## Groundwater Issues Associated with the Vickery Extension Project

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### Introduction

I have been requested by EDO NSW (acting for their client, Lock the Gate) to prepare an expert report analysing groundwater-related issues associated with the proposed Vickery open-cut coal mine. I previously analysed groundwater-related issues in the project's EIS in February 2019 (Currell, 2019). In the current report I was asked to review the relevant materials and address the following questions:

a) In your opinion, have the concerned raised in your previous submission to the Project been adequately addressed, including through any recommended Conditions of Consent? If not, please provide information on any remaining issues of concern.

b) Provide any further observations or opinions which you consider to be relevant.

### My relevant expertise

I am an Associate Professor of environmental engineering in the School of Engineering at RMIT University, Australia. I received my PhD from Monash University in 2011, on the use of environmental isotopes and geochemistry to assess sustainability of groundwater usage and controls on groundwater quality in areas of intensive development. For the last nine years while employed at RMIT I have taught hydrogeology, geochemistry and groundwater modelling to hundreds of environmental and civil engineering students, and supervised multiple Masters and PhD projects in applied hydrogeology research. I have been awarded more than $1 million in research funding as a chief investigator on more than 12 grants, supporting projects examining groundwater sustainability and contamination issues. I have published more than 50 peer-reviewed international journal articles, which have been cited more than 1400 times, and served on the editorial board of the *Hydrogeology Journal* (the journal of the International Association of Hydrogeologists) from 2014 to 2018. I have acted as an independent expert witness regarding groundwater impacts of mining activities many times, including the Victorian Parliamentary Inquiry into Unconventional Gas, proceedings in the Queensland land court and other coal mining and coal seam gas proposals examined by the NSW Independent Planning Commission.

The opinions outlined in this document are my own independent professional views, based on my expertise in hydrogeology. I have prepared this report in accordance with Division 2, Part 31 of the *Uniform Civil Procedure Rules 2005* (**UCPR**) and the Expert Witness Code of Conduct (**Code of Conduct**) which states that:

> *"An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the court impartially on matters relevant to the area of expertise of the witness."*

I have read Schedule 7 of the rules and agree to be bound by it.

## Summary of my previous advice

The following are the key issues raised in my previous expert report, based on my analysis of the Vickery Project EIS, the IESC advice and other relevant material:

1. The need for more in-depth consideration of possible impacts on groundwater dependent ecosystems, due to changes in groundwater levels, water quality and water balance.
2. A need for more in-depth field-based studies to inform assessment of the degree of connectivity between different hydrogeological units and the range(s) of hydraulic parameters used in the groundwater modelling - with important implications for predictions of drawdown in the Namoi Alluvium.
3. A need for more detailed assessment of how changes in groundwater levels and water balance may impact hydraulic gradients and groundwater discharge to/recharge from the Namoi River along its length.
4. A need for more in-depth, field-based studies to examine ground-surface water connectivity (including both spatial changes along the Namoi and temporal changes under different conditions) and the implications for GDEs and water availability.
5. A need for more detailed analysis to understand the potential for mobilization of metals and other chemical constituents in groundwater and surface water due to the project.

### *Additional matters for consideration*

Since my report was completed, further issues of relevance to the groundwater assessment have been raised by other submitters, which are also relevant to this assessment. The primary issues include:

6. Questions over the water balance calculations used to assess the mine's water requirements – including the view that significantly more groundwater will be required because a) available water has been over-estimated (particularly in dry years); b) mine site water requirements may have been under-estimated; and c) a lack of consideration of the wide variability in available water in the Namoi System under different climatic conditions. These issues were raised by landholder David Watt and have been the subject of further consideration by DPIE.
7. Question regarding future water quality risks due to the placement of mine spoil/waste on the western side of the project area, including an area of approximately 200 ha where mine overburden is proposed to be placed on top of the Namoi Alluvium.

Following the submissions, the proponent prepared a response (Whitehaven, 2019), while DPIE appointed a peer reviewer to examine the hydrogeological assessment and groundwater modelling, including the issues raised above (HydroGeoLogic, 2019a). Groundwater issues were further considered and discussed in DPIE's Assessment Report (DPIE, 2020) and other correspondence with DPIE Water in early 2020, before a set of recommended Conditions of Consent were drafted.

