Before a joint hearing of the

Otago Regional Council and

Waitaki District Council **RM 20.024**

Under	the Resource Management Act 1991
In the matter of	applications by Oceana Gold (New Zealand) Limited for resource consents for the Deepdell North Stage III Project

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Statement of evidence of Dusk Lily Mains for Oceana Gold (New Zealand) Limited

4 August 2020

1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is Dusk Mains.

1.2 I am currently employed by GHD Limited in the position of Senior Hydrogeologist.

1.3 I hold a Bachelors degree (first class honours) in geology from the University of Otago and a Master of Science (MSc) in hydrogeology from the University of Western Australia.

1.4 I have thirteen years' experience, working on a range of groundwater projects including dewatering assessments for mining and construction, groundwater supply assessments and water quality assessments. My previous roles include being a site hydrogeologist for a mine in Australia with significant groundwater and dewatering requirements. I am familiar with the Macraes site, having undertaken a university research project based at the mine.

1.5 I have prepared the assessment of potential effects on groundwater from the proposed Deepdell North III Project (the Project).

1.6 In preparing this evidence I have reviewed the following:

1.6.1 Deepdell North III Project Assessment of Environmental Effects (AEE), January 2020 prepared by Oceana Gold (New Zealand) Limited (OGNZL)

1.6.2 Macraes Phase III Project: Groundwater Contaminant Transport Assessment - Deepdell Creek, North Branch Wakouaiti River and Murphys Creek Catchments, prepared by Golder Associates, 2011.

1.6.3 Deepdell North Stage III Project: Receiving Water Quality Analysis. Report prepared for Ocean Gold New Zealand Limited, November 2019.

1.6.4 Records of groundwater levels and water quality provided by OGNZL from the period of 2001 to 2019 for the Deepdell area at Macraes site.

1.7 The reports and statements of evidence of other experts giving evidence relevant to my area of expertise, include:

1.7.1 The parts of the section 42A report relevant to my area of expertise.

1.7.2 Evidence of Peter Cochrane on behalf of ORC relating to groundwater

1.7.3 Submissions relevant to my area of expertise

1.8 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

2. SCOPE OF EVIDENCE

2.1 I have been asked by OGNZL to prepare evidence in relation to groundwater for the Project. This includes:

2.1.1 Characterisation of the groundwater environment in the vicinity of the Project.

2.1.2 Assessment of potential effects on groundwater levels and flows.

2.1.3 Assessment of potential effects on groundwater quality.

2.2 I confirm that my evidence relates to the proposal known as Deepdell North III as described in Section 3 of the AEE.

2.3 I confirm that I am an author of the GHD report dated January 2020 entitled Deepdell North Stage III Project – Groundwater Assessment.

3. EXECUTIVE SUMMARY

3.1 The study completed by GHD specifically assessed the potential impact of the Project on changes in groundwater levels from the proposed dewatering of the pit and from the formation of a pit lake (post closure). The potential effects on groundwater quality from the Project activities were also qualitatively assessed.

3.2 A conceptual model of the groundwater system was developed based on existing groundwater reports and site monitoring data from the Project area. The conceptual model was used to show the groundwater response during mining and post closure.

3.3 An analytical assessment of groundwater inflow into the proposed mine pit was undertaken. This assessment showed that the effect of the proposed dewatering is not expected to impact groundwater levels outside of the land owned by OGNZL. The estimated radius of groundwater drawdown impacts is 580 m from the centre of the pit. No other groundwater users are expected to be impacted by dewatering activities.

3.4 Post closure, the mine pit will be left to fill as a lake. Considering the groundwater elevation in this area, low groundwater inflows and high rates of evaporation, the pit lake level is expected to stabilise at approximately 430 m RL. This is lower than the design overflow level of 465 m RL.

3.5 The effects on groundwater quality from waste rock stack (WRS) seepage and interaction with pit lake water are expected to be less than minor.

