

Advice to decision maker on coal mining project

IESC 2020-118: Central Queensland Coal Project (EPBC 2016/7851) –New Development

Requesting agencies	The Australian Government Department of Agriculture, Water and the Environment The Queensland Department of Environment and Science
Date of request	27 October 2020
Date request accepted	28 October 2020
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 Agriculture, Water and the Environment and the Queensland Department of Environment and Science to provide advice on Central Queensland Coal Pty Ltd's and Fairway Coal Pty Ltd's Central Queensland Coal Project in Queensland. 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 2018a).

Summary

The proposed Central Queensland Coal Project (the 'project') is a greenfield development located in the Styx Basin, approximately 130 km northwest of Rockhampton in Central Queensland. The proposal is to produce up to 10 million tonnes per annum (Mtpa) of semi-soft coking coal and high-grade thermal coal from an open-cut mine for 18 years.

The IESC previously provided advice on this proposal in December 2017 (IESC 2017, 2017-091) and July 2018 (IESC 2018b, 2018-094) (see [Appendix A](#)). As part of this previous advice, the IESC expressed numerous concerns that the project presents very significant risks to nationally and internationally recognised assets with high ecological values, including the Great Barrier Reef World Heritage Area

(GBRWHA) and the Broad Sound Fish Habitat Area (Queensland's largest fish habitat area and is on the Directory of Important Wetlands in Australia) located approximately 10 km downstream of the site. Other high-value environments near the site, and which may be impacted by the project, include Tooloombah Creek, Deep Creek, the Styx River estuary as well as two state-listed wetlands. Although the proponent has undertaken substantial additional hydrological, water quality and ecological studies, many of the concerns noted in IESC (2017) and IESC (2018b) remain. Results of the proponent's additional studies reinforce the IESC's extreme concern that the predicted impacts are not readily mitigated, especially the discharge of mine-affected water into Broad Sound and the GBRWHA. Proposed mitigation options primarily entail offsetting residual impacts (e.g. for the 8.35 km of stream-length that will be removed) and are likely to be completely inadequate for this region because of its relatively undisturbed setting.

Additional investigations, modelling and analyses will not alter the material risks associated with this project, in particular the potentially severe consequences for local and downstream water-related assets. The IESC cannot envisage any feasible mitigation measures, including offsets, that could safeguard these irreplaceable and internationally significant ecological assets and their associated water resources.

Key potential impacts from this project, also identified from IESC (2018b), are:

- significant and irreversible damage to internationally valued estuarine and near-shore ecosystems subjected to mine-affected water;
- changes to surface water quality from controlled and uncontrolled discharges, with the potential to impact aquatic environments within, adjacent to, and downstream of the project site;
- from drawdown below some 165 ha of riparian groundwater-dependent ecosystems (GDEs) and to stygofaunal communities in the Styx River alluvium;
- from drawdown (of up to 4.7 m along sections of Tooloombah Creek and up to 60 m reduction along 11.8 km of Deep Creek) that will reduce the volume and persistence of dry-season pools and reduce baseflow in both creeks for decades post-mining;
- groundwater interaction with the backfilled voids that could mobilise contaminants from the waste rock and coal rejects within the voids and discharge these contaminants to surface waterways, posing a legacy water quality issue;
- direct loss of approximately 8.35 km of waterways that provide fish passage during periods of high rainfall and flood; and
- disturbance of sodic soils, which are prone to erosion, potentially increasing sediment loads in local waterways and contributing sediment to the GBRWHA.

Context

The project is located within the lower catchments of Tooloombah Creek and Deep Creek, which are sub-catchments within the Styx River Catchment, Queensland. Both creeks feed directly into the Styx River, part of a coastal management district of the Great Barrier Reef, which discharges into the Broad Sound Fish Habitat Area. The GBRWHA lies approximately 10 km downstream of the project within the Styx River estuary of Broad Sound.

The proposal involves mining a maximum combined tonnage of 10 Mtpa of semi-soft coking coal and high-grade thermal coal for 18 years. The project is a greenfield site and will comprise two open cut operations, a train loadout facility (TLF) to load coal onto trains and provide a new connection to the North Coast Rail Line, and a transport corridor to transport coal from the mine to the TLF. At full production, the project will require two coal handling and preparation plants.

Response to questions

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

Question 1: Has the proponent considered and addressed the IESC's previous advice and concerns (IESC 2018b-094 and IESC 2017-091):

- Through the revised groundwater model and its predictions?
- Relating to the risks and impacts to water resources and water-related assets, including Tooloombah Creek and Deep Creek, GDEs, fish habitat and the GBRWHA?

1. The proponent has undertaken substantial further investigation and analyses in response to our previous advice (IESC 2018b). The IESC still has major concerns that the project presents very significant risks to nationally and internationally recognised assets with high ecological values, including the Great Barrier Reef World Heritage Area (GBRWHA) and the Broad Sound Fish Habitat Area downstream of the project. Other high-value environments which may be impacted by the project include Tooloombah Creek, Deep Creek, the Styx River estuary, and two state-listed wetlands.

Groundwater model and predictions

2. Despite improvements to groundwater and GDE data and modelling, inherent uncertainties limit the reliability of groundwater predictions for drawdown, intrusion of seawater into aquifers, and alterations of fresh groundwater discharge to Tooloombah Creek and to the Styx River estuary. The large and mostly irreducible uncertainties in the timing, magnitude and spatial extent of predicted groundwater-related impacts confound assessment of the likely environmental impacts. Furthermore, trigger action response plans (TARPs) will be hampered by the timelags, potentially of several decades, for groundwater-related impacts to be detected. Lack of mitigation options means that the recent changes in project design are likely to be inadequate.
3. The independent peer review of the groundwater model recommended revisiting the history matching and uncertainty quantification of the groundwater model. The IESC agrees with the model shortcomings identified by the reviewer (AGE 2020, Appendix 6E), and also notes:
 - a. inadequacies in the improved model, both in terms of the inability to fit all historical measurements (e.g. Figures 7-10a-c, Hydro Algorithmics 2020), and of the high levels of parameter non-uniqueness (e.g. Attachment 16, Hydro Algorithmics 2020);
 - b. the lack of observed head differences in nested monitoring facilities and estimated baseflows at the Tooloombah Creek and Deep Creek gauges within the history matching dataset which exacerbates the uncertainty of some simulated predictions;
 - c. the incomplete representation of all uncertain model parameters and boundary conditions within the uncertainty analysis such as the riverbed conductance parameters and the coastal boundary conditions, including along the Styx River mouth. This is likely to underestimate prediction uncertainties, hampering reliable risk assessment of the project;
 - d. the incomplete representation of potential model prediction structural error in the uncertainty analysis;
 - e. the lack of long-term pump testing to provide a more laterally extensive estimate of the integrated hydraulic properties of the aquifer (Central Queensland Coal 2020, Chapter 11, p. 47);

- f. that the risk of aquifer seawater intrusion has not been quantified or characterised to a sufficiently high resolution, given the six delineated hydrolithologic units at the coastal boundary;
- g. the uncertainty of the simulated potential impact of climate change which also does not account for the model parameter and boundary condition uncertainties listed above;
- h. the hydraulic conductivity of the backfilled material was modelled (using time-varying material properties) with a higher hydraulic conductivity compared to the undisturbed material (Hydro Algorithmics 2020, Table 8-2, p. 164). However, it is not clear if the modelled hydraulic conductivity of the emplaced spoil decreases over time (due to consolidation) and how this compaction will affect the predicted long-term groundwater mounding of the final landform; and,
- i. no information was provided on the reinjection methods and quality of the mine-affected water reinjected into groundwater.

Risks and impacts to water resources and water-related assets

- 4. The proponent predicts that reductions in surface water hydrology and water quality are expected to result in negligible to minor impacts to ecological values. However, the IESC has limited confidence in these predictions (refer to Paragraph 2 and 6) because changes to surface water hydrology and water quality are likely to affect the persistence of GDEs in the areas where additional mitigation measures are likely to be required (refer to Paragraph 12). This concern was also highlighted in the previous IESC advice (IESC 2018b, Paragraph 19).
- 5. The coal conveyor near Deep Creek will be a constant source of coal dust into the waterway, posing serious risks to water quality and other water-related assets. These risks are particularly severe during the low-flow period in the dry season when dilution effects are minimal.
- 6. Assessment of groundwater dependence (3d Environmental 2020) indicated that some vegetation at Wetland 1, Forest Red Gums (*Eucalyptus tereticornis*) along Tooloombah Creek, and Forest Red Gums and Weeping Paperbarks (*Melaleuca fluviatilis*) along Deep Creek are GDEs. Drawdown, enhanced leakage and decreases in bank storage are predicted to increase the numbers of low-flow and no-flow days in several pools along Tooloombah and Deep creeks, and impact on the condition of vegetation, particularly along Deep Creek (Eco Logical Australia 2020, pp. 21, 40, 59–61, 93–96). Site surveys recorded Greater Gliders (*Petauroides volans*) and Koalas (*Phascolarctos cinereus*), particularly in areas containing Forest Red Gums, taller trees or trees with hollows. Damage to or loss of this vegetation due to groundwater drawdown is likely to impact these two species, both listed by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Vulnerable, as well as other arboreal native wildlife. Other predicted impacts of mine-associated drawdown on the three types of GDEs in the project area include:
 - a. loss of stygofauna habitat from the Styx River alluvium around the mine, and isolation of stygofaunal communities upslope of the mine from downstream ones;
 - b. complete drying or declines in volumes of permanent pools along Tooloombah and Deep creeks during the dry season, compromising their ecological roles as aquatic refuges (Paragraph 10) and overall aquatic habitat connectivity;
 - c. reductions in baseflow, potentially affecting ecologically important components of the streamflow regime (e.g. number of low-flow days) which may adversely affect stream and riparian biota; and,

- d. impacts on the water quality of surface water and groundwater associated with drawdown of up to 60 m beneath Deep Creek.

Question 2: Advice is sought on whether the measures and commitments proposed in the revised documentation are appropriate to effectively manage impacts to water resources and water related assets?

7. The proponent's measures and commitments to monitor impacts to water resources and water related assets are generally appropriate, although several deficiencies are noted (Paragraph 8). However, the IESC remains extremely concerned that residual impacts (after amendments to the mine layout to minimise direct disturbance, the proposed destocking to reduce sediment inputs, and the riparian zone revegetation to partially compensate for impacts to groundwater-dependent vegetation) can only be mitigated by offsetting and/or financial remuneration. The IESC believes that these mitigation options are very unlikely to adequately compensate for the predicted impacts of the project on many highly valued water resources in this greenfield context, including downstream assets such as the Broad Sound Fish Habitat Area and Great Barrier Reef World Heritage Area. As noted previously, the IESC cannot envisage feasible mitigation measures, including offsets, that could safeguard these irreplaceable and internationally significant ecological assets and their associated water resources.
8. The proposed monitoring has the following deficiencies:
 - a. inadequate description of post-closure monitoring;
 - b. lack of clear differentiation in the draft GDEMMP between reference or impacted sites for proposed monitoring of groundwater; and,
 - c. lack of monitoring bores between the mine and the mapped fault.
9. The proponent's modification of the mine plan to backfill both final voids has reduced but not eliminated potential environmental impacts post-closure. However, the physical and geochemical characteristics of the materials that are placed in the final voids could provide a long-term source of contaminants that could gradually leach and mobilise through groundwater flow. The risks posed by potential contaminant transport from the final landform have not been assessed. In particular, the impact of redox cycling on the long-term mobility and bioavailability of arsenic, selenium and aluminium (elevated in the spoil) to sensitive receptors has not been considered.
10. The current proposed commitment to the monitoring and mitigation does not adequately consider:
 - a. sediment monitoring to establish baseline data prior to clearing of the site and mine development, followed by ongoing sediment monitoring at the Dam 1 release point or if any uncontrolled releases occur;
 - b. seasonal sampling of sediment-laden flows and characterisation of the entrained sediments (e.g. particle size and chemical composition) to assess impacts to ecological processes; and
 - c. geomorphic monitoring which also targets areas that are listed as high-risk instability.
11. The proponent acknowledges that there will be a 'high' risk that stygofauna will be lost from the area of impact around the mine, and that communities upslope of the mine will be isolated from downstream communities (Central Queensland Coal 2020, App. A10a, p. 47). The proposed mitigation measure is to 'apply an adaptive monitoring approach through the GDEMMP, involving the monitoring of groundwater and stygofauna in the alluvium'. However, this monitoring approach will not mitigate the impacts, nor will it ensure post-mining recovery.

