Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development

CONSULTATION DRAFT – NOT FOR OFFICIAL USE

Public consultation - Information guidelines for proponents preparing coal seam gas and large coal mining development proposals

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is seeking comment on the updated *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*.

The IESC welcomes feedback on the content, usability and applicability. In particular, views are sought on:

- **the content of the updated Information Guidelines, particularly any areas where further explanation would be useful;**
- **the relevance to your specific area of work; and**
- **potential options to increase uptake and adoption.**

The IESC and the Information Guidelines

The IESC is a statutory body under the *Environment Protection and Biodiversity Conservation Act 1999 (Cth).* One of the IESC's key legislative functions is to provide independent scientific advice to the Australian Government Environment Minister and relevant state ministers in relation to coal seam gas (CSG) and large coal mining (LCM) development proposals that are likely to have a significant impact on water resources.

The IESC Information Guidelines outline the information project proponents should provide to enable the IESC to provide robust scientific advice on the potential water-related impacts of CSG and LCM developments proposals.

The Information Guidelines were first published in February 2013. The Guidelines were reviewed and amended in April 2014, June 2015 and May 2018, to update reference material, cover developments in leading practice and knowledge, take account of the IESC's recent experience and incorporate comments from users.

For some topics, Explanatory Notes have been written to supplement the Guidelines, giving more detailed guidance to help the coal seam gas and large coal mining industries prepare environmental impact assessments. These topics are chosen based on the IESC's experience of providing over 140 pieces of advice on development proposals. Case studies and practical examples of how to collect and present relevant information are also included.

Independent Expert Scientific Committee
on Coal Seam Gas and Large Coal Mining Development

Information guidelines for proponents preparing coal seam gas and large coal mining development proposals

XX (TBD) 2021

Australian Government

This initiative is funded by the Australian Government

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Background

The role of the IESC

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) is a statutory body under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

The IESC's key legislative functions are to:

- provide scientific advice to the Commonwealth Environment Minister and relevant state ministers on coal seam gas (CSG) and large coal mining development proposals that are likely to have a significant impact on water resources;
- provide scientific advice to the Commonwealth Environment Minister on bioregional assessments (CoA 2015a) of areas of CSG and large coal mining development;
- provide scientific advice to the Commonwealth Environment Minister on research priorities and projects;
- collect, analyse, interpret and publish scientific information about the impacts of CSG and large coal mining activities on water resources; and
- provide scientific advice on other matters in response to a request from the Commonwealth or relevant state ministers.

Further information on the IESC's role is on the IESC website.

Purpose of the Information Guidelines

The Information Guidelines outline what types of information a proposal should include for a CSG or large coal mining project. This information is needed to enable the IESC to provide robust scientific advice to government regulators on the potential water-related impacts of such proposals. They are also written in a manner which allows use by proponents for projects that extract other minerals or hydrocarbons.

The guidelines were first published in February 2013. The guidelines were reviewed and amended in April 2014, June 2015, May 2018 and XX (TBD) 2021, to update reference material, cover developments in leading practice and knowledge, and take account of the IESC's recent experience and incorporate comments from users.

Explanatory Notes

For some topics, Explanatory Notes have been written to supplement the IESC Information Guidelines, giving more detailed guidance to help proponents prepare their environmental impact assessments. These topics are chosen based on the Committee's experience of providing advice on well over 100 development proposals. Explanatory Notes have been prepared for the following topics:

- Uncertainty analysis – Guidance for groundwater modelling within a risk management framework
- Assessing groundwater-dependent ecosystems
- Deriving site-specific guideline values for physico-chemical parameters and toxicants, and
- Characterisation and modelling of geological fault zones (in draft).

Explanatory Notes are intended to assist proponents in preparing environmental impact assessments. They provide tailored guidance and describe up-to-date robust scientific methodologies and tools for specific components of environmental impact assessments. Case studies and practical examples of how to present certain information are also discussed.

Explanatory Notes provide guidance rather than mandatory requirements and proponents are encouraged to refer to issues of relevance to their particular project.

The IESC recognises that approaches, methods, tools and software will continue to develop. The Information Guidelines and Explanatory Notes will be reviewed and updated as necessary to reflect these advances.

The IESC has also developed several Fact Sheets on key scientific issues associated with the water-related impacts of CSG and large coal mining development. Fact Sheets have been prepared for the following topics: coal seam gas extraction and co-produced water; connectivity between water systems; Environmental Assessments; environmental water tracers; subsidence from coal seam gas extraction; and subsidence from longwall coal mining. The IESC website also provides links to reports from commissioned studies and reviews that may also be useful for proponents.

The nature of advice from the IESC

The IESC provides scientific advice to Australian government regulators on CSG and large coal mining development proposals. The IESC does not make regulatory decisions. Advice is provided in response to a request from a relevant government regulator. The advice and considerations provided by the IESC are designed to support regulators in considering leading practice science in their decision-making.

The Commonwealth and relevant state regulators (in accordance with Section 505E of the EPBC Act) seek advice from the IESC at appropriate stages in the assessment and approval process as per the relevant protocols. More information on protocols can be found at:

- Commonwealth: http://iesc.environment.gov.au/committee-advice
- New South Wales: http://www.planning.nsw.gov.au/Policy-and-Legislation/Mining-and-Resources/Gateway-Assessment-and-Site-Verification, https://www.planning.nsw.gov.au/Policy-and-Legislation/Mining-and-Resources and https://www.planningportal.nsw.gov.au/development-assessment/state-significant-applications/state-significant-development-ssd
- Queensland: https://www.qld.gov.au/environment/pollution/management/eis-process/national-partnership-agreement-on-csg-and-large-mining-development
- Victoria: http://www.dtpli.vic.gov.au/planning/environmental-assessment
- South Australia: https://www.waterconnect.sa.gov.au/Industry-and-Mining/CSG-Coal-Mining/SitePages/Home.aspx

In accordance with Section 505D of the EPBC Act, the IESC is required to:

- provide advice to the regulator within two months of receiving a request; and
- publish the advice no more than ten days after it is provided to the regulator.

Regulators can request advice on a project multiple times during the assessment process. The statutory timeframe for the IESC to provide advice is two months. The Chair may agree to expedite supplementary advice in exceptional circumstances.

