WGA

TECHNICAL MEMORANDUM

PROJECT NO.: WGA210764
DATE: 4 SEPTEMBER 2023

COMPANY NAME	West Coast Regional Council
ATTENTION	Tony Ridge
SUBJECT	Review of TiGa resource consent application – Barrytown Mine

1. INTRODUCTION

The West Coast Regional Council (WCRC) has received an application by TiGa Minerals and Metals Limited for resource consents authorising the development of a mineral sands mining operation at Barrytown. A range of technical documents have been lodged with the WCRC in support of the application.

The WCRC commissioned Wallbridge Gilbert Aztec (WGA) to review the technical documents lodged in support of the application. The review by WGA covered the hydrological and hydrogeological aspects of the application. Ecological, geotechnical, water quality and other aspects of the application were considered only in regard to identifying aspects of the site and surrounding area that may be impacted by changes in the hydrological system. The WGA review was documented in a memorandum to WCRC dated 4 July 2023[1].

A series of requests for information were raised in the WGA (2023) memorandum. Responses to these requests have been provided by the applicant. WGA's review of the responses is provided below. This document should be read in conjunction with the earlier memorandum (WGA 2023). The objective of this review is to determine if there are any remaining gaps in technical information provided by the applicant in support of the resource consent application.

This memorandum also takes into account information provided:

1. Verbally and through screen sharing on a Teams call between Tony Ridge (WCRC), Brett Sinclair (WGA) and Jens Rekker (Kōmanawa) on 19th July 2023.
2. Verbally through a telephone discussion with Zeb Etheridge (Kōmanawa) in preparation for the above conference call.

2. TABLE OF RESPONSES

A table (Table A1) presenting a list of the requested information and a summary of the applicant's responses is provided in Appendix A to this memorandum. Where the information provided in response to the request is sufficient to address the gap in information, this is indicated in Table A1 and no further comment is made in the body of this document. If the information provided is insufficient to address the request, or a further need for clarification arises in response to the information provided, this is addressed in more detail in the body of this memorandum.

[1] WGA 2023. Review of TiGa resource consent application – Barrytown Mine. Technical memorandum from Wallbridge Gilbert Aztec to WCRC. WGA document number WGA211239-MM-HG-0001. Dated 4 July 2023.

3. HYDROLOGICAL REPORT (KŌMANAWA 2023A) REVIEW

The main body of the hydrological report is reviewed in Section 3.1 below. The appendices to the hydrological report reviewed separately in Sections **Error! Reference source not found.** and **Error! Reference source not found.** below.

3.1 Main report

Section 2.6.7.2 presents calculations of groundwater volumetric flow rates and velocities under the proposed mine site. calculations presented use commonly accepted equations and the results are accepted. However, the calculation ignores the groundwater flows in the gravel bed underlying the mineral sand deposit. This gravel bed is hydraulically linked to the mineral sands, as demonstrated by the pumping test on PB-1. Any operation to dewater the mineral sands during mining will automatically result in partial depressurisation of the underlying gravel bed, with water discharging from this bed into the overlying pit.

The groundwater throughflow calculations have been updated in the response to s92 Request 8 above. In summary, the mineral sand aquifer has a throughflow of between approximately 2 L/s and 13 L/s, depending on the hydraulic conductivity applied to the calculation. The basal gravel has a throughflow of between approximately 13 L/s and 22 L/s, depending on the hydraulic conductivity applied to the calculation.

The piezometric map provided in response to s92 Request 7 suggests some 50% of the mineral sands groundwater through-flow under the site reports to Canoe Creek lagoon and 50% to either Northern Boundary Drain, Rusty's Lagoon or another coastal lagoon further to the northwest. The proposed groundwater effects management measures would be appropriate irrespective of the eventual groundwater discharge areas.

The $MALF_{7d}$ for Collins Creek as provided in Table 6 is 16 L/s. The continuous monitoring period documented in the report was from May to November 2022, which excludes a summer period. The lowest recorded flow during this period at the upstream monitoring site was 25 L/s. Therefore, the $MALF_{7d}$ for Collins Creek documented in Table 6, which was not based on flow monitoring in Collins Creek, appears reasonable.

The unmitigated depletion rates for Collins Creek provided in response to questions listed in Appendix A could effectively cause Collins Creek to fall dry during several periods over the first half of the mine life. Therefore, the effective operation and monitoring of the proposed groundwater recharge system consisting of infiltration and injection processes is a key factor in minimising the potential effects on Collins Creek. The same is expected to apply to effects on the Northern Boundary Drain and water dependent ecosystems beyond that drain.

The depletion effects on Canoe Creek Lagoon are effectively self-managed as water not used to manage groundwater drawdown along the northern and southern edges of the mine is to be discharged, following treatment, to the lagoon. The key question with regards the effects on Canoe Creek Lagoon therefore becomes one of receiving water quality monitoring and management.

4. GEOTECHNICAL REPORT (RDCL 2023) REVIEW

The geotechnical report is an important component of this review because a key factor in water management for the proposed development is the defined setback of the pit rim from nearby surface water bodies. Any failure of the pit wall needs to be contained within this setback. Furthermore, any failure of the pit wall should not lead to enhanced seepage from the adjacent surface water bodies and therefore exacerbated failure risks for the remaining pit wall.

The first three sections of the geotechnical report are introductory and set the background for the report.

Section 4 of the report describes the geological setting in generic terms, which is acceptable for the purposes of the geotechnical report. In Section 4.2 it is stated that "*groundwater levels are assumed 1 to 2m below current ground level.*" Depths to groundwater vary across the site and in response to weather patterns.

1. **Please clarify if there may be any impacts of a shallower groundwater table on the proposed 20 m offset (considered further below) and what the potential impacts are.** The concern is whether a shallower groundwater table would change the cut slope stability characteristics to the extent that a 20 m offset is insufficient to accommodate any potential slope failures.

RDCL Response

The stability model currently assumes a groundwater level 1m below ground. A shallower groundwater table will not significantly change the cut slope stability.

Additionally, stability (and deformation) has also been checked against a Maximum Credible Earthquake, assuming a 1m deep groundwater. This is a very conservative condition unlikely to be encountered due to the short time the pit perimeter is exposed in the mining cycle.

Thank you. This response is accepted, bearing in mind the static groundwater table is simulated as being at a depth of 1 m below ground up to the edge of the simulated pit wall.

Section 5 of the report provides a high-level summary of the mining method and Section 6 summarises the tailings management process.

In Section 6.1, the report states that the tailings "are 'clean' with no toxic potential", supporting a subsequent statement that "liners for containment are not required". The source of this information is not provided. However, this statement is not necessarily consistent with the water quality information presented in the Hydrology report. No request for further information is presented with regards to these statements as guidance on water quality is more appropriately provided by the authors of the Hydrology report.

2. In Section 6.1 of the report it states "*Freeboard always > 3m to ground level from final tailings surface as ~30% of the material is extracted as ore.*" **Please clarify if the freeboard referred to is measured from the original ground level or the final proposed ground level.**

RDCL Response

Freeboard of >3m is with reference to the original ground level.

Freeboard is based on the assumption that 30% of the volume of material will be extracted as "ore". This means that there will always be a deficit in the volume of the backfill (tailings), resulting in freeboard.

We understand that extraction is now more likely ~20%. At 10m depth of mining, freeboard will be ~2m, at 15m freeboard will be 3m.

Thank you. No further information required.

Section 7 of the report summarises the geotechnical assessment of the mining operation. Review of the geotechnical components of the mine is outside the scope of this memorandum and is outside the reviewer's area of expertise. The groundwater component of work has been considered in this review.

The hydraulic conductivity values presented in Table 2 (Section 7.2 of the report) are not fully consistent with those derived from on-site testing and documented in the hydrology report. The mineral sand hydraulic conductivity is consistent between the two reports. However, the gravel underlying the mineral sand is characterised by a hydraulic conductivity of 1×10^{-7} m/s in the geotechnical report compared to approximately 1×10^{-3} m/s in the hydrology report. The implied 'underdrainage' of the mineral sands in the pit wall during the mining operation would suggest potentially high inflow rates around the toe of the pit wall. It is not clear that this feature of the groundwater system during the mining operation has been taken into account in the slope stability assessment.

3. **Please confirm that the hydraulic conductivity values presented in Table 2 have been applied in the slope stability analyses documented in Appendix B of the same report**.

RDCL Response

Hydraulic Conductivity of Barren Gravel Base has been changed to 1×10^{-3} m/s to match the hydrogeological model.

- Table 2 in Section 7.2 will be updated accordingly.
- Slope Stability models in Appendix B will also be updated accordingly

Adjusted outputs attached for information.

Thank you. No further information required.