## Extent to which the issues identified above have been addressed

Below, an analysis of the seven issues noted above is provided, specifically the extent to which I believe they have been adequately addressed, including through recommended Conditions of Consent.

### 1. Groundwater dependent ecosystems assessments

The proponent's Submissions Report included a new figure mapping potential GDEs within the project area (Whitehaven, 2019, figure 4 – reproduced as Figure 1 below). This only partly addresses the request from the IESC that the proponent produce:

> "Maps… that illustrate the distribution of potential groundwater-dependent ecosystems (GDEs), particularly terrestrial ones, **superimposed on contours of estimated depths to the water table (in metres below ground level) both pre-mining and at maximum predicted drawdown.**

> **These maps should also show the locations of bores used to estimate the water table depths. These maps are needed to fully understand potential impacts to GDEs.**" [emphasis added] (IESC, 2018).

The map produced (see below) includes the location of potential GDEs, based on the BOM's National Atlas of GDEs. However, it does not show any contours of estimated depths to water table at different stages before or during mining or relevant bore locations (as requested by the IESC). While the peer reviewer (HydroGeoLogic, 2019a) believes the information provided is sufficient (as noted in the DPIE Assessment Report Table 7), the full scope of the original request of the IESC has not been fulfilled, and I believe it is important to see how water table patterns (and potentially, drawdown) are expected to develop in relation to the potential GDE locations as mining progresses.

The proponent argues in the Submissions Report that water table drawdown is not predicted to exceed 1m beyond the Maules Creek Formation (i.e., towards the Namoi River and its alluvium), which it implies to mean that such maps are superfluous. However, as discussed in further detail below, the assumption of limited drawdown is predicated on assumptions regarding inter-aquifer connectivity and aquifer hydraulic parameters which are yet to be sufficiently characterized at the site.

Irrespective of how much drawdown is predicted, the creation of these contour maps is important in order to assess potential changes to hydraulic gradients which may occur during the project, potentially impacting the rates of groundwater flow from the alluvium towards the open cut, or from the project area (e.g. western emplacement) towards the alluvium and river. Notably, there are places where the Maules Creek Formation (in which significant drawdown is predicted to occur) is immediately adjacent to the Namoi River and as such water table levels in this unit during mining must also be considered in any GDE risk assessment (as is recommended to be conducted by the IESC, according to the methods of Serov, 2012).

As such, more in-depth assessment of risks to GDEs, incorporating more detailed studies of inter-aquifer connectivity and analysis of current and potential future hydraulic gradients under different modelling scenarios are still needed to ensure a full consideration of impacts to GDEs, alluvial groundwater and surface water.

**2. Hydraulic parameters, inter-aquifer connectivity and potential effects on Namoi Alluvium**

The issue of hydraulic parameters and particularly, the degree of inter-aquifer connectivity is a major one and in my view the IPC were correct to flag this (in its Issues Report) as an important deficiency in the EIS groundwater assessment. The project will cause significant drawdown in the Maules Creek Formation due to the open cut mining – e.g. decrease in groundwater levels expected to exceed 150m during and following the completion of mining. The current predicted impact of this drawdown on groundwater levels the Namoi Alluvium (an aquifer of great importance in the region) is small to negligible, as discussed in the Submissions Report (Whitehaven, 2019). However, this is predicated on the assumption of low hydraulic conductivity in the Maules Creek Formation, and limited connectivity between this unit and the Namoi Alluvium in the project area. In the Submissions Report, the proponent states:

> "As the Project open cut is constrained to the Maules Creek Formation, the groundwater modelling indicates the 1 m drawdown contour would not extend beyond the Maules Creek Formation towards the Namoi River and its alluvium. Therefore negligible impact to potential GDEs is predicted."