The IESC's advice primarily focuses on potential impacts (direct, indirect and cumulative) of CSG and large coal mining proposals on all aspects of water resources. This includes surface water and groundwater quantity, water quality, ecosystems and ecological processes that contribute to the state and value of the water resource and water-dependent assets (CoA 2007). The IESC can also provide advice on projects other than CSG and large coal mining with the written approval of the Commonwealth Environment Minister and if they have sufficient expertise.

In providing advice, the IESC will consider whether a proponent's environmental assessment documentation has:

- used suitable data and information to identify and characterise all relevant water resources and water-related assets;
- applied appropriate methods and interpreted model outputs in a logical and reasonable way to investigate the risks to those assets from the proposed project;
- considered potential cumulative impacts from past, present and other reasonably foreseeable actions;
- adequately described appropriate avoidance or mitigation strategies to avoid or reduce potential impacts to water resources;
- proposed effective monitoring and management to detect and ameliorate the risk of potential impacts, and to assess the effectiveness of proposed mitigation strategies and other management measures; and
- addressed the inevitable uncertainties in predictions of potential impacts on water resources and water-related assets.

The advice of the IESC can include but is not limited to an assessment of:

- the likely risk to water resources and water-related assets;
- the adequacy of water and salt balances, local and regional scale groundwater and surface water models, and any implications for water quality;
- whether the information used and methods applied are fit for purpose, and whether the assessment of risk and uncertainty is appropriate;
- critical data and information gaps that need to be addressed to complete an adequate assessment;
- the potential cumulative water-related impacts of the proposal in the context of past, present, and reasonably foreseeable actions; and
- the adequacy of proposed environmental objectives and management measures for mitigating risks, including for legacy issues such as groundwater level and water-table recovery, rehabilitation, restoration, final land use, closure, residual voids and brine management.

Information to provide in the proposal

General requirements

The proposal should present sufficient evidence for independent verification of:

- the processes of cause and effect between the project and water resources; and
- the materiality and likelihood of the potential impacts and risks to water resources.

Enough information should be provided to allow an independent reviewer, such as the IESC, to consider the appropriateness of assertions made in the environmental assessment documentation. For example, this would include the basis of the conceptual or ecohydrological models, the underlying assumptions on which numerical models are based and why an ecosystem is not groundwater-dependent.

In short, an independent reader of the environmental assessment documents should be able to verify all significant conclusions made by the proponent.

Specific requirements

The available information will vary for individual proposals, depending on the point in the regulatory assessment process at which the proposal is referred. The type and amount of information provided to the IESC will also vary depending on whether the project is a new development (greenfield) or an expansion of an existing operation (brownfield).

The documentation provided to the IESC must include the most comprehensive information possible, based on and including all the available data. For example, this should include historical water quality data to demonstrate compliance with existing conditions, bore logs to support geological conceptualisations, and/or the results of pump tests to support model parameterisation. This is particularly relevant for existing mines undergoing modification/extension or in regions where there are a lot of historical data.

Early in the assessment process (e.g., for Gateway projects in New South Wales), preliminary conceptual and numerical or analytical models should consider all available data and be used to identify further data that may be needed. Conceptual and ecohydrological models should identify water resources and water-dependent assets in the project area and surrounding areas, including their significance under state and Commonwealth legislation, and identify any potential stressors and exposure pathways that may impact water-dependent assets.

At the assessment stage, there is expected to be a clear and evidence-based determination of potential significant impacts to water resources and water-dependent assets, supported by detailed modelling. Modelling should include detailed conceptual, ecohydrological and numerical models at spatial and temporal scales suitable to represent physical, chemical and ecological processes associated with each identified water resource or water-dependent asset. The information provided should include a comprehensive assessment of the risks to water resources and water-dependent assets from the proposed project at all phases (i.e., construction, operation and post-closure), and details of proposed mitigation measures to manage these risks.

Proposals for expanding or modifying existing mining operations should outline historical and existing operations, current water-related environmental approval conditions and associated approved monitoring and management plans. They should:

- clearly identify any potential impacts to water resources and water-dependent assets from existing actions, the proposed expansion or modification, and cumulative impacts from other actions in the area;
- use current and historical monitoring data to justify assertions about impacts;
- use existing project data to verify model predictions; and
- outline how existing data have been used to assess the potential impacts of the proposed project.

It is expected that all the required information will be provided by proponents in their project assessment documentation. This information may be augmented by further information required or generated by the relevant regulator.

The text below provides general guidance on IESC information needs. A checklist of specific information requirements is at Appendix A. The checklist will assist proponents and regulators to ensure that requests for advice to the IESC are supported by appropriate information. Explanatory Notes will be developed progressively to provide further guidance to proponents on the information needs of the IESC. These can be found on the IESC website.

1. Description of the proposed project

The proposal should provide a regional overview of the project area, including a description and appropriately scaled presentations of the geological basin, coal resource, surface water catchments, groundwater systems and water-dependent assets. The proposal should also describe current and reasonably foreseeable coal mining, CSG developments and other water-intensive activities, including water storages and irrigation. The description should include any relevant information generated by a bioregional assessment. Where a bioregional assessment has not been done, the best available information should be used in describing the existing location and condition of water resources and water-dependent assets in the region.

The proposal should clearly describe the project's location, purpose, scale, duration, disturbance area, water supply and the means by which the project is likely to have a significant impact on water resources, water quality and water-dependent assets. For proposals such as mine extensions that will use existing approved infrastructure, the proposal should clearly identify which components are new.

The statutory context, including information on the proposal's status within the regulatory assessment process, and any applicable water management policies or regulations, including state or Commonwealth regulation of potentially impacted water resources, should also be provided.

2. Risk Assessment

Environmental assessments provide information on environmental risks and how these may be mitigated. Any modelling and technical work should be directed towards assessing and mitigating risks that arise from potential impacts, reducing uncertainty, and communicating this (see Middlemis and Peeters 2018). The level of analysis of any management objective should be commensurate with the level of risk, as determined by considering the probability and potential consequences of the risk, and the value, condition and vulnerability/sensitivity of the asset.

The risk assessment process should be commenced at an early stage of the proposed project as the progressive results provide important inputs to other stages of the environmental assessment process. Risk assessment should be an iterative process based around causal pathways with progressive results used to continually refine conceptual models, residual risk and plans for mitigation, management and monitoring. As the process progresses, effort is expected to focus on those assets at greatest risk.

The proponent will need to determine the scope, likelihood and consequences of all potential impacts. This could include the assessment of the risk from, for example, potential uncontrolled discharges, containment failure, drilling and hydraulic stimulation chemicals, beneficial reuse of discharges, and potential waste contaminants (e.g., brines).

