Before the Hearing Commissioners
Appointed by the Grey District Council
and West Coast Regional Council

Under	the Resource Management Act 1991
In the matter of	Resource consent applications by TiGa Minerals and Metals Ltd to establish and operate a mineral sands mine on State Highway 6, Barrytown (RC-2023-0046; LUN3154/23)

Supplementary Evidence of Jens Haaye Rekker (Hydrology & Hydrogeology)

7 February 2024

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Statement of Supplementary Evidence

1 My full name is Jens Haaye Rekker, I am principal hydrogeologist at Kōmanawa Solutions.

2 I am contributing technical, groundwater and science information to inform this Hearing at the request of TiGa Minerals and Metals Ltd (**TiGa MM**). I have previously provided a Statement of Evidence dated 19 January 2024. My qualifications and experience are set out in that statement of evidence.

3 I repeat the confirmation given in that statement that I have read and agree to comply with the Code of Conduct for Expert Witnesses in the Environment Court.

Supplementary Evidence Arising from Hearing Questions (Homework)

4 I was asked for supplementary responses on the following topics

(a) Dewatering – Recharge systems used elsewhere in the country or the world that utilise infiltration / injection or artificial recharge (Orange County mentioned in hearing).

(b) Confirmation of the sites of highest and lowest pit pond pumping.

(c) Sensitivity analysis of the 20:80 shallow – deep groundwater mixing ratio.

Dewatering - Recharge Systems with parallels to the mitigation proposed for Application Site

5 In response to a question from the Commissioner regarding national or international examples of infiltration or injection mitigation of mining projects, I responded with the following examples –

(a) Infiltration of 580 L/s of treated mine water into the Earnscleugh Aquifer, Central Otago,

(b) Infiltration of construction dewatering and open loop groundwater heat pump systems at University of Canterbury, Ilam Campus,

(c) Injection wells used to create a curtain of freshwater recharge across the Talbert Gap on the Pacific coast margin of the Orange County groundwater basin, California,

Earnscleugh

6 L & M Mining (trading as Mintago Investments Ltd) undertook the mining of alluvial gold resources amongst the Earnscleugh outwash terrace from 2009 to 2016, resulting in the pumping of groundwater from the travelling pit at rates up to 900 L/s. The pumped mine water was treated by settlement in four settling ponds prior to

infiltration back into the Earnscleugh Aquifer. Four primary and settling ponds extended over 1.4 hectares (ha) to remove suspended solids, while most infiltration occurred within a 0.2 ha infiltration basin, as illustrated in the aerial photograph of the ponds below:

7 In 2014, dewatering pumping of approximately 580 L/s was directed into the infiltration basin excavated into coarse sandy gravel outwash with a mean overall infiltration rate of 3,000 millimetres per day[1]. This replenished the Earnscleugh Aquifer for the benefit of orchardists and domestic water supplies, while also buffering the depletion of flow in the lower Fraser River, which was in contact with the water table and a receptor for aquifer seepage.

8 The Earnscleugh practices were in line with the broad outlines of a review of the use of Managed Aquifer Recharge in mining[2]. Managed Aquifer Recharge has been and continues to be activity employed in water management and environmental mitigation in mineral projects across the world, but particularly win developed

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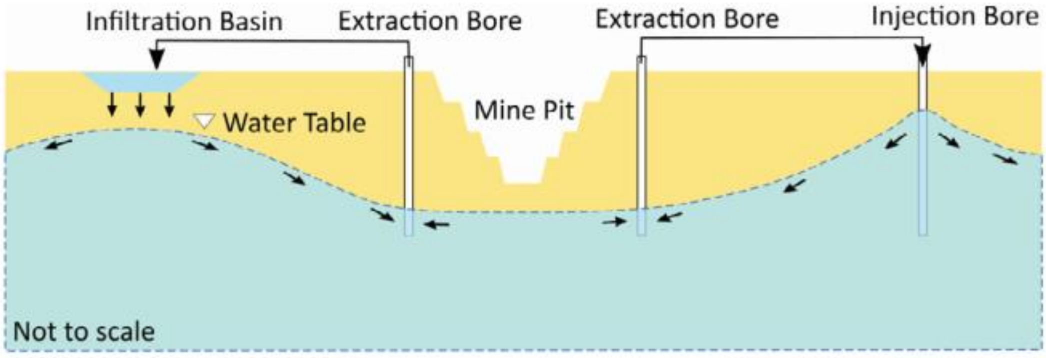
[1] Golder Associates NZ Ltd. 2014. Earnscleugh Mine, Central Otago – Resource Consent Application; Assessment of Groundwater Effects. Prepared for Mintago Investments Ltd, Golder Associates Technical Report No. 138410604-001-R-Rev4, 78 pages including appendices, Christchurch, NZ.