12. Potential impacts of the mine, especially via mine-affected water, on ecological processes and species downstream, including within the Styx River estuary, the Broad Sound Fish Habitat Area and the GBRWHA are poorly understood. Consequently, mitigation and rehabilitation options have not been outlined in detail should environmental impacts occur (including catastrophic events such as the unintentional release of mine-affected water during severe weather events). Mitigation measures proposed as part of trigger action response plans to protect these sensitive environments are inadequate and are unlikely to protect these values because of the timelags (at least several decades) between detection of impacts and responses.

Date of advice	11 December 2020
Source documentation provided to the IESC for the formulation of this advice	Central Queensland Coal 2020. <i>Environmental Impact Statement</i> . Central Queensland Coal. CQC SEIS, Version 3 October 2020.
References cited within the IESC's advice	<p>3d Environmental 2020. Groundwater Dependent Ecosystem Assessment. <i>Central Queensland Coal Project. Prepared for Ecological Australia Pty Ltd</i> (Appendix A10d – Groundwater Dependent Ecosystem Assessment. CQC SEIS, Version 3 October 2020). Doc. No. Revision 3_Final 30 July 2020.</p> <p>AGE 2020. <i>Central Queensland Coal groundwater model peer review – Stage 4</i>. Prepared for Central Queensland Coal Pty Ltd, (Appendix A6e – GW Model Peer Review. CQC SEIS, Version 3 October 2020). Australasian Groundwater and Environmental Consultants Pty Ltd. Doc. G2001, 16 July 2020.</p> <p>Central Queensland Coal 2020. <i>Environmental Impact Statement</i>. Central Queensland Coal. CQC SEIS, Version 3 October 2020.</p> <p>Eco Logical Australia 2020. <i>Aquatic Ecology, Groundwater Dependent Ecosystems, Marine Ecology and the Great Barrier Reef</i>. Technical Report. Prepared for Central Queensland Coal Pty Ltd, (Appendix A10a – Aquatic Ecology, Groundwater Dependent Ecosystems, Marine Ecology and the Great Barrier Reef. CQC SEIS, Version 3 October 2020). Project no. 14869. Version 5a. 11 September 2020.</p> <p>Hydro Algorithmics 2020. <i>Numerical Groundwater Model and Groundwater Assessment Report</i>. Central Queensland Coal Project. Prepared for Central Queensland Coal Pty Ltd, (Appendix A6b – Numerical Groundwater Model and Groundwater Assessment Report. CQC SEIS, Version 3 October 2020). Doc. ID HA-WAR1 V5 July 2020.</p> <p>IESC 2017. <i>Advice to decision maker on coal mining project IESC 2017-091: Central Queensland Coal Project (EPBC 2016/7851) – New Development</i>. Available [online]: http://www.iesc.environment.gov.au/projectadvice/central-qld-project-advice-2017-091 accessed November 2020.</p> <p>IESC 2018a. <i>Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals</i> [Online]. Available: http://www.iesc.environment.gov.au/system/files/resources/012fa918-ee79-4131-9c8d-02c9b2de65cf/files/iesc-information-guidelines-may-2018.pdf.</p> <p>IESC 2018b. <i>Advice to decision maker on coal mining project IESC 2018b-094: Central Queensland Coal Project (EPBC 2016/7851) – New Development</i>. Available [online]: https://iesc.environment.gov.au/system/files/iesc-advice-central-queensland-2018-094.pdf accessed November 2020.</p>

Orange Environmental 2020. *Surface Water Quality Technical Report*. Prepared for Central Queensland Coal Pty Ltd, (Appendix 5a Surface Water Quality Technical Report. CQC SEIS, Version 3 October 2020). Report Ref. CQC-SCPRT001. Revision 0, 6-Oct-2020.

Appendix A – IESC 2018b.

Advice to decision maker on coal mining project

IESC 2018-094: Central Queensland Coal Project (EPBC 2016/7851) – New Development

Requesting agency	The Australian Government Department of the Environment and Energy and The Queensland Department of Environment and Science
Date of request	19 June 2018
Date request accepted	26 June 2018
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 Queensland Department of Environment and Science to provide advice on the Central Queensland Coal Pty Ltd and Fairway Coal Pty Ltd's Central Queensland Coal Project in Queensland. 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 Central Queensland Coal Project is an open-cut coal mine that will extract up to 10 million tonnes per annum (Mtpa) of coal for 18 years. The greenfield project is to be located 130 km northwest of Rockhampton in the Styx Basin where there are no current coal mining operations. The IESC previously reviewed the project in December 2017 and highlighted a number of issues with the impact assessment, modelling and proposed mitigation and management measures. Many of these issues have not been adequately addressed in the updated assessment documentation provided by the proponent.

The project presents very significant risks as it is located near sensitive environments of high ecological value, including the Great Barrier Reef World Heritage Area and Marine Park, the Broad Sound Fish

Habitat Area, Tooloombah Creek, Deep Creek, the Styx River and two state-listed wetlands. Given the proximity to extremely valuable assets and the high and poorly characterised risks associated with this project there is the need for a much more rigorous level of analysis than has been presented. To do this, substantially more data across a number of areas must be collected as the current baseline data are inadequate. Collection of adequate baseline data will require considerably further time. Once these data are available they must be used to improve the quality of the groundwater and surface water modelling, including rigorous uncertainty analyses, as this is essential for increasing confidence in predictions of impacts made by these models. If the risks associated with this project are not appropriately characterised, assessed, mitigated and managed, as befits such a sensitive and high value area, there is a high potential for adverse impacts to these environments. The IESC considers that not all risks have been adequately characterised and assessed, and that proposed mitigation and management options contain insufficient detail to determine the likelihood of their success.

Key potential impacts associated with this project are:

- controlled and uncontrolled discharges could affect surface water quality, with the potential to impact aquatic environments within, adjacent and downstream of the project site. Many of these aquatic environments are of high ecological value and are nationally or internationally protected.
- mining operations will disturb sodic soils, which are prone to erosion, potentially increasing sediment loads in local waterways and contributing sediment to the Great Barrier Reef World Heritage Area.
- groundwater interaction with the backfilled voids could mobilise contaminants from the waste rock and coal rejects within the voids and discharge these to surface waterways, posing a legacy water quality issue.
- groundwater drawdown may adversely impact riparian groundwater-dependent ecosystems (GDEs). This could result in increased erosion and increased sediments loads if riparian vegetation is lost, as well as loss of faunal habitat.
- groundwater drawdown will reduce the volume and persistence of dry-season pools along Tooloombah and Deep Creeks and affect baseflow in both creeks for decades post-mining.

If the project progresses, it needs to be recognised that the risks are high and the standard of information and analysis provided is insufficient to adequately assess all the impacts from this project. Currently risk characterisation is poor due to a lack of baseline data and inadequate modelling which must be improved. Proposed mitigation and management measures are not well described and evidence to support their likely effectiveness is lacking. A considerable amount of additional work is needed on proposed management and monitoring measures, such as the proposed supplementary water scheme, before a decision can be made on their capacity to adequately mitigate risks.

Context

The proposed Central Queensland Coal Project (the project) is to be located 130 km northwest of Rockhampton within the Styx Basin, and will produce up to 10 Mtpa of thermal and semi-soft coking coal for 18 years.

The project was previously reviewed by the IESC in December 2017. For further contextual information on the project, refer to IESC 2017 which is at Attachment A at the end of this advice.

The greenfield project is to be located within the Styx River Catchment which includes high ecological value riparian areas around Tooloombah Creek and Deep Creek, two state-listed wetlands including a Wetland Protection Area (WPA), and the Broad Sound Fish Habitat Area (FHA). The Great Barrier Reef World Heritage Area lies approximately 10 km downstream of the project within the Styx River estuary of

Broad Sound. The Great Barrier Reef Marine Park is located approximately 40 km downstream of the project.

The proponent has revised the mine plan and provided some additional information since the IESC last provided advice on this project. However, most of the issues the IESC outlined in its previous advice remain unresolved. These are discussed in more detail in this advice (see paragraph 5). Substantial gaps remain in the understanding of the project's potential impacts and hence it is unclear whether the impacts will be able to be sufficiently mitigated and managed. Better information, especially on the baseline condition of, and the type and magnitude of potential impacts to, surface water, groundwater and groundwater-dependent ecosystems (GDEs) is essential for this project as it is located near sensitive and high-value environmental assets. This information, together with details of proposed mitigation measures and their likely effectiveness, is necessary to assess the likelihood of risks being adequately mitigated.

Key Potential Impacts

In December 2017, the IESC identified a range of key impacts potentially arising from the project. These potential impacts, which have not been adequately addressed, are briefly summarised below (see IESC 2017 for further details).

- Changes to surface water quality due to controlled and uncontrolled discharges.
- Adverse impacts to GDEs from groundwater drawdown and widespread and prolonged disconnection of surface water and groundwater.
- Adverse impacts to surface water quality and sensitive downstream environments of high ecological value due to erosion, sedimentation and exposure of potentially acid-forming material or development of acid sulfate soils.
- Changes to the tidal-affected stream length, including possible seawater intrusion into aquifers.

The inadequacy of the baseline data and modelling were identified in the previous IESC advice (IESC 2017) and these remain key deficiencies in the current documentation. Additional baseline data on groundwater, surface water, ecology, geology and soils must be collated as outlined in the IESC Information Guidelines (IESC 2018). These data will need to be obtained over a minimum of two years to provide adequate temporal resolution given the seasonality of the project site, though a longer period is preferable given that the area is subject to extreme events such as cyclones. The potential risks associated with this project cannot be adequately characterised and assessed, nor potential management and mitigation options assessed without adequate data and modelling.

The amended proposal to backfill the voids (i.e. no final residual voids) reduces or removes some of the risks highlighted in IESC 2017. However, it has introduced new risks. This proposal will also reduce potential risks from non-benign waste rock being stored ex-pit and is a better option for managing long-term legacy risks from the project. The revised proposal has introduced additional potential impacts which the proponent has not considered. As complete recovery of the groundwater system is expected after mining, it is likely that groundwater will flow through the backfilled voids. Contaminants contained within the waste rock and tailings could be mobilised and transported by groundwater, eventually discharging to surface water and potentially posing a long-term legacy risk of impacting sensitive high-value environments downstream.

Response to questions

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

Question 1: Advice is sought on:

- the adequacy of the revised groundwater model and its predictions, including the predicted drawdown in each hydrogeological unit, given it is rated as a Class 1 model.
- whether the limited time-series data from site monitoring bores is adequate to inform the model and predict the duration, extent and magnitude of groundwater contours for the life of the mine.

13. The revised groundwater model is inadequate for predicting potential impacts with the required degree of confidence. The revised conceptualisations are a significant improvement on those previously presented. However, their translation into, and the subsequent parameterisation of, the groundwater model appear to be non-systematic and poorly justified. A high degree of confidence in groundwater modelling and modelling results, including rigorous modelling uncertainty analysis, is required to enable an assessment of the materiality of risks posed by the project. Without an adequate groundwater model, the magnitude, duration and extent of potential impacts cannot be determined and adequate mitigation and management measures cannot be identified and implemented. This is essential for assessment of this project as it is located next to sensitive and high value environmental assets.
14. The proponent's Class 1 model (as defined in Barnett et al. 2012) is not sufficient for impact prediction for such a high-risk project located within close proximity to a World Heritage Area. As discussed in IESC 2017 (paragraph 3) and below, modelling needs to be based on representative site-specific data for hydraulic parameters (such as hydraulic conductivity and specific storage), including in deeper layers. The groundwater model needs to be calibrated with additional data that capture the spatial and temporal variability in hydraulic head.
15. The IESC also notes that most of the concerns raised in IESC 2017 (Attachment A) relating to the limitations of the groundwater impact assessment and modelling (see IESC 2017 paragraphs 3 and 4 in particular) have not been adequately addressed.
16. The major factors that contribute to the low degree of confidence in the revised model are discussed below.
 - a. There are limited time-series data available with which to calibrate and validate the model. Time-series data are available at 18 locations spread across the six layers of the groundwater model according to the calibration hydrographs provided in the *Groundwater Technical Report* (SEIS, App. 6, Figures 24a, 24b and 24c). Of the available sites, 16 have less than 12 months of data. Most of these sites have five observations made between November 2017 and March 2018. These data are inadequate to characterise the likely seasonal variations in groundwater levels. Additionally, this lack of appropriate seasonal data compromises the model's ability to predict future variability. A baseline dataset of at least two years of contiguous monthly sampling is required and given the seasonal nature of rainfall and the high likelihood of extreme events such as cyclones, even this may not be sufficient. The requirements for baseline data were discussed in IESC 2017.
 - b. Despite the completion and testing of several new bores to determine some hydraulic parameters spatial coverage is limited and the groundwater model is mostly constrained by information derived from the shallow aquifers. Further data, preferably from long-term pump tests, are needed for realistic and justifiable model parameterisation (for all parameters and layers). This will improve confidence in model predictions.