The potential cumulative impact of all past, present and reasonably foreseeable actions and activities that are likely to impact on water resources and water-dependent assets should be considered.

The IESC will consider whether the proponent has demonstrated that the risks can be either avoided or suitably mitigated and may suggest further actions to avoid, mitigate or manage residual risks.

The IESC will review and evaluate the proponent's assessment of risk in conjunction with information provided by the relevant regulators in their request for advice. The IESC will consider a proponent's risk assessment and other assessment documentation in the context of Commonwealth and state water resource plans and schemes (e.g., the Murray-Darling Basin Plan, Hunter River Salinity Trading Scheme) where these are applicable to the proposed development.

Available bioregional assessments will assist with risk analyses by identifying possible likelihood and consequences of impacts to water resources and water-dependent assets from CSG and large coal mining development proposals within specific bioregions. The bioregional assessments, which are a snapshot in time, used a modification of the failure modes and effects analysis (FMEA) method (Ford et al. 2016). This may be an appropriate approach for proponents to use. Where the proposed development occurs within an area with a bioregional assessment, the IESC will consider the bioregional assessment in its review of the proponent's risk assessment.

3. Description of impacts to water resources and water-dependent assets

For all relevant water resources and water-dependent assets, the proposal should:

- describe existing conditions, values and sensitivity to potential impacts (see Doody et al. 2019 in relation to groundwater-dependent ecosystems (GDEs));
- provide conceptual, ecohydrological and/or numerical modelling of potential impacts; and
- propose effective avoidance or mitigation strategies and management measures.

For each causal pathway, the intensity, duration, magnitude and geographic extent of the potential impacts to the water resource, the resultant impact to any water-dependent assets, and the consequence or significance of the impact, should be clearly described.

Potential impacts on water-dependent assets should be compared with project-specific environmental objectives and the legislated environmental values and water quality objectives for surface waters and groundwaters under relevant state and national environmental legislation, including the ANZG 2018 guidelines.

For brownfield projects, the impacts on water resources and water-dependent assets from the existing project should be described separately, using all available historical data, from the potential impacts of the project expansion. The potential cumulative impacts of the project in its entirety should also be described.

3.1 Conceptual models

Conceptual models are pictorial or descriptive hydrological, hydrogeological and ecological representations of the project site showing the inputs, outputs, stores, flows and uses of water, including use of water by ecosystems. Robust conceptualisations provide the scientific basis for developing analytical and/or numerical models and site water and salt balances. Conceptual models are also useful in the problem formulation stage of ecological risk assessment to show stressors, sources, exposure pathways and the possibility of multiple cause-effect pathways (see Doody et al. 2019). They also help identify the areas of scientific uncertainty in the risk assessment.

Conceptual models must be based on leading practice and consider relevant field data and investigations, expert advice, scientific literature, and other appropriate information sources. Conceptual models should identify the geological formations, water resources, stressors, exposure pathways and, water-dependent assets likely to be impacted by the proposed project, and consider how relevant geological features (e.g., faults, fractures and aquitards) could respond to, or affect, potential causal pathways. They should be developed at appropriate scales which enable clear description of important causal pathways, how these would be influenced by the proposal, and the expected responses in water resources and water-dependent assets.

An ecohydrological conceptual model is a type of conceptual model that integrates the hydrological (surface and groundwater) components with the ecological components (e.g., specific taxa, communities and ecosystems) to show the likely pathways by which a proposed project might impact on key aspects of water resources (e.g., water quality, flow regime, biota, ecological function). This ecohydrological conceptual model should also indicate the likely relative importance of these pathways during and after the proposed project. As more data become available, the model can be refined so that it better guides mitigation measures and captures site-specific features.

In some cases, it may be necessary to develop conceptual models for different components of the designated region or several models depicting different spatial and/or temporal scales. The level of detail within a conceptual model should be based on the aim of the model and on the environmental objectives; risk assessment outcomes; data availability; and knowledge of the water resources, water-dependent assets and processes in the region.

Further information regarding conceptual modelling, including issues of scale and uncertainty, can be found in *Modelling water-related ecological responses to coal seam gas extraction and coal mining* (CoA 2015c). Relevant research commissioned using the advice of the IESC can also be accessed from the IESC website (CoA 2015b) and may be helpful in the formation and evaluation of project hydrological conceptualisations.

3.2 Analytical and numerical modelling

Numerical models can predict potential impacts on water resources and water-dependent assets from a proposed project and support the exploration of management approaches to mitigate potential impacts. It is recognised that for projects presented to the IESC early in the assessment process (e.g., Gateway projects in New South Wales), the data needed for detailed modelling may not yet be available.

Models should be developed at an appropriate spatial (local vs regional) and temporal (life-of-project or longer if post-project or long-term impacts are predicted) scale to fulfil a specific purpose such as understanding potential impacts to a particular water resource or water-dependent asset. This purpose should inform the model design (e.g., consider the level of model complexity required to achieve the model purpose) and assumptions, which should be clearly described and justified in the project assessment documentation (Middlemis and Peeters 2018).

In developing their purpose, it is important to keep in mind that models are there to support decision making by the regulator. In simple terms, decision-support modelling should (Doherty and Moore 2021):

- quantify the uncertainties of predictions of management interest so that risks can be associated with contemplated courses of management action;
- take model simplifications and abstractions into account when assessing these uncertainties;
- reduce predictive uncertainties through assimilation of pertinent data; and
- provide a guarantee (to the extent that this is possible) that the uncertainties of decision-critical model predictions are not underestimated so that project stakeholders and regulators can be sure that management risks are not understated.

In doing so, the model(s) should be constructed in accordance with the conceptual model(s), and calibrated and verified with appropriate baseline data. Climate change should also be considered in the construction of models; the proponent should use appropriate climate scenarios specific to the project's area and design life.

Results from modelling should show the range and likelihood of possible outcomes, based on sensitivity and uncertainty analysis. These predictions should be sufficiently robust to support risk analysis and regulatory decision-making. Further discussion of sensitivity and uncertainty analysis in relation to groundwater modelling and the IESC information needs, is provided in Middlemis and Peeters (2018).

A detailed description of any methods and evidence (e.g., monitoring data from past and present mining at the site, expert opinion and analogue sites) used in addition to or instead of modelling, should also be provided. Sufficient detail to justify the use of these methods and to provide evidence to support all conclusions is needed, based on the stage of the proposed project within the assessment process.