[2] Sloan, S; Cook, P G; and Wallis, I. 2023. Managed Aquifer Recharge in Mining: A Review. Groundwater Journal, Review Paper, Vol. 61, No. 3, May-June 2023, pages 305-317) https://ngwa.onlinelibrary.wiley.com/doi/epdf/10.1111/gwat.13311

nations where more expedient but environmentally damaging practices are discouraged.

9 Managed Aquifer Recharge in mining settings tends to be coupled with dewatering taking groundwater out of the aquifer, while replacing the same water with either infiltration systems or reinjection bores / wells as shown in the schematic below:



Schematic of MAR types used in mining.

10 The Sloan *et al* (2023) review of Managed Aquifer Recharge and Aquifer Re-Injection Schemes in mining applications summarises 27 such systems or advanced trials in seven countries, primarily Australia and the USA. The scheme types are categorised as infiltration ponds (IP), bore injection (BI)reservoir infiltration (RI), rapid infiltration basins (RIB), or river basins (RB).

11 The infiltration trenches would be categorised IP, while the injection wells would be BI. The Canoe Creek Infiltration Basin would be categorised as RIB.

University of Canterbury

12 University of Canterbury and construction engineering contractors working with the dewatering of basements under multistorey buildings designed reinjection in preference to surface water discharge. This included an initial trial bore and eight additional operations bore connected in a reinjection network to receive dewatering surplus groundwater[3].

13 Earlier installed open loop groundwater heat pump system water was also able to utilise this injection system.

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[3] Lough, H; Brough, A; Oudshoorn, R; and Moloney, P. Reinjection Of Construction Dewatering Water at the University of Canterbury. Proceedings of the Water NZ 2010 Conference, Christchurch, 22-24 September 2010. https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=1137

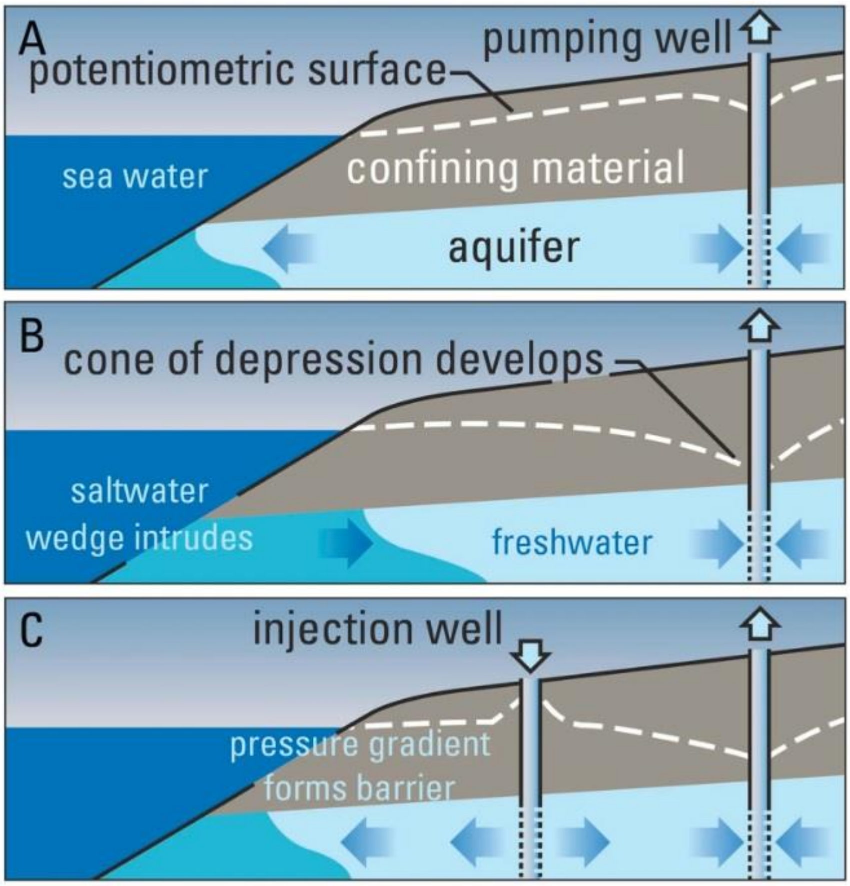
Orange County, California

14 Orange County of California, which lies within the Santa Ana River Basin has confronted increasing challenges in obtaining sufficient domestic, commercial and industrial water supply at volumes that began to outstrip the natural water balance of the basin.

