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FROM:	**George Pieter van Dyk and Diane Duthe – Itasca Africa (Pty) Ltd**
DATE:	**20/05/2020**
SUBJECT:	**Irrigation Scheme Groundwater Supply Assessment**

1 INTRODUCTION

Itasca Africa (Pty) Ltd (Itasca) was requested by B2Gold and ECC Environmental to perform a hydrogeological assessment to evaluate the potential impacts of groundwater abstraction for an Irrigation scheme that will utilize groundwater as the sole source of water. The irrigation scheme is situated approximately 8 km east of the B2Gold mining operation close to Otjikoto Namibia (Figure 1-1) using groundwater that will be abstracted from three boreholes The impact of groundwater abstraction was evaluated using the existing groundwater model developed for the B2Gold flow and solute transport groundwater specialist assessment, to evaluate the cumulative impact from both mine dewatering and groundwater abstraction from these three holes.

The following important information applies to the underground development and the groundwater model development:

- The proposed cumulative abstraction rate from the irrigation scheme was reported at 2.5 million m^3/a (6912 m^3/d) at any given moment. For the purpose of this assessment it was assumed that each borehole can yield 27 L/s.
- It was assumed that the irrigation scheme will extend over a 10 year period for the initial assessment and can be updated for longer periods once more information is available.
- The boreholes were drilled into the Karibib Marble, dolostone and lime formations which is a prominent major aquifer system that supplies most of the groundwater to surrounding groundwater users.
- Current pit dewatering at the B2Gold mine includes abstraction from one borehole PD01 at 150 m^3/Hr which maintains the groundwater level at 130 to140 meters below ground level (mbgl) (approximately 1350 meters above sea level (mamsl)). The abstraction is

mainly from the underlaying marble (TP marble and OTB marble) although hydraulic connectivity between the mine marbles and the Karabib marble formation can occur.

- The total future underground mine development will include an area of approximately 10 ha and ranging in depth from 1263 mamsl at the northern boundary to 1135 mamsl towards the southern boundary. The underground development will reach a maximum depth of approximately 380 mbgl. The model considers a maximum depth of 655 mbgl as a conservative approach
- The proposed underground development will extend over a period of 6 years which includes the entrance and decline development for the first 21 months.

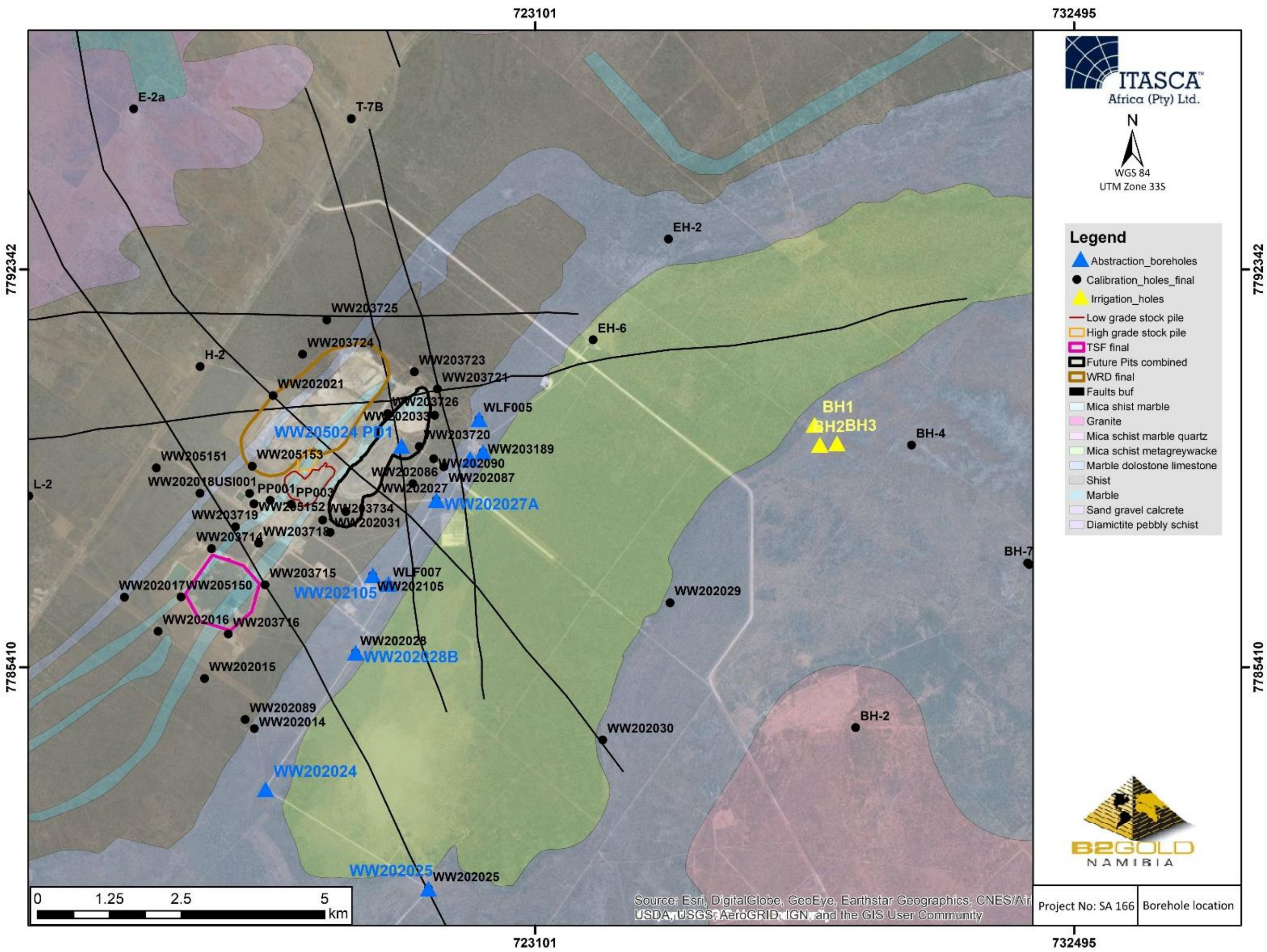


Figure 1-1 **Irrigation borehole location**

2 IRRIGATION BOREHOLE INFORMATION

2.1 AQUIFER TESTING AND PARAMETERS

The irrigation boreholes are situated approximately 8 km east of the B2Gold mining area. The required abstraction rate from these holes for the irrigation scheme was reported at 2.5 million m^3/a (6912 m^3/d). The information that was supplied by the client included pump test data and borehole locations which were summarized in Table 2-1. The drillers reports can be observed in Appendix A: Drillers reports which indicates that all three boreholes were drilled in marble formation and blow yileds range between 80 m^3/Hr to 200 m^3/Hr.

The average depth of the boreholes is 122 mbgl and the average static water levels from these holes is 25 mbgl. Assuming that the test pump inlet was installed at 100 then the average available drawdown for abstraction is 75 m. Abstraction for the pump tests took place at an average rate of 1680 m^3/d. The total cumulative abstraction for the individual pump test is 5040 m^3/d. This implies that the pump tests were conducted at 73% of the required yield and as they were not pumped simultaneously the overlapping impact between boreholes must be taken into consideration.

The average pump test duration was 80 hours after which an average drawdown of 36 m was reached which implies that 48 % of available drawdown was reached after approximately 3.5 days of abstraction at 70% of the required abstraction rate. The average recovery was 8.9 m deeper than the pre-test static water level. Estimated average hydraulic conductivities from the pump test analysis is 0.7 m/d for the marble, dolostone, lime formations of the Karibib.

The current mine groundwater abstraction is tabulated in Table 2-2. The total abstraction rates from all the abstraction boreholes as monitored for 2019 are 8017.8 m^3/d with the maximum abstraction rate measured at the main dewatering borehole, PD01 abstracting 2368.9 m^3/d.

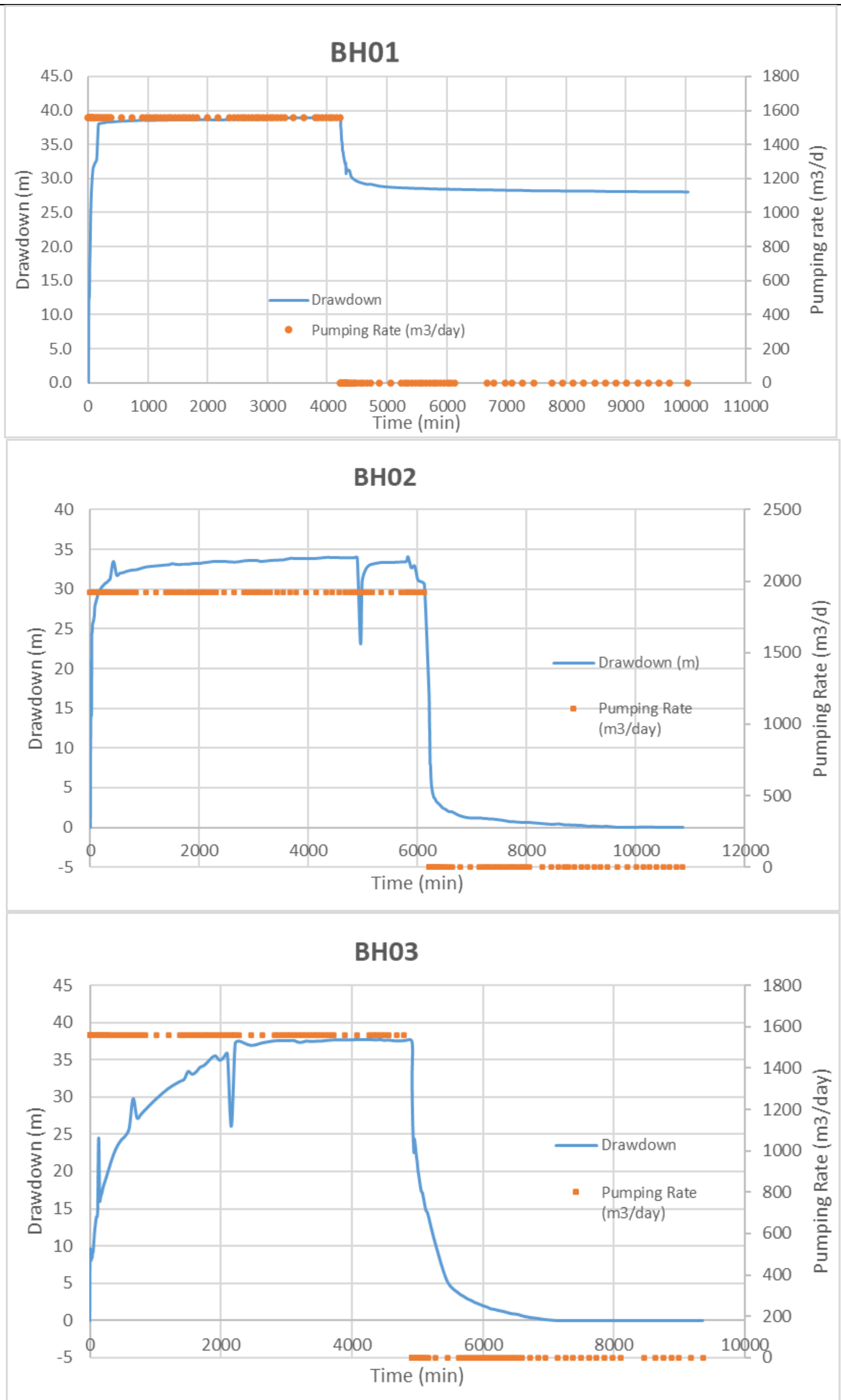
The pump test graphs indicated in Figure 2-1 for BH01 and BH02 illustrates the immediate drawdown in groundwater level as wellbore storage gets depleted within a matter of minutes. The groundwater level steadily stabilises with a slow linear decrease over time which implies matrix flow from the marble, dolostone and limestone aquifer. BH03 indicated a longer period to deplete wellbore storage and also had a more stable matrix flow than BH02 and BH01. BH01 did not recover at all and BH02 and BH03 recovered over a 33-hour period.