Impact analysis should be based on modelling results, including uncertainty analysis (or other methods, where appropriate), and should clearly articulate the potential causal pathways. The proposal should describe a clear 'line of sight' between each potential impact and its cause, so that effective monitoring and management strategies can be targeted and justified. Details of the proposed monitoring and management plans should be clearly linked to the impact analysis.

3.3 Water and salt balances

The proposal should provide site-specific water and salt balances, for both pre- and post-development scenarios under a range of potential climatic conditions (guided by, for example the Australian Climate Futures Tool (CSIRO 2015). These should show an understanding of the surface water and groundwater inputs, outputs and diversions in the region.

The water and salt balances should use consistent water metrics and definitions and be accompanied by relevant contextual information and statements of accuracy (see the *Water Accounting Framework for the Minerals Industry,* (Minerals Council of Australia 2014) and *Coal seam gas extraction: modelling groundwater impacts,* (CoA 2014a)). The assessment documentation should provide a Water Accounting Framework for the Minerals Industry – input-output statement for each site, including the accuracy table (which provides information on the accuracy of the data and whether the data used were measured, estimated or simulated).

Information is needed about the set of water and salt stores for the site and the movement of water and salt between stores, tasks (e.g., coal handling and processing, dust suppression, underground mining), and treatment plants within the site. This should include:

- estimates of water use in transpiration, including seasonal and interannual variations;

- predicted changes to vegetation water use and access as a result of the proposed project; and
- assessment of the potential impact of any changes to any take, store or flow of water and mass or concentration of salt, including long-term storage, arising from the proposed project on water-dependent assets.

Estimates of the quality and quantity of external water supply and operational discharges under dry, median and wet conditions, and the likely potential impacts on water-dependent assets should be provided. Volumes and quality of operational discharges, as well as beneficial uses, should be described and predicted over the project life.

For greenfield coal seam gas projects there is a large degree of uncertainty around produced water volumes and salt loads. Despite this, estimates of water and salt volumes are required, and the uncertainty associated with these estimates should be quantified and communicated in the assessment documentation. Proposed management options for produced salt and brines should consider the uncertainty in these estimates and the potential for, and nature of, possible contaminants in the salt and brines. Management options for salt and brines should be considered with regard to their appropriateness over all time scales from short to long term and after project closure.

4. Baseline Data

Baseline data provide the foundation for developing environmental objectives and outcomes. Baseline measurements are also required to measure changes to water resources and water-dependent assets as a result of the proposed project.

Baseline data are needed for all water resources, including contextual information such as dates and locations of measurements, sampling protocols, flow conditions and elevations of the reference points from which water levels were measured.

Baseline monitoring data for physico-chemical parameters, and contaminants (e.g., metals and metalloids) in surface and groundwaters, should be included. Physico-chemical results should be compared to national/regional guidelines or to site-specific guidelines (see Huynh and Hobbs 2019) derived from reference condition monitoring if available. Baseline contaminant concentrations should be compared to national guidelines, allowing for local background correction if required.

To inform ecological risk assessment, baseline ecological data should be sufficient to identify all surface water-dependent and groundwater-dependent assets and their current condition and value as well as stressors on these assets to inform ecological risk assessment (see Doody et al. 2019). Results of habitat, fauna (including stygofauna) and flora surveys should be included.

Adequate ecological and hydrological (for quick response systems) baseline data for the project area would generally be for a period in excess of two years, at a frequency sufficient to capture likely variability in the system and taking into account seasonal variability. Baseline groundwater data should be presented from site-specific monitoring bores, and surface water flow values from site-specific sampling sites, ideally taken from stream gauges. Relevant information generated by a bioregional assessment, or previous site-specific (i.e., for an existing project) and regional information (including for water-dependent ecosystems), should be included where applicable.

Key areas of uncertainty identified in conceptual models should be evaluated (e.g., with uncertainty analysis and targeted field programs) to inform the risk assessment. Common uncertainty factors in CSG and coal mining developments are:

- connectivity between geological formations and key water-dependent assets,
- sources of water sustaining GDEs, and
- the hydraulic properties of faults and aquitards.

These can be evaluated using a range of approaches (for example, see Murray and Power (2021; in draft) for approaches specific to faults), including coring programs, downhole logging, geophysical measurements, and environmental tracers that are selected commensurate with the risks of the project to water assets.

Baseline data should be provided and presented clearly (e.g., graphs, contour diagrams of drawdown). Proponents should specify how the baseline data have been used in the proposed project's risk assessment, the design of the monitoring program and intended evaluation of the effectiveness of mitigation strategies.

5. Monitoring and Management

Proposed management and mitigation measures should be detailed, and references provided to previous projects, case studies and scientific literature that support the adequacy and feasibility of the measure in the project context. The monitoring plan should detail how the performance and effectiveness of the proposed mitigation measures will be assessed. It should also outline contingency plans if the environmental objectives are not met. If offsets are proposed, the potential management options that were considered and investigated prior to proposing offsets should be described.

Detailed plans for ongoing monitoring and management are expected where significant impacts to water resources and water-dependent assets are predicted. These plans should focus on a robust monitoring program to inform the management and mitigation of likely impacts, and to reduce the uncertainty of predicted impacts. In particular, the monitoring plan should explain how the effectiveness of mitigation strategies will be measured.

The monitoring program should include groundwater, surface water and associated water quality, ecological attributes, and be capable of tracking changes from pre-development conditions. There is usually a need for concurrent baseline monitoring from unimpacted control and reference sites to distinguish project-induced impacts from background variation (e.g., induced by other water users and climatic variability) in the region. This can be done using a before-after-control-impact (BACI) model design (see Downes et al. (2002)).

The rationale and design for the monitoring program should be provided, including appropriate quality assurance and quality control. The questions to be answered by the monitoring program must be clearly stated, along with the temporal and spatial frequency (or resolution) of monitoring, the potential parameters and indicators to be monitored, and the analytical methods to be applied. Where methods vary from standard ones, the reasons for these differences should be explained.

The monitoring plan should specify the thresholds associated with environmental objectives and outcomes and the proposed management measures if those guideline values are exceeded. Guideline values should be based on leading-practice science (as outlined by Huynh and Hobbs (2019)). Any departures from published guidelines or standard monitoring methods should be justified based on site-specific data.