4. GROUNDWATER CONCEPTUAL UNDERSTANDING

4.1 A conceptual model of the groundwater system was developed based on site information provided by OGNZL and other reports. As the project is an extension of a previously mined area, the effect of the past dewatering activities on groundwater levels was used to further the conceptual understanding of the system. The approximate dates of relevant mining activities are listed below:

4.1.1 2001 – 2002 Mining in Deepdell North Pit

4.1.2 2002 – 2003 Backfilling of Deepdell North Pit

4.1.3 2002 – 2003 Mining of Deepdell South Pit, pit void left to fill as a lake

4.2 Groundwater levels recorded in six monitoring wells (DDB01 – 06) from 2001-2019 were reviewed as part of this assessment; groundwater level plots for the six wells are included in Attachment 1. The groundwater monitoring records show a delay (lag) in groundwater response to dewatering activities in the Deepdell area, with minimum groundwater levels recorded in early 2004, after mining and backfilling of Deepdell North Pit had finished.

4.3 Based on the groundwater levels recorded, two groundwater contour maps were created to show groundwater conditions in 2004 and in 2019. These plots are included in Attachment 1. It is assumed that Deepdell Creek acts as a groundwater divide, capturing groundwater flow from both sides of the waterbody. Therefore, surface water elevations in Deepdell Creek (approximate from topographic contours) were used to constrain the groundwater elevation to the south of the project area. The 2019 contour map incorporates water levels recorded in the Deepdell South Pit Lake. The groundwater contours map shows:

4.3.1 Groundwater flow towards towards Deepdell Creek

4.3.2 The shape of the groundwater contours and groundwater gradients are similar for the two monitoring events, with the following exceptions:

4.3.2.1 The 2004 contours show a lower groundwater level in the north of the project area, particularly around DDB02 due to the dewatering activities.

4.3.2.2 The impact of the Deepdell South Pit Lake intercepting groundwater from the north and west and inferred to discharge to the south and east (towards Deepdell Creek)

4.3.3 The elevation of the groundwater surface is below the elevation of valley inverts. This suggests that the small surface watercourses on the north side of Deepdell Creek are unlikely to receive significant groundwater base flow. It is possible that localised fractures in the schist may intercept perched groundwater and discharge to surface water.

4.4 The GHD assessment adopts the hydraulic conductivity (permeability) of the schist rock mass as presented in Golder, 2011. While there are localised variations in permeability depending on the degree and connectedness of fractures, Golder (2011) considered that the permeability of the schist mass as a whole does not vary substantially across the site. However, variations in hydraulic conductivity can be caused by weathering and structural features. The Macraes area has numerous northwest striking high angle faults. In calibrating the groundwater model, Golder (2011) determined a higher permeability in the northwest-southeast (Macraes grid north-south) direction compared to the southwest-northeast (Macraes grid east-west) orientation.

4.5 The groundwater conceptual model for the groundwater system is presented in Figure 1 below. The simplified conceptual model shows the current groundwater conditions (A), groundwater drawdown at maximum pit depth (B) and formation of a pit lake (C). The conceptual model shows:

4.5.1 Groundwater flows from the northwest to the southeast towards Deepdell Creek

4.5.2 Greater drawdown impact on the northwest side of the pit compared to the southeast

4.5.3 The base of the pit is higher than the elevation of Deepdell Creek, therefore drawdown impacts are not expected to extend to the Creek.

