GLENDELL
CONTINUED OPERATIONS

GLENCORE

GLENDELL CONTINUED OPERATIONS PROJECT

Response to Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development Advice

FINAL

AUGUST 2020

umwelt
Environmental & Social Consultants

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Prepared by
Umwelt (Australia) Pty Limited
on behalf of
Glencore

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1.0 Introduction

The Environmental Impact Statement (EIS) for the Glendell Continued Operations Project (SSD 9349) (the Project) was placed on public exhibition from 11 December 2019 to 14 February 2020. A total of 359 submissions were made in response to the public exhibition of the Project EIS. This included 16 agency submissions and 343 community and interest group submissions. The 343 submissions received included 205 submissions in support of the Project.

The existing Glendell Mine forms part of the Mount Owen Complex located within the Hunter Coalfields in the Upper Hunter Valley of New South Wales (NSW), approximately 20 kilometres (km) north-west of Singleton and 24 km south-east of Muswellbrook (refer to **Figure 1.1**). The Mount Owen Complex is owned by subsidiaries of Glencore Coal Pty Limited (Glencore). The proponent is proposing to extend the life of operations at the Glendell Mine and optimise the use of infrastructure at the Mount Owen Complex by extending mining in the existing Glendell Pit to the north (the Project).

A Response to Submissions (RTS) is currently being prepared by Umwelt (Australia) Pty Ltd (Umwelt) on behalf of Glencore to address the issues raised in the submissions received during the public exhibition period. The RTS is divided into two separate reports (Part A and Part B). Part A was submitted to the NSW Department of Planning, Industry and Environment (DPIE) in May 2020 and Part B is expected to be submitted to DPIE in August 2020.

This document provides a response to the issues raised by the submission from the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, established under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (IESC). This document has been prepared by Umwelt with the assistance of Australasian Groundwater and Environmental Consultants (AGE) on groundwater related responses and GHD Pty Ltd on surface water related responses on behalf of Glencore and seeks to address the issues raised in the IESC advice. The following sections include a brief summary of the Project and the assessment process to date.

1.1 Project Overview

The Project is the proposed extension of open cut mining operations at the current Glendell Mine, to extract the coal reserves in the mining authorities to the north (refer to **Figure 1.2**). This extension would extract an additional 135 Mt, approximately, of ROM coal. This proposed extension of the Glendell Pit is referred to as the Glendell Pit Extension. The mining of the Glendell Pit Extension will involve the extraction of reserves down to and including the Hebden seam. Assuming approval in 2021, the Project would extend the life of mining operations at Glendell to approximately 2044 and provide significant ongoing employment opportunities. The Glendell Pit Extension mining area represents one of the last remaining unmined and easily accessible resources in the greater Ravensworth area.

The Project represents a brownfield continuation of the existing Glendell Pit and fits within Glencore's commitment to cap its global coal production at around 150 Mtpa of saleable product. The Project will occur at a time when production at Glencore's adjacent Liddell Coal Operations, and the Ravensworth East and Glendell Mines have ceased. The coal produced by the Project is 'replacement production' that will help to maintain Glencore's long term production profile.

As a continuation of the existing mining operations, the Project will utilise where possible existing infrastructure at the Mount Owen Complex currently servicing mining at Glendell. ROM coal sourced from the Glendell Pit Extension will continue to be processed through the Mount Owen CHPP, including ongoing coal stockpiling and train loading at Mount Owen Complex for the life of the Project.

This will extend the life of the CHPP for approximately an additional 8 years beyond that currently approved by the Mount Owen Consent (i.e. to 2045) and includes an allowance for the processing of coal mined in the latter stages of 2044 in the 2045 calendar year.

The Project will necessitate some changes to the location of existing Mount Owen Complex infrastructure and associated services which will also be sought through the modification of the Mount Owen Consent. The Project will also link with the Mount Owen Complex Water Management System (WMS). Through the linkage with the Mount Owen Complex WMS, the Project will be connected with Glencore's Greater Ravensworth Area Water and Tailings Scheme (GRAWTS) which enables the transfer of water and tailings between the mining operations linked to the GRAWTS. At present, the Mount Owen Complex, Integra Underground, Liddell Coal Operations and Ravensworth Coal Operations are all linked via this scheme. The GRAWTS includes pipeline infrastructure which enables the transfer of tailings material between operations to enable tailings facilities to be managed more efficiently.

The Project will require the removal of the existing Glendell Mine Infrastructure Area (MIA) (including the administration, training and workforce deployment area, bathhouse facilities, carpark etc.) and the construction of a new MIA. In order to access the pit from the proposed MIA and allow for the maintenance of mobile mining fleet, a Heavy Vehicle Access Road is also required. The Project will necessitate the realignment of a section of Hebden Road, realignment of part of Yorks Creek and the relocation of Ravensworth Homestead. The key features of the Project are shown conceptually in **Figure 1.2**.

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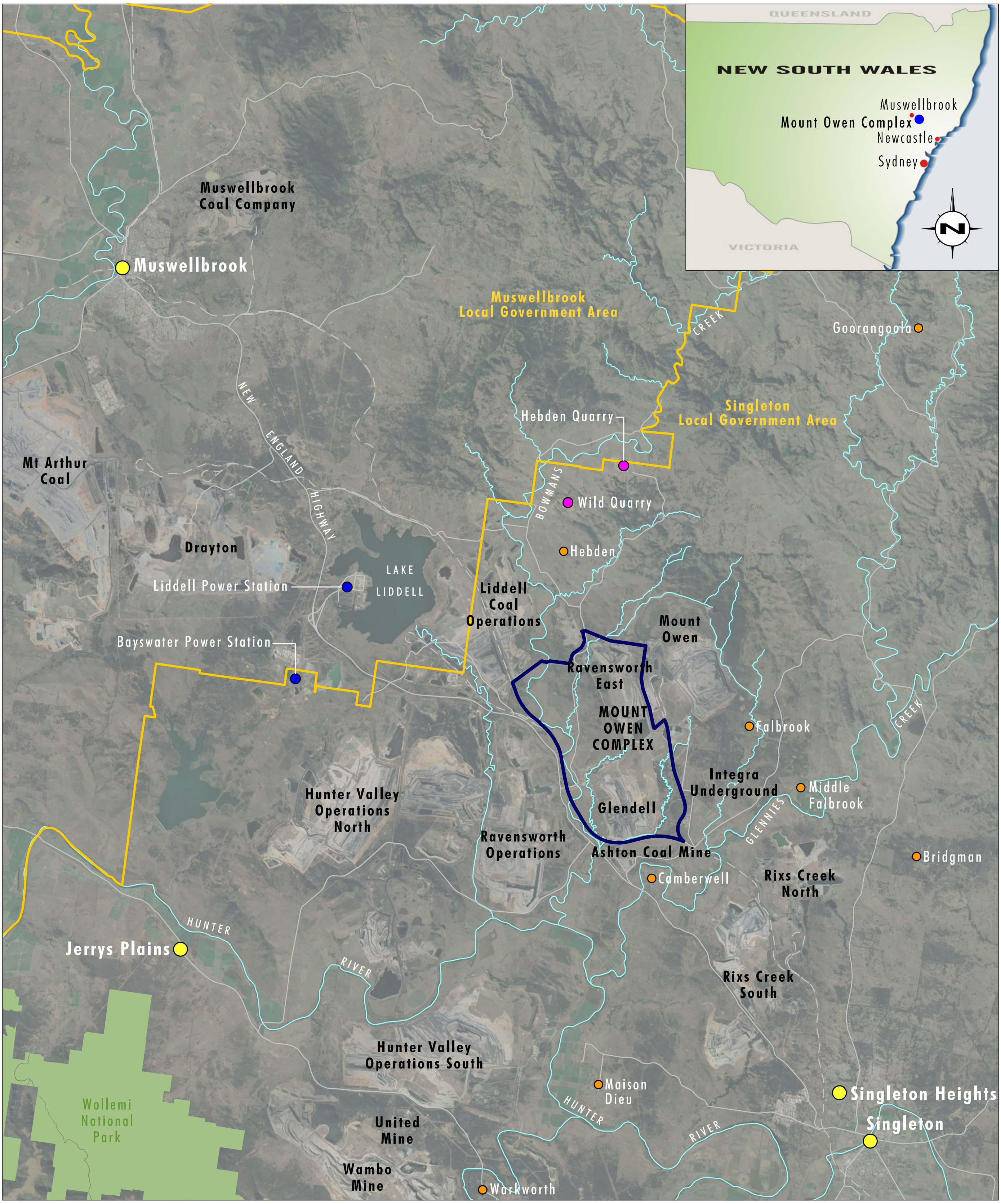

Image Source: Google Earth (2018)
Data Source: Glencore (2019), OEH (2018)

0 2.5 5.0 10km

Legend
- Project Area
- Local Government Area Boundary
- National Park
- Road
- Railway
- Drainage Line
- Towns
- Village/Localities
- Power Stations
- Quarry

FIGURE 1.1

Project Locality

File Name (A4): R18/4166_611.dgn
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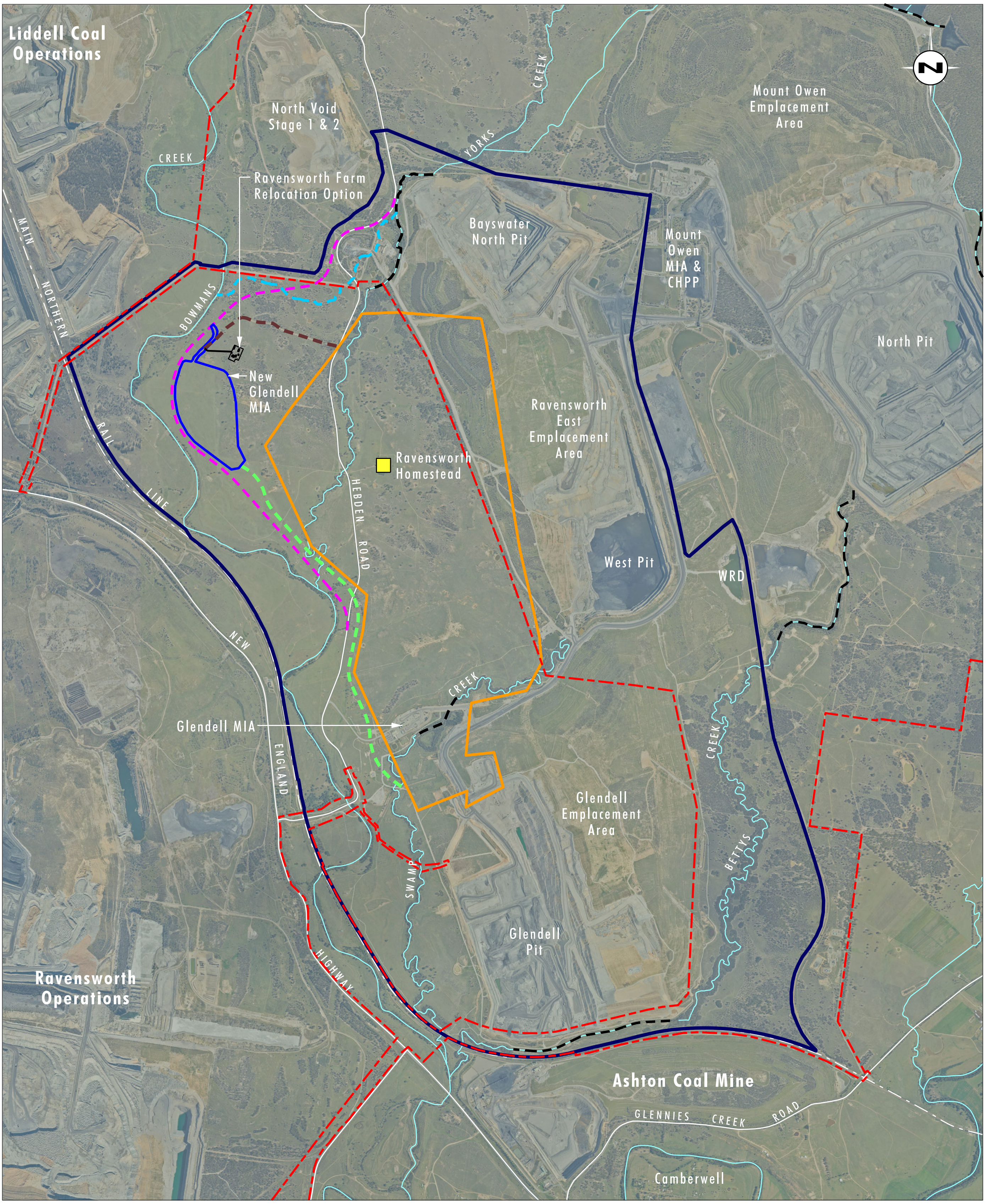

Image Source: Glencore (Dec 2018)
Data Source: Glencore (2019)
Notes: Ravensworth Homestead to be relocated, Mount Owen Consent Boundary assumes Narama Pipeline Modification is approved

0 0.5 1.0 2.0km

Legend

- Project Area
- Glendell Pit Extension
- Mount Owen Consent Boundary
- Ravensworth Homestead
- Existing Creek Diversion
- Construction Access Road

Project Features:

- New Glendell MIA
- Heavy Vehicle Access Road
- Yorks Creek Realignment
- Hebden Road Realignment

FIGURE 1.2

Glendell Continued Operations Project Key Project Features

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1.1.1 Assessment Process to Date

Being development for the purpose of coal mining, the Project is declared to be State Significant Development (SSD) under the provisions of State Environmental Planning Policy (State and Regional Development) 2011 and will require development consent Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The NSW DPIE is the delegated consent authority to make decisions on SSD applications where there are less than 25 objections to the application, the local council does not object, and there have been no reportable political donations.

The NSW Independent Planning Commission (IPC) is the consent authority for SSD applications where:

- there have been 50 or more objections to the application (other than from a council), or
- the local council has objected, or
- a reportable political donation has been made.

A total of 127 community and interest group objections were received following the public exhibition of the EIS and therefore the IPC will be the consent authority for the Project.

The EIS for the Project was prepared to assess the environmental and social impacts of the Project and accompanied by a Development Application under Part 4 of the EP&A Act. The new development consent being sought is proposed to replace the existing Glendell development consent and the Project will operate under the new SSD consent which will regulate future mining at the Glendell Mine including both the existing and proposed mining areas. The Project also requires modifications of the approved operations regulated under the existing Mount Owen Consent, in particular, the extended use of the Mount Owen CHPP and associated transport infrastructure, and the potential use of the Mount Owen MIA. The changes to approved operations under the Mount Owen Consent are being sought as a modification of the Mount Owen Consent under section 4.55(2) of the EP&A Act.

The EIS for the Project was prepared in accordance with the requirements of the EP&A Act and the *Environmental Planning and Assessment Regulation 2000*, including the Secretary's Environment Assessment Requirements (SEARs) which were issued by DPIE on 7 June 2018 and reissued on 11 July 2018 and 12 August 2019 and identified specific requirements to be addressed by the EIS.

The Project was determined to be a Controlled Action (2019/8409) requiring approval under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) from the Commonwealth Minister for the Environment due to its potential impact on Matters of National Environmental Significance (MNES). The assessment path for the Project was confirmed to be under the bilateral agreement between the Commonwealth and NSW Governments, and the Department of Environment and Energy (DoEE) issued its assessment requirements which were incorporated into the SEARs for the Project and addressed in the Project EIS.

As discussed above, the Project EIS was submitted and then placed on public exhibition from 11 December 2019 to 14 February 2020. A total of 359 submissions were received, which included 16 agency submissions and 343 community and interest group submissions. The 343 submissions received from the community and interest groups included 205 in support, 127 submissions which objected to the Project and 11 were provided as comments.

2.0 Response to IESC Submission

The initial questions posed to the IESC, including the comments/recommendations in the numbered paragraphs are identified in the following sections in text boxes. The response to the IESC comments/ recommendations in these paragraphs are provided following each relevant text box.

The responses to groundwater related questions have been prepared in consultation with Australian Groundwater and Environmental Consultants Pty Ltd (AGE) which prepared the Groundwater Impact Assessment (GIA) for the Project (refer to Appendix 16 of the EIS). The responses to surface water assessment issues have been prepared in consultation with GHD which prepared the Surface Water Impact Assessment (SWIA) for the Project (refer to Appendix 17 of the EIS). **Appendix 1** includes additional technical analysis undertaken by GHD to support the response.

2.1 General

Question 1: Do the groundwater and surface water assessments in the EIS provide adequate mapping and delineation of surface and groundwater resources?

1. The Environmental Impact Statement (EIS) generally provides adequate mapping and delineation of surface water and groundwater resources at a broad scale.

Noted.

2. Modelling of a 'unit' pool to predict potential impacts on refugial pools has limited value given each refugial pool will have unique characteristics that cannot be captured by modelling of a single 'representative' pool. The IESC instead suggests the proponent undertake further field studies to map refugial pools and determine their characteristics including groundwater connectivity. This information should be obtained for all refugial pools in potentially affected creeks, particularly those within Yorks Creek that will likely be lost and which should, ideally, be recreated within the diversion.

Section 2.0 of **Appendix 1** includes a further assessment of the Project's potential impacts on water levels in three pools within Bowmans Creek using survey data. Overall, the results of the modelling using the surveyed actual pools is consistent with the results presented in the SWIA, which supports the conclusion that no measurable surface water impacts on the persistent pools in the lower part of Bowmans Creek is expected as a result of the Project.

As discussed in the GIA (AGE 2019), there is strong evidence to support the connectivity between remnant pools and the Bowmans Creek alluvium. While the modelled impacts on persistent pools indicates that the Project's impacts are unlikely to be measurable, the connectivity between the pools and alluvium will provide significant buffering capacity in terms of water quality and temperature change. The modelled minor flow reductions are not considered to be of a scale that would have an observable effect on dissolved oxygen levels.

2.2 Surface Water

Question 2: To what extent can decision makers have confidence in the prediction of potential impacts on surface water resources provided in the EIS, including in regard to potential stream flow losses, water quality, uncontrolled discharges and flooding?

3. Stream flow losses have been predicted considering both changes in alluvial groundwater discharges and altered catchment areas. Results have been presented for each creek potentially impacted by the project. Predicted streamflow was provided for current, operational and post-mining (both proposed and approved final landforms) periods. Although only limited confidence can be given to the absolute estimates of existing streamflows, the changes to catchment areas are modest and thus it is reasonable to assume that the associated changes to flows are small compared to the natural variability of the system. However, considerably less confidence can be given to the impacts on baseflows given uncertainties concerning alluvium recharge behaviour, as discussed in Paragraphs 14-15. The proponent notes that they currently do not hold sufficient water access licences (WALs) for some water sources but has committed to obtaining any WALs required during operational and post-mining phases. It is currently unclear what volumes will require licensing in the post-mining phase. This information, determined from updated modelling, should be provided in the Rehabilitation Management Plan.

The licensing requirements in relation to groundwater take (and any associated impacts on stream flow) is informed though groundwater modelling rather than actual measurements of intercepted groundwater. The modelled licencing requirements for the Project during operations are set out in Section 7.5.8 of the EIS with post-closure take licencing requirements set out in Table 7.29 of the EIS.

The current NSW regulatory arrangements require that relevant licences are held at the time that 'take' occurs; there is no requirement that licences relevant to post closure take are held prior to project approval. Section 7.5.8 of the EIS also outlines the proposed licensing strategy for the Project which is consistent with the existing regulatory arrangements in place for the Mount Owen Complex.

The timing and magnitude of modelled post-closure take is directly linked to the recovery of the regional groundwater system. As discussed in the EIS, the recovery of the groundwater system is strongly contingent on the timing of approved and historical mining at both the Mount Owen Complex and surrounding mining operations. The modelling undertaken for the Project and reported in the GIA indicates the predicted cumulative groundwater impact and the projects incremental impacts based on currently approved operations and the timeframes for mining at those operations.

Throughout the life of the Project, the regional groundwater model will be periodically reviewed (at least every 3 years) and updated and revised as new information becomes available. These updates will include any changes to approved mining operation, including timing assumptions. These updates will provide ongoing guidance on the take requirements associated with the operation both during the life of the Project and following the cessation of mining.

The Mine Closure Planning process will commence at least 5 years prior to the cessation of mining and include a full review of modelled groundwater impacts following the cessation of mining. A process of ensuring that all long term take, including surface water take, is appropriately licensed in accordance with regulatory processes in force at that time will be developed in consultation with the relevant regulators. These arrangements will be documented in the final mine closure plan for the Project developed at least 2 years prior to the planned cessation of mining.

4.	**Potential water quality impacts have not been explored in detail as the proponent expects that the existing management strategies will be adequate to prevent impacts and no discharges are permitted from the project site. Further spatial and temporal detail of water quality data (e.g. plots of analytes at individual sites over time) could have been provided to improve the characterisation of historical conditions within water resources that may be impacted by the project. The IESC suggests some refinements of the current surface water and groundwater monitoring programs which are outlined in the response to Question 12.**

The Project does not involve any material changes to activities at the Mount Owen Complex that are expected to have any impact on surface water quality relative to approved operations.

As discussed in Section 7.5.9.2 of the EIS, the Mount Owen Complex Surface Water Management and Monitoring Plan will be updated to reflect the changes associated with the Project. The proposed management recommendations contained in the EIS include a commitment to update site specific guideline values used in the Surface Water Management and Monitoring Plan.

This issue is discussed further in response to Question 12 (refer to **Section 2.3**).

5.	**The likelihood of uncontrolled discharges from water storages at the project site has not been reported. As the project will be part of the GRAWTS, the proponent will have considerable flexibility to move water across several mining operations to where storage capacity is available which will limit the likelihood of uncontrolled discharges. The water balance showed that forecast water inventory will be considerably less than available storage capacity across the GRAWTS, particularly from the early- 2020s when mining will begin to cease at adjacent mines and their pits will be available for water storage (Umwelt 2019a, pp. 271-272). Should any of the adjacent mines be extended leading to an increase in the volume of produced water requiring management through the GRAWTS or a decrease in storage capacity, the proponent will need to update their water balance.**

The operation of the GRAWTS is subject to a range of operating controls including available water licences, environment protection licences (EPL), and Hunter River Salinity Trading Scheme discharge restrictions at Ravensworth Operations and Liddell Coal Operations. The site water balance for the GRAWTS prepared as part of the Surface Water Assessment (Appendix 17 of the EIS) assumed no change to existing licence allocations. This assessment concluded that the GRAWTS has sufficient storage and groundwater and surface water allocations to meet water demands at all operations within the GRAWTS including the proposed Project.

Connections and modifications to the GRAWTS between operations is dealt with through modifications to existing consents. The assessment of these modifications includes consideration of the implications for the water balance within the GRAWTS.

6.	**The proponent should clarify where the rehabilitated former Swamp Creek catchment will be routed in the final landscape. Gippel (2019, p. 21) suggested that it would be redirected upstream of the proposed Yorks Creek diversion which conflicts with GHD's (2019, p. 69) suggestion that flows in Bettys Creek would be increased by flows from the former Swamp Creek Catchment. Additionally, the proponent will need to confirm that flood modelling, diversion design, streamflow changes and catchment area changes have been determined appropriately for where Swamp Creek will be routed.**

The changes to the former Swamp Creek catchment area proposed by the Project only affect those sub-catchment areas currently within the Mount Owen Complex Water Management System (WMS) which are currently approved to be rediverted back into Swamp Creek.

The Project does not result in any increased diversion of the former Swamp Creek Catchment to the Yorks Creek catchment. The assessed changes in catchments are described in Appendix C of the SWIA and, in particular, Figures 3.2 to 3.3 of Appendix C.

The northern parts of the former Swamp Creek catchment include clean water catchment areas (which currently report to two dams north of Mount Owen's North Pit emplacement area) and areas currently managed within the Mount Owen Complex WMS. The clean water catchment areas currently report to Yorks Creek and have been considered as part of the existing catchment for the purposes of the streamflow analysis and flood modelling. These assessments also consider the progressive release of catchment runoff from the northern areas of the North Pit emplacement areas throughout the life of the Project to Yorks Creek consistent with existing approved operations. The Project does not affect these currently approved distributions of catchment flows over time.

The central areas of the Mount Owen Complex are located in what was the middle sections of the Swamp Creek catchment (pre-mining). These areas of the former Swamp Creek Catchment (outside of the Bayswater North Pit void catchment area) are currently approved to be returned to Swamp Creek via a reinstated creek line to the south of the capped West Pit emplacement area. The changed landform associated with the in-pit emplacement of overburden in the Glendell Pit Extension as the pit progresses to the north necessitates the redirection of these areas of the former Swamp Creek catchment to the south and into Bettys Creek, as noted in GHD's assessment (2019).

Question 3: Are the assumptions used in the surface water models reasonable and justifiable, and have the respective models been validated with sufficient monitoring data to provide meaningful prediction, including worst-case impacts on surface water resources?

7. The limitations in available streamflow data and the large discrepancies between the observations and AWBM model outputs (in the case of Bowmans Creek) mean that little confidence can be given to the absolute estimates of streamflows. The assumptions used to assess the relative impacts of changed catchment areas on streamflows under final and worst-case conditions are reasonable. However, the surface water assessment of baseflow impacts is dependent on the defensibility of the alluvial groundwater behaviour as characterised by AGE (2019), and this is subject to the limitations and uncertainties discussed in Paragraphs 14-18.

This is discussed further in relation to the responses to Paragraphs 14-18 (refer to **Section 2.4**).

2.3 Flooding

Question 4: Has the flood assessment undertaken in the EIS adequately assessed the flood risk profile of the Project and the impacts on the extent of flooding (flood depths and changes in velocity) and stability of downstream watercourses through changes in the landform (including the proposed realignments of Yorks Creek and Hebden Road) and the resulting changes to the catchment area?

8. The flood modelling and assessment provided in the EIS has considered changes to flood depths and velocities at several locations. Scenarios were modelled for different project stages (operational and final landform) and included changes to infrastructure relevant to that stage, including the realignment of Hebden Road. Changes in catchment areas were also considered. Changes in flood depth and velocity are clearly presented and allow comparison between different scenarios. Overall, it is considered that the adopted methodology is consistent with the most recent national flood guidance (Ball et al. 2019) and the assessment was undertaken to a good standard.

Noted.

9.	**The flood modelling results have identified that the greatest increases in flood depths and velocities appear to occur in Bettys Creek. Cross-sectional shear stress within the Yorks Creek diversion for the 1% annual exceedance probability (AEP) event may exceed stability thresholds (GHD 2019, App. C, p. 29) although it is unclear where exactly within the Yorks Creek diversion this may occur. The proponent has stated that further detailed modelling is needed to identify appropriate mitigation measures. This modelling should be completed to inform the detailed design phase of the Yorks Creek diversion and development of the Rehabilitation Management Plan. If cross-sectional shear stresses are great enough to require rock armouring for channel stability, this will affect the habitat that can be produced in the diversion and potentially limit local riparian revegetation, disrupting its continuity along the diverted channel.**

Section 3.0 of **Appendix 1** includes a further assessment of velocity and shear stresses in each of Bowmans Creek and the proposed Yorks Creek Realignment.

Actual measures to mitigate potential impacts associated with the stability of the Yorks Creek Realignment will be confirmed during the detailed design phase with equivalent performance to be achieved using a range of measures developed in accordance with the design principles outlined in the SWIA. This will be completed through an iterative design process where the channel geometry and materials properties selected to mitigate potential impact of channel stability, in turn influence the design hydraulic characteristics.

The Yorks Creek Realignment Conceptual Detailed Design (refer to Appendix 7 of the EIS) is designed to be stable and incorporate geomorphic characteristics consistent with the existing creek line. The conceptual design currently includes details of proposed riparian vegetation treatments, hard landscaping features such as placed logs and boulders, an alluvial fan with shallow slope, low flow channel in areas of fill and sections of exposed rock bed at the base of the channel as well as stilling ponds in steeper cutting areas to dissipate energy. This is combined with a channel sinuosity that has been selected to reflect the sinuosity of the natural creek system. The detailed design will continue to be developed in accordance with the conceptual design to provide a more 'natural landform' rather than rely on hard engineering treatments.

10.	**Additional discussion of predicted flood depths and velocities at the confluence of Bowmans Creek and the Yorks Creek diversion, and within the lower reaches of the Yorks Creek diversion (up to at least the Hebden Road crossing) should be provided. Current predictions show that the lateral extent of flooding within Bowmans Creek at the confluence is less than in many other parts of Bowmans Creek and that ponding in the lower reaches of Yorks Creek diversion is not expected. Given the significant change in bed slope from 0.04 m/m to relatively flat conditions that occurs 150 m before the confluence (Gippel 2019, p. 37), further assessment of the stability of the watercourse (see Paragraph 36) is required.**

Section 3.0 of **Appendix 1** includes a further assessment of velocity and shear stresses in each of Bowmans Creek and the proposed Yorks Creek Realignment. This assessment indicates reasonable and feasible measures are available to manage potential stability risks. Final measures for managing stability risks will be selected as part of the detailed design phase.

11.	**The proponent has considered the potential worst-case scenario for flooding through the probable maximum flood (PMF) event, which is an indication of the upper limiting flood magnitude with an annual exceedance probability that is notionally less than 10-6.**

Noted.

12.	**The proponent has used modelling of the 0.2% and 0.5% AEP flood events as a proxy for assessing the effects of potential climate change. It is not clear from the documentation why this approach was used in lieu of the simple temperature-scaling approach recommended in the national guidance (Ball et al. 2019); however, it is assumed that the results are intended to represent the impacts of climate change on the 1% AEP event. While unconventional, this is a reasonable approach that is notionally indicative of the impacts on rainfall intensities under climate change.**

The use of the 0.2% and 0.5% AEP flood events as a proxy for assessing potential climate change impacts was identified as a requirement of the NSW Office of Environment and Heritage (as it then was) in the Secretary's Environmental Assessment Requirements for the EIS:

> *"The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios: a. Current flood behaviour for a range of design events as identified in 11 above. This includes the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change."*

The IESC's comment that this approach is considered to the reasonable are noted.

13.	**The stability of downstream watercourses beyond Bowmans Creek has not been discussed in detail. As limited erosional changes are predicted within Bowmans Creek downstream of the diversion (Gippel 2019, p. 47), changes further downstream are likely to be also minimal but this prediction should be confirmed with additional monitoring (see Paragraphs 49 and 51).**

Section 3.2 in **Appendix 1** includes specific consideration of downstream scour and erosion risks associated with the proposed Yorks Creek Realignment. Despite this risk of erosion and scour remaining low, downstream monitoring is proposed as a precautionary measure.

The additional review of the hydraulic conditions downstream of the confluence of Bowmans Creek and Yorks Creek Realignment in **Appendix 1** identified two areas of Bowmans Creek where the reaches are generally constricted and slight increases in velocity and shear stress are predicted by the modelling. These two reaches are considered the most likely location for potential impacts of the Yorks Creek Realignment on Bowmans Creek, if any, to manifest as measurable changes. Watercourse stability monitoring is therefore proposed in these areas to monitor the potential impacts from the Yorks Creek Realignment.