Table 2-1 Irrigation borehole test information

Well no	Easting	Northing	Well Depth (mbgl)	Static Water level (mbgl)	Pump test date	Available drawdown assuming pump depth inlet at 100m	Test abstraction (m³/d)	Drawdown reached (m)	Percentage of available drawdown reached (%)	Test duration (hr)	Recovery (m)	Estimated Transmissivity (m²/d)	Hydraulic Conductivity (m/d)
BH1	727969	7789635	126	24.24	25-Mar-20	75.76	1560	39.93	52	70.15	52.24	109.8	0.9
BH2	728062	7789288	126	25.25	04-Apr-20	74.75	1920	30.59	41	98	25.18	87.8	0.7
BH3	728360	7789312	114	25.46	24-Apr-20	74.54	1560	37.42	50	79	24.18	50.9	0.4
Total							**5040.0**			**247.2**	**101.6**		
Average			**122**	**25.0**		**75.0**	**1680.0**	**36.0**	**47.7**	**82.4**	**33.9**	**82.8**	**0.7**

Table 2-2 B2Gold groundwater abstraction

ID	Easting	Northing	Average abstraction 2019 (m³/d)
WW202024	718403	7783282	403.7
WW202027A	721380	7788322	1251.8
WW202028B	719973	7785663	494.4
WW203189 (CAMP)	722195	7789160	3.7
WW202022	719438	7779559	38.6
WW202025	721241	7781549	976.0
WW202105	720270	7787013	23.3
WLF005	722123	7789732	1287.9
WLF006	721963	7789043	125.9
WLF007	720543	7786862	1043.6
WW205024 PD1	720773	7789267	2368.9
Total			**8017.8**
Average			**728.9**



ITASCA Africa (Pty) Ltd.	**Pump test curves for the three irrigation boreholes**	
	B2Gold Irrigation Scheme	Calibration statistics

Figure 2-1 Time/ Drawdown curve with recovery

2.2 IRRIGATION BOREHOLE WATER QUALITY

Samples were collected from the recently drilled irrigation boreholes, and compared to the hydrochemistry of the mine concession boreholes as shown in the Table 2-3 below. Each hydrochemical parameter is represented by the mean concentration for monitoring year 2019. It must be noted that only 2 of the 3 irrigation boreholes were sampled. As evident from Table 2-3, majority of the hydrochemical parameters are comparable between the Karibib boreholes, Okonguarri boreholes and the irrigation boreholes. Both the pH and Electrical Conductivity (EC) of the Irrigation boreholes are similar to the Okonguarri and Karibib boreholes, however the Karibib and Okonguarri boreholes have higher mean concentrations for sulphate, chloride and nitrate. Whereas the irrigation boreholes have higher mean concentrations for calcium and fluoride.

Table 2-3 Mean Concentrations for the Hadrochemical parameters collected in the 2019 monitoring year

Borehole info	Hadrochemical Parameters (mg/L)										
	Ca	Mg	Na	K	HCO_3	CO_3	Cl	SO4	F	pH	EC
Irrigation Borehole	199,5	10,3	4,4	0,7	462,5	0,0	9,5	8,5	0,5	6,5	78,3
Karibib Borehole	159,0	17,1	9,3	2,7	419,3	0,0	18,9	17,7	0,3	6,7	85,9
Onkonguarri Borehole	121,1	30,8	38,0	7,3	421,2	0,0	35,3	18,7	0,3	6,8	89,1

The major cations and anions (in %meq/L) for the Okonguarri, Karibib and Irrigation borehole samples are plotted on a Piper diagram as shown in the Figure 2-2 below. A piper diagram is used to classify the samples in terms of their chemical signature and identify mixing between different sources and changes in composition along flow paths. Both the Karibib and Irrigation boreholes plot on the left-hand side of the piper diagram (Figure 2-2), with the dominant cation and anions being Ca and HCO3 respectively. Whereas the Okonguarri boreholes plot in various fields on the piper diagram, with 2 trends developing. The first trend is towards the upper apex of the diagram, which is indicative of mining activity due to an increase in concentration of salts (sulphate, chloride etc). The second trend is towards the lower apex of the diagram, which is indicative of natural ion exchange within older deeper groundwater in the Okonguarri formation. Thus, it is largely suspected that the Irrigation boreholes are abstracting water from the Karibib marble, as these samples have a similar chemical signature to the samples collected from the Karibib boreholes.

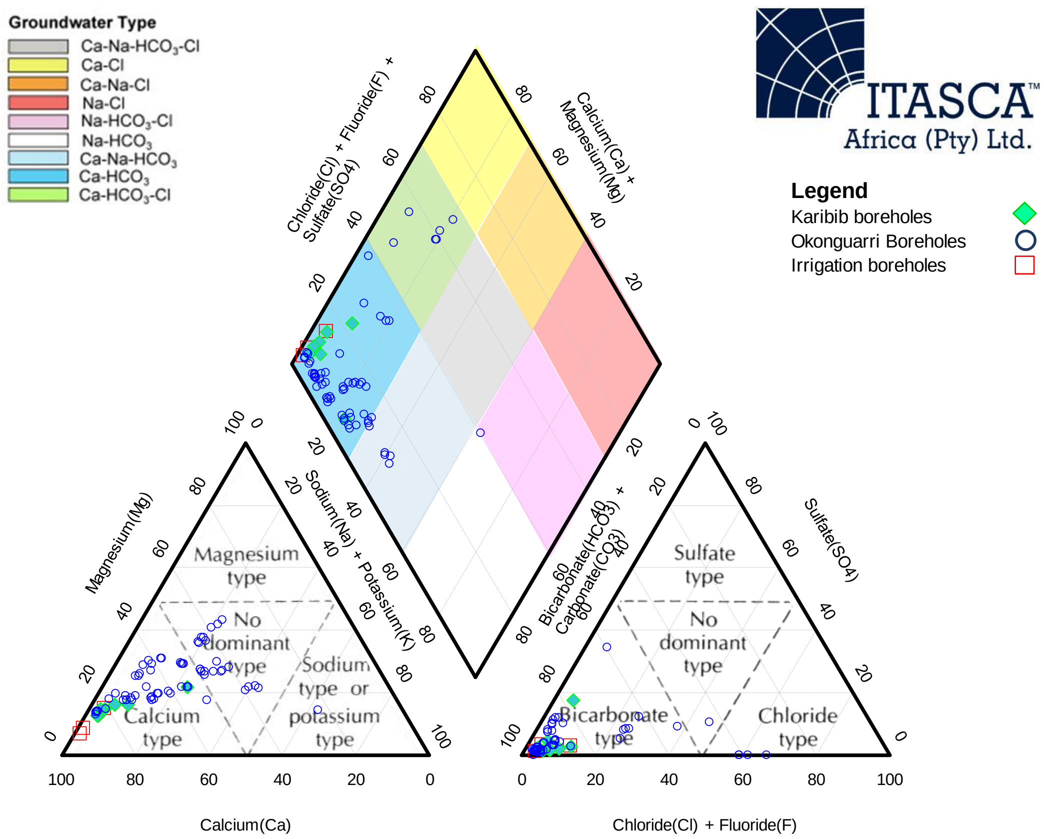


Figure 2-2 **Piper Diagram for the Karibib, Okonguarri and Irrigation boreholes**

3 GROUNDWATER MODEL CONSTRUCTION AND CALIBRATION

The numerical groundwater flow and solute transport model was developed using FEFLOW 7.1. The model domain was kept at the same dimensions developed for the 2018 monitoring assessment. The model domain measured 1,514 km² in surface area with total volume measuring 929 km³. An extra two layers was added to the model domain to represent detailed geology input over the mining area and the less permeable Ghaup layer. The model domain layers now include a top 15 m weathered profile layer which pinches out at the higher elevated areas and a second 10 m thick layer which only incorporates the less permeable Ghaub section, then two 150 m layers representing the main aquifer sequence followed by a 40 m layer that also represents the main aquifer and includes the highly permeable “supertube”. The sixth layer represents the consolidated deeper bedrock (Figure 3-2). The model data and input information were sourced from historical reports and aquifer tests as well as previous models and data provided by B2Gold mine (Table 3-1)

Table 3-1: Model Data Sources and Input Conditions

Model data	
Model input data	**Data Sources**
DTM data	Received from B2Gold surveyor's office and Grid to 10m spacing
Rainfall data	Supplied by B2Gold, measured from mining weather station
Geology	Supplied by B2Gold geological department and previous model delineation
Drainages	Delineated from detailed satellite images and elevation profiles
Steady state conditions and assumptions	
Model input	**Conditions**
Model recharge	Input as percentage of measured MAP 475 mm/a and previous 2018 monitoring report (Annual Groundwater Report 2017)
Aquifer Permeability	Input based on aquifer testing and reference from previous 2018 monitoring report (Annual Groundwater Report 2018)
Boundary conditions	Southern boundary: constraint hydraulic head; Western and eastern boundaries: no flow due to elevation high areas; northern boundary: open boundary due to elevation low and main drainage direction.
Model drainages	Constraint hydraulic head to act as drains to the system in steady state conditions

The steady state flow calibration was conducted with model input parameters, mainly permeability and recharge, to obtain a good fit with recently measured aquifer properties including groundwater levels from monitoring points. Recharge were increased for calibration purposes and the hydraulic conductivity were kept the same as the 2018 model input to obtain precision from the simulated water levels and representing the real aquifer conditions prior to any mining activities. The model parameters that were used are illustrated in Table 3-2. The marble and marble/dolostone/limestone formations were considered as major aquifer systems as described from the conceptual hydrogeological model. These aquifers represent high permeability and recharge zones and the dewatering well PD-01 intersected these marble formations at depth. The Irrigation boreholes also intersected this formation and the average hydraulic conductivities estimated from the pump tests was 0.7 m/d. The assigned hydraulic conductivity to the marble/dolostone/limestone formations as part of the calibration process was 0.5 m/d. The faults were considered as higher permeability zones acting as pathways for groundwater flow in terms of recharge and connecting the different marble units regionally.