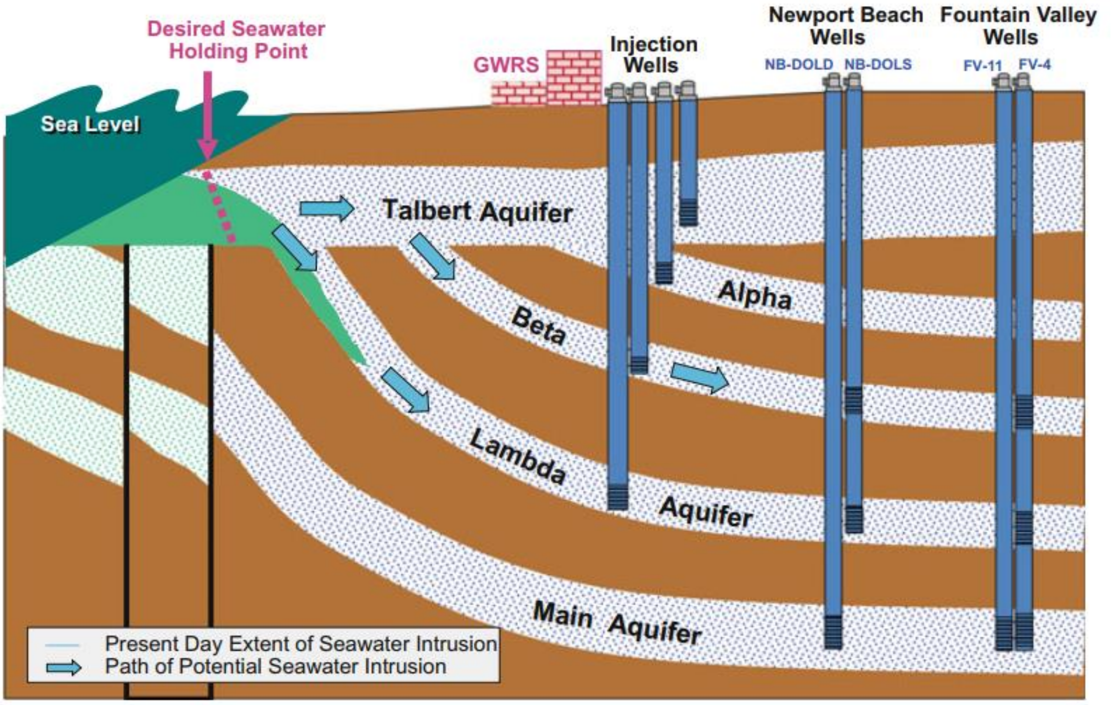
15 Among the challenges is the entry of seawater through the groundwater basin contact with the Pacific Ocean as a result of reversal of groundwater gradients consequent to groundwater pumping exceeding replenishment.

16 A number of measures were taken by authorities in the Santa Ana basin, chief among whom was the Orange County Water District. These measures include importing out-of-basin water, renovation of wastewater to make it fit as recharge water, infiltration basins and injection wells to lift water tables and deeper groundwater pressures.

17 Among the measures relevant to this discussion were reinjection wells arranged across the Talbert Gap to provide a hydraulic curtain in opposition to seawater intrusion. As this hydraulic curtain became established and the landward replenishment topped up the groundwater pressure state, groundwater pumping could be increased to meet water demand. The principle as a schematic cross-section is shown below:



18 A basin-wide cross-section of the measures is provided shown as follows[4]:



Schematic north-south cross section of the Talbert Gap salinity barrier section. Highly treated wastewater is injected into four separate aquifers. *Source* Orange County Water District

19 The line of injection wells across the Talbert Gap imparts a pressure curtain as a flow hydraulic divide pushing groundwater towards the coastline and landwards into the basin. The pressure curtain becomes a means of minimising the movement of coastline groundwater into the Santa Ana groundwater basin, thus substantially reducing the risk of seawater intrusion through aquifers[5].