- c. The number of bores at which baseline data are collected should also be increased as currently there is insufficient spatial and depth coverage across the groundwater model domain. Monitoring in the Basement aquifer is discussed further in the response to Question 3. When these bores are installed, testing (e.g. pump tests) should be undertaken to provide site-specific measurements of hydraulic parameters which can be used to parameterise the groundwater model.
- d. Several features and processes that should be incorporated in the groundwater model are either not included or inadequately incorporated. The following need to be included to improve confidence in model predictions.
 - i. The backfilled voids require appropriate and realistic parameterisation of their hydraulic properties (e.g. hydraulic conductivity of backfilled material will be greater than the undisturbed material). Changes to permeability and specific storage which may occur with consolidation of the waste rock and tailings should also be considered and incorporated into the groundwater model.
 - ii. All surface water features must be included, whether natural or constructed for the project (e.g. dams and leakage from these). Surface water-groundwater connectivity is a key component of the hydrological, hydrogeological and ecological systems at the project site. There is large uncertainty on the influence of groundwater discharge on surface water flows as no site-specific information has been derived for streamflows in the catchment (see paragraph 6 below).
 - iii. Potential hydraulic loading impacts from the waste rock dumps must be considered. Understanding how this process could affect groundwater discharges to GDEs and alter groundwater flow paths and groundwater quality, including within the backfilled voids, is important for characterising potential impacts to GDEs and long-term surface water quality.
 - iv. Current modelling does not predict that groundwater drawdown will occur in areas where seawater may be present. However, given the limitations of the modelling this possibility should be investigated further. This should include collecting further information to inform additional modelling approaches such as field studies to identify the location of the seawater-freshwater interface. Further discussion of monitoring relating to potential seawater intrusion is provided in the response to Question 3. These data are needed to implement the additional modelling approaches (e.g. using SEAWAT) discussed in paragraph 3d of IESC 2017.
- e. While sensitivity and uncertainty analysis has been undertaken it is inadequate given the high risks associated with the project. The analysis is primarily a sensitivity analysis. The analysis was not undertaken in a rigorous and systematic manner and there is insufficient justification provided for the range of parameter values examined. Further model improvements as outlined above are required and then a rigorous sensitivity and uncertainty analysis will be needed. Given the high risks from the project, this analysis should objectively quantify uncertainty and examine the correlation between parameters, likelihoods and parameterisations that are representative of the natural variability. Additionally, as discussed in paragraph 4 of IESC 2017, this analysis should examine a broader range of model parameterisations, model boundary conditions and episodic versus periodic recharge.
- f. An independent peer review of the groundwater model has not been reported. This review should be undertaken as recommended by the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012). This was highlighted in paragraph 3f of IESC 2017.

Question 2: The amended EIS proposes changes to the mine plan (specifically no final voids, reduction from three pits to two pits and relocation of the coal overland conveyor) and mining sequences. Noting this, what does the IESC consider to be the key risks and impacts of the project?

17. The key risks identified in IESC 2017 (paragraphs 20-39) remain inadequately addressed with the exception of risks related to the location of the coal conveyor (moved in the current plan) and the pit lakes (backfilled in the current plan). Changes in the mine plan have altered the magnitude and nature of key risks and potential impacts associated with surface water and the final landform, and are described below.

Surface Water

18. The surface water modelling of streamflow yields and floods are not supported by any period of local gauging and no consideration is given to the uncertainty in the regional parameterisation. The estimates are considered to have a weak level of defensibility and are insufficient for evaluating impacts on sensitive and high value environmental assets. No advice is provided on the implications of the streamflow yields being towards the lower limits of their associated confidence limits, or flood estimates being towards their upper limits. No attempt has been made to make use of streamflow gauging records in adjacent river basins, either to confirm the applicability of the regional parameters, or to correlate with short-term surface water gauging in the catchments of interest. Given the large uncertainty involved in relying solely on regional information, it is essential that more than one method be used to derive single best estimates of hydrological characteristics (Ball et al. 2016; Nathan and McMahon 2017).

19. The coal conveyor location has been revised. It will now follow the Bruce Highway corridor and pass under the highway. The conveyor has not been explicitly included in the flood model. The proponent states that they will undertake assessment of flood immunity at the time of final design (SEIS, Ch. 9, p. 9-150). From maps of flood modelling, the proposed location appears to be subject to flooding that connects to Deep Creek downstream in a 9.5% annual exceedance probability (AEP) event. The risks to downstream water quality from flooding the coal conveyor (or at least around the coal conveyor) must be assessed.

20. One of the key surface water risks is release of sediment to the downstream environment, including the Great Barrier Reef World Heritage Area and Marine Park, the Broad Sound Fish Habitat Area, the Styx River Estuary and the riparian habitat of Tooloombah Creek and Deep Creek. The proponent has stated that they will develop an Erosion and Sediment Control Plan (ESCP) (SEIS, Ch. 5, Section 5.11) to manage this potential risk. Given the high likelihood of erosion (and hence sediment release from the project site) due to the prevalence of sodic soils, and the high value and sensitivity of the downstream environment, this plan should be provided before the project progresses to allow an assessment of the adequacy of potential mitigation and management options. The plan should include estimates of the total sediment load (in tonnes) attributable to the project with and without mitigation measures encompassing both typical and flood conditions. Additionally, the seasonal timing and frequency of sediment-laden flows and the characteristics of the entrained sediments (e.g. particle size and chemical composition) should be considered with regards to light and sediment sensitive ecological processes which may be occurring simultaneously (e.g. laying of demersal eggs or recruitment of seedlings).

21. The proponent does not adequately assess the risks arising from erosion either within waterways or across the landscape during high-flow events, even though the high potential risk from land erosion is acknowledged (SEIS, Ch. 5, Table 5-48). Factors contributing to erosion risks and associated water quality impacts that require further consideration are discussed below.

- a. Soils in the area are highly dispersive, leading to a high erosion risk for any exposed soil. This is a risk for the site overall, but is likely to be particularly acute in areas where water flow is

concentrated such as flow diversion structures. The proponent plans to install a number of bunds and diversion drains to manage water flow. It appears that bunds will be constructed from local, possibly dispersive material, since the proponent states that they do not anticipate the need for new borrow pits outside the mining lease (SEIS, Ch. 3, p. 3-42). No mitigation measures have been described in the current documentation to manage erosion in these structures and at their outflow locations.

- b. Water infrastructure at the site will be ineffective in containing sediment-laden water during most flood events. This means that there will be no opportunity for sediment to settle or to receive treatment with flocculants prior to discharge.
 - i. Environment dams (where sedimentation is the main treatment) have been sized to capture a 9.5% AEP rain event. There is more than an 80% chance that one or more floods of at least this magnitude will occur over the 18-year life of the mine; however no assessment is provided on how release of sediment-laden water will impact high value and sensitive downstream environments. Similarly Dams 1 and 2 are subject to flooding during a 9.5% AEP flood. These dams contain water from open-cut dewatering and from the mine infrastructure area (MIA). There has been no assessment of the potential impacts from this flooding. An assessment of the potential impacts to sensitive and high value downstream environments from uncontrolled discharges from these structures is needed.
 - ii. Flood and hydrodynamic modelling does not incorporate the proposed diversion bunds beside the Bruce Highway, or the structure in which the conveyor will be located beneath the Bruce Highway. The bunds will channel water from rainfall events towards Deep Creek and possibly into the conveyor structure. Flows are likely to be high-velocity, causing large shear stresses. Given the highly erosive nature of the soils, there is a significant risk of scour along the bunds, particularly where they discharge into Deep Creek and possibly within the conveyor structure.
 - c. The factors described above will lead to higher erosion during high flows. Additionally, when environment dams overtop, they cannot function to remove sediment from runoff. Water quality targets for the Great Barrier Reef are defined in terms of sediment flux. The proponent does not calculate – nor have targets for – the total sediment flux expected from the project. Total sediment flux from the project should be estimated for typical and high-flow conditions. The *Reef 2050 Water Quality Improvement Plan* (State of Queensland 2018) contains a target for no net increase in sediment transport in the Styx River catchment.
22. Given the large uncertainty involved in characterising flood (and hence related erosion and water quality) risks, an assessment should be included that ‘stress tests’ the proposed flood protection of mine infrastructure on the basis of flood loading estimates that approach the upper bounds of the associated confidence limits. If the consequences of failure differ materially over this range, or there is a threshold effect above which there is an important change in the impacts, then it may be appropriate to adopt a design which accommodates a level of flood risk above the best estimate.
23. The IESC’s previous concerns regarding controlled discharges (IESC 2017 paragraphs 33-35) have not been addressed. The proponent continues to propose dry weather discharges which could have significant impacts on the flow regime, ecology and water quality of the receiving creeks and further downstream. The IESC additionally notes that some of the proposed water quality objectives exceed the default ANZECC/ARMCANZ (2000) guideline values. Analytical limits of reporting are cited as the reason for this (e.g. for copper). The IESC does not consider this is an appropriate justification for adoption of less stringent guideline values.
24. It is unclear whether the proponent will need to extract surface water for operational activities. If they do, this may affect the downstream environment, particularly if extraction occurs during periods of low

flow. Discussion of the updated water balance implies that harvesting water from Tooloombah Creek will no longer be required (SEIS, Ch. 9, p. 9-49). However, the proponent states elsewhere that ‘a *reliable source of water is required for years 10–12 of the construction and operation of the project*’ (SEIS, Ch. 3, p. 3-33). Additionally, the results of the water balance are contingent on uncertain model inputs, including groundwater inflows. To clarify whether water will need to be extracted from Tooloombah Creek the proponent should provide an input-output statement following the Water Accounting Framework for the Minerals Industry as suggested in the IESC Information Guidelines (IESC 2018). This statement should include whether the data are measured, estimated or simulated and must specifically examine the dry season water balance. In the event that extraction will be required, the proponent should clarify where the water can be sourced from and if sufficient water is available considering existing users. They should also explain how they plan to minimise potential environmental impacts from this extraction.

Final Landform

25. Given the risks associated with the final landform, the proponent should describe, design and provide evidence of how they propose to construct and manage the final landform so that it does not pose an ongoing risk to the downstream environment. Evidence should include examples of successful cover design and restoration from similar sites. Information should be provided at the assessment stage that: i) justifies the choice of plan for the final landform and, ii) provides a monitoring program to measure the effectiveness of site restoration. For successful remediation of mine sites with dispersive material a recent ACARP report (Dale et al. 2018) found that seven factors need to be addressed (outlined below). The proponent should explain how they plan to address each of these factors (from Dale et al. 2018, p. 152):
- a. soil and spoil characterisation: critical to inform design, treatment management and monitoring of dispersive sites;
 - b. soil and spoil amelioration: practices that ameliorate dispersive or erosive soil and spoil properties;
 - c. landform design: design factors that minimise concentration of the erosive force of incident rainfall;
 - d. practice control factors: soil design and management factors to reduce erosive energy;
 - e. crop management factors: vegetation management practices to reduce erosive energy;
 - f. tunnel initiation factors: site and management factors contributing to reduced tunnel development; and,
 - g. monitoring and maintenance: monitoring requirements to guide timely and targeted remedial treatment.
26. The change to backfilling the voids provides the proponent with an opportunity to reduce the risk of acid mine drainage (AMD) and other contaminant-bearing material entering the downstream environment. While the IESC considers the proposed backfilling of the voids is the best option to reduce long-term legacy risks from the proposed project, the changed final landform poses a number of new risks that do not appear to have been assessed.
- a. Potentially acid-forming (PAF) material in rejects will initially still be stored in above-ground waste rock dumps (SEIS, Ch. 8, p. 8-39 and p. 8-41). While this is unavoidable for short-term storage, the material is proposed to be stored in waste stockpiles close to Deep Creek and Tooloombah Creek and is not proposed to be placed in the pits. These above-ground stockpiles will therefore potentially pose long-term leachate contamination risks to both watercourses.