If there is locally higher hydraulic conductivity material within the relevant formation(s) and/or greater connectivity between the Maules Creek Formation and Namoi Alluvium than currently simulated in the modelling, then drawdown in the Namoi alluvium may be significantly greater than anticipated. This could result in un-foreseen effects on GDEs, groundwater users, and potentially surface water (e.g. through increasing the hydraulic gradients and leakage rates from the Namoi and its alluvium towards the open cut). The project's proposed open cut boundary comes close to the Namoi River – within approximately 2 km - where both moderate and high potential GDEs have been mapped using the BOM's Groundwater Dependent Ecosystem Atlas (see Figure 4 of the Submissions Report, reproduced below):

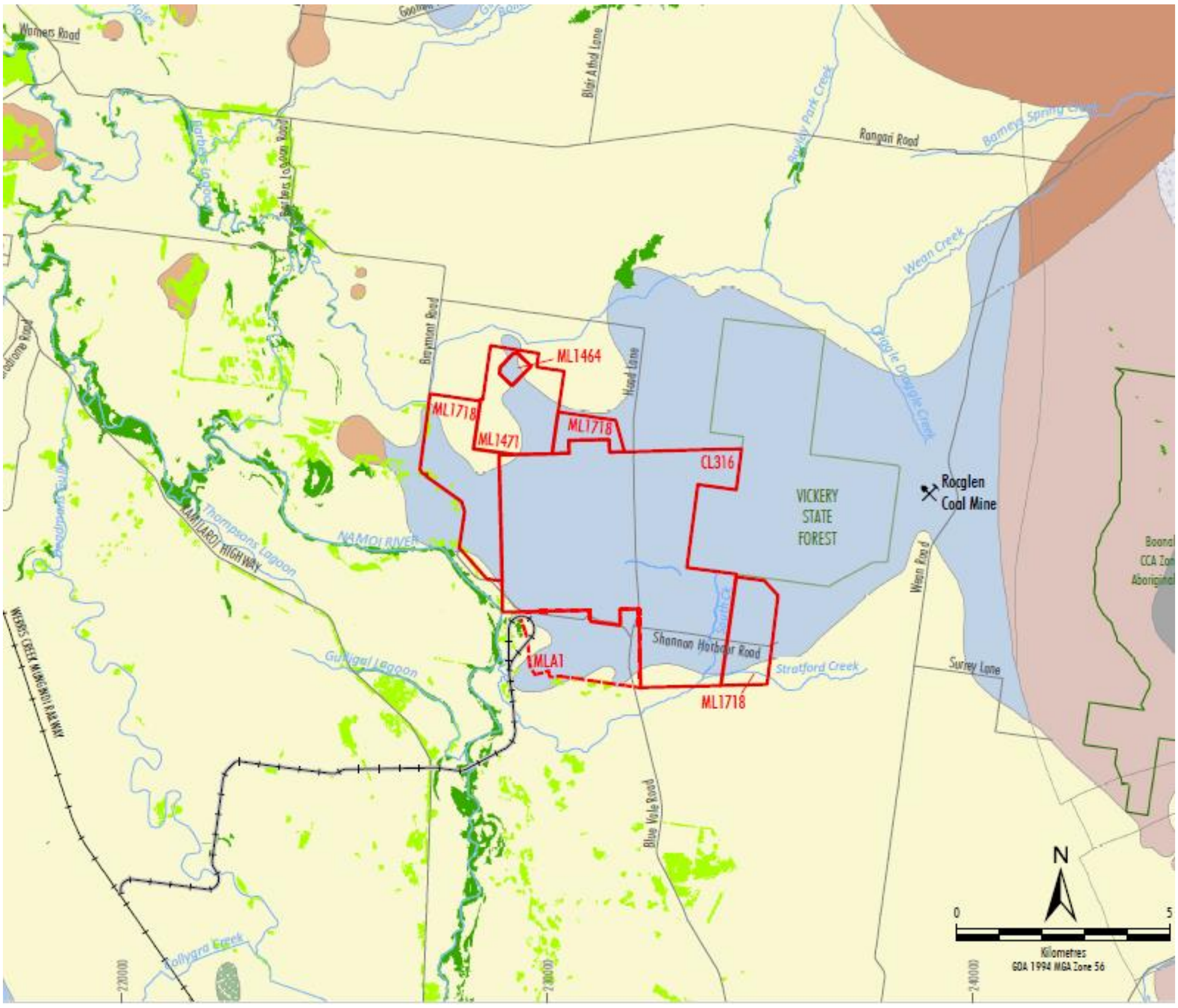


**Figure 1** Location of mapped high potential (dark green) and moderate potential (light green) GDEs – from Whitehaven, (2019). Grey shaded area indicates the Maules Creek Formation, in which groundwater drawdowns exceeding 100m are expected to occur.

