

Advice to decision maker on coal mining project

IESC 2019-107: Moranbah North Extension Project (EPBC 2018/8338) – Expansion

Requesting agency	The Australian Government Department of the Environment and Energy
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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 to provide advice on Anglo Coal (Moranbah North Management) Pty Ltd's Moranbah North Extension Project in Queensland. This document provides the IESC's advice in response to the requesting agency's questions. These questions are directed at matters specific to the project to be considered during the requesting agency's 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

Moranbah North Mine (MNM) is an operating longwall coal mine located approximately 7 km north of Moranbah township in Central Queensland. This proposed project involves extending mining operations into an area to the east of the current mine and will require a new Mining Lease to proceed. The proposed project will target the Goonyella Middle (GM) Seam and mining will be at a maximum production rate of 12 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal. The proposed project will extend the life of the MNM by approximately 16 years. Mining will be undertaken using the existing mine portals and drifts to gain underground access as well as using existing surface infrastructure. No upgrades to the infrastructure are required.

Key potential impacts from the proposed project are:

- damage to the coal seam gas (CSG) wells as a result of subsidence impacts. This damage may release residual methane into the overlying geological formations and possibly to the surface, potentially impacting surface water quality. There is also potential for this damage to increase hydraulic connections between aquifers;
- subsidence impacts altering the topography of the project area, including localised ponding and changes to surface runoff patterns (including sediment movement), streamflow regimes and overbank flooding; and
- cumulative impacts to those from previous and current CSG development and coal mines on flow regimes, overbank flooding and water-dependent ecosystems, with possible repercussions for the Isaac River.

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

- Assess whether altered flow regime and/or overbank flooding patterns might affect viability (including plant recruitment) of water-dependent ecosystems, including gilgai and the Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community listed as Endangered by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
- Improve confidence in groundwater modelling by:
 - undertaking additional sensitivity analysis across a plausible range of parameter values, including boundary conditions;
 - providing hydrographs showing the observed and predicted water levels for all calibration targets;
 - considering and acknowledging risks posed by the model's limitations;
 - commissioning an independent and comprehensive peer review; and
 - committing to reviews on a periodic basis (e.g. two to five years) to incorporate relevant development information as it becomes available, as well as in the event of a major discrepancy between predictions and monitoring data.
- Undertake sufficient surface water quality monitoring to provide appropriate baseline data for all watercourses in the project area. These baseline data should include a broader suite of contaminants (e.g. metals), as well as sediment quality sampling. This is required to assess any impacts to water quality associated with subsidence-induced changes in flow regime or migration of residual gas from the CSG wells.
- Provide quantitative estimates of all surface water losses resulting from subsidence. This should include analysis of the impacts on streamflow persistence and other ecologically important flow components (e.g. timing, frequency and duration of low- and zero-flow periods).
- Develop or update management plans to address identified risks. For example, the operational water balance should be updated to include the proposed project.
- Undertake additional stygofauna monitoring, focused in the alluvium and Tertiary sediments, in accordance with the Queensland Guidelines for the Environmental Assessment of Subterranean Aquatic Fauna (DSITI, 2015).

- Clarify how cumulative impacts from CSG and other mining developments have been incorporated into the groundwater and surface water models, and assess their potential impacts on surface water processes (e.g. sediment regimes, surface runoff, overbank flooding), water quality and water-dependent ecological communities.

Context

Moranbah North Mine (MNM) is an operating longwall mine approximately 7 km north of Moranbah township in Central Queensland. The mine commenced operations in 1998 and produces export coking (metallurgical) coal. The proposed project involves extending mining operations into an area east of the current mine and will require a new Mining Lease to proceed.

The proposed project will target the Goonyella Middle (GM) Seam and mining will be at a maximum production rate of 12 Mtpa of ROM coal. The ROM coal is to be processed on-site at the coal handling and preparation plant (CHPP). The extension will use the existing mine infrastructure, CHPP, mining methods and workforce. The proposed project will extend the life of the MNM by approximately 16 years.