- b. The final landform is proposed to be covered in subsoil and topsoil removed from the pit area prior to mining (SEIS, Ch. 11, p. 11-30). Given much of the local soil is highly dispersive and any sodic material will be disposed of within waste rock 'cells', it is possible that insufficient locally sourced topsoil or subsoil will be available to fully cover and rehabilitate the disturbed site. Re-spreading of any sodic or erosive soils would not be appropriate given it would represent a significant water quality and sedimentation risk to the high value and sensitive downstream environments, including the Great Barrier Reef World Heritage Area and the Broad Sound Fish Habitat Area.
 - c. The potential impacts to both groundwater and surface water quality from the backfilled voids have not been fully considered. The proponent expects that groundwater will recover post-mining and flow through the backfilled voids where mobilisation of contaminants (e.g. metals, acids, salts) could occur over a long period of time. Based on the hydrogeological conceptualisation (see SEIS, Ch. 10, Figure 10-43) this potentially contaminated groundwater would then flow north (depending on potential hydraulic loading due to the waste rock emplacements – see paragraph 4d(iii)) and discharge to Tooloombah Creek, Deep Creek and the Styx River, potentially adversely affecting these and other sensitive environments downstream.
 - d. There is also the potential for infiltration through the cover and backfilled voids (minus losses to vegetation) to cause localised groundwater mounding and to mobilise contaminants.
 - e. Coarse and fine coal rejects are proposed to be mixed with waste rock prior to being disposed of within the open cut pits and waste rock stockpiles. Disposing of coal rejects in the open cut pit and backfilling will provide an additional source of contaminants that could be mobilised in groundwater that flows through the final landform following groundwater recovery. This potential contaminant loading should be evaluated and the long-term loads quantified.
27. No flood or hydrodynamic modelling incorporating the final landform has been undertaken. The IESC notes that the highly dispersive soils and seasonally high-intensity rainfall in the project area make design and restoration of an environmentally acceptable final landform challenging. The final landform will need to minimise the risks from erosion, contaminant release and invasive species, plus be aesthetically suitable given it is located in a greenfield area. If not appropriately designed and implemented, the final landform could present a long-term hazard. The IESC considers that the final landform should be modelled and its potential influence on flood extent and flow velocity assessed.
28. Construction of post-mining landforms in areas with sodic soil is acknowledged to be a significant issue that poses challenges for successful restoration. Avoiding placement of sodic material at the surface is recognised as best practice, though not always feasible (Vacher et al. 2004; Dale et al. 2018). It is imperative that sodic materials in the final landform are carefully managed, as remediation of tunnel erosion is difficult and not always possible (Vacher et al. 2004). The high value and sensitivity of the downstream environment makes management of this issue particularly important.
29. Given the high erodibility of soils at the site and the sensitive downstream environments, landscape evolution modelling of final landform options should be undertaken (e.g. with models such as CAESAR and SIBERIA, see Section 2.2.1 of Lowry et al. 2015). This is needed to identify the most environmentally acceptable final landform and to assess the potential long-term impact of erosion on the downstream environment, including the Great Barrier Reef World Heritage Area and Marine Park, the Broad Sound Fish Habitat Area, the Styx River Estuary and the riparian habitat of Tooloombah Creek and Deep Creek.

Question 3: Advice is sought on whether the measures and commitments proposed in the amended EIS are appropriate to effectively manage impacts to water resources and water-related assets, including:

- the proposed use of supplementary water to maintain refuge pools for aquatic species and GDEs, noting that recovery of the water table is expected approximately 80 years after mining commences.
- whether the proposed monitoring framework (in conjunction with the current level of site-specific baseline data) in the amended EIS is adequate to identify and monitor the impacts of the proposed project and to trigger suitable additional management measures to avoid and minimise identified impacts.
- whether the proposed bore monitoring network in the amended EIS is adequate to identify water-related impacts and inform suitable management measures.

30. Responses to Questions 1 and 2 in this advice cover a number of inadequacies in the assessment of impacts. Additionally, many of the inadequacies in the impact assessment noted in the response to Question 1 of IESC 2017 remain unaddressed. As potential impacts have not been adequately characterised, it is not possible to fully evaluate the effectiveness of potential monitoring and mitigation measures. This is further hampered by the general lack of detailed descriptions of proposed management and mitigation measures (e.g. management plans) and the absence of evidence to support an assessment of their likely effectiveness.

Groundwater-dependent ecosystems

31. Any significant groundwater drawdown beneath Deep Creek or Tooloombah Creek would be highly detrimental to GDEs. For example the loss of groundwater discharge to permanent pools will adversely impact likely important refugia for aquatic species during the dry season. These refugia would provide crucial sources of colonists when flows resume, as has been observed in other dryland rivers (e.g. Perkin et al. 2015). Additionally, drawdown in the alluvial aquifer will reduce the vertical extent of known stygofauna habitat by approximately 90% (SEIS, Ch. 10, Table 10-66). The IESC has little confidence in the proponent's predictions of the magnitude of expected groundwater drawdown impacts, due to deficiencies in groundwater modelling discussed in the response to Question 1.

32. The proponent has proposed to manage these impacts through supplementary flows. Insufficient information about supplementary flows has been provided.

a. The potential use of supplementary flows was discussed in detail in paragraphs 49-52 of IESC 2017. Work that would need to be undertaken prior to an assessment of the feasibility of the proposed management measure includes (see IESC 2017 paragraph 49 for further details):

- i. mapping of GDEs that may require supplementary flows for ongoing survival;
- ii. studies to characterise the dynamics of surface water-groundwater connectivity, the preferred sources of water for different GDEs and the seasonal characteristics of groundwater used by GDEs;
- iii. an analysis of water availability, potential sources and the suitability of water quality of potential sources for use as supplementary flows;
- iv. an assessment of potential impacts to the quality of water in the alluvial aquifer due to recharge from the supplementary flows;
- v. studies to determine the volumes and discharge rates of supplementary flows needed to maintain GDEs; and,

- vi. investigations to identify suitable variables that would be monitored to identify when supplementary flows were needed and the effectiveness of flows.
- b. While the proponent has provided some discussion indicating that this work is needed in the future, none of the work has commenced and no indication of when this will occur has been provided.
- c. Without undertaking the suggested field work and providing the associated analyses, an assessment of whether this is a feasible management option which can adequately address potential impacts cannot be made. The proponent's own risk assessments have highlighted that if this management measure were not successful, there would be high risks of adverse impacts to GDEs (SEIS, Ch. 15, pp. 15-102 to 15-105; SEIS, Ch. 10, pp. 10-223 to 10-226).
- d. The IESC also notes that there are inherent risks in reliance on a single mitigation measure that requires ongoing maintenance for several decades after a project's closure, especially as the mine site is proposed to become a conservation area that could support a diverse vegetation community including deep-rooted plants. Consideration of potential alternative measures is needed.
- e. Detailed information has not been provided on what monitoring would be undertaken during the period in which supplementary flows are used. Monitoring to determine when supplementary flows are required and for determining their success would be extensive. This program would need to consider monitoring of groundwater levels and quality, surface water flows and quality, and the ecological condition of riparian vegetation, permanent pools and stygofauna. The proponent will need to install gauging stations on Deep Creek and Tooloombah Creek preferably in the vicinity of permanent pools to quantify our understanding of surface water-groundwater interactions. Monitoring bores should be installed in the vicinity of these gauging stations to allow more detailed investigation of the relationship between groundwater levels and permanent pools.
- f. The use of supplementary flows to manage these impacts would have to continue well beyond the end of mining based on these predictions. It does not appear that the proponent has fully considered the time over which this active management would be required or where the water for the supplementary flows will be obtained once pit dewatering ceases.

Proposed monitoring framework

- 33. The proposed monitoring framework as presented in the supplementary EIS is not adequate to identify and monitor impacts, or to trigger suitable management measures. IESC 2017 discussed a number of improvements to monitoring and management which require implementation during operational and post-closure phases (see IESC 2017 paragraphs 42d-f, 44-48 and 54-56). These have not been adequately addressed.
- 34. Plans that detail monitoring and management measures for both operational and post-closure phases, including restoration and final landform monitoring and management, are critical. These plans provide the information needed to ensure appropriate management measures are available, identified and implemented and should cover both short-term and potential legacy risks. Given the high risks associated with this project, such plans (which have not been provided) are needed during the assessment phase of this project so it can be determined if potential risks from the project can be adequately mitigated.
- 35. As was discussed in paragraphs 40, 43 and 47 of IESC 2017, no detail has been provided about any potential trigger action response plans (TARPs) or similar adaptive management approaches for managing impacts on groundwater, surface water, GDEs or the final landform. Due to the high risks associated with the proposed project's location next to sensitive and high-value ecological assets, these plans should be presented during the assessment phase.

36. The proposed locations of the upstream monitoring sites (reference sites) are not appropriate. Only one site is proposed on each of Tooloombah Creek and Deep Creek. As stated in paragraph 46 of IESC 2017, these sites may be affected by runoff from the mine and should be relocated further upstream. Given the high value and sensitivity of the receiving environments, having only one reference site on each stream is not considered leading practice; at least three reference sites per creek should be established to provide reliable estimates of spatial variance in water quality and compensate for any losses of a reference site.
37. The proponent has collected additional baseline water quality data in 2017 and 2018. A longer time-series is required to capture seasonality and interannual variability and needs to include baseline data at all reference sites (noting comments in the above paragraph regarding their location and number). These data will assist in the development of site-specific water quality guideline values (WQGVs). Site-specific WQGVs should be developed separately for both wet and dry seasons.
38. Surface water quality monitoring will need to continue post-closure to monitor for potential impacts from erosion of the final landform. This monitoring plan should consider event-based telemetered surface water quality and continuous flow monitoring in Deep Creek and Tooloombah Creek to identify if changes in water quality are occurring compared to upstream reference sites and during flow events. This should be supplemented with grab samples analysed for a wider suite of parameters (e.g. metals and organics). All of this monitoring should continue post-mining to capture the effectiveness of restoration.
39. While the proponent has committed to sediment monitoring (SEIS, Ch. 9, p. 9-78), as the IESC noted previously (IESC 2017 paragraphs 33 and 45c), the proponent should undertake sediment monitoring that is suitable to assess the potential for metal and organics accumulation. No details of parameters proposed to be monitored are currently provided.
40. The exposure of Acid Sulfate Soils (ASS) poses a risk to the sensitive and high ecological value downstream environments. The proponent's assessment of risks from ASS is based upon national mapping (SEIS, Ch. 5, p. 5-108). The assessment of risks from potential acid sulfate soils (PASS) or ASS generation within the area of groundwater drawdown needs to be informed by a site-specific investigation undertaken prior to dewatering activities.
41. The proponent has presented an indicative management approach for disturbance of PASS/ASS within the disturbed area of the project site (SEIS, Section 5.10.4). No management plan or actions have been described for exposure of PASS/ASS elsewhere as may occur through groundwater drawdown. The proponent needs to provide measures to treat or prevent the exposure of ASS outside of the project disturbance area but within the zone of hydrogeological impact.
42. According to the proponent, monitoring and management of the final landform are proposed to be undertaken in accordance with the Environmental Management System, which includes a number of intended management plans that will provide restoration goals (SEIS, Ch. 11, p. 11-54). These management plans should consider:
 - a. monitoring for differential consolidation and settlement of backfilled material in the void. This process can affect the hydraulic properties of the backfill. As discussed in paragraph 4d above, realistic representation of the hydraulic properties of the backfill in the groundwater model is needed.
 - b. monitoring of the final landform using LIDAR or INSAR imagery. This would provide a way to determine elevation changes due to erosion and/or settlement, allowing identification of where repair work may be needed on the final landform.
 - c. if there is sufficient water of a suitable quality available for irrigation of the initial groundcover and subsequent deep-rooted vegetation on the final landform. Given the local soils are prone to

erosion and dispersion, a key requirement in developing the final landform is the rapid initial establishment of preferably locally endemic grass to prevent erosion due to rainfall impact and overland flow during the wet season.