The monitoring will be integrated into the monitoring program for the Yorks Creek Realignment and including baseline monitoring in these areas prior to the commissioning of the realignment. The variability in bed and channel condition means that the identification of specific points should be based on site inspections. Specific monitoring locations will be identified in the Detailed Yorks Creek Realignment Plan and be incorporated into the broader Mount Owen Complex monitoring program.

2.4 Groundwater

Question 5: Is the conceptual regional groundwater model developed based on a sound understanding of the altered hydrogeological environment of the area due to historical open cut and underground mining, including the alluvial aquifers within the Project's zone of influence?

14. The qualitative conceptual model provided (Umwelt 2019b, App. B) shows expected changes to the hydrogeological regime at the site as the project progresses. However, the magnitudes of changes, particularly those relating to changes in upward leakage from the Permian aquifer and downward leakage from the alluvial aquifers are not quantified. Recharge rates to the shallow alluvium aquifer are also not quantified. As the water balance for the alluvial aquifers has not been adequately quantified, it is not possible to evaluate whether the conceptual model is based on a sound understanding of the current and likely future hydrogeological environment of the area. The proponent should provide further quantitative information on leakage and recharge rates and on the interaction of groundwater in the alluvium and along the watercourses. Additionally, the conceptual uncertainties of the water balance fluxes should be explored further in the uncertainty analysis (see Paragraph 18).

Paragraph 18 states that the magnitude of changes in groundwater flow within the Bowmans Creek alluvium have not been quantified. This is not correct. The focus of the groundwater assessment from commencement was to assess the groundwater level changes within the Bowmans Creek alluvium, and the associated changes to exchanges with the underlying Permian bedrock. The process was undertaken using the long term baseline water level records and numerical modelling.

The project site has a good baseline dataset to understand interaction between the alluvium and Permian with the GNP monitoring network installed in 2012. The GNP-series of monitoring bores and vibrating wire piezometers (VWPs) are located along the Bowmans Creek flood plain.

The records from these bores generally show a downward trend in groundwater pressure and level within the coal seams due to depressurisation induced by surrounding mining. Adjacent to the Project site the coal seams have now been depressurised to a level which is below the base of the Bowmans Creek alluvium. This means in many areas there is no potential for upward flow of groundwater from the Permian coal measures to the Bowmans Creek alluvium as the hydraulic gradient has reversed and is downwards from the alluvium to the underlying Permian. The fact that the overlying Bowmans Creek alluvial aquifer shows no notable drawdown in response to open cut mining indicates the volume of groundwater moving downwards to the Permian is limited and less than recharge rates from rainfall and streamflow that serve to buffer any losses. The fact the alluvial aquifer remained largely saturated during the 2018/2019 drought period indicates that losses to the underlying Permian strata are not large.

Four cross sections passing through the Bowmans Creek flood plain have been prepared to show the relationship between the alluvial aquifer, the Permian bedrock and the approved and proposed mining activities. The locations of the sections are shown in Figure 2.1. The cross sections are in Figure 2.2 to Figure 2.5 and illustrate the:

- geology and main coal seams occurring in the area
- open cut and underground mining areas
- modelled water table prior to significant mining in the locality (1980), at the end of mining and after the groundwater regime has recovered post mining

- the piezometric surface in the Middle Liddell coal seam also at the end of mining, and also after the groundwater regime has recovered
- monitoring bores and vibrating wire piezometers in close proximity to the section line.

The cross sections illustrate how the water table remains within the Bowmans Creek alluvial aquifer at the end of the project, whilst the coal seams are depressurised and water levels have fallen below the base of the alluvium due to the cumulative impact of the Project and surrounding activities. This condition currently exists due to existing mining activities and is observed in monitoring in the GNP series of monitoring bores. Currently there is a downward hydraulic gradient established from the alluvium into the underlying Permian bedrock due to the depressurisation of the bedrock strata by mining, and this remains at the end of the Project. The water levels on the sections show how the piezometric surface within the coal seams rebounds after mining ceases, but does not reach the level of the water table within the Bowmans Creek alluvium. A downward hydraulic gradient between the alluvium and Permian remains post mining, albeit not as steep as whilst all mining activities are occurring. The impact of this downward hydraulic gradient post mining would be a limited loss of alluvial groundwater into the underlying Permian strata, resulting in drawdown within the alluvium of generally less than 1 m, and between 1 m and 2 m immediately adjacent to the final void. This amount of drawdown will not desaturate the alluvial aquifer.

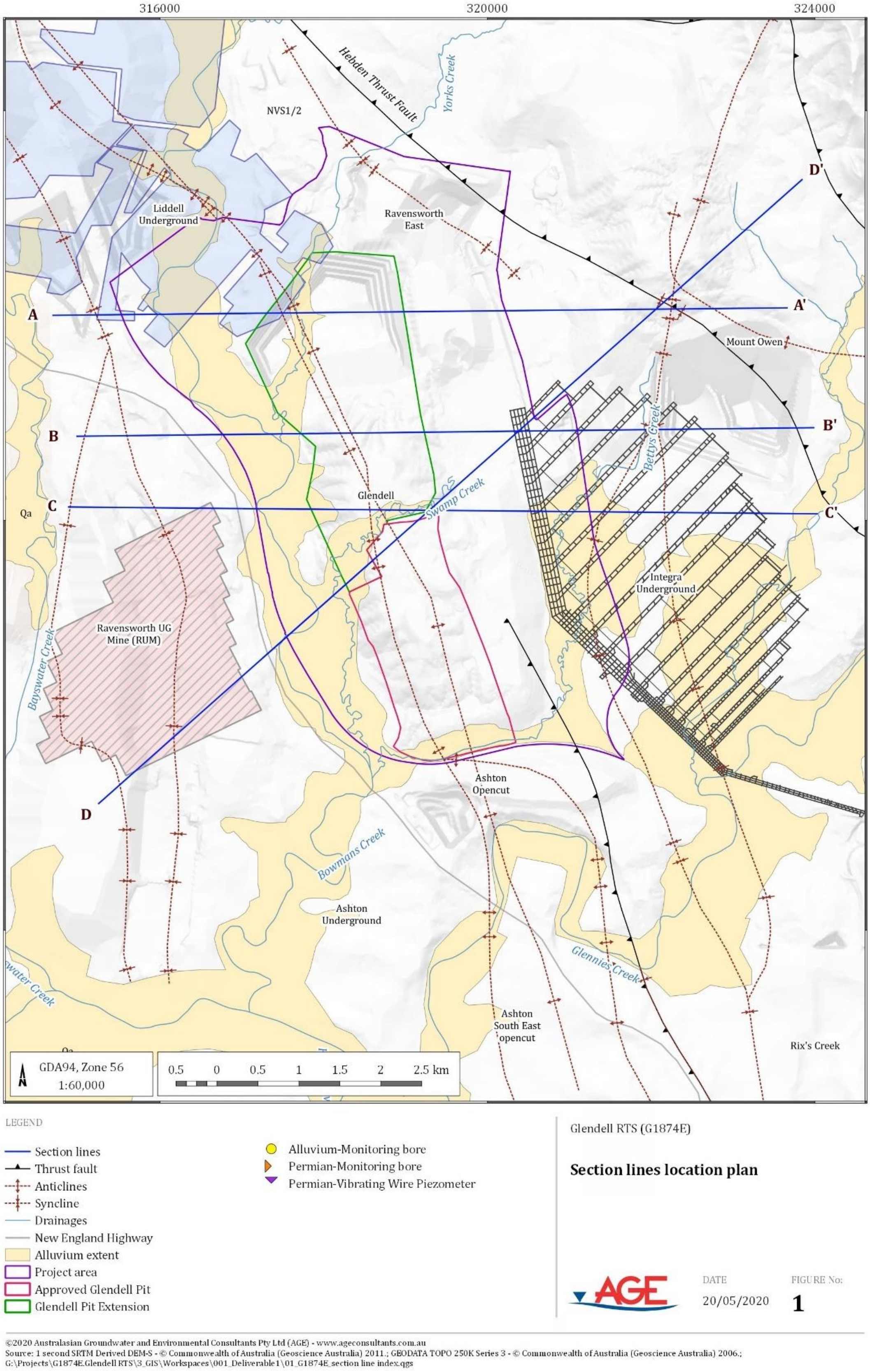

Figure 2.1 Section Key Map

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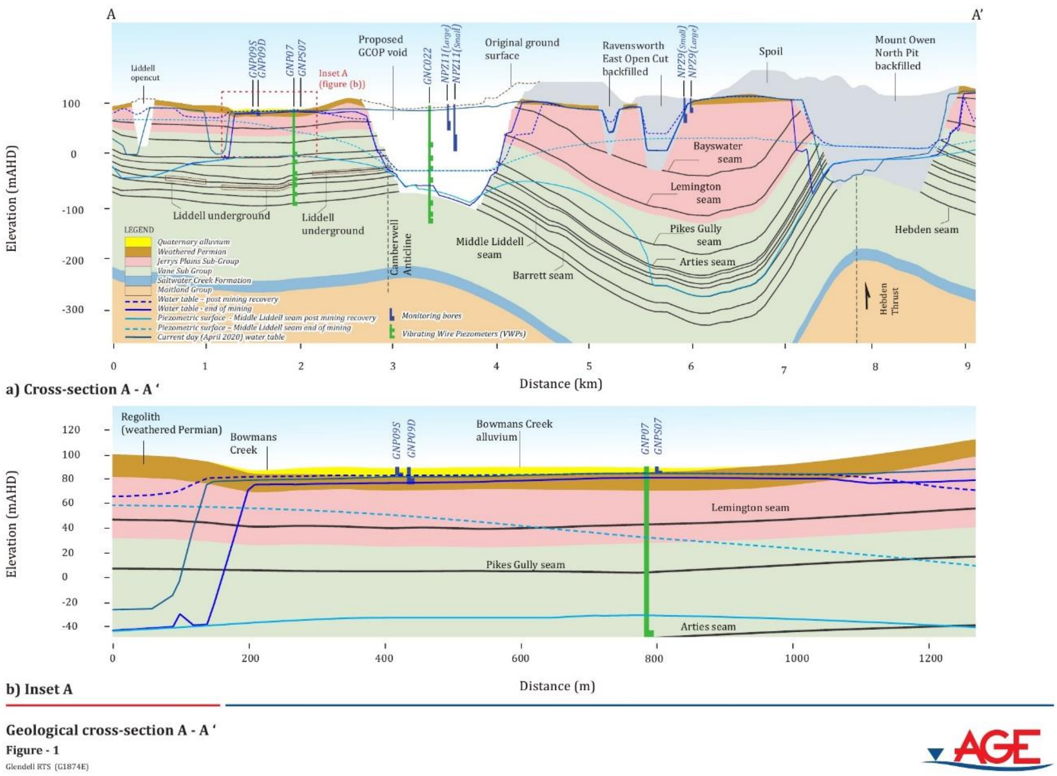

Figure 2.2 Section A – A'

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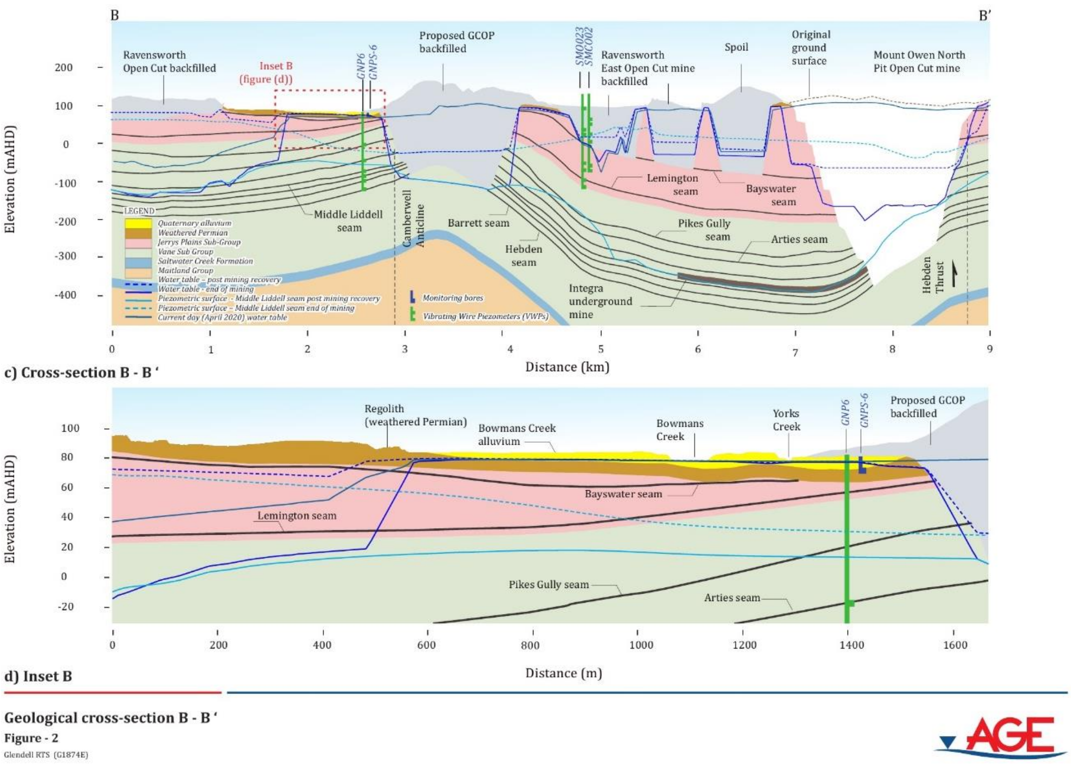

Figure 2.3 Section B – B'

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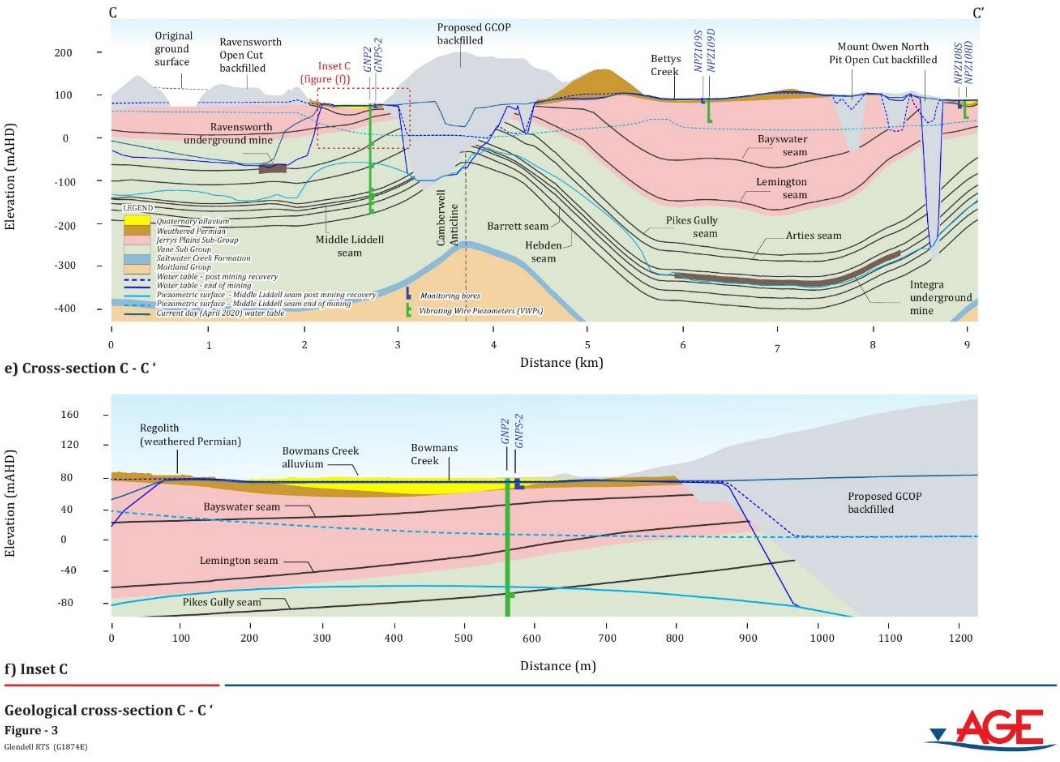

Figure 2.4 Section C – C'

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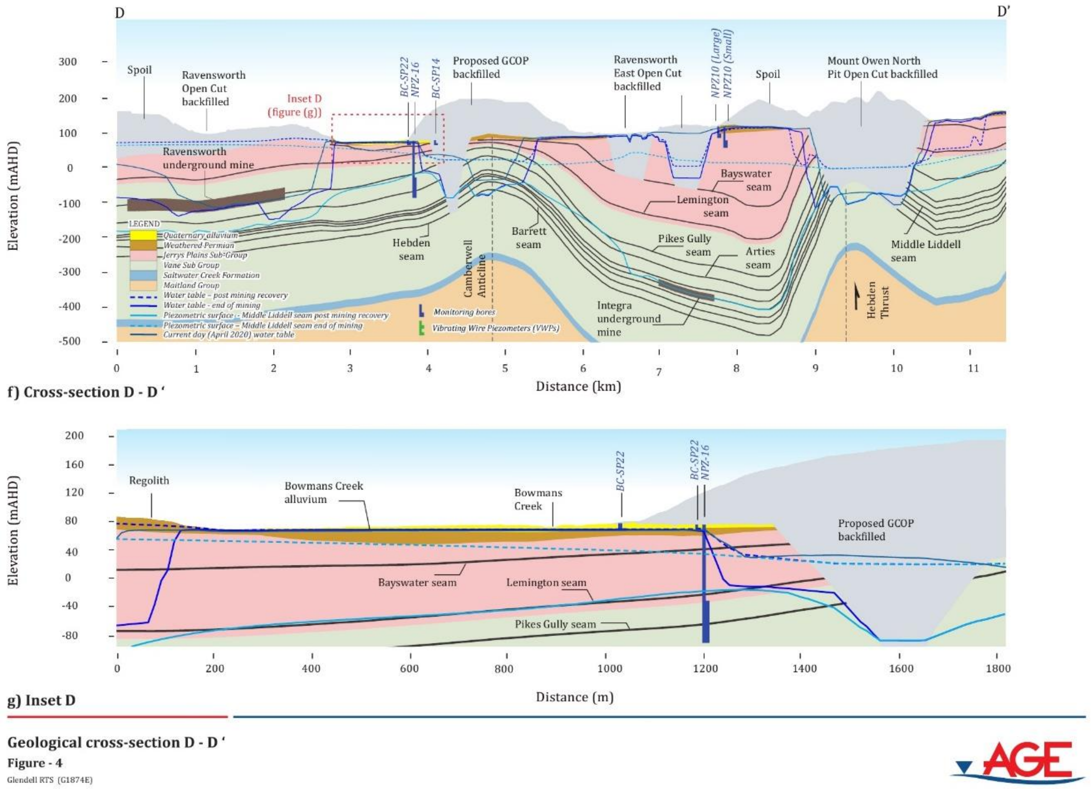

Figure 2.5 Section D – D'

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A summary of the water budget for the alluvium between each section line is provided in Table 2.1 . The water budget is taken at the end of the proposed mining. The table includes the following water budget elements:

- diffuse rainfall recharge to the alluvial aquifer
- flow from Bowmans Creek into and out of the alluvial aquifer
- groundwater inflow to the alluvial aquifer from upstream at the location of the section and downstream outflow
- evapotranspiration from the water table within the alluvium
- downward flow from the alluvial aquifer into the underlying bedrock.

Table 2.1 Alluvial Zones Water Budget At End Of Mining (m^3/day)

Water budget item	Section A – A'		Section B – B'		Section C – C'		Section D – D'	
	No Project	With Project	No Project	With Project	No Project	With Project	No Project	With Project
Diffuse rainfall recharge	103.6	103.6	18.9	18.9	34.5	34.5	123	123
Streamflow leakage into alluvium	1.9	1.9	1	1	1	1	0.8	1
Lateral flow into alluvium	0	0	12.5	11.1	16.6	12.8	22.5	21.1
Permian bedrock flow into alluvium	0.4	0.3	0.6	0.7	1.7	1.5	3.4	1.4
Total input to zone	105.9	105.8	33	31.7	53.8	49.8	149.7	146.5
Evapotranspiration out alluvium	3.9	3.7	1.5	1.5	1.7	1.6	37.2	30.1
Discharge to baseflow	2.1	1.5	3.4	1.5	17.9	12.7	36.3	32.3
Lateral flow out of alluvium	0	0	2.1	3.3	0.1	0.1	0.6	2.4
Alluvium flow into Permian bedrock	101.4	105.1	23.6	27.7	21.6	26.1	62.6	71.6
Total output to zone	107.4	110.3	30.6	34	41.3	40.5	136.7	136.4

The water budget tables show how the alluvial aquifer receives recharge from three sources (i.e. diffuse rainfall across the flood plain, seepage of stream flows and from the upstream alluvial through-flow). The tables indicate the predicted volume of groundwater leaking to the underlying bedrock due to the depressurisation of the Permian strata from the mining activities in the model. The difference in flows for the versions of the model with and without the Project quantifies the influence of the Project. It is important to note the water balance is for the end of mining and the groundwater system is not in equilibrium, therefore the sum of the water balance elements does not equal zero due to changes in aquifer storage. Further, it is important to note that the water budgets for the predictions are based on average rainfall recharge rates.

Section A-A' is located in an area where the alluvium is predicted to become unsaturated due to the cumulative impact of surrounding approved mining and the Project. The water budget for alluvial through-flow is therefore zero in this case. The outflows at this point are close to being in balance. Under both the Project and No Project scenarios for the average rainfall conditions modelled, resaturation of the alluvium would be expected in above average rainfall years due to increases in creek flows and rainfall recharge.

Table 2.1 shows that the combined volume from the recharge inputs exceeds the losses through the base of the alluvium into the underlying bedrock for Section C-C' and D-D'. This is why this area of the alluvial aquifer is not predicted to be significantly drained by the approved and proposed mining activities. Losses slightly exceed inputs for the alluvial aquifer at Section B-B' which is why drawdown is predicted within the alluvium in this area adjacent to the open void. At section A-A' losses also slightly exceed inputs for the alluvial aquifer for both approved mining and the Project. It is noted that the incremental net losses modelled for each section which are attributable to the Project are very small and do not exceed 5 m^3/day (0.005ML/day) at any of the sections considered.

As noted above these model predictions are supported by the observations from the baseline monitoring bore network along Bowmans Creek that has recorded the water table remaining within the Bowmans Creek alluvium, whilst the underlying coal seams are depressurised by adjacent open cut and underground mining activities. In effect the approved mining in the region has already disconnected the alluvial water table from the Permian strata and this condition will continue even if the Project is not approved. As can be seen from the water budgets and the cross sections B, C and D, there is little discernible difference between existing, approved and predicted water levels and water take.

When interpreting the model predictions it is important to note that the movement of groundwater from the Bowmans Creek alluvium into the underlying depressurised bedrock can never be measured. It can only be inferred to be occurring from water level measurements between layers and by using numerical modelling to provide estimates of water transfers. This means there will always be some inherent uncertainty in the volumes of water moving from the alluvial aquifer into the underlying bedrock. However, given the limited scale of predicted impacts and observations from existing monitoring further uncertainty analysis beyond what is presented in the GWIA is not considered warranted.

15. The proponent has provided monitoring data from several sites to demonstrate that depressurisation of the Permian groundwater system has not propagated into the alluvial groundwater system during approved mining at Glendell Mine. Within the Bowmans Creek alluvium, they have conceptualised that fresh recharge to the aquifer is greater than the prior upward leakage from the Permian groundwater system (AGE 2019, p. 58). However, the proponent noted that within other alluvial groundwater systems, water quality data suggested fresh recharge was less than upward leakage (AGE 2019, p. 70). It is unclear how this conceptualisation has been considered in the groundwater model as calibrated rainfall recharge to the alluvium is stated to exceed downward losses (AGE 2019, p. 96). Also, it is unclear whether groundwater drawdown within the Permian groundwater system could also propagate into overlying alluvial aquifers associated with creeks other than Bowmans Creek, and how this is likely to change over decades. The proponent should further evaluate this potential impact, particularly for Swamp Creek where project-specific drawdown is already predicted but could potentially be greater if upward leakage is a larger portion of inflows to the alluvial aquifer than currently modelled.

The GWIA (Section 5.2) detailed the clusters of monitoring bores installed to evaluate the hydrogeological properties of the Swamp Creek and Yorks Creek alluvium. In contrast to Bowmans Creek the monitoring bores installed within Quaternary alluvium along Yorks Creek and Swamp Creek record very limited saturated thickness or are dry. Figure 5-2 in the GWIA shows both Yorks Creek and Swamp Creek, which will be intersected by the proposed mining, have a relatively narrow flood plain with the alluvium being relatively thin and largely above the water table. The monitoring bore logs indicate a lower energy depositional environment with coarse gravels uncommon and finer sandy clay sediments predominant within the alluvial sequence. The available data indicates the alluvium occurring along Yorks Creek and Swamp Creek exhibits limited aquifer saturation only where it merges with the Bowmans Creek alluvium and is predominantly dry upstream of these low lying areas where it is proposed to be removed by mining. East of the Project Area Yorks Creek and Swamp Creek rise into areas of higher elevation and the bed of the creeks rise above the water table occurring within the underlying weathered rock.

Question 6: Has the numerical groundwater model been calibrated with sufficient monitoring data to provide meaningful model outputs, including worst-case impacts on groundwater resources?

16. All available monitoring data appear to have been used to history match (calibrate) the groundwater model. However, the history-matched model does not replicate observations closely for several history-matching target locations. Additionally, multiple history-matched hydrographs provided show that the observed groundwater levels are not within the 95% confidence interval of the prediction hydrographs (AGE 2019, App. B2 of App. B). Examples include DDH223-120 (observed head approximately 50 m lower than predicted head), CS4658-BRT (observed head almost 50 m lower than predicted head) and GCP34 (observed head approximately 30 m lower than predicted head). The IESC considers that while it is important that sufficient monitoring data are used to history match groundwater models, the ability of the model to replicate observed data is crucial for providing confidence in the model predictions.

The calibration process for the numerical model aimed to reproduce the water levels measured in the monitoring network within or close to the Project site and Bowmans Creek as this is where the Projects impacts would be most significant and require the most confident prediction. The GNP series installed along Bowmans Creek was the focus of the calibration and these sites were weighted using PEST to focus the history matching calibration on these sites. The calibration hydrographs for these bores generally align with measured levels (refer AGE 2019, Appendix B2).

Monitoring bores and VWPs located more distant from the Project site were assigned a lower weighting during the calibration process to ensure calibration effort remained where it was most required at the Project site. Paragraph 16 refers to several sites as providing underpredictions of groundwater level including DDH223-120, CS4658-BRT and GCP34. DDH223-120 is part of a multilevel piezometer nest with seven VWPs installed between 120m and 478m below surface. This site is relatively remote, being located some 2.5 km south-east of the Project site. CS4658-BRT is a further 6.5 km west within Ravensworth Mine, and GCP34 is 6 km south adjacent to Rix's Creek Mine on the southern side of Glennies Creek. Whilst a closer match between measured and modelled groundwater levels at these sites would be pleasing, the relatively distant nature of these bores from the Project site means the achieved outcome is not expected to have significantly affected the nature of the predictions around the Project.

The model utilised to assess the impact of the Project is a large regional model with a relatively large number of monitoring sites and water level records. The water levels also exhibit significant variability due to the depressurisation that varies spatially and vertically through the geology due to mining within the model domain. The hydraulic properties of each model cell were allowed to vary during the calibration process within a predefined range to maximise the potential to reproduce the measured water level trends and allow the natural heterogeneity occurring in the alluvial sediments and porous/fractured rock units to be represented. Continued calibration of the groundwater model may have achieved closer matches between measured and simulated water levels at some sites. However, this could be at the risk of adopting hydraulic properties and recharge rates outside realistic ranges to achieve the improved match. It is therefore considered the approach to the model calibration has produced model properties that provided a useful prediction of impacts and uncertainty to guide management of groundwater resources around the Project site, particularly within the Bowmans Creek alluvial groundwater system.

17.	**The IESC notes that residuals are greater in the 0-50 m AHD range meaning that the model is not replicating observations in this depth range, which the proponent has acknowledged (AGE 2019, App. B, p. 38). Further information is required on which strata and model layers occur within the 0-50 mAHD range including clearly identifying these on the conceptual model graphics. Additionally, an analysis of spatial history-matching trends is needed. History-matched results should be provided showing residuals by model layer and location. This information is needed to understand the predictive scenarios for which the model should be used. For example, it currently appears that the model may not be fit for predicting potential impacts to the alluvium and within the 0-50 mAHD depth range. Figure B 30 (AGE 2019, App. B, p. 59) highlights the inability of the model to replicate inferred baseflows by up to two orders of magnitude. Such comparisons are particularly relevant to the predictions of impact on baseflows.**

Water Level Residuals

The groundwater assessment included a chart (Figure B-6) that compared water levels measured in bores and VWPs in the Glendell area with the residuals error determined from modelling. The residual error is the difference between the measured and model simulated water level. The groundwater assessment concluded that the observations above 50 mAHD were more closely matched by the numerical model, whilst the observations from deeper VWPs and monitoring bores that have recorded mining induced depressurisation are not replicated as closely. Most of these discrepancies were considered in the groundwater assessment report to be related to timing offsets in drawdown response. This is a common outcome in regions with a long mining history that in some areas may not be fully known, and must be represented within numerical models with a relatively coarse division of time such as quarterly or longer stress periods. Finer details in underground mines such as development headings and advanced gas drainage are often not represented and can create timing off-sets between model predictions and site measurements.

To respond to the comment in Paragraph 17, a further review of the monitoring sites with the largest residuals was conducted. The monitoring sites with the largest residuals within the 0 - 50 mAHD water level range were identified and are shown in Figure 2.6 below. The locations of the nine monitoring sites with the most significant residuals are shown on Figure 2.7. Charts comparing the measured and modelled water levels at each bore are provided in Figure 2.8. Note these charts are reproduced from the groundwater assessment report Appendix B-2.

All of the sites with the larger water level residuals are relatively remote from the Project site and none are located within the alluvium.

Five monitoring sites are located between about 3 km and 6 km west within the Ravensworth operations. Three of these sites have been removed by mining operations. Some of these sites recorded rising groundwater levels when declining trends were predicted by the numerical model due to the representation of the progressing Ravensworth Operations open cut and underground mines. Whilst the reason for these rising trends is not known with confidence, it could be due to local pit water storage not represented in the numerical model, anomalous sensor measurements, or data processing. Regardless of the reason, the resulting higher residuals at these points are not expected to have influenced the calibration significantly as a low confidence weighting was applied to these sites during the calibration process as they are located remote to the Project area. This is the approach promoted by the Australian Groundwater Modelling Guidelines that recommends against adjusting of model parameters to simulate observed water levels where there may be no rational basis to support this, a process known as overfitting. It should also be noted the groundwater modelling was reviewed by Dr Noel Merrick and the calibration was considered suitable for the intended purpose.