4. **If groundwater flows are simulated in the pit wall stability modelling, does this change the model outcomes with respect to the area potentially affected by ground failure?**

RDCL Response

No. Because of the high permeability of the insitu materials, drawdown is expected behind the pit crest in any case, but drawdown has not been modelled and groundwater levels in the model have been kept elevated (1m below surface) as an additional safety check.

Groundwater flow has been modelled in the pit wall as per previous question with acceptable results.

To be clear, stability models work on groundwater pressures to calculate effective strength parameters. Effective strength of geotechnical materials is reduced by elevated groundwater pressures and levels, generally reducing resistance to failure and Factor of Safety or deformation.

Groundwater flow modelling produces a drawdown curve due to drainage which may be extensive (high permeability) or steep (low permeability), which impacts distribution of pore pressures.

The response is understood, thank you. We note that groundwater infiltration and injection systems will be required to be installed within 20 m of the pit wall, along the outer edges of the proposed mining area. The proposed infiltration trenches are unlikely to result in the shallow groundwater table rising substantially above that provided for in the SLIDE models. However, injection wells are also proposed, with these screened in the sandy gravels at the base of the mineralised sands or in the deeper basal gravel.

The concern is that the operational injection pressures for these bores and consequently in the immediately surrounding aquifer may be above ground level and the associated injection flows may cause instability at the toe of the pit wall. The injection pressures need to more than offset the near-pit drawdown caused by the opencast pit excavation, otherwise the intended drawdown mitigating effect is not achieved. Unless numerous injection wells are used, it is possible that the injection pressures may need to be a few metres above ground level. This expectation is based on the s92 RFI responses provided by Kōmanawa.

It appears that there could be a significant amount of mine water management infrastructure installed within 20 m of the pit wall. Hence the concern regarding the pit wall stability when these injection systems are operating. This links to Question 8 below.

No further request for information with regards to this question.

Section 8 of the report focuses on pit wall stability and tailings management at the site.

Section 8.2.2 documents the assessment of the inferred permeability of the deposited tailings. The anticipated range in hydraulic conductivity is from 1 x 10^{-4} to 1 x 10^{-7} m/s. The assessment took into account the grain size distribution for the ore sands, a methodology for hydraulic conductivity analysis based on grain size distributions and the expected mixing of waste streams during deposition in the operational pit. The outcomes from this analysis and the expected hydraulic behaviour of the deposited wastes are reasonable. The outcomes are subject to a degree of uncertainty, due to uncertainty regarding the mixing of deposited tailings with fines separated during the initial ore processing stage. The key impacts of this uncertainty in terms of geotechnical behaviour of the stored tailings relate to drainage times and material workability. These are principally operational matters that may impact site rehabilitation procedures rather than environmental effects. Therefore, the uncertainty regarding the permeability and consolidation behaviour of the stored wastes as described in this report is acceptable at this stage of the project. Adjustments to mining and waste storage processes can reasonably be addressed through the Water Management Plan (Kōmanawa 2023b).

Section 8.4 of the report addresses pit wall stability. Earlier in the report, in Section 8.1, the report states: "*The proposed initial pit slope will be excavated at 50° - 65° to a depth up to 14 m below original ground surface*." The pit wall is expected to be left unbuttressed by the placement of tailings for periods of days to weeks, which is a reasonable expectation given the proposed mining methodology. In Section 8.4.1 the report states "*The open pit is expected to be stable for the proposed configuration with no substantial ground displacement due to instability expected > 5m from the pit crest based on this study*." This conclusion is important in that it presumably supports the designation of the 20 m offset between the pit rim and any sensitive surface water features.

5. **Please also confirm the aquifer parameters applied to the units simulated in the stability analysis. If the hydraulic conductivity applied to the basal gravel unit is not in accordance with the values provided in the Hydrology report, please adjust the value applied in the geotechnical model accordingly.**

RDCL Response

Hydraulic Conductivity of Barren Gravel Base updated to 1x10-3 m/s and applied to stability analysis (attached).

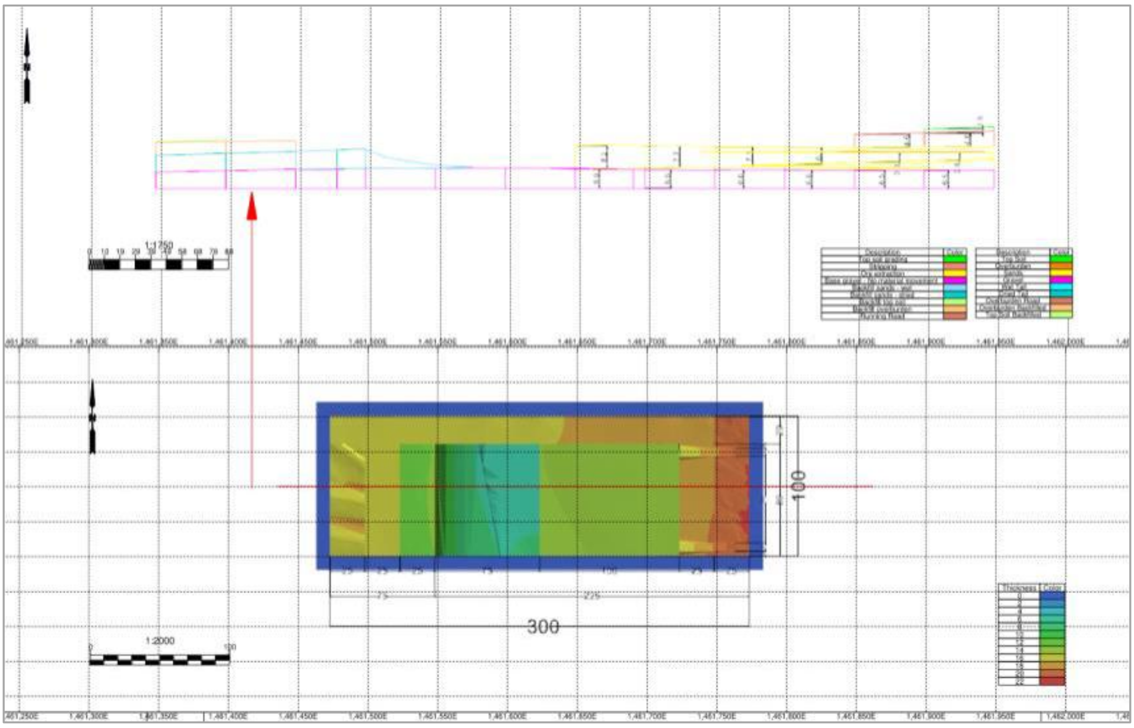
Final report will include revised results.

Thank you. No further information required.

6. The slope stability models documented in Appendix B indicate mineral sand extraction will extend to the top of the basal gravel layer. The basal gravel layer constitutes a more permeable aquifer that the overlying mineral sands, according to the Hydrology report. Additionally, it is not clear from either the Hydrology report or the Geotechnical report whether mineral sand extraction is to extend to the top of the basal gravel layer. **Please confirm the slope stability models correctly represent the layout of the pit walls according to the current mine plan. If the model layout does not provide an appropriate conceptual representation of a pit wall under the current mine plan, please adjust the models to more accurately represent the of the pit shell layout with respect to the geological units simulated.**

RDCL Response

The slope stability models correctly represent the layout of the pit walls and sand extraction is extended to the top of the base layer in accordance with drawings from Palaris (as seen below):



Thank you. No further information required.

7. The slope stability models documented in Appendix B to the report appear to support the above statements with respect to the pit slope stability. However, these models also appear to have been run with static groundwater levels applied, without groundwater flows being simulated. The concern is that a setback of 20 m may not be sufficient to ensure adjacent streams and drains are not impacted by ground settlement, with associated potential development of preferred seepage paths into the planned opencast pit and possible piping along any seepage paths. **Please clarify if groundwater seepage flows have been taken into account in the slope stability analysis. If groundwater flows have not been taken into account, please run the models with seepage flows simulated to confirm the above statement regarding the limit of expected ground stability.**

RDCL Response

Models in RDCL report referenced R-220986-01 issued 13 April 2023 analysed static water only.

Slide Models will be added to incorporate Groundwater flow analysis:

- Groundwater seepage flows have been taken into account.
- Stability Analysis reanalysed under these conditions.

From a geotechnical perspective, this is all the same question as it relates to Section 7.2, Table 2 and Appendix B.

The updated models (Attached) will be updated in the final (revised report). Results of the stability analysis under groundwater analysis show the 20m offset is considered sufficient to protect the adjacent wetlands.

Thank you. No further request for information although it would be worth documenting the model throughflow with several decimal places as the figures indicate a flow of zero.