The local region has been heavily modified through agriculture (grazing and irrigated cropping), coal mining and unconventional gas operations. Much of the project area is susceptible to water erosion. Despite these pressures, there remains some riparian vegetation, particularly along Teviot Brook and Skeleton Gully (Anglo Coal 2018, App. E, p. 3, 75) providing habitat for terrestrial and aquatic native species on and adjacent to the project area. There are also areas of woodland/open forest along the eastern and western boundaries of the project area.

Response to questions

The IESC's advice, in response to the requesting agency's specific questions, is provided below.

Question 1: Advice is sought on whether the modelling provided is appropriate for a project of this type and at this stage of development? If not, what changes or improvements should be made to the modelling?

1. The presentation of the information and results of modelling is often confusing and should be clarified as part of further project assessment to ensure risks are appropriately identified, managed and communicated. In this project, the key physical driver of concern is the impact of subsidence on topographic gradients. This will potentially have impacts on surface water hydrology (surface runoff, overbank flooding and streamflow regime) and consequently water-dependent ecosystems (potentially including EPBC Act-listed vegetation). Regional groundwater modelling is less likely to be crucial in this context, despite the unusual situation of longwall mining proposed within a CSG wellfield.

Groundwater

2. The current groundwater model predictions provided by the proponent indicate that the impacts from the proposed project will largely be confined to the Permian coal measures (Anglo Coal 2018, Att. 5, p. 5-7). Drawdown is not predicted in the Tertiary basalt, Tertiary sediments or alluvium (Anglo Coal 2018, App. C, p. 31). Given that the CSG production has required drawdown in the GM Seam to 75 m above that seam (Anglo Coal 2018, App. 4, p. 4), the IESC considers these predictions to be plausible.
3. Consideration of the issues outlined below would further increase confidence in the groundwater impact assessment and associated modelling.

- a. A sensitivity analysis has been undertaken to assess the response of the model to varying hydraulic properties. The IESC commends the use of a sensitivity analysis during this early stage of assessment. However, several concerns need to be addressed.
 - i. Boundary conditions are considered by the proponent to be set at a sufficient distance from the proposal to not significantly influence model predictions (Anglo Coal 2018, App. C, App. IV, p. 4). As no sensitivity analysis of the model results to model boundary conditions (type and location) was undertaken, it is unclear how the applied boundary conditions may be affecting model predictions. The proponent should demonstrate that these boundary conditions do not significantly influence model predictions.
 - ii. The sensitivity analysis varied parameters by $\pm 50\%$ (Anglo Coal 2018, App. C, App. IV, p. 10). Justification is required for this range of parameter adjustment as horizontal hydraulic conductivity could vary over several orders of magnitude. Sensitivity analysis should adjust parameters within a plausible range (Barnett et al. 2012).
 - iii. Mine inflows were found to be sensitive to significant increases in the combined vertical and horizontal hydraulic conductivities. The proponent should undertake further quantified sensitivity analysis if results from the monitoring differ from predicted results.
 - b. Hydrographs for all calibration locations showing modelled and observed groundwater levels should be provided to support assessment of the reliability of model parameter estimates.
 - c. There is an inadequate presentation of how the impacts from CSG or other mining developments in the area have been incorporated into the model making it difficult to fully interrogate the groundwater modelling results (refer to response to Question 4).
 - d. Further discussion of the limitations of the groundwater model and the consequences of these on impact predictions should be provided.
 - e. An independent peer review of the groundwater report should be provided, as well as a commitment to update modelling on a periodic basis or sooner if there is increasing divergence between predicted and observed responses.
4. The groundwater model developed by the proponent is focussed on simulating regional groundwater flows under the assumptions inherent in an equivalent porous media model. This model does not directly incorporate the impacts of surface cracking or subsidence. However, groundwater drawdown at the surface is unlikely given the depth of cover and the fact that the GM Seam has already been depressurised due to CSG production. Therefore, the use of this model does not invalidate the conclusions regarding groundwater drawdown. In predicting groundwater level recovery after mining and CSG development, the impacts of surface cracking and subsidence on the model parameters and simulated outputs should be explicitly considered.

Surface water

5. The physical context for the surface water modelling is informed by estimates of subsidence impacts of up to 2.4 m in Teviot Brook and up to 2.6 m in Skeleton Gully (Anglo Coal 2018, App. D, p. 8). This subsidence will probably change the flow regimes in these surface water systems, and may impede low flows, cause transient ponding, and potentially modify flood break-out areas. Limited modelling has been undertaken to assess potential impacts on surface water patterns and streamflow regime, and on aquatic and riparian ecological communities. Nor has any modelling been undertaken for surface water management purposes. Such modelling is required to assess risks, and without it the IESC is unable to comment on its adequacy.

