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Queensland Government

Department of
Regional Development, Manufacturing and Water

24 January 2023

Ms Kimberly Foster
Director (Energy & Extractive Resources)
Department of Environment and Science

Email: Kimberly.Foster@des.qld.gov.au

Dear Ms Foster

Request for advice on groundwater matters relating to Arrow (Hopelands) Environmental Authority amendment application

Thank you for your advice request dated 14 December 2022 in relation to a current Environmental Authority amendment application for Arrow Hopelands.

The Office of Groundwater Impact Assessment's (OGIA) advice is formulated on the basis of information provided by the Department of Environment and Science (DES) dated 22 December 2022 and 5 January 2023, a number of clarifications sought from Arrow Energy (Arrow) during a meeting with DES and OGIA on 11 January 2023, and subsequent verbal and written clarifications from Arrow on 12 and 13 January 2023. A list of all the reports and clarifications considered in formulating the advice is provided as *Attachment 1*. Responses to specific advice questions are provided as below.

1. If the revised modelling will affect the previous (OGIA) advice, in particular Arrow's conclusions on risks of mobilisation of contaminants

Overall, Arrow's key conclusion – that *'….the potential for this development scenario to significantly affect the site contamination is low'* (Arrow Energy 2022, pg 44) – is reasonably supported by the information and modelling presented by Arrow in various reports and subsequent clarifications listed in *Attachment 1*. There is, however, room for further improvements to modelling, underlying conceptualisation and the way the outputs are presented in reporting – as discussed in later sections of this advice, in response to Question 3. This advice should also be considered in the context provided in the following paragraphs.

1.1. OGIA understands that the purpose of the model by Arrow is to understand the impact of its proposed development (61 CSG wells in this instance) on the potential movement of contaminants around the former Linc site – compared to the 'base case' which includes existing and already approved CSG development occurring around the site.

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1.2. The focus of Arrow's assessment is on 'changes' resulting from the proposed development in terms of potential for mobilisation of contaminants. Characterisation of former Linc site contaminants, underground coal gasification (UCG) reservoir pressure conditions as well as overall movement, mobilisation and fate of contaminants are outside of that scope.

1.3. The proposed development will certainly affect the groundwater flow regime – primarily around the site. A groundwater flow model coupled with particle tracking is therefore considered an appropriate combination of tools to assess changes in movement of a contaminant away from the source – acknowledging that the potential movement, mobilisation or attenuation of contaminants in groundwater is driven by a range of processes. A change in groundwater flow regime is only one such process that is driven by groundwater heads and the presence of gas in the reservoir in this instance.

1.4. In the absence of site characterisation and fate of contaminants under the prevailing conditions without the proposed development, the underlying assumption from Arrow is that contaminants will attenuate within the next 20 years with or without the proposed development. This is an important assumption and needs to be explored further.

1.5. Arrow's assessment and modelling also lacks a clearly articulated supporting conceptual model for potential movement of contaminants with or without the proposed CSG wells. It appears to instead rely on conceptualisation from other sources, such as OGIA's regional conceptualisation from 2016 or AECOM (2018).

1.6. The revised modelling commissioned by Arrow for the assessment is also materially different to its modelling from 2019, which was reviewed by OGIA in providing the previous advice to DES in early 2021. Some of the key differences include significantly more data being used for 2021 and 2022 model calibration, addition of uncertainty analysis, change in input development scenario, and lack of solute transport modelling.

1.7. The modelling suggests a low probability of particles moving offsite, however some assumptions in model design are likely to result in an underestimation of particle travel distances in both the baseline and development cases. The model predictions suggest that with the proposed development, 95% of particles would stay within a few hundred metres of the former Linc site[*] at the end of 20-year simulation period. This is a substantial increase in transport distance compared to the previous model, which predicted a maximum transport distance of less than 50 m from the site. Note that implications of preferential pathways (due to formation heterogeneity and fracturing) are not explicitly considered.

1.8. The reported uncertainty analysis does not allow for a thorough analysis of the probability of a small number of particles travelling a longer distance. Upon request from OGIA, Arrow subsequently provided the maximum travel distances for the development case for each model utilised in the uncertainty analysis (see *Attachment 1*). This provides sufficient evidence to conclude that contaminant particles are likely to remain within a few hundred metres of the source.