8. The slope stability models do not take into account the proposed reinjection of water pumped from the operational pit into the same aquifer to manage potential impacts on Collins Creek and the Northern Boundary Drain, as described in the Hydrological report (Kōmanawa 2023a). The Water Management Plan indicates reinjection bores are to be installed between the open pit and the adjacent surface water bodies. This reinjection may require injection heads and the development of groundwater heads around the injection bores that exceed ground level. **Please run the slope stability models with the groundwater pressure effects of these reinjection bores taken into account and provide the model outcomes to confirm the stability of the proposed cut slopes and the appropriateness of the proposed setback.**

RDCL Response

As previously, groundwater levels have been modelled at 1m below surface.

We do not anticipate artesian pressures (which we infer is the question) to develop as a result of injection due to the permeability of the existing materials and tailings.

Please note that the mine water reinjection systems proposed by Kōmanawa may need to be operated with positive injection pressures without impacting on the pit wall stability.

Based on the s92 RFI responses provided by Kōmanawa, our concern is that the operational injection pressures for the proposed reinjection bores, and consequently in the immediately surrounding aquifer, may need to be a few metres above ground level. The injection pressures need to more than offset the near-pit drawdown caused by the opencast pit excavation, otherwise the intended drawdown mitigating effect is not achieved. The injection pressures required to achieve the intended mitigation are directly linked to flow rate. To achieve the intended drawdown mitigating effect, there is a balance between the number of injection bores used and the injection pressures applied at each well. Clearly there is an economic reason to minimise the number of injection wells installed. Therefore, the question remains as to what injection pressures can be sustained without leading to pit wall instability.

It appears that there could be a significant amount of mine water management infrastructure installed within 20 m of the pit wall. Hence the concern regarding the pit wall stability when these injection systems are operating.

The report indicates that the slope stability model incorporating the backfilled tailings has tailings placed to a level of 3 m BGL. However, the model images provided in Appendix B of the report suggest tailings placement to a level approximately 7 m BGL. This discrepancy is **advisory only** as the lower level of tailings placement is unlikely to improve the modelled stability of the pit wall.

Section 8.4.2 of the report addresses coastal interaction. In this section of the report there is a statement "*The rehabilitated ground will be made up of hydraulically and mechanically placed tailings overlain by a clay cap placed and compacted by machines including oversize, finished to pasture for dairy use.*" There is no mention of an engineered clay cap as part of the site rehabilitation process in either the Rehabilitation Management Plan (TiGa 2023), the Water Management Plan (Kōmanawa 2023b) or any of the other documents reviewed.

9. **Please clarify if an engineered clay cap to the rehabilitated tailings is planned. If such a cap is planned, please clarify its intended purpose and verify that such a cap can be practically installed on a foundation of tailings backfill.**

RDCL Response

An "engineered clay cap" (taken to infer something like for a landfill) is not planned. The stripped overburden will be placed on the dried tailings as the beach front progresses. The tailings backfill will not be fluid and will drain with time so that equipment can be run on the surface. This is standard operating procedure for this style of mining.

Thank you. No further information required.

Section 9 of the report provides a risk assessment for the tailings storage. This risk assessment appears to have been principally undertaken on the basis that the storage area may be considered as a storage dam. Risks and failure modes have been evaluated on the basis of a potential dam failure. An assessment of this aspect of the project is outside the scope of this review. However, it is noted that the top of the stored tailings is to be at least 3 m BGL. No embankment above the level of the surrounding ground is proposed. Furthermore, mining is to be undertaken in a dewatered pit. Therefore, it seems unlikely that any geotechnical failure in the proposed tailings storage could potentially lead to mine water or tailings being discharged from the operational pit area to the surrounding environment. **No concerns are raised through this review with respect to the contents of Section 9.**

5. REHABILITATION MANAGEMENT PLAN (TIGA 2023)

The rehabilitation management plan has not been reviewed in detail, as it is recently expected that this plan will be adjusted as mining operations progress. Overall, the plan provides appropriately for site rehabilitation in terms of the aspects affecting water management at the site following closure. However, two aspects of the rehabilitation management plan raise implications for the overall review of the hydrological aspects of the proposed mining operation.

The water treatment ponds at the northwestern corner of the mine footprint (Ponds 3 and 4) are shown as having been backfilled and rehabilitated as pasture in Figure 7 of the rehabilitation management plan. The closing and backfilling of these ponds as part of the site rehabilitation was not mentioned in the rehabilitation report.

10. **Please confirm that the planned water treatment ponds are to be backfilled and rehabilitated as pasture following the completion of ore extraction operations. If this is not the case, please clarify the proposed rehabilitation for this area of the site.**

The cross sections showing the current and post mining profiles for the site, as presented in Figures 8, 9 and 10, appear to indicate that the rehabilitated ground surface will be predominantly above the current ground surface. It is not clear if this understanding is correct or an artefact of the alignment of the cross sections presented in these figures. Although the final landform topography is presented in Figure 7, this figure is difficult to understand as contour elevations have not been provided.

11. **Please provide a version of Figure 7 with contours labelled and proposed farm drains identified, to enable a better understanding of the expected final landform.**

12. **Please confirm the bulking factor applied to the mine backfill and verify that there will be sufficient material available at the close of mining operations to refill and rehabilitate the final mine void and the water treatment ponds.**

Section 7 in the Hydrology report (Kōmanawa 2023a) states "*Material from above the water table to the east of the proposed excavation area, where the seasonal high water table is between 1 m and > 3 m deep, will be excavated and transferred to the mined area to replace the heavy mineral concentrate material removed from the site*." This clarifies the situation with respect to availability of material for site rehabilitation. However, the above requests for information have been left in place to ensure there is no uncertainty regarding material availability for site rehabilitation.

> We note a response to one question asked in relation to the geotechnical assessment states "We understand that extraction is now more likely ~20%". It is not clear whether this reduction in ore recovery is incorporated in the current mine rehabilitation plan and reflected in the proposed final landscape design. The questions asked above may have been responded to but the responses have not yet been seen by this reviewer.

6. EROSION AND SEDIMENT CONTROL PLAN (RIDLEY 2023)

The erosion and sediment control plan (ESCP) has been reviewed to confirm that management measures incorporated in the plan are in line with those described in the Hydrology report (Kōmanawa 2023a).

Overall, the ESCP is appropriate for the nature of the proposed mining operation. Management measures with respect to various disturbed surfaces have been presented and are considered appropriate. The treatment of water from disturbed areas is to be addressed through a multi-stage process, with Pond 4 being the ultimate treatment stage for mine water.

Prioritised options for the discharge of treated mine water from pond 4 I described in section 4.3.1 of the ESCP. The first priority is to use treated mine water for groundwater recharge around the mine boundaries. If the available water exceeds the capacity of the recharge systems, and the treated water quality is acceptable for direct discharge to Canoe Creek Lagoon, this will be the next option applied. If the water quality is not sufficiently good for direct discharge to the lagoon, the treated water will be pumped to infiltration basin adjacent to canoe Creek or will be returned to the opencast pit in extreme situations.

The plan provides for appropriate turbidity and sediment monitoring in the mine water to support the real-time management of mine water quality through the proposed disposal options.

No concerns are raised through this review with respect to the ESCP.

7. BARRYTOWN MINERAL SAND MINE ECOLOGICAL EFFECTS ASSESSMENT (ECOLOGICAL SOLUTIONS 2023)

My detailed review of this document is outside the scope of this memorandum. However, there are a number of aspects of the ecological effects assessment report that rely on information provided in the hydrology report (Kōmanawa 2023a). Given the requests for information raised with respect to the Hydrology report,

Dilution ratios presented in Section 9.9.4 of the Ecological Assessment report have been taken from the Hydrology report. A request has been made for information to support these dilution ratios. If the ratios change in response to this request, then the receiving water contaminant concentrations may need to be revisited.

The report states in Section 9.9.4 with respect to the assessment of receiving water quality that "*Modelling inputs were based on the median of estimated treated clean process water*". This text refers to median contaminant concentrations. However, it appears that these medians have been calculated directly from groundwater sampling analysis data with no consideration of the proportional contributions of groundwater from the mineral sands, the underlying gravels and the mine waste backfill have to the mine water discharges. Normally, mass load calculations would be used to calculate these relative contributions and the expected discharge water quality. Questions have been raised in the review of the Hydrology report with respect to this aspect of the assessment. If the responses to these questions indicate the contaminant concentrations in the mine discharge water are higher than indicated in the Ecological Assessment, then the assessment of receiving water quality may need to be revisited.

> Verbal responses to the above concerns provided by Z. Etheridge (Kōmanawa) indicated a check on receiving water quality has been undertaken. The results of this check indicated the receiving water quality outcomes documented in the Ecology report would not be significantly changed if 96% the groundwater inflows to the mine were sourced from the underlying basal gravels. This would imply that the overall groundwater quality would effectively be the same as the basal gravel aquifer groundwater. Can the above conclusions please be confirmed.

