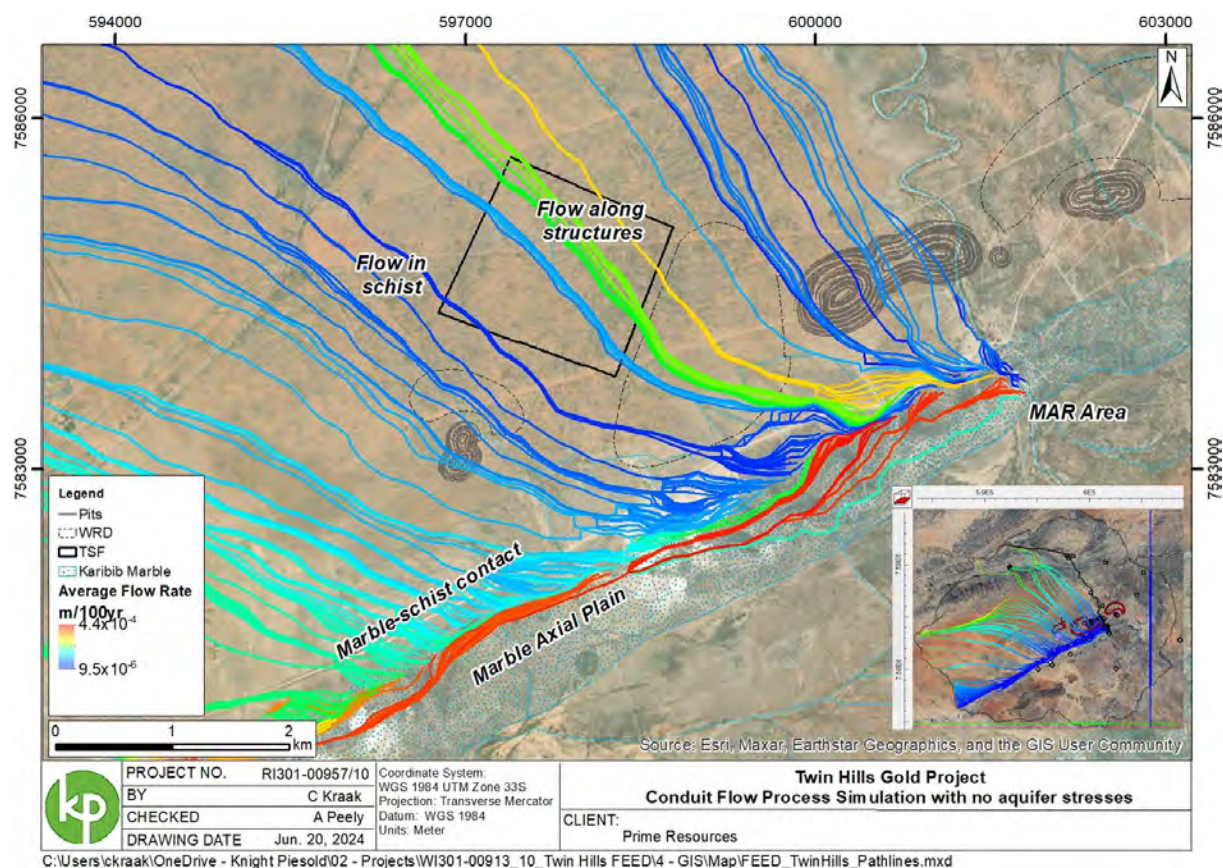


Figure 5-2: Relative flow rates from the CFP simulation.

5.2 MULTI-WELL PUMPING TEST

The numerical model, updated with the calculated hydrodynamic coefficients computed from the analytical solution, was run to assess the impact of the multi-well pumping test on groundwater. As a transient simulation to calibrate the model. The model was considered calibrated when the simulated maximum drawdown matched the observed drawdown from the multi-well pumping test.

The data are a reasonable fit to the model predictions, as shown in Figure 5-3 to Figure 5-6.

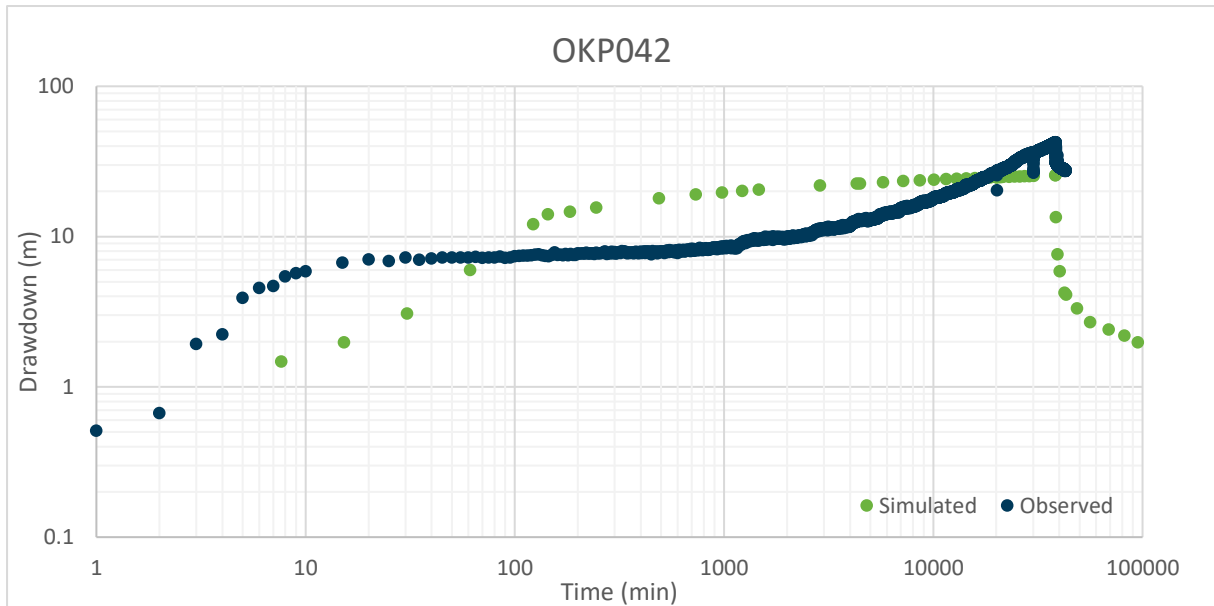


Figure 5-3: Observed and simulated drawdown in WW 206662 (OKP042).

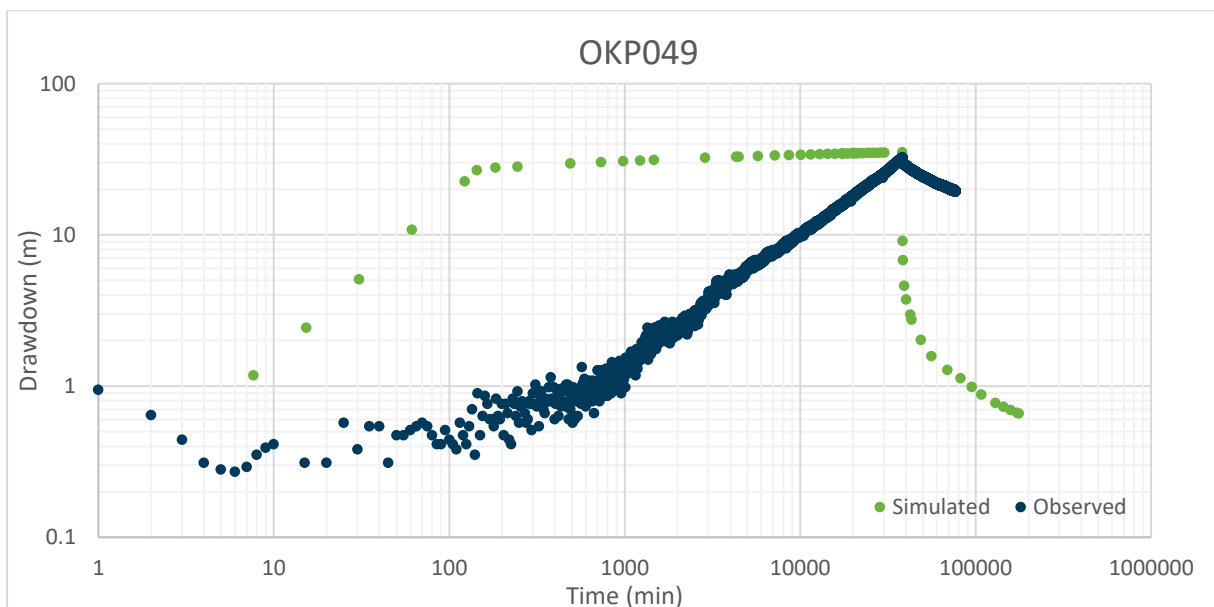


Figure 5-4: Observed and simulated drawdown in WW 206666 (OKP049).

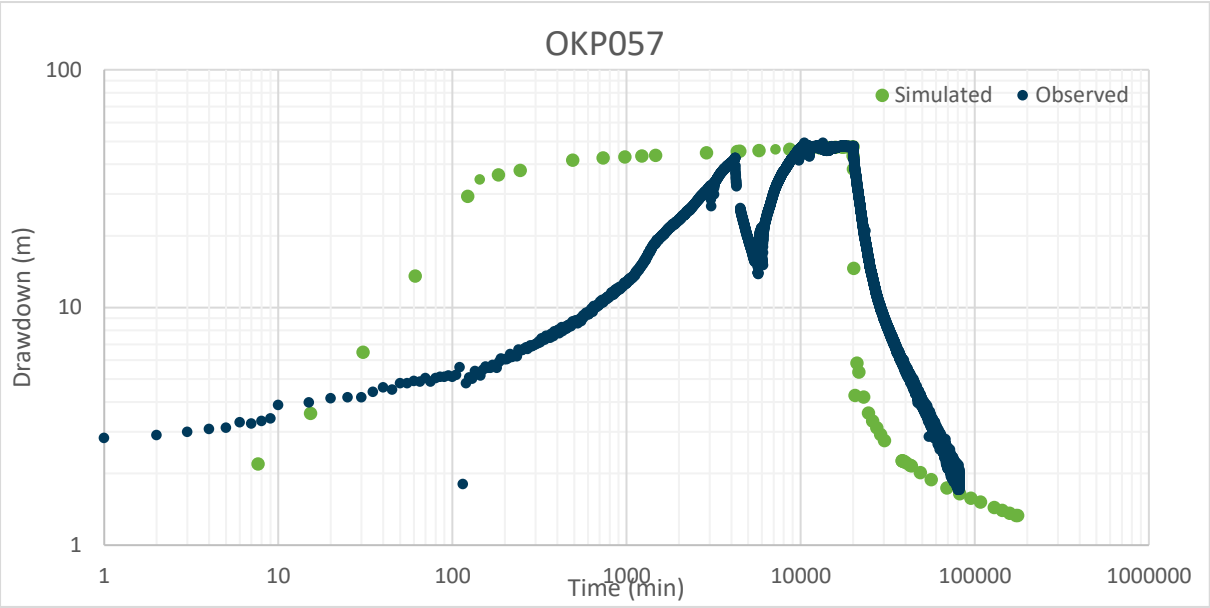


Figure 5-5: Observed and simulated drawdown in WW 206665 (OKP057).

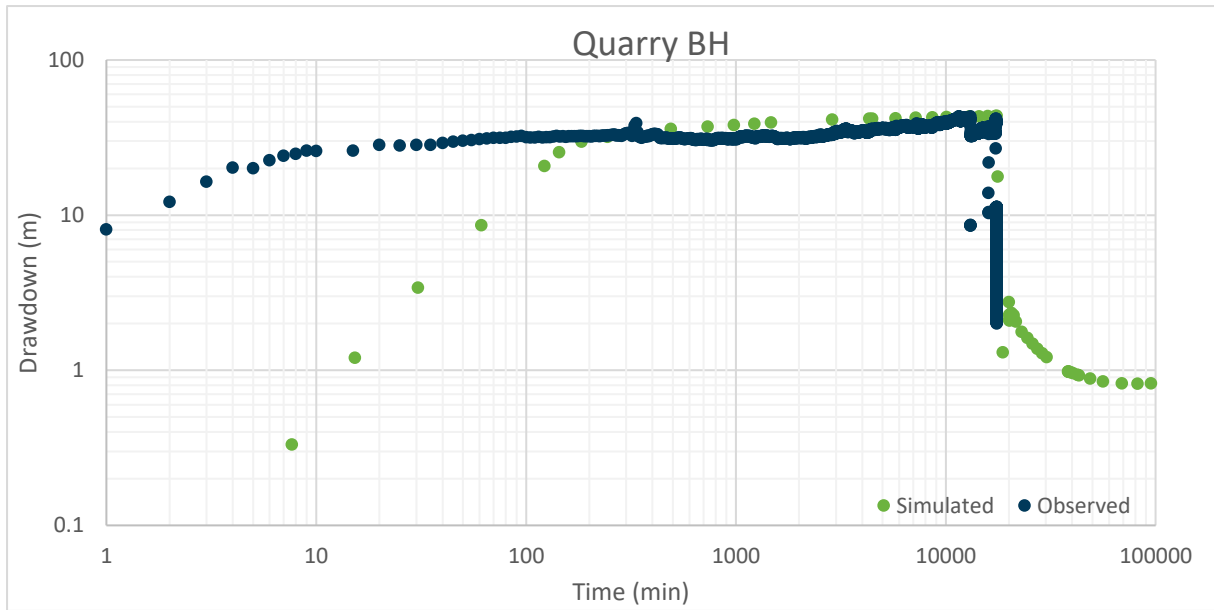


Figure 5-6: Observed and simulated drawdown in WW 206663 (Quarry BH)

5.3 MODEL CALIBRATION

In the calibrated model, the pumping boreholes on the southern limb were assigned calculated sustainable yields on a 16-hour pumping cycle to assess the impact on the groundwater level (Figure 5-7). Boreholes on the northern limb have not yet been tested to determine their sustainable yields, and the proposed pumping rates (SLR, 2023) were assigned a 16-hour pumping schedule.