Two sites are located at the Liddell Mine and also have recorded short term rising trends. One of the sensors is within the closed Liddell Underground mine and only disagrees with the numerical model for early measurements. This discrepancy is expected to be a function of the water management within the underground mine, which historically is not known with full accuracy and fluctuates as open cut mining progress through old underground mining areas and water levels are controlled by pumping from bores in the workings for geotechnical stability.

Two VWP sensors installed within the southern footprint of the approved Glendell open cut mine also recorded high residuals, with some rising trends when the model was predicting drawdown. Again, this is concluded to be related to small scale local water management measures not represented within the numerical model, which are not significant at the regional scale.

The approach to the calibration of the numerical modelling was to apply a higher confidence to water level records within close proximity to the proposed mining area to ensure the best water level match was achieved in the area where impacts are most likely to occur. Other more distant monitoring sites were assigned a lower weighting and therefore had a lesser influence on the properties adopted through the calibration process. Therefore, all of the sites with larger residuals are not expected to have unduly influenced the model calibration as they are relatively distant from the Project area and were assigned lower weightings during calibration. The fact the numerical model predicts generally declining water levels due to mining at the monitoring sites indicates the model provides conservative impacts and the calibration has not been unduly influenced by water level observations. None of the subject sites are installed within alluvium.

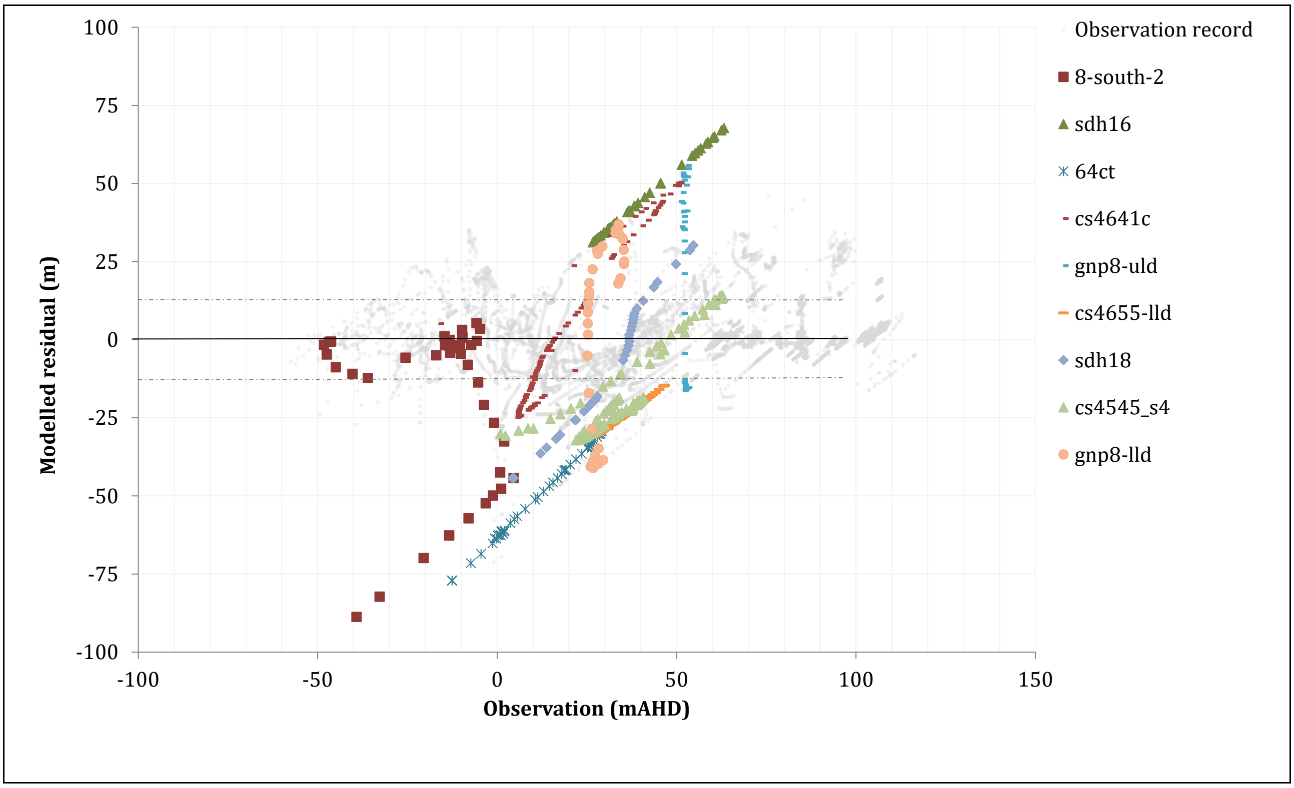

Figure 2.6 Observations versus residuals

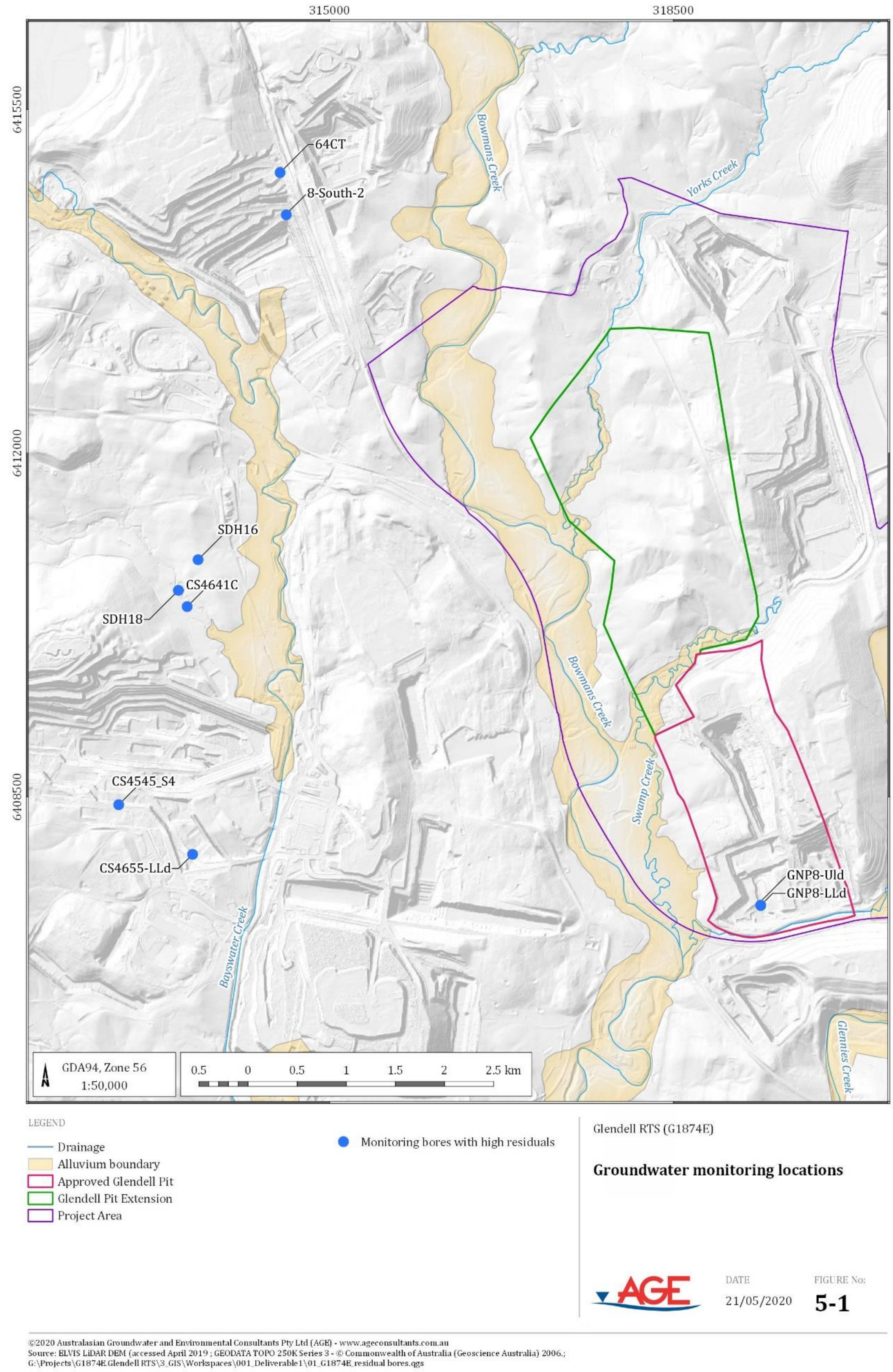

Figure 2.7 Locations of monitoring sites with significant residuals

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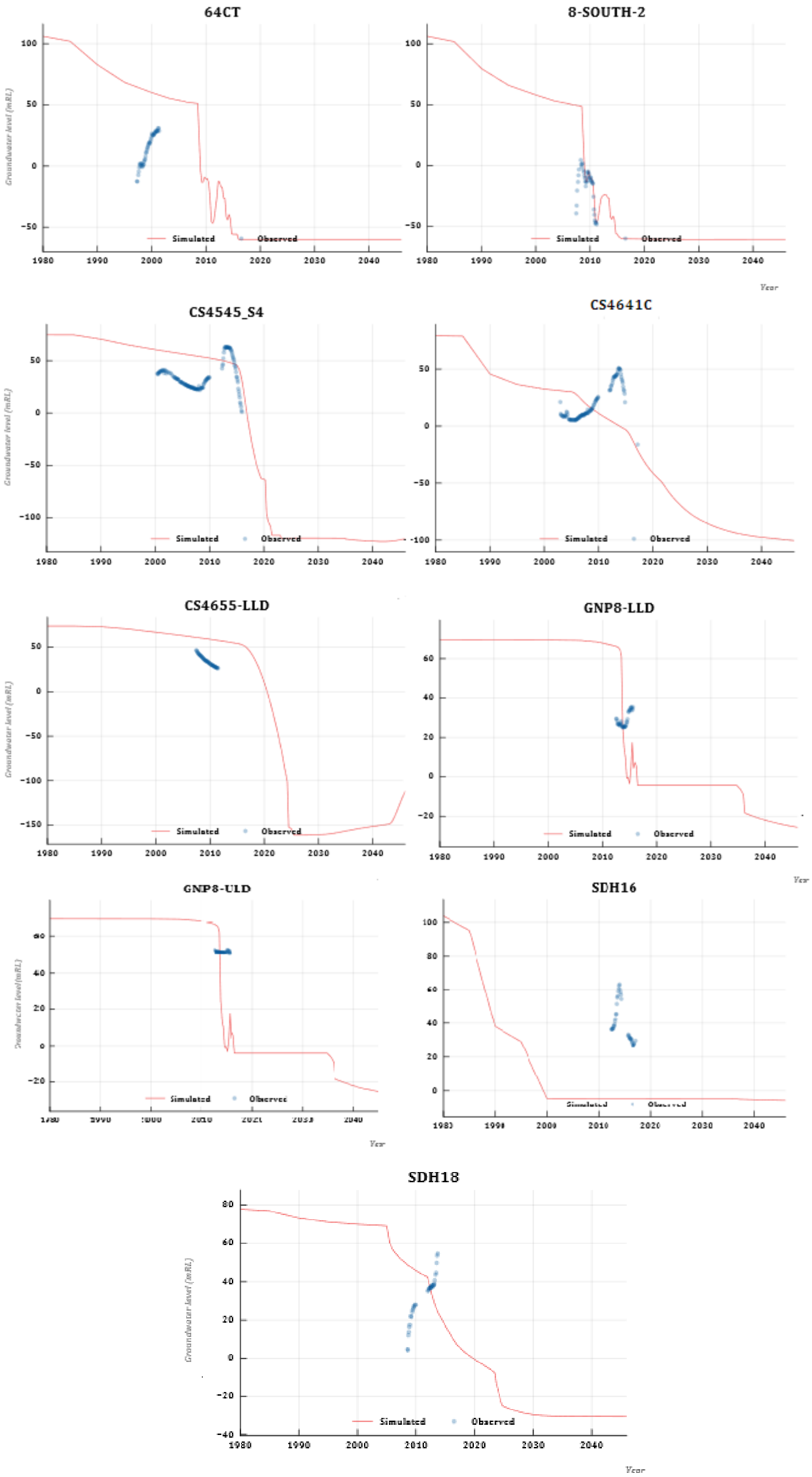

Figure 2.8 Hydrographs for monitoring sites with significant residuals

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Baseflow

The groundwater flow model calculates groundwater flow and baseflow in quarterly stress periods. This means the calculated baseflow is averaged in the groundwater model over the three-monthly stress period. In contrast stream flow gauging and rainfall runoff modelling is conducted on a daily basis. The chart provided within AGE 2019 (Figure B 30 App. B, p. 59), shows the groundwater model is able to predict baseflow trends observed in the monitoring data to generally less than one order of magnitude during periods of low flow. When higher flows are recorded the model shows poorer match to the measurements. This is likely to be a function of the separation of baseflow from rainfall runoff that becomes more challenging during periods of higher flow. Simulating runoff is not the purpose of the groundwater model, and it is the low flows that are most important in terms of baseflow and environmental impacts. The model is considered to simulate these periods with appropriate accuracy for the assessment of potential ecological impacts.

The major impact on the mining operations on high flows is due to capture of mine affected water from catchments. This has been modelled in the SWIA (refer to Section 9 of the SWIA).

18.	**The proponent has provided a Null-space Monte Carlo uncertainty analysis to examine a range of plausible model parameterisations. The probabilities of drawdown exceeding 2 m within the alluvium are presented graphically (AGE 2019, App. B, p. 72). Worst-case take predictions are also explored as part of the uncertainty analysis, and predictions are stated to be within licence volumes except for the Jerrys and Glennies Water Sources (AGE 2019, p. 114). The proponent notes that "Extreme combinations of high recharge, low permeability and low storage promotes groundwater decant through the spoil into surrounding strata" (AGE 2019, p. 114). Further discussion of this should be provided so that the likelihood of these extreme parameterisations (i.e. is this the potential worst-case scenario?) can be assessed, and potential impacts identified and managed. Further discussion is also required to understand how the predictive uncertainty analysis has incorporated the large degree of model-to-observation misfit and whether there are systematic biases at different calibration target locations that need to be accounted for in the predictive uncertainty analysis.**

Spoil decant

The groundwater assessment included an uncertainty analysis as well as a targeted sensitivity analysis investigating a number of conceptual model aspects. The scenarios conducted for the sensitivity analysis are described in the groundwater assessment report, Section B5.4. Scenario 2 was conducted to examine conditions which could promote mounding of water within the pit shell and potentially the flow of groundwater out of the backfilled mining area into the surrounding rock mass post mining and connection to surface and alluvial groundwater systems. To examine this scenario the model adopted a low permeability and high recharge rate for the backfilled spoils to promote the formation of a groundwater mound within the backfilled spoils post mining. Analysis of the model results show all sensitivity scenarios, demonstrated net sink conditions for the entire Glendell Pit Extension, with hydraulic gradients promoting groundwater flow through the backfilled material and into the final void lake with no decant through spoil to surface water or alluvial systems.

Observation misfit and uncertainty analysis

The response to comments in Paragraph 17 investigated the monitoring sites with the larger residuals and discussed the impact on the model calibration. The information on parameters obtained from the calibration process was used to constrain the parameter ranges adopted for exploration in the uncertainty analysis. The parameters were varied within a constrained range of ±50% of the prior range values determined from the calibration. Any models that failed to calibrate after these changes were made to the parameters were discarded.

As discussed in the response to Paragraph 17, the largest residuals occurred due to water level rises recorded in piezometers in close proximity to underground and open cut mining areas and is likely due to short term water storage in these mining areas. There are numerous mining voids (open cut and underground) in the region and temporary water storage within voids following significant rainfall events is common with fluctuations often occurring over periods shorter than the model time steps. The numerical model investigated uncertainty in model parameters only, however the bores with the highest residuals are affected by localised short term events not represented in the model. As discussed in the response to Paragraph 17 the fact the numerical model predicts generally declining water levels due to mining at the monitoring sites with higher residuals indicates the calibration has not been unduly influenced by these water level observations and the model is a conservative tool for regional impact assessment. It therefore follows that the uncertainty analysis, that was constrained by the calibration of the model is also a suitable tool for evaluating the magnitude and likelihood of Project impacts.

19. A peer review of the groundwater modelling was provided. The reviewer noted that reporting of history-matching performance and changes to the magnitude of model outputs when sensitive parameters were varied would be useful (AGE 2019, App. F, pp. 5-6). The IESC agrees that this information should be provided.

The peer review report did not note that "history-matching performance ... would be useful". The groundwater assessment report includes calibration hydrographs within Appendix B2, which was acknowledged in the peer review checklist. The peer reviewer's report noted that an identifiability procedure (Type 3 uncertainty analysis) was used instead of sensitivity analysis by perturbation (Type 1 sensitivity analysis). Identifiability is considered superior to 'sensitivity' as the interactions between parameters are taken into account automatically. The benefit of traditional Type 1 sensitivity analysis is that the effect of varying a single parameter during a prediction simulation is readily observable, whereas this is not possible with a Type 3 identifiability analysis because every parameter is changed. The peer review noted this was a downside of the Type 3 method, but did not indicate it would be useful to vary sensitive parameters to see their effects on model outputs as this is a Type 1 sensitivity analysis approach and is typically only suited to low risk projects. It is considered the Type 3 uncertainty analysis applied in the groundwater assessment is more appropriate for higher risk projects because it provided a more thorough investigation into the range of predicted impacts. Therefore, the combination of identifiability analysis and uncertainty analysis is considered appropriate given the complexity of the Project.

20. Post-mining recovery predictions have not considered the impacts of climate change when assessing rates of groundwater recovery and long-term impacts on GDEs. This should be discussed further by the proponent and be addressed in the Rehabilitation Management Plan.

The post mining rainfall recharge rate in the numerical model was estimated using a soil moisture balance as described in the groundwater assessment (AGE 2019, Section B2.5.1). The soil moisture balance used daily rainfall and evaporation from SILO to evaluate when the soil profile is fully saturated and subsequent deep drainage to the underlying water table occurred. Climate change is predicted to influence rainfall and evaporation, and therefore influence rainfall recharge rates.

Section 4.0 of **Appendix 1** includes the results of modelling of the potential impact of climate change on long term behaviour of water level and water quality in the proposed final void using predictions from a range of global climate models. The worst global climate model scenario predicts the potential for rainfall to reduce by 15.5% and evapotranspiration to increase by 9.9%. The best case was an increase in rainfall of 8% and an increase in evapotranspiration of 9% (refer to GHD 2020, Section 4, Table 4-5). These predicted changes were utilised in the soil moisture balance to determine the potential impact on rainfall recharge, which was an input to the groundwater model. The worst case scenario indicated the potential for average annual recharge to reduce by up to 22%, whist the best scenario indicated an increase in recharge of 22%. The wide range in potential outcomes indicates the potential for climate change to result in either a decrease or increase in groundwater levels post mining.

The GDEs with potential to be impacted by cumulative impacts of climate change and the Project are the riparian vegetation along Bowmans Creek, aquatic ecosystems within Bowmans Creek and stygofauna and hyporheic fauna. Changes in temperature associated with climate change also have potential to impact on terrestrial and aquatic ecosystems and this is also likely to have flow on effects to interrelated groundwater ecosystems. None of the ecosystems under consideration have been identified as high priority GDEs under the relevant water sharing plans under the NSW *Water Management Act 2000*.

The Bowmans Creek system has been significantly impacted by clearing and other development over the past 200 years. In particular, riparian vegetation and aquatic habitat has been extensively modified through both clearing and altered flow patterns resulting from increased run-off from cleared areas and landform changes associated with farming and coal mining. Figures 4.9 and 4.10 in the EIS show historical aerial imagery of the Project area and surrounds. As can be seen from this imagery, the riparian vegetation currently present along Bowmans Creek has largely grown in the past 40 years. This vegetation, and associated aquatic and groundwater ecosystems, will continue to respond, adapt and potentially transition to different communities in response to a variety of factors over time, including past and future land use impacts and climate change. Differentiating the climate change related impacts and land use changes (including those associated with the Project) from natural succession processes in the GDEs is therefore difficult to both predict and measure; particularly given the wide variability in potential climate change impacts on recharge (which will also vary over shorter time periods as a result of natural variability). The ongoing monitoring proposed as a result of the Project and other mining operations in the area will provide further information over time to better inform management decisions and enable appropriate mitigation measures to be implemented having regard to the ongoing natural processes within these ecosystems.

Further detailed groundwater and pit lake modelling will be undertaken as part of the mine closure planning process. More detailed predictions on potential climate change impacts are also likely to be available at this time and will be included in groundwater, surface water and final void modelling undertaken as part of the detailed mine closure planning process which will commence at least 5 years prior to the planned closure of the operations. Potential cumulative impacts associated with climate change impacts will be taken into consideration as part of the ongoing review of monitoring and management practices. This process will be regulated through both the Rehabilitation Management Plan (RMP)/ Mining Operations Plan (MOP) and Rehabilitation Strategy approved under the development consent and mining lease conditions.

Question 7: To what extent can decision makers have confidence in the predictions of potential impacts on groundwater resources provided in the EIS, with regard to groundwater inflows, drawdowns in aquifers and potential impacts on private bores and groundwater dependent ecosystems?

21. The proponent notes that groundwater inflows to the Glendell Pit only result in very limited 'free flowing' groundwater which is generally removed via evaporation with insufficient volumes entering sumps for quantification (AGE 2019, p. 84). Estimates of inflows are less than 1 ML/day (AGE 2019, p. 84). Decision makers can be confident in this prediction based on the understanding that the Glendell Pit is a relatively dry pit.

Noted.

22.	**Two privately owned bores are predicted to be impacted by less than 0.2 m due to the project and less than 0.5 m due to cumulative impacts, leaving approximately 4 m of saturated aquifer still accessible (Umwelt 2019a, p. 270). This level of impact is well within the limits permitted under the New South Wales Aquifer Interference Policy and will be managed under make good provisions. The IESC agrees with the peer reviewer that this level of accuracy could not be expected from the groundwater model (AGE 2019, App, F, p. 6).**

Noted.

23.	**Groundwater take from some water sources is predicted to increase post-mining (Umwelt 2019a, p. 264 and 284). The proponent has committed to obtaining the required licences for any take; however, they should further explain why takes will increase post-mining, and when and at what volume takes are expected to peak and equilibrate.**

Licensable take relates to licencing obligations under the NSW Water Management Act. Licensable take differs from absolute or cumulative take and is calculated by reference to specific base years for the different water sharing plans. The licensable take attributable to the Project is calculated by subtracting cumulative (absolute) take under the relevant base case scenario model from cumulative take under the Project Scenario model. Figures 7-14 to 7-16 in the GWIA show this calculation process graphically for the alluvial aquifer systems. As can be seen from these figures, overall take from the various groundwater systems declines over time as the systems recover. The Project will delay this recovery in some areas but there remains an overall decline in total take. The process of calculating licensable take however means that the licensable take attributable to the Project increases. This 'increase' in licensable take attributable to the project occurs against an overall decline in cumulative take.

The modelled licencing requirements for the Project during operations are set out in Section 7.5.8 of the EIS with post-closure take licencing requirements set out in Table 7.2.9. Section 7.2.9 of the EIS also outlines the proposed licensing strategy for the Project which is consistent with the existing regulatory arrangements in place for the Mount Owen Complex.

24.	**Further discussion of the predicted impacts and the confidence in those predictions for GDEs is provided in the response to Question 10.**

Noted. Refer to **Section 2.7** for response to IESC comments on Question 10.

2.5 Final Void and Pit Lake

Question 8: Has the EIS adequately analysed the evolution of change in water quality and level in the Glendell Mine final void pit lake in the proposed final landform, any potential risk of spills or leaching on downstream environments, and cumulative impacts due to multiple voids across the Mount Owen Complex due to groundwater flowpath interactions?

25. The proponent has stated that the final void pit lake will be a groundwater sink (Umwelt 2019a, p. 270). However, they also stated that the pit lake was predicted to "be a source of water to the hard rock aquifers in strata sub-cropping below the water level of the pit lakes" (Umwelt 2019c, p. 23). The proponent needs to provide further discussion to reconcile these statements (e.g. will the void be a sink for one aquifer and a flow-through system for a different aquifer?) and clearly identify whether and when the pit lake will be a groundwater sink or a flow-through system. This should include clearly depicting the processes on the conceptual model graphics so that the connectivity of the final void pit lake with all aquifers over time is better explained (especially for the post mining phase shown in Figure 4 (Umwelt 2019b, App. B, p. 6)). If the pit lake is identified as a flow-through system, the proponent must identify the flowpath and endpoints of the final void's potentially contaminated water and any groundwater and surface water resources that could be impacted. Additionally, a monitoring plan should be developed that includes monitoring for metals which have been identified as characteristic of seepage from waste material (see Paragraph 45) within the pit lake, particularly if flow-through conditions will occur. This plan should clearly outline the proposed sampling locations, frequency and the period over which monitoring will occur post mining.

The final void will form a sink, not source. The cross sections provided in Figure 2.2 to Figure 2.5 have been included to illustrate this process. The cross sections pass through the proposed final void and adjacent approved mining operations. The cross sections show the recovered water table and piezometric surface within the Middle Liddell coal seam predicted by the numerical modelling, and its relationship with surrounding mining and the alluvial aquifers. The piezometric surface for the Middle Liddell seam was included on the sections as this seam is mined at adjacent open cut and underground mines, and is therefore most subject to cumulative impacts.

The sections show the water table and piezometric surfaces have an inward hydraulic gradient towards the final void at the end of mining, and the inward gradient remains after the groundwater levels recover and reach a new equilibrium post mining. There is no potential for outflow from the final void as the equilibrium level of the lake within the final void is well below the recovered water level in the surrounding alluvial and Permian groundwater systems. Whilst modelling indicates the void will form a sink, if outward seepage conditions were to occur groundwater leaving the final void would move through moderately permeable coal seams to adjacent operations and be captured in residual mining voids, meaning risks associated with any outward seepage would be low.

The simulated rate of groundwater flow into the proposed final void was extracted from the numerical model and is shown in **Figure 2.9** below. The net negative flow rate indicates an inflow to the final void post mining. The rate of inflow to the void changes over time as the water level rises in the void lake due to the influence of other recovering open cut and underground mining areas within the model.

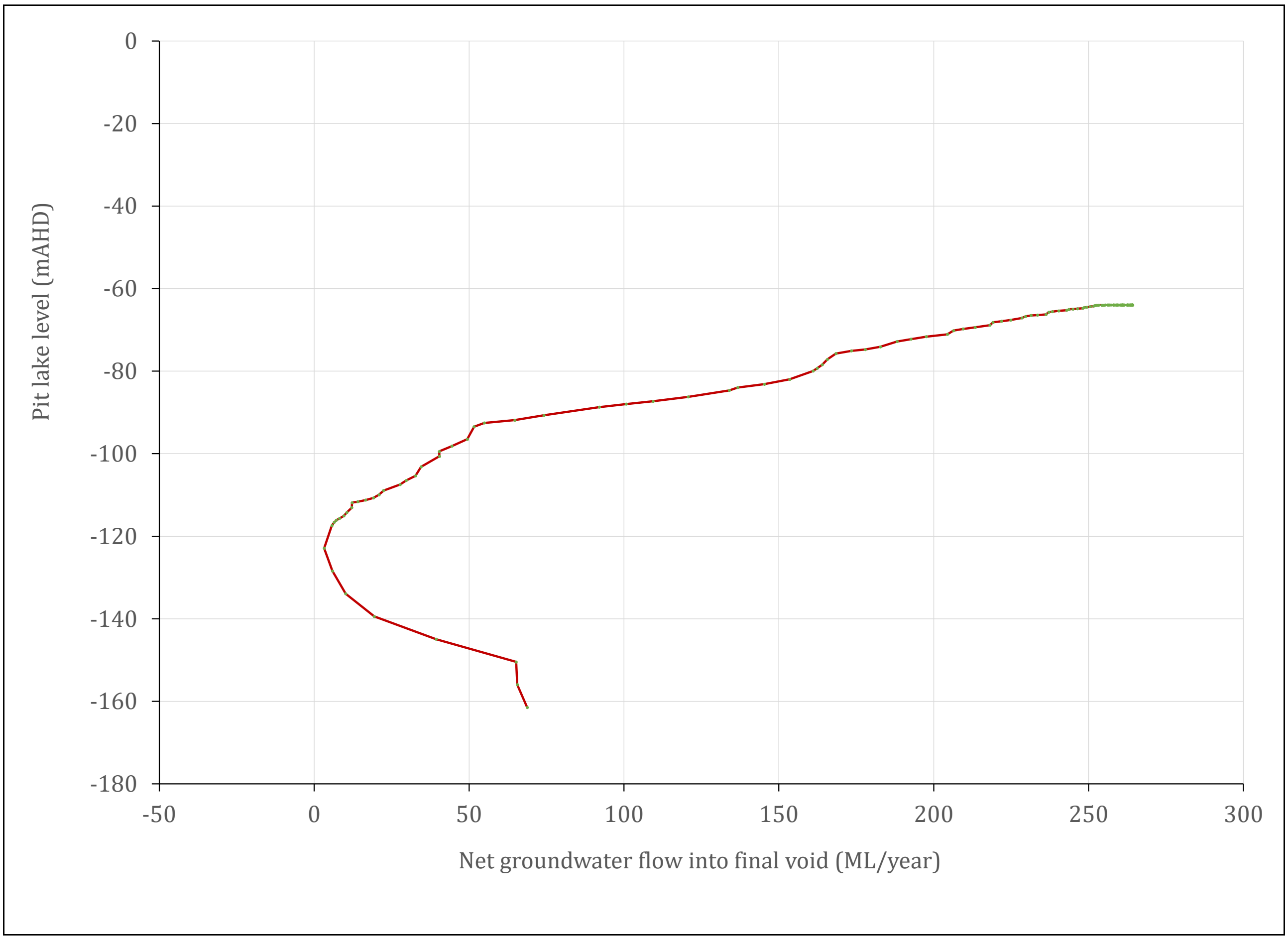

Figure 2.9 Groundwater flow to final voids versus water level elevation

26.	**Evaporation is predicted to exceed inflows to the pit lake and also exceed rainfall; however, the proponent has stated that salinity is not predicted to increase above the concentration of the most saline input (groundwater) (Umwelt 2019a, p. 270). Detailed temporal information of the estimated proportional contribution of various water sources, salinity changes over time of the water sources and applied evaporation rates are required to understand how the pit lake salinity evolves and to explain how the pit lake will not become more saline given the predicted evapo-concentration. This discussion should also address why predicted pit lake salinity in the vicinity of the Mount Owen Complex is generally lower than at other Hunter Valley Mines (see GHD 2019, Table 8-3, p. 60).**

The process for modelling void recovery and salinity is set out in Section 8.1 of the SWIA. The evolution of pit lake salinity over an approximately 450 year period post closure is shown in Figure 8-3 of the SWIA which is reproduced in **Figure 2.10**.