6. The surface water modelling relevant to the potential impacts of subsidence on overbank flood behaviour has been well considered. The hydrologic models (RFFE and XP-RAFTS) are appropriate choices for deriving flood estimates. No information is provided on the configuration of the storage routing elements used within XP-RAFTS, but the sub-area definition and sourcing of loss and ensemble temporal pattern data are appropriate. The adoption of the two-dimensional TUFLOW model for hydraulic analysis is consistent with best practice, and the use of LiDAR data to inform the digital terrain model and the adopted model parameterisation is appropriate. However, it is noted that this modelling has not been used to assess the impacts on water-dependent ecosystems (see Paragraphs 8, 10).
7. The consideration of multiple independent modelling approaches to estimate the selected design floods is commended given the absence of local gauging, though some account could have been given to the (now closed) gauge at Isaac River at Burton (130402). The flood estimates for this site (after scaling non-linearly for difference in catchment area) lie approximately midway between the rainfall-based and RFFE estimates and thus provide additional confirmation that the flood estimates adopted for analysis are appropriate.

Question 2: Advice is sought on whether the proponent's assessment of groundwater and surface water provide reasonable estimations of the impacts to water resources, their severity and likelihood of occurrence? Does the Committee consider that any other impacts are likely?

Surface Water

8. As noted earlier, the key physical impact is subsidence caused by the longwall mining operations that will alter the topography of the drainage network, surface runoff patterns, overbank flooding and streamflow regimes. These changes may have impacts on water-dependent plants and animals, and ecological processes such as carbon cycling. The proponent has not presented detailed baseline data, developed an ecohydrological model of potential impact pathways, or assessed the cumulative impacts of longwall mining and other activities (such as CSG development and nearby open cut mines).
9. The proponent has identified likely subsidence impacts to Teviot Brook and, to a lesser extent, Skeleton Gully. Subsidence depressions will result in ponding and cracking above subsided longwall panels which will alter surface water flows. Confidence in this assessment is sound due to:
 - a. the good historical dataset of subsidence and surface cracking used by the proponent in their assessment;
 - b. the thick depth of cover that reduces the likely magnitude of subsidence impacts; and
 - c. the use of conservative assumptions in the subsidence assessment.
10. However, there is little information provided on how subsidence and associated ponding and sedimentation could alter the flow regime of Teviot Brook or Skeleton Gully. There is no information about how altered geomorphology may affect flow regime (e.g. timing, frequency and duration of low- and zero-flow periods), overbank flooding, or sediment input to watercourses. Further, as flow in these ephemeral streams may largely be due to surface runoff, subsidence-induced changes to the drainage basin's topography, vegetation cover and streambed profile are all likely to alter streamflow regimes downstream. In ephemeral streams, changes to the flow regime usually lead to loss of native aquatic biota as well as altered rates of crucial ecological processes such as organic matter cycling, in turn impairing the provision of ecosystem services (Datry et al. 2018).
11. The IESC notes that subsidence depressions are expected to fill with sediment to pre-impact bed level within a few wet seasons (Anglo Coal 2018, App. F, p. 42, App. D, p. 24). The MNM Subsidence Management Plan (Response to DoEE, App. E, p. 19) also proposes to remediate interruptions to

creek flow due to elevated bed levels by cutting through them with a bulldozer and adding rock armouring to minimise erosion. The IESC is concerned that these 'hard engineering approaches' may have unintentional ecological impacts and recommends that the proponent explore more passive remedial options. Discussion and justification of these remediation options should be fully provided in a revised subsidence management plan.