Typically, sedimentary aquifer material is heterogeneous, and the connectivity between different units may be significantly enhanced by local scale heterogeneity and geological features (e.g. lenses of high permeability material, local fractures and other potential conduits). Groundwater modelling of the type conducted in the EIS assumes bulk hydraulic parameters across the different geological units, and therefore doesn't account for such local-scale heterogeneity. Therefore, it is critical to conduct field-based studies to identify possible areas where connectivity between different geological units may be enhanced, to complement the modelling. Even if such areas are small and localized, they can have a significant effect on inter-aquifer connections, by enhancing flow and propagation of drawdown between aquifers that otherwise have limited connectivity (e.g., Bianchi et al., 2011).

More detailed field-based characterization of hydraulic properties and inter-aquifer connectivity is therefore required (in my opinion) to properly understand the full extent of possible drawdown in both aquifers, and effects on GDEs. The proponent should (for example) commission one or more pumping tests at targeted locations on the western and southern extents of the project area, utilizing nested monitoring bores, to examine whether inducing significant drawdown within the Maules Creek Formation – which will occur during mining - results in measurable water level changes within the Namoi Alluvium (and vice versa). In the EIS, the fieldwork conducted to estimate hydraulic properties (vertical and horizontal hydraulic conductivity) is outlined in section 3.1 (e.g. Table 7 and Table 8). A combination of slug tests, low flow constant rate pumping core sample analysis were completed to estimate these parameters, but it is unclear whether pumping tests of the type described above have been conducted.

The peer reviewer (HydroGeoLogic, 2019) commented that the characterisation of hydraulic parameters and connectivity of the two different units derived from field studies was adequately documented in the EIS, along with the predicted water table drawdown impacts (as was noted in the DPIE's assessment report paragraph 150). While this may be true in a general sense – e.g. multiple lines of evidence were indeed used to estimate hydraulic parameters used in the groundwater modelling – this, in my opinion, has not been sufficiently targeted to understand the specific issue of inter-aquifer connectivity and scope of potential drawdown and GDE impacts described above.

*Storage coefficients and drawdown predictions*

A further issue raised by the IESC is the question of the appropriate values of storage coefficients (e.g., specific storage) used in the groundwater modelling and impact predictions. This is important, as this property can vary widely in geological materials, and such variation can have a significant effect on the amount of drawdown experienced in response to extraction of a given volume of water:

> "The proponent should undertake further transient predictive model simulations to investigate the full range of plausible parameterisations for specific storage. As specific storage is a critical parameter for determining the extent and magnitude of drawdown the proponent needs to provide clarification of, and justification for, the values used in the groundwater model. The IESC notes that the specific storage values used in the alluvial areas of model layer two could be unrealistically high. This may cause the predicted extent and magnitude of drawdown to be under-estimated and could result in non-compliance with the *NSW Aquifer Interference Policy"* (IESC, 2018)

It is unclear from EIS groundwater assessment the extent to which specific storage (or specific yield) values are informed by analysis of field data (e.g. pumping tests within the local area) and/or the level of confidence in the adopted parameter values (Table 13 of the EIS groundwater assessment shows adopted model values based on calibration fitting but gives little indication of plausible ranges in these parameters). This does not appear to have been clarified in the Submission Report. The sensitivity analysis conducted by HydroSimulations in 2019 (referred to in the Submissions Report) indicates that changes in the specific storage values of one order of magnitude, and changes in specific yield by a factor of three do result in changes in predicted water levels up to and exceeding 10m in some bores – which may be significant in the context of possible impacts to GDEs and water users. There also does not appear to have been any specific attempt to study how changing specific storage values in the alluvial aquifer (layer 2), in line with the IESC's comment above, influences the predictions of drawdown - e.g. whether a reduction in these values leads to significant changes in the predicted drawdown levels in the alluvium.

This issue is relevant to assessing the likely degree of drawdown induced by pumping at the proposed borefield (as well as the open cut) – i.e., if the storage coefficient(s) in the alluvium have been over-estimated, drawdown predictions may be unrealistically low, and the extent of drawdown may propagate further from the borefield within the Namoi Alluvium towards the Namoi River. As discussed below, given the inherent uncertainty in predictions from a complex numerical groundwater model of this kind, a wide range of possible impact scenarios (e.g. multiple maps showing different drawdown patterns that occur when different combinations of model parameters are selected) is needed to give a sense of possible variation in the geographic extent and magnitude of drawdown impacts. The updated model outputs (in response to the IESC advice) should (for example) include maps of modelled drawdown with lower Ss values (as well as other variations in hydraulic parameters) to address the IESC's comment.