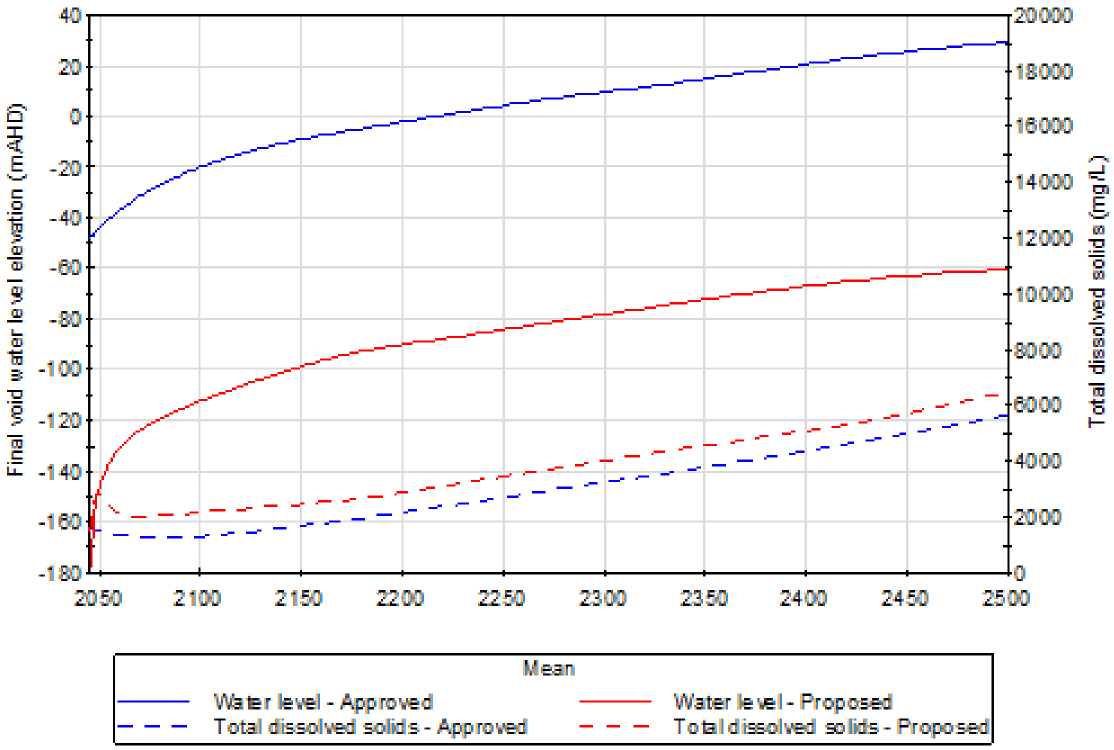

Figure 2.10 Forecast water level and TDS in approved and proposed final void

© GHD, 2019

As identified in the EIS, at the point at which the pit void water level is modelled as reaching equilibrium (approximately 450 years post closure), the modelled TDS of the pit lake is 6500 mg/L which is lower than the Permian aquifer systems. As shown on **Figure 2.10**, evapoconcentration effects would be expected to result in a continual rise in the TDS levels within the pit void over time.

The comparison between the modelled salinity for different voids in the Hunter Valley is based on reported salinity predictions in relevant assessment documentation. All of the voids compared in the model have different volumes, depths and catchment areas; these factors all have a significant impact on the time in which the voids reach an equilibrium water level and the evolution of salinity in the pit lake over this period. Additionally, the modelling for these different predictions use slightly different approaches and assumptions which can also affect model predictions.

The final void modelling undertaken in the SWIA is based on the conceptual final landforms identified for the site. Further detailed pit lake modelling will be undertaken as part of the mine closure planning process which will have regard to different land use options for the site, potentially including changes to the final void design and catchment area. This modelling will also have regard to updated groundwater modelling results which will also take into consideration any changes to mining conditions at the Mount Owen Complex and surrounding operations which have the potential to affect groundwater inflow rates. Potential end land uses for the void may also affect the recovery rate which would in turn impact on salinity levels. More detailed predictions on potential climate change impacts are also likely to be available at the time that mine closure planning commences.

27. Flood modelling results are stated to indicate that while flood water would enter the pit lake during a PMF event, over 100 m of freeboard would remain which means that spillage would not occur (Umwelt 2019a,

p. 281). Additionally, the proponent identified that a relatively minor change to the proposed final landform would prevent flood water from entering the pit lake even during the PMF event. The proponent should provide further information on what constitutes this relatively minor change. If no adverse impacts to landform stability and biota are identified, then the proponent should consider making the design change.

The mine design modelled included a levee to ensure the pit was not inundated in a 0.1% AEP event due to flows along the Yorks Creek Realignment. The additional earthworks required along the bund that forms the Yorks Creek Realignment to prevent flood water in a PMF from entering the void are considered unlikely to have any adverse impacts on landform stability or visual impacts as the additional flood levels in a PMF are only marginally higher than the 0.1% AEP event at the points at which inflows could occur. No additional impacts on biodiversity are expected as the earthworks required to prevent overtopping in a PMF would all be located within the Project Disturbance Area and the works would not impact on aquatic ecosystems.

The Proponent will design the final landform to incorporate the flood levee associated with the Yorks Creek Realignment to prevent overtopping in a PMF. This design criteria will be incorporated in the detailed design for the realignment. Similarly, the design of the final landform will also include the closure criteria for the Project, noting that this is also an existing criteria for the Bayswater North Pit and North Pit final voids at the Mount Owen Complex.

28. The proponent has stated that the additional mining proposed and the changed location of the final void (compared to the approved final void) may affect the recovery timing of the North Pit and Bayswater North Pit final voids (Umwelt 2019a, p. 242). This potential impact should be discussed further so it can be identified whether it will affect groundwater flow paths or ecological assets and, if so, how.

The recovery of the Mount Owen North Pit and the Bayswater North Pit has been assessed as part of previous approvals. The groundwater model for the Project was setup to ensure consistency with approved conditions at surrounding mines. The water level recovery within these final voids was therefore fixed and held at recovered levels determined from previous approvals. Cumulative interactions between final voids may have the potential to slow water level recovery in surrounding approved mining areas. These impacts are considered likely to be temporal only and have limited impact on the magnitude of drawdown and take in any systems.

As noted in the response to Paragraph 20, further detailed groundwater and pit lake modelling will be undertaken as part of the mine closure planning process. This modelling will take into consideration any changes to mining conditions at the Mount Owen Complex and surrounding operations which have the potential to affect groundwater inflow rates. As all of these operations will cease prior to the mine closure planning timeframe for the Glendell Continued Operations, detailed modelling of these operations will be available and will have regard to the planned mining at Glendell. This process is regulated through both the Rehabilitation Management Plan (RMP)/ Mining Operations Plan (MOP) and Rehabilitation Strategy approved under the development consent and mining lease conditions. Whilst future modelling will be undertaken, the modelling undertaken to date is sufficient to conclude that the post mining void will be a permanent sink, and the adjacent alluvial aquifer will recovery with limited residual impacts. If the extent, depth or duration of mining were to be reduced this would likely accelerate recovery of the final void and alluvial aquifer water levels.

29. It is unclear from modelling whether climate change has been accounted for in the post-mining phase. Given the predicted recovery period of approximately 450 years for groundwater levels (AGE 2019, p. 105) following mining, climate change should be considered as it may affect the time taken for recovery which could result in impacts to water resources occurring over longer periods and affect rates of possible post-mining recovery of water resources.

Section 4.0 of **Appendix 1** contains an assessment of final void pit lake water level recovery and salinity evolution under various climate scenarios. This modelling indicates that under all modelled climate scenarios, pit lake equilibrium levels would be lower and salinity levels slightly higher at the point of water level equilibrium than the base case modelled. The modelling results indicate that the future climate scenarios show that risk of seepage from the final void through the coal seam to the adjacent voids is marginally reduced.

The modelled potential impacts of climate change on water levels and water quality are not expected to alter the potential uses of the final void.

As noted in the response to Paragraphs 20 and 26, further detailed pit lake modelling will be undertaken as part of the mine closure planning process which will have regard to different land use options which will also take into consideration any updated climate change forecasts available at the time which may impact on void recovery.

30. The influence of all voids remaining in the final landform on groundwater flowpaths is captured within the groundwater modelling of the post-mining phase as nearby voids have been incorporated in the groundwater model.

Noted.

2.6 Cumulative Impacts

Question 9: Does the EIS provide an adequate assessment of cumulative impacts to surface and groundwater resources during the mining operations and during the recovery phase post mining including changes in catchment areas, the rate of recovery of groundwater levels and saturation of alluvial aquifers? Do these assessments adequately differentiate impacts due to the Project, historical mining already undertaken and currently approved operations (i.e. mining yet to occur)?

31. **Cumulative surface water and groundwater impacts have been assessed at a range of scales (including project-specific) for the expanded Glendell Mine and for the entire Mount Owen Complex. Impact predictions are provided at multiple time-points including during operations and post mining. Changes to catchment areas over time are considered. Although the rate of groundwater recovery is not clear, the proponent discusses when groundwater levels are likely to be similar to current levels. The saturated thickness of alluvium is provided for operational and end-of-mining time-points although again the rate of recovery and hence the length of time during which impacts may be occurring to GDEs and surface waters is not clear. Further discussion is needed of rates of recovery under different cumulative scenarios that differentiate impacts due solely to the project, historic mining, current mining, and approved mining likely to occur, and include potential effects of predicted climate change during the recovery period.**
32. **Desaturation of a section of the Bowmans Creek alluvium to the west of the project is predicted to occur due to cumulative impacts (Umwelt 2019a, p. 266). Although modelling suggests that the project will not cause this desaturation, the proponent notes that the project appears to increase the time taken post mining for the alluvial groundwater levels to recover (Umwelt 2019a, p. 266). Further discussion of how the project causes this delay, what the additional recovery time is, and if it is likely to impact GDEs (including stygofauna) should be provided.**

The groundwater assessment identified an area of the Bowmans Creek alluvium west of the Project where the thickness of the alluvial sediment potentially thins due to rising bedrock (bedrock high). Interpolation of groundwater levels measured in the monitoring bores indicates the saturated thickness of alluvium in this area is limited and is predicted to become dry due to the cumulative impact of mining operations in the region (refer AGE 2019, Figures 7-3 and 7-4). When mining operations in the region cease the model predicts the water level slowly recovers and re-saturates the alluvial sediment in the area where the bedrock high potentially occurs (refer AGE 2019, Figures 7-13).

To further illustrate the time taken for recovery of the alluvial water table in this area predictions were extracted from the numerical model in the area where the bedrock high potentially occurs.

Figure 2.11 shows the area where the alluvium will potentially be de-saturated and the point where water levels were extracted from the numerical model. **Figure 2.12** shows the water levels predicted post mining by versions of the model that included and excluded the Project.

The graph illustrates the Project is predicted to delay the re-saturation of the alluvial groundwater system by about 35 years and result in a long term drawdown relative to existing approved conditions in the order of 1 m in the selected location.

It is noted that these predictions are based on the model using average rainfall assumptions over the predictive phase. As shown in figure 2 (Inset) of **Figure 2.11**, inflows and outflows from the alluvium are close to balance and even small increases in rainfall above the average rate applied in the model are likely to increase alluvial recharge from both rainfall and stream flow in this area and upstream catchments such that the alluvial in this area becomes resaturated. In this regard, the alluvium in this area is considered to be ephemeral with periodic resaturation and drying occurring. It is considered likely that prolonged periods of desaturation are only likely during extended drought periods such at that observed in 2018-2019.

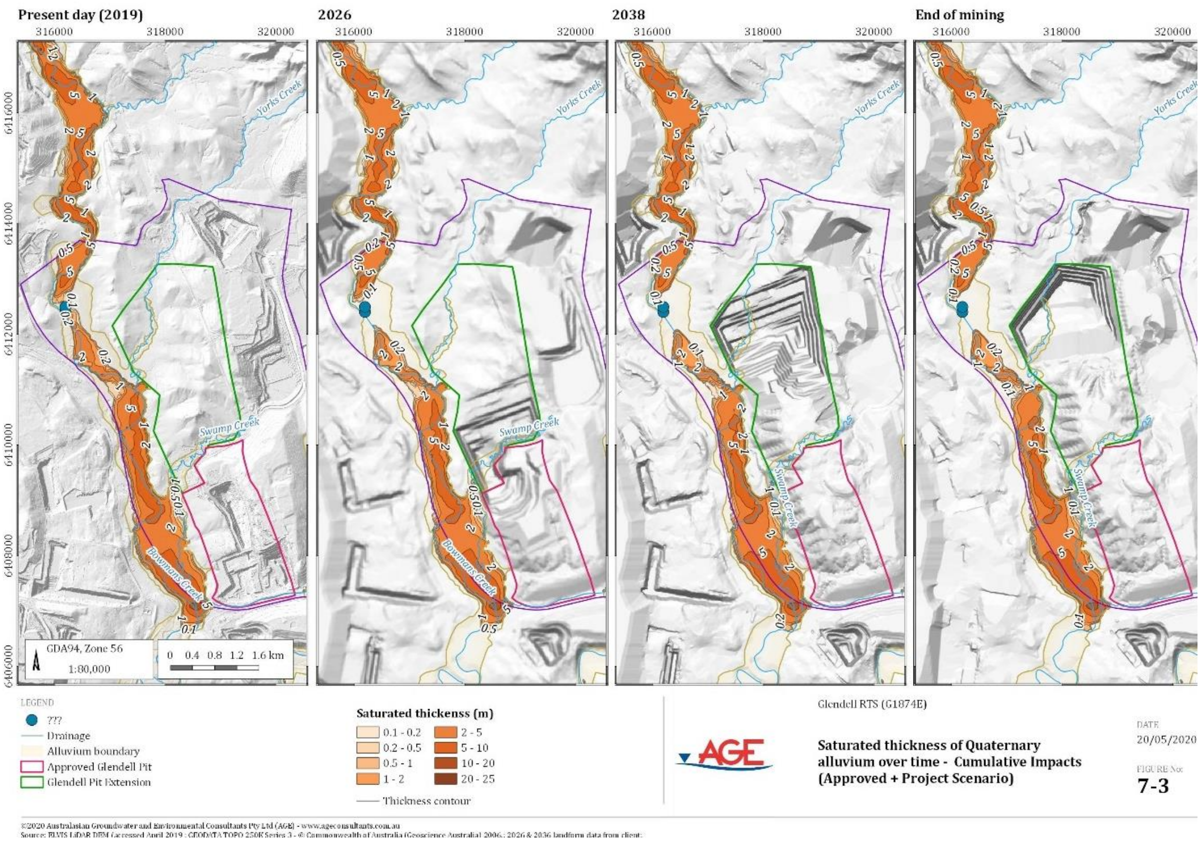

Figure 2.11 Location of water level (Figure 2.12) in Bowmans Creek alluvium

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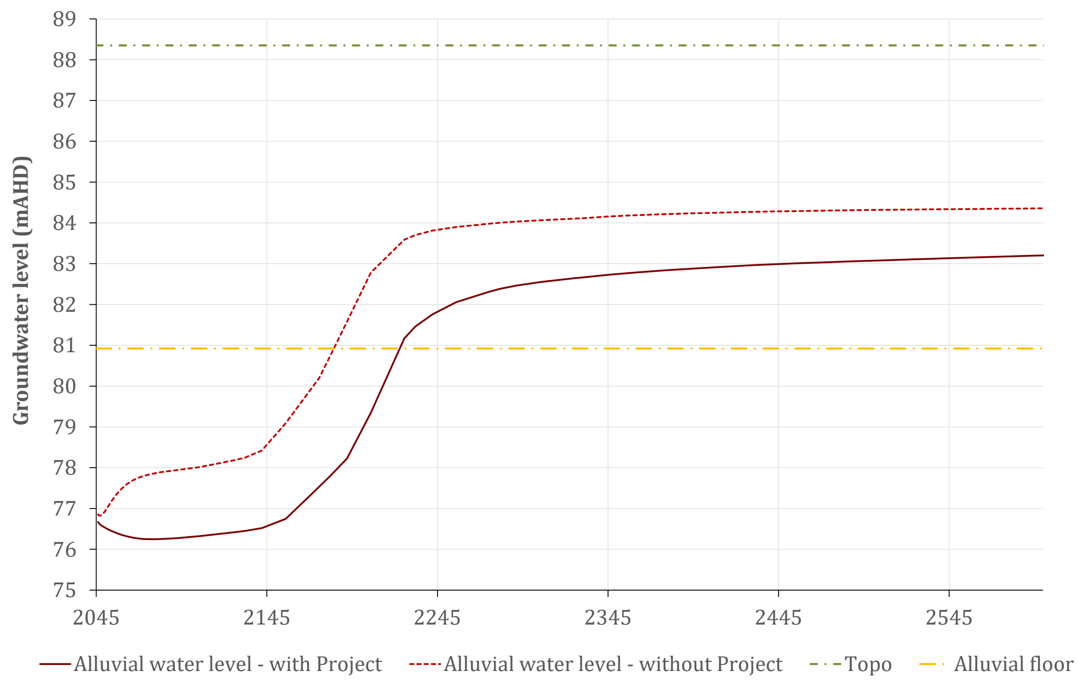

Figure 2.12 Predicted post mining water level in Bowmans Creek alluvium

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33. The proponent states that post mining, the project will result in up to 1 m of depressurisation to the north of the mine which is not expected to have a material effect on the alluvium (Umwelt 2019a, p. 265) although this is subject to the uncertainties discussed in Paragraphs 14-18.

The reference in the EIS to an increase in modelled depressurisation of up to 1 m to the 'north east' of the Glendell Pit Extension is incorrect and should instead refer to an area to the 'west of the northern extent' of the Glendell Pit Extension. This area of additional drawdown is shown in Figure 7-12 of the GWIA which is reproduced below in Figure 2.13 . This area closely aligns with the Bowmans Creek Alluvium area shown in Cross Section A-A' (refer to Figure 2.2) and discussed above in response to Paragraph 32.

This maximum drawdown is calculated by identifying the maximum difference at any point in time between the Project Model (which includes all mining related impacts) and the model of existing approved operations (refer to Figure 2.13). As described in the EIS, the groundwater systems in this area are in a state of flux due to historical and proposed mining operations but will generally be in a state of recovery for most of the life of the Project following the cessation of mining at Liddell Coal Operations. As shown in Figure 2.13, the depressurisation of the Permian associated with the Project will slow but not prevent this recovery. The graphical means of displaying maximum depressurisation in **Figure 2.13** does not reflect a reduction in water table relative to existing conditions but rather the maximum difference between modelled water tables under the two scenarios**.**

In situations where predicted impacts are relative to recovering systems, it is more appropriate to focus on changes in the saturated areas of alluvium relative to absolute maximum levels of impact and the duration of these impacts rather than point of time differences. A review of the predicted saturation in this area indicates that the water table in the area to the north west of the Glendell Pit Extension continues to recover and the Project does not result in a further reduction (either extent or depth) in saturated areas of alluvium relative to the maximum predicted cumulative impact from existing approved operations.

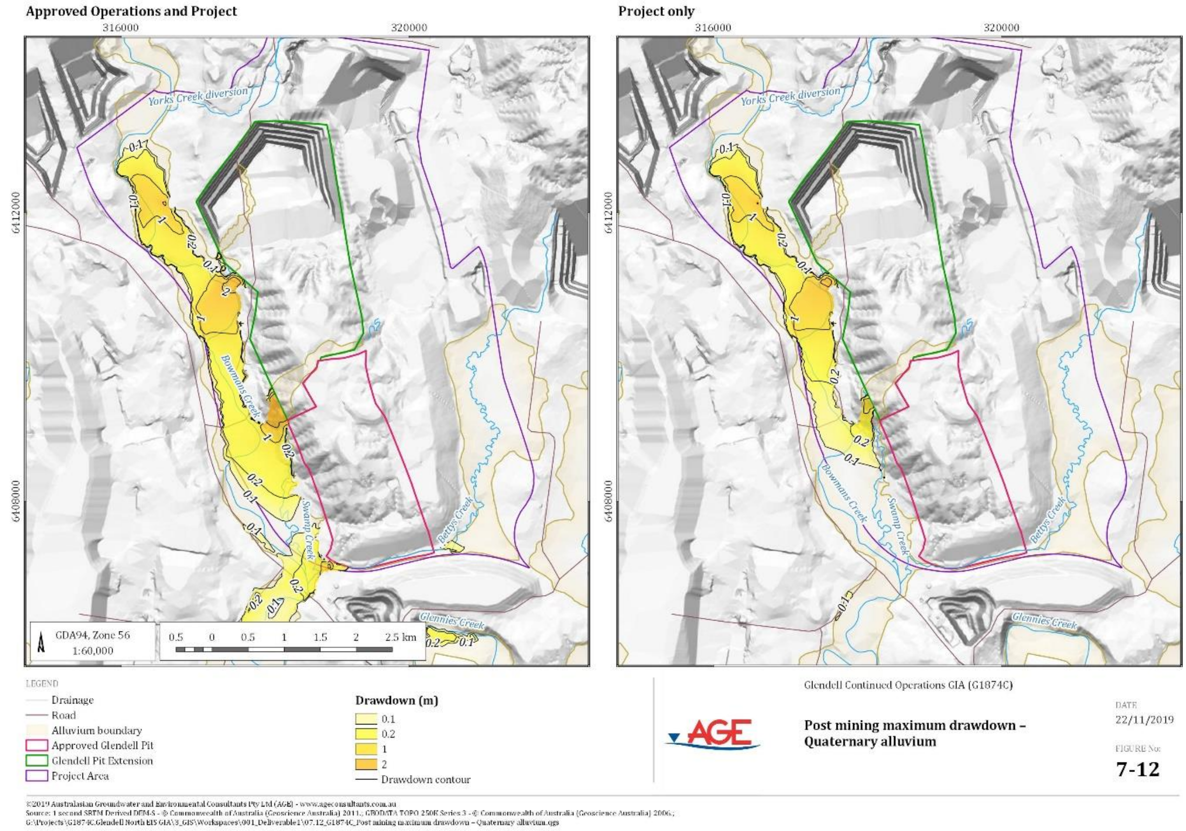

Figure 2.13 Post Mining Maximum Drawdown – Quarternary Alluvium

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34. The predicted impacts of the project are differentiated from those of historic and existing mining. However, the future potential impacts from approved but yet-to-commence operations are not clearly identified.

The primary purpose of the groundwater impact assessment was to identify the impacts of the Project, and secondly to separate this from the combined cumulative impact of the other approved and foreseeable mining operations in the surrounding region. The groundwater impact assessment was not designed to individually identify and report on the impacts of every approved mine or foreseeable project in the region. The impacts of other mines is described in the appropriate approvals documents for these mines. The numerical model includes all approved mining at the following sites:

- Mount Owen Complex including approved Glendell Mine, Ravensworth East Bayswater North Pit and Mount Owen North Pit MOD2
- Integra Underground Mine including MOD8
- Rix's Creek North Mine
- Liddell Mine

- Ashton Open cut and Underground Mine
- Ravensworth Operations, and
- Hunter Valley Operations (HVO) North.

The progression of mining modelled is discussed in Section B2.4.6 in Appendix B of the GWIA.

The only approved but not yet commenced mining operations which is not modelled is the Ashton South-East Open Cut Project. The likelihood of commencement of the Ashton South East Open Cut remains unclear. The Ashton South East Open cut is likely to have localised impacts on reaches of the Bowmans Creek alluvium to the south of the existing Glendell operations. The depressurisation impacts associated with this operation are unlikely to have a significant interaction with impacts from the Glendell Pit Extension.

Should the Ashton South East Open Cut commence operations, the Regional Groundwater Model used for the Project will be updated to include consideration of this Project to assist in the differentiation of cumulative impacts, particularly to the south and west of the existing Glendell Pit.

2.7 Water-dependent Ecosystems

Question 10: Have the surface and groundwater impacts of the Project on the local and regional aquatic ecological values (aquatic biota and riparian habitat) and groundwater dependent ecosystems (including stygofauna) been adequately described and assessed?

35. Yorks Creek diversion will be partially located in fill (upper reaches) and partially cut into bedrock (lower reaches) (Gippel 2019, p. 37). The proponent acknowledges that this will present geochemical and geotechnical challenges. However, these challenges have not been fully discussed nor have design, mitigation and management options that could address these challenges. The IESC notes that the current design presents further challenges with recreating existing habitats, especially floodplain terraces and refugial pools. During the detailed design phase, the proponent needs to consider the geochemical and geotechnical challenges that they have identified and:

a) whether the proposed diversion will provide suitable instream habitat that is consistent with that occurring within the lower reaches of a creek in this region;

b) how riparian habitat and alluvial terraces comparable to those along the existing Yorks Creek will be recreated, especially in the reach which is to be cut into bedrock; and,

c) how the subsurface alluvial and hyporheic ecosystems present within the current Yorks Creek can be recreated in the diverted channel.

The Geochemical Assessment prepared for the Project (refer to Appendix 19 of the EIS) has identified that the majority of overburden material to be handled by the Project is non-acid forming (NAF). Only overburden material identified as being NAF will be used for the construction of the Yorks Creek Realignment. This overburden is also the parent material for soils in the area. As identified in the Geochemical Assessment, weathered Permian material may be sodic and dispersive; some finer grained fresh Permian material may also exhibit these properties. Should any of this material be used in the Yorks Creek Realignment works, treatment with gypsum or lime may be required to manage these risks.

The existing Yorks Creek alignment has limited floodplain terraces or refugial pools and has been assessed as having minimal key fish habitat. Re-creation of these design elements in the realigned section of Yorks Creek with similar ecological value is considered to be readily achievable.

The conceptual detailed design of the Yorks Creek Realignment includes consideration of potential impacts on the passage for aquatic fauna. As discussed in Section 3.4.4.2 of the Assessment of Commonwealth Matters Report (Appendix 10 of the EIS), the conceptual detailed design of the Yorks Creek Realignment includes the use of woody debris in the channel (where practicable) and the creation of riffle areas and ponds within the channel to create instream habitat values when the creek is flowing. The use of a bridge for the Hebden Road crossing, rather than culverts (as is the case for the existing road crossing), will also minimise instream barriers to fish movement. Further consideration of suitable instream habitat (including alluvial terraces and refugial ponds) will be included in the detailed design.

36.	**The proposed Yorks Creek diversion will include a reach with a bed slope of 0.04 m/m commencing 150 m upstream of its confluence with Bowmans Creek (Gippel 2019, p. 37). The proponent notes that bed slopes this steep are not common along lower reaches of streams (GHD 2019, p. 83). Further consideration of options to decrease the steepness of the bed slope or detailed information on proposed management of this reach is required to ensure that the reach will provide habitat that is suitable for biota currently living in the lower reaches of Yorks Creek. The proponent should also discuss whether sediment could accumulate in the relatively flat reach which is proposed immediately downstream of the steep reach and upstream of the confluence with Bowmans Creek, and how this would affect surface and subsurface hydrological and ecological connectivity between Yorks Creek and Bowmans Creek. The likelihood of deposited sediment partially or completely infilling refugial pools in the lower reaches of the diverted channel should be assessed and if necessary mitigated.**

The proposed realignment will be subject to a detailed design process prior to construction. This will include development and refinement of the design, key design objectives and performance criteria, and confirmation of the ongoing monitoring requirements. This design process will be iterative and have regard to the relative effects and impacts of creek stability measures on habitat values and sediment movement. Section 7.9.4.3 of the EIS includes specific consideration of the design principles and objectives for the Yorks Creek Realignment. The key design objectives (Table 7.49 of the EIS) have been informed by geomorphic studies which have specifically considered sediment load and movement within Yorks Creek and existing habitat features such as depressions and woody refuse material (refer to the Yorks Creek Realignment Constraints Analysis – Appendix 18 of the EIS). Preliminary modelling of the Conceptual Detailed Design indicates sediment deposition and entrainment processes will be similar to that of the existing Yorks Creek. It is also noted that there are only limited refugial pools within the current Yorks Creek alignment and these typically only hold water for short periods following flow events.

The detailed design process will include further consideration of sediment sources, sediment depositional zones and the sediment transport capacity. The design will include specific consideration of habitat values along the entire length of the realignment, including the steep sections. This design process will also inform the development of required management, mitigation and monitoring requirements. Ongoing monitoring will include regular inspection and maintenance of the built watercourse to check functionality.

37.	**The proponent has identified and investigated potential impacts at three persistent pools within Bowmans Creek that they consider likely to be groundwater-dependent. The analyses identified that complete drying of these groundwater-dependent pools was unlikely (see GHD 2019, Figures 9-10 and 9-11, pp. 73-74) though this assessment is subject to the uncertainties in baseflow contribution as predicted by the groundwater model (see Paragraphs 7 and 14-18). Further consideration of how decreases in pool depth would impact water quality, including dissolved oxygen and water temperature, should be provided to fully understand potential impacts to aquatic biota.**

Section 2.0 of **Appendix 1** includes further modelling of water levels within these refugial pools based on surveys of the pools. The modelling using the survey of actual pools is consistent with the results presented in the SWIA, which supports the conclusion that no measurable surface water impacts on the persistent pools in the lower part of Bowmans Creek is expected as a result of the Project.

As discussed in Section 5.6 of the GWIA, there is strong evidence to suggest the persistent pools within Bowmans Creek are directly connected to the Bowmans Creek alluvial aquifers. Despite the long period of drought in 2018-19 and early 2020, little evapo-concentration of salts was observed in these persistent pools indicating continued interchange of water between the alluvium and the surface pools. This interchange is also likely to have a buffering effect on temperature within the pools. The modelled changes to pool depths associated with the Project (relative to existing and approved conditions) are considered unlikely to have any impact on temperatures within the pools.

As was observed in the 2018-19 drought period, there was little to no surface flow in Bowmans Creek meaning the persistence of these pools was due to subsurface flows within the gravel beds or interchange with the alluvium. Despite the long period of drought, there was no evidence of aquatic fauna mortality within persistent pools associated with reduced oxygen levels or elevated temperatures. In the absence of surface flow, dissolved oxygen levels within the pools would be largely dependent on direct surface interchange within the pool itself rather than aeration of water through streamflow. The pool modelling undertaken in **Appendix 1** indicates that the Project's impacts on depth of the pools is unlikely to have an impact on surface area that would meaningfully affect the aeration of pools. The predicted changes in baseflow, and their potential effects on surface flows and persistent pools, are considered unlikely to significantly impact dissolved oxygen or temperature levels within pools in Bowmans Creek.

