

Advice to decision maker on Tahmoor South coal mining project

IESC 2019-101: Tahmoor South Coal Project (EPBC 2017/8084; SSD 8445) – Expansion

Requesting agency	The Australian Government Department of the Environment and Energy and The New South Wales Department of Planning and Environment
Date of request	21 January 2019
Date request accepted	24 January 2019
Advice stage	Assessment

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) provides independent, expert, scientific advice to the Australian and state government regulators on the potential impacts of coal seam gas and large coal mining proposals on water resources. The advice is designed to ensure that decisions by regulators on coal seam gas or large coal mining developments are informed by the best available science.

The IESC was requested by the Australian Government Department of the Environment and Energy and the New South Wales Department of Planning and Environment to provide advice on Tahmoor Coal Pty Ltd.'s Tahmoor South coal mining project in NSW. This document provides the IESC's advice in response to the requesting agencies' questions. These questions are directed at matters specific to the project to be considered during the requesting agencies' assessment process. This advice draws upon the available assessment documentation, data and methodologies, together with the expert deliberations of the IESC, and is assessed against the IESC Information Guidelines (IESC, 2018).

Summary

The proposed Tahmoor South coal mining project is a longwall-mining extension to the existing underground Tahmoor Coal Mine, approximately 80 km southwest of Sydney in the Southern Coalfields of NSW. It is proposed that up to four million tonnes per annum of run-of-mine coal (coking and thermal) will be extracted from 2023 to 2035. The proposal also includes expansion and upgrades of existing surface infrastructure.

The proponent, the NSW Department of Planning and Environment, and the Australian Government's Department of the Environment and Energy have identified a range of potential impacts to water

resources. These potential impacts would be primarily concentrated in the catchment of the Bargo River. The Bargo River flows into the Nepean River, adjacent to the Metropolitan Special Area, which provides drinking water to Sydney. Conservation areas to the west of the mine include Thirlmere Lakes National Park, which has been subject to a number of studies and an Inquiry relating to water level variations in the lakes and the potential cumulative impacts of multiple land-use activities, including mining.

The proponent acknowledges that streambed cracking and surface flow diversions are likely for streams directly above the proposed longwalls, altering the flow regime (especially during periods of low flow) and reducing pool persistence. This will remove aquatic habitat and potentially reduce downstream water quantity and quality. Convincing evidence for self-remediation of streambed cracking or the potential success of active remediation (e.g. grouting) has not been provided.

The IESC considers that the base case of the numerical groundwater model understates the likely height of fracturing above longwall panels. The modelled groundwater drawdown should therefore not be relied upon until alternative cases in the groundwater model are revised to incorporate both measured mine water inflow and the height of vertical fracturing above the longwall as observed in the geotechnical report (EIS, Appendix G). It is also of limited use in predicting impacts to creeks because it does not incorporate the potential effects of surface cracking and near-surface fracturing on baseflow capture. Although the groundwater model has strengths in its inclusion of cumulative impacts of mining and generally good use of available data, the fundamental problems with the way fracturing is treated severely reduce confidence in its predictions.

Water quality monitoring downstream of the mine shows variable chemical properties, including elevated levels of metals and salinity. However, it is not clear what proportion of contaminants is from mine wastewater. The project area supports a range of surface water and groundwater-dependent ecosystems (GDEs). The proposed project will potentially impact these ecosystems and species reliant on them, especially those in undermined sections of Tea Tree Hollow, Dog Trap Creek and their tributaries. Although the proponent has identified all likely impacts, the IESC considers their potential magnitude may be underestimated and possibly irreversible.

Key potential impacts from this project are:

- changes to groundwater and surface water hydrology and water quality due to ground movement comprising subsidence and other mining induced ground movements including: strata deformation, surface fracturing and near-surface fracture networks, upsidence, valley closure, shear and bed plane movements;
- reduced flow and pool persistence in watercourses in the project area, particularly in Tea Tree Hollow, Dog Trap Creek and their tributaries due to surface cracking and near-surface fracture networks;
- possibly irreversible changes to surface water ecosystems, GDEs and water-dependent species (including several *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) - listed species);
- groundwater drawdown that will potentially affect numerous private bore users (existing modelling indicates that more than 2 m of drawdown could occur in approximately 120 bores); and
- cumulative impacts associated with past, current and future mining in the context of all land and water uses in the region.

The IESC has identified areas in which additional work is required to address the key potential impacts, as detailed in this advice. These are summarised below.

- Mining-induced ground movement from previous mining in the local region outlined in the geotechnical report (EIS, Appendix G) suggests that fracturing will be more extensive than is presented in the groundwater report (EIS, Appendix I). The groundwater modelling should reflect the observations of vertical flow losses that occur above the height of complete groundwater drainage above the longwall (observations in EIS, Appendix G).
- Further analysis and modelling of existing baseline data are needed to better inform estimates of the upper and lower bounds of potential impacts on surface water losses (EIS, Appendix J) to near-surface fracture zones (EIS, Appendix F). These effects are not currently incorporated in groundwater modelling (EIS, Appendix I). New model-independent data on the extent of near-surface fracturing should be obtained and used to develop a modelling approach that is capable of incorporating the hydrological effects of near-surface fracturing.
- Consideration should be given to reducing impacts of connective fracturing above the longwall and reducing surface cracking and near-surface fracturing on creeks and associated GDEs by additional alterations to the mine plan. This could be accomplished, for example, by altering the longwall placement or orientation so that creeks are not undermined or by other alterations to the mine design and geometry of panels and pillars.
- Development of a Receiving Environment Management Plan. This should include management and monitoring measures to effectively protect the environment from discharges.