While future modelling, evaluation and 'validation' of the groundwater modelling with new site data (as proposed in the recommended consent conditions) may to some extent help refine predictions of drawdown and increase confidence in these and appropriate model parameters in future, it is important at this stage that a full range of plausible impacts to groundwater are assessed and presented, to inform judgements as to the full possible scope and consequences of the project for GDEs and water users.

**3 & 4 Hydraulic gradients along the Namoi River, and field-based studies to examine ground-surface water connectivity**

In a similar vein to the IESC's request for maps of water table depth to inform assessment of possible impacts on GDEs (issue 1 above), a close analysis of the local-scale hydraulic gradients along the Namoi River should (in my view) be produced, in order to better constrain the level of baseflow and/or leakage from the river to the adjacent aquifer(s). The IESC made the following observation:

> "Because the direction of surface water-groundwater exchange in the river bed and banks strongly affects biogeochemical processes in the sediments, more information is needed on how groundwater drawdown may alter spatial and temporal patterns of surface water-groundwater exchanges in the Namoi River." (IESC, 2018).

Further:

> "The direction of surface water-groundwater exchanges across the bed and banks of most alluvial rivers strongly influences the rates and types of biogeochemical processes (e.g. nitrogen transformation, dissolved carbon dynamics) in the bed sediments (Boano et al. 2014). Changes to surface flow or the effects of groundwater drawdown may reverse the direction of surface water-groundwater exchange, alter the locations of upwelling and downwelling zones, or even cause repeated reversals of surface water-groundwater exchange over time. Given the significance of these biogeochemical processes to river water quality, especially during low flows, more information is needed on how these exchanges may be affected by the proposed project."

While the EIS did show contour maps of groundwater elevations in the area (as of 2017), which indicate the Namoi River is likely to be predominantly a losing stream (i.e., leaking into the underlying groundwater), as well as some maps of predicted drawdown at the end of mining (EIS Figs 50, 51 and 62), there is limited ability to assess hydraulic gradients at the local scale which control and/or are indicative of ground-surface water interaction in the project area. A conceptual model sketch is provided (in cross section) showing indicative flow directions between the aquifer(s) and Namoi River (Fig. 33 of the EIS groundwater assessment), however it is unclear how consistent this conceptualization is with monitored field data showing water levels at different times, either in the pre-development phase, or during the peak of mining (i.e., based on model predictions).

According to the map from the Submission Report reproduced above (Fig 1) there are areas where the Maules Creek Formation appears to be directly adjacent to the Namoi River (as well as areas where the river is flanked by extensive alluvium), and there is a high potential for GDEs to occur along the stream length. As such understanding effects of water level changes on near-stream hydraulic gradients both within the Namoi Alluvium and the Maules Creek formation, under current conditions and a range of possible modelled scenarios, is key to understanding groundwater, surface water and GDE impacts.

Ground-surface water interaction can be highly variable over time (e.g. changing depending on river levels, recent climate and groundwater usage rates) – e.g. Winter et al., (1998). This can have important consequences for water users and ecosystems at particular times – e.g. during low-flow periods when the climate is dry and rivers are highly dependent on baseflow (groundwater discharge).

This issue should have been addressed using:

1. Further detailed analysis of existing groundwater monitoring data – e.g. showing groundwater elevations at transects of monitoring wells at different distances from the river, changes in these elevations through time, and any corresponding observed changes in groundwater electrical conductivity (to inform a detailed assessment of gaining/losing sections of the stream under different hydrological and climatic conditions);

2. More extensive analysis of modelling outputs – e.g. maps showing water table and drawdown patterns that occur with a range of different model set-ups and parameter selections (e.g. drawing on the sensitivity analysis, in which model parameters were modified and the resulting changes in model outputs recorded), and ranges of possible changes to baseflow under different modelling assumptions/parameter combinations.