38.	**The predicted drawdown resulting from the project is greatest in Bowmans Creek and what will be the remnant downstream reach of Yorks Creek (AGE 2019, Figure 7-2, p. 92). It is unclear whether the drawdown prediction for the remnant downstream reach of Yorks Creek has considered the impact that greatly reduced surface water flows (due to diversion of the upstream reaches) will have on groundwater levels through reduced recharge. The IESC notes that this reach of Yorks Creek will be severely impacted by the Yorks Creek diversion. However, further discussion should be provided including predictions of how the current water-dependent biota in this reach will respond to lowered groundwater levels and reduced stream flows, whether any post-mining recovery is expected, and whether the recreated habitat in the diverted channel is intended to replace that lost habitat, including associated GDEs.**

The remnant downstream section of the existing Yorks Creek alignment remaining after the realignment is less than 200 m in length. **Figure 2.14** shows the section of Yorks Creek immediately upstream of the confluence with Bowmans Creek. No surface flow was present at the time the photo was taken.

Figure 2.14 Yorks Creek at Confluence with Bowmans Creek (25 January 2018)

The pools visible in **Figure 2.14** are the only persistent pools present in Yorks Creek and are thought to be connected to the Bowmans Creek alluvial aquifer. Yorks Creek, including this lower reach, has been assessed as having minimal fish habitat values.

This section of Yorks Creek will not be directly impacted by the Project, however the Project is expected to result in a decline in the water table in the area around the confluence. During operations, this section will still receive inflows from runoff from the relocated Hebden Road and will have catchment in the final landform from the rehabilitated in-pit emplacement area.

The assessment of indirect potential impacts on water dependent ecosystems in Section 3.4.5.1 of the Assessment of Commonwealth Matters Report applies to this small section of Yorks Creek. The modelled reduction in the water table of up to 2 m over a 25 year period is within the natural variability in water tables (in excess of 4 m) observed in this area, however a reduction would likely result in the pools visible in **Figure 2.14** becoming more ephemeral and linked to surface flows rather than the water table. Should these pools dry, this would result in a very localised impact on some aquatic species. While this is a significant impact on the ecosystem potentially impacted, there are no recorded threatened or endangered species within the area of potential impact and no significant impacts on broader aquatic species populations are expected as a consequence of this localised impact. The trees in this area are expected to be able to adapt in the timeframes concerned with the Project and ‘chase’ the water through deeper roots. Accordingly, no significant impact upon the River Oak Woodland community in this location is expected as a result of either the Project or cumulative impacts. The changes in water table are unlikely to have an impact on stygofauna and hyporheic fauna within this area as the alluvium will remain saturated despite the lower water table. Overall, these impacts will be very localised and are not considered to be significant.

The detailed design of the Yorks Creek Realignment will include consideration of instream aquatic habitat values and the shallow grade sections are expected to re-establish alluvial type conditions over time which can be recolonised through both upstream and downstream movement of fauna.

Flows within Bowmans Creek at the current Yorks Creek confluence will not be significantly affected by the loss of catchment in Yorks Creek as the Yorks Creek Realignment will return much of the existing Yorks Creek flows to Bowmans Creek upstream of the current confluence point. Further, the progressive release of rehabilitated catchment areas at Liddell and Mount Owen are redirected to drain to the watercourses and will further assist in maintaining overall stream flow within Bowmans Creek. These changes in streamflow are detailed in Section 9 of the SWIA and the positive effect of these changes on water levels in persistent pools is shown in Section 2.0 of **Appendix 1**.

39.	**The proponent has predicted drawdown and changes to the saturated thickness of the alluvium. Project-specific potential drawdown beneath terrestrial GDEs that do not overlie alluvium is less clearly identified. Figure 7-10 (AGE 2019, p. 103) shows cumulative water table drawdown. To the north of the project and immediately adjacent to the project boundary, drawdown of up to 50 m is predicted beneath an area identified as having a high potential to be a terrestrial GDE. Given the proximity to the project and the magnitude of the predicted drawdown which will disconnect the GDE from the water table, the proponent should discuss the proportion of predicted water table drawdown that is caused by the project. If the project is causing or contributing substantially to the disconnection, then mitigation and management options should be developed.**

The area referred to in this paragraph is assumed to be the area of Swamp Oak – Weeping Grass Grassy Riparian Forest of the Hunter Valley – forest (PCT 1731) mapped on Yorks Creek to the north of the Project Area. The predicted (cumulative) drawdown in this area appears to be associated with the Hunter Thrust and mining in the Bayswater North Pit and historical mining at Ravensworth East. Figure 3.11 in the Assessment of Commonwealth Matters Report, which shows the change in depth to water table associated with the project relative to approved operations indicates that this modelled lowering of the water table at the end of mining is a result of existing approved operations and is not affected by the Project. A review of the modelled water table in this area for the Approved and Proposed scenarios indicates the project has little to no impact on the water table in this area.

40.	**Sampling of alluvial bores in the project area yielded seven stygofaunal taxa that, at the broad taxonomic level routinely used in these surveys, have been collected throughout the Hunter River alluvial aquifer and aquifers of tributary streams such as Pages River, Kingdon Ponds and Dart Brook (Eco Logical 2019, p. 15). Groundwater modelling indicates that drawdown due to nearby mines will desaturate two sections of the Bowmans Creek alluvium, fragmenting this aquifer and constituting a significant threat to the local stygofauna. Although the proponent acknowledges that drawdown associated with the project will delay reconnection of the fragmented aquifer, it is asserted that this impact on the regional stygofauna community is negligible (Eco Logical 2019, p. 31). The IESC considers that this community and the potential impact of the project has been adequately described and assessed, but recommends that stygofaunal monitoring of the isolated 5.5-km fragment of alluvial aquifer of Bowmans Creek should be done during and after mining to confirm that reconnection occurs and the stygofaunal community recovers as predicted.**

This suggestion is noted and will be added to the proposed monitoring program to be developed as part of the Biodiversity Offset Management Plan. Five yearly monitoring is proposed given the temporal nature of the impact being monitored. Should monitoring indicate that reconnection occurs as a result of natural variability, the need for any further monitoring will be reviewed.

41.	**The diversion of Yorks Creek will remove approximately 2 km of riparian habitat in its lower reaches (Umwelt 2019a, p. 279). There will also be impacts on riparian habitat along parts of Swamp Creek and at the proposed confluence of Bowmans Creek and the diverted channel of Yorks Creek (Umwelt 2019a, p. 311). A section of River Oak Riparian Grassy Tall Woodland of the Western Hunter Valley along Bowmans Creek outside the development area will be affected by groundwater drawdown (Umwelt 2019a, p. 316). Although the proponent acknowledges that loss of riparian habitat may disrupt fauna moving between habitats in the area, it is considered that these impacts will be minor given the existing disturbed and fragmented landscape (Umwelt 2019d, pp. 82-83). More evidence is needed to support this assertion of minimal impacts, especially as the current riparian vegetation is likely to be disproportionately important because of the existing landscape-level fragmentation. The proponent should also assess the significance of other roles (e.g. organic matter contribution, shading, bank stability) of the riparian vegetation that will be temporarily lost or impaired so that appropriate plans for mitigation of these impacts can be developed.**

The riparian corridor of Yorks Creek is currently fragmented. The removal of this corridor will potentially disrupt the movement of fauna however this impact has been assessed as part of the BDAR and will be adequately offset. Additionally, the proposed realignment, once established, will provide replacement habitat and a vegetation corridor to assist with the movement of fauna species.

Appropriate mitigation and management measures will be developed and implemented to appropriately mitigate any impacts to retained vegetation along retained sections of Yorks Creek and the confluence of Bowmans Creek. Impacts to riparian vegetation associated with predicted drawdown and associated changes to the water table level will occur progressively over an extended period, which will allow groundwater dependent species sufficient time to adapt.

42.	**Modelling indicates that the number of zero-flow days in Bowmans Creek will increase, resulting in declines in pool depth and water quality (GHD 2019, pp. 73-74). Although the proponent has surveyed aquatic biota at multiple locations along Bowmans Creek and other creeks in the project area in 2018 (Umwelt 2019d, App. F, pp. 13-16), there does not appear to have been a survey of potential refugial pools and their biota along each of these creeks during a low-flow period or shortly after flow ceased. This lack of data severely limits predictions of how alterations in depth, water quality and persistence might affect aquatic fauna (e.g. macroinvertebrates, tadpoles) seeking refuge in these pools. Given that reductions in flow duration and pool persistence in ephemeral streams can have major effects on aquatic biota (Stubbington et al. 2017), the IESC recommends targeted sampling of persistent pools during a low-flow period or shortly after flow ceases so that the proponent can better assess the potential impacts on surface water biota of the predicted changes in hydrology, especially in Bowmans Creek.**

As discussed in the Aquatic Impact Assessment (refer to the Biodiversity Development Assessment Report - Appendix 20 of the EIS) the survey included sampling at three locations along Bowmans Creek including one at the existing confluence with Yorks Creek, one upstream of the proposed Yorks Creek Realignment confluence and one downstream of the existing confluence. The sampling was limited to refuge pools only due to the prolonged dry period that occurred over the period of preparation of the EIS. Despite the long period of no flow prior to sampling, these pools indicated a high level of diversity although no threatened species were identified.

Given the relatively low changes in baseflows associated with the Project, the small modelled increase in no flow days is considered unlikely to have any impact on biota in Bowmans Creek and the persistence and depth of refuge pools within Bowmans Creek is considered to be linked more closely to groundwater levels within the alluvium than to streamflow. The assessment of changes in water table (refer to Section 3.4.3 of the Assessment of Commonwealth Matters Report (Appendix 10 of the EIS) indicates the Projects' impacts on groundwater levels which may affect pool persistence is limited to the area immediately adjacent to the Yorks Creek confluence point. These predicted changes are not considered to have a significant impact on the biodiversity values of Bowmans Creek.

Further monitoring on Yorks Creek is not considered to be warranted. This system is dry for large periods of time and persistent pools are considered to have limited aquatic biodiversity value (refer to Appendix F Section .2.2.3 of the Biodiversity Development Assessment Report - Appendix 20 of the EIS). The habitat values of the existing Yorks Creek system should be able to be recreated within the realigned section with minimal impacts on overall biodiversity values within this system.

2.8 Avoidance, Mitigation and Monitoring

Question 11: Does the EIS provide reasonable strategies to effectively avoid, mitigate or minimise the likelihood, extent and significance of impacts, including cumulative impacts to significant water-related resources?

43. Proposed strategies for avoidance, mitigation and minimisation of impacts to water resources rely on updating existing management plans and continued implementation. Some summary information about proposed updates was provided but this was often limited because the proponent does not plan to update most plans until the project is approved. The IESC has not assessed the adequacy of existing management plans because these do not explicitly incorporate the project. Nonetheless, suggested improvements and required updates for relevant management plans are provided in the responses to Questions 12 and 13 below.

Noted.

Question 12: Are the proposed updates to the surface water and groundwater monitoring proposed in the Mount Owen Complex WMS appropriate and adequate to capture the potential impacts of the Project on the significant water resources?

44. The groundwater and surface water monitoring networks provide adequate spatial coverage of the broader project area. However, as multiple maps have been provided for each network, it is unclear which sites will continue to be monitored during different project phases. When the relevant water management plans are updated, this information should be clearly outlined along with details of the monitoring programs (e.g. locations, sampling frequency and analyte suites) and site-specific guideline values for both water levels and quality.

The recommendation is noted. As detailed in the EIS, the Mount Owen Complex Surface Water Management and Monitoring Plan (SWMMP) will be updated to take into account the changes associated with the Project. This will include additional monitoring associated with the proposed Yorks Creek Realignment and the review of groundwater monitoring locations to ensure areas of Bowmans Creek potentially impacted by the Project and cumulatively are appropriately monitored.

45.	**The geochemical analysis has highlighted that waste material could potentially release cobalt, iron, manganese, nickel, zinc, aluminium, arsenic, copper, cadmium, chromium, barium, boron and molybdenum (Environmental Geochemistry International 2019, pp. 20-47). The groundwater and surface water monitoring suite of parameters should be expanded, particularly at sampling locations along and at the endpoints of these seepage pathways, to incorporate all analytes that may indicate seepage from waste material. This will allow potential seepage of contaminants to be identified early and appropriate mitigation and management measures to be implemented.**

As discussed in the Geochemical Assessment (Appendix 19 of the EIS), water extraction and leach column testing of non-acid forming (NAF) overburden/interburden and rejects indicated these materials have low salinity potential and are unlikely to release significant metal/metalloid concentrations. The vast majority of overburden/interburden, coal and washery wastes for the Project are expected to be NAF with excess acid neutralising capacity and are not expected to require special handling. Dilution and mixing during mining are sufficient to mitigate acid rock drainage (ARD) from any occasional thin zones of pyrite that may be present in pit walls and pit backfill, and prevent any significant impacts on downstream water quality.

The monitoring of potential toxicants and the use of reference sites is discussed in Section 5.5.1 of **Appendix 1**. As discussed in **Appendix 1**, the update of the Mount Owen Complex SWMMP will include details of reference sites to be used for the Project and updated site specific guideline values for these sites which have regard to all relevant guideline materials (refer to response to Paragraph 46 below). Consistent with the recommendations in Section 5 of **Appendix 1,** once a suitable baseline is established, sampling for metals will only be undertaken in response to exceedance of the physical chemical stressors site specific guideline values.

46.	**Recent groundwater quality data (AGE 2019, Table 5-3, pp. 75-76) show that the ANZG (2018) default guideline values for freshwater aquatic ecosystems (95% species protection level) are exceeded at multiple sites for many analytes, particularly those which could indicate seepage (e.g. aluminium, arsenic, chromium, copper, manganese, nickel, zinc, cadmium and selenium). The IESC recommends that the proponent characterise the typical concentrations of these analytes at relevant monitoring locations (as outlined in Paragraph 45) and develop site-specific guidelines from suitable reference sites that can be used within a trigger action response plan (TARP) for waste material seepage.**

Appendix 1 includes a discussion of existing monitoring undertaken at the Mount Owen Complex and the selection of reference sites and identification of site-specific guideline values. This is discussed further in response to paragraph 47 and 48 below.

47.	**Site-specific surface water quality guideline values for electrical conductivity and total suspended solids have been developed for several sites within the clean water system (GHD 2019, Table 5-2, p. 31). However, it appears that these site-specific guideline values have not been derived from reference sites and may have been determined from impacted sites as the values vary for each site. The IESC recommends that the proponent revises these site-specific guideline values to ensure that these are appropriately derived as outlined in ANZG (2018) and Huynh and Hobbs (2019). The proponent should also develop site-specific guideline values for a range of metals prior to commencing the project, particularly at sites where observed concentrations (e.g. copper, nickel, chromium, lead) commonly exceed default guideline values. Site-specific guideline values should also be developed for analytes that may be characteristic of seepage from waste material (see Paragraph 45) as part of a TARP. Suggested analytes include aluminium, copper, cobalt, iron, manganese, nickel, zinc, arsenic, cadmium and chromium.**
48.	**Current surface water quality monitoring data from some sites (e.g. SC3, BC2, BC3, BC4 and BC5) show elevated salinity and total suspended solids. The cause of this is unclear. Further discussion should be provided which examines potential causes, including the potential for mine seepage particularly at SC3, BC2, BC3, BC4 and BC5.**

Section 5 of **Appendix 1** includes an analysis of historical surface water monitoring at the Mount Owen Complex having regard to the guidance provided by ANZG (2018) and Huynh and Hobbs (2019). The analysis in **Appendix 1** includes consideration for the issues raised in paragraph 48.

As discussed in **Appendix 1**, there are limited opportunities for reference sites for the Mount Owen Complex from unimpacted areas due to the long history of mining related development in the surrounding area and the nature of the geology in the surrounding area such that the geology in upstream areas is different to that downstream from the complex and areas potentially impacted by the complex. The ephemeral nature of the systems being monitored provides further complexity in the establishment of site-specific guideline values.

The site-specific guideline values referenced in the SWIA were obtained from a 2019 update to the Mount Owen Complex SWMMP which occurred prior to the publication of Huynh and Hobbs (2019). **Appendix 1** includes a full review of data used to establish these site specific guideline values and has recommended that further monitoring of physical chemical stressors (pH, EC and TSS) and selected metals and metalloids be undertaken at all potential reference sites to establish site specific guideline values based on the 95th percentile of these results. Until such time as there is sufficient data available to establish site specific guideline values, interim revised site specific guideline values have been identified based on the review of the existing monitoring data and these will be incorporated into the Mount Owen Complex SWMMP updated for the Project.

Question 13: Are there any additional mitigation, monitoring, management or offsetting measures that should be considered by decision makers to address the residual impacts of the Project on water resources?

49. The proponent should install a flow gauge to measure flows through the Yorks Creek diversion. These monitoring data will provide useful information for assessing the hydrological and hydraulic performance of the diversion. Monitoring of the assemblage composition and condition of aquatic biota and riparian vegetation along the Yorks Creek diversion and in suitable reference sites is also recommended as this information will be needed as part of the proposed Before-After-Control-Impact (BACI) monitoring program (discussed below in Paragraph 51) to assess potential ecological impacts (including residual ones) of the diversion.

The monitoring program will be developed as part of the detailed design of the proposed diversion and the update of the Mount Owen Complex SWMMP. The Proponent will include flow monitoring within the Yorks Creek Realignment as part of the updated monitoring program.

50. Continued monitoring of existing GDEs and riparian vegetation established along the Yorks Creek diversion is needed to identify potential impacts, assess rehabilitation progress and initiate mitigation programs if impacts are identified. Any TARPs developed should use baseline data collected during the recent drought period (2017-2019) cautiously, as ecological parameters such as species richness and community composition are likely to have been already impacted by reduced access to water, potentially resulting in a misleadingly conservative baseline.

Continued monitoring of existing GDE's and riparian vegetation will be undertaken. Further baseline data will be captured prior to the impacts to Yorks Creek occurring to inform the development of the monitoring program and TARP. The monitoring program will also include non-mined upstream reference sites.

51. A BACI-based monitoring program has been proposed to assess the impacts of the Yorks Creek diversion and the success of the constructed design in meeting the relevant design objectives (Umwelt 2019a, p. 262). The IESC agrees with this program design and that monitoring should rely on objectively measured data rather than rapid visual assessment approaches (Gippel 2019, p. 58). Further detail of the proposed monitoring program will need to be provided before its adequacy can be determined.

Continued monitoring of existing GDE's and riparian vegetation will be undertaken. Further baseline data from the existing Yorks Creek alignment will be captured prior to it being impacted by realignment works. The monitoring program will also include the use of reference sites and include an overlapping period of monitoring in both the existing Yorks Creek riparian areas and the reference sites to better inform baseline conditions and the appropriateness of the ongoing use of reference sites. The monitoring of the existing Yorks Creek riparian vegetation and reference sites will inform the development of the monitoring program and TARPs to be implemented following the Yorks Creek Realignment works. The monitoring program and TARPS will be documented in the Yorks Creek Realignment Plan and form part of the Rehabilitation Management Plan (RMP)/ Mining Operations Plan (MOP) monitoring program.

52.	**The proponent has stated that an initial inspection will be undertaken to identify issues which may delay revegetation establishment; however, further monitoring may not commence until revegetation has demonstrated satisfactory growth (Umwelt 2019c, p. 59). It is unclear how 'demonstrated satisfactory growth' will be determined without regular monitoring following the initial inspection. When the Rehabilitation Management Plan is developed, a comprehensive monitoring plan to assess the success of rehabilitation will be required. Data on the current composition of riparian vegetation along Yorks Creek will provide a useful baseline to guide riparian rehabilitation.**

Noted. The scope of the rehabilitation monitoring program will be developed and refined through the preparation of the RMP/MOP. As discussed in response to Paragraph 50, additional baseline data will be captured to confirm the current composition of the riparian vegetation along Yorks Creek, as well as reference sites prior to the impacts occurring.

53.	**It is unclear whether the potential impacts of groundwater drawdown on the likely groundwater-dependent state-listed threatened species Acacia pendula have been fully considered. A monitoring and management plan may be needed to detect and mitigate potential groundwater drawdown impacts to this species. Alternatively, there may be a need for suitable offsets if effective mitigation is not feasible.**

There are thirteen individual planted *Acacia pendula* located within the area of impact. These individuals will be cleared and no further mitigation or monitoring will be required. The removal of the *Acacia pendula* has been considered as part of the Biodiversity Development Assessment Report prepared for the Project (refer to Appendix 20 of the EIS).

54.	**The IESC notes that the bushfires of the 2019/2020 Australian summer have impacted a considerable area of national parks within the project region. Vegetation across the project site, especially along unburnt riparian corridors, is likely to be providing crucial refuge habitat for a range of biota currently. Maintenance of this habitat will be particularly important until surrounding areas of burnt bushland have recovered adequately to provide suitable habitat again.**

No vegetation in the vicinity of the Project Area has been impacted by recent bushfire. The closest large scale burnt area is located greater than 20 km from the Project Area and it is considered unlikely that the vegetation within the Project Area is currently providing refuge to fauna displaced as a result of the 2019/2020 bushfires. Additionally, clearing of the most significant areas of vegetation within the Project Area will not occur until the later stages of the Project as mining progresses into the northern end of the Glendell Pit Extension.

3.0 References

AGE (2019) Glendell Continued Operations Project, *Groundwater Impact Assessment.*

ANZG (2018). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), (2019), Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia.

GHD (2019). Glendell Continued Operations Project, *Surface Water Impact Assessment.*

CSIRO and Bureau of Meteorology [BOM] (2019) Climate Change in Australia website. Retrieved from http://www.climatechangeinaustralia.gov.au/.

Huynh T and Hobbs D (2019). Deriving site-specific guideline values for physico-chemical parameters and toxicants. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy.

APPENDIX 1

Response to IESC Advice – Surface Water

Umwelt (Australia) Pty Ltd

Glendell Continued Operations Project

Response to IESC advice - Surface water

August 2020

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1. Introduction

1.1 Background

GHD Pty Ltd (GHD) was engaged by Umwelt (Australia) Pty Ltd (Umwelt) on behalf of Glendell Tenements Pty Limited (the Proponent), a subsidiary of Glencore Coal Pty Ltd (Glencore), to prepare a surface water impact assessment (SWIA) for the Glendell Continued Operations Project (the Project). This assessment forms part of an environmental impact statement (EIS) to support a State significant development (SSD) application under Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act) to facilitate the extension of mining at the existing Glendell Mine, an open cut coal mine located in the upper Hunter Valley of NSW.

Following submission of the SWIA, the Independent Expert Scientific Committee (IESC) provided advice to the NSW Department of Planning, Industry and Environment (DPIE) at their request in response to their questions. Some of the questions and advice relate to the potential surface water impacts of the Project.

1.2 Purpose of this report

The purpose of this report is to provide advice to Umwelt, on behalf of the Proponent, regarding specific issues raised in the IESC's advice to DPIE, as summarised in Table 1-1.

Table 1-1 IESC advice

IESC reference	Where addressed
Surface water Question 2: To what extent can decision makers have confidence in the prediction of potential impacts on surface water resources provided in the EIS, including in regard to potential stream flow losses, water quality, uncontrolled discharges and flooding? Advice 2 Modelling of a 'unit' pool to predict potential impacts on refugial pools has limited value given each refugial pool will have unique characteristics that cannot be captured by modelling of a single 'representative' pool. The IESC instead suggests the proponent undertake further field studies to map refugial pools and determine their characteristics including groundwater connectivity. This information should be obtained for all refugial pools in potentially affected creeks, particularly those within Yorks Creek that will likely be lost and which should, ideally, be recreated within the diversion.	Section 2
Flooding Question 4: Has the flood assessment undertaken in the EIS adequately assessed the flood risk profile of the Project and the impacts on the extent of flooding (flood depths and changes in velocity) and stability of downstream watercourses through changes in the landform (including the proposed realignments of Yorks Creek and Hebden Road) and the resulting changes to the catchment area? Advice 10. Additional discussion of predicted flood depths and velocities at the confluence of Bowmans Creek and the Yorks Creek diversion, and within the lower reaches of the Yorks Creek diversion (up to at least the Hebden Road crossing) should be provided. Current predictions show that the lateral extent of flooding within Bowmans Creek at the confluence is less than in many other parts of Bowmans Creek and that ponding in the lower reaches of Yorks Creek diversion is not expected. Given the significant change in bed slope from 0.04 m/m to relatively flat conditions that occurs 150 m before the confluence (Gippel 2019, p. 37), further assessment of the stability of the watercourse (see Paragraph 36) is required.	Section 3

IESC reference	Where addressed
Advice 13. The stability of downstream watercourses beyond Bowmans Creek has not been discussed in detail. As limited erosional changes are predicted within Bowmans Creek downstream of the diversion (Gippel 2019, p. 47), changes further downstream are likely to be also minimal but this prediction should be confirmed with additional monitoring (see Paragraphs 49 and 51).	Section 3
Final void and pit lake Question 8: Has the EIS adequately analysed the evolution of change in water quality and level in the Glendell Mine final void pit lake in the proposed final landform, any potential risk of spills or leaching on downstream environments, and cumulative impacts due to multiple voids across the Mount Owen Complex due to groundwater flowpath interactions? Advice 29. It is unclear from modelling whether climate change has been accounted for in the post-mining phase. Given the predicted recovery period of approximately 450 years for groundwater levels (AGE 2019, p. 105) following mining, climate change should be considered as it may affect the time taken for recovery which could result in impacts to water resources occurring over longer periods and affect rates of possible post-mining recovery of water resources.	Section 4
Avoidance, mitigation and monitoring Question 12: Are the proposed updates to the surface water and groundwater monitoring proposed in the Mount Owen Complex WMS appropriate and adequate to capture the potential impacts of the Project on the significant water resources? Advice 47. Site-specific surface water quality guideline values for electrical conductivity and total suspended solids have been developed for several sites within the clean water system (GHD 2019, Table 5-2, p. 31). However, it appears that these site-specific guideline values have not been derived from reference sites and may have been determined from impacted sites as the values vary for each site. The IESC recommends that the proponent revises these site-specific guideline values to ensure that these are appropriately derived as outlined in ANZG (2018) and Huynh and Hobbs (2019). The proponent should also develop site-specific guideline values for a range of metals prior to commencing the project, particularly at sites where observed concentrations (e.g. copper, nickel, chromium, lead) commonly exceed default guideline values. Site-specific guideline values should also be developed for analytes that may be characteristic of seepage from waste material (see Paragraph 45) as part of a TARP. Suggested analytes include aluminium, copper, cobalt, iron, manganese, nickel, zinc, arsenic, cadmium and chromium.	Section 5
Advice 48. Current surface water quality monitoring data from some sites (e.g. SC3, BC2, BC3, BC4 and BC5) show elevated salinity and total suspended solids. The cause of this is unclear. Further discussion should be provided which examines potential causes, including the potential for mine seepage particularly at SC3, BC2, BC3, BC4 and BC5.	Section 5

1.3 Limitations

This report: has been prepared by GHD for Umwelt (Australia) Pty Ltd and may only be used and relied on by Umwelt (Australia) Pty Ltd for the purpose agreed between GHD and the Umwelt (Australia) Pty Ltd as set out in this report.

GHD otherwise disclaims responsibility to any person other than Umwelt (Australia) Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Umwelt (Australia) Pty Ltd and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Refugial pools

A feature of Bowmans Creek, particularly during periods of low flows, are persistent pools throughout its lower reaches. Assessment of these pools presented in the SWIA made use of a streamflow model to model the characteristic “unit” pool, with depth 600 mm, and considered direct rainfall, seepage and potential evaporation from the open water surface. The IESC has recommended modelling of actual specific pools, as characterised by detailed site survey, rather than the “unit” pool approach taken in the SWIA. As a result, detailed survey of three existing pools near the Yorks Creek confluence with Bowmans Creek, including two downstream from the existing confluence of Bowmans Creek and Yorks Creek, has been collected to inform the modelling. The location of the surveyed pools are identified in Groundwater Impact Assessment (AGE 2019). The purpose of this section is to present the updated modelling methodology and results.

2.1 Methodology

A detailed survey of three pools along Bowmans Creek was undertaken 13 May 2020 and a model of the existing base of the pool derived. From this model, a stage-storage rating curve was developed, which related the water storage volume in the pool at various water surface elevations. The stage storage relationships of each pool are shown in Figure 2-1, Figure 2-2 and Figure 2-3, with pool 1 being the furthest upstream and pool 3 the furthest downstream.