1.9. Effective porosity is an important consideration in assessing mobilisation of contaminants with changes in groundwater conditions. Porosity values in the model are derived from the calibrated specific yield by assuming that effective porosity is

[*] On 25 January 2023, this was further clarified to be from where Arrow started the particle tracking, which is adjacent to the gasifiers.

one per cent higher than the specific yield. This offset amount is not supported by data or literature. Overestimation of porosity would likely result in a reduced particle velocity and shorter travel paths in the specified 20-year predictive period and, ultimately, an underprediction of travel distance in both the baseline and development cases.

1.10. In summary, the modelling, underlying assumptions and conceptualisation could be improved further, and those improvements will affect the groundwater regime in both cases – i.e. with the proposed development (the development case) and without it (the base case). Any potential improvements to the base case will also affect the development case and, hence, conclusions about the net change resulting from the proposed development are unlikely to be affected materially.

2. Is Arrow's modelling considered to adequately represent current and predicted groundwater movement in and around the site for ongoing management?

For the purpose of this question, it is assumed that 'management' implies, among other things, ongoing updating of the understanding of groundwater flow conditions as additional monitoring data becomes available. This will also include an assessment of how the updated understanding may change potential movement of contaminants from the former Linc Energy site in response to the proposed development.

In this context, Arrow's modelling forms a good basis, provided that a supporting simple conceptual model is developed and regularly updated as additional monitoring data becomes available. The conceptual model should clearly identify mobilisation pathways and present the groundwater pressure and flow regime around the site, accompanied by a description of how contaminants would migrate over time with and without the proposed development. This should also identify uncertainties in conceptualisation resulting from formation heterogeneity, preferential pathways and structural influences. The numerical groundwater flow model should then be updated with reference to the conceptual model, supported by an uncertainty analysis.

3. Any additional comment and/or recommendations, if relevant, in the context of the purpose of the model

As stated in response to Question 1 earlier in this advice, while Arrow's key conclusion is reasonably supported by the information presented, some improvements can be made to future iterations of assessment and reporting for, if required, amendments and ongoing management. These are listed as below.

3.1. *Improvements to reporting* – The reporting from Arrow on the latest groundwater model generally does not provide sufficient clarity around the basis for assumptions and conclusions. As such, various clarifications and additional material were sought from Arrow, including some additional analysis – in particular the comparison between the base case and development case particle travel distances. Upon specific requests from OGIA, Arrow provided two additional runs from the uncertainty analysis, representing a low and high case, and has provided the maximum travel distances in each model (see *Attachment 1*).

3.2. *Improvements to uncertainty analysis* – While a parametric uncertainty analysis was undertaken for the current model, this was not fully utilised to support the conclusions in the report. It would be prudent for future reports to utilise uncertainty analysis to further support key conclusions. For example, presenting maps of the probability of a particle going through a cell, or histograms of the differential travel

distance of particles between scenarios, would enable a more rigorous and transparent assessment.

3.3. *Former Linc site characterisation* – Uncertainty remains regarding the characterisation of contaminants, reservoir pressure conditions as well as mobilisation, movement, and fate of contaminants. Additionally, current water chemistry data may be affected by drilling, and gas pressure may alter groundwater movement in and around the UCG reservoir, limiting the use of current datasets. An improved characterisation will greatly support conceptualisation and modelling for the assessment of potential movement of contaminants in response to the proposed development.

I trust this meets your requirement. Please do not hesitate to contact me if you require further clarification on any aspect of the advice.