- d. how to prevent ponding of water on saline sodic soil. High soil salinity, which occurs in some soils at the project site, can mask dispersive behaviour. If the salts are leached due to ponding of water, the soil will become more dispersive and tunnel erosion can be initiated (Dale et al. 2018).
- e. whether any specific treatments of the topsoil applied to the final landform (e.g. lime, mulching) will be required to prevent erosion and allow rapid establishment of vegetation prior to the next wet season and to reduce weed invasion.

Groundwater monitoring network

43. Areas where spatial coverage must be improved include:

- a. the addition of compliance monitoring and reference bores targeting the Basement aquifer; and,
- b. further reference bores located to the northwest (between RMB09 and RMB10) and to the east of the project (between RMB05 and RMB03) targeting all aquifers.

44. The groundwater monitoring plan needs to explicitly consider monitoring for potential impacts from the final landform including:

- a. regular (preferably at least three-monthly) groundwater quality monitoring down hydraulic gradient of, and close to, the backfilled voids in all aquifers for identification of potential contaminant mobilisation.
- b. groundwater quality monitoring and monitoring for shallow groundwater discharge that may occur where the final landform and the original land surface contact to identify if leaching of contaminants from the ex-pit waste rock dumps is occurring.
- c. monitoring of the alluvial and Styx Coal Measure aquifers where discharge to Tooloombah and Deep Creek is likely to occur. This is needed to identify if hydraulic loading from the waste rock dumps is affecting surface water-groundwater connectivity.

45. Monitoring for potential seawater intrusion is needed. The proponents groundwater modelling indicates that this is unlikely, however, given the low confidence in the current groundwater model this risk cannot be discounted. The monitoring program for seawater intrusion will need to consider the points discussed below.

- a. The current location of the seawater-freshwater interface in different hydrolithologic units will need to be established.
- b. Monitoring will need to include both electrical conductivity (EC) and hydraulic head in different aquifers to allow for density corrections to be made so that groundwater flow directions can be determined (Post et al. 2007). An appropriate approach may consist of a combination of nested bores to monitor hydraulic head and separate bores that are fully screened across their length to measure EC.
- c. Bores must be sited to allow for early warning of seawater intrusion.
- d. Monitoring details, thresholds and effective management responses should be defined in a TARP.

46. The monitoring bores which are equipped with loggers to monitor groundwater levels daily (currently unclear as to which bores) should also be telemetered so that water levels can be regularly reviewed. This, plus the development and implementation of management triggers for both short-term and long-term groundwater drawdown, will improve the early-warning capabilities of the monitoring network and was noted in paragraphs 42e and 43 of IESC 2017. Daily site-specific rainfall data will also need to be collected to allow interpretation of changes in groundwater levels.
47. If the proposed project progresses, the compliance bores should be monitored more frequently than six-monthly during the first years of mining (i.e. monthly or quarterly depending on the amount of variability identified in the baseline dataset) as these data would be valuable for validation of the groundwater model and re-calibration if required.

Date of advice	31 July 2018
Source documentation available to the IESC in the formulation of this advice	CDM Smith 2018. <i>Central Queensland Coal Project Supplementary Environmental Impact Statement May 2018</i> . Available [online]: http://cqcoal.com.au/publications-approvals/ accessed July 2018.
References cited within the IESC's advice	<p>Ball J, Babister M, Nathan R, Weeks W, Weinmann PE, Retallick M and Testoni I (editors) 2016. <i>Australian rainfall and runoff: A guide to flood estimation</i>. Commonwealth of Australia (Geoscience Australia), Canberra.</p> <p>Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A 2012. <i>Australian groundwater modelling guidelines</i>. Waterlines report. National Water Commission, Canberra.</p> <p>Dale G, Thomas E, McCallum L, Raine S, Bennet J and Reardon-Smith K 2018. <i>Applying risk-based principles of dispersive mine spoil behaviour to facilitate development of cost-effective best management practices</i>. ACARP Project C24033.</p> <p>IESC 2017. <i>Advice to decision maker on coal mining project IESC 2017-091: Central Queensland Coal Project (EPBC 2016/7851) – New Development</i>. Available [online]: http://www.iesc.environment.gov.au/projectadvice/central-qld-project-advice-2017-091 accessed July 2018.</p> <p>IESC 2018. <i>Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals</i>. Available [online]: http://iesc.environment.gov.au/publications/information-guidelines-independent-expert-scientific-committee-advice-coal-seam-gas accessed July 2018.</p> <p>Lowry J, Erskine W, Pickup G, Coulthard T and Hancock G 2015. <i>Future directions for application of landform modelling by the Supervising Scientist: Response to the review of the application of CAESAR-Lisflood model by the eriss Hydrological, Geomorphic and Chemical Processes program</i>. Supervising Scientist Report 210. Supervising Scientist, Darwin, NT. Available [online]: http://environment.gov.au/science/supervising-scientist/publications/ssr/future-directions-landform-modelling accessed July 2018.</p> <p>Perkin JS, Gido KB, Cooper AR, Turner TF, Osborne MJ, Johnson ER and Mayes KB 2015. Fragmentation and dewatering transform Great Plains stream fish communities. <i>Ecological Monographs</i> 85:73–92.</p>

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- Post V, Kooi H and Simmons C 2007. Using hydraulic head measurements in variable-density ground water flow analyses. *Ground Water* 45(6):1-8.
- Nathan RJ and McMahon TA 2017. Recommended practice for hydrologic investigations and reporting. *Australasian Journal of Water Resources*, 21(1):3-19.
- The State of Queensland 2018. *Reef 2050 water quality improvement plan 2017-2022*. Available [online]: <https://www.reefplan.qld.gov.au/about/> accessed July 2018.
- Vacher CA, Loch RJ and Raine SR 2004. *Identification and management of dispersive mine soils*. Australian Centre for Mining Environmental Research. Available [online]: <https://eprints.usq.edu.au/1311/> accessed July 2018.
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Attachment A – IESC 2017.

Previous IESC advice on the Central Queensland Coal Project – December 2017.

Advice to decision maker on coal mining project

IESC 2017-091: Central Queensland Coal Project (EPBC 2016/7851) – New Development

Requesting agency	The Australian Government Department of the Environment and Energy and The Queensland Department of Environment and Heritage Protection
Date of request	1 November 2017
Date request accepted	1 November 2017
Advice stage	Assessment

Summary

The proposed Central Queensland Coal Mine is an open-cut coal mine to be located 130 km northwest of Rockhampton. The project is targeting a maximum extraction of up to 10 million tonnes per annum (Mtpa) with a project life of 20 years.

The proposed mine presents significant risks to areas of high ecological value, including, the Great Barrier Reef World Heritage Area and Marine Park, the Broad Sound Fish Habitat Area, the Styx River Estuary, two state-listed wetlands and the riparian habitat of Tooloombah Creek and Deep Creek. These risks require further investigation, management and mitigation. Located approximately 10 km upstream of Broad Sound, part of the Great Barrier Reef World Heritage Area, this project will:

- be the first coal mine in the Styx Basin, targeting a coal resource that is unproven for open cut extraction and not well-characterised in terms of potential hydrogeological and geochemical risks;
- be located close to a number of high-value environmental assets, with the nature and extent of many potential impacts uncertain as this is a greenfield development with limited available baseline environmental data;
- remove a significant wetland (as identified by the Queensland Government);
- impact the natural flow regime of Tooloombah Creek, Deep Creek and possibly further downstream;
- discharge mine-affected waters directly upstream of the Styx River estuary which is considered to be of high environmental value; and,
- disturb areas likely to contain acid sulfate soils, potentially leading to releases of acidic water and mobilisation of metals.

The proponent has collected information and data to inform the Environmental Impact Statement for this project. The IESC considers that a greater level of detail in the information and analysis is required to determine the full range of potential impacts to water resources. Information to support the proposal must have finer geographical resolution and be collected more frequently to improve confidence in predictions. There is not enough information to assess risks or to determine whether risk mitigation measures are likely to be effective. Furthermore, existing land use such as grazing and cropping must be considered to understand the baseline condition of the Styx River Catchment before development.

There is uncertainty in the assessment of surface water and groundwater impacts as the mine design has not been finalised and may be varied from that presented in the current Environmental Impact Statement. It is not possible to assess, from the information provided, whether alternative mine layouts would result in lower impacts and risks to the receiving environment, much of which is of high environmental value. More detailed information is required to fully assess the relationship between mine design and potential impacts and to inform a comprehensive risk assessment.

Context

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) was requested by the Australian Government Department of the Environment and Energy and the Queensland Department of Environment and Heritage Protection to provide advice on the Central Queensland Coal Pty Ltd and Fairway Coal Pty Ltd's Central Queensland Coal Project in Queensland.

This advice draws upon information in the Environmental Impact Statement (EIS), together with the expert deliberations of the IESC. The project documentation and information accessed by the IESC are listed in the source documentation and references at the end of this advice.

The Project is a proposed greenfield open-cut coal mine to be located 130 km northwest of Rockhampton in the Styx River Catchment. The proposed project will target production of up to 10 Mtpa of thermal and semi-soft coking coal from the Styx Coal Measures within the Styx Basin for a project life of 20 years. There are no current operating coal mines targeting the Styx Basin, although some small-scale historic mining occurred up until the 1960s. The basin has also had limited petroleum exploration.

The proposed mine layout includes three open-cut pits, two overburden dumps, two coal handling and preparation plants (CHPP), a train loadout facility (TLF), and mine water infrastructure including 11 water storages. The total mine disturbance area will cover approximately 12 km² of the 3,013-km² Styx River Catchment. The proposed mine pits are located between Tooloombah Creek and Deep Creek. The two creeks merge just to the north of the mine, forming the Styx River. The proposed layout is divided by the Bruce Highway, which separates the north and south of the site. A coal conveyor is proposed to pass under the highway at Deep Creek Bridge and three causeways will be built for haul roads to cross Deep Creek.

The proposed project area is predominantly used for low-intensity grazing on native or improved pastures. The site contains several existing farm dams, drainage bunds to capture runoff and two wetlands listed as matters of state environmental significance. The adjacent riparian habitats are potentially groundwater dependent and are of high environmental value.

Key Potential Impacts

Key potential impacts on water resources and water-related assets are outlined below.

- Surface water quality could be diminished by controlled and uncontrolled discharges. This includes potential spills from the mine water storages and flooding of the proposed coal

conveyor. Impacts could occur on-site and as far downstream as the GBRWHA and may adversely affect high-value ecosystems.

- Groundwater drawdown from the proposed project will extend beyond the project site and will impact groundwater-dependent ecosystems (GDEs). It could also result in extensive disconnection of surface water and groundwater. This will cause changes to baseflow volumes, flow regime, water quality, and aquatic habitat availability and could result in further fragmentation or loss of riparian vegetation.
- Groundwater drawdown may also affect GDEs through reduced groundwater availability and groundwater quality. These could arise because of a lowering of the water table or through seawater intrusion and inundation causing changes in groundwater salinity.
- Groundwater drawdown may increase the tidal-affected stream length which could impact fish breeding, particularly in Tooloombah Creek, and cause the loss of riparian vegetation if it is not tolerant of brackish conditions.
- Groundwater drawdown could also affect groundwater discharges into the coastal marine environment potentially impacting on coastal vegetation and marine GDEs.
- Project construction, operation and long-term management has the potential to expose highly sodic soils, and potentially acid-forming (PAF) material and mobilise metals through the development of acid sulfate soils (ASS). These materials require appropriate handling and management to prevent erosion and adverse water quality impacts from occurring. These impacts could occur on-site and as far downstream as the GBRWHA. Increased erosion could result in sedimentation of the high ecological value riparian areas and increased sediment loads further downstream. Sediment, sediment-bound contaminants, acidification and metals mobilised in the surface water could all impact ecosystem health downstream.

Response to questions

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

Question 1: Advice is sought on whether the information provided in the EIS documentation (including baseline and modelled data), and the conclusions drawn by the proponent, is adequate to assess the project's impacts. If not, what additional information should be provided to identify and assess impacts on water resources?

1. The proponent identifies potential impacts to water resources within the EIS documentation provided. However, the consequences, management and mitigation measures have not been comprehensively explored. Baseline data is generally inadequate as it does not characterise seasonal variability and is insufficient to fully calibrate and validate models. This limits confidence in the predicted impacts. The responses to questions 1 and 2 discuss these issues in further detail.