Context

Tahmoor Mine lies within the Southern Coalfields of NSW where considerable mining has occurred for about 200 years. The proposed project, Tahmoor South, is an extension of the existing Tahmoor North project, which has been mined since the late 1970s. The proposed project would use longwall mining to extract coal from the Bulli seam. Coal extraction of up to four million tonnes of run-of-mine coal per annum is proposed, with processing at the existing Coal Handling and Processing Plant, and transport via the existing rail network. In addition to the Tahmoor Mine, there are eight nearby mining operations: six mines to the east and two to the southwest, which are in various phases of operation or maintenance.

The project is located in a region containing large areas dedicated to conservation. This includes the Metropolitan Special Area (MSA), part of Sydney's drinking water catchments, located to the east of the project. Waters from the MSA flow via the Nepean River northward into the Hawkesbury-Nepean River catchment system. The proposal itself is mostly within the Bargo River catchment whose waters contribute to the Nepean River downstream of the MSA. To the west of the project are located Thirlmere Lakes National Park and Nattai Wilderness Area. The Thirlmere Lakes have been the subject of several studies (some still ongoing) and an Inquiry as to the causes of long-term water-level changes, especially since longwall mining occurred in the vicinity. Guided by feedback at workshops about social values of the region (EIS, Appendix D), the project has been revised to avoid longwall mining directly under the MSA and various other sensitive environmental and cultural features.

It is understood that the proponent has already made significant changes to their proposal to avoid directly undermining the Metropolitan Special Area and it is considered that these changes have greatly ameliorated some of the potential risks to the MSA. However, there remain a number of significant uncertainties around the potential impacts, as discussed below.

General issues

1. In some of the questions below, the IESC has been asked to provide advice on model accuracy. Models are necessarily based on imperfect information and are simplified representations of reality. In this sense, models cannot be perfectly accurate, and the IESC considers that questions of accuracy should be framed in terms of confidence in model predictions. Evidence to support the degree of confidence in model estimates must be supported by analyses of uncertainty. In a high risk environment, this should include many simulations to explore how model parameters and assumptions influence the likely upper and lower bounds of model predictions.
2. There are two main drivers that need explanation to provide context for the responses to the questions that follow: mining-induced ground movement and groundwater drawdown.

Mining-induced ground movement

3. The key physical driver of concern is the extent to which mining-induced ground movement causes surface cracking and near-surface fracturing, which has important consequences for the interactions between groundwater and surface waters and their resources. The estimates of surface subsidence are largely based on the use of a single empirical method (Incremental Profile Method (IPM)). While this method might be appropriate to estimate subsidence across the broader landscape, it is noted that the model materially underestimates observations of ground movement within watercourses and near the Nepean fault (EIS, Appendix F – subsidence assessment, and Appendix G – geotechnical assessment). Accordingly, the IESC has little confidence in the estimates of subsidence (and other associated ground movements) in these locations. Additional geological characterisation, groundwater level analysis and targeted seismic surveys across fault zones may help to understand the hydrological influence of the fault zones.
4. It is difficult to resolve the implications of the differences in results presented in the Subsidence Report (EIS, Appendix F) and the Geotechnical Report (EIS, Appendix G). The former presents the results of the subsidence observations and predictions, whereas the latter presents data, observations and geotechnical modelling to evaluate changes in hydraulic conductivity and subsidence, including at Longwall 10A. There are also differences between the reports in reporting of maximum subsidence in some areas. For example, Appendix F (Figure 3.11) indicates maximum subsidence for longwall panel LW26 was approximately 900 mm whereas in Appendix G (section 3.2) it is reported as 1382 mm. Also, in Appendix F the largest subsidence in Figure 3.9 is not represented in Figure 3.6. The proponent should explain whether these differences are likely to be the result of changes in conditions – such as depth of cover, strata lithology or weathering – and what the implications are for mining-induced ground movements from the current project. Maps clearly showing depth from ground surface to the predicted height of fracturing (both vertical and horizontal) would help to identify the areas in which topography causes increased risks. These discrepancies and omissions make it difficult to assess potential impacts on surface water and groundwater environments, especially as actual subsidence can often be greater or lower than predicted due to differences in the expected geological conditions particularly, in this case, near the Nepean Fault and possibly, the Central Fault.
5. There is also a discrepancy in the assumed height of the fracture zone above the longwall panels and available observations. From the observations presented in EIS Appendix G, the zone of vertically connected fractures was observed in an open-rock bore to be approximately equal to the width of the longwall panel at the Tahmoor North project. Given the longwall panels for the Tahmoor South project are generally to be 305 m wide, these observations strongly suggest that the vertically connected fractures could extend to approximately 300 m above the seam. However, the Tammetta (2013) method used to calculate the height of fracturing for the groundwater model predicts a fracturing height of 61 to 256 m (EIS, Appendix I, section 4.6.1). It was acknowledged in Appendix I that the Tammetta method was developed to estimate the height of complete drainage above the seam. A

model sensitivity run to test a greater height of fracturing resulted in predicted mine inflow water volumes greater than that shown in the base model run (EIS, Appendix I, p. 80). This has implications for predictions of groundwater drawdown and the possibility of connectivity between surface water and deep strata via tortuous flow paths.