The IESC commented on this issue and raised it as a key area for additional work:

> "Further transient predictive model simulations are needed to examine a greater range of variability in hydraulic conductivity and specific storage. This information is needed to improve the current understanding of potential variability of drawdown impacts that could occur and to further support the proponent's statements that seepage losses from both the Upper Namoi Alluvium and the Namoi River will be limited given the intensive use of these water resources."

The Submissions Report does not explore this issue in further detail. The sensitivity analysis (e.g. Tables 2 and 3 of the Submissions Report) includes information about the degree of difference in water levels observed at certain points in the model under different model parameter values, but this has not (to my knowledge) been translated into an updated set of predictions of possible water table patterns, hydraulic gradients and seepage losses/baseflow under different parameter combinations (in line with the IESC advice).

Because groundwater modelling is inherently uncertain, predictions of potential impacts with a range of alternative assumptions and parameters should supplement the 'mean' or 'calibrated' model predictions, to give a more complete sense of 'best and worst case' impacts. This should be carefully combined with field studies and monitoring programs that provide more local scale insight into hydrological processes that can't be captured by the modelling (which, as noted above, typically adopts averaged parameters which may not capture local scale variability).

In my opinion, conducting such work following commencement of the project (e.g. during 5-yearly model validations, as per the draft recommended conditions) would leave open the prospect of significant unforeseen impacts occurring. The DPIE assessment report states that conditions have been recommended which will require the proponent to "comply with a range of water management performance measures including ensuring negligible impacts to alluvial aquifers beyond those predicted in the EIS". However, without a detailed understanding of ground-surface water interactions and inter-aquifer connectivity (incorporating local-scale heterogeneity) under current conditions, and a wide range of possible outcomes under consideration (informed by a range of modelling scenarios), it is likely to be difficult to achieve this aim. There is risk the proponent and regulator may be forced into ‘reactive’ monitoring and mitigation in response to impacts which differ from modelling predictions. The potential for time-lags to delay the full manifestation of impacts from a development activity on groundwater systems means that such ‘reactive’ monitoring and mitigation can be ineffective (e.g. Currell, 2016; Thomann et al., 2020).

**5. Geochemistry and water quality issues (affecting groundwater and/or surface water).**

A need to further characterize geochemical conditions in groundwater and surface water, to properly understand possible water quality impacts, was another issue raised by the IESC:

> “Further geochemical analyses should be undertaken using a range of environmental conditions (especially pH) that are representative of what may occur at the project site, particularly as the solubility and bioavailability of metals depends on water chemistry.” (IESC, 2018).

The IESC further pointed out the need to monitor a greater number of chemical species in groundwater, at a greater frequency than proposed, adopt trigger levels and water quality objectives based on 95% species protection guidelines (as groundwater discharges to local surface water systems), and adopt more extensive water quality objectives and monitoring plan for discharge from sediment dams.

DPIE’s hydrogeology peer reviewer noted that the information provided in the Submission Report in this regard was not adequate (particularly in relation to post-mining impact assessment). In my view the information provided is also inadequate for effective impact assessment and development of monitoring and management protocols throughout the operation of the project as well.

The DPIE Assessment Report, relying on the assessment of the peer reviewer, notes that the information provided is not yet satisfactory, but believes this work can be carried out during operation of the mine, in accordance with the recommended consent conditions (e.g. Table 7 of DPIE, 2020). These conditions include a requirement to develop a Groundwater Management Plan, which includes:

> “..trigger levels for identifying and investigating any potentially adverse groundwater impacts associated with the development, on:
>
> − regional and local aquifers (alluvial and hardrock); and
>
> − groundwater supply for other water users such as licensed privately-owned groundwater bores;”

As well as:

> “(monitoring of) geochemical characteristics of groundwater flows to the open cut, to inform the progressive development of the final landform and optimise the final void dimensions, to be described in the rehabilitation strategy required by condition B104.”

And:

> “water quality in sediment dams prior to discharge into the environment; − controlled and uncontrolled discharges and seepage/leachate from the site;”

From the current recommended conditions it remains unclear whether the groundwater quality monitoring program will include objectives and/or trigger levels designed to protect aquatic ecosystems in surface water bodies dependent on groundwater discharge (as well as irrigation and stock uses), as per the IESC’s advice.