As observed in Figure 5-8 and Figure 5-9, the cyclic pumping of the boreholes maintains the groundwater level above the maximum drawdown. However, over the years, there is an overall drawdown. Therefore, the pumping rate must not surpass the recommended sustainable yield, particularly for the Quarry borehole with the greatest drawdown.

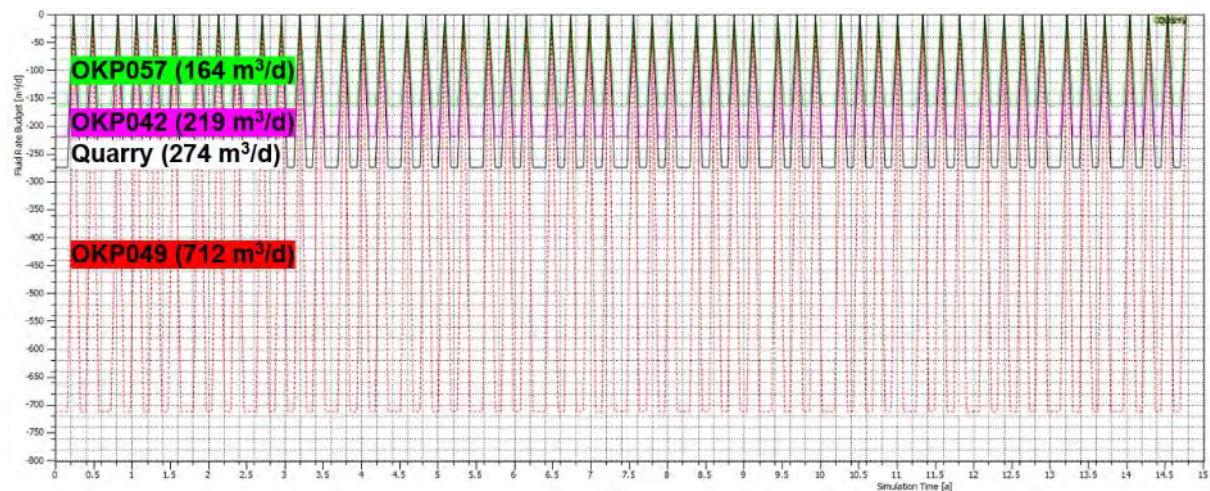


Figure 5-7: cyclic pumping rate in the pumping boreholes.

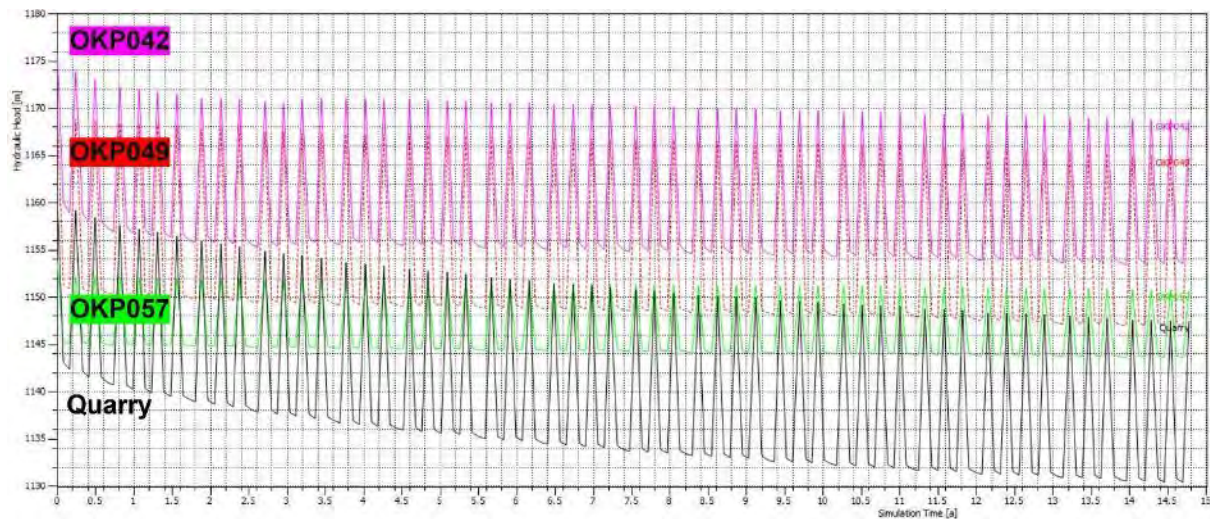


Figure 5-8: hydraulic head in the southern limb pumping boreholes.

The hydraulic head simulated in the northern limb pumping boreholes shows a deeper drawdown at each borehole. However, the maximum drawdown is not reached during the LOM.

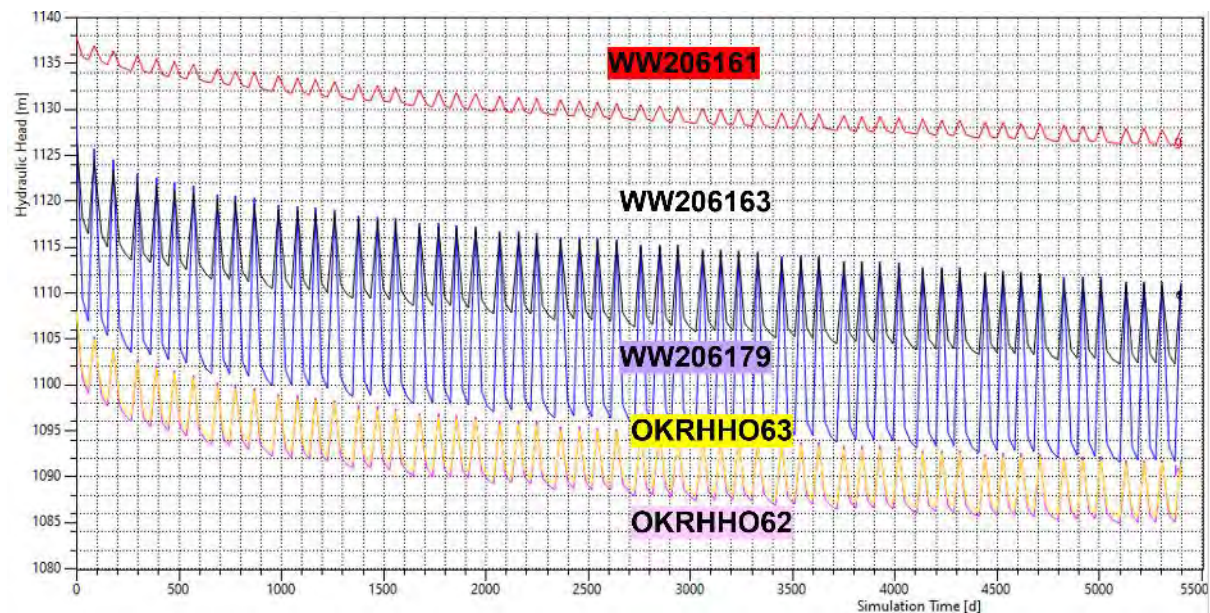


Figure 5-9: Hydraulic head in the northern limb pumping boreholes.

5.4 CONE OF DRAWDOWN

Figure 5-10 illustrates the cone of drawdown (COD) caused by the pumping boreholes and the passive dewatering from the pits over LOM. Excluding the Quarry boreholes, the other pumping boreholes in the southern limb do not impact the groundwater level considerably. However, the recommended pumping rates for the boreholes in the northern limb show a notable effect on the groundwater so that the induced COD will overlap with the COD around the pits.

The COD is ellipsoid in shape along the SW-NE strike of pits and has a total length of approximately 10 km, which is about 1.5 km SW of the West Pit and 2 km NE of the Cloud Pit. Pumping along the

northern limb has created a COD along strike and has merged with the pit's COD along the Okawayo River. The COD does not extend significantly to the south or reach the adjacent Dobbelsberg Farm.

The 5 m COD contour is simulated to be more than 5 km from Twinhills 3 and Dobblesberg boreholes.

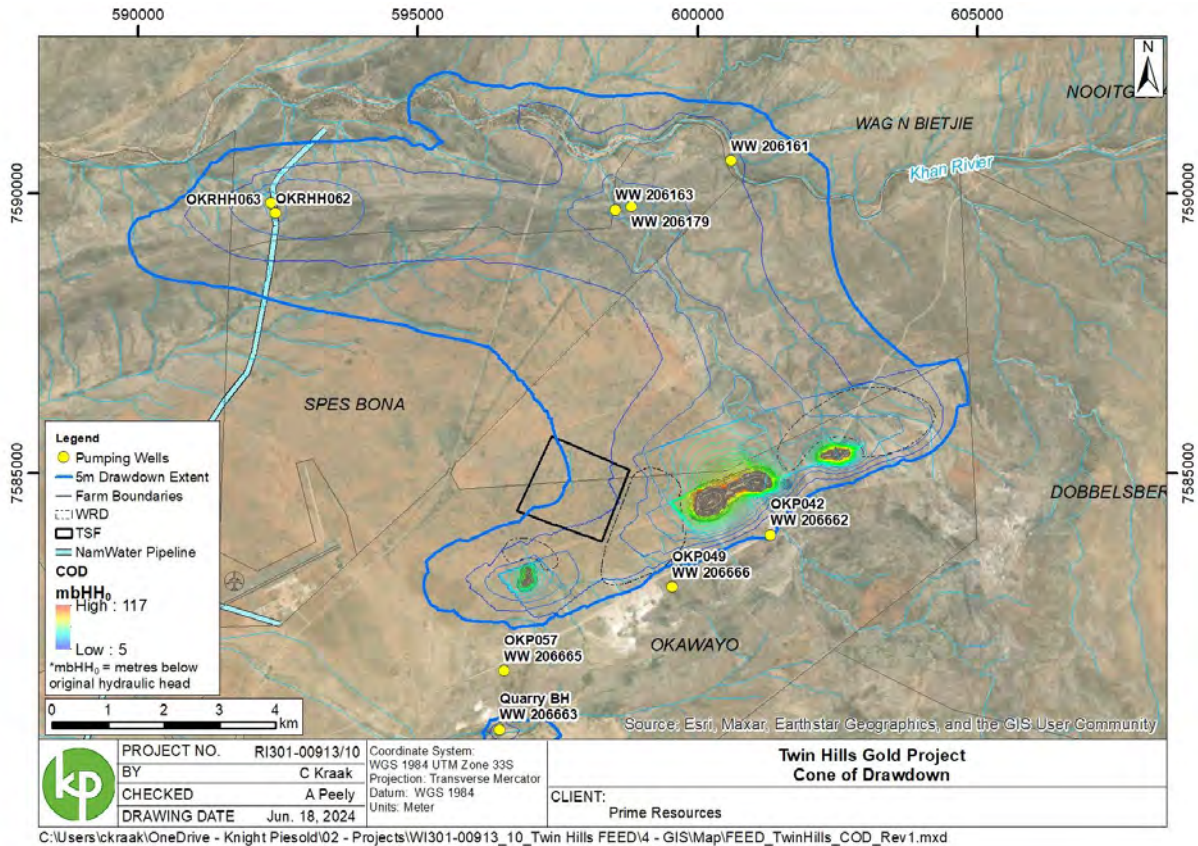


Figure 5-10: cone of drawdown caused by the pumping boreholes and the pits.

5.5 PIT INFLOWS

Figure 5-11 shows the pit inflows over LOM. The peaks at the beginning of each year are because the pit volume is excavated at an annual time-step, resulting in the instantaneous release of groundwater storage from those volumes. Therefore, the stabilised inflow at the end of each year is the more representative. However, regarding the impact of evaporation, the following must be considered:

- The model is calibrated using actual groundwater inflows and groundwater recharge (runoff, infiltration and evapotranspiration considered over the region)
- The Groundwater Flow (GWF) represents direct seepage into the pit area before it is exposed to evaporation.

Figure 5-11 shows the GWFs in each pit without the impact of evaporation, and Figure 5-12 illustrates the stacked flow rate of the pumping boreholes and pit inflows without consideration of evaporation. Section 5.6 discusses the effect of evaporation.