8. CONCLUSIONS

A substantial amount of work has been put into the hydrological assessment of the proposed mine and the design of water management systems. The work undertaken generally appears technically reasonable and defensible. The requests for further information mainly relate to gaps in documentation rather than gaps in assessment work undertaken. The responses to these requests have supported the work documented in the Hydrological Assessment by Kōmanawa (2023a).

Overall, the groundwater and surface water information provided by Kōmanawa indicates that the mining operation can be undertaken with less than minor effects on surface water flows, provided the proposed groundwater and surface water mitigation measures are implemented and effectively monitored and managed.

The key concern with respect to the geotechnical assessment of the pit wall stability remains whether the injection wells proposed by Kōmanawa as part of the mine water management and effects mitigation system can be operated within 20 m buffer zones along the mine northern and southern boundaries without leading to pit wall stability issues. Any ground movement initiated along these boundary zones is likely to be further exacerbated by the operation of infiltration trenches within the same buffer zones. The viability of the proposed management measures to mitigate the identified groundwater and surface water effects depends on the ground stability within these buffer zones.

Yours Sincerely

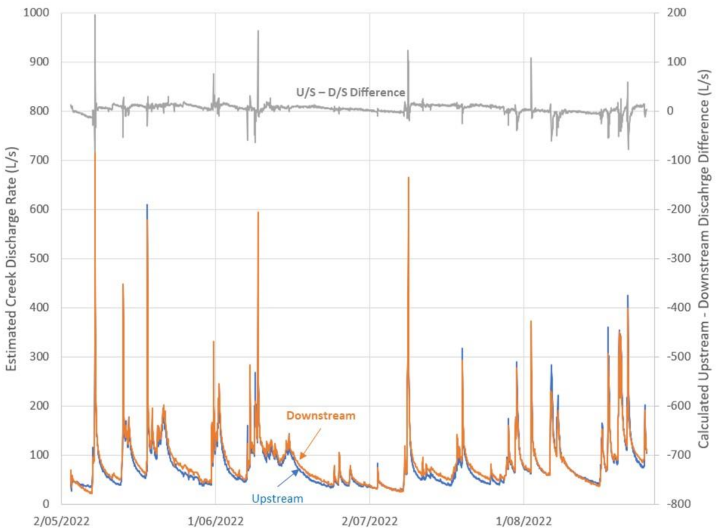
Brett Sinclair
Senior Principal Hydrogeologist
WALLBRIDGE GILBERT AZTEC

APPENDIX A SITE PLANS

APPENDIX A
APPLICANT RESPONSE SUMMARY TABLE

Table A1. Applicants Table Summarising Responses to Requests for Information.

WGA MEMO NO.	REQUEST SUMMARY	FILES IN SUPPORT
3. 1	Please provide a map with contours of the projected cumulative pit floor and confirm the maximum depth of mining below ground level.	Written response
3.1 Response	Palaris provided a PDF contour map of the AMSL/RL contours of the base of the excavation. This shows the maximum contour to be -8 m MSL in an isolated patch. About 70% of the depth contours are greater than -5 m MSL, ranging between -1.4 m and -5 m MSL for the southern and eastern parts of the sand extraction area. A nominal -5 m MSL is used as the base of the sand extraction in the MODFLOW model. The maximum depth of excavation is estimated to be approximately 14 from the peak of the peak of a “hump” in the “Hump & Hollow“ topography. Thank you. No further information required.	File: 3-1 Floor of Sand_Roof of Gravel.PDF Additional - File: 4-11 Mining Depth From Topography.PDF
4. 2	Please provide a map identifying the locations of both flow monitoring sites	Written response
4.2 Response	The flow sites are located on Collins Creek. The upstream site is immediately upstream of the SH6 bridge and called Collins Upstream or Colins U/S. The downstream site is located at the farm lane ford across Collins Creek and called Collins Downstream or Collins D/S. Thank you. No further information required.	File: 4-2_CollinsCk_ Flowsites.PDF

4. 3	Flow gauging records and the flow rating curves developed for each of the stream flow monitoring sites	Written response
4.3 Response	Rating curve generation was generated from four gauging instances, but the scatter around the linear best fit was significant to result in an R^2 of between 0.79 and 0.66. Rating curve generation was problematic. Ultimately, a rating was taken from two gauging instances (11/05/2022 and 7/02/2023). Thank you. No further information required.	Files: 4-3_Rating_US.xlsx and 4-3_Rating_DS.xlsx
4. 4	Please provide a chart showing the difference in calculated creek flows between the two monitoring sites through the duration of the recorded period.	Written response
4.4 Response	The chart below shows the difference between upstream and downstream creek discharge. A Powerpoint file is attached containing the chart graphic. The period covered is 4 May – 25 August 2023, which provides an indication of the correspondence.  Thank you. No further information required. Identification of monitoring sites for the records in the lower chart is incorrect – should be the other way around.	File: 4-4_CreekDischarge Diff_Chart.pptx

4. 5	Please provide the PB-1 test water level curve for both the abstraction test and the injection test	Written response
4.5 Response	PB-1 was a 125 mm (5 inch) diameter testing bore that would not resemble the proposed injection wells at the Cowan Block, Barrytown. This small bore diameter also hampered the ability to take even manual water depth measurements. The injection of creek water into the screened section did not represent an injection test. Only manual measurements of PB-1 water level could be made with some difficulty due to the slender space between injection hose (and couplings) and the internal diameter of the bore casing, and therefore level measurements were not taken during injection. The injection of creek water was undertaken as a last development stage of the test bore before testing began. We noted that the bore did not at any stage during injection overflow, thus indicating a maximum mounding effect. Final pumping step depths to water and drawdowns were available from the pumped bore PB-1, i.e., one final drawdown per step for four steps. Pumped bore depths to water during the constant rate tests were not taken as the objective was to measure the water levels and drawdowns in the observation bores TB-1, TB-2 and TAC-157. Thank you. No further information required.	File: 4-5 Step Drawdown Final Drawdown plot.xlsx
4. 6	Please provide the groundwater up-coning response curves for these bores and an indication of the extent and magnitude of up-coning achieved during the test	Written response
4.6 Response	See response for 4.5. Injection testing was not recorded beyond measuring the injection rate at the beginning of injection. Thank you. No further information required.	
4. 7	Please provide a reviewed version of the interpreted piezometric map. The aspect of primary interest is what proportion of the groundwater currently flowing across the planned mine pit area is reporting to either the Northern Boundary Drain or Rusty Lagoon.	Written response
4.7 Response	Figure 32 in the hydrological assessment report was found to be in error. The error was a stray line between contour 7 m and 8 m AMSL that gave the appearance or impression that the hydraulic gradient against the Northern Boundary Drain was steeper than measured and corrected level measurements in fact indicated. The stray line has been removed and the editing reviewed, with a PPT file included showing the edited Figure 32, plus Figure 31 and Figure 35 for easy reference to information presented of relevance to the Northern Boundary Drain. Thank you. No further information required.	File: 7_Edited Fig32 gw Contour Map.pptx

4. 8	Please provide a calculation of groundwater through-flow within the basal gravel bed underlying the site, taking into account the transmissivity values derived from the pumping test	Written response
4.8 Response	It was not our belief that the PB-1 pumping test accessed the hydraulic properties of the basal gravel layer. PB-1 was screened to a depth elevation of -0.95 m MSL, while project top of the basal gravels is -4.2 m MSL, thus 2022 pumping tests did not extend into the basal gravels. Instead, the sole pumping test of the basal gravel at a site approximately 1.2 km to the north of the Northern Boundary Drain at bore NB-7, which had a depth of 24.7 m BGL and was screened from 18.7 m BGL (-10.1 M MSL) to 24.7 m BGL (-16.1 m MSL). The bore log showed the screened section was clearly consistent with the basal gravels described elsewhere (" GRAVEL, sandy, fine to coarse gravel and cobbles"). A 2½ hour, 2.4 L/s pumping test determined a transmissivity of 340 m^2/d. The hydraulic gradient of the deep (basal gravel) along Burke Road (bores WS3200D and NB-7) was measured at 0.002 m/m. These values were transferred into the Cowan Block throughflow calculation and the deep throughflow added to the throughflow calculated for the shallower layer. During the conference call, Mr Rekker indicated the gravelly sand unit screened in PB-2 is expected to have a similar hydraulic conductivity to the underlying basal gravel unit described above. This expectation is supported by the PB-2 test data analysis and the information provided above. Response to S92 request for throughflow calculations indicates: Mineral sands throughflow: 600 m^3/day, 7 L/s. Basal gravel throughflow: 1,340 m^3/day, 15.5 L/s. Thank you. No further information required.	File: 4.8_Basal_gravel_Layer2_Throughflow_Calc.docx
4. 9	Please reassess the relative combined groundwater flow estimates compared to the surface water flows, as documented in the final paragraph of Section 2.6.7.2.	Written response