Table 3-2: Model Input Parameters

Model geology	Hydraulic conductivity (m/d)	Transmissivity (m^2/d)	Storativity	Recharge (%)	Recharge (m/d)
Layer one (15m)					
Sandy Gravel/ Calcrete	1.30E+00	20	1.00E-04	1.46%	1.90E-05
Mica /Schist /Marble	1.00E+00	15	1.00E-04	1.46%	1.90E-05

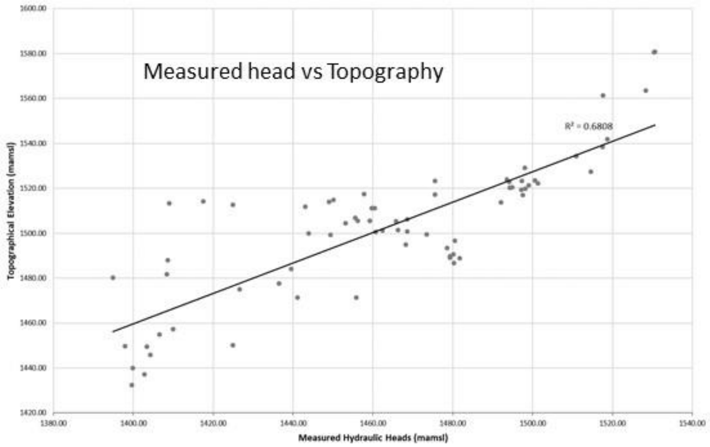
Mica /Schist /Metagreywacke	5.00E-03	0.08	1.00E-04	1.46%	1.90E-05
Mica /Schist /Marble/Quartz	1.00E+00	15	1.00E-04	1.46%	1.90E-05
Marble/ Dolostone/ Limestone	1.00E+00	15	1.00E-04	2.69%	3.50E-05
Marble	1.33E+00	20	1.00E-04	2.69%	3.50E-05
Granite	1.00E+00	15	1.00E-04	1.46%	1.90E-05
Diamictite/ Pebbly Schist	1.00E+00	15	1.00E-04	1.46%	1.90E-05
Schist	6.70E-01	10	1.00E-04	1.46%	1.90E-05
Local Faults	1.67E+00	25	1.00E-04	3.07%	4.00E-05
Regional Faults	1.67E+00	25	1.00E-04	3.07%	4.00E-05
Layer two (10m)					
Mica /Schist /Marble	3.00E-02	0.30	3.33E-07		
Mica /Schist /Metagreywacke	1.50E-02	0.15	3.33E-07		
Mica /Schist /Marble/Quartz	3.00E-02	0.30	3.33E-07		
Marble/ Dolostone/ Limestone	5.25E-01	5	3.33E-07		
Ghaup layer	2.00E-03	0.02	3.33E-07		
Marble	2.25E-01	2	3.33E-07		
OTB and PT Marble	2.25E-01	2	3.33E-07		
Granite	1.50E-04	0.002	3.33E-07		
Diamictite/ pebbly Schist	2.25E-01	2	3.33E-07		
Schist	9.75E-02	1	3.33E-07		
Local Faults	7.50E-01	8	3.33E-07		
Regional Faults	7.50E-01	8	3.33E-07		
Layer three (140m)					
Mica /Schist /Marble	3.00E-02	4	3.33E-07		
Mica /Schist /Metagreywacke	1.50E-02	2	3.33E-07		
Mica /Schist /Marble/Quartz	3.00E-02	4	3.33E-07		
Marble/ Dolostone/ Limestone	5.25E-01	74	3.33E-07		
Marble	2.25E-01	32	3.33E-07		
OTB and PT Marble	2.25E-01	32	3.33E-07		
Granite	1.50E-04	0.02	3.33E-07		
Diamictite/ pebbly Schist	2.25E-01	32	3.33E-07		
Schist	9.75E-02	14	3.33E-07		
Local Faults	7.50E-01	105	3.33E-07		
Regional Faults	7.50E-01	105	3.33E-07		
Layer four (150m)					
Mica /Schist /Marble	3.00E-02	5	3.33E-07		
Mica /Schist /Metagreywacke	1.50E-02	2	3.33E-07		
Mica /Schist /Marble/Quartz	3.00E-02	5	3.33E-07		
Marble/ Dolostone/ Limestone	5.25E-01	79	3.33E-07		
Marble	2.25E-01	34	3.33E-07		
OTB and PT Marble	2.25E-01	34	3.33E-07		

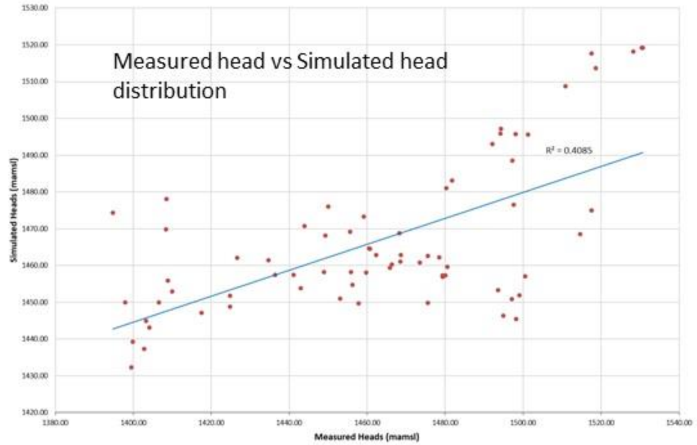
Granite	1.50E-04	0.02	3.33E-07		
Diamictite/ pebbly Schist	2.25E-01	34	3.33E-07		
Schist	9.75E-02	15	3.33E-07		
Local Faults	7.50E-01	113	3.33E-07		
Regional Faults	7.50E-01	113	3.33E-07		
Layer five (40m)					
Mica /Schist /Marble	3.00E-02	1	3.33E-07		
Mica /Schist /Metagreywacke	1.50E-02	1	3.33E-07		
Mica /Schist /Marble/Quartz	3.00E-02	1	3.33E-07		
Marble/ Dolostone/ Limestone	5.25E-01	21	3.33E-07		
Marble	2.25E-01	9	3.33E-07		
OTB and PT Marble	2.25E-01	9	3.33E-07		
Granite	1.50E-04	0.01	3.33E-07		
Diamictite/ pebbly Schist	2.25E-01	9	3.33E-07		
Schist	9.75E-02	4	3.33E-07		
Local Faults	7.50E-01	30	3.33E-07		
Regional Faults & high permeable zone	7.50E-01	30	3.33E-07		
Layer six (300m)					
Mica /Schist /Marble	1.00E-02	3	1.66E-07		
Mica /Schist /Metagreywacke	5.00E-03	2	1.66E-07		
Mica /Schist /Marble/Quartz	1.00E-02	3	1.66E-07		
Marble/ Dolostone/ Limestone	1.75E-01	53	1.66E-07		
Marble	7.50E-02	23	1.66E-07		
Granite	5.00E-05	0.02	1.66E-07		
Diamictite/ pebbly Schist	7.50E-02	23	1.66E-07		
Schist	3.25E-02	10	1.66E-07		
Local Faults	2.50E-01	75	1.66E-07		
Regional Faults	2.50E-01	75	1.66E-07		

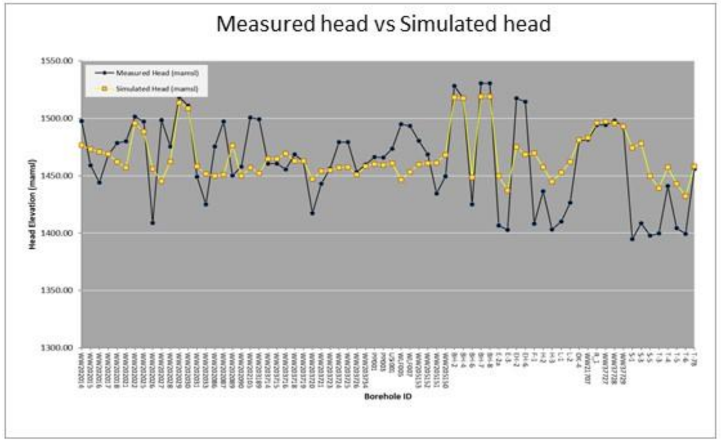
The steady state model calibration statistics and observations are shown in Figure 3-1. The measured field hydraulic head observations compared to topographical elevation indicates a 68% correlation implying a dynamic aquifer system which is probably due to the dewatering and abstraction from both the mine and surrounding groundwater users in this area. The bubble plot in Figure 3-2 indicates that the shallower water levels correlates with the higher elevation areas and increases towards the west and north west. The water levels in and around the mine site indicates deeper water levels at lower elevation, which indicates the effect of dewatering from the mine. The steady state conditions were reached when the measured hydraulic head and simulated hydraulic head correlated at 64% and mean absolute error measured at 23 m. The rough spacing from the DTM and dynamic nature were considered as the major variables in the calibration process.

The initial steady state hydraulic head indicates that groundwater flows towards the west from the mining area as indicated in Figure 3-3 (top insert). The current groundwater regime and status can be observed in the bottom insert of Figure 3-3 and the zone of impact created by the dewatering is indicated in Figure 3-4. The impact zone has an approximate radius of 2 km with an increased extent towards the south of approximately 4 km. The indicated ZOI depth is measured from the initial calibrated water level and were estimated at 170 mbwl (Figure 3-4).