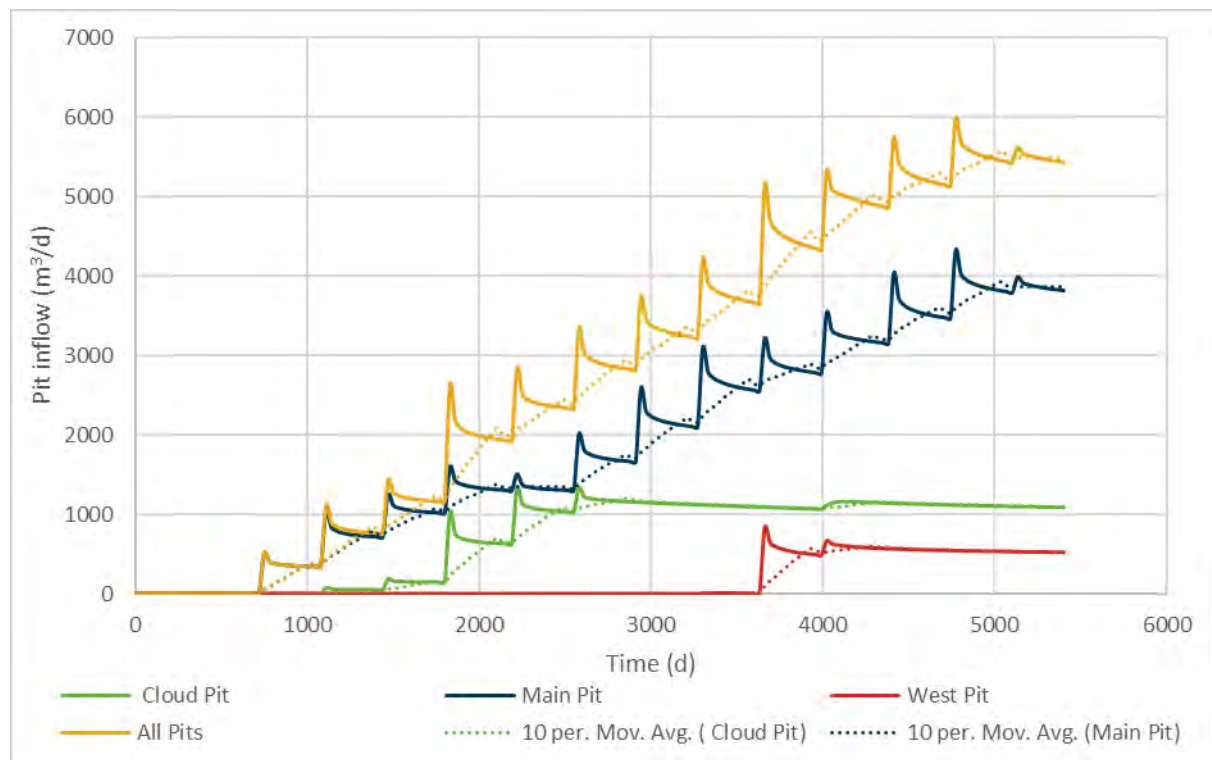


Figure 5-11: inflow rates per pit over LOM without evaporation.

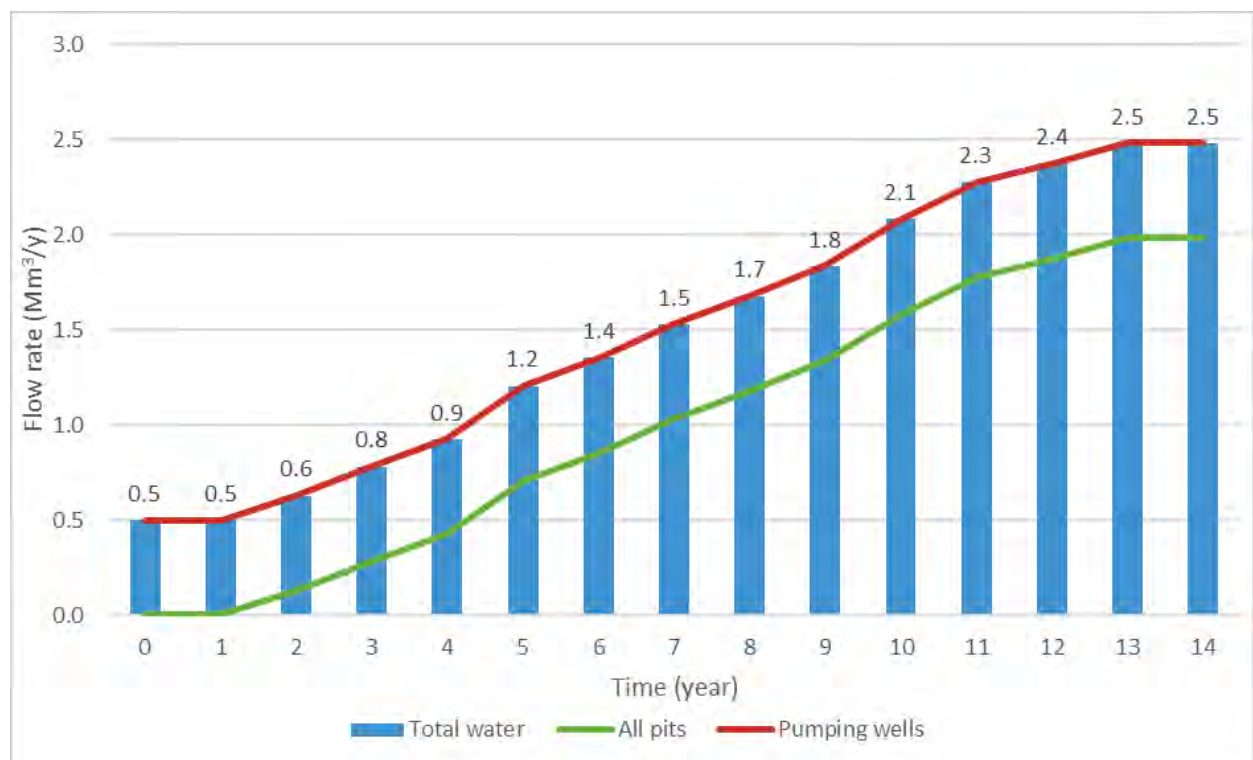


Figure 5-12: Stacked flow rate of the pumping boreholes and GWF to the pits without evaporation.

5.6 EVAPORATION

The FEFLOW outputs indicate the seepage from groundwater into the pit, exclusive of other external factors such as evaporation, overland flow and direct rainfall. A high-level pit water balance was conducted to determine the volumes expected in the pit sump during the LOM.

Evaporation from the pit is dynamic and is affected by several factors, such as pit lake surface and pit wall surface exposure to sunlight versus shadow, temperature, wind, humidity, etc. Typically, evaporation is estimated by applying a pan factor to convert pan evaporation to open-water evaporation. Considering the abovementioned factors, a much lower pan conversion factor was used. However, no specific literature could be found to support this number, so a sensitivity analysis was undertaken to assess the impact of the chosen factor. Figure 5-13 indicates the combined pit volumes at 15%, 30% and 45% evaporation factors. Figure 5-14 shows the nett pit inflows for a 15% factor, while Appendix A includes detailed values per pit for each sensitivity factor applied. It is evident that the total inflow is the same for each factor used, but the nett inflow after evaporation is significantly less where the evaporation factor is 45% compared to 15%.

The adjusted volumes using the evaporation factor of 15% were incorporated into the overall water volumes available from the northern and southern marble boreholes (each at 0.5Mm³/yr) and adjusted pit volumes (evaporation accounted for). The overall water volumes can be found in Figure 5-15.

The following points are to be noted:

- The nett pit inflows are determined from the pit lake water balance (WB), which accounts for evaporation, direct rainfall into the pit, overland flow and GWF over the LOM. The evaporation used is based on the water balance model detailed in the DFS summary report (KP, 2023: WI301-00913/06-A).
- The open pit DFS WB assumes that evaporation on the walls lowers through LOM as the pits get deeper. The following assumptions were made for this calculation:
 - 25% of the pit wall is assumed to be exposed to sunlight during the day.
 - A factor of 15% was used to convert open-water evaporation to wall evaporation.
- The average evaporation is 0.6 Mm³/year from year 6 to year 14.
- The overall WB model will need to be updated in the detailed design, considering the final pit developments, the pit dewatering plan, and the impact of the licensing limitations on borehole abstractions.

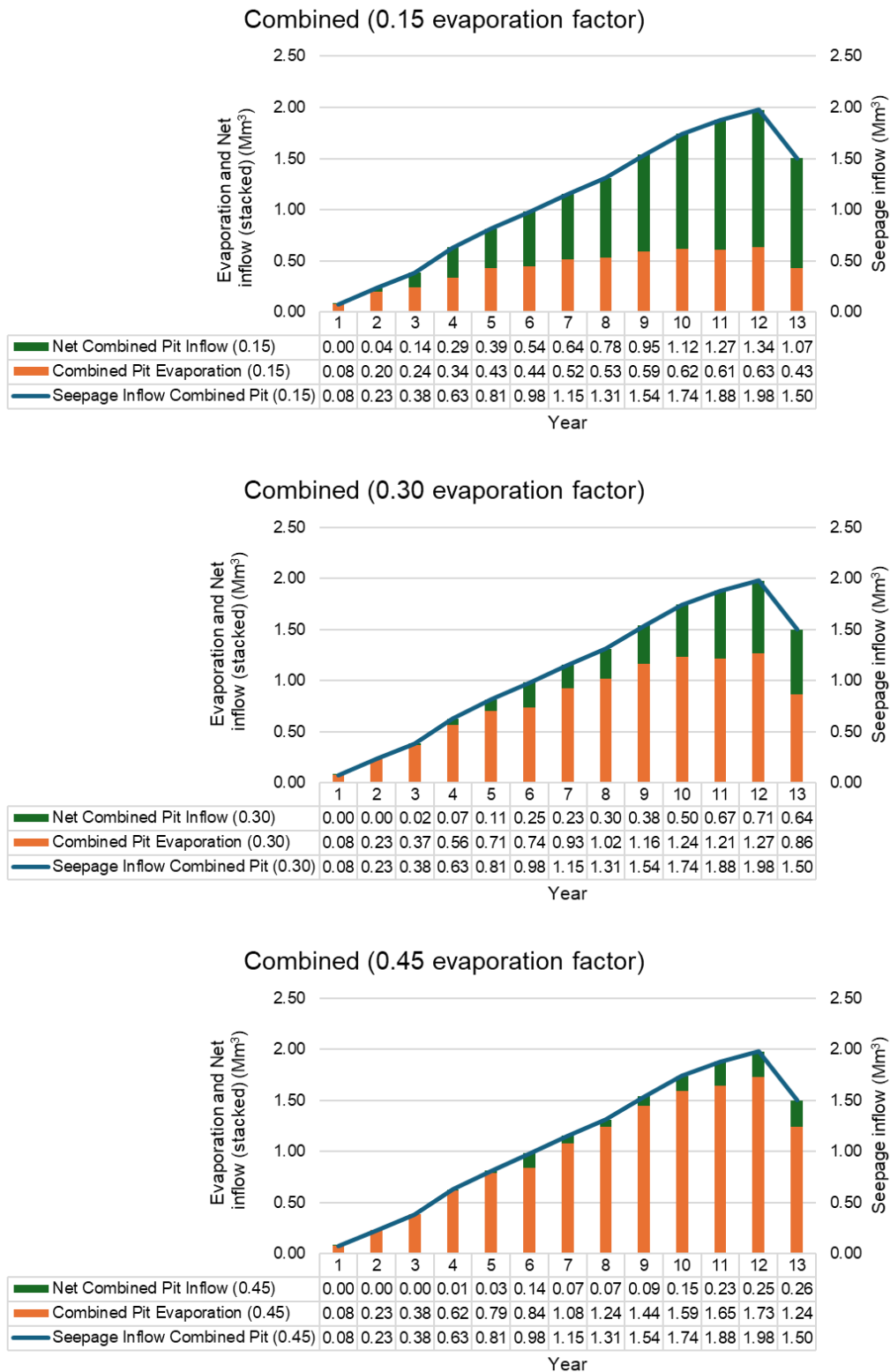


Figure 5-13: Evaporation sensitivity assessment on pit seepage.