20 The analogue of preventing saline intrusion applies equally to the proposed mine panels in proximity to Canoe Creek Lagoon, since reducing the extent to which the lagoon loses replenishing groundwater during mining activities is beneficial to the lagoon water balance or levels.

Examples Specific to Sand & Gravel, or Quarrying

21 “Techniques and developments in quarry and surface mine dewatering” by Martin Preene traverses the whole subject matter indicated in the title, including the artificial recharge of water produced in dewatering[6].

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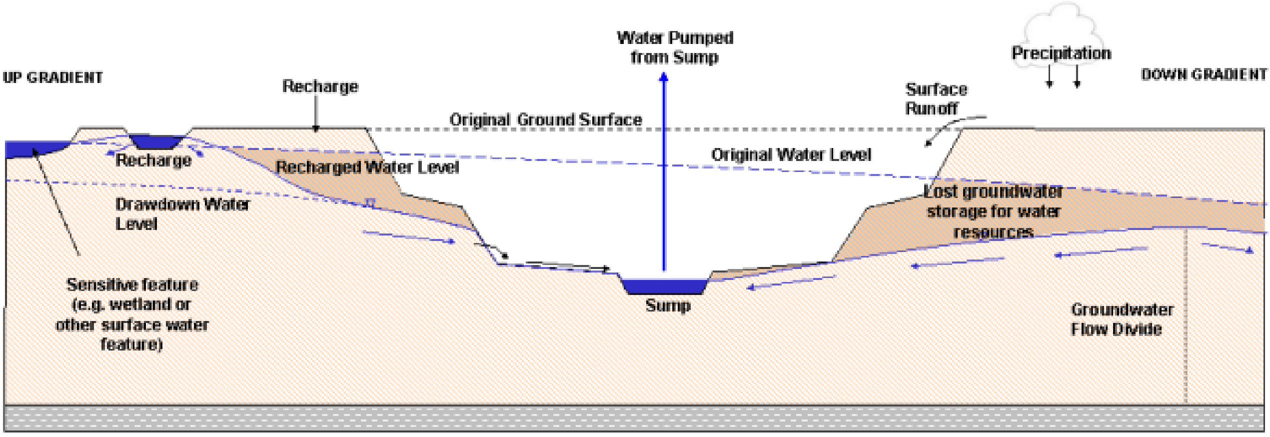
[4] GWRS = Groundwater Replenishment System, which refers to wastewater renovation and reuse.

[5] Maliva, R G. 2019. *Anthropogenic Aquifer Recharge*. Springer Hydrogeology. Pages 683-715. https://link.springer.com/chapter/10.1007/978-3-030-11084-0_21#citeas

[6] Preene, M. 2015. Techniques and Developments in Quarry and Surface Mine Dewatering. Pp. 194-206 in Hunger, E. and Brown, T.J. (Eds.) Proceedings of the 18th Extractive Industry Geology Conference 2014 and technical meeting 2015, EIG Conferences Ltd, 250pp

22 “Mitigating the Impacts of Quarry Dewatering in Sand and Gravel Deposits Volume 1: Research Overview and Good Practice Guidance” by Goodwin, Thompson, Huxley, Gill, and Buckley (2007) includes detail on infiltration and water injection[7]. The schematic cross-section below shows a representation of infiltration mitigation strategies (Figure 3.3. of Goodwin et al, 2007).



23 “The use of recharge trenches to maintain groundwater levels” by Cliff and Smart (2015) covers the utilisation of infiltration trenches. The trenches are located to provide minimisation of adverse effects from dewatering[8].

24 The above papers and book sections provide confirmation that the minimisation and remedies for the projected effects of mine activity dewatering are widely used in similar roles throughout the world.

Sites of Highest and Lowest Pit Pond Pumping

25 The Commissioners asked about the locations of highest and lowest pit pond pumping from the point of view of the sites where the greater or less dewatering effect might be exerted.

26 This question was better approached by interrogating the groundwater flow model used to predict unmitigated pit pond pumping utilising the latest conceptual model and associated hydro-stratigraphic settings.