Similarly, the full suite of chemical constituents to be monitored in groundwater and surface water storages (e.g. sediment dams), or frequency of monitoring are not apparent from the conditions.

There does not appear to be any further request or requirement for studies to better understand the effect of changing pH or other geochemical characteristics on the mobility of metals in ground and/or surface water, as per the IESC advice. Much of the discussion of water quality impacts and geochemistry in the Submission Report, DPIE Assessment Report and peer reviewer's reports appears to focus on post-mining impacts, whereas the IESC advice specifically related to the development of a more comprehensive understanding of potential water quality impacts during project operation, and a more comprehensive groundwater and surface water quality monitoring program designed to account for this.

**6. Potential issues with site water balance/water budget**

Concerns that the project's water balance has under-estimated the volumes of water required to be sourced from groundwater – e.g. the proposed bore field - particularly during periods of low rainfall, have been the focus of recent discussions between the proponent, landholders and DPIE (as discussed in DPIE's Assessment Report paragraphs 164-190).

There appears to be uncertainty as to how the mine will secure sufficient water supplies to suppress dust on the site, during dry years where surface water in the Namoi River is limited or unavailable (as has occurred in recent times). Landholders argue that this will likely result in the proponent seeking to extract additional groundwater (beyond the volumes predicted in the EIS), which in turn would have implications for the Namoi Alluvium aquifer, and other water users dependent on it in the region.

In order to manage this issue, the proponent proposes to conduct 'periodic water balance reviews', adjust its operations during dry years (e.g. scale mining back to suit water availability and/or adopt additional 'water efficiency measures'), or obtain additional entitlements through the open water market.

The DPIE assessment report noted this issue and conducted analysis of the water balance and climatic data (e.g. paragraphs 164 to 181). This analysis indicates that during particularly dry years, it is indeed likely there will be a shortfall in available water to meet the mine's normal operating requirements. DPIE believe the issue can be managed through recommended consent conditions, including requiring Whitehaven to:

> "ensure it has sufficient water supply for all stages of the development and adjust operations to match supply;"

and

> "provide compensatory water supply to privately-owned landowners if directly impacted as a result of mining operations, with the burden of proof resting with Whitehaven to demonstrate that loss is not due to the development;" (DPIE, 2020).

DPIE also repeatedly note in their Assessment Report (and the recommended conditions), that securing sufficient water entitlements will be the responsibility of the proponent.

Given the high degree of water stress experienced in the Namoi catchment in recent times, this issue is of potential concern. Without further details, it is difficult to judge whether additional 'water efficiency measures' or 'scaling back operations' is actually going to be feasible, or if so, whether this will be adequate to save enough water to make up the shortfall, which appears to be inevitable in very dry years (DPIE, 2020). If the required water savings and/or additional entitlements cannot be achieved, then there is a risk the mine will not be able to secure sufficient water. Presumably this would have major consequences – e.g. inability to adequately control dust emissions. Presumably, once the mine reaches a certain size, it will be difficult to scale back the operations in response to low water availability in a given year or season (and the ongoing availability of water is likely to be difficult to predict in advance). Questions about the long-term viability and sustainability of the project, from the perspective of its ongoing water requirements, thus remain unresolved.

**7. Possible water quality impacts of placing mine overburden on top of the Namoi Alluvium**

The potential for water quality impacts resulting from the placement of mine waste on the Namoi Alluvium, at an embayment of the river in the northwest of the project area, was highlighted as a potential concern by DPIE Water. It is estimated the area covered would be approximately 200 ha. The hydrogeology peer reviewer also commented on this issue. The concern is that leaching of metals and other potentially harmful elements in the overburden could occur, recharging the underlying groundwater and therefore impacting water quality within the Namoi Alluvium. HydroGeoLogic (2020) expressed a view that due to long term development of ‘sink’ conditions in the mine void, any poor quality water recharging the alluvium will ultimately discharge back into the mine void (being within the void’s ‘capture zone’). In my view this is still not comprehensively demonstrated. If the conceptual model outlined in Figure 33 of the groundwater assessment (reproduced below) is correct, it is assumed there will continue to be a groundwater divide between the Namoi River and mine pit at the peak of mining. This would mean there could be a potential flow-path towards the alluvial aquifer and river, from the area of emplaced overburden. It is not fully demonstrated in the figures provided (e.g. Hydrogeologic 2020; Whitehaven, 2019) that all flow would indeed be captured by the mine void (as specific flow paths are not mapped). Due to the inherent uncertainty in groundwater modelling of this type, it is reasonable to conclude that the specific water table patterns that develop in the later stages of mining may vary from the predicted pattern. This may include the development of water table mounding below the emplaced mine overburden, with some flow directed back towards the alluvium, rather than towards the mine void.