Groundwater

2. Available baseline data for both groundwater quality and head is limited in its coverage of depth, location and time. The proponent is currently expanding their groundwater monitoring network to improve the spatial deficiencies, although additional bores will be needed to target aquifers other than the alluvial aquifer. When these bores are installed, testing should be undertaken to determine the range of hydraulic parameters across the project area. Monthly monitoring of groundwater quality and head over a period of two years, as outlined in ANZECC/ARMCANZ (2000), will be needed to address the temporal data limitations given the highly seasonal climate

at the project site. This monitoring should be completed before any mining commences in order to characterise pre-impact condition, and the following issues should be considered.

- a. Monitoring should include bores in all potential aquifers in the area, with nested bores used to determine the general groundwater behaviour and connectivity between aquifers. This information is needed to refine the hydrogeological conceptualisation and update the groundwater model.
 - b. The data collected will provide important information on pre-impact conditions and seasonal variability. This information is needed to improve hydrogeological conceptualisation, validate the groundwater model, and derive trigger values for both groundwater quality and head for management plans.
 - c. Baseline groundwater quality monitoring should include physicochemical parameters, nutrients, metals and hydrocarbons.
 - d. Monitoring should also include environmental tracers (such as stable isotopes of water and bromide) to investigate groundwater-surface water connectivity and potential mixing with sea-water. This monitoring could occur seasonally. Additional studies are needed to characterise groundwater-surface water connectivity and its temporal variability as discussed in paragraphs 7, 37 and 49.
3. The proponent acknowledges the limited confidence in the groundwater model and its predicted impacts. The groundwater model requires further development including improved conceptualisation and parameterisation. The proponent should complete the work outlined below.
- a. Collect site-specific data on a range of hydraulic parameters such as hydraulic conductivity, storativity and recharge to assist with model characterisation and parameterisation.
 - b. Undertake a thorough review of the underlying geological and hydrogeological conceptualisations. There is still uncertainty in these conceptual models which should be addressed through collection of additional site-specific geological and hydrogeological data.
 - c. Update the groundwater model to fully incorporate a range of possible configurations and dimensions of the final voids so the range of impacts on groundwater can be assessed (discussed further in paragraph 29).
 - d. Implement an additional modelling approach which allows investigation of potential seawater intrusion and seawater inundation (groundwater recharge by saline tidal waters). This will require the use of a variable density groundwater flow and solute simulator such as SEAWAT (USGS 2016).
 - e. Undertake further testing and validation of the groundwater model when suitable data becomes available with predictions regularly checked against ongoing groundwater head observations. A robust criterion should be developed to identify when re-calibration and potentially re-conceptualisation is needed.
 - f. Obtain a peer-review of the groundwater model as recommended in the *Australian Groundwater Modelling Guidelines* (Barnett *et al.* 2012).
4. Sensitivity and uncertainty analysis should be used to examine different model parameterisations, model boundary conditions, the effects of applying recharge uniformly versus a more realistic episodic recharge regime, and the likelihood of various impact scenarios. This would assist in understanding and assessing the potential range of changes to the groundwater system and the

possible associated ecological impacts. The outputs of these analyses would also be useful to inform management and mitigation options.

5. The timing of maximum groundwater drawdown and the extent and timing of recovery are unclear from the EIS documentation. This information is needed to assess potential long-term impacts and the ability of the system to recover.

Surface water

6. The available baseline hydrological data is limited. While some surface water quality sampling has occurred sporadically in 2011 and 2017, further sampling is needed to establish the inter- and intra-annual variability in both water quality and flow regimes.
 - a. Monthly water quality sampling should be undertaken over two years, as outlined in ANZECC/ARMCANZ (2000), and include physicochemical parameters, nutrients, metals and hydrocarbons. This should be done at sites on Tooloombah Creek, Deep Creek, Styx River and in Broad Sound, and occur before mining commences to ensure pre-impact conditions are characterised.
 - b. Flow monitoring data is needed for Tooloombah Creek and Deep Creek. This data should be collected more frequently than monthly using suitable data loggers.
 - c. The data collected in these baseline studies is needed to characterise seasonal variability, to identify all potential impacts, to derive site-specific trigger values and management plans, and to determine appropriate discharge regimes for releases of mine-affected water.
7. Detailed information on stream morphology and flow regime is lacking. Further studies, including field studies, are required to determine the location of refugial pools; areas of groundwater-surface water connectivity and their exchange dynamics; the upstream extent of the tidal influence in both Tooloombah Creek and Deep Creek; creek substrate and associated aquatic habitats; and to identify exposed geological features.
8. Further modelling should be undertaken to fully assess the potential impacts of the project as detailed below.
 - a. A hydrodynamic model incorporating all reaches of Tooloombah Creek and Deep Creek which can be tidally impacted and downstream into Broad Sound should be developed. The hydrodynamic model will require collection of data on the tidal regime of the Styx River and Broad Sound. This model should be coupled with water quality modelling to identify how the tidal regime affects flushing and dilution of project discharges. This modelling is needed to:
 - i. ensure that there are no adverse impacts to the ecologically high-value environments downstream;
 - ii. confirm the proponent's assumption that sufficient dilution will occur to meet the varying downstream water quality objectives;
 - iii. determine that adequate flushing occurs throughout the surface water system with no areas of contaminants, suspended or dissolved, in the water column or deposited in sediments; and
 - iv. identify if tidal movements and storm surge can cause contaminated water to be pushed up into parts of Tooloombah Creek and Deep Creek that may become isolated when surface water levels fall.

- b. Uncertainty and sensitivity analysis of the flood modelling to examine possible climate conditions beyond the historical climate records should be undertaken. This is needed to understand how climate change and variability could affect legacy management.
- c. Separate water balances for the CHPPs and the TLF are required to identify the volume and frequency of any discharges or extraction requirements. The updated modelling should include uncertainty and sensitivity analysis for water use and availability. The modelling should also include peak water demand at maximum CHPP processing capacity.
- d. Salt balances should be calculated for the CHPPs given the large recycled water component. These are needed to determine likely water quality of dam water and the maximum frequency of discharge needed.

Water-dependent Ecosystems

9. The assessment of wetland, riparian and terrestrial GDEs is based on desktop studies and limited field studies. Further work is needed to identify and characterise GDEs in the area potentially impacted by the project. This is particularly important given the proposal to use supplementary surface water flows to manage potential impacts to some GDEs. The further work required is discussed in the response to question 3.
10. The assessment of potential impacts arising from groundwater drawdown to wetlands was not always sufficient. The proponent often assumed that these features were supported by surface water inputs only. The Wetland Protection Area (WPA) located near the western boundary of the project is an example. For this wetland, the assumption was based on two field observations and groundwater levels at an unspecified bore possibly several hundred metres from the wetland. This information is insufficient for concluding that the WPA is not a GDE. Further work is needed at all wetland sites to determine groundwater dependency. This work could include the installation and monitoring of bores located at the edge of the wetland area, development of reference sites, the use of satellite and aerial imagery to identify potential groundwater use (e.g. Eamus et al. 2015), hydrogeochemical sampling and development of criteria to determine groundwater connectivity and dependency.
11. Two aquatic ecology surveys were undertaken for this project, both under sub-optimal climatic conditions (i.e. water temperatures were cold or weather conditions were described as very hot and dry). Further site-specific reference surveys are needed to assess the baseline conditions and were suggested by the proponent's consultant (EIS, App. 9e, p. 49). These surveys should focus on areas both onsite and off-site that may be impacted by the project. The surveys should be conducted under favourable conditions such as when water temperatures are likely to result in faunal activity. The proponent notes the likely occurrence of aquatic EPBC-listed taxa including the Estuarine Crocodile (*Crocodylus porosus*).
12. Stygofauna sampling has been undertaken at several sites with some sites sampled twice; however, additional stygofauna sampling is needed. This sampling should target the alluvial aquifers of Tooloombah Creek and Deep Creek which may be affected by groundwater drawdown and where limited sampling has occurred thus far. Stygofauna sampling should be repeated annually during operational and closure phases of the project, as suggested by the proponent's consultant (EIS, App. 9f, p. 30).
13. There is limited consideration in the EIS of the potential for fresh groundwater from the Styx River catchment to discharge into the marine environments of Broad Sound and Shoalwater Bay. Discharge of fresh groundwater into these saline environments could be ecologically important to coastal vegetation, such as mangroves. Further work is needed to identify if the Styx River

catchment could be a source of fresh groundwater discharges and, if so, what impacts could result from any groundwater drawdown associated with the project.

14. No attempt to determine the location and movements of the seawater intrusion interface in aquifers is reported in the EIS. Groundwater drawdown from the project could allow the seawater intrusion interface to move inland which would affect groundwater quality and may impact groundwater accessibility (due to increased salinity) for GDEs. Further work is required to characterise this potential impact as outlined in the responses to questions 1 and 2. It is noted that determining the location and complexity of the seawater intrusion interface may be a difficult task as the location, shape and thickness of the interface may vary between aquifers.

Geochemistry

15. The potential impacts from ASS have not been assessed in detail. Given that the project is located within 10 km of an estuary, potential ASS could be present. Groundwater drawdown from the project could cause ASS impacts to properties within and outside the project site. Further field studies are needed to identify the potential for ASS and, if present, assess possible impacts.
16. Geochemical analyses, although limited in their application, have identified a small volume of PAF material. Further work is needed, as outlined below to assess the potential impacts of this material.
 - a. Further geochemical analysis such as additional kinetic testing should be undertaken. Leach tests should be conducted on a more representative selection of samples that includes some with properties similar to the expected tailings and for longer periods to identify any potential legacy management issues.
 - b. The assessment of potential impacts from reactive materials, such as PAF material, should consider the characteristics of more extreme samples and not just the median values. While the median values are representative of the bulk of the material sampled, the characteristics of the extreme samples indicate that these materials are likely to require more specialised management.
 - c. Additional work should be completed to determine potential correlations between geology and reactive materials as this may assist in refining estimates of the volumes of material requiring additional management.
17. The proponent is considering the use of chemical dust suppressants. No information is provided in the EIS documentation on the nature of the dust suppressants or the circumstances under which they will be used. This information should be provided along with a risk assessment for water resources.
18. Hydrogeochemical analysis to characterise potential groundwater-surface water connectivity and mixing with ocean water, as was outlined in paragraph 2d should be undertaken.

Final Landforms

19. Proposed final landforms and final voids will significantly modify drainage across the floodplain. Structures such as bunds, levees and drains are proposed to be left in place and elevations in some areas of the floodplain will be raised from 30m AHD to 90m AHD, although the stated rehabilitation goals include a landform that blends with the surrounding landscape (EIS, Ch. 11, p.16). Further information and assessment is needed as outlined below.

- a. Hydrodynamic modelling of drainage under the proposed final landform should be undertaken. This should include an assessment of drainage and isolation of the floodplain, and changes to groundwater recharge.
- b. Information on the depth to groundwater in the final landforms is needed to determine risks related to saline intrusion and perched water tables.
- c. Modelling should include all foreseeable scenarios where the proposed permanent dams become full and then overflow. This is of concern if water quality within a dam is compromised (such as by contact with PAF material).

Question 2: What does the Committee consider are the key risks and impacts of the project to water resources and water-related assets? In this regard comment is sought on the following matters identified by the Queensland Government:

- a. The potential impacts to surface and groundwater quality from open pit mining, waste rock dumps, dams, the disposal of waste products, the train load out facility, and the proposal to leave two residual voids within the floodplain.
- b. The potential impact to Deep Creek and downstream environmental values from the flooding of the proposed conveyor (transporting raw coal product between Open Cut 1 and the Mine Infrastructure Area) located underneath the Deep Creek Bridge.
- c. The potential impacts from the release of controlled and uncontrolled mine-affected water on surface water quality and aquatic ecosystem health including downstream impacts to the GBRWHA.
- d. The potential for aquifer disruption and mobilisation of the saltwater-groundwater interface near the coast, including impact on the GBRWHA.
- e. The potential impact of dewatering on groundwater/surface water interactions and GDEs.
- f. Location of the raw water dam within an existing watercourse and the mine pit dewatering dam within a State significant wetland.

20. The IESC agrees that the issues identified in this question include the key risks and impacts of the proposed project. The response to this question addresses the specific issues raised in the sub-questions. Further commentary on other key potential risks and impacts is provided within the responses to questions 1 and 3.