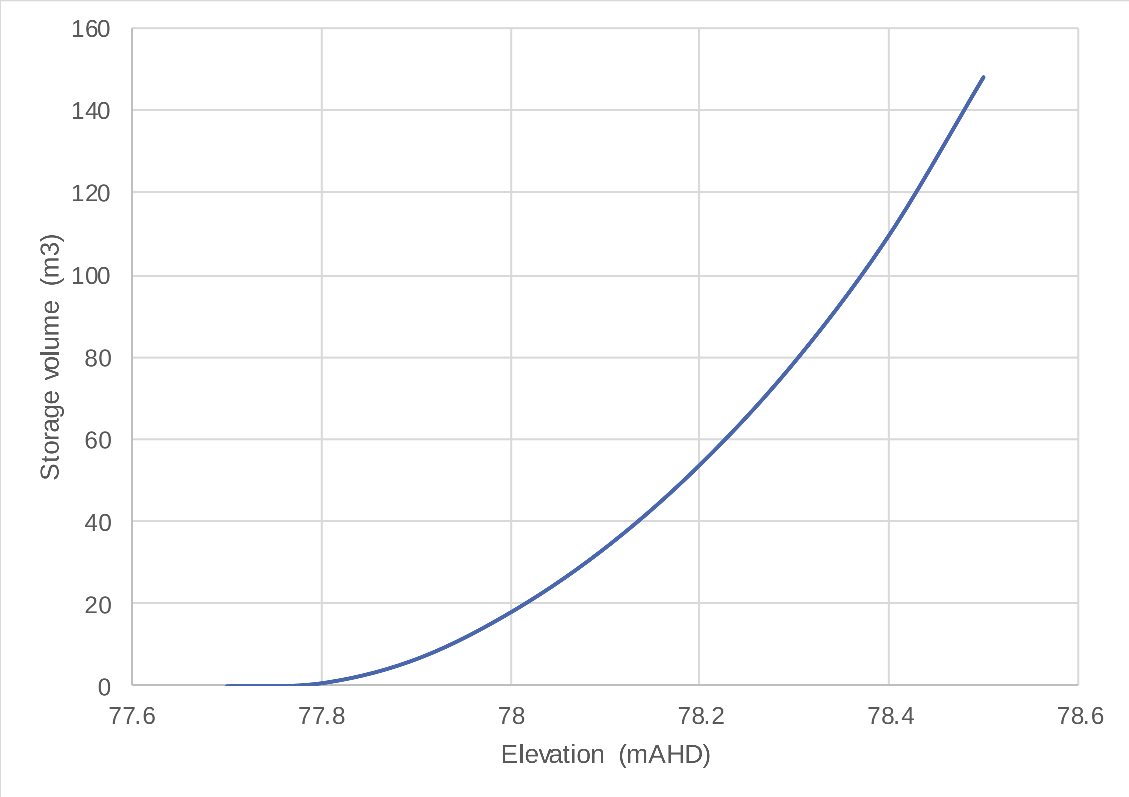

Figure 2-1 Stage-storage curve of pool 1

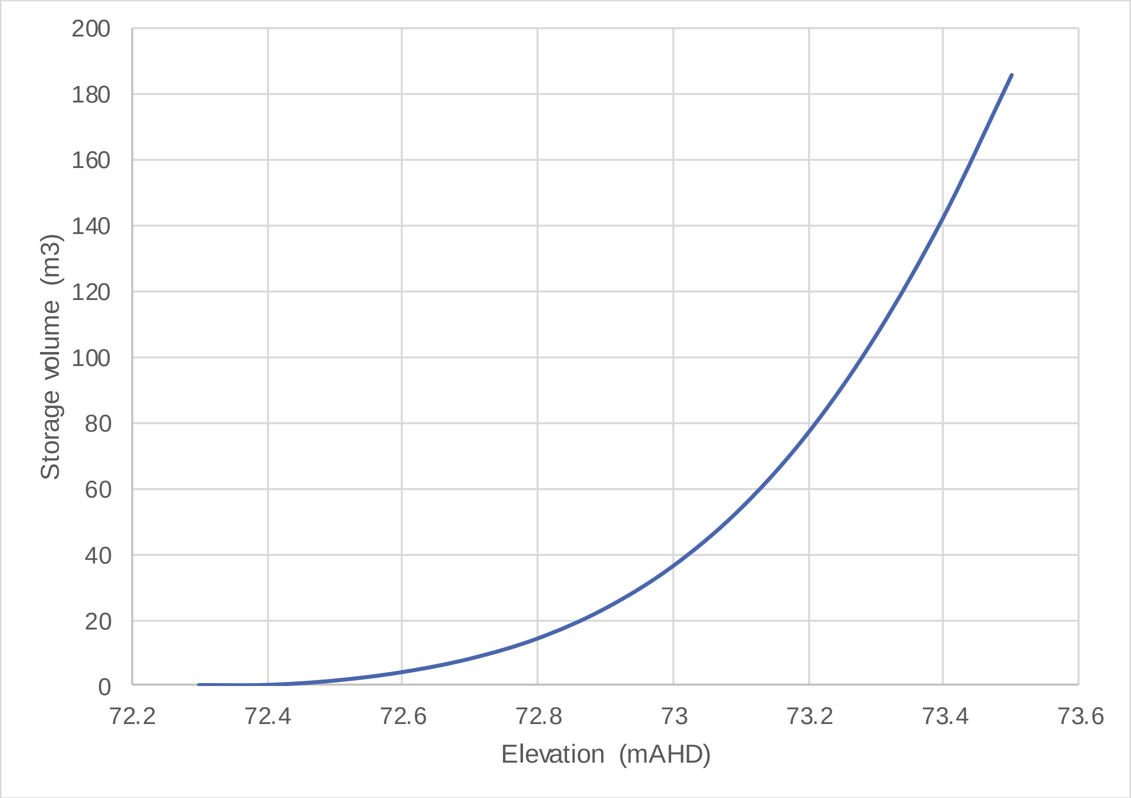

Figure 2-2 Stage-storage curve for pool 2

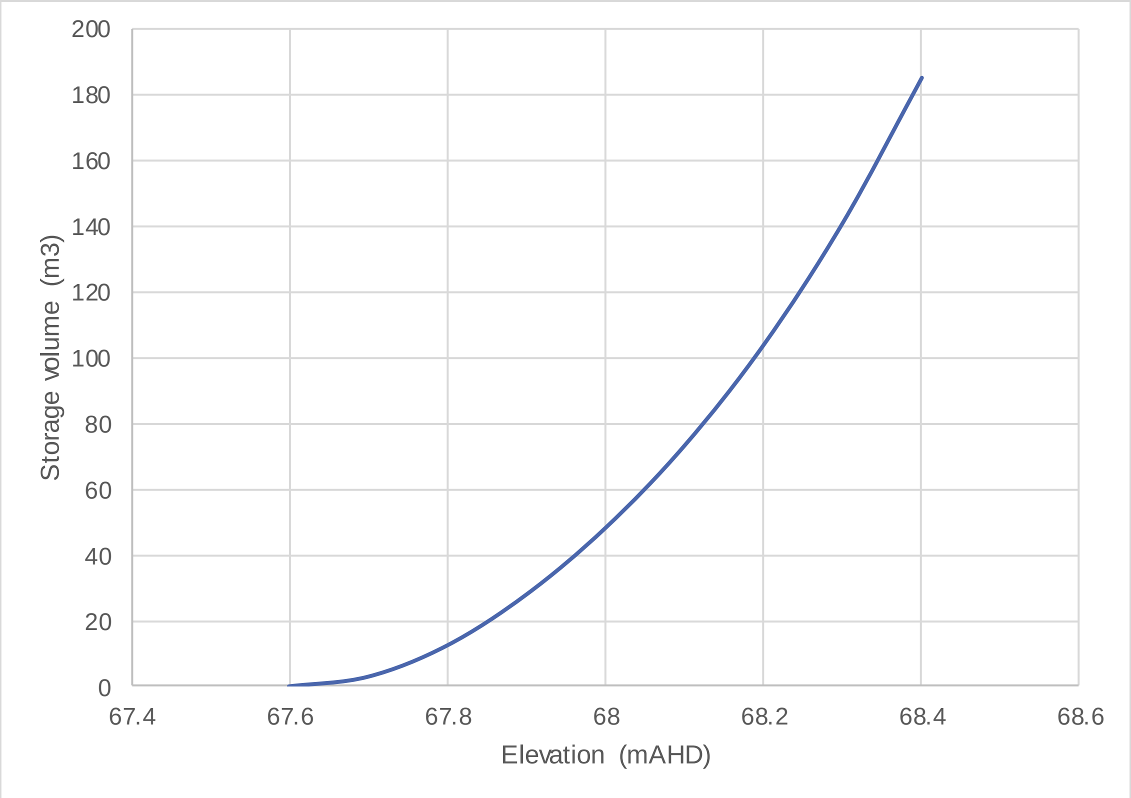

Figure 2-3 Stage-storage curve for pool 3

The streamflow modelling described in the SWIA was repeated for each pool, using these stage storage relationships to represent the existing geometry of the pools.

2.2 Results

The modelled depth duration curves of the three surveyed pools are presented on Figure 2-4, Figure 2-5 and Figure 2-6. These figures may be compare to Figure 9-11 of the SWIA.

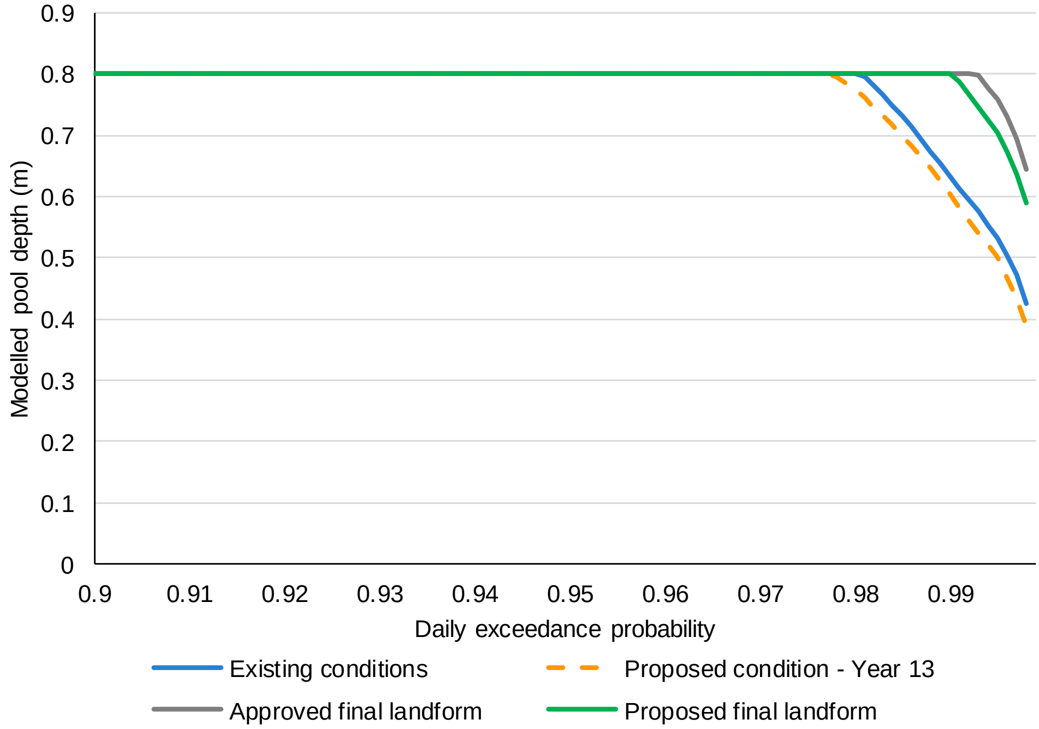

Figure 2-4 Potential impact on Bowmans Creek pools - pool 1

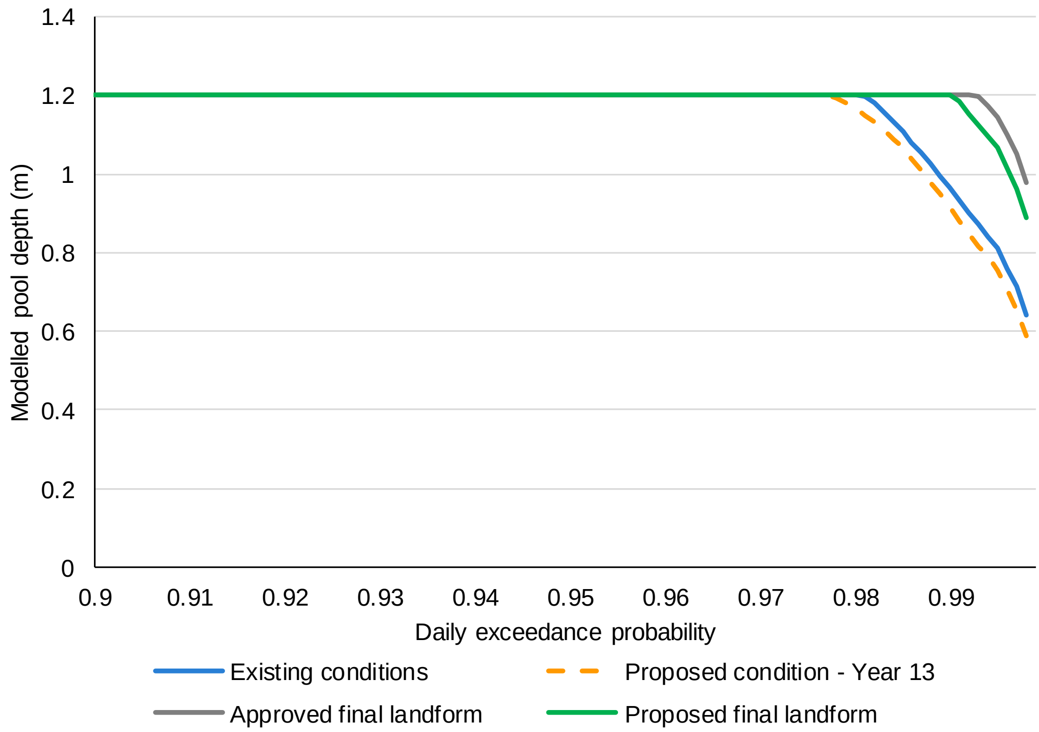

Figure 2-5 Potential impact on Bowmans Creek pools - pool 2

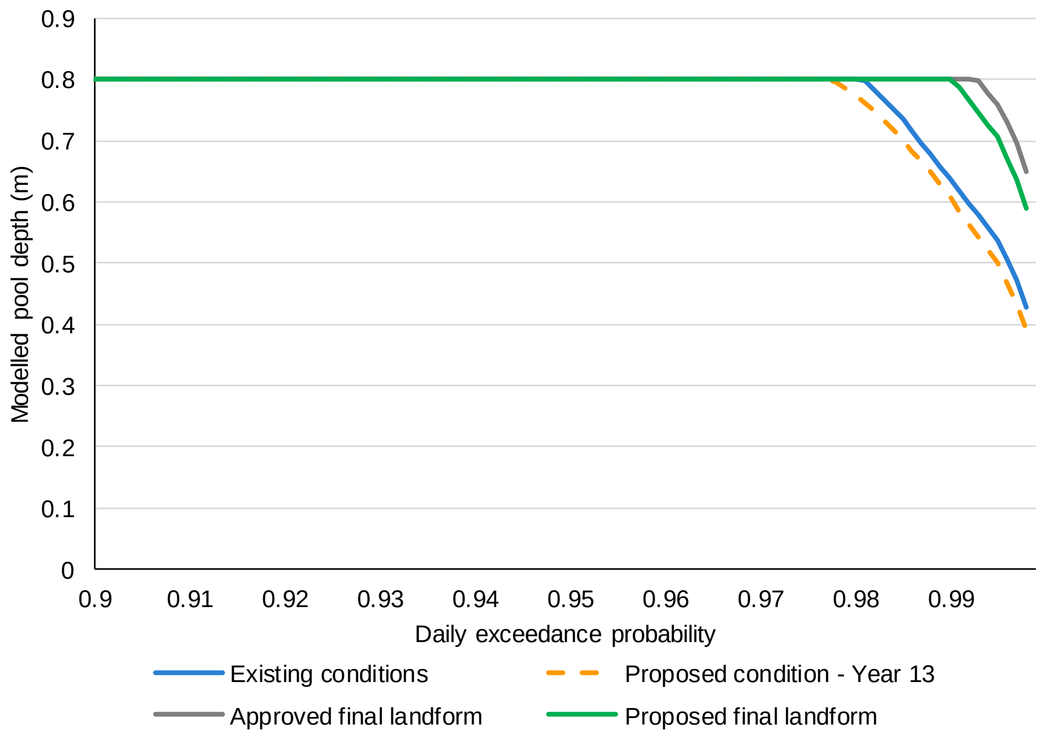

Figure 2-6 Potential impact on Bowmans Creek pools - pool 3

Figure 2-4, Figure 2-5 and Figure 2-6 all show very similar results to the “unit pool” result presented in the SWIA. The duration with less than a full pool is similar, as this reflects the flow duration of Bowmans Creek. The minimum depth is greater than the “unit pool” result, which reflects the more realistic geometry of the surveyed pools where evaporative losses decrease proportionally as the water level and water surface area fall.

Overall, the results of the modelling using the surveyed actual pools is consistent with the results presented in the SWIA, which supports the conclusion that no measurable surface water impacts on the persistent pools in the lower part of Bowmans Creek is expected as a result of the Project. Based on the modelling results, the pools are unlikely to completely dry out due to surface water impacts, and the similarity of modelled pools depths under all modelling scenarios indicates that measurable changes in water quality properties such as temperature and dissolved oxygen are unlikely.

3. Confluence of Bowmans Creek and Yorks Creek realignment

3.1 Flood modelling

During the preparation of the SWIA, GHD undertook detailed flood modelling of the lower Bowmans Creek catchment. Reporting in the final SWIA focused on summarising the key potential impacts of the project, and did not present the entire set of modelling results. This section addresses specific issues raised by IESC advice on the stability of Bowmans Creek downstream of the confluence with the Yorks Creek realignment, and monitoring of this area of Bowmans Creek.

Modelling considered existing watercourses upstream and downstream of the proposed Yorks Creek realignment. This spatial extent is sufficient to capture the potential flow regimes in the proposed Yorks Creek realignment to inform the selection of mitigation measures for treatment of potential erosion in the lower reaches of Bowmans Creek, including the confluence with the proposed Yorks Creek realignment. More detailed modelling will be necessary to finalise the detailed design, to confirm the actual design measures to mitigate potential impacts associated with the stability of the Yorks Creek realignment. Indicative ‘hard engineering’ scour protection measures, based on Fischenich (2001), are nominated for the purpose of comparison only, but in reality equivalent performance can be achieved using a range of measures developed in accordance with the design principles outlined in the SWIA. This includes an iterative design process where the selected channel geometry, sinuosity, material properties (including use of in situ rock in cut), large boulders and woody debris will be selected to mitigate potential impact of channel stability, and in turn influence the design hydraulic characteristics, while considering more detailed geotechnical investigation.

3.1.1 Velocity

The peak velocity of the 1% AEP flooding event at the confluence of Bowmans Creek and Yorks Creek realignment is presented below in Figure 3-1 . The change in velocity compared to existing Bowmans Creek is presented in Figure 3-2. Figure 3-1 shows that in Bowmans Creek upstream of the confluence the peak velocities are generally between 2.3 to 3.6 m/s. The peak velocity is maximum velocity simulated within the flood model and does not necessarily reflect the generally lower velocity that may occur during the peak flow of an actual flood. Downstream of the confluence, velocities are generally higher and exceed 3.6 m/s in the centreline of the channel. Although these velocities are very high, Figure 3-2 demonstrates that they have generally not changed considerably compared to the existing conditions. The confluence with the Yorks Creek realignment at this location has been calculated to reduce velocities in Bowmans Creek upstream of the confluence and increases them downstream by less than 0.25 m/s. The stability of Bowmans Creek at this location is considered low risk. The exception to this is at the confluence itself, shown in Figure 3-2, which indicates that the modelled velocities increase by more than 0.5 m/s at this location. As velocities approach 4 m/s, additional measures equivalent to D_{50} rip rap of 300 mm or greater may be required to mitigate potential impacts associated with channel stability.

Figure 3-1 shows that within the upper segment of Yorks Creek realignment the velocities generally do not exceed 2.3 m/s and therefore D_{50} rip rap of 150 mm or equivalent should be sufficient to maintain channel stability. The lower segment of Yorks Creek realignment is much steeper and consequently the velocities much greater. Flood modelling results indicate the peak velocities of up to 5 m/s in this part of the channel including at the outlet into Bowmans Creek. These velocities are relatively high and where the channel is not cut into the in situ rock, a combination of stilling basins and large boulders are likely to be required to provide protection equivalent to D_{50} rip rap of 600 mm.

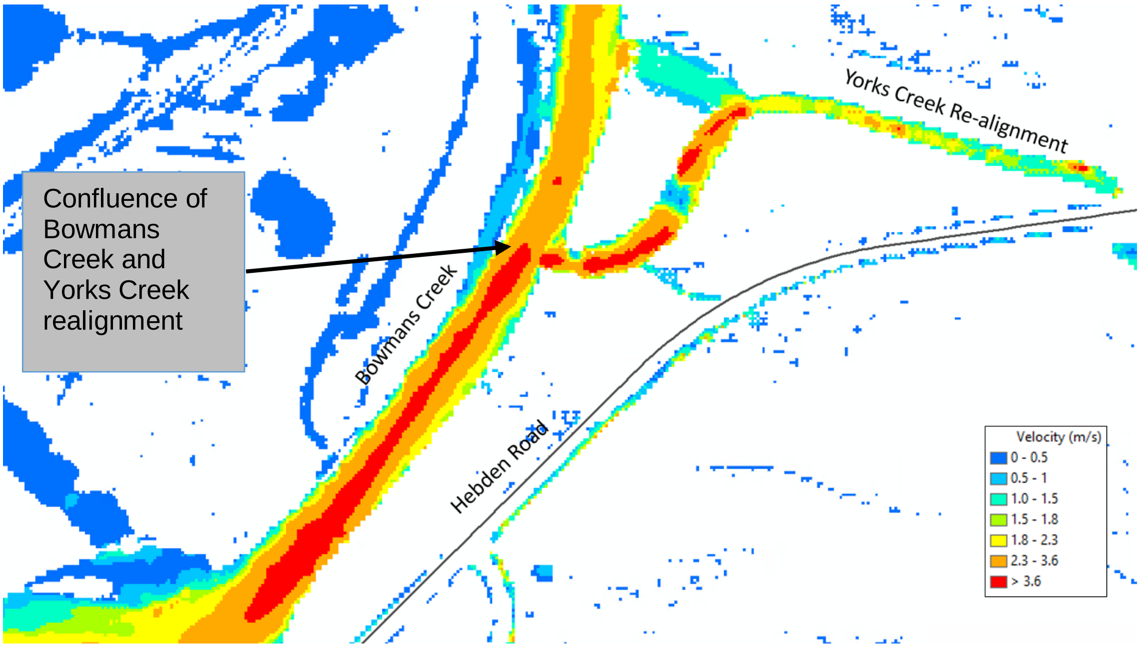

Figure 3-1 Final Landform 1% AEP water velocity at the confluence of Yorks Creek Re-alignment and Bowmans Creek

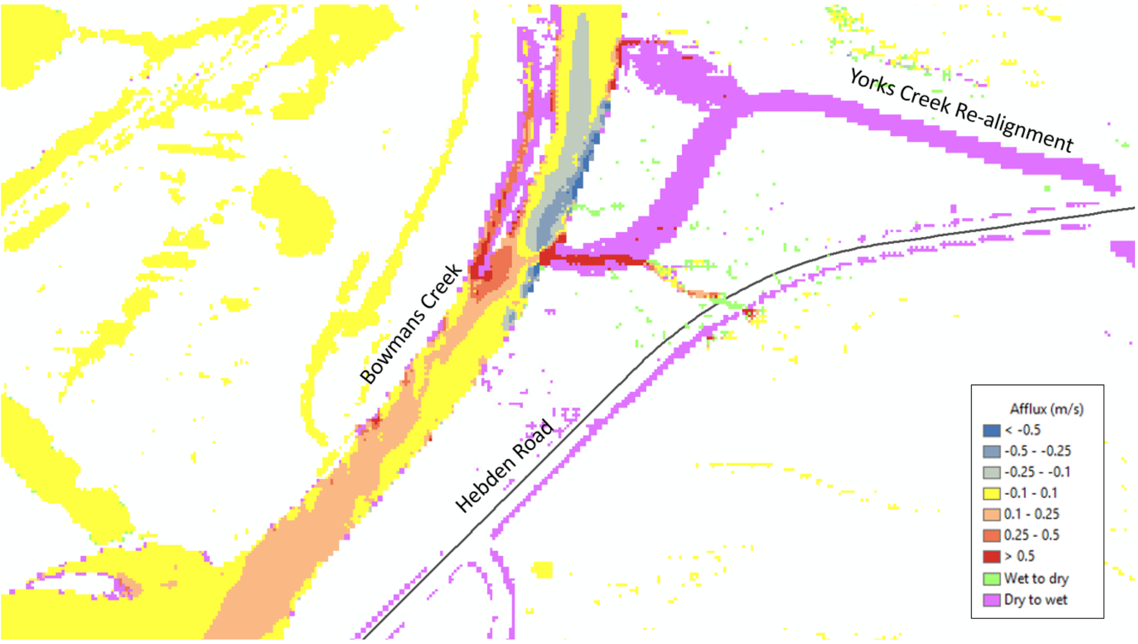

Figure 3-2 Final Landform 1% AEP change in velocity at the confluence of Yorks Creek Re-alignment and Bowmans Creek

3.1.2 Bed shear stress

As part of the flood modelling for the SWIA, bed shear stress was also simulated, however the results were not included in the SWIA considering the generally low risk of the potential impact identified. Bed shear stress is a measure of erosional power of flood waters and provides an additional indicator of channel stability.

The peak shear stress of the 1% AEP flooding event at the confluence of Bowmans Creek and Yorks Creek realignment is presented below in Figure 3-3. The peak shear stress is maximum shear stress simulated within the flood model, and does not necessarily reflect the generally lower shear stress that may occur during the peak flow of an actual flood. The change in shear stress compared to Bowmans Creek as it currently exists is presented in Figure 3-4. Figure 3-3 shows that in Bowmans Creek upstream of the confluence the shear stresses are generally less than 150 Pa in the centre of the channel and rise to approximately 1000 Pa at the channel edges. Downstream of the confluence shows much the same pattern as upstream. Although these shear stresses are relatively high in some locations, Figure 3-4 demonstrates that they have generally not changed compared to the existing conditions and there is no evidence of instability in the existing Bowmans Creek channel at that location. The flood modelling results indicate that the confluence of the Yorks Creek realignment at this location actually reduces shear stresses in Bowmans Creek upstream of the confluence and has minimal effect downstream. Potential impacts associated with the stability of Bowmans Creek at this location are considered minimal, except at the confluence itself. Figure 3-4 shows that shear stresses may increase by more than 100 Pa at this location, however this remains a minor change relative to the absolute shear stresses of about 1000 Pa.

Figure 3-3 shows that within the upper segment of the Yorks Creek realignment the shear stresses generally do not exceed 200 Pa and therefore relatively minor works are required, including incorporating sinuosity in the channel and vegetation to achieve a performance equivalent to lining with D_{50} rip rap of 225 mm.

The lower segment of Yorks Creek realignment is relatively steep and consequently the flood modelling results shows that shear stresses are expected to be greater, approaching 1000 Pa in parts of the channel including at the confluence with Bowmans Creek. These shear stresses are relatively high. Where the channel is not cut into the in situ rock, a combination of stilling basins and large boulders are likely to be required.

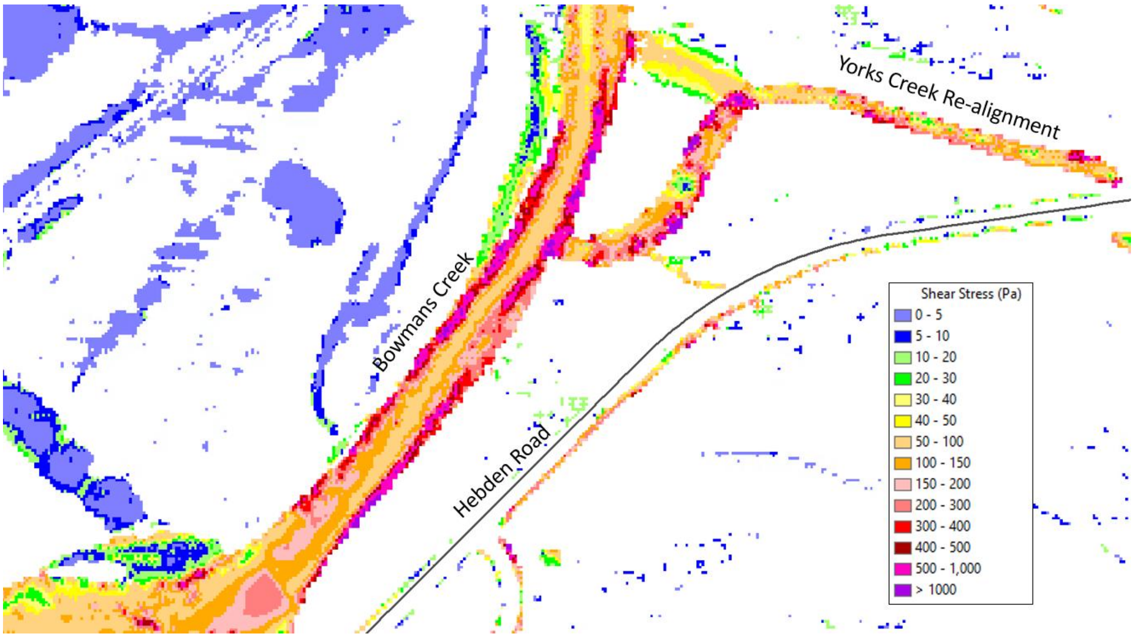

Figure 3-3 Final Landform 1% AEP shear stress at the confluence of Yorks Creek Re-alignment and Bowmans Creek

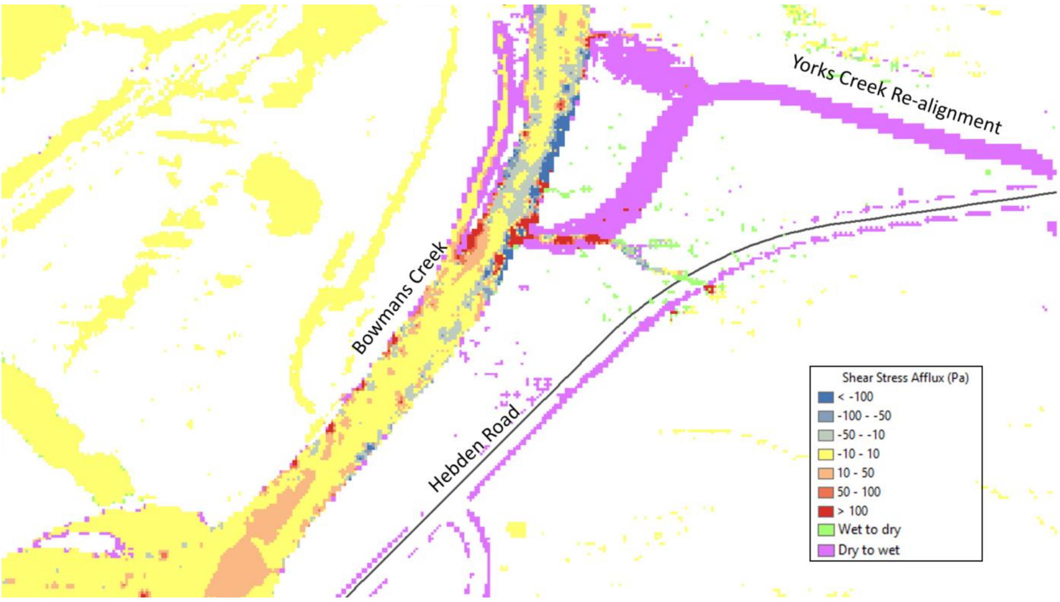

Figure 3-4 1% AEP change in shear stress at the confluence of Yorks Creek Re-alignment and Bowmans Creek

3.1.3 Summary

Overall, more detailed consideration of the flood modelling results indicates the potential for high velocity and bed shear stress in the lower steeper reaches of the Yorks Creek realignment. The detailed design of the realignment will confirm the design features required to mitigate potential downstream water quality due to erosion and scour, including detailed hydraulic modelling of the realignment. The flood modelling results of the upstream and downstream conditions indicate that, regardless of the refinement of the detailed design of the Yorks Creek realignment, the potential hydraulic changes in Bowmans Creek due to the Yorks Creek realignment are expected to be minor and within the natural geomorphic variation of Bowmans Creek.

3.2 Monitoring locations

The IESC have recommended that the watercourse stability monitoring of the Yorks Creek realignment should be extended downstream of the confluence with Bowmans Creek. This recommendation is supported, despite this risk of erosion and scour remaining low. The monitoring should be integrated into the monitoring program for the Yorks Creek realignment, including baseline monitoring. The variability in bed and channel condition, means that the identification of specific points should be based on site inspections as part of the development of the monitoring program during detailed design.

