Submission regarding implications for groundwater from the *Mineral Resources (Galilee Basin) Amendment Bill 2018*

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[redacted]

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To the Committee Secretary,

This document outlines technical, scientific and management issues associated with groundwater, which would likely be affected by the passage of the *Mineral Resources (Galilee Basin) Amendment Act 2018.*

My background and expertise

My background is in the discipline of hydrogeology. I hold a PhD in Geosciences, awarded by Monash University, and I am currently an Associate Professor in Environmental Engineering at RMIT University. I am the Program Manager for environmental engineering and have taught courses in hydrogeology and environmental engineering to civil and environmental engineering students for the past eight years. Since 2013, I have conducted extensive work as an independent hydrogeology expert for non-government and government organisations, including parliamentary inquiries into coal seam gas and other resource development activities with impacts on groundwater. I have published over 40 peer-reviewed articles in top international journals about the science and management of groundwater, including papers examining the impacts of coal and gas projects, and the policies used to regulate these activities. Between 2014 and 2017 I served on the editorial board of the *Hydrogeology Journal* and have been a member of the Victorian branch committee of the International Association of Hydrogeologists for more than 5 years.

Overall summary

The prevention of coal mining development in the Galilee Basin, including termination of current coal mining licenses, would have multiple beneficial effects on the region's aquifers, groundwater users and groundwater dependent ecosystems.

Hydrogeological investigations, including groundwater modelling that have been conducted as part of the assessments for individual coal mining projects, as well as cumulative modelling of multiple coal mines, indicate that widespread impacts on groundwater will occur if the mines proceed. These include:

-A cumulative area impacted by significant groundwater drawdown (more than 1m) exceeding the area of Tasmania (in the units targeted by mining)[1]

[1] Turvey et al., 2015

-Significant areas (thousands of square kilometres) in which drawdown will occur in the lower aquifers of the Great Artesian Basin – Australia's largest connected system of confined aquifers[2]

-Loss and/or potential damage to springs (due to reduced groundwater discharge), and ecological and cultural values associated with these[3];

-Impacts on streams due to increased leakage to the underlying groundwater system and/or reduced baseflow[4];

-Interference with bores extracting water from the basin (e.g., those utilized to support cattle grazing operations)[5]

-Long term water quality and quantity impacts associated with mine voids, tailings dams and other mine infrastructure.

There is also a significant degree of uncertainty regarding the precise nature and magnitude of many of the impacts associated with the proposed mines on groundwater, water users and connected surface water systems and springs[6]. Despite these uncertainties being identified years ago, and some efforts to resolve them (for example through the work commissioned under the Galilee sub-region Bioregional Assessment), conclusive resolution has yet to be achieved in many instances. This is in part due to the inherent difficulty of making accurate predictions of the impacts of large-scale mining operations on groundwater in 'greenfields' areas. However, it is also due to a general unwillingness by the proponents of coal mining projects in the region (to date) to conduct rigorous and detailed scientific studies, based on spatially and temporally comprehensive baseline datasets and other field investigations[7].

In this context, passage of the bill would provide certainty to water users and those who value the cultural and ecological attributes of groundwater dependent ecosystems of the region, that these will remain un-harmed by coal mining development into perpetuity.

[2] Ibid.
[3] Lewis et al., 2018
[4] Ibid.
[5] Turvey et al. 2015, Lewis et al., 2018
[6] Lewis et al., 2018.
[7] Currell et al., 2017; IESC, 2012; IESC, 2013; Land Court of Queensland, 2014; Land Court of Queensland, 2015.

1. Importance & value of groundwater in the region

Groundwater in the region targeted for coal mining in the Galilee Basin and adjacent affected areas is important for supporting people's lives and livelihoods, as well as ecological communities which are of high environmental and cultural significance. While not intensively utilised for farming in comparison to other areas, the groundwater resources in central Queensland nonetheless serve as important water supplies to graziers and towns in the region[8], and this is particularly significant given the relative lack of other available water sources, such as permanent surface water sources. For example, the Land Court of Queensland examined the possible impacts of the Alpha coal mine in response to court action brought by graziers in the area who depend on groundwater. It concluded that the potential risks to groundwater from the project and uncertainty regarding these impacts warranted rejection of the mine, or at the least modifications to the conditions attached to its Environmental Authority and Mining Lease[9]. A significant number of bores are likely to be affected if the proposed mining projects proceed (see below).