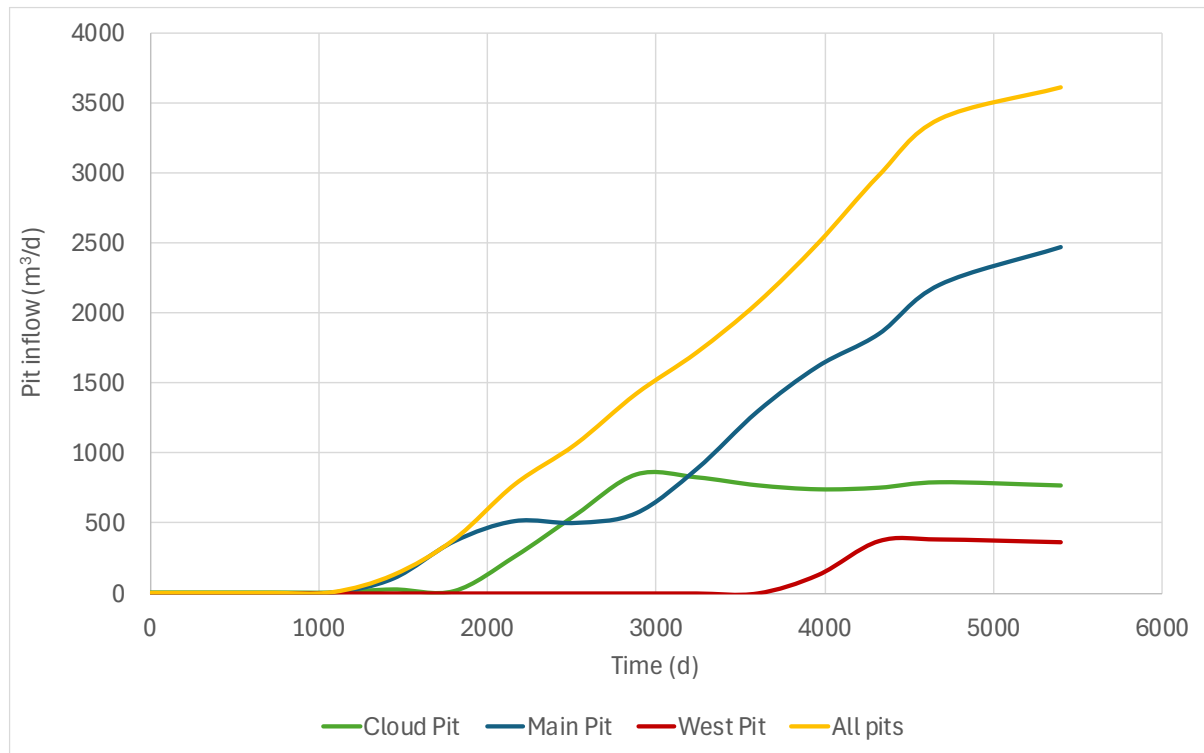


Figure 5-14: Inflow (pit lake volume) rates per pit over LOM with a 15% evaporation factor.

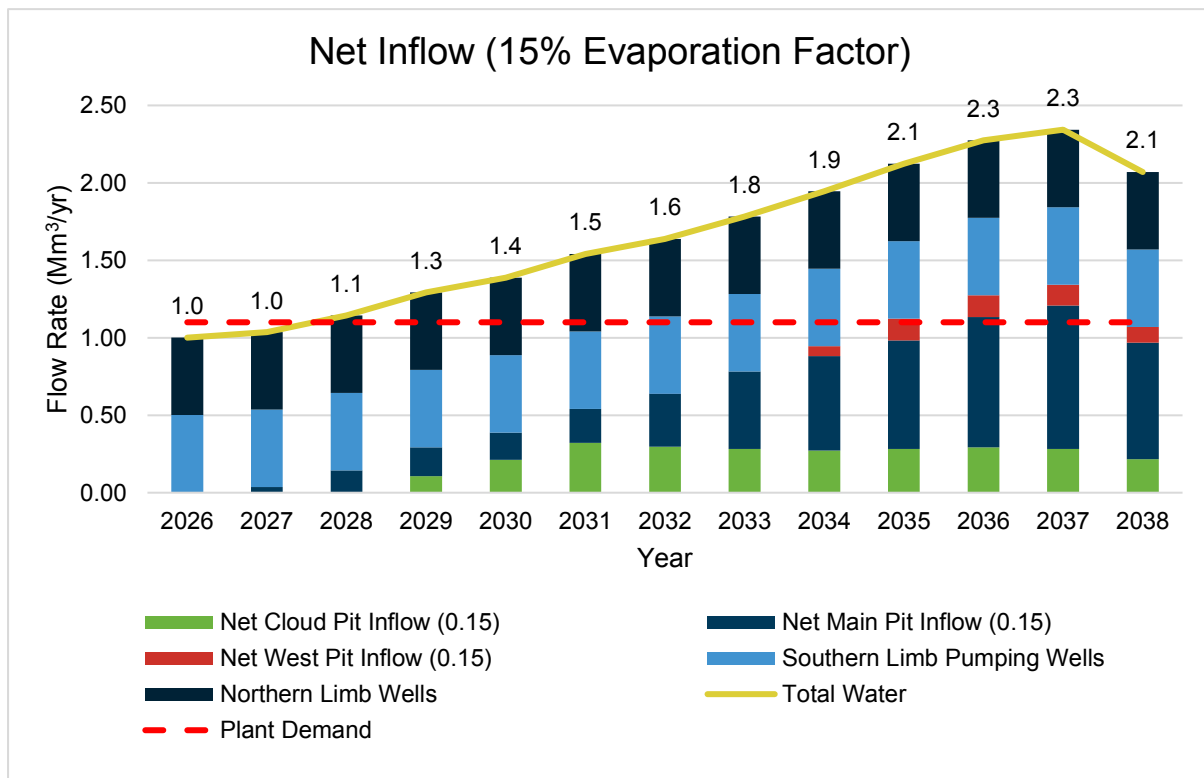


Figure 5-15: Stacked flow rate of the pumping boreholes and pit inflows (pit lake volume) with a 15% evaporation factor.

5.7 MANAGED AQUIFER RECHARGE

The managed aquifer recharge (Figure 5-16) was defined in the model with the following assumptions:

- 5 m dam: the structure with very low permeability (0.10×10^{-5} m/d)
- 4 m sediments: the materials precipitated brought with the floods
- Rainfall and recharge (maximum 16% in March and no recharge from rain in August) occur every year. Higher recharge: hypothetically, the MAR area has higher recharge than the rest of the area because of higher head and higher permeability material
- Fluid transfer with incremental head rise starting from the maximum head in the MAR area to 4 m higher than the maximum head with conductance or transfer rate as K/d (K = hydraulic conductivity and d =4 m).

Figure 5-17 and Figure 5-18 illustrate the hydraulic head (HH) after mining in year 14 without and with managed aquifer recharge (MAR) in the south. As the figure shows, the enhanced recharge from the MAR area can increase the groundwater head by more than 6 m. The MAR contribution to the pits inflows is shown in Figure 5-20.

Taking the results into consideration:

- The induced recharge from the MAR increases the groundwater hydraulic head in the marble aquifers
- The pit inflow increase is minor, from 2.20 to 22 m³/day from year 3 to year 14.
- The increased pore pressures are manageable and would not jeopardise the pit wall stability.
- The marble aquifer and particularly OKP042 would be recharged
- The Khan River in the north would be recharged, and the Spes Bona aquifer would have a lesser drawdown from abstraction (Figure 5-19).

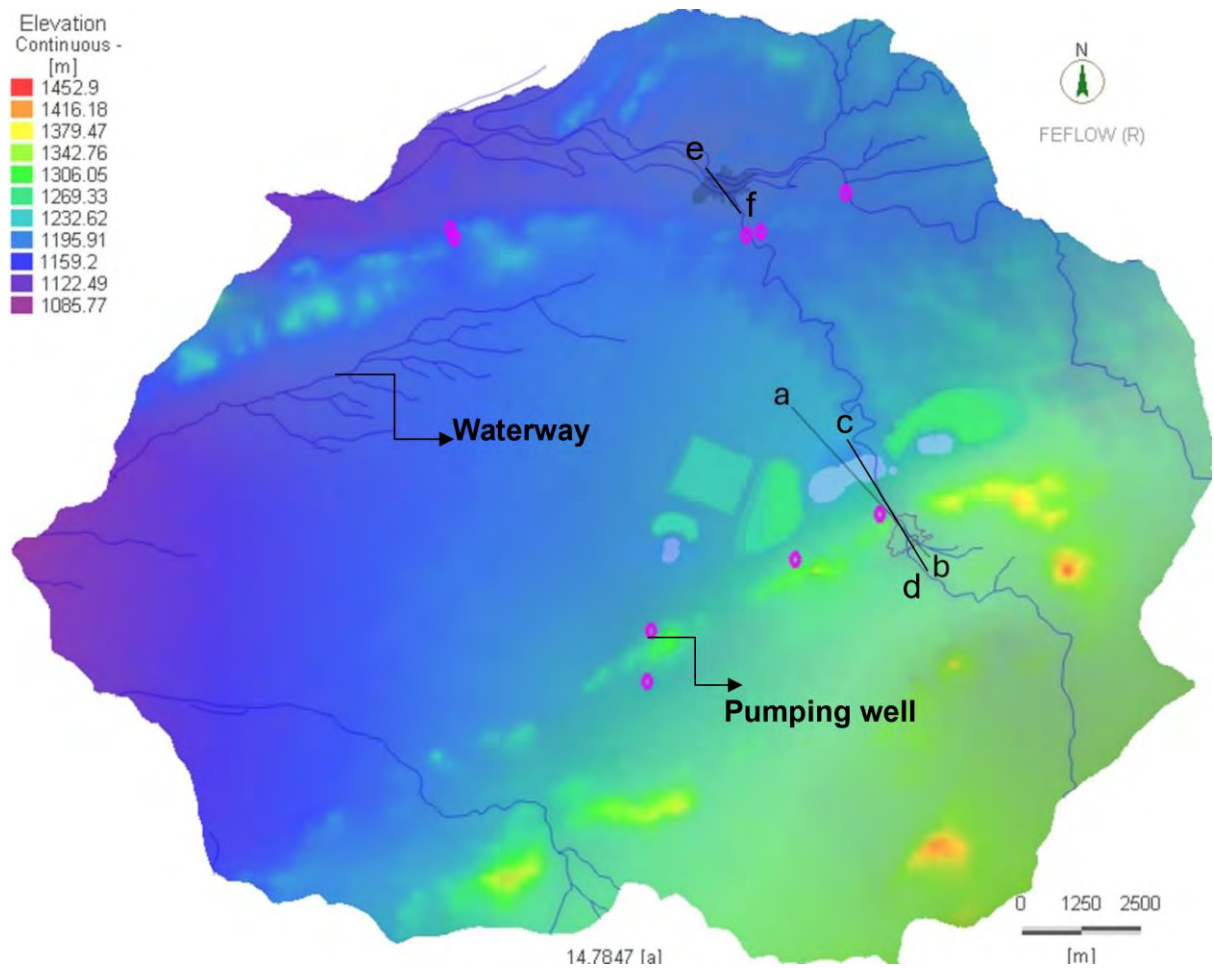


Figure 5-16: the location of the MAR area, pumping wells and cross sections.

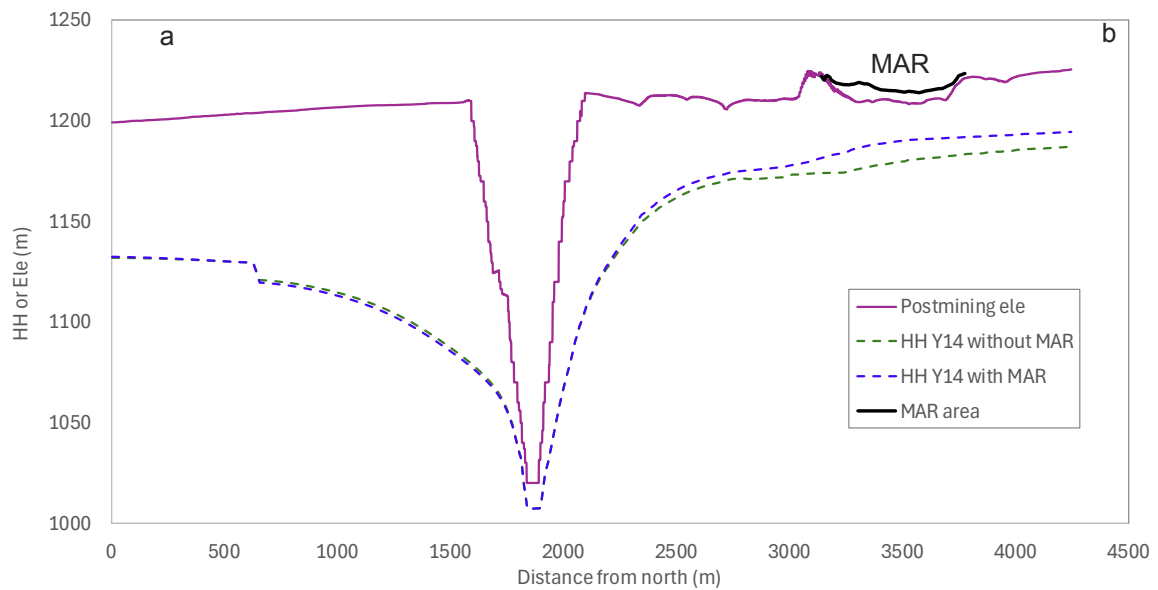


Figure 5-17: Section a-b: hydraulic head (HH) in year 14 after mining without and with managed aquifer recharge (MAR).