A review of the hydraulic conditions downstream of the confluence of Bowmans Creek and Yorks Creek realignment yielded several locations where watercourse stability monitoring would provide the best indications of the potential impacts from the Yorks Creek realignment. These are generally constricted parts of Bowmans Creek where slight increases in velocity and shear stress are predicted by the modelling. These areas are considered the most likely location for potential impacts of the Yorks Creek realignment on Bowmans Creek, if any, to manifest as measurable changes.

Figure 3-5 shows the indicative locations of the proposed monitoring reaches of Bowmans Creek. A detailed monitoring plan for the realignment will be developed and this will include sites within the realignment and upstream and downstream of the confluence of the realignment with Bowmans Creek. The monitoring will include survey sites, fixed photo points and physical inspections. The detailed monitoring plan will be incorporated into the water management plan for the project. The plan will include surface and groundwater responses that will identify remedial measures triggered by indicators of potential impacts, including repair and remediation of impacted watercourses.

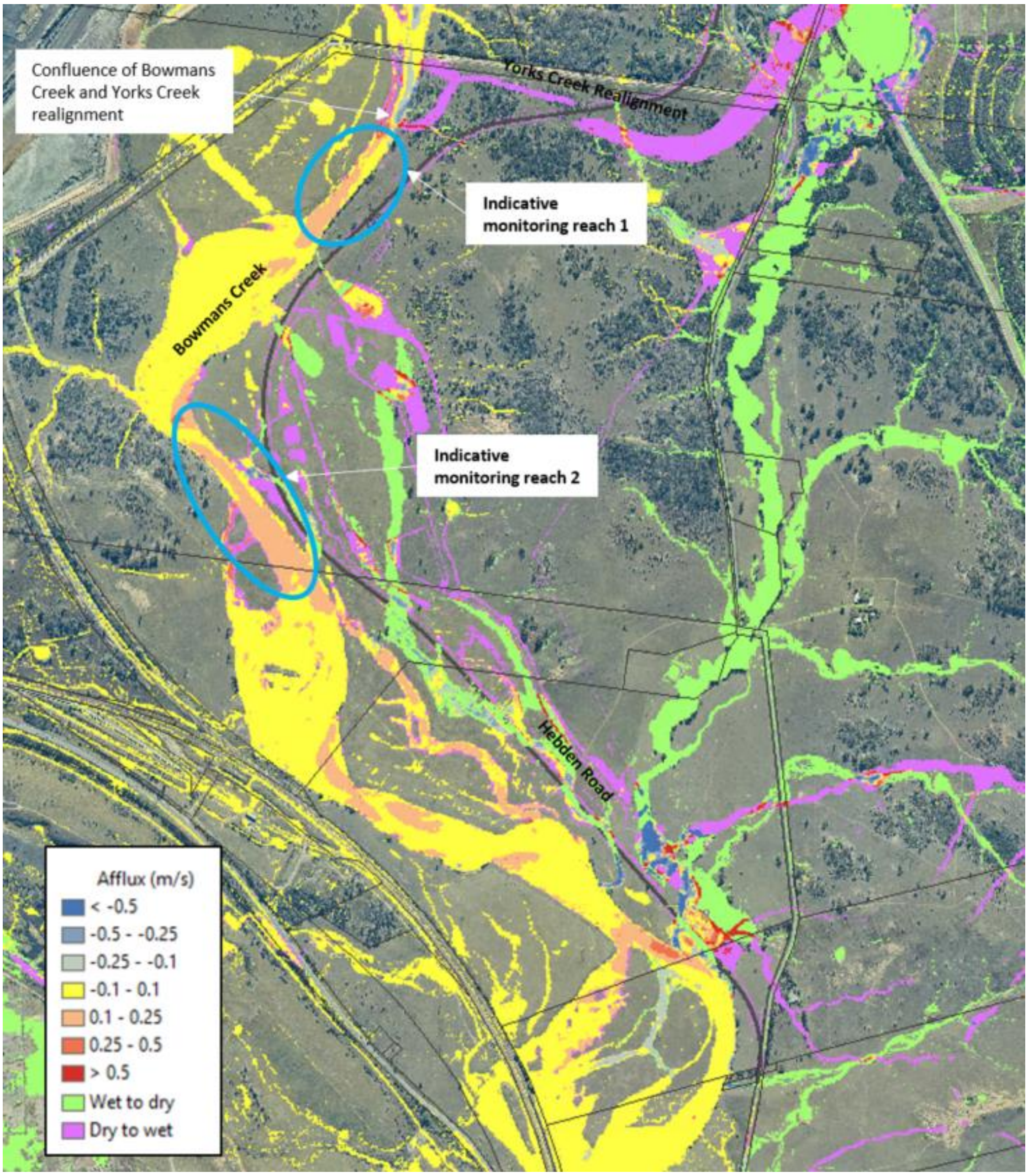

Figure 3-5 Proposed creek stability monitoring reaches

4. Climate change and the final void

The SWIA did not consider the potential impact of climate change on long term behaviour of water level and water quality in either the approved Glendell final void or the proposed Glendell Extension final void. The IESC has recommended that climate change be considered, given the long period of recovery expected. This section presents an approach to assessing the potential impacts of climate change on the final void using nationally recognised approaches and the outcomes of additional modelling.

4.1 Industry guidance and data sources

For both the approved Glendell final void and proposed Glendell Extension final void, climate change has the potential to influence the key climate drivers of the water balance: rainfall (precipitation) and potential evaporation. This in turn may influence the timing and ultimate level of the recovery of the final void. Although prescriptive guidance is available on the direct influence of average temperature changes on rainfall intensity during intense rainfall events (Ball et al 2019), the potential changes to the overall hydrologic cycle is less certain and the industry guidance less prescriptive.

Climate Change in Australia (CCIA) (CSIRO 2019) is published on the climate futures website by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BOM) to provide information about climate change projections for Australia. CCIA presents the results from a range of climate models based on the most recent set of simulations as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5).

The NSW and ACT Regional Climate Modelling (NARCliM) Project is a research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW. The NARCliM projections use four global climate models (GCMs) from the earlier CMIP3 project, dynamically downscaled by three regional climate models (RCMs).

Although the NARCliM projections are downscaled, they are based on the earlier CMIP3 project. There have been several advances since CMIP3 that are captured in CMIP5:

- Many more global climate models were applied.
- More models have higher resolution.
- Many more experiments have been performed leading to a much greater availability of different climate simulations.

For the purpose of this analysis, the CMIP5 projections presented in CCIA were used rather than NARCliM as they allow for a greater variety of climate science questions to be studied. Bi-linear interpolation was used to estimate changes from the model results grid, consistent with other aspects of CCIA.

4.2 Regional climate change context

For the east coast region, in which the project is located, CCIA identifies the following general changes to climate:

- Average temperatures will continue to increase in all seasons (very high confidence).
- More hot days and warm spells are projected with very high confidence. Fewer frosts are projected with high confidence.
- Decreases in winter rainfall are projected for East Coast South with medium confidence. Other changes are possible but unclear.

- Increased intensity of extreme rainfall events is projected, with high confidence.
- On annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years and for rainfall.

4.3 Representative concentration pathways

Notwithstanding the uncertainty in the climatic processes represented by the range of GCMs, climate change projections also depend on future anthropogenic forcings. Representative concentration pathways (RCPs) are prescribed pathways for greenhouse gas and aerosol concentrations, together with land use change, that are consistent with a set of broad climate outcomes used by the climate modelling community. The pathways are characterised by the radiative forcing produced by the end of the 21st century. Radiative forcing is the extra heat the lower atmosphere will retain as a result of additional greenhouse gases, measured in W/m^2.

Compared to CMIP3, the RCPs represent a wider set of futures than that used by the previous emissions scenarios used by the climate modelling community, and now explicitly include the effect of mitigation strategies. No particular scenario is deemed more likely than the others, however, some require major and rapid change to emissions to be achieved. Three RCPs were considered:

- RCP8.5 - a future with little curbing of emissions, with a CO_2 concentration continuing to rapidly rise, reaching 940 ppm by 2100.
- RCP6.0 – lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentration rising less rapidly (than RCP8.5), but still reaching 660 ppm by 2100 and total radiative forcing stabilising shortly after 2100.
- RCP4.5 - CO_2 concentrations are slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040), and the CO_2 concentration reaches 540 ppm by 2100.

Both RCP4.5 and RCP6.0 are compatible with the proposed life of the Project, RCP6.0 was selected as it provides a conservative estimate of potential impacts of climate change with the modelling of the RCP4.5 scenario likely to fall between the results presented in the SWIA and the RCP6.0 scenario results. RCP8.5 is generally considered unlikely as it combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements (Riaha et al 2011).

4.4 Methodology

For the purpose of this analysis, a risk assessment methodology was developed based on the guidance provided by CCIA, as outlined in Table 4-1.

Table 4-1 Climate change risk assessment approach

Assessment stage	Consideration
Establishment of context	The overall context of the project is established in the EIS and SWIA. This assessment considers advice provided by the IESC in response to the SWIA, as presented in Table 1-1.
Identification of known risks	The known risks associated with the water balance of the final void are that the void may become a source of saline water to the local groundwater or surface water system. The temporal scale extends beyond the end of the twentieth century, with void forecast to reach equilibrium in about 2500. The final void is expected to be hydrologically isolated and therefore it is appropriate to consider annual changes over this long period.
Risk analysis	The risks associated with the final void were analysed in the SWIA in terms of the time to reach equilibrium water level, the equilibrium water level (and freeboard) and the TDS at the time to reach equilibrium water level.
Planning horizon	The final void was forecast to reach equilibrium water level in about 2500.
Analysis method and data sources	The Delta Change Method was selected as the most appropriate method considering the advantages and disadvantages identified in the CCIA guidance: *Advantage*: Simple to implement and suitable for many applications. Facilitates assessment of outputs from a large number of GCMs *Disadvantage*: Limited applicability where changes in variance are important. This is not relevant as changes in variances likely to buffered out by over time in the final void. *Disadvantage*: May not capture projected climate behaviour around complex topography. This is not relevant as the site is located on the wide floor of the Hunter Valley.

Table 4-1 shows that the delta change method applies the projected changes in mean climate, as simulated by a climate model, to observed climate data. The observed climate, catchment, geometry and groundwater flows from the SWIA were used, with the projected changes identified in Section 4.5 applied. The groundwater inflows remained unchanged from those presented in the SWIA, as, although they are influenced by groundwater recharge rates, their relative contribution to the void recovery is small relative to rainfall inflows.

4.5 Projection data selection

Climate science provides a range of possible regional climate change responses for any given increase in greenhouse gases. This range in regional response is not usually reduced to a single best estimate (based on the model mean or median), and instead the full range of projections relevant to the application are considered. The literature maintains emphasis on the range of plausible climate change scenarios, and does not highlight detailed aspects (such as fine spatial detail) of the climate model simulations available as confidence in this detail is generally low.

CCIA provides the Australian Climate Future tool to assist understanding and application of climate change projections for impact assessment and adaptation planning. It provides methods to explore the projected changes in two climatic variables simultaneously. The key variables for this assessment were rainfall and potential evaporation. A combination of reduction in rainfall and increase in potential evaporation would result in a lower water level in the final void.

Similarly, a combination of increase in rainfall and reduction in potential evaporation would result in a highest water level in the final void. Based on these considerations, results produced by Australian Climate Futures tool are summarised in Table 4-2.

Table 4-2 East Coast Climate Futures representative models (2090)

Emission Scenario	Case	Representative Model	Consensus
RCP 4.5	Highest water level	NorESM1-M	Low
	Lowest water level	GFDL-ESM2M	Low
	Maximum Consensus	ACCESS1-0	Low
RCP 8.5	Highest water level	NorESM1-M	Low
	Lowest water level	GFDL-ESM2M	Moderate
	Maximum Consensus	ACCESS1-0	Moderate

The Australian Climate Futures tool is limited to RCP 4.5 and RCP 8.5. As the maximum consensus case model (ACCESS1-0) does not have projections for the desired assessment of the RCP 6.0 scenario, further investigation was required to identify an appropriate model for the maximum consensus case. The more advanced Australian Climate Futures Projection Builder tool was used to identify the model with the closest agreement to ACCESS1-0, with projections for RCP6.0, and no identified data limitations. The results of the Australasian Climate Futures Projection Builder tool are summarised in Table 4-3.

Table 4-3 East Coast Climate Futures Projection (time period 2090)

		Annual Evaporation (%)			
		Large Decrease <-4.59	Small Decrease -4.59 to -1.00	No Change 1.00 to 4.59	Large Increase > 4.59
Annual Rainfall (%)	**RCP 4.5**				
	Much Wetter > 15.00				
	Wetter 5.00 to 15.00				2 of 28 (7%) IPSL-CMSA-MR, NorESM1-ME
	Little Change -5.00 to 5.00			1 of 28 (4%) GISS-E2-R-CC	7 of 28 (25%) BCC-CSM1-1-M, MIROC5, MIROC-ESM-CHEM, HadGEM2-ES, CCSM4, **NorESM1-M**
	Drier -15.00 to -5.00			4 of 28 (14%) GISS-E2-H-CC, GISS-E2-H, GISS-E2-R, GFDL-ESM2G	8 of 28 (29%) BNU-ESM, CanESM2, **ACCESS1-0,** Inmcm4
	Much Drier < -15.00				6 of 28 (21%) **BCC-CSM1-1,** ACCESS1-3, CSIRO-Mk3-6-0, IPSL-CM5A-LR, GFDL-CM3, **GFDL-ESM2M**
	RCP 8.5				
	Much Wetter > 15.00				2 of 29 (7%) NorESM1-ME, **NorEMS1-M**
	Wetter 5.00 to 15.00				4 of 29 (14%) **BCC-CSM1-1-M,** FGOALS-s2, MIROC5, MIROC-ESM
	Little Change -5.00 to 5.00				7 of 29 (24%) BNU-ESM, CanESM2, IPSL-CM5A-MR, MIROC-ESM-CHEM, CCSM4, CESM1-BGC, CESM1-CAM5
	Drier -15.00 to -5.00				9 of 29 (31%) **ACCESS1-0,** ACCESS1-3, CSIRO-Mk3-6-0, IPSL-CM5B-LR, HadGEM2-CC, HadGEM2-ES, MRI-CGM3, GISS-E2-R-CC, **GFDL-ESM2M**
	Much Drier < -15.00				

Based on these considerations, the four models and the reasons for their selection are summarised in Table 4-4.

Table 4-4 Selected CMIP5 Models

Selected Models	Climate Futures	Other notes
GFDL-ESM2M	Lowest water level for East Coast region Represents warmest and driest model	Good representation of extreme El Nino. Model has results for RCP 4.5, 6.0, and 8.5
NorESM1-M	Highest water level for East Coast region Represents warmest and wetter model	Model has results for RCP 4.5, 6.0, and 8.5
ACCESS1-0	Maximum consensus for East Coast region	Model has results for RCP 4.5 and 8.5 but no data for RCP 6.0
BCC-CSM1-1	Represents the next best consensus for East Coast region but has results available for RCP 6.0.	Model has results for RCP 4.5, 6.0, and 8.5

For completeness, the maximum consensus model, ACCES1-0 was still considered for RCP4.5 and RCP8.5. This validated the selection of BCC-CSM1-1 as a surrogate maximum consensus model for RCP6.0, and also provided coverage of RCP4.5 and RCP8.5

These models were global climate models with a grid-spacing of more than 200 km and annual data. Regional climate change data from each model were expressed as percent annual change for a specific time period. Site specific percent change was obtained using bi-linear interpolation of the gridded data.

Site specific percent annual changes for rainfall and potential evapotranspiration were applied to the observed SILO dataset (refer to the SWIA). This produces a “new” projected rainfall and potential evaporation data from the simulation period.

Percent annual changes applied to the final void water balance model for time period 2090 onwards is presented in Table 4-5 while comparison of percent annual changes for interim time period until 2090 are shown in Figure 4-1 and Figure 4-2.

Table 4-5 Percent annual change for rainfall and potential evapotranspiration (time period 2090 onwards)

Scenario	RCP	GCM	Percent annual rainfall change	Percent annual potential evapotranspiration change
Maximum consensus	6.0	BCC-CSM1-1	- 0.4%	+9%
Lowest water level	6.0	GFDL-ESM2M	-15%	+10%
Highest water level	6.0	NorESM1-M	+8%	+9%
Maximum consensus	4.5	ACCESS1-0	-12 %	+9%
Maximum consensus	8.5	ACCESS1-0	-1%	+15%

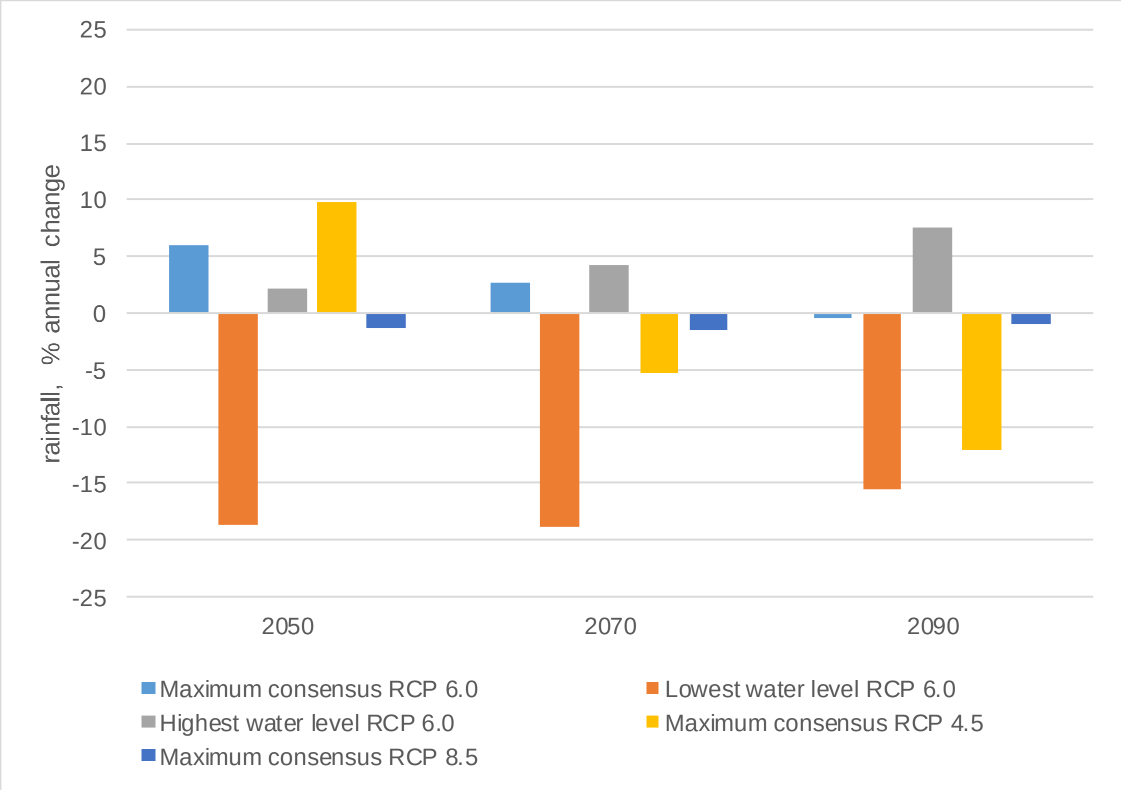

Figure 4-1 Rainfall percent annual change

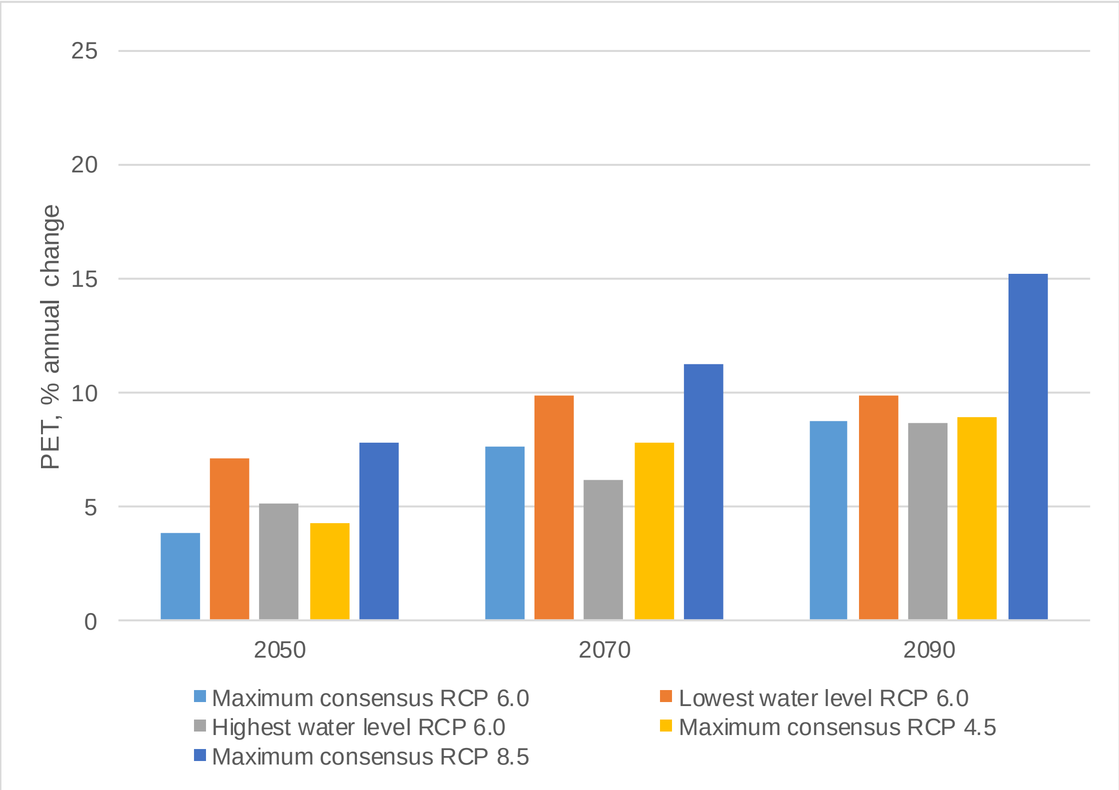

Figure 4-2 Potential evapotranspiration percent annual change

4.6 Modelling results

Comparison of results between all five scenarios with climate change factors and base case is presented on Figure 4-3 for approved conditions and Figure 4-4 for proposed conditions.

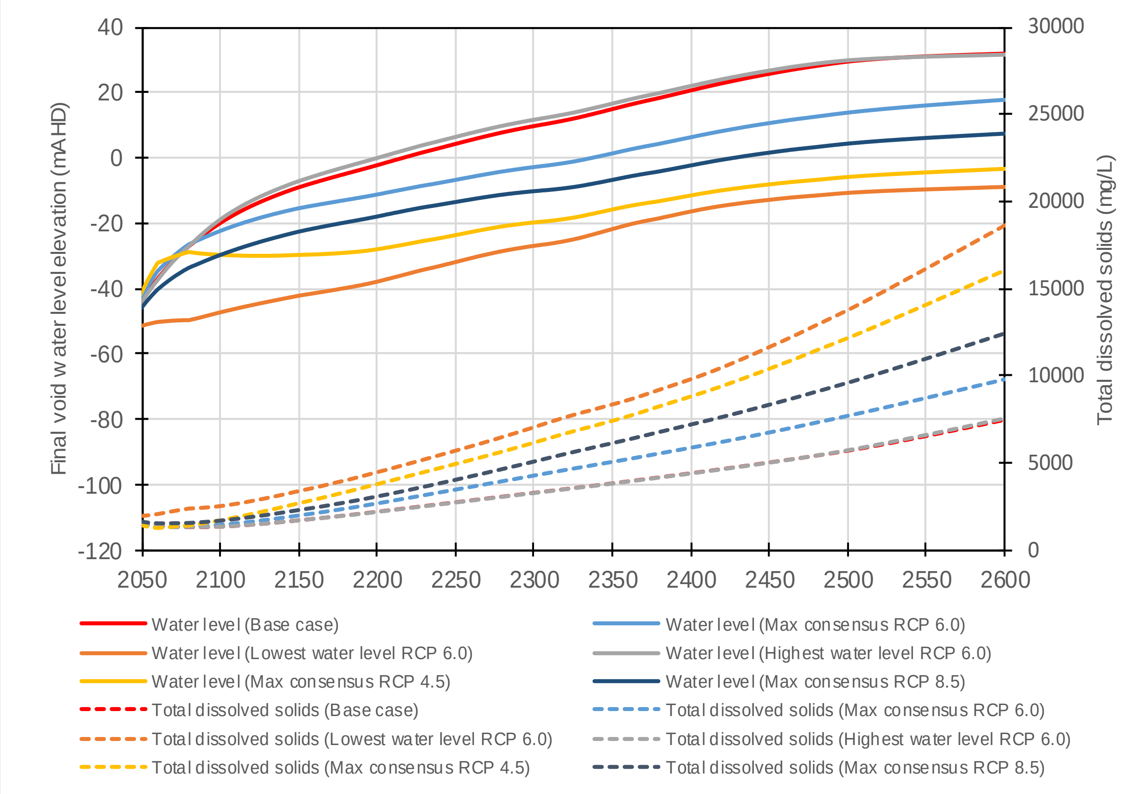

Figure 4-3 Forecast water level and TDS in approved final void

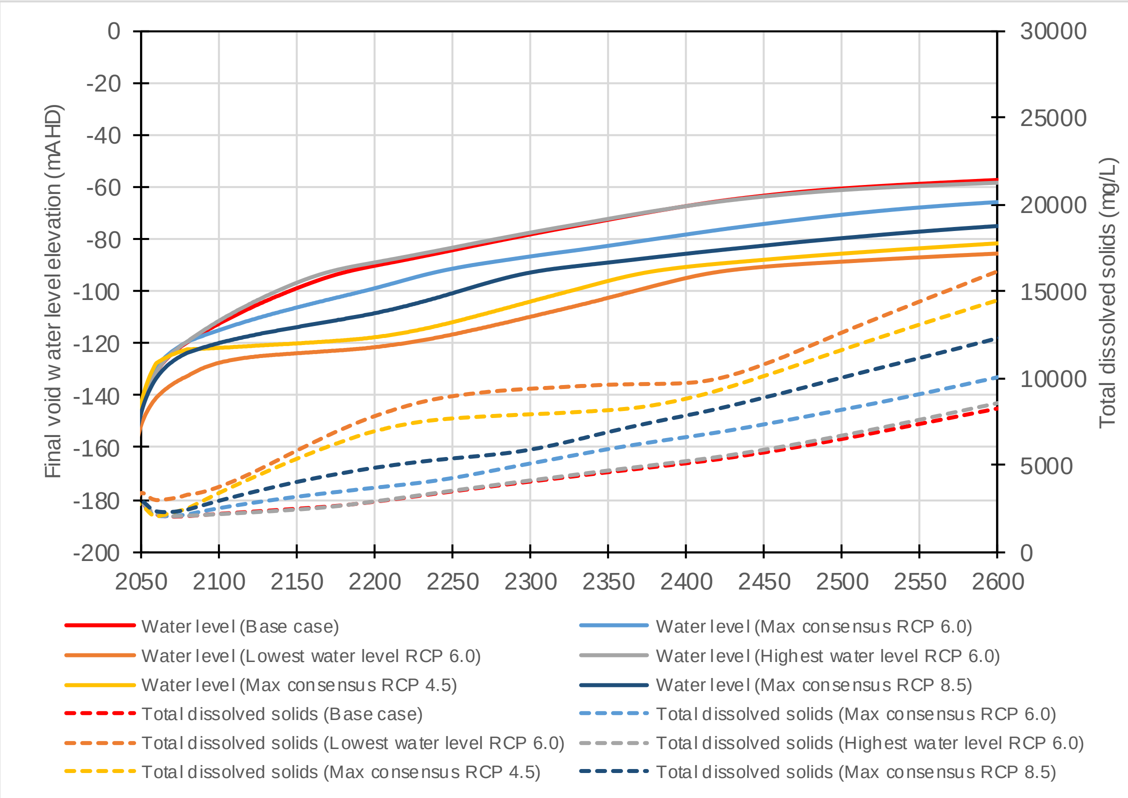

Figure 4-4 Forecast water level and TDS in proposed final void

Figure 4-3 and Figure 4-4 shows that all RCP6.0 scenarios project a lower final void equilibrium water level elevation with an increase in TDS values compared to base case. The results for the RCP4.5 scenario show similar water levels and TDS to the base case. The variance in curvature on the TDS over time is attributable to the inconsistencies in the climatic assumptions between the water balance and groundwater modelling inputs. This is considered a minor effect considering the relative risk of the climate scenarios.

In summary, a comparison of results between the base case (no climate change) scenario as presented in the SWIA and the maximum consensus model for RCP 6.0 on forecast water level and TDS in the final void from the completion of mining until the time of equilibrium water level (defined as when the average rate of increase was simulated to be less than 50 mm/year) for the approved and proposed final void are summarised in Table 4-6.

Table 4-6 Summary of final void modelling result

	Approved conditions		Proposed conditions	
	Base case	Maximum consensus (RCP 6.0)	Base case	Maximum consensus (RCP 6.0)
Equilibrium water level (m AHD)	29.38	14.12	-60.27	-70.79
Freeboard at equilibrium water level (m)	40.62	55.88	140.27	150.79
Time to reach equilibrium water level (years)	2500	2500	2500	2500
TDS of water in final void at equilibrium (mg/L)	5674	7678	6498	8215

Table 4-6 shows that the maximum consensus model for RCP 6.0 results in a lower final void water level elevation while having higher TDS values compared to the base case scenario for both approved and proposed conditions. Both scenarios are expected to reach equilibrium water level in an almost similar time frame by about year 2500.

Overall, the modelling results indicate that under the comprehensive range of climate change scenarios analysed, the final void is still projected to act as a hydraulic sink and have an even more remote likelihood of filling and discharging into downstream watercourses. The corresponding increase in TDS is minor in comparison to the range of predicted TDS at the equilibrium water level of other approved final voids in the Hunter Valley presented in the SWIA. The modelled impacts of climate change on water levels and water quality are not expected to alter the potential uses of the final void.

5. Site specific guideline values

5.1 Response to IESC advice

This section specifically responds to relevant issues in the IESC advice with further discussion in subsequent sections.

Advice 47 (1). Site-specific surface water quality guideline values for electrical conductivity and total suspended solids have been developed for several sites within the clean water system (GHD 2019, Table 5-2, p. 31). However, it appears that these site-specific guideline values have not been derived from reference sites and may have been determined from impacted sites as the values vary for each site. The IESC recommends that the proponent revises these site-specific guideline values to ensure that these are appropriately derived as outlined in ANZG (2018) and Huynh and Hobbs (2019).