Springs, which are natural surface expressions of groundwater discharge to the landscape, are also of great ecological and cultural significance in the Galilee Basin. This is particularly true of the Doongmabulla Springs Complex, a complex of over 180 wetlands, where it has been determined there is a significant probability of some level of detrimental impact due to proposed mining development[10]. The Wangan and Jagalingou People describe the Doongmabulla Springs as their most important cultural site[11], and the springs provide habitat for rare and endangered ecological communities, including an unusually large number of endemic species, found nowhere else in the world[12].

Streams in the Galilee Basin are typically ephemeral (flowing only at certain times of the year) and those which are permanent depend on groundwater discharge. The low rainfall and limited permanent surface water mean that the surface water features of the basin are particularly vulnerable to hydrological changes arising as a result of drawdown and water balance changes.

All of these values and functions associated with the groundwater systems of the Galilee Basin stand to be impacted on a large scale due to the proposed mines. The sections below examine the current knowledge regarding the likely extent of these impacts.

2. Assessment of groundwater impacts of Galilee Basin coal mines to date

Assessment of groundwater impacts from proposed (including approved) coal mines in the Galilee Basin has been conducted to various degrees by the mining companies involved as part of their environmental impact statements and for various other approval processes. Most of these assessments have involved groundwater modelling, to investigate the likely magnitude, timing and spatial extent of groundwater drawdown. The models have made assumptions (as is generally required) regarding the nature of the geology in the basin, including the hydraulic parameters and degree of connectivity between aquifers and surface hydrological features. Rigorous independent scrutiny of these mine hydrogeological studies (for example, those completed for Adani's Carmichael Coal Mine and Hancock GVK's Alpha mine) uncovered a lack of conclusive field data and some questionable assumptions

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[8] Evans et al., 2018

[9] Land Court of Queensland, 2014.

[10] Evans et al., 2018.

[11] See: https://sacredland.org/doongmabulla-springs-australia/

[12] Fensham et al., 2016.

underpinning the models. For example, the scientific basis for presuming minimal effect of the Carmichael mine on the Doongmabulla Springs Complex was found to be dubious[13].

The Independent Expert Scientific Committee for Large Coal Mining and Coal Seam Gas (IESC) also assessed many of the mining applications. The IESC determined that much of the modelling associated with the individual projects has been based on insufficient baseline data and site-specific field studies required to make confident predictions of impacts. The gaps in field data (many of which are yet to be filled) have implications for the magnitude of possible impacts on groundwater, surface water and GDEs in the basin. For example, in relation to the Carmichael mine, the IESC concluded:

> "*Regional Faults:* The conceptual model would benefit from an assessment of regional faults. The proponent's groundwater model does not take into consideration the influence of faulting within the Rewan Formation. The Committee notes that faults have been identified on the eastern boundary of the Galilee Basin within the Rewan Formation in other project proposals, but their potential role on groundwater flow processes has not been considered in this project.
>
> *Subsidence Fracturing:* The assessment of the height of the subsidence fracture zone above longwall mining was not based on local site data nor with due consideration of multi-seam mining. The draft SEIS notes that these factors are significant and may result in underestimation of the fracture zone height above longwall mining. Likewise the connectivity of the fracture network and the relative increase in hydraulic conductivity of strata within this zone needs verification. Subsidence fracture zone height and hydraulic connectivity could have implications for the GAB and surface water resources."

The IESC also pointed out that the individual project assessments generally neglected to properly consider cumulative impacts of multiple projects in the region[14]. Subsequent modelling has been conducted which helps provide a better indication of the degree of some of the cumulative groundwater and surface water impacts of seven proposed coal mines in the basin. The Bioregional Assessment of the Galilee Basin sub-region was recently published, examining cumulative drawdown impacts resulting from future coal mining, within a simplified representation of the geological sequence[15]. The methodology adopted to model groundwater impacts (analytic element modelling) was capable of predicting changes in water levels at a regional scale as a result of mining. However, the approach has limitations, in that it does not produce detailed future water balances or water level patterns as mining progresses. Such information is important for comprehensively understanding possible changes in the amount of groundwater discharging to springs and groundwater-surface water interactions. Modelling conducted by HydroSimulations in 2015[16] did allow for predictions of water balance changes (e.g. discharge of groundwater to surface water and inflow of groundwater to mine pits). However, this modelling did not explicitly model springs or assess the impact of water balance changes (as distinct from drawdown) on these. This model was also unable to conduct any uncertainty analysis or in-depth sensitivity analysis.