4.5.4 Formation of a lake in the pit void.

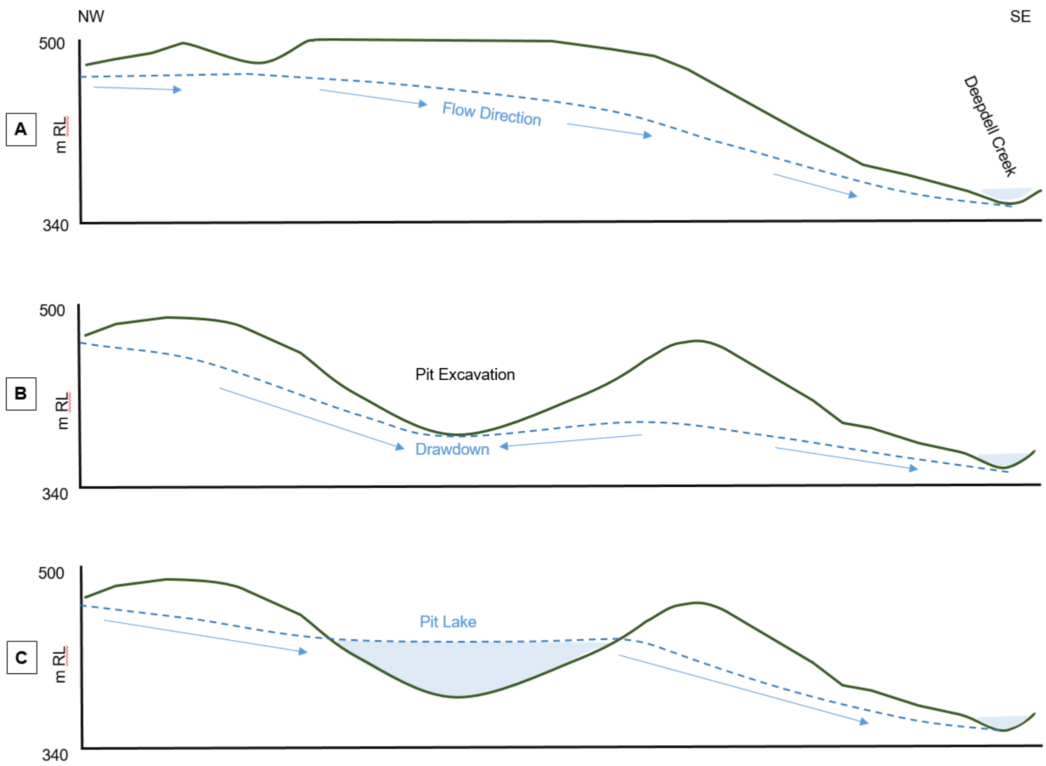


Figure 1: Conceptual model of the groundwater system

5. GROUNDWATER INFLOW (DEWATERING OF PIT)

5.1 Analytical solutions were used to estimate groundwater inflows (dewatering rate) into the proposed pit and radius of groundwater drawdown. The pit inflow calculations are presented in Attachment 2.

5.2 The analytical method is considered to be conservative (i.e. it is likely to over-estimate inflows to the pit). A key assumption of the analytical method is that the pit inflows are axially symmetric, (i.e. inflows are the same in all directions), whereas the groundwater model calibration indicates that groundwater flow is anisotropic due to faulting and other structural features in the schist. The pit inflow calculation has used the hydraulic conductivity K_x of the more permeable northwest-southeast (Macraes north-south) orientation. In addition, the assessment has been based on the maximum drawdown using the groundwater level at the northern end of the proposed pit. Due to the steep groundwater hydraulic gradient the drawdown effects are expected to be much less on the southern side (nearer to Deepdell

Creek), this is consistent with the historical water level measurements in the Deepdell monitoring wells.

5.3 The analytical solution indicates groundwater inflows of approximately 1.5 L/s at the maximum pit depth (elevation of 372 m RL).

5.4 The groundwater drawdown impact is expected to extend approximately 580 m from the centre of the pit, with a lesser impact on the south-southeast side of the pit. The groundwater drawdown effects are expected to be constrained within the boundaries of land owned by OGNZL, therefore no other groundwater users are expected to be impacted by dewatering activities.