27 The annotated figure below provides an approximated indication of the pit pond pumping rate to achieve the target pond water level:

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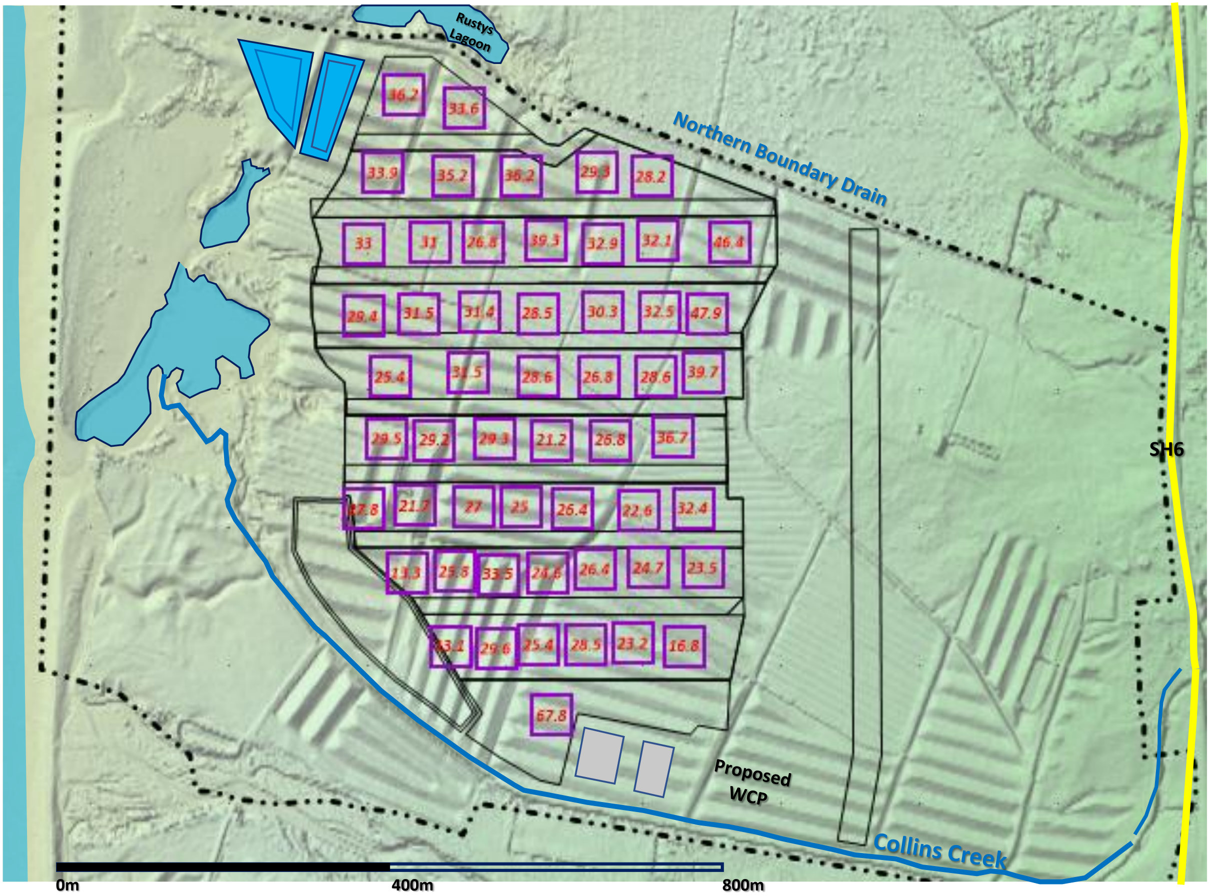
[7] Goodwin, A., Thompson, A., Huxley, C.L., Gill, T.S. and Buckley, C. (2007): Mitigating the Impacts of Dewatering in Sand and Gravel Deposits. Volume 1: Research Overview and Good Practice Guidance. Report to the Minerals Industry Research Organisation and the Department of the Environment, Food and Rural Affairs. Capita Symonds Ltd, East Grinstead.

[8] Cliff, M. I., & Smart, P. C. 1998. The use of recharge trenches to maintain groundwater levels. Quarterly Journal of Engineering Geology and Hydrogeology, 31(2), 137–145. doi:10.1144/gsl.qjeg.1998.031.p2.09
10.1144/gsl.qjeg.1998.031.p2.09



28 Spatial varying inflow rates in litres per second (L/s), are annotated in red italicised script within purple squares.