4.9 Response	Instead of groundwater throughflow being estimated at 1/10 of surface water discharge, the throughflow estimate taking a conservatively high estimate of basal gravel throughflow places combined throughflow at about ¼ of surface water discharge. The calculations provided and the information on which these calculations have been based are accepted as reasonable. The principal change in response to the request for information has been the incorporation of the basal gravels into the through flow calculation. The key parameter in that calculation is the hydraulic conductivity applied, is it has the greatest potential for uncertainty. The value applied in the calculation is consistent with the results from a pumping test performed on site, although that test was performed on sandy gravels immediately over line the basal gravel unit. The hydraulic conductivity value applied is also consistent with results from analysis of a pumping test performed on corresponding material to the north of the site. Therefore, the hydraulic conductivity value is accepted for the purposes of indicating groundwater through flow beneath the site. Thank you. No further information required.	File: 4.8_Basal_gravel_Layer2_Throughflow_Calc.docx
4. 10	Please provide a contour map of the interface between the base of the mineral sand deposits into the top of the basal gravel deposits.	Video response
4.10 Response	Palaris provided a PDF contour map of "the base of sand surface is the roof of the gravel surface." The information provided in response to this question, combined with the response to Question 3.1 above, clearly defines the interface between the mineral sands and the underlying basal gravels. Thank you. No further information required.	File: 4-10 Insitu Sand Post Mining.PDF
4. 11	Please provide a contour map of the thickness of mineral sands left in place between the base of the pit shell (as per Request 1 above) and the top of the basal gravels underlying the pit.	Video response
4.11 Response	Palaris provided a contour map of the "vertical thickness contour map between the floor of sand and topography". This contour map shows the maximum depth from surface topography would be 14 m. However, the Hump & Hollow topography is a significant influence on the peak difference between pit floor and ground surface. Post-stripping depths are likely to be significantly less and less volatile. Thank you. No further information required.	File: 4-11 Mining Depth From Topography.PDF

4. 12	Please advise whether the sump as described above is also to collect water extruded from the accumulating tailings backfill.	Written response
4.12 Response	Palaris provided the following response: *It* (the sump) *is designed so that water from the tails will be collected with work area run off and ground water ingress at the same sump with all water being pumped from the pit sump back to the Mine Water Facility. This consolidates all water management within the working pit area into one location and reporting back to the Mine Water Facility for re-sure and water quality management.* Stephen Miller, General Manager, APAC Metal / Palaris, 18 July 2023. Thank you. No further information required.	
4. 13	Please provide an estimate of mine discharge water quality based on estimates of relative mass load contributions from the various contaminant sources to the mine water management system. In lieu of a calculated discharge based on contributing mass loads, please provide an indication of the ‘worst case’ contaminant concentrations in the mine discharge water and the reasoning behind the values provided.	Written response

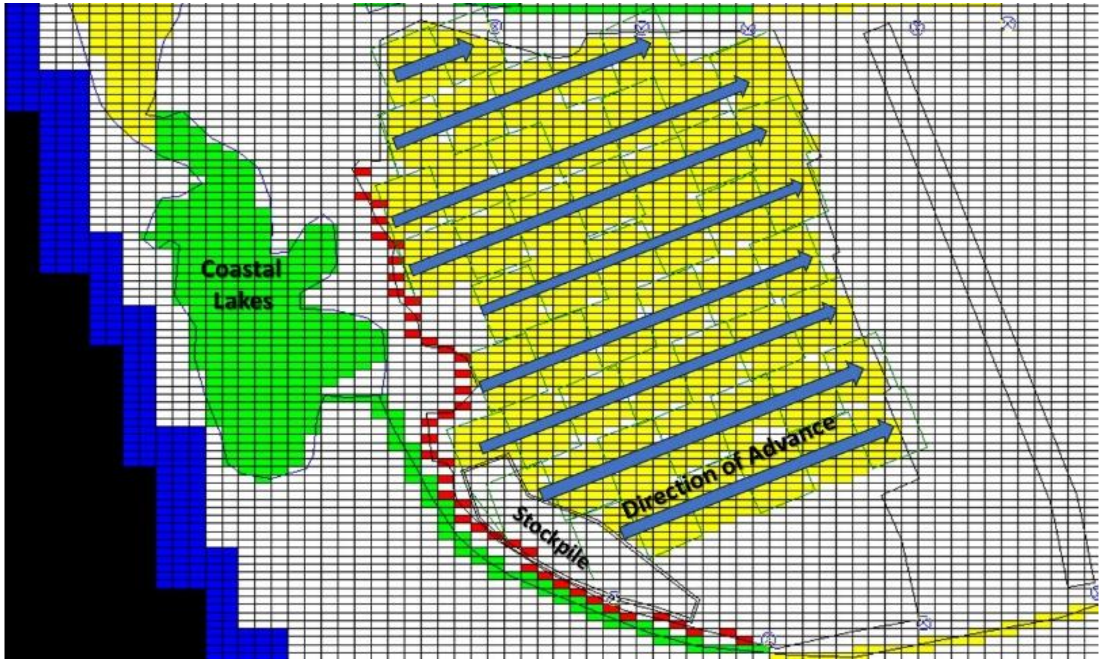
4.13 Response	Should the discharge of tails dissolved metals be encouraged to infiltration from the tailings in the wake of the mining in each mine panel, the solutes may enter and combine with the groundwater within the basal gravels under pre-mining vertical hydraulic gradients. In this case, the more likely site of groundwater discharge from the deeper basal gravels aquifer would be at the coastline, into the Tasman Sea. Section 4.2.2.2 of the assessment document states that "*A proportion of the seepage may discharge into the coastal lagoon, but most of the influx to the lagoon comprises inflows from Collins Creek and hence any seepage from backfilled material to the lagoon would be diluted significantly. The estimated groundwater throughflow rate at the site is 10 L/s (see Section 2.6.7.2). The mean flow of Collins Creek is estimated to be ~ 50 L/s (Section 2.5). Assuming that all groundwater throughflow beneath the site discharges to the lagoon (which is unlikely to be the case, a significant proportion is likely to flow underneath the lagoon and discharge at the coast), the rate of dilution with Collins Creek water will be at least fivefold, giving a maximum concentration of 0.04 mg/L. This is below the ANZG screening value of 0.055 mg/L*." The revised throughflow analysis envisages the following throughflow rates - 7 L/s in Layer 1 15.5 L/s in Layer 2, most likely discharging at the coast. The revision would see the superficial groundwater throughflow to the Coastal Lagoon change from 10 L/s to 7 L/s and therefore a reduction of the discharge containing solutes discharging into the lagoon. Hence the dilution would be sevenfold and the maximum concentration would be 0.03 mg/L, still beneath the ANZG screening value of 0.055 mg/L. Water pumped from the pit sump with be a mixture of: 1. Seepage water from the mineral sands (already considered in the groundwater assessment lodged with the application) 2. Seepage water from the basal gravels (volumetric flow rate uncertain) 3. Seepage of water from tailings returned to the pit (volumetric flow rate uncertain) Despite the uncertainty in some of these parameters, the key factors relate to the water quality for each flow component. The calculations indicate water quality in the coastal lagoon should remain below ANZG screening values, which is accepted. Compliance monitoring for the mine discharge and the lagoon receiving water can be defined to confirm this projection is achieved. If receiving water quality risks arise, this circumstance would be first detectable through monitoring of water quality in the Terminal Treatment Ponds, combined with monitoring of the receiving coastal lagoon water quality. The applicant has already identified a management option whereby mine water may be discharged via an infiltration basin system to Canoe Creek close to the coastline. This option, assuming it is approved, provides for water quality management in advance of an issue arising in the coastal lagoon, which is one objective of the Water Management, Monitoring and Mitigation Plan lodged with the application.	