[13] Currell et al., 2017
[14] IESC, 2012; IESC, 2013
[15] For the outcome synthesis, see Evans et al., 2018.
[16] Turvey et al., 2015

In both cases, little further collection of field data (e.g. new drilling campaigns or geophysical work) was conducted in association with the modelling, and as such the models potentially contain significant conceptual uncertainty. These limitations should be understood when assessing the nature of the predicted impacts on groundwater discussed below.

3. Drawdown and Bore interference impacts

The Bioregional Assessment modelling estimated the extent of the area which would be likely to experience drawdown of various magnitudes (0.2, 2 and 5m) as a result of coal resource development. The modelling estimated that seven approved mines (Hyde Park, China Stone, Carmichael, South Galilee, Alpha, Kevin's Corner and China First) would result in an area affected by groundwater drawdown of more than 14,000 km^2. Importantly, this does not include consideration of the Alpha North project, which has more recently commenced an application for approval. This mine would link the drawdown caused by the seven other mines, which would otherwise form two discrete areas in the southern and northern Galilee Basin (see figure below). The Bioregional Assessment also concluded that in the shallow, unconfined aquifers of the region, it is very likely that an area exceeding 1500 km^2 will experience more than 2m of drawdown. This level of drawdown would be expected to have a significant effect on any surface water bodies in the region.

Drawdown impacts in the lower Great Artesian Basin aquifers (e.g. Clematis Sandstone) and Permian units (targeted by the mines) were also examined in the Bioregional Assessment modelling, although it is unclear from the reporting what the total extent of the predicted areas of drawdown of a given magnitude is in these layers.

The cumulative impact modelling conducted by Hydrosimulations in 2015, incorporated the mine plans from the same seven approved mines and adopted a different methodology (fully saturated groundwater flow model). In this modelling, drawdown in the lower Great Artesian Basin (Clematis Sandstone layer) is predicted to extend over two areas each approximately 40 by 50 km, near the southern and northern mine clusters, respectively. Testing of a scenario in which the vertical hydraulic conductivity was increased (considered plausible in light of a lack of detailed field evidence), resulted in these two areas of drawdown linking, creating a continuous zone of approximately 300 by 50 km (see figure below). In addition, the area affected by drawdown within the units targeted by mining – the Permian sequence – is estimated to exceed 80,000 square kilometres (larger than the land area of Tasmania).

In terms of impacts on groundwater bores, the Hydrosimulations modelling also predicted that between 89 and 126 registered bores are likely to be impacted by significant drawdown, ranging in magnitude from 1m to 53m[17]. This is a significant number of bores in an area with few viable alternative water sources.

[17] Turvey, 2015. The range represents the results derived from the 'base case' model, and the 'sensitivity' test case, whereby vertical hydraulic conductivity was increased by a factor of 10 in key layers (a not implausible scenario given uncertainty over these conductivity values).