Groundwater drawdown

6. The likely underestimation of the height of the fracture zone above longwall panels in the base case of the groundwater model means that the estimated extent of groundwater drawdown presented in Appendix I is likely to be under predicted. While the sensitivity analysis included a run with the height of fracturing increased by 50 percent, the proponent did not provide all the results for this run, nor accompanying drawdown maps. The IESC does not have a high level of confidence in the modelled water balance and predicted drawdown, particularly for shallow model layers because extraction from non-mining bores is unknown and so was not modelled. When a revision of modelling is undertaken, it would further aid assessment of potential impacts to GDEs if an ecologically relevant drawdown map was provided that shows the extent of the 0.2 m water table drawdown contour at the time of maximum impact for both the base case and uncertainty analysis. The EIS only includes mapping showing the base case 2 m drawdown contour, which is predicted to occur almost entirely within the project boundary (EIS, Appendix I, Fig. 5-8).
7. Further, there is an unknown quantity of water losses through delayed flow via tortuous flow paths including fractures and bedding plane separations and shears in deeper strata overlying longwall panels (PSM 2017 and associated peer reviews including Mackie 2017 for a discussion of such processes). Due to these processes, it is possible that a component of surface water flows may not be returned to catchment. The implications of this potential water loss for creeks and groundwater-dependent ecosystems during long-term operations and recovery of water levels after closure need to be considered in a manner that bounds the likely upper and lower range of impacts.
8. The groundwater model developed by the proponent is focussed on simulating regional groundwater flows under the assumption of porous media flow (i.e. continuum model). This model does not incorporate the impacts of surface cracking and near-surface fracturing. This means the groundwater model does not address what is likely to be the main impact pathway on baseflow in nearby watercourses, and this has implications for assessing likely impacts on riverine biota and ecological function. Accordingly, the IESC has a low level of confidence in the proponent's estimates of mining impacts on surface water-groundwater interactions.
9. The type of models employed in the EIS also cannot simulate the dynamic changes in hydraulic properties associated with mining-induced ground movement. Continuum models (EIS Appendix G and Appendix I) are not currently suitable for predicting changes in groundwater flow and storage due to mining-induced ground movement. For example, the possibility of turbulent groundwater flow through fractures are not considered. Also, specific storage values are assumed to be constant over time, whereas it is known that this hydraulic parameter changes in strata overlying a longwall panel extraction (David et al. 2017).
10. To assist in providing more confidence in impact predictions, further investigations and monitoring (as discussed in paragraphs 37 - 39), supported by the further analysis of existing data should be focused on quantifying losses of surface water into near-surface fracture zones and the possibility of partial or complete returns of these flows to surface water at some point and time to support GDEs.
11. Notwithstanding several crucial modelling issues noted above, the groundwater model does not include an adequate uncertainty analysis and thus cannot be used to evaluate cumulative impacts. The impact of model assumptions and limitations noted above should be quantified and demonstrated. Key physical processes that are excluded must either be justified or rectified. Thus an uncertainty analysis must rigorously test and quantify uncertainties in model conceptualisation,

parameters, physics and assumptions. The proponent notes that the complexity of the model and its regional focus result in long model run times, making uncertainty analysis difficult. This difficulty suggests that future modelling of local scale processes should be designed to facilitate uncertainty analysis. For example, a revised version of the current groundwater model could be used to provide boundary conditions for a local model of surface-groundwater interactions.

Surface water and groundwater-dependent ecosystems

12. The deficiencies in the groundwater modelling of potential impacts to surface water systems affect the predictions of reductions in stream flow (especially during low-flow periods) and pool persistence in the surface water assessment (EIS, Appendix J).
13. While induced near-surface fractures may not cause a net loss of water from the catchments it is expected that local impacts on pools and low flows will occur for sections of the river that lie upstream of where lateral sub-surface flows return. There is also the possibility of net loss of water from the catchment if the near-surface fractures are also connected to deeper tortuous flow paths. The impacts on stream and pool persistence from this flow loss, altered depth and change in storage below the creek bed, and implications for loss from baseflow capture, are not quantified. The extent of this region, and thus the local and cumulative impacts on riverine biota and ecological processes, cannot therefore be assessed adequately. The proponent appears to assume that the lateral extent of impacted subsurface flow paths is limited to the extent of the subsidence zone. The near-surface impacts could extend a considerable distance beyond the subsidence zone along geological structures such as fault zones.

Response to questions

The IESC's advice, in response to the requesting agencies' specific questions, is provided below. To minimise repetition and to present the advice as clearly as possible, the regulators' questions have been reordered (though the original numbering has been retained).

4. Does the IESC agree that the predicted impacts on surface water resources have been accurately modelled and assessed in the EIS?