6. GROUNDWATER INFLOWS INTO A PIT LAKE

6.1 OGNZL do not intend to back fill the pit, at closure the pit will be allowed to fill as a lake with a combination of surface water (run-off) and groundwater. An assessment of groundwater inflows into the pit lake was undertaken using analytical solutions (Marinelli and Niccoli, 2000). The water balance model (GHD, 2019) predicts that the pit lake will reach an elevation of 430 m RL by 2060 as discussed in the evidence of Sioban Hartwell. At a lake level of 430 m RL and using the groundwater elevation on the northern (higher) side of the pit, the analytical solution indicates a groundwater inflow rate of approximately 0.05 L/s.

6.2 The groundwater contour map indicates the groundwater elevation at the southern end of the pit is approximately 430 m RL, it is likely that the lake level will equilibrate with the groundwater system on the southern side as shown in the conceptual model. Due to this, and low inflows and high evaporation rates, it is likely that the pit lake will stabilise at approximately 430 m RL and not reach the overflow level of 465 m RL.

7. EFFECT ON SURFACE FLOWS

7.1 The effect of the dewatering flows into Deepdell Creek is expected to be less than minor as the Creek is outside of the zone of dewatering impacts and at a lower elevation than the base of the pit. Therefore, the groundwater level will not be drawn below stream bed elevation.

7.2 While the proposed dewatering is not expected to directly impact groundwater levels near Deepdell Creek, it may reduce groundwater discharge to the stream. However, as groundwater is only a very small proportion of flows[1] in Deepdell Creek , the effect of the project on surface water flows are likely to be less than minor.

8. GROUNDWATER QUALITY

8.1 The Project has the potential to impact groundwater quality through seepage from WRS entering groundwater and the interaction of pit lake water and groundwater.

8.2 An assessment of WRS seepage on surface water quality is presented in the water balance model, (GHD 2019) and discussed in the evidence of Sioban Hartwell. The WRS are designed with toe drains to capture seepage, which is then directed to sediment ponds and ultimately Deepdell Creek or other streams. The WBM assumes that all WRS seepage is collected by toe drains. It is possible that a small proportion of seepage may be intercepted by fractures in the schist at ground surface and migrate into groundwater. This groundwater would ultimately discharge to Deepdell Creek. I have not directly assessed the groundwater impacts. However, both flow paths ultimately flow into Deepdell Creek, and the water quality effects of the WRS seepage has already been accounted for in the WBM.

8.3 Following mine closure, groundwater will flow into the pit void from all directions. However, as the lake fills, groundwater will predominantly flow into the pit from the north-northwest. In later stages, when equilibrium conditions are met, lake water will migrate into groundwater and flow down gradient towards Deepdell Creek.

8.4 A review of water quality data collected from the existing Deepdell South pit lake showed changes in water quality as the pit lake evolved. Initially the

[1] Mean flow to Deepdell catchment DC04 is ~150 L/s, but stream flows regularly drops below 10 L/s, based on this groundwater inflows are assumed to be <10 L/s (GHD WBM)

concentration of arsenic was elevated (~0.5 g/m^3). The concentration of arsenic decreased over a 4-5 year period to 0.2 g/m^3 (Golder, 2014). This is interpreted to reflect the transition from groundwater dominated to a surface water dominated lake and the rapid weathering of relict arsenic minerals in the pit wall. It is likely that a similar process will occur in the proposed Deepdell North Pit Lake prior to any discharge to groundwater.

9. S42 STAFF RECOMMENDING REPORT

9.1 I have read the Hearings report issued by the ORC and associated draft consents. With regards to groundwater aspects, the technical review undertaken by Peter Cochrane agrees with the conclusions of my assessment with regards to groundwater levels and groundwater quality.

9.2 Mr Cochrane's report discusses the potential impact of reduced groundwater inflows to Deepdell Creek, but considers that any potential impact would be mitigated by the proposed discharge of flows from Camp Creek Dam.