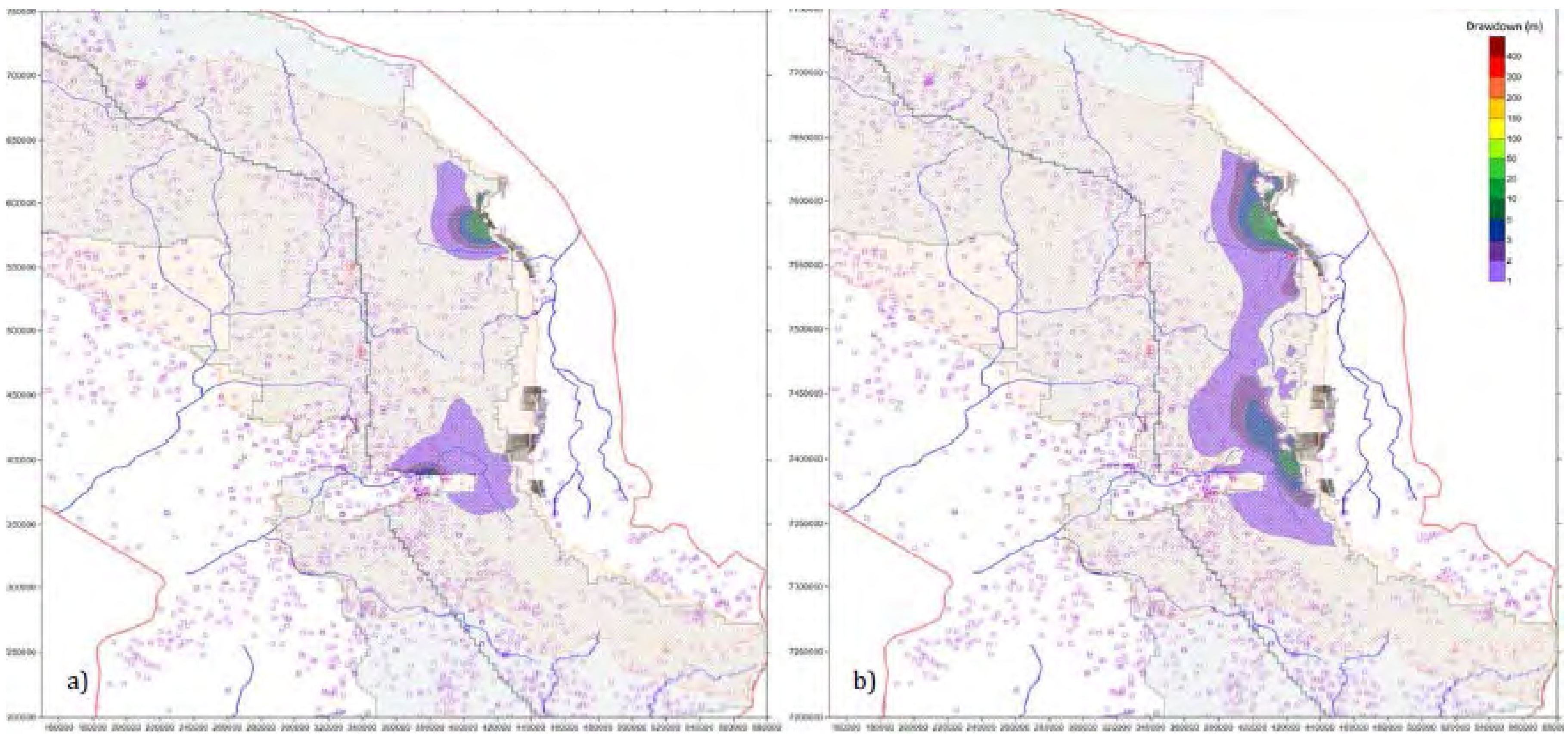

Figure 6-3 Maximum predicted drawdown in Layer 8 (Clematis Sandstone) for a) Base Case and Sensitivity #2 (no TVM) and b) Sensitivity#1 –increased K_z

Figure source: Turvey et al., 2015.

4. Changes to water balances

The Bioregional Assessment modelling utilised a methodology that did not allow for detailed assessment of changes to the regional or local water balances. The modelling discussed below is instead based on that conducted by Hydrosimulations:

Combined groundwater inflow to the seven modelled mine pits is estimated to average approximately 238 megalitres (ML) per day over the course of mining. To contextualise this number, the average groundwater abstraction rate throughout the Galilee Basin between 1983 and 2012 was approximately 613 ML/day[18]. This would mean the mines would effectively increase groundwater abstraction in the region by 35 to 40%. The water inflows into the mines would need to be captured during or (more likely) before the progression of mining, through de-watering infrastructure such as borefields and drains. There is hence the prospect of significant changes to the regional water balance, with implications for groundwater and connected surface water systems. Currently, the groundwater which would be abstracted during mining circulates within the deep aquifers of the basin, contributing to:

a) groundwater in storage, available for utilisation by current and future water users;
b) discharge of water to connected aquifers and ultimately, surface water systems including streams and springs.

Detailed studies of the effects of groundwater extraction in the United States have shown that in general, a large proportion of the groundwater abstracted through pumping is ultimately sourced from the 'capture' of water which would otherwise discharge as surface water at springs and streams[19]. This proportion increases over time as groundwater is extracted (e.g., over the life of a mining operation), in accordance with the foundational work of Theis, (1940). The implication is that given the long time period over which mining and associated groundwater extraction would occur in the Galilee Basin across multiple projects, a significant proportion of the groundwater inflows captured by mining would otherwise be providing flows that support surface water systems (springs and streams) in the region.