14. The IESC does not have confidence in the predictions of impacts on surface water resources that are modelled and assessed in the EIS because of:
 - a. inconsistencies between modelled and observed subsidence and mining-induced ground movements near watercourses and the Nepean Fault;
 - b. limitations in the ability of the groundwater model to adequately consider the effects of fracturing, particularly in the near-surface zone;
 - c. a paucity of baseline data to substantiate assumptions regarding impacts of existing mining activities; and
 - d. a general lack of information about the influence of modelling assumptions on the likely upper and lower bounds of estimates on surface and water impacts.

Surface hydrology

15. To conclude that mining activities have had little impact on streamflows, the proponent has used the Australian Water Balance Model (AWBM). However, the use of simple visual comparisons of modelled versus observed flow behaviour is not compelling as the simulations are influenced by limitations in model calibration that could impact on different components of the flow regime. More defensible insights could be drawn by undertaking a trend analysis on the differences between model

simulations and observed flows over time (i.e. by analysing the modelled residuals), but without such evidence it is not possible to have confidence in the current conclusions.

16. The IESC has some confidence in assessment of the *relative* impacts on the flood risks estimated by the modelling, and agree that the likely impacts on flooding risk due to mining activities is low. However, the degree of confidence regarding the *absolute* estimates of the flood risks is low because the configuration of the adopted flood model was based solely on regional information without calibration, and no information is provided on some of the key modelling assumptions (e.g. whether the flood estimates were derived using deterministic or ensemble rainfall patterns). Accordingly, it is suggested that the results of this modelling be reviewed if further analysis of the uncertainty in mining-induced ground movements indicate the relative impacts on surface water resources may be greater than that currently estimated. Surface water resources identified within the predicted area of subsidence include water quality and aquatic habitats in Tea Tree Hollow, Dog Trap Creek and their tributaries, as well as riparian corridors including potentially groundwater-dependent vegetation. Outside the predicted area of subsidence, there may be impacts on Thirlmere Lakes and streams of the Metropolitan Special Area (MSA) (see responses to questions 2 and 5). However, these impacts cannot be assessed because of the inadequacies of the modelling of surface-water/groundwater interactions.

Water quality

17. It is noted in the EIS (Appendix I, p. 49) that surface cracking can result in subsurface flow and, where flow re-emerges downstream, water quality is affected. This change in water quality is not assessed further in the EIS. The proponent should use existing data from Tahmoor North to provide an assessment of the likely impacts of this process on water quality and the implications for ecosystems dependent on this water.
18. Water quality monitoring during 2012–2015 found that water from all impacted and reference sites exceeded multiple water quality parameters when compared to ANZG (2018) guidelines for aquatic ecosystem protection. Although increased salinity, metals and barium precipitate identified downstream of the wastewater discharge sites are attributed to mine water, explanations are not provided for the observed exceedances of national and site-specific guideline values across most sites. More recent monitoring data should be used to confirm that the contaminant concentrations have been reduced with improvements to the Waste Water Treatment Plant (WWTP).

Surface water ecosystems

19. Streams and their associated riparian corridors are the predominant surface water resources in the project area. Five will be undermined for substantial lengths (Dog Trap Creek: 3.1 km; Tributary 1 of Dog Trap Creek: 2.6 km; Tributary 2 of Dog Trap Creek: 2.4 km; Tea Tree Hollow: 1.9 km; tributary of Tea Tree Hollow: 2.4 km (Table 18, EIS Appendix K)). The proponent states that in these undermined stream reaches, fracturing is likely to result in complete or partial loss of surface water, hydrological connections along the streams will be less frequent, pools will overflow less often and there will be less aquatic habitat available. Water quality is predicted to deteriorate and where cracking promotes emergence of ferruginous groundwater, iron flocs are likely to smother benthic biota. There will also be subsidence-induced changes to stream gradients that will increase potential ponding in some reaches (e.g. upstream of the tailgate of LW103 in Dog Trap Creek) whereas erosion will increase in other reaches where subsidence troughs form (EIS, Appendix K). Where little sediment is present, fracturing and surface water loss may persist for years and the proponent states that remediation may be required when mining is completed, although it is unclear whether this is likely to succeed. Collectively, these impacts on surface water hydrology, pool persistence, water quality and hydrological connectivity over some twelve stream-kilometres are predicted to adversely affect aquatic biota such as small native fish, tadpoles and aquatic macroinvertebrates. Total biomass will

be reduced (EIS, Appendix K). Bats, birds and other fauna that feed on these animals are also likely to be impacted but these impacts have not been assessed by the proponent.

20. Riparian habitats in the project area include groundwater-dependent vegetation. The proponent does not appear to have assessed the likely groundwater dependence of vegetation in areas where drawdown is predicted. This may be particularly relevant for threatened flora such as Rufous Pomaderris (*Pomaderris brunnea*) which was recorded along Tea Tree Hollow. The proponent reports about 300 individuals in the study area, a significant find as the known total population of this species in NSW in 2011 was about 600 individuals (Sutter, 2011). Most of the plants in the project area occur on the mid-bank to higher banks of Tea Tree Hollow (EIS, Appendix K, p. 102) and it was inferred that the drying of pools or predicted changes to the flow regime as a result of subsidence was therefore unlikely to result in die-back of this *P. brunnea* population. However, the proponent needs to assess whether this EPBC Act-listed species is occasionally dependent on groundwater and therefore might be affected by groundwater drawdown. No offset has been proposed for *P. brunnea*, because the proponent considers that the species will not be impacted by the project. Similar investigations of groundwater-dependence and potential risks from drawdown would be appropriate for other flora likely to be found near creek lines in the project area as well as vegetation used by threatened fauna such as koalas.