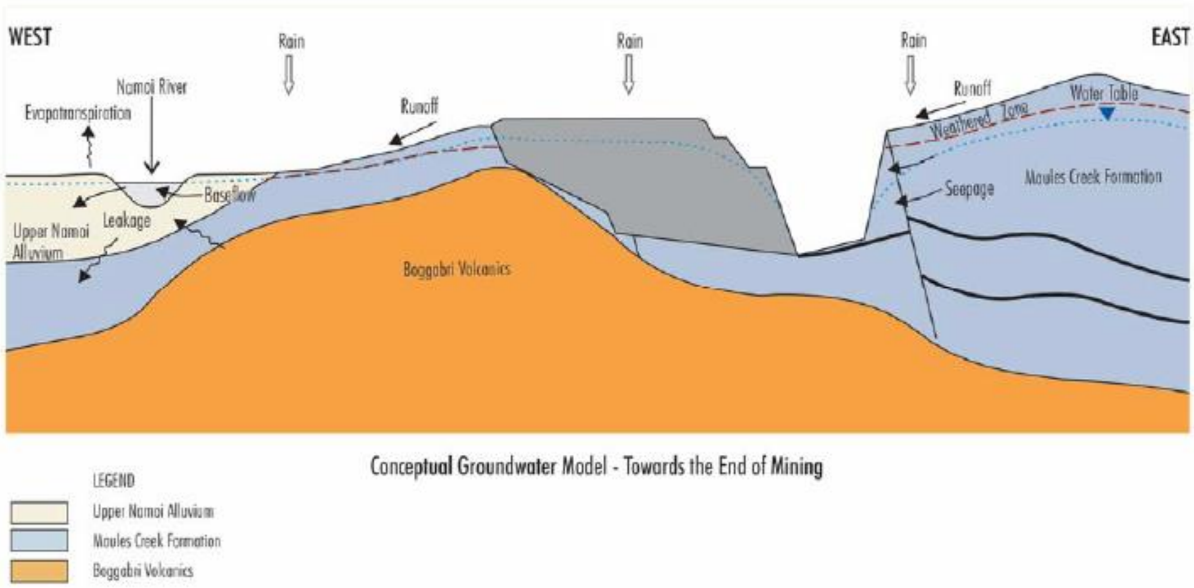


**Figure 2 –** Conceptual groundwater flow model at peak of mining (reproduced from HydroSimulations, 2018 in the project EIS).

## Summary

Based on my reading of the relevant material, there are still multiple areas that were highlighted by the IESC and my previous review, which have yet to be addressed (including in the recommended consent conditions). This has significant implications for groundwater-related impacts arising from the Vickery Project:

- Potential risks to groundwater dependent ecosystems (GDEs) are currently poorly understood; which is likely to hamper the detection and mitigation of impacts to these resulting from the project;
- The potential for the project to affect ground-surface water interaction is not well understood, and unforeseen impacts may arise, such as greater than expected changes to baseflow and/or stream leakage, affecting available quantities of water for ecosystems and other water users;
- The extent and magnitude of drawdown impacts from the project may differ from what is currently predicted in the modelling, and at present there is little understanding of the full potential range of these impacts (e.g. based on a wide range of plausible aquifer hydraulic parameters and conceptual elements).
- Connectivity between different geological units at the local scale (including possible heterogeneity) is not well characterized, meaning current estimates of changes in water levels in the Namoi Alluvium likely to occur during mining are uncertain;
- There is ongoing uncertainty regarding the likelihood of the mine being able to secure sufficient water supplies and/or modify its operations during dry periods;
- Groundwater and surface water quality impacts occurring during the project are not well understood and suffer from a lack of detailed baseline water quality and geochemical baseline data;
- Long-term water quality risks associated with the placement of mine waste above the Namoi Alluvium cannot be ruled out.

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