Operators of the mines such as the Carmichael project, have been granted an associated water license that allows effectively unlimited extraction of groundwater for de-watering purposes. Hence, if the mine operators find that in practice higher than predicted volumes of water are required to be removed in order to mine, there would be no practical mechanism available to prevent additional impacts associated with resulting water balance changes, should these be of greater magnitude than currently predicted.

5. Impacts on streams, springs and groundwater dependent ecosystems

The Bioregional Assessment modelling indicated that there was a significant possibility of a reduction in groundwater baseflow in streams over large areas of the basin:

> "In the zone [impacted by mining development], 8% of the 2801 km of groundwater-dependent streams show some level of risk of ecological and hydrological changes (Box 10), including parts of Native Companion, North and Sandy creeks, and the Belyando and Carmichael rivers[20]"

[18] Turvey et al, 2015.
[19] Konikow and Leake, 2014
[20] Evans et al, 2018

The same modelling also indicated that there was a risk of drawdown occurring at 188 known spring wetlands in the basin, 181 of which are part of the Doongmabulla Springs Complex[21]. This complex supports multiple threatened and endangered ecological communities and has been acknowledged for its extraordinary ecological significance[22].

While the Bioregional Assessment modelling predicts that drawdown in the aquifers feeding the various Doongmabulla Spring wetlands is generally likely to be less than 0.2m, it is clearly documented that drawdown of such magnitudes can constitute an existential threat to the survival of springs in this and other settings[23]. This is due to the fine balance between groundwater hydraulic head levels, flow directions and the shape of the land surface[24]. There is also ongoing uncertainty (acknowledged in the Bioregional Assessment) regarding the source aquifer of these springs[25]. If, as is still considered a plausible scenario, the springs receive a component of their flow from an aquifer below the Rewan Formation (which has been assumed to act as an aquitard without strong conclusive field evidence), mining would most likely result in catastrophic impacts to these springs (loss of multiple wetlands and the species they support)[26].

Mining in the region will also result in the complete loss of the Mellaluka Springs and their associated ecological communities, as they depend on discharge from the Permian strata targeted by mining. In the context of many springs throughout the arid and semi-arid parts of Australia having been lost over the past 100 years[27], the loss of these springs will further erode the natural ecological, cultural and hydrogeological values of the country. Additional possible impacts on springs dependent on discharge from the Hooray Sandstone and Clematis Sandstone were also flagged in the Hydrosimulations modelling but these impacts have not been investigated in detail.

6. Mine voids and rehabilitation

The permanent legacy impacts created by the excavation and eventual abandonment of hundreds of kilometres of mine pits will create permanent hydrological changes, significant potential water quality risks, and impact environmental and cultural values of the region forever. Following closure of the Galilee Basin coal mines, groundwater levels will eventually begin to rise. This will likely result in the formation of pit lakes within the many resulting mine voids, which in many cases are not proposed to be fully back-filled[28]. Such pit lakes typically develop into saline, poor quality water bodies, which may then:

a) represent an ongoing environmental risk to the nearby environment, through surface and sub-surface leakages, and/or:
b) create permanent sinks for groundwater flow from the surrounding aquifers, preventing restoration of pre-development groundwater conditions

The significance of the issue of mine rehabilitation has been acknowledged by the Queensland Government, and has been examined in detail during recent and ongoing reforms

[21] Ibid.
[22] Land Court of Queensland, 2015; Fensham et al., 2016a
[23] Land Court of Queensland, 2015.
[24] Currell, 2016.
[25] Lewis et al., 2018
[26] Currell et al., 2017.
[27] Fensham et al., 2016b.
[28] E.g., GHD and Adani Mining, 2013.

of the relevant legislation[29]. However, due to the timing of the granting of environmental authorities for Galilee Basin mines and the legislation, it appears that approved mines such as the Carmichael project will not be subject to the new best-practice requirements[30]. As such, the nature of the legacy impacts and the risks these create will be substantial and will not be addressed within a modern best-practice framework.

I would be happy to further discuss and/or elaborate on any of the issues contained in this submission.

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[29] Queensland Government, 2017.
[30] See: https://www.edoqld.org.au/finally_new_mine_rehab_and_financial_assurance_laws_passed_in_qld

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