10. MATTERS RAISED IN SUBMISSIONS

10.1 I have reviewed the submissions that relate to my evidence.

10.2 The Kā Rūnaka submission notes that *Wai Māori in the Project area may be negatively affected by excavation of the pit results in decreased surface and subsurface flow.* My assessment indicates that Deepdell Creek is outside of the zone of groundwater drawdown impact and at a lower elevation, therefore dewatering of the pit is not expected to impact groundwater levels near the Creek. However, there is the potential of a small reduction in groundwater discharges to the Creek during period of active dewatering and until the pit lake fills to its equilibrium level. I consider that the adaptive management approach is appropriate for the site and is sufficiently flexible for OGLNZ to respond, such as providing supplementary flow from Camp Creek Dam if required.

11. CONCLUSIONS

11.1 In conclusion, I consider that effects of the Project on groundwater levels and groundwater quality will be less than minor. To assess the impact of the proposed dewatering on groundwater levels, it is recommended that monthly monitoring of groundwater levels in DDB01-06 is continued.

Dusk Mains

4 August 2020

References

GHD, 2019. Deepdell North Stage III Project: Receiving Water Quality Analysis. Report prepared for Ocean Gold New Zealand Limited, November 2019.

Golder Associates, 2011. Macraes Phase III Project: Groundwater Contaminant Transport Assesssment – Deepdell Creek, North Branch, Waikouiti River and Murphys Creek Catchment. Report prepared for Oceana Gold (New Zealand) Ltd, April 2011.

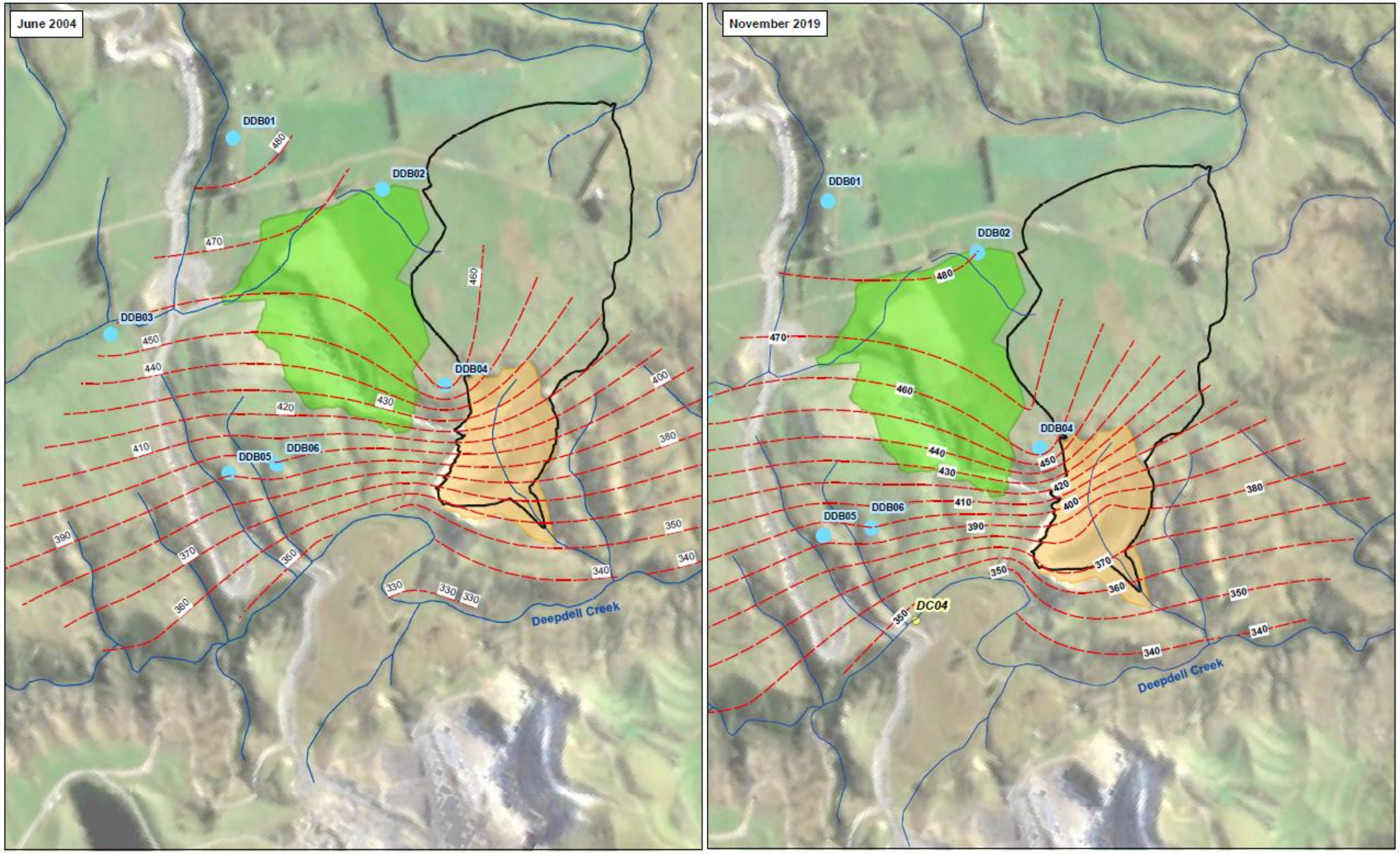
Golder Associates, 2014. Macraes Gold Project: Review of Deepdell South Pit Lake Monitoring Data (Draft). Report prepared for Oceana Gold (New Zealand) Ltd, October 2014.