12. Water balance modelling has not been undertaken for the proposed project, noting the most recent update occurred in 2015 (Response to DoEE, App. E, Water Management Plan, p. 26). While increases to mine inflows are not predicted by the proponent (Anglo Coal 2018, Att. 2, p. 2-9), the IESC is unable to assess the validity of these predictions or the potential contribution to discharges to the Isaac River or groundwater seepage from the Co-Disposal Area that is already occurring (Response to DoEE, App. E, Water Management Plan, p. 24).
13. Further characterisation of water quality in all surface waterways within the project area is required. This includes additional baseline data for ephemeral waterways, as the current dataset (one sample from each of five sites and two farm dams for a very limited suite of analytes) is not considered sufficient to detect an impact to water quality from the proposed project. The results of the current limited sampling could be augmented by data from nearby operations and event-based monitoring (ANZG, 2018). Additional parameters, such as metals, should also be monitored in waters and sediments.
14. The movement of sediment has been considered a potential impact to aquatic ecology; however, toxicants such as metals attached to sediment have not been considered. Sediment quality sampling has not been undertaken and is required to determine potential impacts to the environmental values of Teviot Brook and the downstream Isaac River. The existing MNM Environmental Authority (EA) specified that metals in sediment should be included in monitoring (Response to DoEE, App. D, p. 13). As there is an upstream discharge of mine-affected water from the Burton Coal Mine into Teviot Brook, a contamination pathway could exist and therefore baseline data should be collected.
15. The presence of over 100 CSG wells introduces an additional risk from subsidence that does not appear to be discussed in the subsidence reports or other documentation provided. The IESC is not aware of other areas where longwall mining and CSG production have coincided and further work is required to determine the significance of this potential risk.
16. Even after these CSG wells are plugged and abandoned, many will be affected by the collapse of the goafs and surface subsidence. If this causes multiple ruptures to these wells, there may be a conduit for residual gas to migrate to the surface, increasing groundwater interconnection between geological units and potentially causing impacts to surface water quality.

Groundwater quality

17. There are some potential impacts to groundwater quality that have not been fully assessed. These are discussed further below.
 - a. Post-mining, the underground workings will be allowed to flood, which may affect groundwater quality and flow locally. However, the risk to regional groundwater quality is likely to be low. The nature of this mining does not imply a high risk of impacts to groundwater quality. Therefore, monitoring should continue to ensure that any unexpected changes to groundwater quality can be detected, investigated and addressed.
 - b. The proponent presents time-series groundwater quality data that ends after the first quarter of 2017. Some exceedances of water quality guidelines for aluminium, selenium and arsenic were found, but not discussed. Data for other metals, such as copper, zinc and nickel, were either not collected or not reported. More recent data on a wider range of water quality parameters should be provided to facilitate the assessment.

- c. Prior to mining, hydraulic stimulation may also be used for coal seam gas drainage using a series of horizontal holes drilled into the coal seam of the adjacent unmined longwall (Anglo Coal 2018, App. C. pp. 34-35; Att. 2 p. 2-7). The proponent assumes that fluids from hydraulic fracturing used in the Moranbah Gas Project (MGP) will be removed during mining operations. Therefore, the proponent does not consider this groundwater contamination pathway likely (Anglo Coal 2018, Att. 5, pp. 5-10, 5-11). The proponent expects that all residual fluid from the stimulation activities will also be removed during mining of the coal seam. Confirmation, via geotechnical analysis, is needed to demonstrate that there will be no residual fluid left in the seam beyond the extent of mining.
- d. The proponent provides a brief assessment of the risks from six stimulation chemicals. Only acetic acid and BE-9 (a biocide) are assigned a moderate hazard rating; all other chemicals are assigned a low rating. The IESC considers that the assignment of low hazard and unlikely exposure ratings to these chemicals, especially for sodium hydroxide, requires further justification. DoEE (2017) and Santos (2014) both identify sodium hydroxide as a potential concern for the environment.
- e. The IESC recommends that any future assessment should consider the latest results of CSG activity in the region and ensure best-practice management principles are applied. It was not clear whether underground mining would only occur in CSG well locations after local CSG activities had ceased.