Many monitoring plans will include trigger action response plans (TARPs) that define the required actions if a threshold is exceeded or if there is some early indication from the monitoring data that an impact on a water-related asset is likely or has happened. TARPs should be simple, robust, regularly reviewed and explicitly linked to the monitoring program. The proposal should describe how each TARP is linked to one or more objectives and monitoring programs, and how – if detected – impacts will be adaptively managed.

The development of a safety case/plan produced using a method such as Features, Events and Processes (Tatomir et al. 2018) may be necessary depending on the severity of the worst-case scenario.

The proposal should specify how the strategies described in the management program address long-term risks, including those persisting after rehabilitation and relinquishment of the site.

6. Cumulative impacts

An assessment of cumulative impacts of multiple actions and stressors is needed to determine the collective impacts and risks posed by the proposed project and others within the region, coupled with other global impacts (e.g., climate change). Local-scale cumulative impact assessments should be undertaken by the proponent. These would ideally be informed by regional assessments such as strategic assessments, Cumulative Management Area models and bioregional assessments.

The assessment of cumulative impacts needs to consider all relevant past, present and reasonably foreseeable activities, including the potential impacts from water-intensive activities other than mining and CSG, and programs and policies that are likely to impact water resources. Even if potential impacts from a new project are small, when these are considered with the impacts from existing developments a threshold of acceptable total impact may be crossed. Proposals should provide robust measurements to assess whether thresholds are being approached or exceeded.

The scale of a cumulative impact assessment needs to cover spatial and temporal boundaries large enough to include all potential significant impacts on water resources from the proposed project, when considered with other activities within the region (CoA 2013; Kaveney et al. 2015). For example, when predicted impacts from the proposed development (e.g., groundwater drawdown) overlap with those from another operation, that operation will need to be included in the cumulative impact assessment.

A quantitative assessment of cumulative impacts is preferred. However, a qualitative or semi-quantitative approach may be used if data are lacking (e.g., if data for other operations are not publicly available and cannot be estimated). Assessments may also require consideration of interactive or synergistic impacts in addition to a summation of individual proposals or impacts, and their changing impacts over time.

There may be a need to further develop groundwater and surface water models to enable the prediction of cumulative impacts.

Glossary

For the purpose of the Information Guidelines:

Analytical models make simplifying assumptions (for example, properties of the aquifer are considered to be constant in space and time) to enable an exact mathematical solution of a given problem.

Assessment documentation is all documentation required by the relevant regulator to fulfil the requirements of the environmental assessment process at the relevant stage for the proposed project.

BACI design refers to impact assessment using the before-after-control-impact model. At a minimum, a BACI design requires data from two sites: a control site and an impact site. Data are collected from both sites a number of times before and after the impact occurs.

Baseline data, also called pre-operational data, are collected before a development begins to establish conditions against which impacts can be identified when developments commence.

Bioregional assessments are a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion, with explicit assessment of the potential direct, indirect and cumulative impacts of CSG and coal mining development on water resources. The central purpose of bioregional assessments is to inform the understanding of impacts on and risks to water-dependent assets that arise in response to current and future pathways of CSG and large coal mining development.

Coal seam gas development is defined under the EPBC Act as any activity involving CSG extraction that has, or is likely to have, a significant impact on water resources (including any impacts of associated salt production and/or salinity), either in its own right or when considered with other developments, whether past, present or reasonably foreseeable.

Conceptual models are pictorial or descriptive hydrological, hydrogeological and ecological representations of the project site showing the inputs, outputs, stores, flows and uses of water, including use of water by ecosystems. In the context of assessing likely impacts of a proposed project, they provide the basis for developing water and salt balances and inferring water-related ecological responses to changes in hydrology, hydrogeology and water quality. See also **Ecohydrological conceptual model.**

Cumulative impacts typically result from the collective and interacting effects of multiple stressors, and often arise from multiple sources of multiple activities. For example, collective impacts of stressors such as surface water extraction, native vegetation clearance and groundwater drawdown from several adjacent mines may combine with these and other stressors arising from nearby activities such as agriculture and urbanisation to cumulatively impact on water quality and valued environmental assets such as wetlands.

Ecological processes are part of the components that contribute to the physical state and environmental value of a water resource. Examples include nutrient cycling and carbon metabolism.

Ecohydrological conceptual models are a type of conceptual model that integrates the hydrological (surface and groundwater) components with the ecological components (e.g. specific taxa, communities and ecosystems) to show the likely pathways by which a proposed project might impact on key aspects of water resources (e.g. water quality, flow regime, biota, ecological function).

Environmental objectives for each water resource or water-dependent asset are the desired goals that, if met, will indicate that the project is not expected to have an unacceptable impact on the environment.

Environmental outcomes are statements of an acceptable level of impact to a water resource or water-dependent asset that must not be exceeded, or a level of protection that must be achieved. The outcomes will be aligned with an environmental objective and must be quantitatively measurable, auditable and achievable.

Environmental water tracers (EWTs) as defined by OWS (2020), *"are substances or properties that can be measured in surface and groundwater to better understand recharge and discharge processes and water movements. The applications for EWTs could include: surface-groundwater interaction; groundwater recharge and discharge; groundwater flow rates; groundwater flow direction; and mixing between water sources. Environmental tracers for water studies can include physico-chemical properties such as heat and electrical conductivity; gases form the atmosphere (e.g. chloroflurocarbons (CFCs)) which have dissolved in groundwater during recharge; radioisotopes derived from radioactive decay processes; and stable isotopes. EWTs may be naturally occurring or the result of human activity".*

Groundwater-dependent ecosystems (GDEs) are ecosystems that require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. GDEs include terrestrial vegetation, wetlands (swamps, lakes and rivers) and ecosystems in aquifers and caves.

Guidelines with reference to water quality are a numerical concentration limit or narrative statement recommended to support and maintain a designated water use (ANZECC/ARMCANZ 2000).

Large coal mining development is defined under the EPBC Act as any coal mining activity that has, or is likely to have, a significant impact on water resources (including any impacts of associated salt production and/or salinity), either in its own right or when considered with other developments, whether past, present or reasonably foreseeable.

Numerical models are computer codes that enable simulation of physical systems and processes such as groundwater or surface water flow and can be applied to assess the potential impacts of project. They are similar to analytical models as they make simplifying assumptions, however, features of the governing equations and boundary conditions (for example, aquifer geometry, hydrogeological properties, pumping rates or sources of solute) can be specified as varying over space and time. This enables more complex, and potentially more realistic, representation of a groundwater or surface water system than could be achieved with an analytical model.