The groundwater balance indicated in Figure 3-4 shows that roughly 34 600 m^3/d are coming in from recharge to the aquifer systems. The positive flux assigned to the Stockpile and WRD facilities also contribute around 48 m^3/d to the aquifer systems. When abstraction from the current mine boreholes and the surrounding groundwater users (assumed 864 m^3/d) are taken into account then at least 25 800 m^3/d are still in storage in the groundwater system.







Measured head vs Simulated head correlation

Observation n = 60	Z (mamsl) RL	Water Level (mbgl)	Measured Head (mamsl)	Simulated Head (mamsl)	Mean Absolute Error (m) MAE	Mean Error (m) ME	Root Mean Sqaure Error (m) RMS
Average	1502.57	39.49	1463.08	1466.84	22.02	-3.76	845.90
Minimun	1432.42	6.54	1394.82	1432.36	0.12	-79.53	0.01
Maximum	1580.76	104.36	1530.62	1519.19	79.53	52.81	6325.81
Correlation (R)				0.64	Σ =1659	Σ =-89	Σ = 60544
					1/n =25.7	1/n =-4.4	1/n =987
							SQRT = 31.4
							RMS%of water level range = 23.4%

Steady state calibration statistics at current groundwater status

B2Gold Irrigation Scheme | Calibration statistics

Figure 3-1 Model Calibration Statistics and Observations

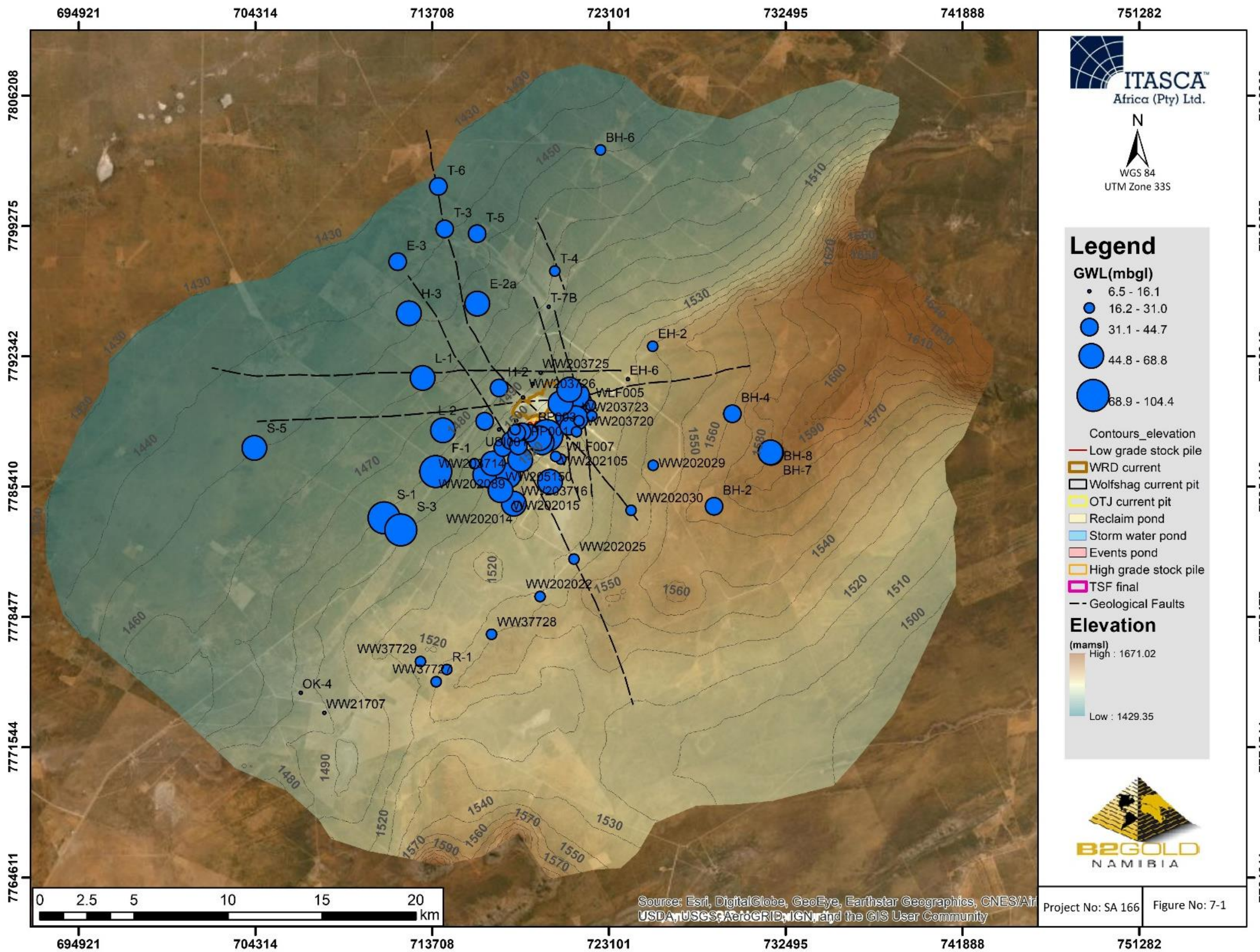
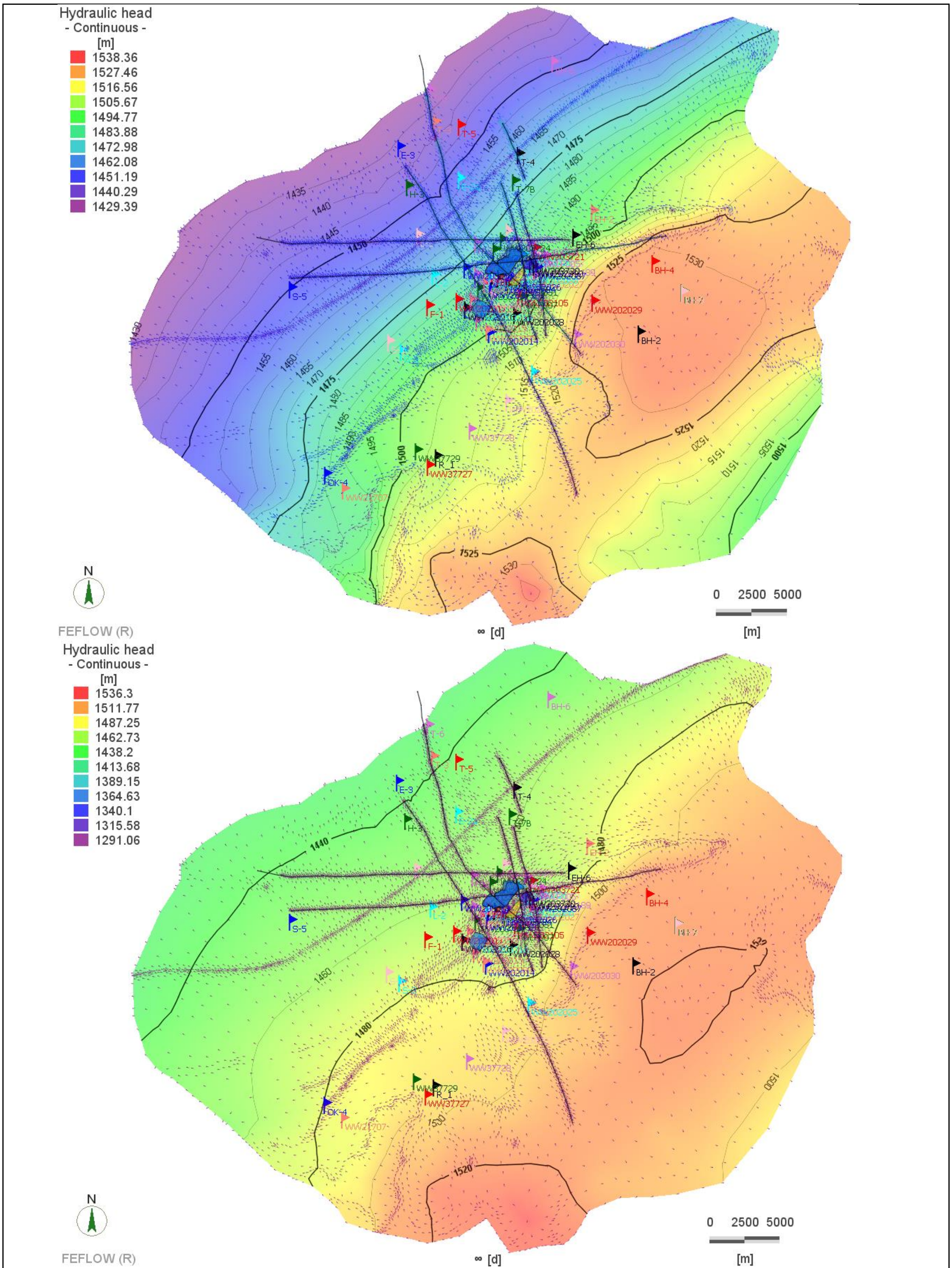
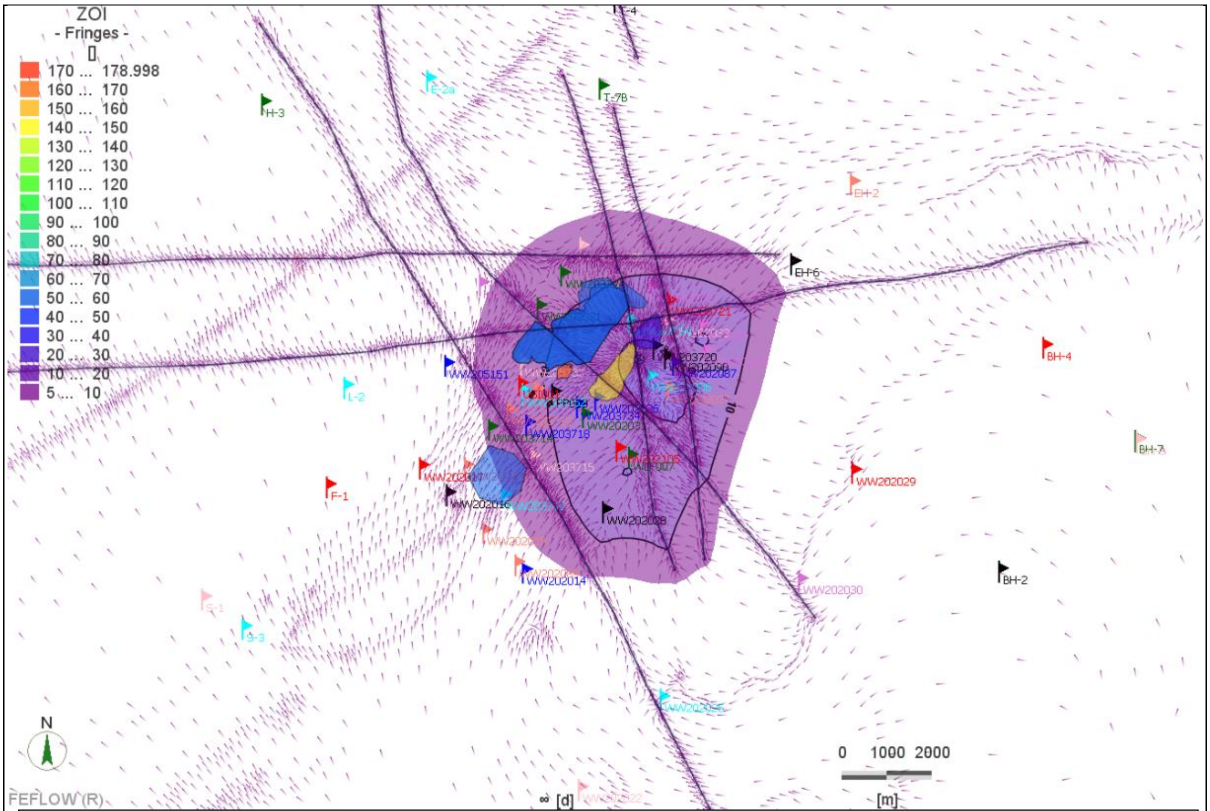