29 The variation in the rates of pit pond pumping above are related to an interplay between the following factors:

(a) The depth or elevation of the target water level (deeper tends to induce more inflow),

(b) The hydraulic conductivity of the shallow mineral sand layer directly surrounding the pit location, which is variable in the groundwater model, and

(c) To a lesser extent, the proximity of surrounding water bodies.

30 Each square represents approximately 35 days of mining activity.

31 Lower inflow rates are generally found in the initial, southerly mine panels. The consistently higher inflow rates are generally found in the mine panels 6 to 10, in the north and west of the mining area.

32 The 67.8 L/s inflow rate for mine panel 9 (adjacent to Pond 2 and the WCP) is across a larger area of the deposit and extracted over a 35 day period, which might not be actually extracted over such a short period. Therefore the rate is likely to be

conservatively high. However, a schedule of the mine panel 9 was not available at the time of model simulation.

33 Apart from the uncertain panel 9, the highest pit pond pumping was simulated as 47.9 L/s at a location in the north west of the mining area. Relatively high rates of 33.6 to 36.2 L/s were simulated in proximity to Rusty’s Pond.

34 The lowest pumping rate was simulated at the starter pit with a simulated inflow of 13.1 L/s. The end station on mine panel 1 was also simulated as 16.8 L/s.

Sensitivity analysis of the 20:80 shallow – deep groundwater mixing ratio

35 The current shallow – deep mixing model considers a 20:80 ratio

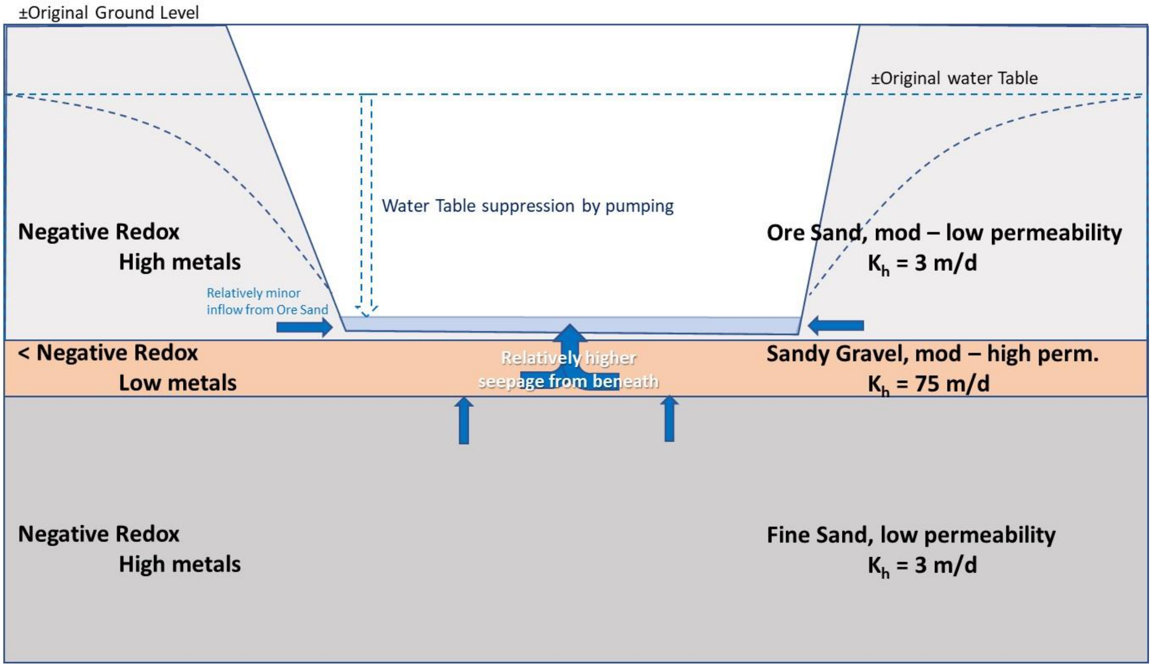
36 A means of expressing the proportions of contribution is to consider dissolved cooper and zinc concentrations:

Table 1: Summary of Calculated Metals Concentrations considering a 20:80 Split for Two Layers