Question 2a

Mining impacts

- 21. The project will cause groundwater drawdown both at the project site and in the wider area based on the predictions of the current groundwater model. This will result in key potential impacts as outlined below.
 - a. Groundwater drawdown is likely to affect riparian vegetation, surface water connectivity, aquatic ecosystems (especially permanent waterholes), stygofauna, wetlands which could be GDEs and surface water quality. Many of these potential impacts have not been fully assessed (see the response to question 1) and proposed management and mitigation measures are limited (see the response to question 3).
 - b. The likely reduction in surface water flows from the Styx River due to groundwater drawdown could increase the length of waterways with a tidal influence and allow increased recharge to the alluvial aquifers by saline and brackish water associated with tidal flows. The area over

which this could occur cannot be determined until connectivity between surface water and groundwater has been more fully characterised.

- c. Drawdown could impact an unspecified number of landholder bores. The proponent proposes to manage these impacts through deepening bores, moving pumping infrastructure, constructing new bores or providing alternative water supplies.
22. The project plans indicate the modification of riparian habitat (including instream modifications) for a conveyor passing under Deep Creek Bridge (discussed in paragraphs 31-32) and three causeways across Deep Creek. This will cause fragmentation of riparian habitat and potentially induce impacts to surface water quality from dust generated from the roadway. Floods may mobilise coal dust deposited in riparian areas as discussed in the response to question 2b.

Waste Rock Dumps

23. The proponent states that weathered material will be put at the base of the waste rock dumps along with tailings (EIS, Ch. 8, pp. 8-34 to 8-36). This material will be covered with unweathered material to reduce the erosion risk associated with the high sodicity of the weathered material. However, this produces a water quality risk. Rainfall is likely to infiltrate the broken rock (unweathered material) rapidly but then be retained above finer-grained weathered material which could also have water-repellent properties due to its high sodicity. This could cause a perched aquifer containing potentially contaminated water to develop. The perched aquifer could enhance leaching of contaminants from the weathered material and the tailings if these are saturated. The perched aquifer could also result in lateral groundwater flow and potentially contaminated discharge at the edges of the waste rock dumps. In the out-of-pit waste rock dumps, it is unclear if this could affect the stability of the waste rock dump.
24. The proponent identifies the potential for waste rock dumps to affect groundwater flow by creating a barrier through hydraulic loading (EIS, Ch. 10, p. 10-45). It is suggested that this could affect groundwater discharges to creeks. There is also the potential for this to affect groundwater flows into the final voids particularly given the position of the waste rock dumps adjacent to the open cut pits. Further information is needed about this potential impact and an assessment should be undertaken to determine if this can affect the functioning of the final voids as groundwater sinks.

Dams

25. No clear commitments are provided in the EIS documentation to line any of the proposed dams. As a result, it is likely that there will be some leakage from the dams, particularly those located in existing watercourses and wetlands where groundwater-surface water connectivity may already exist. Groundwater modelling shows that Dam 2 especially is likely to have a large amount of groundwater mounding beneath it, implying it will leak (EIS, App. 6, Figure 19). This dam will contain mine-affected water, thus leakage could affect groundwater quality. Some leakage will also enter the adjacent open cut pits and thus will have to be managed within the mine water management system, meaning it will be pumped back to Dam 2, possibly with a lower water quality than when it leaked out of Dam 2.

Waste Product Disposal

26. It is possible that waste streams from the water treatment facility and the wastewater treatment plant (if constructed as part of the proposed accommodation camp which is not included in the current project proposal) will be disposed of in-pit. Although the proponent states that these waste streams will be adequately treated, no details of the proposed treatment are provided. If these waste streams were disposed of in this manner, they could leach and enter the surface water or groundwater – a scenario not considered by the proponent. These waste streams should be disposed of through a suitably licenced waste contractor.

Train Loadout Facility

27. Coal will be stockpiled at the TLF and will be transferred onto trains via a front-end loader (EIS, Ch. 3, p. 3-46).
 - a. The facility is located next to a drainage line and riparian habitat, so it is likely that coal dust will be deposited in this area.
 - b. The dam supplying the TLF will contain runoff from the stockpiles and surrounding areas. Insufficient information on water reuse, treatment or requirement to discharge from this dam was provided.

Residual Final Voids

28. The EIS provided considers the situation of two final voids but notes that this could be reduced to one. No discussion is provided of how this alternative scenario would affect the groundwater and surface water modelling results or the impact assessment. The number, location, depth, surface area and shape of the proposed final voids need to be confirmed so that they can be accurately depicted in modelling to enable a full impact assessment.
29. Currently it is unclear whether the final void or voids will be permanent or temporary groundwater sinks. In order to determine this and hence the potential impacts arising from the final voids, they must be incorporated into the groundwater model fully and the following information provided.
 - a. The number, location, depth, surface area and shape (level-volume) of the proposed final void or voids.
 - b. The expected range of water levels in the final void or voids over time. This should be determined by considering not only inflows from rainfall and outflows to evaporation but inflows and potential outflows to groundwater.
 - c. The modelled salinity of the final void or voids. To achieve this, any potential saline aquifer inflows need to be identified. Saline aquifer inflows could cause the water quality within the final void or voids to deteriorate.
 - d. The timing and extent of groundwater recovery around the final void or voids and the potential for interaction depending on relative hydraulic gradients and permeability of void walls.
30. If the final void or voids overtop during rainfall events, they may contribute to changes in flood behaviour, through reservoir outflow, potentially modifying flood timing and extent. This should be incorporated into the flood modelling.

Question 2b

31. Potential impacts to Deep Creek from flooding of the conveyor and the conveyor corridor (which is likely to contain accumulated coal dust) are likely to include an increase in the suspended sediment load and potentially higher dissolved metal concentrations. The distance downstream over which these impacts may be experienced was not assessed by the proponent, and will depend on the volume of the flood (e.g. its dilution capacity) and the amount of accumulated coal dust. Overtime, and with successive floods there is a risk that dissolved and sediment-bound contaminants may travel down the Styx River to the GBRWHA.
32. Alternative design options for the coal conveyor have not been adequately considered. These options should include a flyover of the Bruce Highway and locating the conveyor outside of the riparian corridor. The coal conveyor will flood as it is located adjacent to Deep Creek. The

proposed management options will not stop flooding of the conveyor corridor and may not be practical (i.e. conveyor removal prior to large rain events) given the project's location in the catchment headwaters which may mean that there is minimal warning of flooding. Additionally, riparian vegetation and the aquatic environment are likely to be affected by coal dust during normal operation of the conveyor (e.g. dust deposition) and during minor rain events (e.g. coal dust entrained in overland flow).

Question 2c

33. The proponent does not assess the potential for releases to impact the GBRWHA. Impacts from releases, both controlled and uncontrolled, could occur in the water column, within the sediments, or both.
- a. Within the water column, contaminants could accumulate if insufficient dilution occurs due to releases being too large a proportion of total flows. Additionally, accumulation could occur in parts of the waterways where flushing does not occur frequently or where disconnection from the main waterway happens. This would result in diminished water quality which could adversely affect flora and fauna that utilise the water.
 - b. Accumulation of metals within the sediment is also a possibility, particularly in the estuarine and marine parts of the system. This is because the pH of ocean water is generally higher than that of fresh water and at higher pH values many metals have decreased solubilities and begin to precipitate. This would affect benthic organisms, and potentially enter the food chain to fish and birds in the GBRWHA.
34. The assessment of potential impacts from releases is further limited by the lack of information provided about the mine water management system. The proponent should:
- a. specify the water source for each water storage.
 - b. clearly identify the likely water quality of each water storage and the worst possible water quality that could occur under extreme climate conditions.
 - c. identify all receiving environments for all water storages. This includes where uncontrolled discharges will flow to and other dams if water can be transferred.
 - d. identify the flood and extreme rainfall events that each water storage is designed to contain before an uncontrolled release occurs.
 - e. identify the amount of freeboard that will be maintained.
35. Water which has been in contact with coal and overburden stockpiles and the mine industrial areas (mine-affected water) may be collected in dams where the only treatment is settlement for 48 hours before release to the environment. Best-practice mine water management requires the complete separation of runoff diverted from disturbed areas (generally treated with short-term settlement) and mine-affected water. Mine-affected water requires additional treatment such as longer residence times for increased sediment removal and potentially treatment to remove dissolved contaminants. Improved clarity is needed around the functions of the proposed dams and mine-affected water should be separated from other water streams to ensure this water is appropriately managed to reduce potential impacts to surface water quality and aquatic ecosystem health.

Question 2d

36. Although the proponent states that groundwater drawdown from the project could result in seawater intrusion, no further discussion is provided. The following investigations should be undertaken and information provided to allow a full analysis of potential impacts.
- a. Field studies are required to identify where the seawater intrusion interface is currently located. These investigations need to examine all significant aquifers near the coast, not only the alluvial aquifer.
 - b. Potential seawater intrusion and inundation (e.g. during king tides or cyclones) should be modelled using a new variable density groundwater flow and solute transport model developed to compliment the updated groundwater model (as discussed in paragraph 3d).
 - c. Information on the location of the seawater intrusion interface needs to be incorporated into the variable density flow and solute transport model. Further model calibration and validation are likely to be needed at this time.
 - d. The variable density groundwater flow and solute transport model should be run to determine the maximum possible inland extent of seawater intrusion. The potential for the seawater intrusion interface to interact with the final void or voids must be assessed. If the seawater intrusion interface were to reach a final void this would create additional water quality management issues.
 - e. Use the new modelling results to support an analysis and discussion of the potential ecological impacts. This needs to consider the direct impacts of seawater intrusion or inundation on ecosystems plus indirect effects that could arise such as changes to water quality if riparian vegetation is lost.
 - f. An analysis and discussion should be provided detailing how any predicted changes in the location of the seawater intrusion interface could affect the extent of the tidal influence and hence surface water flows and quality. Potential impacts on estuarine and marine ecosystems, including those of the GBRWHA, should be specified and mitigation strategies should be proposed.

Question 2e

37. The proponent states that groundwater drawdown is likely to impact groundwater-surface water connectivity. They predict up to 15 km of stream length may be affected (EIS, Ch. 10. p. 10-64). These predictions are based on the results of the groundwater model. As discussed in the response to question 1, confidence in these results is limited and considerable work is required to improve confidence. It is possible that a larger stream length could be disconnected from groundwater. The following improvements, in addition to those outlined in paragraph 3 relating to the groundwater modelling, should be made to enable a full assessment of the potential extent and nature of impacts to surface water-groundwater connectivity and GDEs.
- a. Stream sections that are permanently or occasionally connected to groundwater need to be identified. Further fieldwork needs to be undertaken to characterise the nature of the connection and to provide baseline information.
 - b. Sensitivity and uncertainty analysis of the groundwater model should be undertaken to examine the full potential range of drawdown scenarios and their likelihood (also refer to paragraph 4). These results should be compared to the stream connectivity information to identify all possible stream sections that could be impacted.

- c. Further ecological surveying of connected stream sections (e.g. permanent pools, riparian vegetation) should be conducted so that the nature of groundwater dependency can be determined and hence potential impacts on GDEs from groundwater drawdown and possible disconnection assessed.
- d. Potential surface water and groundwater quality impacts should be assessed. If groundwater discharge decreases, water quality in permanent pools and during low flows is likely to deteriorate. Conversely, if groundwater recharge from surface water flows decreases, groundwater quality could deteriorate. Either of these may have impacts on riparian vegetation and other GDEs.
- e. An assessment is needed of the potential combined effects of groundwater drawdown and reduced surface water flows on aquatic and riparian environments, especially those with some reliance on groundwater.

Question 2f

38. The location of the pit dewatering dam should be reconsidered. The proposed location will destroy a wetland identified as a matter of state environmental significance by the Queensland Government. The proposal to destroy this wetland is incompatible with the objectives of the *Draft Reef 2050 Water Quality Improvement Plan 2017-2022* (The State of Queensland 2017). This plan, if approved and finalised, includes a wetland target of “no loss of natural wetlands”. The currently operating plan (Commonwealth of Australia 2015) has a target of “no net loss”. Additionally, based on the groundwater modelling results, this dam may also provide a source of contaminated (mine-affected water) groundwater recharge.
39. The raw water dam is proposed to be located within an existing watercourse to the north of the site. The watercourse is an unnamed, ephemeral, 2nd order tributary of Deep Creek, in an area where vegetation is identified as modified pasture or remnant vegetation of least concern (EIS, Ch. 14, Fig. 14-1). If possible, the dam should be sized to reduce the need for surface water extraction from Tooloombah Creek and appropriately control erosion and flood risk downstream from overflowing.