21. Thirlmere Lakes and streams in the MSA are surface water resources outside the project area. Predicted impacts on these are discussed in response to questions 2, 3, 1 and 5.

Wastewater management and discharge

22. The proponent intends to increase water storage capacity by construction of additional sediment dams and storage of excess water in the goaf. Overflow from sediment dams is proposed to be released into the Bargo River and Tea Tree Hollow. There are no volumetric limits in place for the release of overflow water, although conditions are prescribed for the existing mine. Potential impacts to the surface water receiving environment from overflow discharges are not considered. Condition of the current receiving environment and the extent to which it is impacted by existing activities are not adequately discussed and require information from a more robust monitoring program (see responses to question 8).

23. If it is intended to store the waste water from coal washing and groundwater from dewatering activities in the goafed areas, the IESC considers further information is needed on the underground storage proposal. This should include:

- a. further information on the water quality of the water being stored underground with a full risk assessment of the potential contamination caused by untreated water leaking into the groundwater (potential impacts to the receiving environment);
- b. assurance that the lack of water storage does not lead to releases of untreated water into Tea Tree Hollow and the Bargo River; and
- c. updating the groundwater model to reflect water storage in the goafed area.

2. Does the IESC agree with the project EIS's conclusions that Thirlmere Lakes and the Metropolitan Special Area would not be significantly impacted by mining operations?

24. The IESC does not have confidence in the EIS's conclusions that Thirlmere Lakes and the Metropolitan Special Area would not be significantly impacted by mining operations. Of greatest concern are the potential risks from regional groundwater drawdown and mining-induced ground movements that could occur along geological structures beyond the subsidence zone.

25. The potential role of the Nepean Fault and other geological structures in influencing unconventional subsidence and ground movement is acknowledged (EIS, Appendix F, p. 28) but not assessed.
- The Nepean Fault is located in the eastern section of the project area. The presence of the fault increases the probability of impacts in the MSA, particularly to Cow Creek, located approximately 1000 m from the nearest longwall. It may also act as a conduit for enhanced groundwater drawdown.
 - The location of the geological structure T2, close to the proposed project area and extending towards Thirlmere Lakes, may also increase the probability of unconventional mining-induced ground movements and associated impacts to groundwater. It could also act as a conduit for localised increases in mine water inflow, based on reports from a longwall panel in existing Tahmoor North. Nevertheless, it is noted that cumulative impacts from the currently proposed project are likely to be less than the possibility of impact from the drained longwall panels of the existing Tahmoor North project which are closer to the lakes. This existing impact has not been quantified, and it is unclear whether it is likely to be material.
26. Given variable water levels in the Thirlmere Lakes, the potential influence of coal mining on lake water levels relative to the influence of pumping by non-mining groundwater bores and various other factors needs to be considered (Riley et al. 2012; Pells and Pells 2016; Schädler and Kingsford 2016; Banerjee et al. 2016). Overall, there is a lack of clarity about the volume of groundwater use by production bores in the region, and also the influence of the geological structure T2 and whether or not the structure extends from the coal seam to the ground surface. This structure is known to extend at coal seam level to the edge of the proposed Tahmoor South project. There is a possibility that the T2 structure influences groundwater and that it may continue within the Tahmoor South project between the Nepean Fault (which is known to influence groundwater) and the Central Fault (for which influence on groundwater is apparently unknown).
27. The findings of ongoing studies at Thirlmere Lakes (NSW OEH, 2019) should be used to revise and update future models for the Tahmoor South project. For example, the conceptual model of each individual lake as variably connected or disconnected with regional groundwater should be reviewed and included in model updates. The potential indirect influence of mining, particularly during periods of higher lake water levels and for the two lakes that are located furthest to the west, should also be considered. Once updated predictions of potential impacts of mining on each lake are available, the results should be viewed in the context of historical fluctuations in lake water levels, including periods when the lakes are known to have dried.

3. Noting that the project is predicted to exceed the Level 1 minimal impact considerations under the NSW Aquifer Interference Policy at a limited number of groundwater bores, does the IESC consider the impacts to bores to be accurately modelled and assessed in the EIS?

28. Given modelling issues already identified, the IESC does not consider that the potential impacts to groundwater bores have been appropriately modelled and assessed. The historic and current volumes of pumping from non-mining groundwater bores have not been included in the model, meaning that the calibrated water balance may not be reliable for predicting groundwater drawdown. There was no attempt to test the sensitivity of the model to low and high estimates of pumping from these bores. An uncertainty analysis is required to quantify conceptual and parametric uncertainty on groundwater drawdown and hence potential impacts on groundwater bores.
29. In addition to the issues described above that result in low confidence in groundwater model predictions, the model calibration residual is high. The model's absolute mean residual is 21 m, which is an order of magnitude higher than the impact threshold under the NSW Aquifer Interference Policy of 2 m for groundwater bores. It is unclear how this calibration residual affects the prediction that the 2 m drawdown threshold will be exceeded in approximately 120 non-mining bores due to cumulative

mining impacts. Of these total number of bores, approximately 28 would be impacted for the first time by mining during the Tahmoor South project according to model predictions with the most severe drawdown.