Figure 3-2 Observed groundwater levels used for model calibration



	Steady state calibration: Initial Hydraulic head (top insert) and Current Hydraulic head (bottom insert)
	B2Gold Irrigation Scheme	Calibration statistics

Figure 3-3 Steady state calibration: Initial and current hydraulic head



	Steady State Current conditions			
	Component	Inflow (m³/d)	Outflow (m³/d)	Balance (m³/d)
1	Recharge from precipitation	34671	0	**34671**
2	Abstraction from mine boreholes and PD01 dewatering	0	-8017	**-8017**
3	Assumed abstraction from surrounding groundwater users	0	-864	**-864**
4	Positive flux from TSF, Stockpiles and WRD	48	0	**48**
5	Groundwater to aquifer storage	0	-25790	**-25790**
	Total	**34719**	**-34671**	**48**
			Balance Error (%)	**-0.14%**

ITASCA Africa (Pty) Ltd.	**Steady state drawdown with current mine dewatering**	
	B2Gold Irrigation Scheme	Drawdown current mining

Figure 3-4 Drawdown created by the current mine dewatering and surrounding abstraction boreholes

4 SCENARIO SIMULATIONS

The scenario simulations were conducted in steady state to ensure the worst case in terms of impacts due to abstraction from the irrigation boreholes as well as the future mine underground development. The steady sate conditions also ensured model stability due to the limited dimensions of the model domain and the dynamic nature of the marble aquifer that could create drawdown over a regional area. This would imply an inaccurate drawdown impact that would extend outside the model boundary.

The future mine underground development would extend to an approximate depth of 400 mbgl. Hydraulic head constraints were assigned at this depth over the underground mining layout to acts as drains and represent the underground abstraction. It was assumed that when the underground development commences then groundwater abstraction from the surface boreholes both for mine water use and dewatering would halt. The required water demand for mining operations would be supplied from the underground development dewatering.

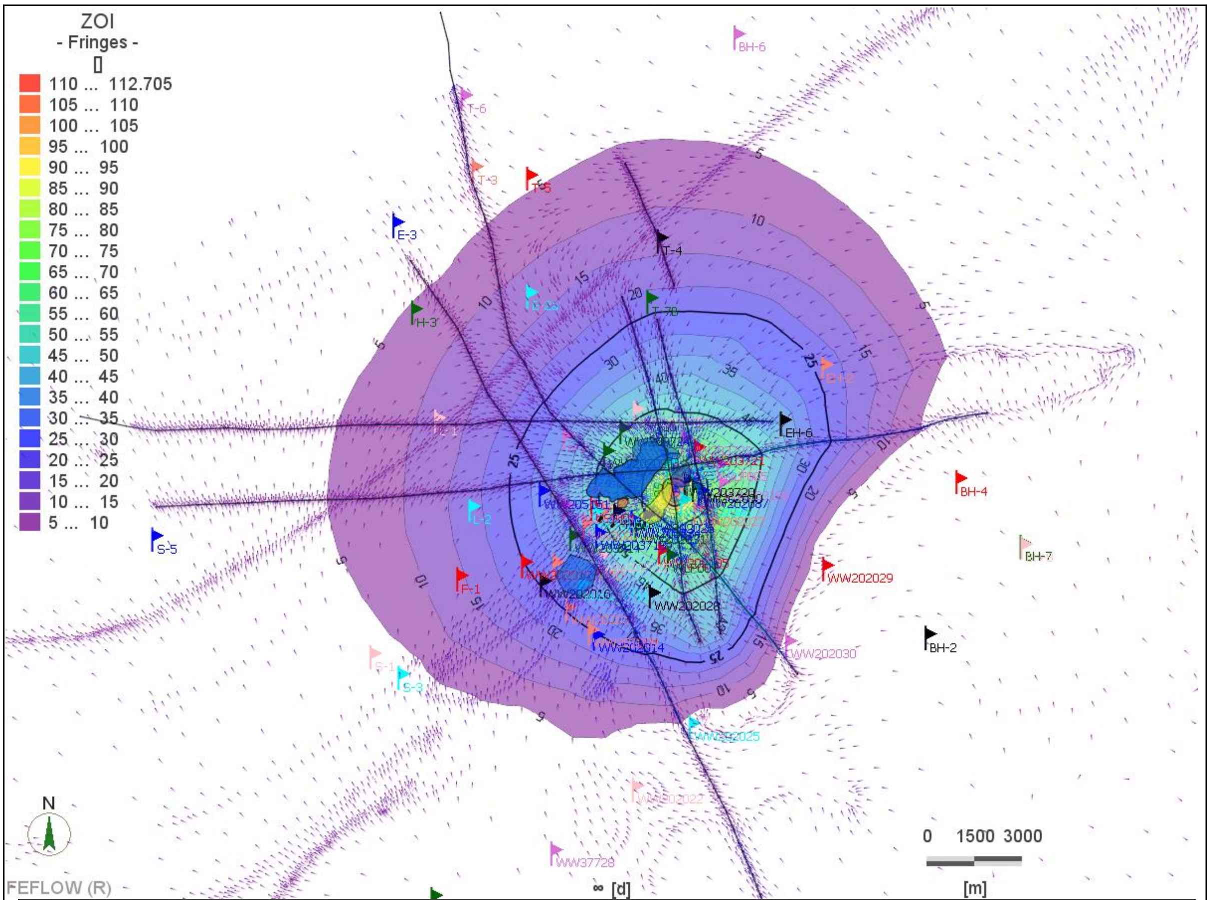
It is not clear how much water gets abstracted from the surrounding groundwater users and an assumed 864 m^3/d (10 L/s) were allocated for this purpose. This rate might be more and a better understanding is needed in terms of groundwater use by the surrounding population.

4.1 GROUNDWATER MODEL RERSULTS

The first simulation focused on the underground dewatering impacts on the groundwater systems and the drawdown effect that will be created when mining develops down to 400 mbgl. Abstraction from the current boreholes in and around the mining area that supplies water to the mine were halted as dewatering will mainly shift to the underground development. The results are indicated in Figure 4-1 which displays the drawdown impact as well as the water balance.

The drawdown impact would roughly be between 3 to 6 km extending radially outward from the mining area. The larger extend could be expected towards the west and north east of the mining area. The depth of drawdown can extend down to 113 meters below the static water level (mbwl) which is roughly 150 to 170 mbgl.

The future mine underground development will dewater at peak mining operations roughly 16 650 m^3/d. The available groundwater remaining in storage considering the surrounding groundwater users and flux from the TSF and WRD facilities were estimated at 17 100 m^3/d.



	Steady State Future Underground mine development			
	Component	Inflow (m³/d)	Outflow (m³/d)	Balance (m³/d)
1	Recharge from precipitation	34671	0	**34671**
2	Abstraction from mine underground development	0	-16647	**-16647**
3	Assumed abstraction from surrounding groundwater users	0	-864	**-864**
4	Positive flux from TSF, Stockpiles and WRD	48	0	**48**
5	Groundwater to aquifer storage	0	-17160	**-17160**
	Total	**34719**	**-34671**	**48**
			Balance Error (%)	**-0.14%**

ITASCA™ Africa (Pty) Ltd.