Question 3: Advice is sought on whether the measures and commitments proposed in the EIS are appropriate to mitigate and manage impacts to water resources and water-related assets. In particular, the proposed use of supplementary water to maintain refuge pools for aquatic species and GDEs. Advice is sought on whether the monitoring framework proposed in the EIS is adequate to identify the risks and impacts of the project and to trigger management measures to avoid and minimise impacts.

40. The proponent provides limited information regarding proposed mitigation and management actions in the EIS documentation. Management plans cannot be finalised because the location and design of all infrastructure have not been finalised. A full impact assessment has not been completed and baseline environmental data and current modelling is insufficient, meaning suitable management and mitigation measures, including impact management trigger values cannot be derived.

Groundwater

41. The management of potential groundwater impacts is not discussed in detail in the EIS documentation. There appears to be a reliance on the final void or voids operating as groundwater sinks. There is currently considerable uncertainty around this as discussed in the responses for questions 1 and 2. The proponent needs to undertake the additional work and provide further information about the final void or voids as previously discussed to confirm that the

final voids will act as long-term groundwater sinks and hence restrict potential groundwater quality impacts to the mine site.

42. The proposed groundwater monitoring network as shown in Figure 10-27 (EIS, Ch. 10, p. 10-74) provides a reasonable spatial coverage close to the project site. However:
- a. it is unclear that groundwater level and quality will be monitored at these bores as the proponent's proposed environmental authority conditions (see EIS, Ch. 23) use different bore identifiers for proposed groundwater level monitoring bores.
 - b. at least some of the proposed monitoring bores would need to be nested installations to ensure that all aquifers are being monitored.
 - c. the groundwater modelling results suggest that most of the monitoring bores are likely to be impacted by drawdown by the end of the mine life (approximately 20 years). Additional monitoring bores are required near and beyond the spatial limit of predicted impact to ensure the full extent of impacts is captured and that reference bores outside the area of impact persist to provide a baseline for comparison after mining.
 - d. the bores near the Styx River downstream of the site should be monitored for electrical conductivity (EC) regularly (up to monthly) to identify potential seawater intrusion or inundation.
 - e. the proponent indicates that some bores may be equipped with water-level loggers to provide higher-frequency observations. The bores identified as MB-6 to MB-14 in Figure 10-27 (EIS, Ch. 10, p. 10-74) should be equipped in this manner. These loggers should be downloaded frequently (at least every three months) or telemetered to provide enhanced early warning capabilities.
 - f. groundwater quality monitoring may need to occur more frequently than currently proposed. The frequency of monitoring should be informed by the results of baseline monitoring. The range of analytes monitored should be informed by the results of the further geochemical analysis suggested in this advice.
 - g. given that groundwater mounding has been predicted beneath the dams, a monitoring bore to the northeast of the TLF should be considered.
43. When the groundwater management plan is developed, groundwater level and quality trigger values will need to be derived. To do this, the proponent will need to collect baseline data as outlined in the response to question 1. Derivation of suitable trigger values should be based on the process outlined in ANZECC/ARMCANZ (2000). The management responses associated with these trigger values should be clearly articulated and allow a rapid response to implement the needed changes to prevent or limit potential impacts. Additionally, the plan should include a commitment to regularly update the groundwater model (e.g. on a five-yearly basis).

Surface water

44. The management of potential surface water quality changes from mine discharges is reliant on dilution. However, appropriate hydrodynamic and water quality modelling has not been undertaken to confirm that the discharge regime proposed in the proponent's draft environmental authority will achieve sufficient dilution to meet the applicable catchment water quality objectives (see EHP 2014). As the proposed discharge conditions are linked to flow in the receiving creeks, gauging stations will need to be installed on both Tooloombah Creek and Deep Creek. Discharge should not be permitted at low creek flows (as is currently proposed) as this may not allow sufficient dilution.

45. The proponent's draft environmental authority (EIS, Ch. 23) is overly complex and quite unclear. This document needs considerable revision and should:
- a. clearly identify water quality objectives and water quality management trigger values for both discharge and non-discharge conditions (i.e. for routine monitoring). Water quality trigger values should be based on the results of the baseline monitoring that is discussed in the response to question 1, or relevant local water quality objectives and the ANZECC/ARMCANZ (2000) guideline values. If other trigger values are suggested, the reasons for using those values should be clearly explained.
 - b. clearly identify when and where monitoring will occur for the discharge and routine scenarios.
 - i. Monitoring of physicochemical parameters such as pH, electrical conductivity, dissolved oxygen and turbidity or total suspended solids can be done continuously with multi-parameter probes. During discharges, these parameters should be monitored at least daily.
 - ii. Routine monitoring during non-discharge periods should occur at least monthly in order to allow detection of potential leakages which can impact water quality. This monitoring should occur at the upstream and downstream monitoring sites and within all water storages.
 - c. include commitments to monitor sediments due to the potential for metal accumulation to occur as discussed in the response to question 2.
46. The proposed upstream and downstream monitoring sites on both Tooloombah Creek and Deep Creek need to be moved. The upstream sites must be moved further upstream to ensure that there is no potential for impacts from the project. The downstream sites should be moved further downstream to ensure that all runoff from the project site has entered the creeks, but should be located before other tributaries enter the creeks.
47. When the surface water management plan is developed, water quality trigger values will need to be derived. The process outlined in paragraph 43 for groundwater trigger values should be followed.
48. The proponent does not provide a clear commitment to monitor seepage from all dams. This commitment is needed to ensure that this potential impact is appropriately monitored and managed.

Groundwater-dependent Ecosystems

49. Insufficient information is provided in the EIS documentation to determine whether supplementary flows are likely to be a successful management and mitigation option to reduce the impacts of groundwater drawdown on aquatic and riparian ecosystems. The proponent recognises that further work is required. This work should include:
- a. mapping of the permanent pools and riparian vegetation that could require the use of supplementary flows. The results of this mapping should also be used to inform the selection of suitable monitoring points (discussed further in paragraph 49f).
 - b. studies to determine the current dynamics of the groundwater-surface water connectivity at potentially impacted sites; the proportions of groundwater and surface water utilised and the seasonality of use by the ecosystems; any source preferences; and the current quality of the water used by different ecosystems. These studies should include field-based work and could incorporate analysis of satellite and aerial imagery (e.g. Eamus et al. 2015).

- c. an analysis of whether the project will have water available at the times when it will be needed for supplementary flows, and whether this water will be of a suitable quality or will require mixing with fresher water that may need to be imported to the project site. If water will need to be brought onto the site, then an assessment is required of availability and potential sources.
 - d. an assessment of how the supplementary flows which are expected to be primarily sourced from groundwater could affect the quality of the alluvial aquifer. While the proponent does commit to treating the water to meet the relevant water quality objectives, the resulting quality could be lower than natural recharge water.
 - e. studies to determine the volumes and discharge rates of the supplementary flows required to achieve sufficient recharge to the alluvial aquifer to maintain or improve the condition of affected ecosystems. These studies will need to consider that once drawdown commences, recharge dynamics will change so the flows required could increase considerably.
 - f. investigations to identify appropriate monitoring variables in order to trigger supplementary flows and to measure their effectiveness. Ecological measures of vegetation health should be monitored; however, response in these can be lagged. Therefore, variables that respond more rapidly to change such as the water table in the alluvial aquifer and soil moisture may also be useful. Consideration should also be given to the use of reference sites.
50. Once the above suggested work has been completed, a more detailed assessment of the likelihood of success of the proposed supplementary flows scheme can be made. This assessment needs to occur prior to the project commencing as other mitigation and management options may need to be considered. Prior ecological work at the project site has highlighted the good condition of the aquatic and riparian ecosystems, the likely occurrence of listed aquatic taxa (e.g. the Estuarine Crocodile) and that there may not be suitable offsets available in the area (EIS, App. 9e, pp. 49-51). Additionally, the riparian vegetation is important for maintaining surface water quality and for habitat connectivity. Therefore, loss of these ecosystems should be avoided.
51. The proponent notes that groundwater drawdown is likely to impact some stygofauna. However, no mitigation or management options are discussed. Further consideration of mitigation and management options is needed as is continued monitoring of stygofauna to confirm the success of mitigation.
52. Adaptive management is proposed, although no details of what this could include are provided. An assessment of the effectiveness of proposed adaptive management measures is therefore not possible at this time.

Geochemistry

53. No details are provided in the EIS about how ASS would be managed. There is the potential for these to occur at the project site, and for groundwater drawdown to contribute to the generation of impacts. The proponent needs to further investigate the likely occurrence through soil profile testing and mapping of ASS, and provide details of proposed management options.
54. Limited information has been provided in the EIS documentation as to how PAF material and sodic material will be managed. Further sampling and analysis are needed as discussed in the response to question 1. Development of an appropriate management plan for these materials needs to consider:
- a. that sodic soils are highly dispersive and prone to erosion when disturbed. Increased sediment loads will impact high-value ecosystems downstream.

- b. the total possible volume of these materials and the uncertainty in these calculations.
 - c. whether encapsulation of some material may be needed. If this is the case, then the location of the encapsulated material within the waste dumps will need to be carefully considered as will the amount and source of material with which to encapsulate.
 - d. contingencies in case more of these materials are identified than currently predicted.
55. There is a lack of clarity in the EIS documentation around the total volume of waste rock predicted to be produced. Successful management of this material necessitates accurate estimates of produced volumes.
56. While the proponent suggests that some monitoring of leachate, tailings and waste rock dumps will be undertaken, very little detail is provided. Without details as to the location and frequency of monitoring and variables to be monitored, the adequacy of proposed monitoring cannot be assessed.

Final Landforms

57. The mine areas are proposed to be returned to grazing with a similar extent as prior to mining. Baseline ecosystem condition assessments are proposed as a way to compare rehabilitation to pre-disturbance condition. Mine closure and rehabilitation management plans are not available. Baseline assessments, mine closure plans and rehabilitation plans are required to establish detailed triggers for management measures and minimise impacts.
58. The information provided regarding the monitoring and management of water held in the final voids is inadequate to determine potential impacts to water resources from the site. This is primarily due to the uncertainty in the predicted volume and quality of water, and the characteristics of the final void or voids as discussed in paragraph 29.

Date of advice	15 December 2017
Source documentation available to the IESC in the formulation of this advice	CDM Smith 2017. <i>Central Queensland Coal Project Environmental Impact Statement</i> .
References cited within the IESC's advice	<p>ANZECC/ARMCANZ 2000. Australian Guidelines for Water Quality Monitoring and Reporting. <i>National Water Quality Management Strategy (NWQMS)</i>. Canberra: Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.</p> <p>Eamus D, Zolfaghar S, Villalobos-Vega R, Cleverly J, Huete A 2015. Groundwater-dependent ecosystems: recent insights from satellite and field-based studies. <i>Hydrology and Earth System Science</i>, 19, 4229-4256.</p> <p>EHP 2014. Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives. Basins 127, 128 and 129, including all waters of the Styx River, Shoalwater Creek and Water Park basins and adjacent coastal water. https://www.ehp.qld.gov.au/water/policy/pdf/styx-shoalwater-waterpark-evs-wqos.pdf</p>

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- Commonwealth of Australia 2015. *Reef 2050 Long-Term Sustainability Plan*.
<https://www.environment.gov.au/system/files/resources/d98b3e53-146b-4b9c-a84a-2a22454b9a83/files/reef-2050-long-term-sustainability-plan.pdf>
- IESC 2015. Information Guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals
<http://www.iesc.environment.gov.au/system/files/resources/012fa918-ee79-4131-9c8d-02c9b2de65cf/files/iesc-information-guidelines-oct-2015.pdf>.
- The State of Queensland 2017. *Draft Reef 2050 Water Quality Improvement Plan 2017-2022*. <http://www.reefplan.qld.gov.au/about/assets/reef-2050-water-quality-improvement-plan-2017-draft.pdf>
- USGS 2016, *SEAWAT: A Computer Program for Simulation of Three-Dimensional Variable-Density Ground-Water Flow and Transport*.
<https://water.usgs.gov/ogw/seawat/>
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