Water-Dependent Ecosystems

- 18. An ecohydrological conceptual model of the project area is required. This model should identify all potential impact pathways associated with subsidence, groundwater depressurisation, altered sediment and flow regimes, and changes in surface runoff, overbank flooding and alluvial recharge. It should also include water-dependent vegetation and faunal assemblages (including stygofauna) as well as Threatened Ecological Communities (TECs) and Regional Ecosystems (REs). Direct and indirect effects should be considered, including those associated with altered water quality. This model is needed for a comprehensive assessment of risks to water-dependent ecosystems and to help guide appropriate monitoring and management measures to address such risks.
- 19. Through-flow of water in the deeper alluvium of Teviot Brook may sustain stygofauna and supply riparian and groundwater-dependent vegetation downstream where alluvial sediments are frequently saturated. Altered runoff, streamflow and overbank flooding patterns associated with Teviot Brook may affect recharge of alluvial sediments that potentially support water-dependent ecosystems such as the EPBC Act-listed Brigalow (*Acacia harpophylla* dominant and co-dominant) ecological community, and the availability of water for gilgai habitat. The proponent should assess the likelihood and magnitude of these potential impacts and, where appropriate, develop suitable monitoring and mitigation plans (see response to Question 4).

Question 3: Advice is sought on whether the proposed monitoring, mitigation and management measures are adequate to identify, avoid or reduce the likelihood and extent of impacts to water resources? If not, what additional measures are required to be implemented to monitor, mitigate and manage impacts to water resources?

- 20. There are mitigation and management measures currently undertaken at the MNM, directed by the requirements of the existing EA. The proponent has provided management plans for their current operations; however, these are yet to be updated for the proposed project. In the interim, further details needed to determine adequacy of the current measures include:
 - a. mitigation and management actions for each trigger in the groundwater monitoring and management program;

- b. a description of the process for reviewing groundwater data and revising the monitoring program, including what performance measures the data will be reviewed against;
- c. prediction of the time it will take for:
 - i. the filling of subsidence depressions by sediment mobilised by flow events; and
 - ii. patterns of flooding and alluvial recharge to return to pre-impact condition, particularly near areas supporting vegetation that may rely on transient flooding or recharge of alluvial sediments.
- d. how the Receiving Environment Monitoring Program will be able to detect impacts to the environmental values of the watercourses from subsidence, noting that sampling aquatic macroinvertebrates and interpreting these data for the baseline and subsequent assessments should consider the suggestions in Chessman et al. (2010) about monitoring the ecological health of dryland streams.

21. Further monitoring should include:

- a. additional stygofauna monitoring focussed in the alluvium (especially in the lower reaches of Teviot Brook and downstream in the saturated alluvium) and Tertiary sediments, in accordance with the Queensland Guidelines for the Environmental Assessment of Subterranean Aquatic Fauna (DSITI, 2015) as one sampling event is not temporally representative. The IESC also notes that stygofauna in the sub-order Harpacticoida were identified in a sample from approximately 13 m below ground level for the Moranbah South Project (C&R Consulting 2013).
- b. consideration of additional groundwater monitoring bores. The four new bores currently proposed provide limited additional spatial and depth coverage. It is unclear whether monitoring data will be shared between adjacent mines. If not, the proponent will need to consider whether further monitoring bores, such as those established during the site investigation program (Anglo Coal 2018, App. C, p. 14), are needed for verifying the extent and magnitude of groundwater drawdown.
- c. baseline ecological sampling of the condition of TECs and REs that may be water-dependent. Some vegetation of these ecological communities is likely to be affected by altered flows/flooding (including transient recharge of alluvial sediments), especially for TECs.

22. Due to the nature of the longwall mining, CSG production wells will be subject to a number of stresses. Compromising the integrity of the plugged and abandoned wells could provide pathways for residual gas to migrate into the overlying geological units and potentially to the surface. Consequently, the proponent should assess the materiality of this risk and explain whether this can be prevented or, alternatively, how these processes will be monitored, and mitigated if required.

Question 4: Advice is sought on whether these assessments give adequate consideration to the project's contribution to cumulative impacts associated with other mining activities and coal seam gas production in the area?

23. The IESC notes that the proponent has incorporated historical data from existing and surrounding mines in their groundwater modelling and subsidence predictions, although this information is poorly presented. As discussed below, further information to clarify how cumulative impacts from CSG and other mining developments have been incorporated into the groundwater model is required.