Significant impact is defined by the Significant Impact Guidelines (CoA 2013) as an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the potentially threatened water resource, and upon the intensity, duration, magnitude and geographic extent of the impacts.

Stressor is any natural or anthropogenic physical, chemical or biological entity that can cause an impact.

Water balance is a mathematical expression of water flows and exchanges, described as inputs, outputs and changes in storage. Surface water, groundwater and atmospheric components should be included.

Water-dependent assets are entities with characteristics having value and which can be linked directly or indirectly to a dependency on water quantity and/or quality (amended from Barrett et al. 2013). Examples may include habitat for threatened species and water access rights. Value may include water-dependent ecosystems, drinking water, public health, recreation and amenity, Indigenous and cultural values, fisheries, tourism, navigation, agriculture, and industry values.

Water-dependent ecosystems are defined by the Water Act 2007 (Cth) as surface water ecosystems or groundwater ecosystems, and their natural components and processes, that depend on periodic or sustained inundation, waterlogging or significant inputs of water for their ecological integrity and includes ecosystems associated with a wetland, stream, lake or waterbody, salt marsh, estuary, karst system or groundwater system. A reference to a water-dependent ecosystem includes the biodiversity of the ecosystem.

Water resources are defined by the *Water Act 2007* (Cth) as:

> *"surface water or groundwater or a watercourse, lake, wetland or aquifer (whether or not it currently has water in it); and includes all aspects of the water resource, including water, organisms and other components and ecosystems that contribute to the physical state and environmental value of the water resource".*

Broadly, a water resource encompasses the water body itself and all aspects that contribute to its physical state and environmental value, such as the associated water quality, organisms, ecological processes and ecosystems.

Checklist of specific information needs

The following checklist provides specific guidance on IESC information needs. This checklist reflects the approach taken by the IESC when assessing project documentation.

The checklist does not stand alone. It should be considered in addition to the general guidance provided in the main body of the Information Guidelines and any Explanatory Notes available on the IESC website.

A project may not need to address all items included in the checklist. For example, a coal mining proposal will not need to address the parts of the checklist related to CSG well construction and operation while a CSG proposal will not need to address the voids and landforms section. Proponents should provide justification and any supporting data and information if not addressing any sections of the checklist.

The IESC recognises that at the early assessment stage – for example, Gateway projects in New South Wales – project documentation may not contain enough data to allow a robust environmental impact assessment. In cases where data and analyses are lacking, it is essential to present a sound conceptualisation of the system, with explicit explanations of underlying assumptions. The proposal must also provide plans to improve the understanding of the system over time, including details of when and how data to support assumptions will be gathered.

Description of the proposal	
☐ Provide a regional overview of the proposed project area including a description of the geological basin; coal resource; surface water catchments; groundwater systems; water-dependent assets; and past, present and reasonably foreseeable coal mining and CSG developments.	☐ Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.
☐ Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies or regulations	☐ Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.
Risk Assessment	
☐ Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk assessment approach consideration should be given to the complexity of the project, and the probability and potential consequences of risks.	☐ Incorporate causal mechanisms and pathways identified in the risk assessment in conceptual and numerical modelling. Use the results of these models to update the risk assessment.
☐ Assess residual risks following the implementation of any proposed mitigation and management options to determine if these will reduce risks to an acceptable level based on the identified environmental objectives.	☐ The risk assessment should include an assessment of: – all potential cumulative impacts that could affect water resources and water-related assets, and

	– effectiveness and feasibility of mitigation and management options that the proponent could implement to reduce these impacts.
Groundwater	
Context and conceptualisation	
☐ Describe and map geology at an appropriate level of horizontal and vertical resolution including: – definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data. – geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace (e.g. Murray and Power 2021 in draft).	☐ Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide these data should have been surveyed.
☐ Define and describe or characterise significant geological structures (e.g., faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. – Site-specific studies that are appropriate for the fault scenario and risks to water assets (e.g., geophysical, coring/wireline logging) should consider characterising and detailing the local stress regime and fault structure (e.g., damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays). See Murray and Power (2021; in draft) for further information. – Discussion of each fault's potential influence on regional-scale groundwater conditions.	☐ Provide hydrochemical (e.g., acidity/alkalinity, electrical conductivity, metals, and major ions) and a suitable suite of environmental tracers commensurate with the risks of the project to water assets (e.g., heat, stable isotopes of water, tritium, helium, strontium isotopes) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations. See for example OWS 2020.
☐ Provide site-specific values for hydraulic parameters (e.g., vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	☐ Describe the likely recharge, discharge, and flow pathways for all hydrogeological units likely to be impacted by the proposed development.
☐ Provide time series level and water quality	☐ Assess the frequency (and time lags if any),

data representative of seasonal and climatic cycles.	location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.
Analytical and numerical modelling	
☐ Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g., expert opinion, analogue sites) employed in addition to modelling.	☐ Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.
☐ Undertaken groundwater modelling in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012), including independent peer review.	☐ Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.
☐ Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g., use baseflow calibration targets where predicting changes to baseflow).	☐ Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters 2018).
☐ Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and hydraulic connectivity between units, if any. Appropriate modelling approaches should be considered for geological fault scenarios that are a risk to water assets (see Murray and Power 2021 in draft).	☐ Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.
☐ Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	☐ Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters 2018).
☐ Describe the various stages of the proposed project (construction, operation, and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	☐ Provide a program for review and update of models as more data and information become available, including reporting requirements.
☐ Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	☐ Provide information on the magnitude and time for maximum drawdown and post-development groundwater level recovery equilibrium to be reached.