1. Have the likely far-field non-conventional groundwater impacts been accurately modelled and assessed in the EIS, including consideration of possible basal plane movements and consequential potential impacts on the Thirlmere Lakes and the Metropolitan Special Area?

30. The IESC has low confidence in the proponent's modelling of groundwater impacts, as described above. The IESC has particular concerns regarding prediction of far-field (outside the predicted area of conventional subsidence) groundwater impacts. This is because the subsurface processes are poorly understood when it comes to inferring potential impacts on Thirlmere Lakes and the MSA.

31. Although the mechanisms by which mining-induced ground movements (basal plane movements, bedding plane separations, upsidence, valley closure and shears) influence groundwater drawdown are also poorly understood, these movements primarily occur in the project area rather than the far-field. However, these project-specific ground movements could contribute to regional groundwater drawdown, which may impact on the MSA and Thirlmere Lakes. There are potential groundwater and baseflow impacts on Cow Creek in the MSA which is located relatively close to the Tahmoor South project as discussed in paragraph 25.

5. Does the IESC consider that the project would comply with the neutral or beneficial effect of development on water quality within the Metropolitan Special Area?

32. As the IESC has low confidence in the predictions of the groundwater model, and as there may also be other unidentified processes that could alter or exacerbate potential impacts on water quality, it is not possible to evaluate whether the project would comply with development intent in the MSA.

6. Does the EIS provide reasonable strategies to effectively avoid, mitigate or reduce the likelihood, extent and significance of impacts (including cumulative impacts with the existing Tahmoor mine) to significant water-related resources?

7. Would the IESC recommend any additional or varied strategies to avoid, mitigate or reduce the likelihood, extent and significance of impacts (including cumulative impacts with the existing Tahmoor mine) on water-related resources? If so, why?

Avoidance

33. Where mitigation is not feasible, avoidance is the most effective management strategy. Given that empirical observations from Tahmoor North suggest that impacts from mining-induced ground movements are likely to be more severe than modelled, further redesign of the mine plan should be considered to avoid impacts. In particular, connective cracking and extensive surface cracking and near-surface fracturing should be avoided at mapped GDEs, Dog Trap Creek and Tea Tree Hollow. These impacts may be avoided by, for example, altering the longwall placement or orientation so that creeks are not undermined or by other alterations to the mine design and geometry of panels and pillars.

Mitigation

34. The IESC presumes that details of mitigation strategies are, or will be, provided in management plans. As these management plans have not been provided, the IESC is unable to provide comment. To underpin these plans and associated risk assessment, an ecohydrological conceptual model is needed that illustrates potential pathways and mechanisms of the effects of altered surface flows, and of the effects on groundwater exchanges and in-stream water quality on surface and groundwater

ecosystems. This conceptual model would help the proponent justify strategies proposed to mitigate and manage potential impacts.

35. The proponent states that cracks will naturally remediate through sediment infilling. However, the creek beds in this area are mainly bedrock or rock bars where suitably fine sediment is unlikely to collect. Moreover, much of the sediment is sandy and infilled cracks would retain some permeability. Although the proponent indicates that grouting may be employed, the IESC is unaware of any successful deployment of this method at a large scale (e.g. along a creek line) in a natural system that has been verified by appropriate stream gauge data over both the short and long term. The proponent has not provided detailed and independently peer-reviewed evidence that streambed subsidence impacts can be remediated.
36. As described above (see response to question 4), potential impacts to surface and groundwater quality from the proposed project could occur through impacts associated with water discharges, water storage and mining-induced ground movements. To mitigate these potential impacts, the IESC considers that:
- a. the proponent's existing operations facilities for water should be improved by ensuring:
 - i. the WWTP is operating as intended to mitigate metal concentrations in water prior to discharge. There is no evidence in the EIS that the WWTP is achieving the required water quality objectives since its 2014 upgrade as no recent data has been provided. It is also noted that no water quality data is provided for LPO3, LPO4, and LPO5; and
 - ii. the water treatment system has the capacity to store and treat contaminated mine water during storm events or during periods of high groundwater inflows. The IESC considers that if the additional water balance work finds a high risk of untreated water discharges, additional storage capacity should be installed so that untreated water is not released or allowed to overflow to Tea Tree Hollow or the Bargo River.
 - b. the proponent should develop a Receiving Environment Management Plan that provides actions to ensure that the downstream environment is not adversely affected by discharges or storage overflows from the proposed mine. Collectively, these plans should:
 - i. provide a trigger action response plan (TARP) in line with ANZG 2018 guidelines; and
 - ii. incorporate appropriate spatial and temporal representation to detect impacts from mine-induced ground movement and mine-water discharge. This redesign should take account of the investigations into reference and impact sites and the water quality guideline value exceedances described above.
 - c. this Receiving Environment Management Plan should be integrated with the existing Water Management Plan and the Biodiversity Management Plan so that the mitigation and management measures will adequately protect environmental values within and downstream of the project area.

8. Would the IESC recommend any additional monitoring or management measures to address any residual impacts on water-related resources?
--

Mining-induced ground movement monitoring

37. The IESC considers the following mining-induced ground movement monitoring should be undertaken to confirm the spatial extent and magnitude of potential impacts.