- a. The cumulative impact assessment should include clear discussion and presentation (including a comparison of potential impacts) of the following development scenarios as a minimum:

- i. impacts from approved (excluding the proposed project) mining developments in the region, where presenting both separate and cumulative impacts from CSG and mines would be useful; and,
 - ii. impacts including all approved CSG and mining developments plus the proposed project.
- b. The groundwater model domain currently includes approved coal and CSG operations within a proximity that the proponent considers could potentially result in cumulative groundwater depressurisation (Anglo Coal 2018, App. C, App. IV, p. 2).
- i. The proponent predicts that depressurisation of the GM seam from the project will be up to approximately 400 m. The proponent also states that the depressurisation from CSG production has resulted in a lowering of the potentiometric surface to 75 m above the top of the GM coal seam. If the CSG production has depressurised the coal seam by this amount, the IESC considers that it is unlikely that this project could depressurise the coal seam by 400 m. This requires clarification.
 - ii. Further, it is not clear whether the depressurisation results include CSG production. However, the IESC assumes that the very small predicted water production rates (6 L/s as the peak inflow) are the result of depressurisation from existing CSG production. Clarification of this is required.
24. Cumulative impacts of this project to surface water processes (e.g. sediment regimes, overbank flooding, low- and zero-flow periods), water quality and water-dependent ecological communities do not appear to have been considered at this stage of the assessment. In particular, the additive effects of the proposed project to those associated with CSG development and nearby coal mines (e.g. Red Hill, Goonyella Riverside, Broadmeadow Mine complex, Moranbah North, Grosvenor, Isaac Plains and Moranbah South) on the Isaac River should be assessed. The IESC considers that surface (and groundwater) management plans should include specific triggers to mitigate potential cumulative impacts.
25. Predictions of post-project recovery trajectories of groundwater, surface flow regimes and ecological communities should be based on assessment of likely cumulative effects under climate change projections.

Date of advice	15 November 2019
Source documentation provided to the IESC for the formulation of this advice	Anglo Coal (Moranbah North Management) Pty Ltd (Anglo Coal) 2018. Moranbah North Extension Project referral documentation. Available: http://epbcnotices.environment.gov.au/publicnoticesreferrals/ .
References cited within the IESC's advice	ANZG 2018. <i>Australian and New Zealand Guidelines for Fresh and Marine Water Quality</i> . Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knappton A and Boronkay A 2012. <i>Australian groundwater modelling guidelines</i> . Waterlines report no. 82. Canberra, National Water Commission.

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- C&R Consulting 2013. *Moranbah South Project: stygofauna report*. Prepared for Hansen Bailey Pty Ltd on behalf of Anglo American Metallurgical Coal Pty Ltd. Report dated 22 March 2013.
- Chessman BC, Jones HA, Searle NK, Growns IO and Pearson MR 2010. Assessing effects of flow alteration on macroinvertebrate assemblages in Australian dryland rivers. *Freshwater Biology*, 55, pp. 1780–1800.
- Datry T, Boulton AJ, Bonada N, Fritz K, Leigh C, Sauquet E, Tockner K, Hugueny B and Dahm CN 2018. Flow intermittence and ecosystem services in rivers of the Anthropocene. *Journal of Applied Ecology*, 55, pp. 353-364.
- Department of Environment and Energy 2017. *Environmental risks associated with surface handling of chemicals used in coal seam gas extraction in Australia*. Project prepared by the Chemicals and Biotechnology Assessments Section (CBAS), in the Chemicals and Waste Branch of the Department of the Environment and Energy as part of the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, Commonwealth of Australia, Canberra.
- Department of Science, Information Technology and Innovation (DSITI) 2015. *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna: Sampling Methods and Survey Considerations*. Queensland Government. Available [online]. <https://publications.qld.gov.au/dataset/f7e68ccd-8c13-422f-bd46-1b391500423f/resource/ba880910-5117-433a-b90d-2c131874a8e6/download/guideline-subterranean-aquatic-fauna.pdf> accessed October 2019.
- IESC, 2018. *Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals*. Available [online]. <http://www.iesc.environment.gov.au/system/files/resources/012fa918-ee79-4131-9c8d-02c9b2de65cf/files/iesc-information-guidelines-may-2018.pdf>. accessed October 2019.
- Santos 2014. *Upstream hydraulic fracturing risk assessment – Appendix D: material safety data sheets, Table D#, Santos Upstream Hydraulic Fracturing Risk Assessment Report*.
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