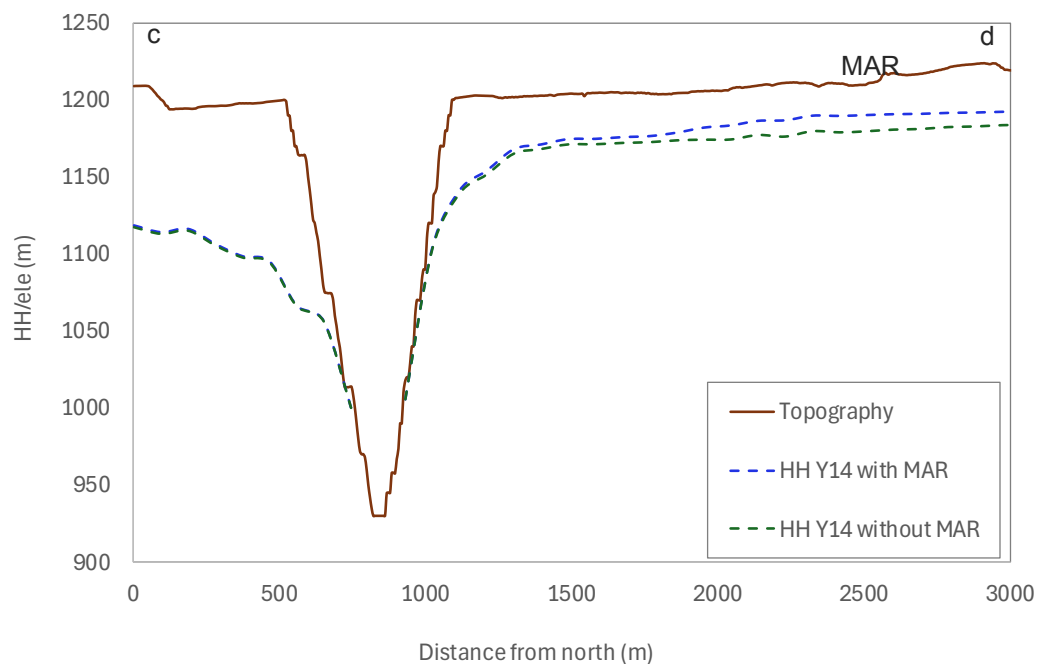


Figure 5-18: Section c-d: hydraulic head (HH) in year 14 after mining without and with managed aquifer recharge (MAR) along the Okawayo River

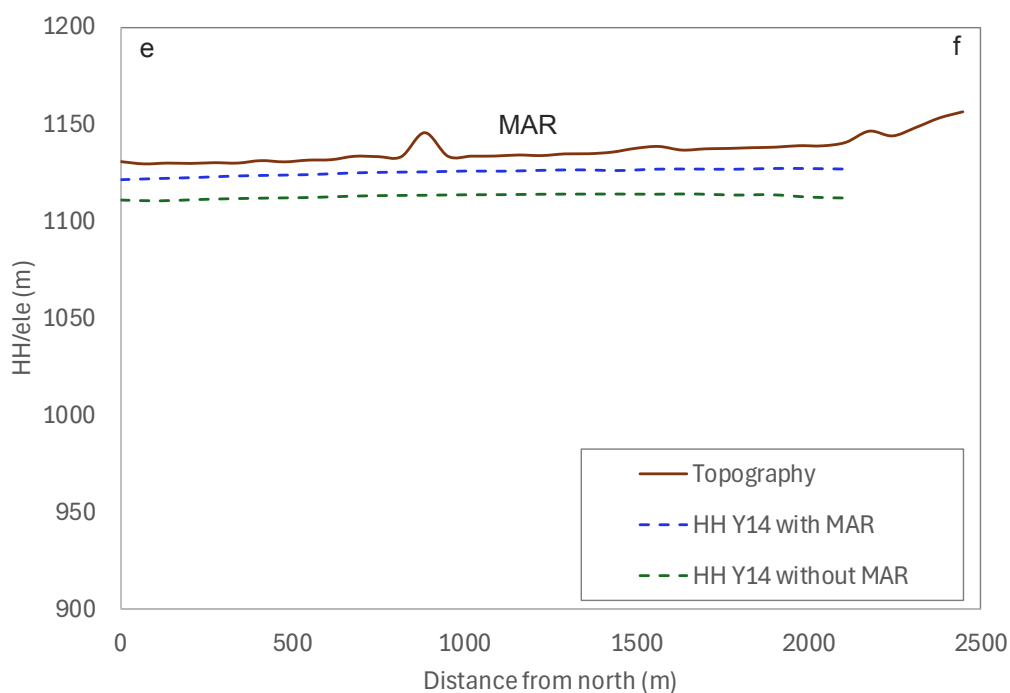


Figure 5-19: Section e-f: hydraulic head (HH) in year 14 after mining without and with managed aquifer recharge (MAR) along the Khan River.

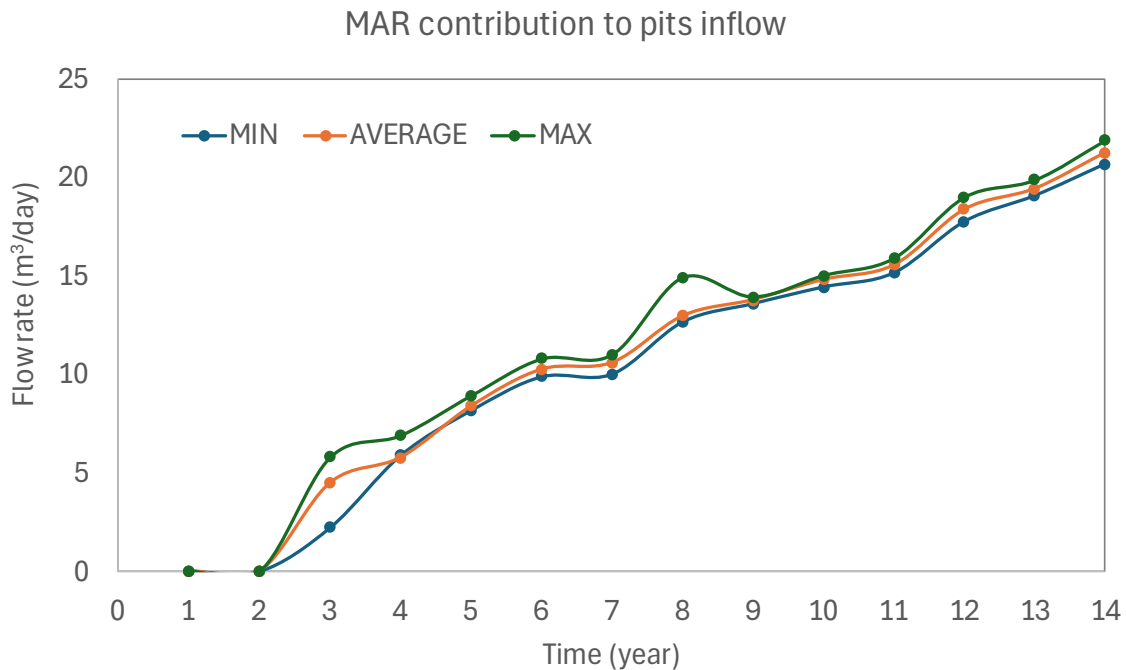


Figure 5-20: MAR contribution to the pit inflows.

5.8 TRANSPORT MODEL

The updated model was run using the unsaturated Richard equation in FEFLOW to simulate the solute transport in the unsaturated zone. Since the measurements show that the groundwater level is shallow, close to the river upstream (10 m in OKP040) and deep (72 m in OKP015), averaging 32 m deep, the unsaturated model was determined to simulate the solute migration more accurately.

Figure 5-21 shows the hydraulic head in the unsaturated zone, which is strongly influenced by the topography, recharge and the saturated hydraulic head. Such variations in the unsaturated zone would not be correctly simulated under the fully saturated flow model (Darcy Equation). The effect of the recharge on the saturation index and the capillary fringe in the vadose zone above the water table is evident in Figure 5-22.

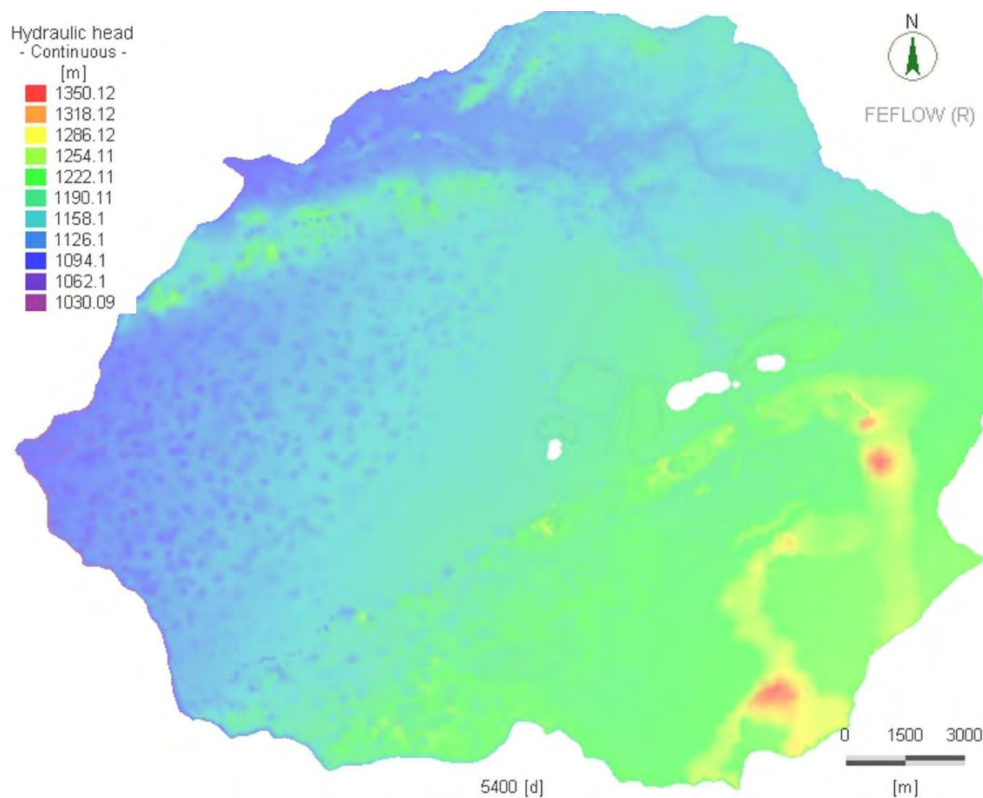


Figure 5-21: hydraulic head in the unsaturated zone.

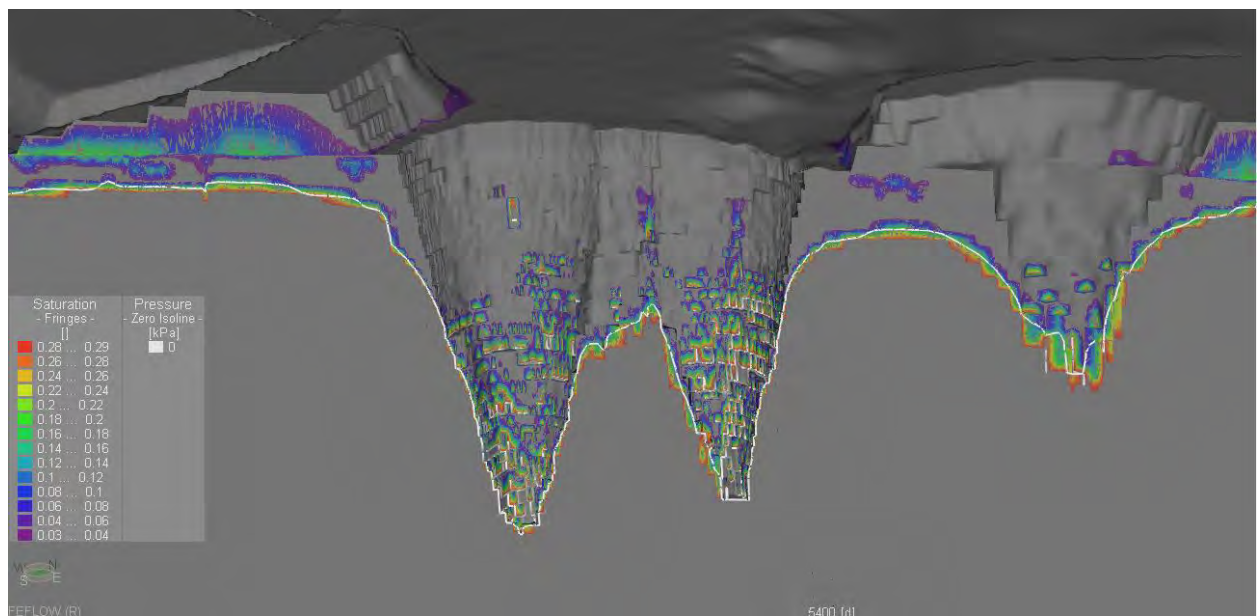


Figure 5-22: cross-section view of saturation fringes.

According to Twin Hills Feed Study Geochemistry Testing (KP, 2024: WI301-00913/11-A report), the maximum SO_4 concentration observed in the first week of the column test was 3270 mg/l. Therefore, this value was assigned as the source concentration to the TSF and WRDs in the numerical model as the worst-case scenario.

The results reveal that the migration of the simulated solute in the unsaturated zone before the main pit is excavated below the regional groundwater level is towards the river (Figure 5-23). However, the solute does not migrate far in the river since groundwater flows primarily towards the pits after year 5. The longest distance that the solute, with the cut-off 10 mg/l concentration, migrates in the unsaturated zone is 450 m from the Cloud WRD towards the Okawayo River. This distance is 290 m with a 100 mg/l concentration, the preferred SO₄ limit, with the acceptable limits at 300 mg/l (Government Gazette, 2023).