Site specific guideline values used in the SWIA were applied from the Mount Owen Complex Surface Water Management and Monitoring Plan (Glencore 2019). These are understood to be derived from a reference condition at sites both upstream and downstream of the potential mining related disturbance with the process of developing site specific guidelines not having the benefit of the guidance provided in Huynh and Hobbs (2019) prior to publication. The intention of such an approach is to fully utilise the extensive historical dataset to reflect the range of conditions at sites. Subsequent to the preparation of the SWIA, further investigation identified that mining related impacts were included in this historical dataset (Section 5.4). A revised approach to site specific guideline values is set out in Section 5.5 based on these considerations.

Advice 47 (2). The proponent should also develop site-specific guideline values for a range of metals prior to commencing the project, particularly at sites where observed concentrations (e.g. copper, nickel, chromium, lead) commonly exceed default guideline values.

There is no evidence that observed concentrations commonly exceed default guideline values at clean water monitoring sites, apart from aluminium, as discussed in Section 5.5.1.

Advice 47 (3). Site-specific guideline values should also be developed for analytes that may be characteristic of seepage from waste material (see Paragraph 45) as part of a TARP. Suggested analytes include aluminium, copper, cobalt, iron, manganese, nickel, zinc, arsenic, cadmium and chromium.

The recommendation is supported as discussed in Section 5.5.1.

Advice 48. Current surface water quality monitoring data from some sites (e.g. SC3, BC2, BC3, BC4 and BC5) show elevated salinity and total suspended solids. The cause of this is unclear. Further discussion should be provided which examines potential causes, including the potential for mine seepage particularly at SC3, BC2, BC3, BC4 and BC5.

Elevated salinity (EC) and TSS reflected in the historical data statistics for BC2, BC3, BC4 and BC5 are at least partially attributable to inflow of groundwater into the Middle Bettys Creek diversion identified in 2014 (Glencore 2015), this is considered in Section 5.4.

SC3 is of limited usefulness or relevance to the project, as discussed in Section 5.4.

5.2 Overarching approach

Both ANZG (2018) and Huynh and Hobbs (2019) provide guidance on the selection of appropriate reference conditions. The overarching principle adopted in the SWIA is " 'continual improvement', where management of waters should aim towards better water quality and ecological health." (Huynh and Hobbs 2019). This idealised principle is weighed against the practicality of historical disturbance and data availability. ANZG (2018) acknowledges that "for modified ecosystems, 'best available' reference sites may provide the only choice for the reference condition".

In practical terms, this is a balance between a system that resists 'creeping normality' that allows slow incremental degradation to water quality, whilst allowing flexibility to reflect local conditions and natural variation so that 'exceedances' of guideline values provide meaningful feedback to site personnel, regulators and the general public.

The SWIA adopted the SSGVs for the Mount Owen Complex presented in the Surface Water Management and Monitoring Plan that were stated to be derived in accordance with the ANZG (2018) guidelines. A revised approach has been prepared in response to the IESC advice which also includes consideration of recent guidance provided by Huynh and Hobbs (2019).

5.3 Reference sites

Huynh and Hobbs (2019) provides criteria for the selection of reference sites. The relevance of these to the project is summarised in Table 5-1.

Table 5-1 Reference site criteria

Reference site criteria	Relevance to the project
Minimal disturbance to local and upstream environments (e.g. from dense urban and industrial activity, extractive industry, intensive livestock or cropping areas)	Mining related activity has disturbed much of the catchment of Yorks, Bettys and Swamp Creeks. Figure 5-1 of the SWIA shows that BMC1, BC1, SC1 and YC1 are upstream of mining related disturbance at the Mount Owen Complex.
No significant point source and diffuse source discharges nearby or upstream (e.g. mine discharges, sewage treatment plant discharges, industrial discharges, major agricultural or storm water drains, agricultural discharges such as those from dairies)	The Mount Owen Complex is a zero discharge site. There are no known point source discharges upstream.
Flow or water regime not significantly altered (if the site is classified as temporary, water body types and wet and dry phase GVs should be defined)	Mining has significantly disturbed much of the catchment of Yorks, Bettys and Swamp Creek, reducing the catchment area as catchment is disturbed and incorporated in the site water management system. Both SC1 and SC2 are located in permanent reservoirs that form part of the clean water diversion. This limits their suitability as reference sites as they will be less likely to reflect seasonal variation due to mixing in the reservoir.
Sufficient water quality monitoring data available, and data from these sites collected, stored and analysed using approved protocols.	Monthly water quality (pH, EC, TSS) has been collected over at least a 10 year period at all monitoring locations (except for the recent addition of BMC5). Anecdotal information on the streamflow conditions and other conditions is documented in the Annual Reviews for the Mount Owen Complex (Glencore 2020).

Table 5-1 indicates the upstream sites BMC1, BC1, SC1 and YC1 are the most suitable reference sites for the project, and provide coverage of each of the potentially affected watercourses. All sites lie along or just north of the Hunter Thrust fault (refer to Groundwater Impact Assessment (AGE 2019)) and the geology of the upslope catchment differ from the catchment adjacent to the existing mining disturbance. Difference in underlying geology may influence the water quality of baseflows, particular EC, and this may limit their suitability as reference sites. Other monitoring locations downstream of the existing mining disturbance associated with the Mount Owen Complex may also provide useful 'reference conditions' for periods in the monitoring record where it is likely that the site was not impacted by mining related activities.

The various Annual Reviews prepared for the Glendell Mine, as part of the broader Mount Owen Complex, identify a number of minor mining related impacts on some parts of the watercourses downstream of the existing mining disturbance. The description of these impacts and subsequent mitigation measures in the Annual Reviews enable mining related impacts at these location to be considered when interpreting the available monitoring record as a reference condition. This analysis is presented in Section 5.4.

5.4 Data investigation

Time series of physio chemical stressors were presented and visually interpreted in the SWIA. Further investigation was undertaken with reference to Annual Review (Glencore 2020) and annual median statistics for pH, EC and TSS shown in Figure 5-1, Figure 5-3 and Figure 5-2, respectively. The median statistic is a measure of central tendency and the most robust against outliers that may otherwise skew the mean statistic.

Figure 5-1 Annual median clean water quality – pH

Figure 5-1 shows that the annual median pH has been relatively consistent over time at all sites. The site most deviated outside the DGV range (of 6.5 to 8.0) is the upstream site, SC1, which likely reflects the typically more alkaline local water quality.

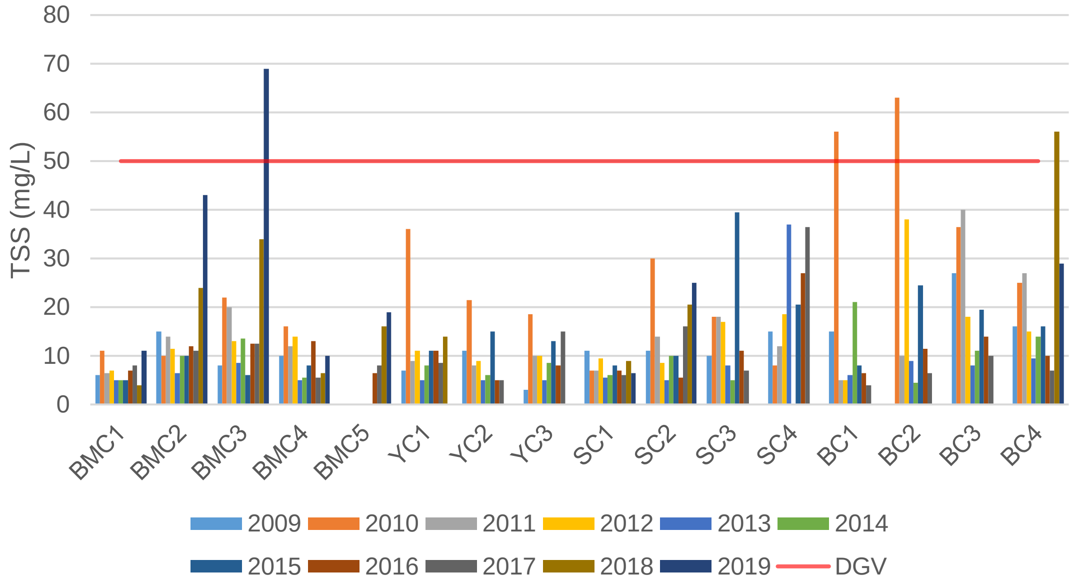

Figure 5-2 Annual median clean water quality - TSS

Figure 5-2 shows that variability in TSS is greater than that of pH. Elevated TSS was observed a number of sites during 2010 and in 2018 and 2019. The more recently elevated TSS recorded at the Bowmans Creek sites BMC2 and BMC3 is likely attributable to drought conditions as the creek did not exhibit any surface flow in part of 2018 and 2019. Low flow and evaporative effects both alone and in combination with potential disturbance by livestock accessing the area are a potential source of elevation TSS observations at these sites. The 2019 monitoring from BMC4 and BMC5, which are lower in the catchment, have not exhibited any significant change in TSS over this period, indicating that elevated TSS is likely associated with localised sources and is unlikely to be indicating mine activities influencing downstream watercourses.

Median TSS has generally been below or only slightly above the DGV of 50 mg/L and is therefore considered a relatively low risk as a potential stressor. TSS is also a less useful indicator of the potential seepage from overburden material than EC. Therefore the remainder of the analysis focuses on EC.

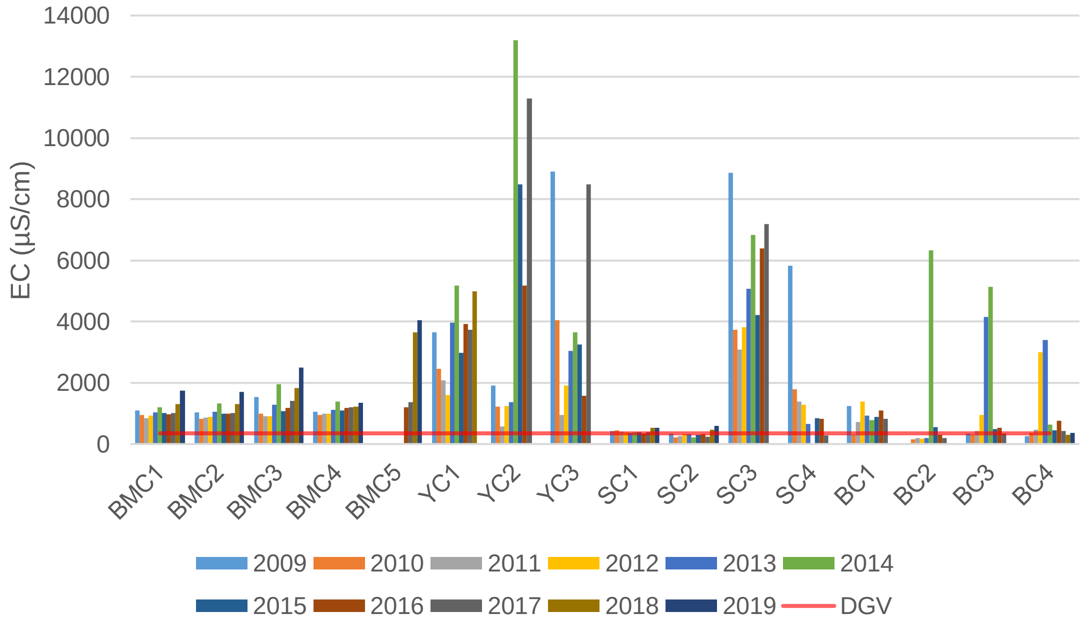

Figure 5-3 Annual median clean water quality - EC

Figure 5-3 shows that the greatest temporal and spatial variation is observed EC.

- Sampling from pools during recent drought conditions appears to be reflected in elevated EC in Bowmans Creek most likely attributable to evapoconcentration. Prior to this period median annual EC was relatively consistent at all Bowmans Creek sites.
- During 2014, an outrush of water and coal fines from a coal transfer bin occurred as a result of firefighting activities upstream of YC3 and groundwater seepage north of a tailing dam north of Bayswater North Pit upstream of YC2 and YC3 (Glencore 2015). This is reflected in elevated EC observed especially at YC2 however it is noted that the EC results in the upstream site at YC1 were also elevated in 2014 indicating the YC2 and YC3 results from that year may also be associated with natural variability.
- During 2014, a minor inflow of water with elevated EC, thought to from mine water dams and infiltration into unconsolidated overburden material, was observed in the Middle Bettys Creek diversion upstream of BC2, BC3 and BC4 (Glencore 2015). This likely accounts for the local peak in annual median EC during 2013 and 2014.

As discussed in Section 5.2, the combination of identified prior mining related impacts and local and climatic influences on water quality should be considered in site specific guide values in areas where there are potential impacts associated with the project. This is explored based on the statistical distribution of EC along Bowmans Creek, Yorks Creek, Swamp Creek and Bettys Creek in Figure 5-4, Figure 5-5, Figure 5-6 and Figure 5-7 respectively. The upper quartile of the plots (75th percentile) approximately correspond to the site specific guideline values derived from the 80th percentile values presented in the SWIA. These results do not exclude data which may be influenced by mining related impacts.

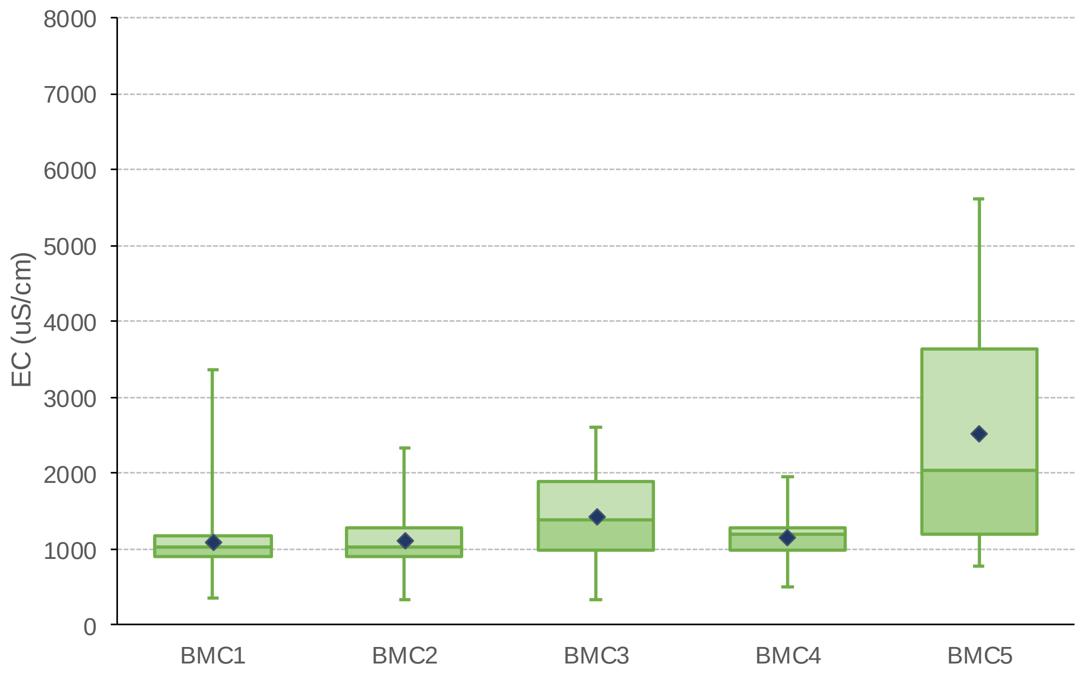

Figure 5-4 Comparison of EC dataset – Bowmans Creek

Figure 5-4 shows that historical EC is generally consistent along Bowmans Creek. EC appears elevated at BMC3, however this most likely reflects that BMC3 may be more influenced by climatic conditions (refer to Figure 5-3), as the lower statistics remain consistent. Monitoring of BMC5 has commenced relatively recently and the relatively elevated distribution likely reflects the drought conditions prevalent over the shorter period of monitoring record compared to other sites which have been monitored over a longer period.

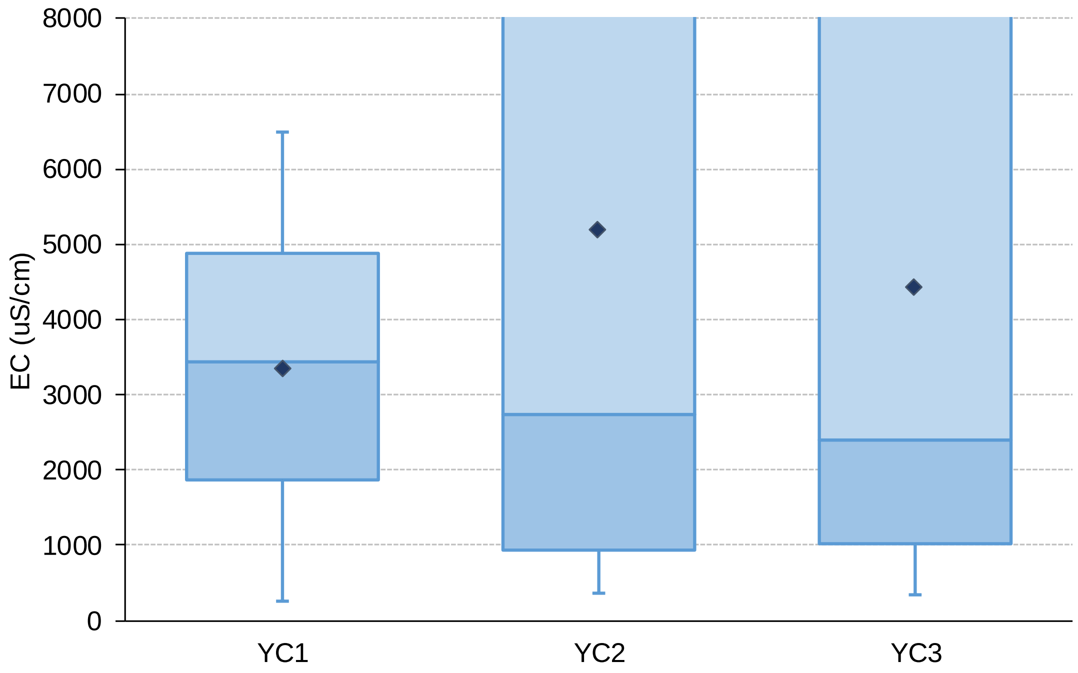

Figure 5-5 Comparison of EC dataset – Yorks Creek

Figure 5-5 shows the upper statistics for Yorks Creek have been skewed by the identified impact in around 2014, with the median and lower statistic results being lower at the downstream sites compared to the upstream. YC1 appears to have naturally elevated EC compared to the other identified upstream references sites, but, due to the Swamp Creek Diversion, YC2 and YC3 are downstream of both YC1 and SC1 (and SC2). Therefore the downstream water quality would be expected to reflect a combination of the upstream reference conditions, accounting for the permanent reservoirs where SC1 and SC2 are located. This demonstrates how a coarse statistical approach that fails to include periods of identified impact may not usefully inform site specific guideline values that attempt to account for local conditions.

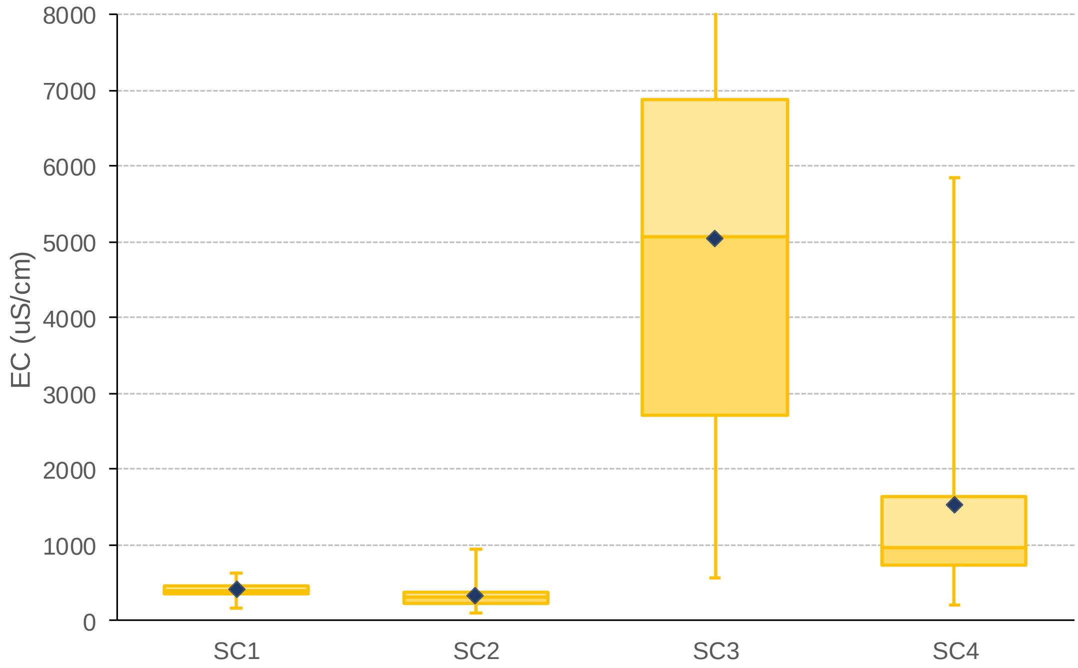

Figure 5-6 Comparison of EC dataset – Swamp Creek

Figure 5-6 shows that SC2 is very similar to the upstream SC1, with a relatively tight statistical distribution. Both SC1 and SC2 are located in permanent reservoirs that form part of the clean water diversion. Therefore these sites still provide a reference condition over a long term period, but are unlikely to exhibit seasonal variation of an ephemeral watercourse.

Elevated salinity (EC) at SC3 does not appear to have any temporal trend nor any strong correlation with the downstream site SC4 that would indicate a propagation of elevated EC downstream as a result of groundwater seepage, as observed historically in Bettys Creek and Yorks Creek. SC3 is a poorly located monitoring site with very little catchment. Almost all of the remaining lower reach of Swamp Creek is proposed to be disturbed by the Glendell Pit Extension. Continued monitoring of SC3 has limited value for the project.

The historical distribution for SC4 is skewed by elevated EC observed in 2009 and has since trended down to be comparable with nearby BC4, BMC4 and BMC5. SC4 is located within the low lying Bowmans Creek floodplain, which is likely to account for elevated EC compared to SC1 and SC2 given that the EC observed at SC4 is similar to that at BC4, BMC3 and BMC4.

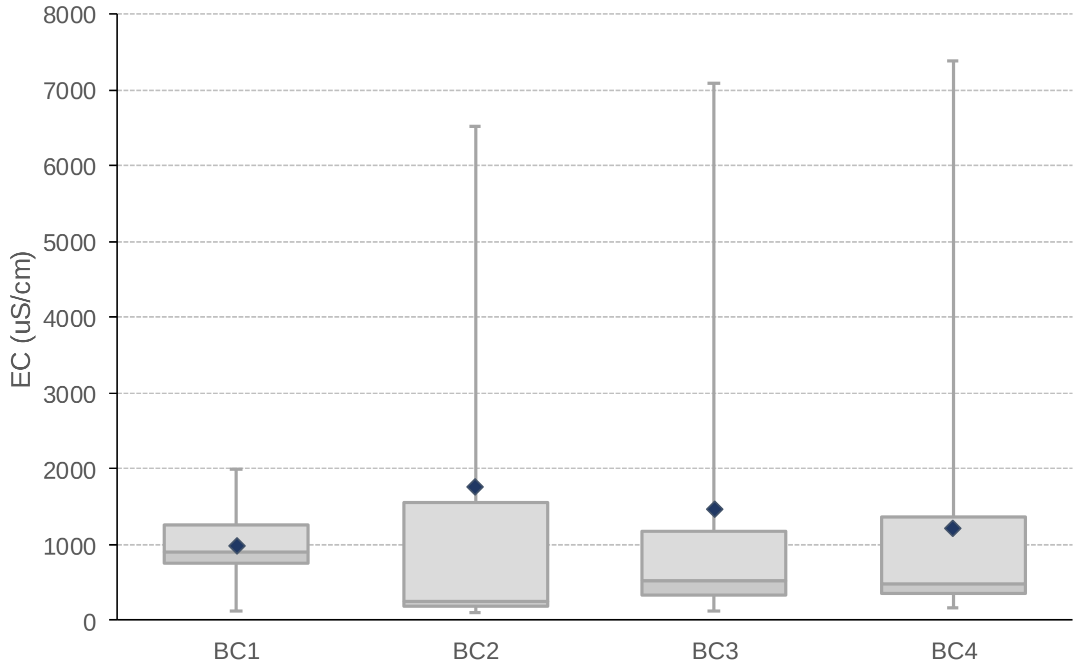

Figure 5-7 Comparison of EC dataset – Bettys Creek

Figure 5-7 shows that the historical distribution of BC2, BC3 and BC4 are skewed by the elevated EC observed in 2014 as a result of identified groundwater seepage. Similarly to Yorks Creek, the diversion of catchments associated with Upper Bettys Creek Diversion may have resulted in lower EC in lower reaches of the Bettys Creek than observed at BC1.

5.5 Revised approach to site specific guideline values

5.5.1 Physio and chemical stressors

ANZG (2018) provides a methodology for comparing monitoring results to a site specific guideline value. In this method, the site specific guideline value is updated after each round based on the 80th percentile of the most recent 24 months of results from the reference site. The advantage of this approach allows the site specific guidelines values to adapt with changes in climatic conditions, especially during low to no flow conditions.

Due to the particular constraints of the reference sites at the Mount Owen Complex identified in Section 5.3, the following additional comparisons are proposed:

- Long term deviation from long term condition. The results for the reference sites themselves should be tested against the 80th percentile of historical record (corresponding to the current site specific guideline values). This is especially important for BCM1 which is downstream of other mining disturbance, but should also be completed for other reference sites for completeness.
- Creek diversions. The various existing and proposed creek diversions and realignments have changed the connections between different parts of the watercourses. For example BC1 is no longer upstream of BC2, and flows at YC2 are dominated by the upper part of Swamp Creek rather than Yorks Creek. Once the changes to water quality due to a creek realignment are well understood at a particular location, it may no longer be necessary to make this comparison on a regular basis.
- Local potential impacts. Due to existing and proposed creek diversions and realignments, local potential impacts may be more appropriately compared to other downstream sites. For example SC4 is much more similar to BC4 than SC1.

Both SC1 and SC2 are located in permanent reservoirs that form part of the Swamp Creek diversion. Even though these sites are unlikely to exhibit seasonal variation of an ephemeral watercourse, they still provide a reference condition over a longer time period.

Based on these considerations, a comparison protocol is proposed in Table 5-2, including the new monitoring locations proposed in the SWIA. In Table 5-2:

- "Long term" corresponds to the 80th percentile of the available historical record. No long term trend has been identified for any reference site, as discussed in Section 5.4.
- "Recent" corresponds to the 80th percentile the more recent 24 months. Periods of no sampling due to no flow should be included in the calculation of the 80th percentile, with the maximum value taken if more than 20% of results are no flow.

Table 5-2 Monitoring results comparison protocol

Monitoring locations	Reference condition for deviation from long term condition	Reference condition for creek diversions	Reference condition for local potential impacts of the project
BMC1	Long term BMC1		
BMC2, BMC3, BMC4, BMC5, BMC6			Recent BMC1
YC1	Long term YC1		
YC2		Recent YC1	Recent SC2
YC3 then YC4		Recent YC1	Recent YC2
SC1	Long term SC1		
SC2		Recent SC1	
SC4		Recent SC1	Recent BC4
BC1	Long term BC1		
BC2	Long term BC2	Recent BC1	
BC3, BC4		Recent BC1	Recent BC2

As limited monitoring has occurred since the preparation of the SWIA, the following interim site specific guideline values are proposed based on upstream reference sites in Table 5-3. The recommended changes are limited to EC. Where the site specific guideline values are within the range of the DGVs, exceedance of the site specific guideline values is only an indication of potential change and does not necessarily indicate the potential for physiochemical stress on the receiving waters. As the existing site specific guidelines for pH and TSS are within the DGVs or the historical range of upstream reference sites, no changes are recommended.

Table 5-3 Interim revised site specific guideline values

<table>
<tr><th>Location</th><th>pH</th><th>EC (µS/cm)</th><th>TSS (mg/L)</th></tr>
<tr><td>BMC1</td><td>7.7 - 8.1</td><td rowspan="5">1288</td><td>10</td></tr>
<tr><td>BMC2</td><td>7.8 - 8.1</td><td>26</td></tr>
<tr><td>BMC3</td><td>7.8 - 8.1</td><td>24</td></tr>
<tr><td>BMC4</td><td>7.5 - 8</td><td>17</td></tr>
<tr><td>BMC5</td><td>7.7 - 8</td><td>14</td></tr>
<tr><td>YC1</td><td>7.1 - 7.7</td><td rowspan="3">5286</td><td>25</td></tr>
<tr><td>YC2</td><td>7 - 7.8</td><td>20</td></tr>
<tr><td>YC3</td><td>7.3 - 7.9</td><td>33</td></tr>
<tr><td>SC1</td><td>7.7 - 8.6</td><td rowspan="4">824</td><td>21</td></tr>
<tr><td>SC2</td><td>7.4 - 8.2</td><td>35</td></tr>
<tr><td>SC3</td><td>7.5 - 8.4</td><td>34</td></tr>
<tr><td>SC4</td><td>7.1 - 7.8</td><td>30</td></tr>
<tr><td>BC1</td><td>7.1 - 7.8</td><td rowspan="4">1882</td><td>16</td></tr>
<tr><td>BC2</td><td>7.4 - 8.3</td><td>40</td></tr>
<tr><td>BC3</td><td>7.1 - 7.9</td><td>50</td></tr>
<tr><td>BC4</td><td>7.1 - 7.8</td><td>50</td></tr>
</table>

5.5.1 Toxicants

Site specific guideline values for aluminium, copper, cobalt, iron, manganese, nickel, zinc, arsenic, cadmium and chromium will be derived based on the 95th percentile of at least 24 months of sampling at each reference location. Based on the 12 samples collected at BMC4 over a six month period during 2014, it is not expected that any of the SSGVs will exceed the DGVs, with the exception of aluminium (refer to Table 5-4).

Table 5-4 Toxicants that exceed default guideline values

Analyte	DGV[1]	95th percentile observed at BMC4 in 2014
Aluminium	0.055 mg/L	0.885 mg/L

The presence of aluminium is not a strong indicator of potential for seepage from waste material, as other analytes, that have been observed to exceed the DGVs at dirty water and mine water monitoring locations, have not been observed at this clean water monitoring sites. Therefore once a suitable baseline is established, it is recommended that sampling for metals is only required to be undertaken in response to exceedance of the physical chemical stressors site specific guideline value.

[1] The DGV is derived from the ANZG 2018 toxicant default guideline value for aluminum with sample having a pH greater than 6.5 in freshwater for 95% level of species protection (slightly to moderately disturbed ecosystems).

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