Yours sincerely

Sanjeev Pandey
Executive Director
Office of Groundwater Impact Assessment

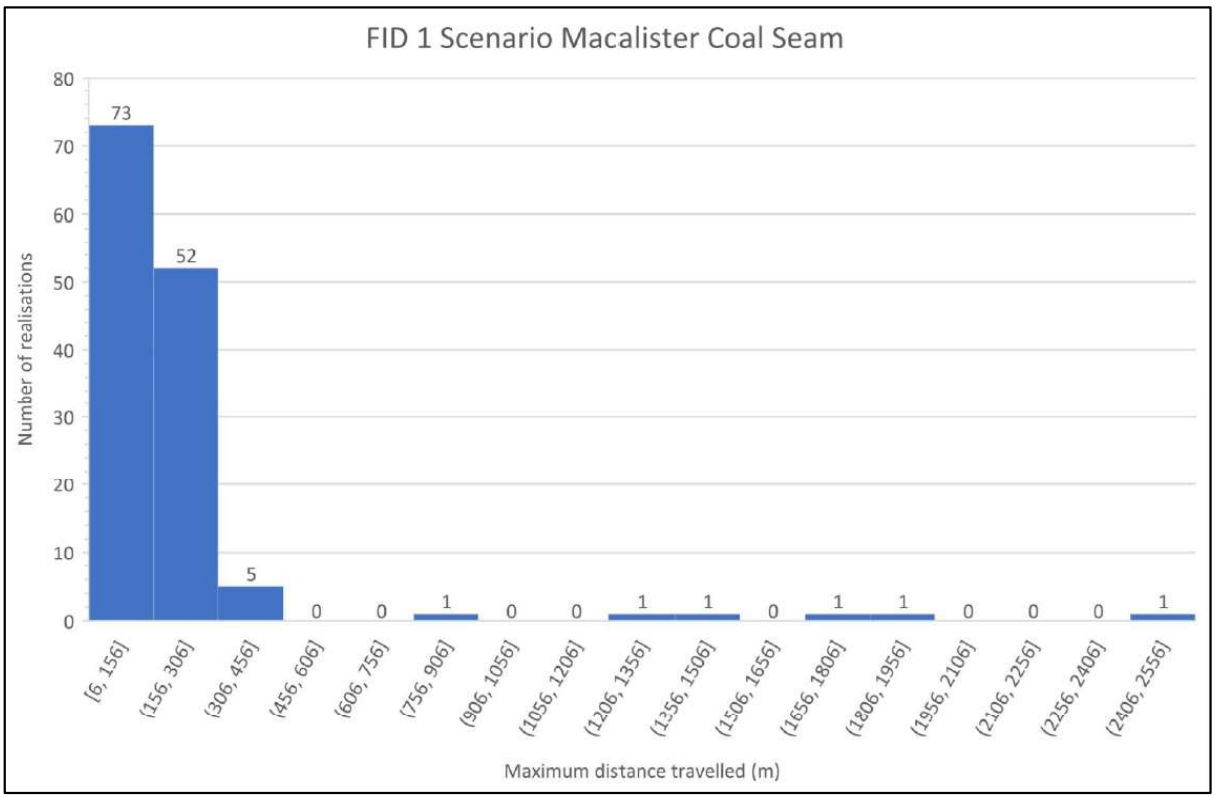
Attachment 1

Reports considered by OGIA (in addition to information provided by DES with the advice request).

- Arrow Energy 2022, Hopeland GCMP Annual Report, Arrow Energy
- Australasian Groundwater and Environmental Consultants Pty Ltd, (AGE) 2022, Arrow 2022 Model Support (PL 253), Project No. ARR5001.001, December 2022
- Australasian Groundwater and Environmental Consultants Pty Ltd, (AGE) 2020, Production Licensing Modelling Support – Arrow Energy
- GHD, 2019, Arrow Hopeland Groundwater Study Groundwater Modelling Report – PL253

Travel distances from additional model run provided by Arrow on 12 January 2022

Maximum travel distances in each model from two additional runs from the uncertainty analysis, representing a low and high case (Arrow).



Maximum travel distances for the development case for each model utilised in the uncertainty analysis (Arrow).

Table 1 Predicted particle tracking impacts (December 2020 to December 2040) – Calibrated parameters

Scenario	Average Distance Travelled (m)	Average Predicted Impact (m)	Maximum distance travelled (m)	Maximum predicted impact (m)
Springbok Sandstone				
FID1 Baseline	129	NA	323	NA
Arrow FID1 scenario	129	0	324	1
Macalister Coal Seam				
FID1 Baseline	138	NA	175	NA
Arrow FID1 scenario	138	0	175	0

Table 2 Predicted particle tracking impacts (December 2020 to December 2040) - Uncertainty realisation 52, minimum migration case

Scenario	Average Distance Travelled (m)	Average Predicted Impact (m)	Maximum distance travelled (m)	Maximum predicted impact (m)
Springbok Sandstone				
FID1 Baseline	57	NA	127	NA
Arrow FID1 scenario	57	0	127	0
Macalister Coal Seam				
FID1 Baseline	75	NA	85	NA
Arrow FID1 scenario	75	0	85	0

Table 3 Predicted particle tracking impacts (December 2020 to December 2040) - Uncertainty Realisation 178, maximum migration case

Scenario	Average Distance Travelled (m)	Average Predicted Impact (m)	Maximum distance travelled (m)	Maximum predicted impact (m)
Springbok Sandstone				
FID1 Baseline	1326	NA	2474	NA
Arrow FID1 scenario	1336	10	2496	22
Macalister Coal Seam				
FID1 Baseline	1462	NA	2470	NA
Arrow FID1 scenario	1474	12	2489	19