Marinelli, R. & Niccoli, W., 2000. Simple Analytical Equations for Estimating Ground Water Inflow to a Mine Pit. Ground Water 38 (2) 311-314

Oceana Gold (NZ) Ltd, 2020.. Deepdell North Stage III Project: Assessment of Environmental Effects. 29 January 2020.

Attachment A: Groundwater level plots and groundwater contour map

Figure A1: Groundwater levels in Deepdell monitoring wells



Paper Size A3

0 55 110 220 330 440

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

LEGEND

Groundwater Contours | Monitoring Wells | Deepdell South Pit Backfill

Watercourses | Deepdell North III Pit Boundary | Deepdell East Waste Rock Stack

Oceana Gold Limited
Deepdell North Stage III Project

Groundwater Contours

Job Number	12502848
Revision	A
Date	22 Jan 2020

Figure A-2

138 Victoria Street, Christchurch Central City, Christchurch 8013 T 64 03 378 0900 E chcmail@ghd.com W www.ghd.com

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Created by:dmains

Attachment B: Analytical assessment of Groundwater inflows

Table 11-1 Adopted hydraulic conductivity (from Golder, 2011)

Geological feature	K_x (m/s)	K_y (m/s)	K_z (m/s)
Weathered schist	3.5×10^{-7}	1.0×10^{-6}	2.5×10^{-7}
Moderately weathered schist	1×10^{-7}	2.5×10^{-7}	6.0×10^{-8}
Slightly weathered schist	9.0×10^{-9}	9.0×10^{-9}	1.0×10^{-9}
Unweathered schist	1.0×10^{-9}	5.0×10^{-9}	5.0×10^{-10}
Waste rock	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}

Table B1: Input parameters for analytical assessment at pit closure

Parameter	Units	Value	Comments
W	m/day	0.0015	Based on recharge of 32 mm/yr
K_{h1}	m/s	9.0×10^{-9}	K_h for slightly weathered schist
K_{h2}	m/s	1.0×10^{-9}	K_h for unweathered schist
K_v	m/s	5.0×10^{-10}	K_v for unweathered schist
h_o	m	108	Height from pre mining water table (at northern end) to base of proposed pit
h_p	m	2	Estimated based on observations of other pits
r_p	m	356	Approximate from pit layout design
d	m	2	Assumed depth of water in pit sump