Steady state drawdown with future mine underground development

B2Gold Irrigation Scheme | Drawdown future mine underground

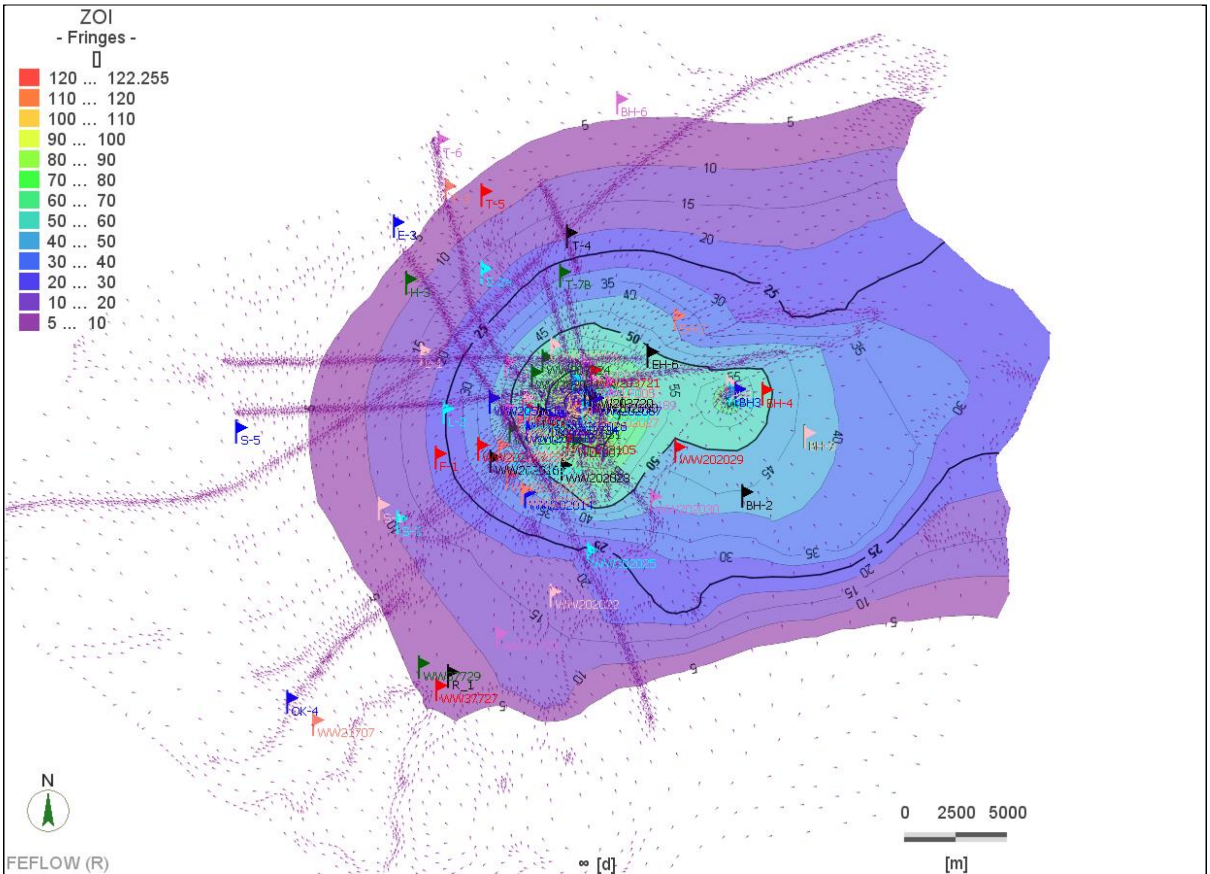
Figure 4-1 Drawdown from future mine underground development and groundwater balance

The second simulation included the abstraction from the irrigation boreholes at 2.5 million m^3/a. An assigned rate of 26.6 L/s were applied to each of the three irrigation boreholes to evaluate drawdown simultaneously as well as looking at the effect of the underground mine dewatering. The results can be observed in Figure 4-2 that shows the drawdown impact extending between 10 to 12 km towards the east and intersects the model boundary. The approximate depth of drawdown at the eastern boundary is 30 mbwl (± 50 mbgl) and could extend up to 15 km eastwards.

The drawdown depth indicates a maximum of a 122 mbwl (±160 mbgl to 180 mbgl) at the mining area and at the irrigation holes around 80 to 100 mbwl (± 120 mbgl). The water balance indicates that dewatering at the mine reduced slightly 16 150 m^3/d due to the abstraction taking place at the irrigation holes. The groundwater storage reduced to roughly 10 700 m^3/d.

The third scenario included abstraction from the irrigation boreholes at 30 % (0.95 million m^3/a) of the required 2.5 million m^3/a (Figure 4-3). The drawdown impact reduces by roughly 5 km to 7 km towards the east and the depth of drawdown also reduce to 115 mbwl (± 150 mbgl) at the mining area. The depth of drawdown at the irrigation holes reached 20 mbwl (± 50 mbgl). The underground dewatering rates were reported at 16 470 m^3/d and approximately 14 750 m^3/d are still in storage.

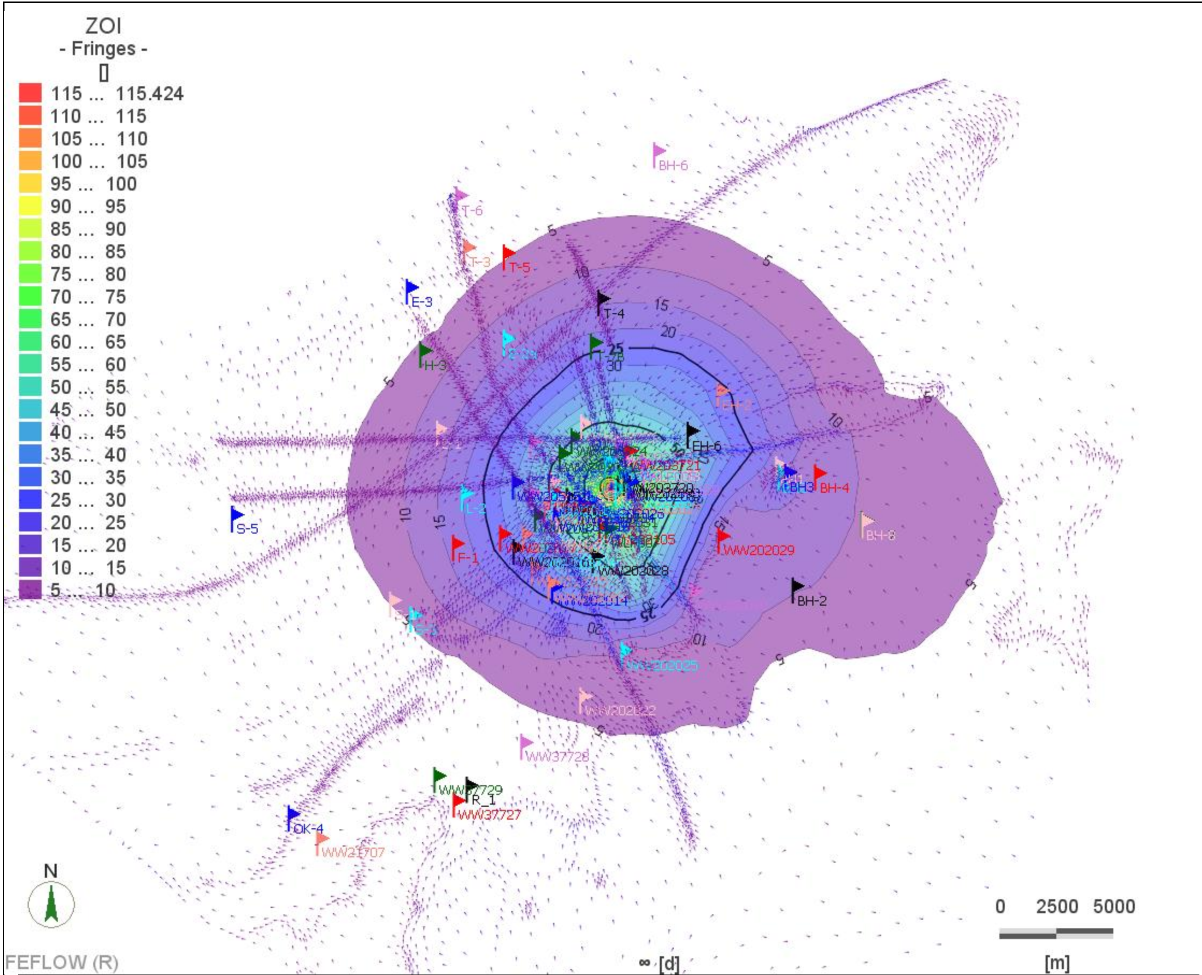
The last scenario was simulated at irrigation abstraction of 20 % (0.5 million m^3/a) of the required 2.5 million m^3/a (Figure 4-4). The drawdown effect is much lower and extends approximately 6 km to the east of the mining area. The drawdown depth remains the same at roughly 115 mbwl (±150 mbgl) at the mining area and 10 mbwl (± 30 mbgl) at the irrigation holes. The underground dewatering rate increased to 16 560 m^3/d and approximately 15 950 m^3/d remains in storage.



	Steady State Underground mining development with irrigation at full required rate			
	Component	Inflow (m^3/d)	Outflow (m^3/d)	Balance (m^3/d)
1	Recharge from precipitation	34671	0	**34671**
2	Abstraction from irrigation Boreholes at required 2.5 million m^3/d	0	-6916	**-6916**
3	Abstraction from mine underground development	0	-16148	**-16148**
4	Assumed abstraction from surrounding groundwater users	0	-864	**-864**
5	Positive flux from TSF, Stockpiles and WRD	48	0	**48**
6	Groundwater to aquifer storage	0	-10743	**-10743**
	Total	**34719**	**-34671**	**48**
			Balance Error (%)	**-0.14%**

ITASCA Africa (Pty) Ltd.	**Steady state drawdown with future mine underground development and irrigation abstraction at required 2.5 million m^3/a**
B2Gold Irrigation Scheme	Drawdown future mine underground and irrigation required rate

Figure 4-2 Drawdown from future mine underground development and irrigation abstraction at required 2.5 million m^3/a with groundwater balance