- a. The proponent should adopt the monitoring recommendations for a 5-yearly catchment-wide geomorphology survey to complement monitoring of subsidence at each longwall, as described in the geomorphology report (EIS, Appendix H).
- b. Subsidence monitoring points should be installed before any mining of second workings for all longwalls in each Extraction Plan. The IESC acknowledges that there is an adaptive management plan for longwall mining. This would be enhanced by a commitment to re-evaluate the subsidence and biodiversity monitoring after mining of each longwall. This would then inform monitoring for subsequent longwall panels.
- c. Data from subsidence monitoring needs to be used to provide better calibrated predictions of subsidence within each consecutive Extraction Plan, particularly within fault zones. Additional geological characterisation, and targeted seismic surveys across fault zones should be designed to improve the knowledge of fault zones. For high risk fault zones, drilling across core and fault damage zones, and studies of the spatial variability and changes over time in response to mining-induced stresses should be undertaken.
- d. Monitoring should be undertaken to determine if leakage from shallow near-surface fractures is occurring and if the flows through fractures are returning to the watercourses. Such monitoring should be undertaken before mining commences to assess the baseline conditions above each longwall, and should include:
 - i. detailed monitoring to determine geomorphological conditions, including creek mapping and high-resolution photography (before, during and after undermining of each longwall) of any rock bars, shallow alluvium (i.e. less than 2 m deep) and permanent or semi-permanent pools within the subsidence impact area;
 - ii. geophysical logging of boreholes that allow changes in groundwater storage and fracture apertures to be quantified and depth of rock deformation to be identified (i.e. observations of non-deformed ground which could be at least 10 – 30 m below surface). Both open-rock and multi-level piezometers will support assessment of changes to hydraulic gradients between different hydrogeological units (such as between alluvium and the underlying sequences); and should also be used for environmental water tracer studies to provide an additional line of evidence for hydraulic connection and disconnection;
 - iii. time-series cross-sections using suitable geophysical techniques (before, during and after undermining of each longwall). This should include profiles across the creek channel and either side of the flood plain, with depth penetration exceeding the depth of alluvium to bedrock, but with metre or sub-metre scale resolution of data in the zone from, at least, 10 – 30 m of the surface.

Groundwater monitoring

38. The IESC considers the following improvements should be made to the groundwater monitoring network.

- a. As recommended in the groundwater report (EIS Appendix I, pp. 22–24, 100–101), a review of vibrating-wire piezometers should be undertaken to identify piezometers that have ceased to function or are providing suspect data. As also noted in the groundwater report, it is expected that a number of replacements may be needed following this review.
- b. Multi-level piezometers and open rock holes should be installed in the following areas:
 - i. within the subsidence zone at key locations above longwall panels that are early in the mining sequence proposed for Tahmoor South to verify the height of complete drainage,

the height of vertical connected fracturing and the height of horizontal fracturing above the coal seam as a function of longwall panel geometry, overburden thickness and other factors;

- ii. beyond the mine subsidence zone between the mine and the MSA, located in an appropriate manner to quantify the influence of the Nepean fault zone on near-field and far-field strata and groundwater conditions;
 - iii. beyond the mine subsidence zone on the topographic high between the mine and the Thirlmere Lakes (e.g. replacement of site TBC039 if it is not suitable or functional);
- c. These monitoring points should be targeted at key depths within each strata overlying the coal seam, with detailed analysis of water level data. Downhole geophysical logs and camera logs in open rock holes should be repeated before and after longwall extraction in a manner similar to that demonstrated in EIS Appendix G. In addition, environmental water tracer studies at these sites should provide another line of evidence of hydraulic connection and disconnection over the short term and long term.
- d. The proponent should also seek to include reliable groundwater head data from all public and private bores. This will allow verification of the depth of near-surface fracturing and connective fracturing.
- e. To measure any impacts to sensitive areas, additional multi-level piezometers and open rock holes should be installed as close as practicable to creeks to monitor:
- i. ecologically sensitive areas, including Cow Creek in the MSA (placed between the mine and Cow Creek) and the *P. brunnea* population along Tea Tree Hollow;
 - ii. sections of streams identified as being of at high risk from mining-induced ground movement;
- f. Detailed investigations and monitoring at these points including downhole geophysics and environmental water tracer studies should be designed to identify and quantify mining impacts as discussed in paragraph 37 part d-ii) and d-iii).
- g. To provide an indication of background groundwater quality, the proponent should reinstate groundwater quality monitoring upstream of the REA.
39. Groundwater quality monitoring is needed to determine whether groundwater that has travelled through shallow subsidence fractures increases the concentration of metals or other contaminants. Results from this monitoring should be compared to those from groundwater monitoring of reference sites upstream and outside the predicted subsidence impact zone.

Surface water monitoring

40. An effective monitoring program needs to justify the selection of reference, baseline and impacted sites. This is especially critical for sampling water quality because water from the reference sites exceeded multiple water quality parameters when compared to the ANZG (2018) guidelines for aquatic ecosystem protection. Sometimes, the same sites have been used inconsistently. For example, sites serving as controls for water discharge also served as impact sites for mine subsidence. This inconsistency needs justification and an explanation of how the potential contributing factors between changes to hydrogeochemistry due to mine subsidence (should it occur) and those caused by mine discharge waters are to be partitioned when interpreting results from future monitoring.