<table>
<tr><td>☐ Undertake model verification with past and/or existing site monitoring data.</td><td>☐ Provide information on the climate change considerations in sensitivity analysis.</td></tr>
<tr><td colspan="2">Impacts to water resources and water-dependent assets</td></tr>
<tr><td rowspan="6">☐ Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe:
– any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.
– the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance.
– the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.
– the possible fracturing of and other damage to confining layers.
– For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.</td><td>☐ Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.</td></tr>
<tr><td>☐ For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.</td></tr>
<tr><td>☐ Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g., water planning rules) for the groundwater basin(s) within which the development proposal is based.</td></tr>
<tr><td>☐ Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.</td></tr>
<tr><td>☐ Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.</td></tr>
<tr><td>☐ Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.</td></tr>
<tr><td colspan="2">Data and monitoring</td></tr>
<tr><td>☐ Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.</td><td>☐ Provide descriptive statistics (ranges, standard deviations and other summary statistics) of long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.</td></tr>
<tr><td>☐ Develop and describe a robust groundwater</td><td>☐ Ensure water quality monitoring complies with</td></tr>
</table>

monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	relevant National Water Quality Management Strategy (NWQMS) guidelines and relevant legislated state protocols (e.g., QLD Government 2018).
☐ Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs and the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system.	
Surface water	
Context and conceptualisation	
☐ Describe the hydrological regime of all watercourses, standing waters and surface-expression GDEs (e.g., springs) across the site including: – geomorphology, including drainage patterns, sediment regime and floodplain features – spatial and temporal (seasonal) trends in streamflow and/or standing water levels – spatial and temporal (seasonal) trends in water quality data (such as turbidity, acidity, salinity, pH, major ions, sulfate, relevant organic chemicals, metals, metalloids and radionuclides), and – current stressors on watercourses, including impacts from any currently approved projects.	☐ Describe the existing flood regime, including flood volume, depth, duration, extent, and velocity for a range of annual exceedance probabilities, including scenarios up to the probable maximum flood. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that have been acquired using LiDAR or other reliable survey methods with accuracy stated. ☐ Provide an assessment of the frequency, volume, seasonal variability, and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.
Analytical and numerical modelling	
☐ Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	☐ Describe and justify model assumptions and limitations and calibrate with appropriate surface water monitoring data (e.g., see Nathan and McMahon 2017).
☐ Use methods in accordance with the most recent publication of *Australian Rainfall and Runoff* (Ball et al. 2019) and consider relevance of regional information (see Nathan and McMahon 2017).	☐ Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios which considers climate change.
☐ Develop and describe a program for review	☐ Provide a detailed description of any methods

and update of the models as more data and information becomes available.	and evidence (e.g., expert opinion, analogue sites) employed in addition to modelling.
Impacts to water resources and water-dependent assets	
☐ Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider: – impacts on streamflow under the full range of flow conditions. – impacts associated with surface water diversions. – impacts to water quality, including consideration of mixing zones. – the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets. This is particularly useful when multiple stressors and mixtures of contaminants in the discharge may have cumulative effects on aquatic biota. – landscape modifications such as subsidence, voids, post rehabilitation landform collapses, on-site earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	☐ Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based. ☐ Identify processes to determine site-specific surface water quality guidelines (e.g., see Huynh and Hobbs 2019) and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets ☐ Propose mitigation actions for each identified significant impact. ☐ Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets. ☐ Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and reasonably foreseeable) are considered in combination. ☐ Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.
Data and monitoring	
☐ Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	☐ Develop and describe a surface water monitoring program that will collect sufficient spatial and temporal data for water and sediments (where sediment contamination is material) to detect and identify the cause of any changes from established baseline conditions, and assess the effectiveness of mitigation and management measures. The program should: – include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g., metals and metalloids)

	– Entail comparison of physico-chemical data to national/regional guidelines or to site-specific guidelines derived from reference condition monitoring if available (Huynh and Hobbs 2019), and – identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.
☐ Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZG 2018) and relevant legislated state protocols.	☐ Describe the rationale for selected monitoring parameters, duration, frequency, and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.
☐ Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and describe data methods, including whether missing data have been patched.	☐ Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate. ☐ Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.
Water-dependent assets	
Context and conceptualisation	
☐ Identify water-dependent assets, including: – water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna, see Doody et al. 2019). – public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	☐ Estimate the ecological water requirements of identified GDEs (see Doody et al. 2019) and other water-dependent assets. ☐ Identify the hydrogeological units on which each identified GDE is dependent.
☐ Identify GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox (Richardson et al. 2011) and GDE Atlas (CoA 2017a) may assist in identification of GDEs (see Doody et al. 2019).	☐ Describe and justify the process employed to determine water quality and quantity impact thresholds for water-dependent assets (e.g., threshold at which a significant impact on an asset may occur).
☐ Provide an ecohydrological model to describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance, and resilience of water-dependent assets. Examples can be found in Commonwealth of Australia (2015).	
Impacts, risk assessment and management of risks	

☐ Provide an assessment of direct and indirect impacts on water-dependent assets, including flora and fauna dependent on surface water and/or groundwater.	☐ Provide estimates of the volume, beneficial uses and potential impacts of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.
☐ Describe the potential range of drawdown at each affected bore, and clearly articulate the scale of impacts to other water users.	☐ Assess the overall level of risk to water-dependent assets through combining probability of occurrence with the predicted intensity, duration, magnitude and geographic extent of the impacts.
☐ Indicate the vulnerability to contamination (e.g., from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	☐ Identify the proposed acceptable level of impact for each water-dependent asset based on the most appropriate methods and site-specific data, and ideally developed in conjunction with stakeholders.
☐ Identify and consider landscape modifications (e.g., voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	☐ Propose effective mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.
Data and monitoring	
☐ Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions	☐ Baseline data (ideally a minimum of two years) on water-related assets within the project area should be acquired for a sufficient number of sites to provide reliable estimates of the composition and 'health' (e.g. condition, ecological integrity) of the assets that may be impacted by the project, including after operations cease. These data should then be used to inform the development of future monitoring programs that are able to detect ecological responses of water-dependent biota to potential impacts of the project. Sampling approaches should match those used to collect baseline data to enable direct comparisons. The program should enable, evaluation of the effectiveness of impact prevention or mitigation strategies and detect whether ecological responses are within identified thresholds of acceptable change (see Doody et al. 2019).
☐ Collect monitoring data from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g., BACI design, see Doody et al. 2019).	☐ Describe the proposed process for regular reporting, review and revisions to the monitoring program.
	☐ Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g., the DSITI guideline for sampling stygofauna (QLD Government 2015)).