The maximum distance of the solute migration, defined as 10 mg/l concentration, in the saturated zone is 80 m in depth towards the main pit in year 15 (Figure 5-25). The solute concentration of 100 mg/l surpasses the unsaturated zone by approximately 45 m distance below the Cloud WRD.

Although the numerical simulation does not show considerable solute migration to the river (290 m in the unsaturated zone), the pumping wells (i.e. OKP042 and OKP049) could be used to capture solute due to the observed hydraulic connectivity through the proposed NW-SE structures.

The simulation for post-closure (Figure 5-24 and Figure 5-26: year 50) shows that the solute's migration is still primarily towards the pits. However, in year 50, when the flow system is more stable and the water table comes closer to equilibrating, the solute movement is primarily in the unsaturated zone.

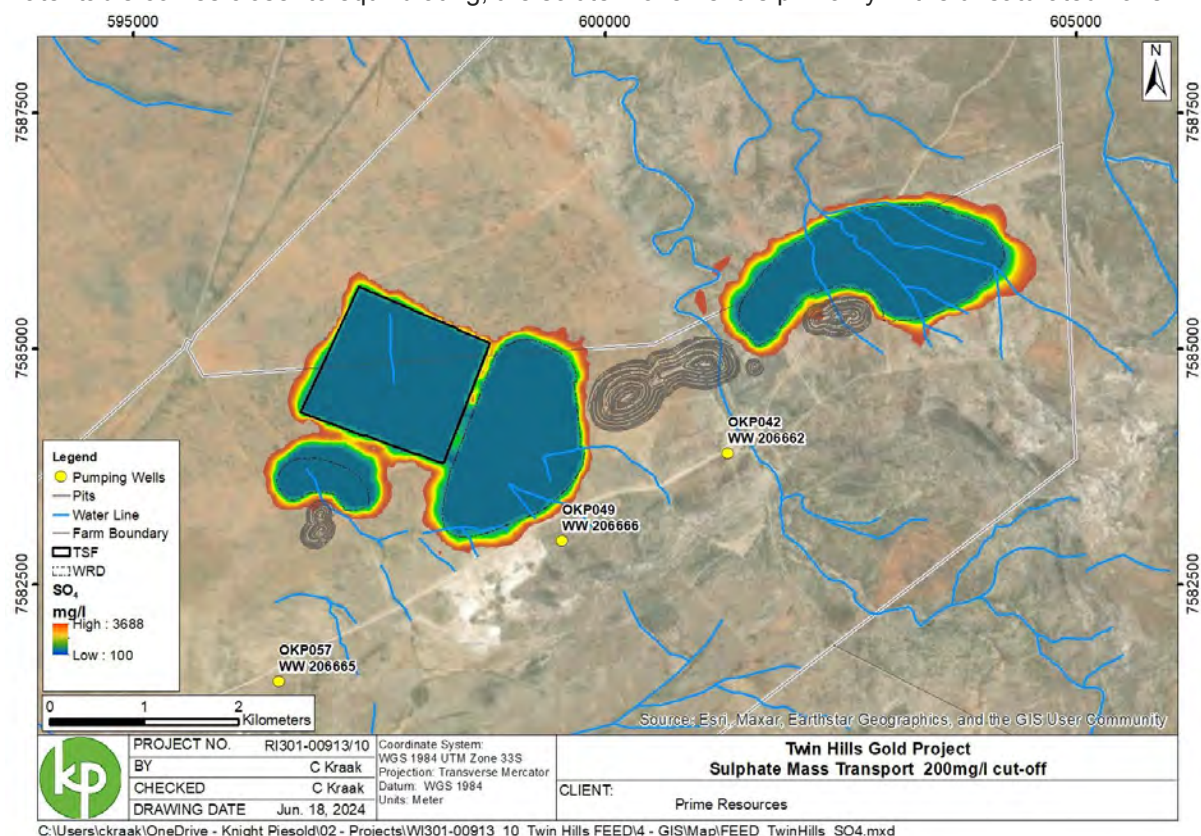


Figure 5-23: solute concentration map in the unsaturated zone in LOM.

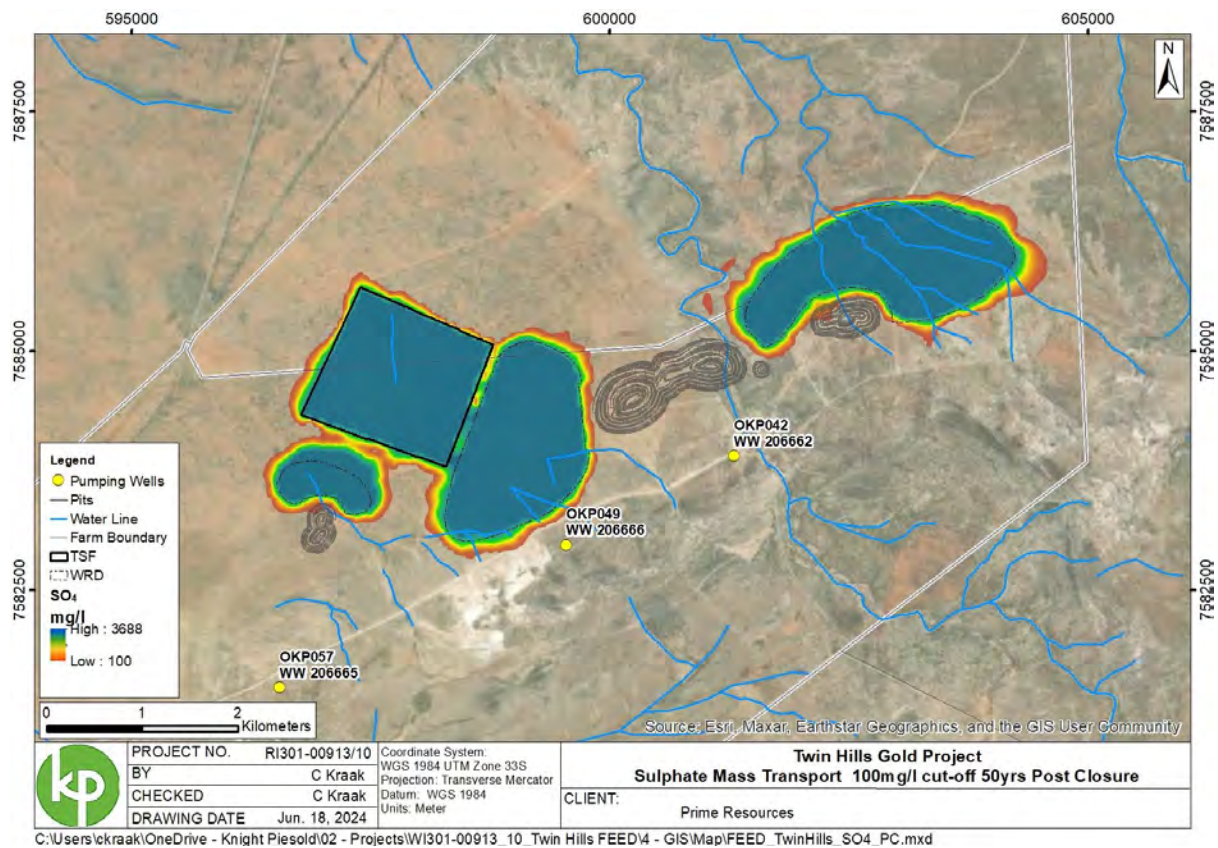


Figure 5-24: solute concentration map in the unsaturated zone in 50 years.

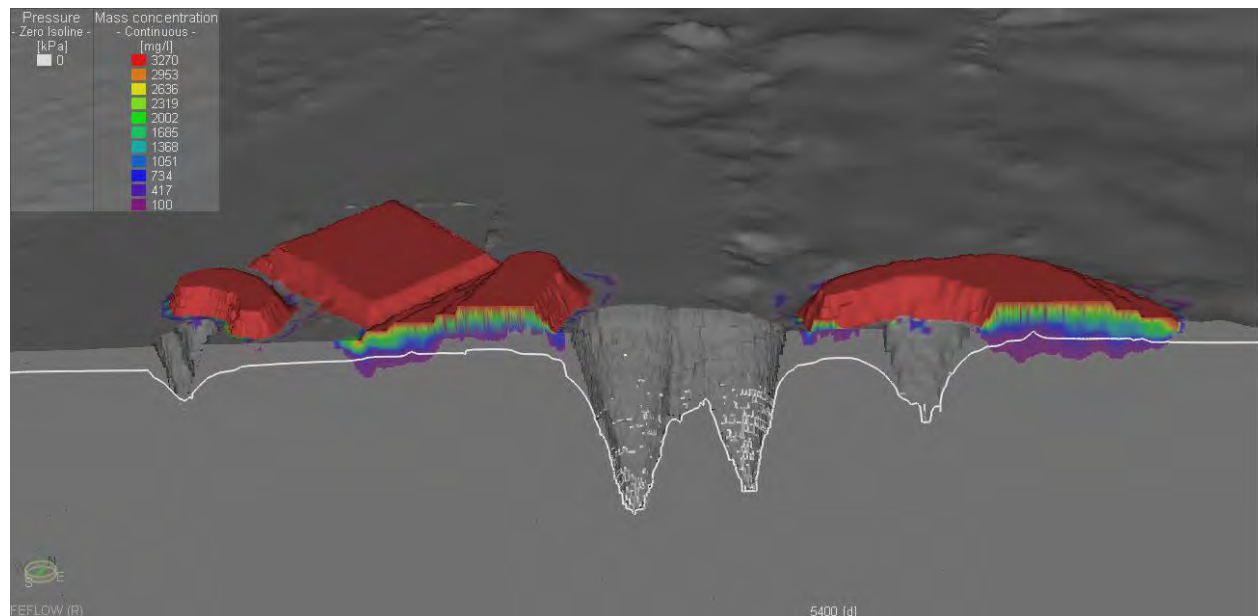


Figure 5-25: solute concentration in the 3D section in the unsaturated and saturated zones at LOM.

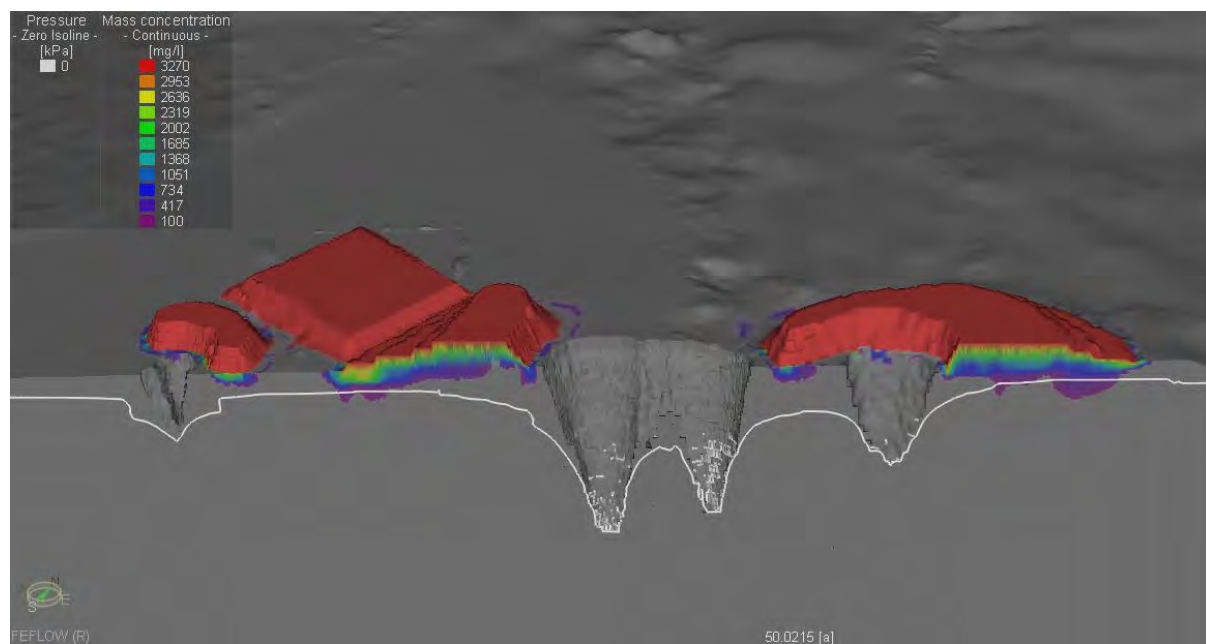


Figure 5-26: solute concentration in the 3D section in the unsaturated and saturated zones at 50 years.

6.0 CONCLUSION

The FEED study addressed the outstanding gaps and reduced the risk of water supply uncertainty through tracer testing and multi-well pumping.

The hydrodynamic coefficients and sustainable yields in the southern marble were calculated using the multi-well test data. If a 16-hour pumping cycle is implemented, the permitted abstraction rate of 500,000 m³/y from the southern limb is sustainable.

Table 6-1: Proposed pumping rates within the permit.

Cycle:		Permitted (pumping 16hr)	
Boreholes (Number)	Borehole IDs	Recommended pumping rate (m ³ /day)	Recommended pumping rate (m ³ /an)
WW 206662	OKP042	219	80,000
WW 206666	OKP049	712	260,000
WW 206665	OKP057	164	60,000
WW 206663	Quarry	274	100,000
Sum:		1370	500,000

The results from the tracer test confirm a hydraulic connection between the proposed MAR area in the south and the marble aquifer and that a MAR scheme will recharge the aquifer.