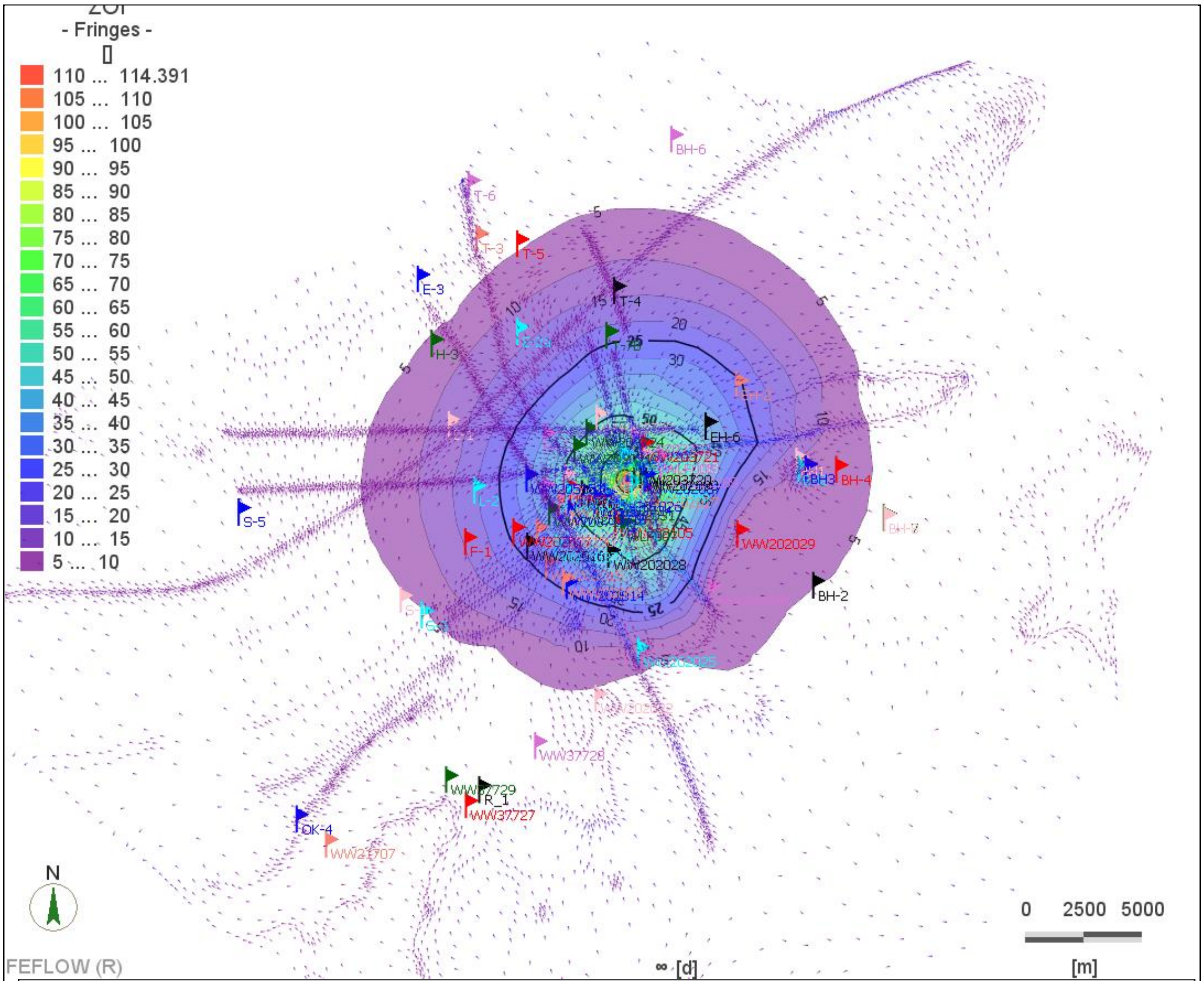


Steady State Underground mining development with irrigation at 30% of required rate				
	Component	Inflow (m^3/d)	Outflow (m^3/d)	Balance (m^3/d)
1	Recharge from precipitation	34671	0	**34671**
2	Abstraction from irrigation Boreholes at required 0.95 million m³/d	0	-2592	**-2592**
3	Abstraction from mine underground development	0	-16470	**-16470**
4	Assumed abstraction from surrounding groundwater users	0	-864	**-864**
5	Positive flux from TSF, Stockpiles and WRD	48	0	**48**
6	Groundwater to aquifer storage	0	-14745	**-14745**
	Total	**34719**	**-34671**	**48**
			Balance Error (%)	**-0.14%**

ITASCA™ Africa (Pty) Ltd.	**Steady state drawdown with future mine underground development and irrigation at 30% (0.95 million m³/a) of the required rate**	
	B2Gold Irrigation Scheme	Drawdown future mine underground and irrigation at 30% of required rate

Figure 4-3 Drawdown from future mine underground development and irrigation abstraction at 30 % of the required 2.5 million m³/a with groundwater balance

ITASCA™ Africa (Pty) Ltd.



Steady State Underground mining development with irrigation at 20% of required rate				
	Component	Inflow (m³/d)	Outflow (m³/d)	Balance (m³/d)
1	Recharge from precipitation	34671	0	**34671**
2	Abstraction from irrigation Boreholes at required 0.95 million m³/d	0	-1296	**-1296**
3	Abstraction from mine underground development	0	-16560	**-16560**
4	Assumed abstraction from surrounding groundwater users	0	-864	**-864**
5	Positive flux from TSF, Stockpiles and WRD	48	0	**48**
6	Groundwater to aquifer storage	0	-15951	**-15951**
	Total	**34719**	**-34671**	**48**
			Balance Error (%)	**-0.14%**

ITASCA™ Africa (Pty) Ltd.	**Steady state drawdown with future mine underground development and irrigation at 20% (0.5 million m³/a) of the required rate**	
	B2Gold Irrigation Scheme	Drawdown future mine underground and irrigation at 20% of required

Figure 4-4 Drawdown from future mine underground development and irrigation abstraction at 20 % of the required 2.5 million m³/a with groundwater balance

5 MINEDW COMPARATIVE SIMULATIONS

An additional predictive simulation was undertaken in transient state using the *MINEDW* numerical groundwater model developed and updated in 2019 for comparison with the FEFLOW model results. The predictive simulation was undertaken to evaluate the cumulative drawdown resulting from the pit and underground workings dewatering as well as the pumping boreholes including the proposed agricultural irrigation boreholes. The details of the model construction and calibration are not discussed here but are discussed in detail "SA171_FINAL_Otjikoto_2019 Model Update Results_05 December 2019".

The predictive simulation was based on Scenario 2 (Itasca, 2020 – Table 6-1) in which the pits, current water supply holes and underground workings were simulated including the proposed 3 agricultural irrigation boreholes BH01-03 with a pumping rate of 26.6 L/s (2298 m3/day) applied to each of the boreholes to meet the required 2.5 million m^3/a. The pumping of the agricultural irrigation boreholes was simulated to start in June 2020 until end of mining in December 2026.

The results can be observed in Figure 5-1 and results show that the drawdown will extend further than the 2019 results (purple contours)and result in a drop in the water levels around the pits and underground development by a maximum of approximately 340m by LOM in December 2026. The drawdown at the agricultural irrigation boreholes is predicted to be a maximum of approximately 26m by the end of mining in December 2026. The resulting drawdown contours extends to 15 km towards the south west and could extend up to 20 km eastwards.

The MINEDW results are within the same order as the FEFLOW results in terms of the extent of drawdown contours and serves to validate the presented results.

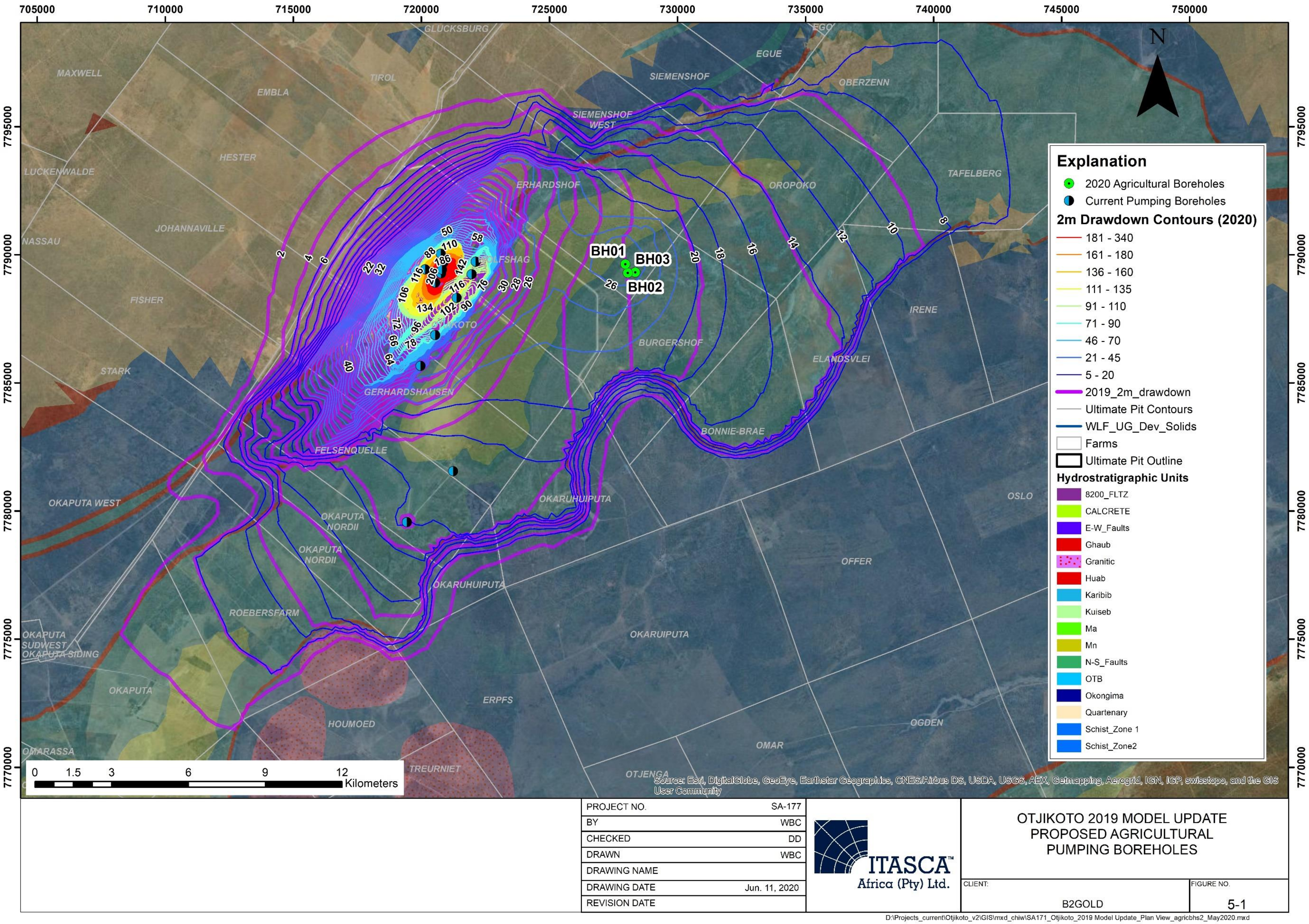


Figure 5-1 **Drawdown from future mine underground development and irrigation abstraction for the required 2.5 million m³/a using *MINEDW***

6 SUMMARY AND CONCLUSION

The model update and inflow simulation indicate the following:

1) The drillers reports indicate that all three boreholes were drilled into marble formation and the blow yields range from 80 m^3/Hr to 200 m^3/Hr.
2) The water quality would suggest that the irrigation boreholes are more associated with the Karibib marble formations and that groundwater abstraction would largely take place from this aquifer system.
3) The dynamic groundwater status and regime due to abstraction from the mine and groundwater users would imply a low correlation between hydraulic head and surface topography especially around the mining area where dewatering is taking place. The model calibration was conducted according to the dynamic nature of the aquifer system.
4) The current mine dewatering drawdown impact extends roughly 2 km around the mining area with and increased extent towards the south of 4 km. The maximum drawdown depth is estimated at 179 mbwl. An estimated 25 800 m^3/d is still available in storage taking into account abstraction from mine dewatering (8017 m^3/d) and abstraction from the surrounding groundwater users (864 m^3/d). The recharge coming into the system was estimated at 34 600 m^3/d.
5) The future underground mine development could have a drawdown impact extending roughly 3 km to 6 km and reach a depth of between 150 mbgl to 170 mbgl. An estimated 16 650 m^3/d of groundwater is abstracted from the mine borehole for water supply to the mine. The remaining available rate in storage is 17 100 m^3/d. These results indicate that although the aquifer system may not be stressed, the drawdown impact may influence some of the surrounding groundwater users.
6) If irrigation takes place at the required 2.5 million m^3/a in conjunction with the underground mining operations than the drawdown impact will be far reaching with increased extension (up to 12 km) towards the east of the abstraction areas. The drawdown depth estimated at the irrigation boreholes can drop to 120 mbgl which is assumed to be the pump installation depth. The remaining available groundwater in storage was estimated at 10 700 m^3/d which would imply that the aquifer is still not under stress however the impact zone could affect the surrounding groundwater users.
7) Abstraction at 30 % of the required rate (0.95 million m^3/a) will reduce the drawdown impact by almost half the distance and drawdown depth will only reach approximately 50 mbgl which is safer in terms of pump installation depth at 100 mbgl is considered. The

remaining rate in storage were estimated at 14 750 m^3/d. This observation implies a more sustainable approach to groundwater abstraction however some groundwater users could still be impacted.

8) Abstracting at 20 % of the required irrigation rate (0.5 million m^3/d) will reduce the drawdown impact to 6 km and ensure at least 15 950 m^3/d remains in storage. The maximum drawdown depth reaches 30 mbgl at the irrigation boreholes.
9) The MINEDW numerical model developed in 2019 indicated a similar drawdown extend in transient state as the Feflow steady state simulations.

7 RECOMMENDATIONS

1) An updated hydrocensus needs to be conducted to evaluate the approximate groundwater use, rate and volume which will aid in better understanding of the dynamic groundwater system and quantify the model calibration better.
2) Abstraction at full required rate while the underground mine is dewatering will impact the surround groundwater users. The aquifer, however, could sustain the abstraction from both the mine and the irrigation scheme considering a constant recharge component. This might be different when real time dependent recharge is applied according to the different seasons.
3) It is recommended that the irrigation abstraction rate be reduced to at least 20% to 30% of the proposed abstraction rate. To sustain the aquifer system, ensure the pump depth inlet is not reached in the irrigation boreholes and to reduce the drawdown impact on the surrounding groundwater users.
4) The additional irrigation makeup water could be sourced from the underground mine dewatering if the mine water requirements only uses a portion of the total volume being dewatered.
5) The surrounding groundwater users that are likely to be impacted, could also be supplied with water from mining and irrigation abstraction. The required rate from the surrounding groundwater users may only be a fraction of the total being abstracted from the mine and irrigation scheme.
6) The different irrigation options in terms of pump cycles and different irrigation seasons need to modeled in transient state with time dependent recharge to the groundwater system.

7) The model updates need to be accompanied by a detailed water balance to evaluate the different options to accommodate all the groundwater users as well as the mine and irrigation scheme.
8) An effective monitoring program need to be applied during irrigation abstraction to collect data for future model updates and water balances and to implement timely mitigation prior to impacts created by drawdown from abstraction. The monitoring program should form part of the B2Gold mining monitoring program and focus on taking regular water levels readings especially at Erhardshof and nearby surrounding groundwater users.

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Senior Hydrogeologist

Reviewed by

Diane Duthe

Principal Hydrogeologist

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8 APPENDIX A: DRILLERS REPORTS

Page 1 of 2

BOREHOLE COMPLETION REPORT

Please indicate at reverse side the position of the borehole and draw a casing plan.

APPLICANT: D. RUDMAN	BOREHOLE NUMBER: WW
FARM: ERHARDSHOF NUMBER: 575	TOPO & WELL NUMBER:
DISTRICT: OTAVI	LATITUDE: K 0727969 °
DATE COMMENCED: 18/09/2019	LONGITUDE: 7789635 °
DATE COMPLETED: 18/09/2019	COLLAR HEIGHT: m

GEOLOGY

from - to in (m)	DESCRIPTION
	marble from start
	to finish.

TOTAL DEPTH FROM SURFACE: 126 m

DIAMETER OF BOREHOLE
254 mm from 0 to 3 m.
203 mm from 4 to 126 m.
mm from ... to ...

FIRST WATER STRIKE 36 m
SECOND WATER STRIKE 103 m
THIRD WATER STRIKE 114 m
WATER LEVEL ... m
YIELD m³/h 100 – 120 m³/h
APPARENT QUALITY OF WATER: Good.
TDS WHEN DRILLED: ...

INITIAL CAPACITY TEST

AIRLIFT YIELD * ☐
PUMP YIELD * ☐
YIELD IN m³/h: ...
DATE: ...
DURATION ...

DRILLING COSTS

ITEM	N$
m drilled N$ per m	
testing of borehole:	
CASING	
plain length m	
N$ per m	
perforated length m	
N$ per m	
TOTAL COST	

State whether the borehole is:*

☑ successful
☐ unsuccessful

☑ Casing left in borehole
☐ Casing recovered

DECLARATION BY DRILLER AND DRILLING INSPECTOR

I, the driller, declare that the information supplied above is true and correct	I, the drilling inspector, declare that the information supplied above is true and correct
Signature: [signature]	Signature: [signature]
Rank: Driller	Rank: Driller
Place: B2 Gold Date:	Place: B2 Gold. Date:

* mark applicable block

Remarks:

.... RESPONSIBLE GEOHYDROLOGIST

.... DATE

Appendix 3.1 Borehole_Completion.doc

Figure 8-1 Drillers report BH01

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Page 1 of 2

BOREHOLE COMPLETION REPORT

Please indicate at reverse side the position of the borehole and draw a casing plan.

APPLICANT: D. RUDMAN	BOREHOLE NUMBER: WW
FARM: ERWARDSHOF NUMBER: 575	TOPO & WELL NUMBER:
DISTRICT: OTAVI	LATITUDE: K0728062 °
DATE COMMENCED: 20/09/2019	LONGITUDE: 778,9288 °
DATE COMPLETED: 20/09/2019	COLLAR HEIGHT: m
GEOLOGY	TOTAL DEPTH FROM SURFACE: 126 m

from - to in (m)	DESCRIPTION
	marble from
	start to finish

DIAMETER OF BOREHOLE

- 254 mm from 0 to 5 m
- 203 mm from 4 to 126 m
- ...mm from ... to ...

FIRST WATER STRIKE 42 m
SECOND WATER STRIKE 110 m
THIRD WATER STRIKE ... m
WATER LEVEL ... m
YIELD m³/h 80 – 100 m³/h
APPARENT QUALITY OF WATER: Good
TDS WHEN DRILLED: ...

INITIAL CAPACITY TEST

AIRLIFT YIELD * ☐
PUMP YIELD * ☐
YIELD IN m³/h: ...
DATE: ...
DURATION ...

DRILLING COSTS

ITEM	N$
m drilled N$ per m	
testing of borehole:	
CASING	
plain length m	
N$ per m	
perforated length m	
N$ per m	
TOTAL COST	

State whether the borehole is:*

☑ successful
☐ unsuccessful

☑ Casing left in borehole
☐ Casing recovered

DECLARATION BY DRILLER AND DRILLING INSPECTOR

I, the driller, declare that the information supplied above is true and correct	I, the drilling inspector, declare that the information supplied above is true and correct
Signature: [signature]	Signature: [signature]
Rank: Driller.	Rank: Driller
Place: B2 Gold Date:	Place: B2 Gold. Date:

* mark applicable block

Remarks:

....
RESPONSIBLE GEOHYDROLOGIST

....
DATE

Appendix 3.1 Borehole_Completion.doc

Figure 8-2 Drillers report BH02

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Page 1 of 2

BOREHOLE COMPLETION REPORT

Please indicate at reverse side the position of the borehole and draw a casing plan.

APPLICANT: D. RUDMAN	BOREHOLE NUMBER: WW
FARM: ERHARDSHOF NUMBER: 575	TOPO & WELL NUMBER:
DISTRICT: OTAVI	LATITUDE: K072.8360 °
DATE COMMENCED: 25/09/2019	LONGITUDE: 77.89312 °
DATE COMPLETED: 25/09/2019	COLLAR HEIGHT: m
	TOTAL DEPTH FROM SURFACE: 114 m

GEOLOGY

from - to in (m)	DESCRIPTION
	marble from
	Start to finish.

DIAMETER OF BOREHOLE

254 mm from 0 to 9
203 mm from 10 to 114m
....mm from .... to ....

FIRST WATER STRIKE 29 m
SECOND WATER STRIKE 89 m
THIRD WATER STRIKE 106 m
WATER LEVEL ....m
YIELD m³/h 150 – 200 m³/h
APPARENT QUALITY OF WATER: Good.
TDS WHEN DRILLED: ....

INITIAL CAPACITY TEST

AIRLIFT YIELD * ☐
PUMP YIELD * ☐
YIELD IN m³/h: ....
DATE: ....
DURATION ....

DRILLING COSTS

ITEM			N$
m drilled	N$ per m		
testing of borehole:			
CASING			
plain	length	m	
N$ per m			
perforated	length	m	
N$ per m			
TOTAL COST			

State whether the borehole is:*

☑ successful
☐ unsuccessful

☑ Casing left in borehole
☐ Casing recovered

DECLARATION BY DRILLER AND DRILLING INSPECTOR

I, the driller, declare that the information supplied above is true and correct	I, the drilling inspector, declare that the information supplied above is true and correct
Signature: [signature]	Signature: [signature]
Rank: Driller	Rank: Driller
Place: B2 Gold Date:	Place: B2 Gold Date:

* mark applicable block

Remarks:

....
RESPONSIBLE GEOHYDROLOGIST

....
DATE

Appendix 3.1

Borehole_Completion.doc

Figure 8-3 Drillers report BH03