Table B2: Input parameters for analytical assessment at lake level 430 m RL

Parameter	Units	Value	Comments
W	m/day	0.0015	Based on recharge of 32 mm/yr
K_{h1}	m/s	9.0×10^{-9}	K_h for slightly weathered schist
K_{h2}	m/s	1.0×10^{-9}	K_h for unweathered schist
K_v	m/s	5.0×10^{-10}	K_v for unweathered schist
h_o	m	108	Height from pre mining water table (at northern end) to base of proposed pit
h_p	m	58	Lake depth- from base of pit to 430 mRL
r_p	m	356	Approximate from pit layout design
d	m	58	Assumed depth of water in lake

Table B3: Results of analytical assessment

	At closure (pit floor 372 m RL)	Pit lake (lake level 430 m RL)
Drawdown cone radius (m)	580	370
Inflow seepage rate (zone 1 - m^3/day)	98	4.5
Inflow seepage rate (zone 2 - m^3/day)	29	0.1
Inflow seepage rate (total - m^3/day)	127	4.6
Inflow seepage rate (total - L/s)	1.5	0.05

Estimating Groundwater Inflow into a Mine Pit

For conceptualisation purposes
Zone 1 exists above the base of the pit and represents flow to the pit walls
Zone 2 extends from the bottom of the pit downward and considers flow into the pit bottom.
Analytical models assume that there is no groundwater flow between Zones 1 and 2

Reference
Marinelli, F., and W.L. Niccoli, 2000: Simple Analytical Equations for Estimating Ground Water Inflow to a Mine Pit. Groundwater Vol 38, No.2

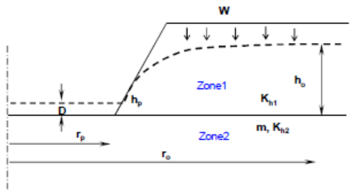
Assumptions
Zone 1
Pit walls are approximated as a right circular cylinder
Groundwater flow is horizontal (Dupuit - Forchheimer approximation is valid)
The static (premining) water table is horizontal
Groundwater flow toward the pit is axially symmetric
Uniform distributed recharge occurs across the site as a result of surface infiltration.
All recharge in the radius of influence is captured by the pit.

$$h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left(r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \left(\frac{r_o^2 - r_p^2}{2}\right)\right)}$$

$$Q_1 = W\pi\left(r_o^2 - r_p^2\right)$$

$$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)\left(h_o - d\right)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$



Zone 2
Hydraulic head is initially uniform throughout the zone. Initial head is equal to the elevation of the initial water table in zone 1
The disk sink has constant hydraulic head equal to the elevation of the pit lake water surface. If the pit is dewatered the disk sink head is equal to the elevation of the pit bottom.
Flow to the disk sink is three dimensional and axially symmetric

If a rectangular pit

Length	800	m
Width	500	m
R_{pit}	356.82	m

Ground level	500	mAHD
Observed WL	20	mBG
	480	mAHD
Base of Pit	372	mAHD
Depth below WL	108	m

Distributed recharge flux (W):	0.00015	m/day	
Horizontal hydraulic conductivity (K_{h1}):	7.70E-04	m/day	
Horizontal hydraulic conductivity (K_{h2}):	8.60E-05	m/day	
Effective pit radius (r_p):	356.82	m	
Saturated thickness at pit wall (h_p):	2	m	(set this to zero to maximise pit inflow)
Radius of influence (r_o):	580	m	
Depth of the pit lake (D):	2	m	
Initial (pre-mining) saturated thickness above base (h):	108	m	

Recharge check: 32 mm/yr

Deepdell North Stage III Project
Estimate of groundwater inflows into Deepdell North Stage III Pit

Groundwater inflow at maximum pit depth (372 mRL)

Step 1 Calculate h_o using an assumed radius of influence

h_o = 107.119 m

Step 2 Iterate to determine the radius of influence until it calibrates the standing water level (h