	Thank you. No further information required.	
4. 14	Please provide an indication of the thickness of the basal gravel unit underlying the mineral sands. Please also advise what underlies the gravel unit and at what depth the Blue Bottom Formation may be found beneath the site.	Video response
4.14 Response	The basal gravel is poorly constrained by available drilling information, especially within the boundaries of the Cowan Block where the top couple of metres of the basal gravels have been the limit of drilling. Drilling along Burke Road to the north of the Cowan Block has constrained the absolute and minimum depths of the basal gravels to some extent. The Blue Bottom Formation was found directly beneath the basal gravel at 24 m BGL (-15.4 m MSL). The top of the basal gravel was found at approximately 11 m BGL (-2.4 m MSL) meaning the measured thickness of basal gravel was 13 m between upper contact and basement contact. Thank you. No further information required.	4.8_Basal_gravel_Layer2_Throughflow_Calc.docx
4. 15	If the direction of groundwater flow within the basal gravel aquifer between the mine and the coastline is at least locally reversed due to drawdown linked to mining operations, what implications will this have for saline water intrusion risks?	Video response

4.15 Response	The precise tipping points of reversal of groundwater flow is difficult to quantify in relation to Layer 2 and the extent of the Cowan Block. A rough estimate of the Layer 2 pore volume of groundwater is 1,500 x 800 x 15 x 0.20 = 3,600,000 cubic metres at 20% effective porosity. Coffey Partners (1991) found at least two lines of evidence that suggest the groundwater is fresh at the coastline or beyond the coast; a) deep (+30 m BGL) groundwater sampling bores at the coastline returned fresh water samples, and b) electrical resistivity profiling in the late 1980s encountered no indications of saline or brackish groundwater despite the profile transect lines being arranged on and parallel to the coastline and in the foredune zone. Hence, landward movement of the seawater – freshwater interface (transition zone) would be required. Several million cubic metres of groundwater displacement by dewatering, in addition to the 490,000 cubic metres per annum flow from the west in Layer 2 over an extended period of time to give rise to the conditions of landward movement of the seawater – freshwater interface in the groundwater system. An approach of sand extraction area to within 350 m of the coastline in model Year 4.7 was assessed by examining modelled groundwater vectors and levels within Layer 1 and 2 in the vicinity of the active sand extraction zone. The groundwater level with the centre of the active sand extraction pit were determined (L1 GWL = -4.3m, L2 GWL = 0.14 m MSL) (L1 GWL = 3.72 m, L2 GWL = 3.77 m MSL) (L1 drawdown = 8.02 m, L2 drawdown = 3.63 m MSL). Groundwater vectors in both layers were also examined and found to have been diverted into the area of active pit water management. The figure *4-15_GwVectors_L1_L2.pptx* shows the swirling of groundwater vectors around, into and past the sand extraction area. Interpretative flow divides were sketched around the model plane around the active sand extraction area. Groundwater vectors show the threshold from cells flowing towards the coastline and cells flow towards the active sand extraction area approximately 150 m from the area or 200 m from the coastline in both model layers. The model outputs indicate the extent of mining-induced groundwater pressure and flow drawdown in the basal gravel is controlled to the west by the presence of the coastal lagoon. The model outcomes are accepted as indicative of the potential effects in terms of saline water intrusion. Thank you. No further information required.	File: 4-15_GwVectors _L1_L2.pptx
4. 16	Please present a modified version of Figure 43 clearly showing all the boundary conditions described in the text with appropriate labels.	Video response

4.16 Response	An edited copy of Figure 43 is provided as a Powerpoint file showing the removal of the stray / superfluous line and repositioning of labels. Boundary annotation is provided in colour coded MODFLOW boundary condition classes: **Dark Blue** = CHD constant head for sea boundary (layers 1 & 2) **Yellow** = DRN drain boundaries for Mahers Swamp, NBD and upper parts of Collins Creek **Green** = RIV river boundaries for coastal lagoons lower NBD and lower Collins Creek **Dark Red** = WEL Simulated infiltration Trenches (SW and Northern) **Black** = HNF basement Head No Flow boundary Note: The yellow coloured State Highway 6 (SH6) is not a boundary, merely a geographic feature. A PowerPoint file is provided mapping and annotating the TMR Groundwater inflows are predominantly rainfall recharge combined with inflows from the wider Telescopic Mesh Refinement model constant head cells. Not clear from the Figure 43 provided but confirmed through a call with J. Rekker. Thank you. No further information required.	File: 4-16_Fig43_annotation. pptx 4-16 TMR GWV screenshoot.pdf
4. 17	Please provide the water balance results and the boundary inflow / outflow results for the refined model to support the model documentation.	Written response

4.17 Response	The basic model water balance is as follows – Description / Inflow (m^3/d) / Outflow (m^3/d) Recharge / 142 / 0 Constant Head / 40,738 / 33,318 River / 13,449 / 17,458 TOTAL / 54,329 / 54,305 ERROR / 0.043 The breakdown beyond this is somewhat problematic due to the TMR exchanges and balancing with other boundaries. A breakdown of seepage removals of model groundwater during sand extraction operations is summarised below - **Boundary** / **Seep (m^3/d)** Mahers DRN / 2,428 NBD DRN / 1,101 Collins Ck DRN / 0 Rusty's RIV / 4,184 CollinsCk Confl RIV / 2,415 CollinsCk Mid RIV / 1,517 NBD Lower RIV / 3,994 The coastal lagoons make a complicated interchange with surrounding constant head boundaries, namely the coastal CHDs. This information is incomplete, possibly due to the issues in interrogating flows to various boundary conditions in the model. However, information provided in response to other questions has enabled a better understanding of the relative flow contributions from various sources to the mine. Therefore, no further information is requested with regards to this question.	
4. 18	Please provide model set-up documentation for the predictive model that was used to generate the flow results documented in Section 6.1, including detail on the progression of the simulated opencast pit across the site.	Video response

4.18 Response	Sand extraction areas were lain into the 6.2-year transient simulation in GWV as 53 rectangular areas within the mine panels. The first stress period in MODFLOW was steady state and this approximated Scenario 0. A common drain elevation per stress period was set within each rectangle in accordance with the elevation of the pit base (see file "3-1 Floor of Sand_Roof of Gravel.PDF"). The pit advance along each mine panel was from west to east, and progressed northward from mine panel 1.  The fluxes within the sand extraction operations period were obtained using boundary reach reports from GWV. Depletions were calculated by subtracting change from the initial steady state stress period. Thank you. No further information required.	File: 4-19 Model Schematic.pptx 3-1 Floor of Sand_Roof of Gravel.PDF
4. 19	Please provide the layout of the parameter zones listed in Table 22 within the refined model mesh area.	Video response

4.19 Response

As outlined in other parts of the report describing groundwater flow model set-up, five zones of hydraulic conductivity in the superficial model Layer 1.

Parameter	Optimised Value (m/d)
Global Recharge	36.5 mm/yr
Zone 1 K_h	2.86
Zone 3 K_h	5.4
Zone 4 K_h	11
Zone 5 K_h	80
Zone 6 K_h	1.9

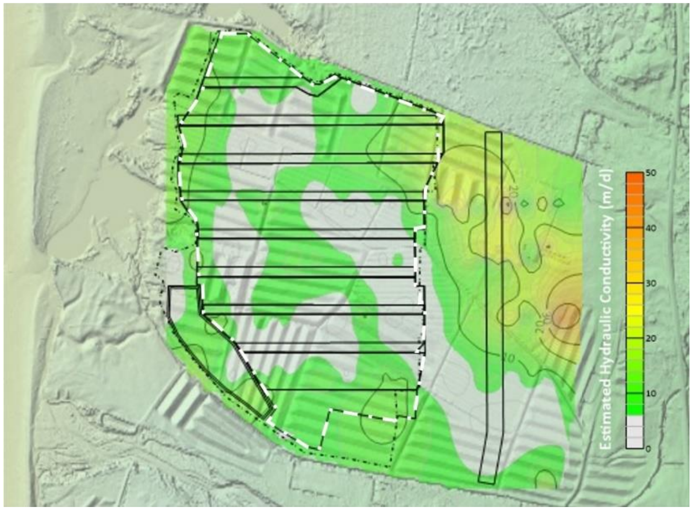
Note: Zone 2 is in model Layer 2

Zone 3 relates to the Eastern Gravel Overburden deposit the does not extend into the sand extraction area. Zone 4 is a fringing halo of the Eastern Gravel Overburden that was found in optimisation to be more permeable. Zone 5 a high permeability zone suggested by optimisation. It is distributed around the coastal lagoon margins and section of middle Collins Creek. Zone 6 is correlated with the low permeability mineral sand, which is a fine sand considered to have hydraulic conductivity of 3 m/d or less. Zone 1 and Zone 6 are adjacent in terms of hydraulic conductivity and physical distribution. The two figures below show the progression from hydro stratigraphic modelling outlined in section 2.6.6 of the assessment report.

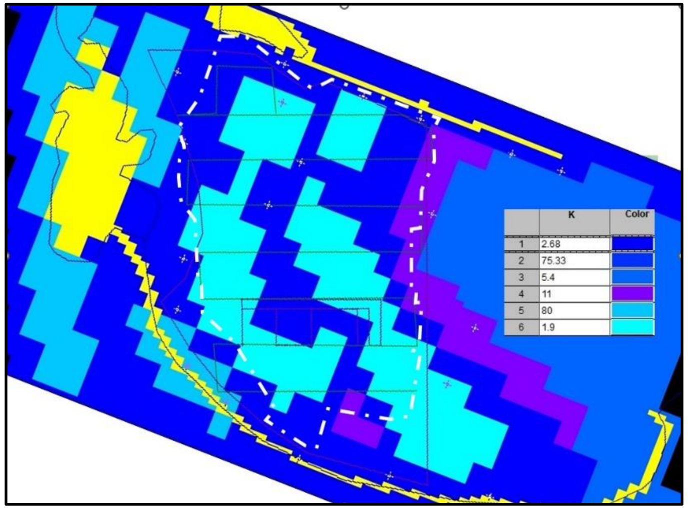
Thank you. No further information required.