- It is evident that the marble aquifer has localised flow in discrete dissolution channels along the anticline axis, and the marble-schist contact allows recharge to the aquifer.
- The marble aquifer is matrix-dominated with localised fracture flow.
- There is connectivity along the NW-SE structures from the marble through the schist.
- The Managed Aquifer Recharge simulations indicate that the hydraulic head in the marble aquifer can be increased.

The numerical model was updated and calibrated with the calculated hydrodynamic coefficients from the tracer and multi-well pumping testing. The following observations are made:

- The pore pressures behind the southern pit walls, specifically near the Okawayo River, do not show a significant impact by the simulated MAR.
- There is no significant difference between the total flow rate of this model and the FEED Interim memo model.
- The total Groundwater flow rate into the pit is 0.60 Mm³/y in year 3, increasing to 2.5 Mm³/y in year 14. However, when compensating for evaporation, the pit volumes will be 0.6 Mm³/y less in the last six years of mining. See Figure 6-1 below.

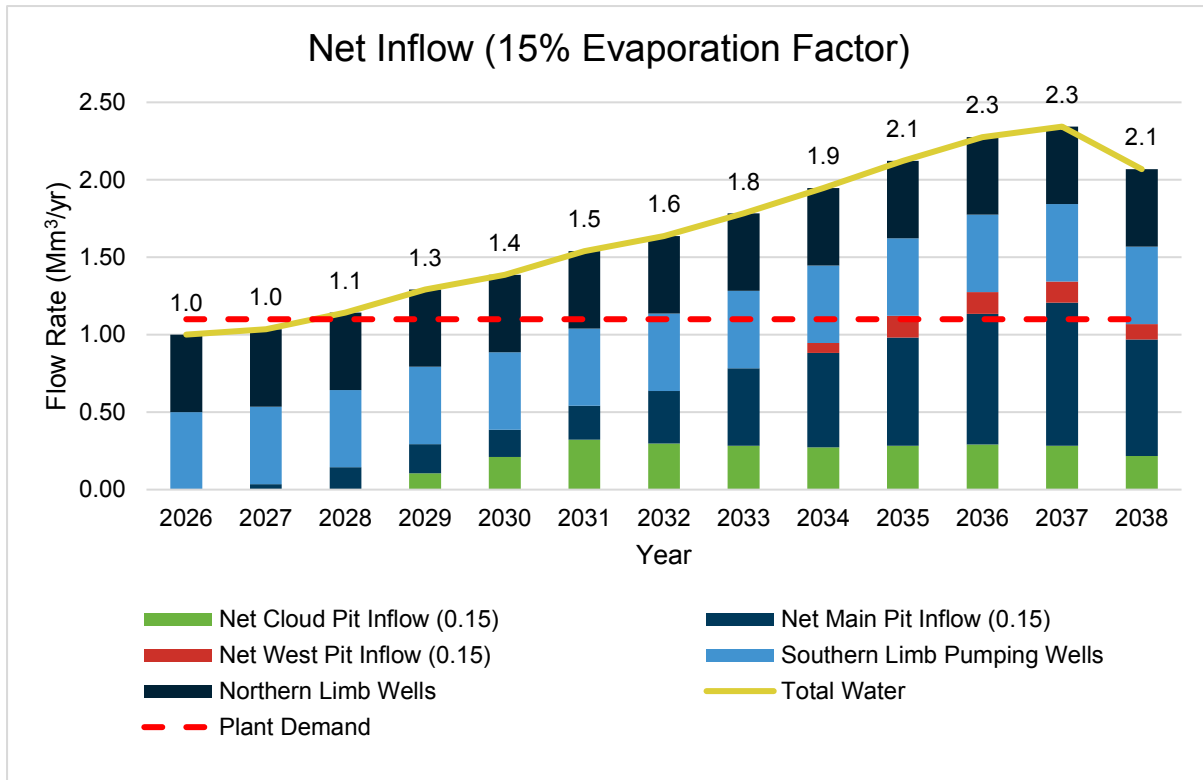


Figure 6-1: Stacked flow rate of the pumping boreholes and pit inflows (pit lake volume) with a 15% evaporation factor.

The extent of the COD around the pits is bigger than in the previous model as it reaches the COD induced by the additional boreholes in the northern limb.

- The COD is ellipsoid in shape along the SW-NE line of pits and has an approximate length of 10km, which is about 1.5 km SW of the West Pit and 2 km NE of the Cloud Pit.
- Pumping along the northern limb has created a COD along strike and has overlapped with the COD along the pits. The COD does not extend significantly to the south or reach the adjacent Dobbelsberg Farm.
- The 5 m COD contour is simulated to be more than 5 km from the Twinhills 3 and Dobbelsberg boreholes.

The maximum distance of the solute migration, using 10 mg/l concentration isolines, in the saturated zone is 80 m in depth towards the main pit in year 15. The solute concentration of 100 mg/l, surpassing the unsaturated zone, exceeds a 45 m distance below the Cloud WRD.

Although the numerical simulation does not show considerable solute migration to the river (290 m in the unsaturated zone), there the solute plume could be captured by the pumping wells (i.e. OKP042 and OKP049) due to the observed hydraulic connectivity through the proposed NW-SE structures.

7.0 RECOMMENDATIONS

The study and results have increased the model's confidence and is suitable for the design phase. However, the following is recommended:

- Tracer testing on the northern limb marbles to define the connectivity along the marble and to confirm the feasibility of a MAR scheme in the Khan River.
- Long-term multi-well pump testing at the northern limb water supply wells to calculate the matrix and fracture flow hydrodynamic coefficients, to determine the sustainable yields and required pumping cycles.
- Test pumping at OKP045 to determine the hydraulic coefficient of the NW-SE striking fault along the Okawayo River. In addition, further structural studies should be undertaken to better define the structure geometries.
- Feasibility design of a combined surface water flood mitigation structure/sub-surface sand dam in the Okawayo tributary upgradient of the mine area as a dual purpose to enhance recharge to the upper contact of the marble unit and ensure safe working conditions in the pit.
- Samples to be collected during the dry season from groundwater and surface water for stable isotopes and tritium to refine the recharge estimates to groundwater. Additional rainfall samples to be collected throughout the season to characterise the rainfall isotope signature better.
- Incorporate detailed pit designs with a monthly cutback to more accurately simulate groundwater inflow into the pit.
- Update the numerical model with the results.
- The observation wells close to the river (e.g. OKP045, OKP042 and OKP049) must be monitored seasonally during operation for any solute transport being in the capture zone of the wells.
- Consider seepage capture to prevent solute from entering the Okawayo baseflow in case of a contamination leak from the Cloud WRD into the unsaturated zone.
- An optimised network of monitoring boreholes around the pits.
- Water balance study for the pits, including the impact of evaporation, with a sensitivity analysis, and to determine pit lake volumes post-closure.
- Pit Lake modelling will be used to determine the water quality of the pit lake after mine closure, including a detailed geochemistry assessment of the pit wall rocks.

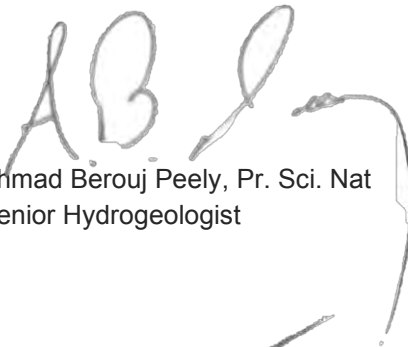
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9.0 CERTIFICATION

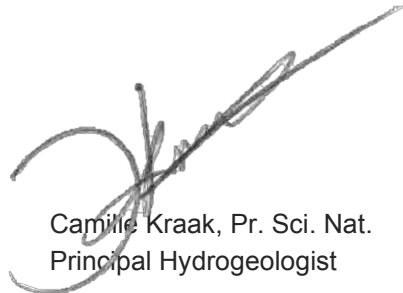
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APPENDIX A

Evaporation Sensitivity Assessment Graphs

Appendix A1 – Evaporation Factor of 15%

Appendix A2 – Evaporation Factor of 30%

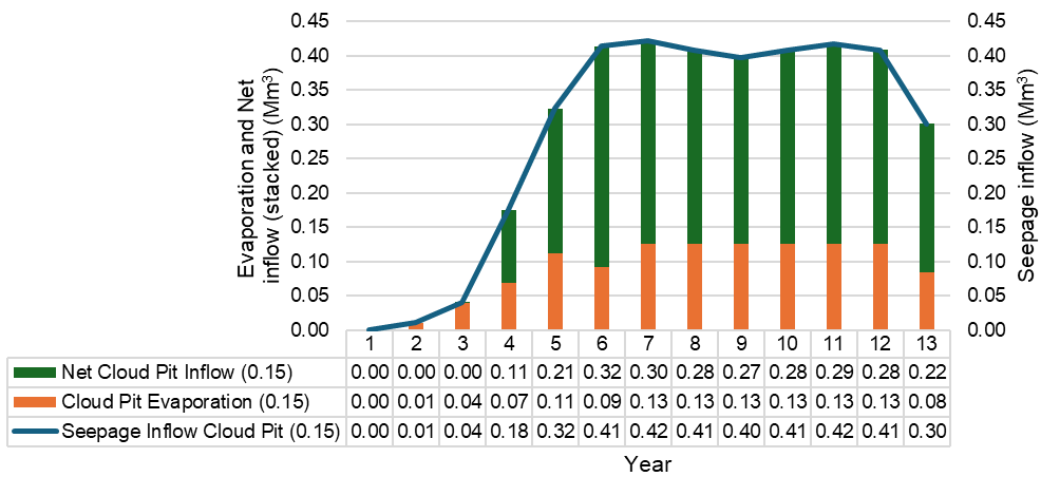
Appendix A3 – Evaporation Factor of 45%

Appendix A4 – Combined

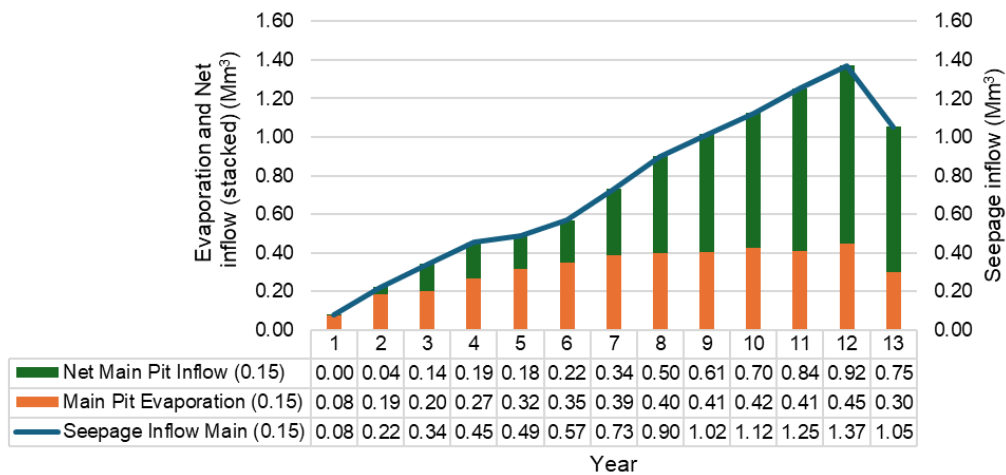
APPENDIX A1

Evaporation Factor 15%

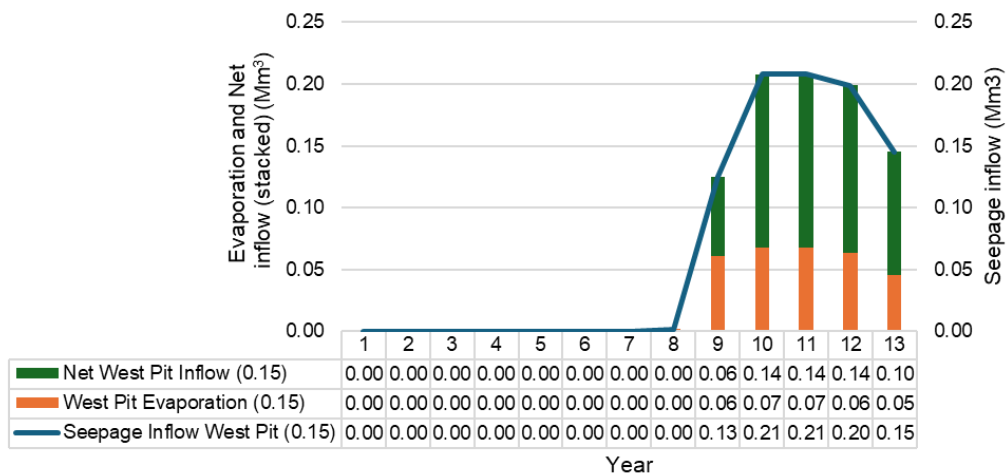
Cloud Pit (0.15 evaporation factor)



Main Pit (0.15 evaporation factor)