Step 3 Calculate pit inflow rate from Zone

Effective pit radius (r_p):	356.82	
Radius of influence (r_o):	580	
Q_1 =	98.53	m^3/day

Step 4 Calculate pit inflow rate from Zone :

Horizontal hydraulic conductivity (K_{h2}):	8.60E-05	m/day
Vertical k (kv) factor	2	
Vertical hydraulic conductivity (K_{v2}):	4.30E-05	m/day
Q_2 =	9.12	m^3/day

Step 5 Calculate total pit inflov

Q_t =	107.65	m^3/day		
	107650	L/day	1.25	L/s

Estimating Groundwater Inflow into a Mine Pit

For conceptualisation purposes:
Zone 1 exists above the base of the pit and represents flow to the pit walls
Zone 2 extends from the bottom of the pit downward and considers flow into the pit bottom.
Analytical models assume that there is no groundwater flow between Zones 1 and 2

Reference
Marinelli, F., and W.L. Niccoli, 2000: Simple Analytical Equations for Estimating Ground Water Inflow to a Mine Pit. Groundwater Vol 38, No.2

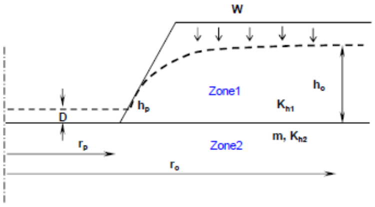
Assumptions
Zone 1
Pit walls are approximated as a right circular cylinder
Groundwater flow is horizontal (Dupuit - Forchheimer approximation is valid)
The static (premining) water table is horizontal
Groundwater flow toward the pit is axially symmetric
Uniform distributed recharge occurs across the site as a result of surface infiltration.
All recharge in the radius of influence is captured by the pit.

$$h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left(r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \left(\frac{r_o^2 - r_p^2}{2}\right)\right)}$$

$$Q_1 = W\pi(r_o^2 - r_p^2)$$

$$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)(h_o - d)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$



Zone 2
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The disk sink has constant hydraulic head equal to the elevation of the pit lake water surface. If the pit is dewatered the disk sink head is equal to the elevation of the pit bottom.
Flow to the disk sink is three dimensional and axially symmetric

If a rectangular pit

Length	800	m
Width	500	m
R_{pit}	356.82	m

Ground level	500	mAHD
Observed WL	20	mBG
	480	mAHD
Base of Pit	372	mAHD
Depth below WL	108	m

Recharge check: 32 mm/yr

Distributed recharge flux (W):	0.00015	m/day
Horizontal hydraulic conductivity (K_{h1}):	7.70E-04	m/day
Horizontal hydraulic conductivity (K_{h2}):	8.60E-05	m/day
Effective pit radius (r_p):	356.82	m
Saturated thickness at pit wall (h_p):	58	m (set this to zero to maximise pit inflow)
Radius of influence (r_o):	370	m
Depth of the pit lake (D):	58	m
Initial (pre-mining) saturated thickness above base (h_o):	108	m

Deepdell North Stage III Project
Estimate of groundwater inflows into Deepdell North Stage III Pit

Groundwater inflow at pit lake level 430 m RL (year 2060)

Step 1 Calculate h_o using an assumed radius of influence

h_o = 58.295 m

Step 2 Iterate to determine the radius of influence until it calibrates the standing water level (h_o)

Step 3 Calculate pit inflow rate from Zone

Effective pit radius (r_p):	356.82	
Radius of influence (r_o):	370	
Q_1 =	4.51	m^3/day

Step 4 Calculate pit inflow rate from Zone

Horizontal hydraulic conductivity (K_{h2}):	8.60E-05	m/day
Vertical k (kv) factor	2	
Vertical hydraulic conductivity (K_{v2}):	4.30E-05	m/day
Q_2 =	0.03	m^3/day

Step 5 Calculate total pit inflow

Q_t =	4.54	m^3/day		
	4540	L/day	0.05	L/s