	Mean Gw. Concentration (g/m^3)			**Combined Mass**	**Combined Concentration**	**ANZG 95 Guideline**
	Shallow sand	**Gravel**		**(g/d)**	**(g/m^3)**	**(g/m^3)**
Copper	0.0024	0.0005		3.8	0.0009	0.0014
Zinc	0.0421	0.0018		42.6	**0.0100**	0.0080

Note: Gw. = Groundwater. * Injection well IW-01 copper concentration equalled <0.0005 g/m^3, so in the interests of conservatism the concentration in the calculations was specified as 0.0005 g/m^3 rather than 0 g/m^3. **Bold** indicates the combined concentration exceeds the relevant ANZG 95 guideline.

37 I considered a scenario where the ratio of more concentrated to less concentrated layering was set at 30:70. This scenario in fact considers a three layer delineation of hydro-stratigraphy and associated hydro-chemistry, as illustrated in the figure below:



38 The proportions of permeability and redox state driven influences on hydro-chemistry (particularly for dissolved metals), result in the majority of pit inflow arising from the sandy gravel layer beneath the base of the mine pit.

39 The less negative redox (oxidation – reduction potential or ORP) and consequent lower metals concentrations groundwater within the sandy gravel layer would have a dominating influence on the mixed pit water reporting to the sump pump(s) due to its higher hydraulic conductivity.

40 With the assistance of the groundwater model simulation's water balance outputs, the split of groundwater reporting to the pumps would be estimated as follows:

(a) Shallow (ore sand) (20% of total pumping)

(b) Deep (sandy gravel) (70% of total pumping)

(c) Deep (fine sand) (10% of total pumping)

41 The higher concentrations in the deep fine sand would tend to counteract the dilution by the sandy gravel layer, but the deep fine sand seepage rate contribution is relatively minor. The assumption is made that the deep fine sand groundwater has metals concentration the same as the mean concentrations for the shallow sand.

42 This effectively results in a shallow – deep mixing ratio of 30:70, as a 20:70:10 ratio of shallow sand – sandy gravel – deep sand. The resulting metal masses and concentrations area shown in the table columns below:

Table 2: Summary of Calculated Metals Concentrations considering a 20:70:10 Split for Three Layers

	Mean Gw. Concentration (g/m^3)			Combined Mass	Combined Concentration	ANZG 95 Guideline
	Shallow sand	Gravel	Deep sand	(g/d)	(g/m^3)	(g/m^3)
Copper	0.0024	0.0005*	0.0024	4.62	0.0011	0.0014
Zinc	0.0421	0.0018	0.0421	60.0	**0.0140**	0.0080

Note: Gw. = Groundwater. * Injection well IW-01 copper concentration equalled <0.0005 g/m^3, so in the interests of conservatism the concentration in the calculations was specified as 0.0005 g/m^3 rather than 0 g/m^3. **Bold** indicates the combined concentration exceeds the relevant ANZG 95 guideline.

43 A comparison of these models is provided in Table 3, below:

Table 3: Comparison of Mixing Ratio Resulting Concentrations listed in Table 1 and Table 2

	20:80 Ratio, 2 Layers	20:70:10 Ratio, 3-Layers (effectively 30:70 Ratio)	Percentage Change	Increase or Decrease
	(g/m^3)	(g/m^3)		
Copper	0.0008	0.0011	27%	Increase
Zinc	0.0080	0.0140	43%	Increase

44 Comparing a two-layer mixing model with equal proportions of shallow and deep contribution (50:50), to the original 20:80 mixing ratio within the statement of evidence provides the following comparison in Table 4:

Table 4: Comparing a two-layer mixing model of the original 20:80 mixing ratio to a 50:50 ratio

	20:80 Ratio, 2 Layers	50:50 Ratio, 2 Layers	Percentage Change	Increase or Decrease
	(g/m^3)	(g/m^3)		
Copper	0.0009	0.0015	39%	Increase
Zinc	0.0100	0.0220	55%	Increase

45 The sensitivity of the dissolved metals concentrations combined at the pit pond and introduced into the mine water is proportional to the difference in concentrations and the changes in the mixing ratio.

46 While the sensitivity analysis is helpful in evaluating the impact on combined concentrations, the analysis does not affect my opinion based on field data of the judgements made in nominating the 20:80 mixing ratio in the first place.