File: 4-19_HydCond_
Plots.pptx
4-19_Hydrostrat_
KDistribution.PDF
4-19_ModelK_Zones.PDF

Hydro stratigraphic Modelling of Layer 1 Hydraulic Conductivity

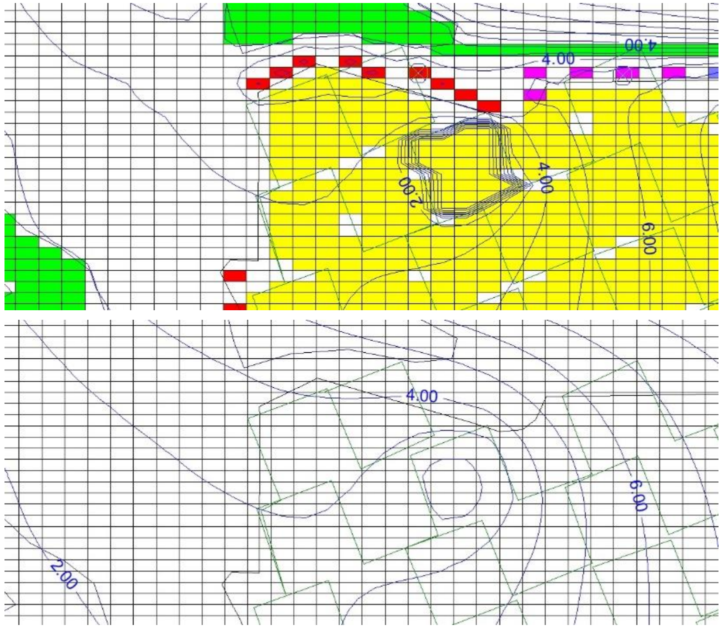


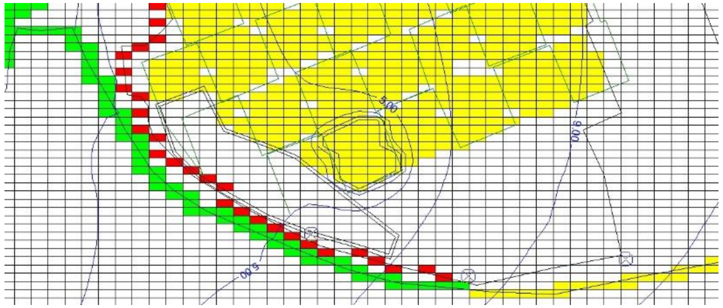
Hydraulic Conductivity Zonation in Layer 1

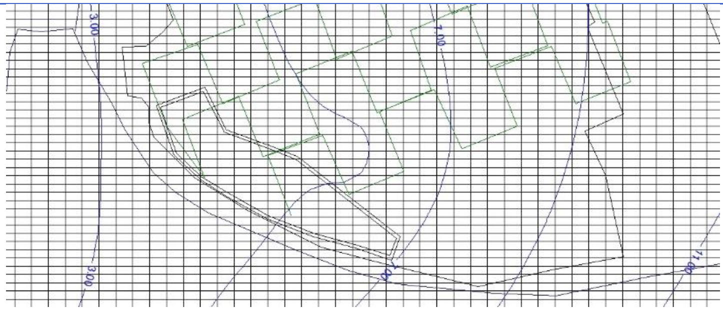


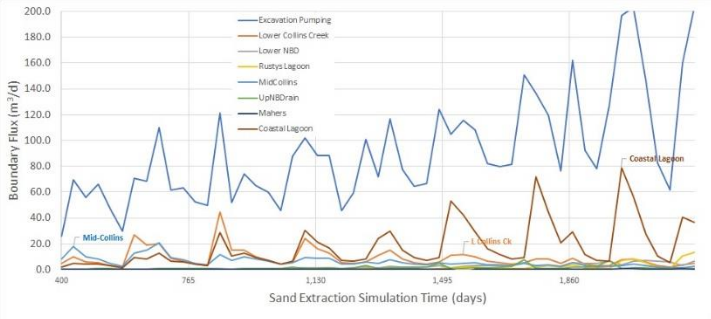
The above figures are in the same position and orientation for reference.

4. 20	Please provide a chart showing the flow rates into the simulated opencast pit for Layer 1 and Layer 2 separately. How much water is entering the pit from the basal gravels compared to the mineral sands? What component of this water is direct recharge water to the pit footprint?	Written response
4.20 Response	The sand extraction area at model Year 4.7 examined in relation to groundwater vectors in responses to 4.15 was examined in relation to stratification of the model water fluxes. In layer 1 the drain cells simulating the pumping of water from the excavation requires a flux of 130 L/s to maintain the excavation at the target water elevation of -4.28 m MSL. Only 4.7 L/s of the groundwater extracted at the drain reach originated from Layer 1. Approximately 125 L/s (96.4%) of the groundwater originated in Layer 2 and flowed up into the Layer 1 drain reach from below. The ratio of groundwater recharge to the mine of 4% from the mineral sands and 96 % from the basal gravels appears to be a reasonable indicator of the relative groundwater contributions from operations across most of the site. A possible exception is along the northeastern boundary of the planned ore extraction area, where the hydraulic conductivity of the materials simulated by Layer in the model increases. The file provided to represent the flow chart was blank. However, the information provided is sufficient as a response to the question. Thank you. No further information required.	
4. 21	Please provide indicative groundwater drawdown maps showing the extent of drawdown when ore extraction is operational in Panel 8 and separately when Panel 9 is operational. Please present the drawdown maps for Layer 1 and Layer 2, together with an overlay of surface water bodies, wetland areas and known springs.	Video response

<table>
<tr>
<td>4.21 Response</td>
<td>Drawdown is more concentrated surrounding the respective active sand extraction areas in the superficial Layer 1 than deeper Layer 2.
Panel 8: Layer 1 (above) and Layer 2 (below)


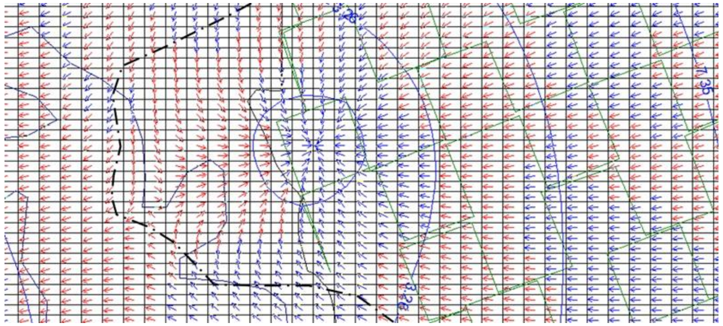
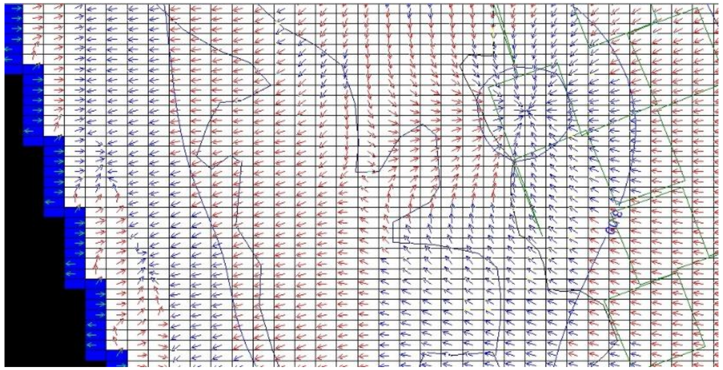
Panel 1: Layer 1 (above) and Layer 2 (below)
</td>
<td>Files:
4-21 Panel8_layer1.PDF
4-21 Panel8_layer2.PDF
4-21 Panel1_layer1.PDF
4-21 Panel1_layer2.PDF</td>
</tr>
</table>

	 The northern panel induced a deeper and greater drawdown compared to the southern panel. The simulated groundwater levels are accepted. It appears that not all of the groundwater level contours for the center of the pit in Panel 1 Layer 1 may be presented in the relevant image. However, the general extent of groundwater drawdown is indicated. The drawdowns presented take into account the operation of the proposed groundwater recharge systems. i.e. They represent mitigated effects scenarios. Thank you.	
4. 22	Please provide model outputs for water losses from adjacent surface water bodies to the mine and compare these to inflow and outflow rates for the surface water bodies in the calibration model.	Written response

<table>
<tr>
<td>4.22 Response</td>
<td>The plot below is the transient or time series of model fluxes drawn from the MODFLOW model simulation that includes the groundwater pumped from the active sand extraction pit and the other eight adjoining boundary groups; Lower Collins Creek, Middle Collins Creek, Lower Northern Boundary Drain (NBD), Upper NBD, Rustys Lagoon, Mahers Wetland and the Coastal (Canoe Creek) Lagoons.