41. The IESC considers the proponent should re-install gauging stations and monitoring at surface-water sites as recommended in the proponent's documentation (EIS, Appendix J, Surface Water Impact Assessment Report, p. 79). Monitoring sites should also be expanded to include high-risk and ecologically sensitive sites.
42. To address gaps in surface water quality information, the proponent should:
- provide an explanation for the source of high contaminant concentrations at reference sites. If high contaminant concentrations are found to be anthropogenic, the proponent should identify the magnitude of impact at control sites to enable an understanding of cumulative impacts;
 - where water quality guidelines are consistently exceeded for individual contaminants, undertake direct ecotoxicity testing of the discharge, upstream water and water immediately downstream of the licenced discharge point, to determine any mixture toxicity; and
 - increase spatial representation of water quality sites, particularly downstream of LDP1.

Biological monitoring

43. Based on the information provided in the EIS, the IESC considers that additional monitoring is needed to identify water regime and groundwater requirements of threatened species (e.g. *P. brunnea*) and keystone GDE and water-dependent species within the project area and where drawdown impacts are predicted downstream. This additional work will identify whether further management measures are needed to avoid or mitigate potential impacts of groundwater drawdown or altered flows on these species.
44. Although the ecological survey methods were generally appropriate and followed standard protocols, survey timing was sub-optimal for the Sydney Hawk Dragonfly (*Austrocordulia leonardi*) listed as threatened under the NSW *Biodiversity Conservation Act 2016*. It is recommended that further surveys are needed during warmer months, when dragonflies are likely to be larger and more active. Summer sampling of adults at sites identified as suitable larval habitats is also needed.
45. There may be a need to collect more up-to-date baseline data against which to judge potential ecological impacts of the proposed project. For example, the macroinvertebrate monitoring was done in 2012 and 2013, but there may have been changes in community composition that should be identified to provide a reliable pre-mining baseline data set. Samples should also be collected from the three tributaries that are to be undermined as these have not been sampled for aquatic invertebrates.

Date of advice	18 March 2019
Source documentation provided to the IESC for the formulation of this advice	Tahmoor Coal Pty Ltd, 2018. Environmental Impact Statement, Volume 1. Prepared by AECOM Australia Pty Ltd. Available: http://www.majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=8445
References cited within the IESC's advice	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

-
- Banerjee BP, Raval S and Timms W 2016. Evaluation of rainfall and wetland water area variability at Thirlmere Lakes using Landsat time-series data. *International Journal of Environmental Science and Technology*, 13:1781–1792. DOI: <http://dx.doi.org/10.1007/s13762-016-1018-z>. Erratum DOI: <http://dx.doi.org/10.1007/s13762-016-1068-2>
- Boughton WC 2004. “The Australian Water Balance Model”, *Environmental Modelling and Software*, 19: 943-956.
- David K, Timms WA, Barbour SL and Mitra R 2017. Tracking changes in the specific storage of overburden rock during longwall coal mining. *Journal of Hydrology*, 553: 304 – 320, <http://dx.doi.org/10.1016/j.jhydrol.2017.07.057>
- IESC 2018. *Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals*. Available at: <http://www.iesc.environment.gov.au/system/files/resources/012fa918-ee79-4131-9c8d-02c9b2de65cf/files/iesc-information-guidelines-may-2018.pdf>.
- Mackie C 2017. *Height of fracturing at Dendrobium Mine - Peer review of Pells Sullivan Meynick Report*. Letter from Mackie Environmental Research Pty. Ltd. to the NSW Department of Planning and Environment. Dated 28 February 2017.
- NSW OEH, 2018. Thirlmere Lakes Research Program website. New South Wales Office of Environment and Heritage. Available at: <https://www.environment.nsw.gov.au/water/ThirlmereLakesInquiry.htm>
- Pells P and Pells S 2016. *The Water Levels of Thirlmere Lakes – Where did the water go and when will it return?* IAHR APD 2016: 20th Congress of the Asia Pacific Division of the International Association for Hydro Environment Engineering & Research, August 28 – 31 Colombo, Sri Lanka <http://www.iahrapd2016.info/>
- PSM 2017. *Height of Cracking – Dendrobium Area 3B, Dendrobium mine*. Report for Department of Planning and Environment, PSM3021-002R, March 2017.
- Riley S, Finlayson M, Gore D, McLean W and Thomas K 2012. *Thirlmere Lakes Inquiry: Final report of the independent committee*, 23 October 2012. Available at: <https://www.environment.nsw.gov.au/resources/water/ThirlmereReport2012.pdf>
- Schädler S and Kingsford R 2016. *Long-term changes to water levels in Thirlmere Lakes – drivers and consequences*. Centre for Ecosystem Science, University of New South Wales, Australia.
- Sutter G 2011. National Recovery Plan for Rufous Pomaderris (*Pomaderris brunnea*). Department of Sustainability and Environment, East Melbourne. Available at: <https://www.environment.gov.au/system/.../pomaderris-brunnea-recovery-plan.doc>
- Tammetta P 2013. Estimation of the height of complete groundwater drainage above mined longwall panels. *Groundwater*, 51(5): 723–734. DOI: <https://doi.org/10.1111/gwat.12003>
-
-