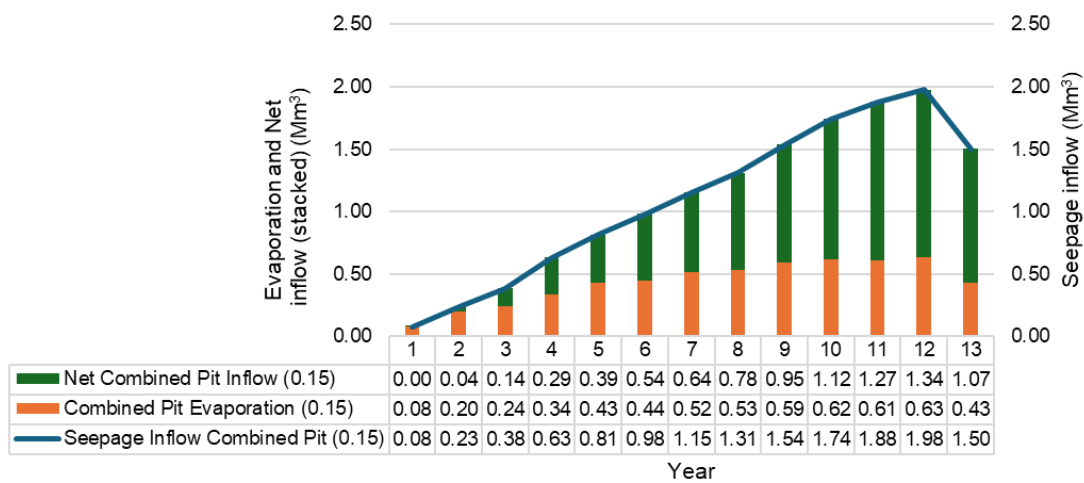
West Pit (0.15 evaporation factor)



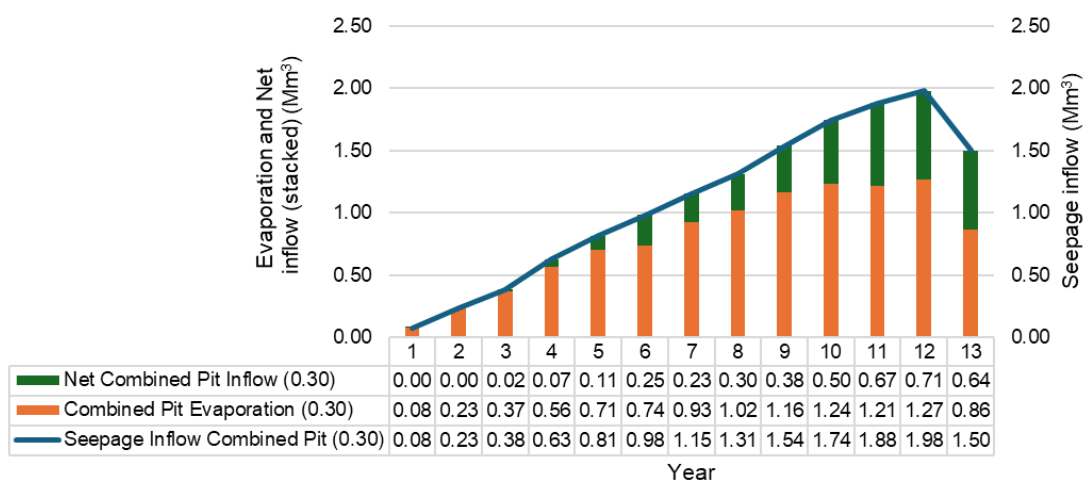
APPENDIX A2

Evaporation Factor 30%

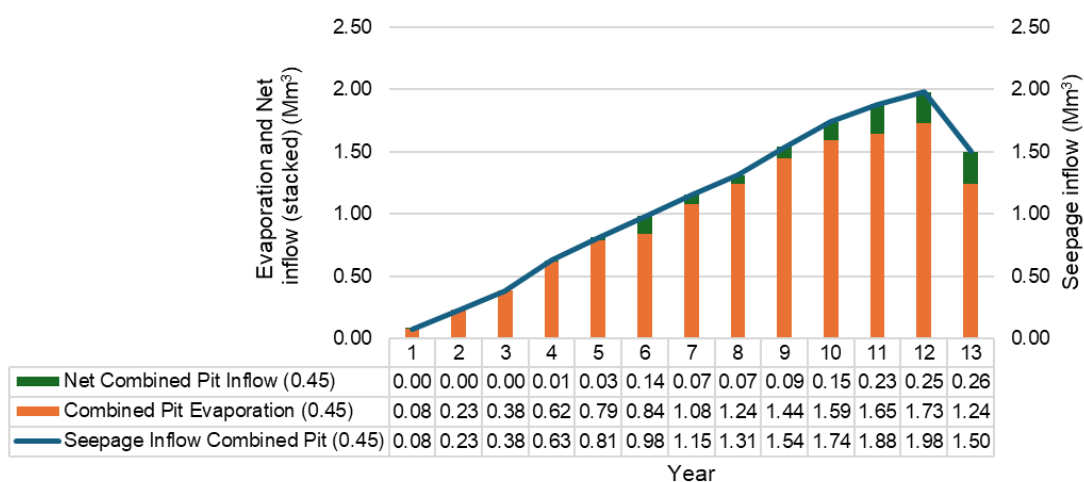
Combined (0.15 evaporation factor)



Combined (0.30 evaporation factor)



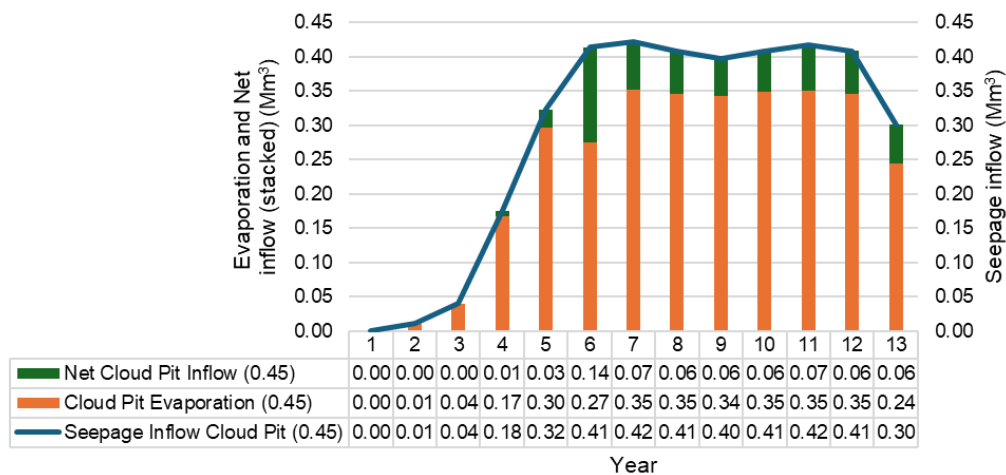
Combined (0.45 evaporation factor)



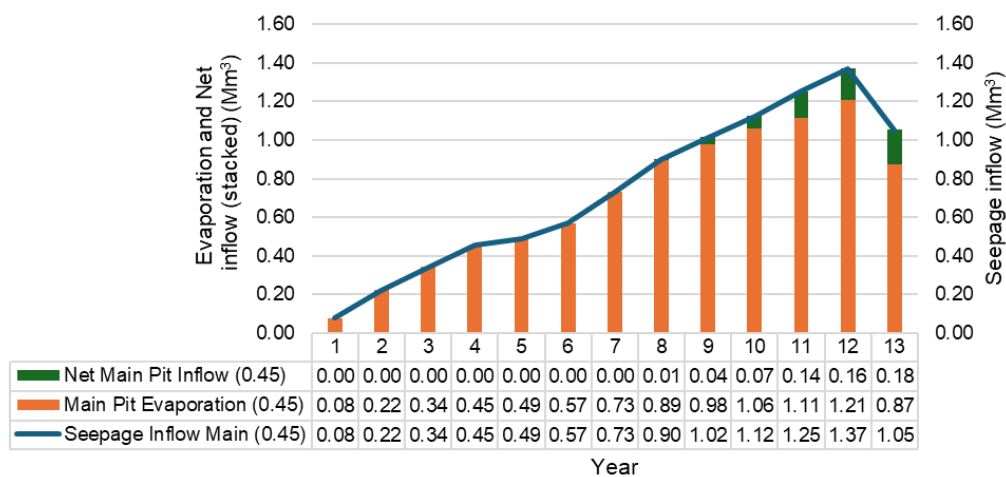
APPENDIX A3

Evaporation Factor 45%

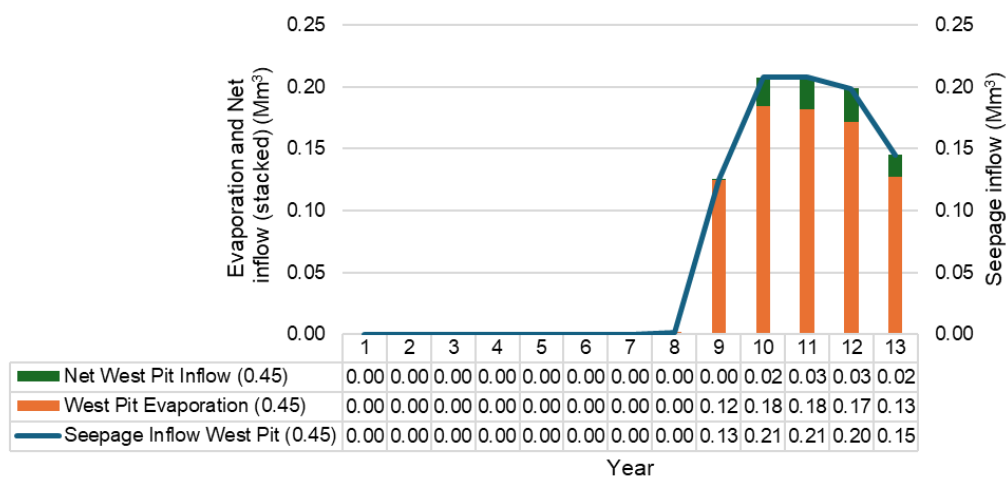
Cloud Pit (0.45 evaporation factor)



Main Pit (0.45 evaporation factor)



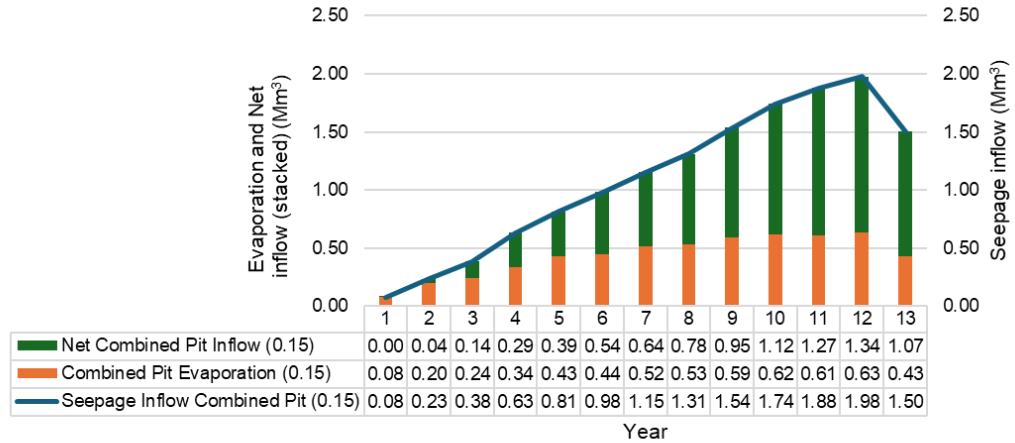
West Pit (0.45 evaporation factor)



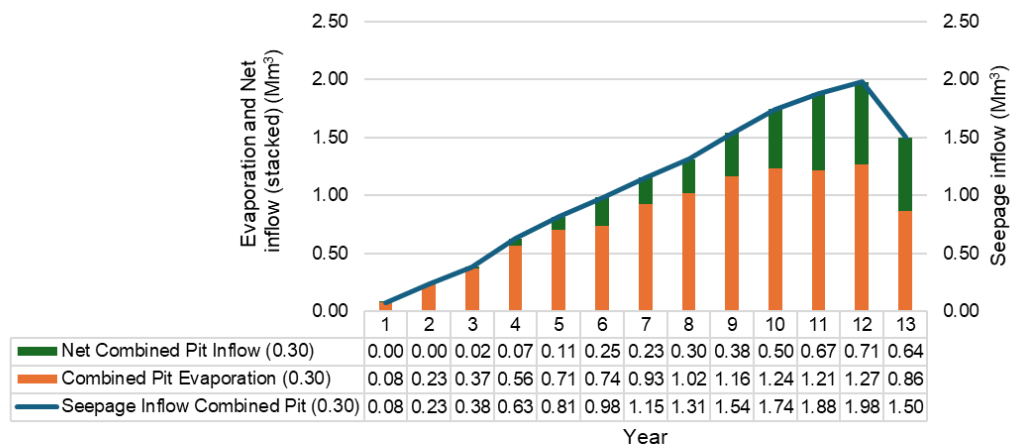
APPENDIX A4

Combined

Combined (0.15 evaporation factor)



Combined (0.30 evaporation factor)



Combined (0.45 evaporation factor)