☐ In some cases (e.g., where drawdown is predicted below potential terrestrial GDEs), direct field measurements of groundwater use (examples of methods in Doody et al. 2019 and Jones et al. 2019) may be needed as evidence to support claims about the likelihood and consequences of impacts from the project.	☐ Consider using metagenomic approaches such as environmental DNA (eDNA) to characterize ecological communities in surface and groundwaters (Deiner et al., 2017; Ruppert et al., 2019). These genomic techniques have many advantages over current field sampling methods and are rapidly becoming cheaper and more feasible for routine monitoring.
Water and salt balance, and water quality	
☐ Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g., dust suppression, coal washing etc.), including all sources and uses.	☐ Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.
☐ Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	☐ Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation.
Cumulative Impacts	
Context and conceptualisation	
☐ Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts (e.g. see Kaveney et al. 2015). ☐ Provide an ecohydrological conceptual model that includes potential sources, stressors and pathways that contribute to cumulative impacts.	☐ Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment, consider the results of the bioregional assessment.
Impacts	
☐ Provide an assessment of the condition of affected water resources which includes: – identification of all water resources likely to be cumulatively impacted by the proposed development – a description of the current condition and quality of water resources and information on condition trends – identification of ecological characteristics, processes, conditions, trends and values of water resources, and – adequate water and salt balances.	☐ Assess the cumulative impacts to water resources considering: – the full extent of potential impacts from the proposed project (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally – all stages of the development, including exploration, operations and post closure/decommissioning

	– appropriately robust, repeatable and transparent methods for estimating cumulative impacts – the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts, and – opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.
Mitigation, monitoring and management	
☐ Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g., case studies) should be provided.	☐ Identify cumulative impact environmental objectives.
☐ Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	☐ Describe appropriate reporting mechanisms. ☐ Propose and justify thresholds, adaptive management measures and management responses.
Subsidence – underground coal mines and coal seam gas	
☐ Provide predictions of subsidence impact on surface topography, water-dependent assets, groundwater (including enhanced connectivity between aquifers) and the movement of water across the landscape (CoA 2014b; CoA 2014c). Consider multiple methods of predictions and apply the most appropriate method, for example, to predict height of fracturing and drainage above coal excavation. Consider the limitations of each method, including the adequacy of empirical data and site-specific geological conditions and justify the selected method.	☐ Describe subsidence monitoring methods, including the use of remote or on-ground techniques and explain the predicted accuracy of such techniques, particularly for coal seam gas and mining projects in areas of soils with shrink-swell properties. Monitoring methods that detect the depth and significance of near-surface fracturing should be provided for all underground coal mines, particularly for wetlands with sediment covering a rock base that may fail due to subsidence. Monitoring methods to verify the predicted height of fracturing and drainage above coal seams should be provided for types of underground mining with a high proportion of coal extraction and caving behaviour.
☐ Provide an assessment of both conventional and unconventional subsidence. For project expansions, an evaluation of past or current effects of geological structures on subsidence and implications for water resources and water-dependent assets should be provided.	☐ Consider geological strata and their properties (strength/hardness/fracture propagation) in the subsidence analysis and/or modelling. Anomalous and near-surface ground movements with implications for water resources and compaction of unconsolidated sediment should also be considered.
Final landform and residual voids – coal mines	
☐ Identify and consider landscape modifications (e.g., residual voids, on-site earthworks, and	☐ Provide an assessment of the long-term impacts to water resources and water-dependent assets

roadway and pipeline networks) and their potential effects on surface water flow, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	posed by various options for the final landform design, including complete or partial backfilling of mining residual voids. Assessment of the final landform for which approval is being sought should consider: – groundwater behaviour – sink or lateral flow from void. – water level recovery – rate, depth and stabilisation point (e.g., timeframe and level in relation to existing groundwater level, surface elevation). – seepage – geochemistry and potential impacts. – long-term water quality, including salinity, pH, metals and toxicity. – measures to prevent migration of void water off-site. For other final landform options considered, sufficient detail of potential impacts should be provided to clearly justify the proposed option.
☐ Assess the adequacy of modelling, including surface water and groundwater quantity and quality, void pit lake behaviour, timeframes and calibration.	
☐ Provide an evaluation of stability of residual void slopes where failure during extreme events or over the long term (for example, due to aquifer recovery causing geological heave and landform failure) may have implications for water quality.	
☐ Evaluate mitigating inflows of saline groundwater by planning for complete or partial backfilling of residual voids.	☐ Assess the probability of residual voids overtopping (e.g., due to climatic extremes) and describe appropriate management options.
Acid-forming materials and other contaminants of concern	
☐ Identify the presence and potential exposure of acid-sulphate soils (including oxidation from groundwater drawdown).	☐ Describe handling and storage plans for acid-forming material (co-disposal, tailings dams and encapsulation).
☐ Identify the presence and volume of potentially acid-forming waste rock, fine-grained amorphous sulphide minerals and coal reject/tailings material and exposure pathways.	☐ Assess the potential impact to water-dependent assets, taking into account dilution factors, and including solute transport modelling where relevant, representative and statistically valid sampling, and appropriate analytical techniques.
☐ Identify other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths. These sources could include coal, waste rock and tailings. Geochemical assessment of waste rock and tailings could include both static leachate tests and column leachate tests (to determine released contaminants over time).	☐ Describe proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.
CSG wells - drilling, hydraulic stimulation and associated activities	
☐ Describe the scale of fracturing (number of wells, number of fracturing events per well), types of wells to be stimulated (vertical versus horizontal) and other forms of well stimulation	☐ List the chemicals proposed for use in drilling and hydraulic stimulation including:

(cavitation, acid flushing).	– names of the companies producing fracturing fluids and associated products – proprietary names (trade names) of compounds (fracturing fluid additives) being produced – chemical names of each additive used in each of the fluids – Chemical Abstract Service (CAS) numbers of each of the chemical components used in each of the fluids – general purpose and function of each of the chemicals used – mass or volume proposed for use – maximum concentration (mg/L or g/kg) of the chemicals used – chemical half-life data, partitioning data, and volatilisation data – ecotoxicology, and – any material safety data sheets for the chemicals or chemical products used.
☐ Describe proposed measuring and monitoring of fracture propagation.	
☐ Identify water source for drilling and hydraulic stimulation, and outline the volume of fluid and mass balance (quantities/volumes).	
☐ Describe the rules (e.g., water sharing plans) covering access to each water source used for drilling and hydraulic stimulation and how the project proposes to comply with them.	
☐ Quantify and describe the quality and toxicity of flowback and produced water and how it will be treated and managed.	
☐ Assess the potential for inter-aquifer leakage or contamination.	
☐ The use of drilling and hydraulic fracturing chemicals should be informed by appropriately tiered deterministic and/or probabilistic hazard and risk assessments, based on ecotoxicological testing consistent with Australian Government testing guidelines (see CoA 2012; MRMMC-EPHC-NHMRC 2009).	☐ Chemicals for use in drilling and hydraulic fracturing must be identified as being approved for import, manufacture or use in Australia (that is, confirmed by AICIS as being listed in the Industrial Chemical Inventory (see CoA 2020)).
☐ Propose waste management measures (including salt and brines) during both operations and legacy after closure.	

Supporting documents

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