Note: the Lower Collins Creek and middle Collins Creek depletion sum to 56 L/s effect on the creek at Day 855.

Note that the vertical axis in the chart shown is not in units of m3/day but rather L/s.
Thank you. No further information required.</td>
<td>File:
4-22 FlowDepletion_adj_ waterbodies.PDF</td>
</tr>
<tr>
<td>4. 23</td>
<td>Please provide a vector map of groundwater flow directions in Layer 2 in the area between the mine and the coastline.</td>
<td>Video response</td>
</tr>
</table>

4.23 Response	An approach of sand extraction area to within 350 m of the coastline in model Year 4.7 was assessed by examining modelled groundwater vectors and levels within Layer 1 and 2 in the vicinity of the active sand extraction zone. The attached graphic shows groundwater velocity vectors within Layer 2 in the vicinity of the active sand extraction area. This graphic includes an interpretive trace of the groundwater flow divide. Beneath that graphic is an expanded area showing velocity vectors and the Tasman Sea at Year 4.7.   This information has been interpreted in conjunction to the response provided for Question 4.15. Thank you. No further information required.	File: 4-23 Vectormap_Layer2. PDF 4-23 Vectors between Pit & Sea.PDF

4. 24	The acceptance capacity calculation incorporates a hydraulic conductivity of 25 m/day, which is above the range for the mineral sands. Please clarify the source of this value. Also, please provide the calculation used to determine the radius of influence for the mound generated by the recharge.	Written response
4.24 Response	The 85 m^2/d transmissivity result derived for test observation bore TB-2 in the PB-1 pumping test was influential in the specification of a hydraulic conductivity of 25 m/d. The TB-2 observation bore was screened in a layer of SAND, silty, with minor fine gravel. The 8.7 m AMSL water table above the base of the materials found at about 5.2 m AMSL, implying a saturated thickness of 3.5 m. Thus, the adjusted hydraulic conductivity for the silty sand with minor gravel of 24 m/d. It is anticipated that the northern and south-eastern infiltration trenches would be established within the coarser overburden materials, above the mineral sands. Thank you. No further information required.	
4. 25	Please provide the calculations that generated the estimates for potential flow rates to the recharge wells as listed in Section 6.5.1.2.	Written response

4.25 Response	Section 6.5.1.2 could have made clearer the differences in infiltration wells between the shallower materials (ore sand with minor gravel, model Layer 1) and the deeper materials (sandy basal gravels, model Layer 2). Infiltration wells may be screened to achieve infiltration across both layers or individually screened to access one layer and associated porous material, the feasibility assessments would evaluate efficacy and environmental effects. Depth to water table also contrasts between the shallower and deeper layers accessed by the recharge barrier injection wells. Measurements of static water levels in monitoring bores to the north of the Cowan Block range in over-pressure from deep to shallow bores between 0 m to 0.81, i.e., negative (downward vertical gradients ranging between 0 and -0.038 m/m. The calculated Theis Equation aquifer mounding effect at 0.5 m radius (assuming 1.0 m well diameter) would conform with the following list of parameters (T & S) and pumping rates (Q) - • Ore sand with minor gravel, ○ T = 30 m^2/d, S = 0.25, Q = 1.5 L/s ○ 7-day mounding = 3.0 m • Gravel in ore sand matrix, ○ T = 90 m^2/d, S = 0.25, Q = 5 L/s ○ 7-day mounding = 3.8 m • Sandy gravels ○ T = 300 m^2/d, S = 0.25, Q = 15 L/s ○ 7-day mounding = 3.8 m The injection well system would be the subject of well field feasibility testing and trialling. The indicated recharge rates and mounding have been checked and are consistent with Theis projections. It would have been useful to have infiltration basin calculations for recharge to the mineral sands. However, the Theis calculations for Layer 1 support the viability of the use of infiltration trenches for management of groundwater drawdown. The response to this question has been reviewed in conjunction with the responses to the following two questions, to clarify the viability of the proposed recharge (infiltration) system Thank you. No further information required.	

4. 26	Figure 56 appears to show the combined injection rates to the four proposed recharge bores located along the northern side of the mine. Please confirm this understanding is correct.	Video response
4.26 Response	Not correct. Figure 56 shows the northern infiltration gallery (i.e., trench) injection rates. Thank you. No further information required.	
4. 27	Figure 58 appears to show the combined injection rates to the proposed recharge bores located along the southern side of the mine. Please confirm this understanding is correct.	Video response
4.27 Response	Not correct. Figure 58 shows the infiltration gallery (i.e., infiltration trench system along south and west margin) Injection wells would have a support role to the main infiltration trench system in instances of surplus, such as the instances shown in Figure 58 when water produced at the mine pit during the early phase of sand extraction exceeds the 42 L/s capacity of the southern infiltration trench / gallery system. Thank you. No further information required.	
4. 28	Please provide the MODFLOW model outputs for water losses from adjacent surface water bodies to the mine with the recharge systems in place and operating. Compare these depletion rates for the adjacent water bodies to inflow and outflow rates for the surface water bodies in the calibration model, and similarly to the model with no management measures in place. Thank you. The combination of responses to several of the other questions provides the information requested. No further information required.	Written response Overlaps 4.22.
4. 29	Please provide a map showing the extent and magnitude of groundwater mounding in Layer 2 that would arise from the simulated recharge bore operation at the northern side of the mine. The mounding should be representative of a date late in the mining period with a high simulated rate of recharge. Please also provide a piezometric map for Layer 2 for the same date. Thank you. The combination of responses provided by conference call together with consideration of the injection rates and corresponding mounding based on the Theis equation provides an indication of the potential mounding response on the northern side of the mining operation. No further information required.	Video response

4.29 Response	Covered in video conference	See also response for 4.21
4. 30	Please provide a map showing the extent and magnitude of groundwater mounding in Layer 2 that would arise from the simulated recharge bore operation at the southern side of the mine. The mounding should be representative of a date early in the mining period with a high simulated rate of recharge. Please also provide a piezometric map for Layer 2 for the same date Covered in video conference Thank you. The combination of responses provided by conference call together with consideration of the injection rates and corresponding mounding based on the Theis equation provides an indication of the potential mounding response on the southern side of the mining operation. No further information required.	Video response See also response for 4.21
4. 31	Please provide the calculations to support the estimation of a 60 L/s depletion rate from Collins Creek.	Written response
4.31 Response	We anticipate a peak during year 2 in the lower Collins of 44.5 L/s and Mid-Collins of 11.7 L/s, equating to 56 L/s of depletion based on transient simulation using the TMR MODFLOW model. This is the basis for supposing that up to 60 L/s of augmentation might be required. Thank you. No further information required.	
4. 32	Please provide simple water balance calculations for the mine site	

4.32 Response	The basic model water balance is complicated by the transient simulation. Mean groundwater exchanges are provided below. The mean operational water balance terms relate to mitigated exchanges (i.e., with infiltration in operation too). The breakdown beyond this is somewhat problematic due to the TMR exchanges and balancing with other boundaries. A breakdown of seepage removals of seepage and seepage change (i.e., depletion) at several during sand extraction operations is summarised below - **Boundary** | **Steady State (m^3/d)** | **Operational Mean Seepage (m^3/d)** | **Long-Term Depletion (m^3/d)** Mahers DRN | 2,428 | 2,420 | 8 NBD DRN | 1,101 | 983 | 118 Collins Ck DRN | 0 | 0 | 0 Rusty's RIV | 4,184 | 4,047 | 137 CollinsCk Confl RIV | 2,415 | 1,648 | 767 CollinsCk Mid RIV | 1,517 | 997 | 520 NBD Lower RIV | 3,994 | 3,785 | 209 Thank you. This is considered in conjunction with the other information provided in above responses. No further information required.	

Boundary	Steady State (m^3/d)	Operational Mean Seepage (m^3/d)	Long-Term Depletion (m^3/d)
Mahers DRN	2,428	2,420	8
NBD DRN	1,101	983	118
Collins Ck DRN	0	0	0
Rusty's RIV	4,184	4,047	137
CollinsCk Confl RIV	2,415	1,648	767
CollinsCk Mid RIV	1,517	997	520
NBD Lower RIV	3,994	3,785	209