

Draining the Life-blood: Groundwater Impacts of Coal Mining in the Galilee Basin



Hydrocology
Environmental
Consulting

In consultation with
Tom Crothers - Stellar Advisory Services



23 September 2013

Front Cover images:

Alpha Test Pit aerial - Greenpeace/Andrew Quilty

Belyando Crossing

Cattle north of Belyando Crossing

Back Cover images:

Ensham mine, Bowen Basin

Belyando Crossing

Emus in a Galilee Basin river channel

Greenpeace images as credited - all other images courtesy Kate Ausburn, Boudicca Cerese and Ellie Smith.

Contents

Executive Summary	5
Impacts outlined in this report	7
Where to from here	9
1: Introduction	10
2: Background	14
2.1 The Galilee Basin geology	14
2.2 Water demand of Galilee coal projects	15
2.3 Galilee Basin aquifers and aquitards	18
2.4 Mining methods proposed for Galilee coal mines	22
2.5 Queensland groundwater regulation	27
2.6 Environment Protection Biodiversity Conservation Act 1999	29
3: Groundwater impacts of Galilee mine proposals	30
3.1 Impacts on the Great Artesian Basin	32
3.2 Scale and impact of mine dewatering	35
3.3 Impacts on groundwater discharge	39
3.4 Impact on aquifer recharge and cross-formation flow	42
3.5 Town and property impacts	44
4: Conclusion	49
References	51
Appendices	54
Appendix 1: Galilee Exploration Permits for Coal	54
Appendix 2 Rainfall data	56



Belyando River, Galilee Basin

Executive Summary

The series of coal mines proposed for Queensland's Galilee Basin, on the edge of Great Artesian Basin recharge beds, stand to have a significant impact on the region's groundwater resources, yet these risks have to date not been sufficiently assessed, and are therefore poorly understood. This report analyses assessment documents prepared by five coal mine proponents, projects additional impacts of a further four proposed mines and finds that, together, the coal mines proposed for the Galilee Basin have the potential to cause permanent and unacceptable impacts on regional groundwater and surface water resources. It is therefore argued that a regional, cumulative impact assessment of the full set of proposed mines be carried out prior to any further approvals being granted, to properly assess the risk of these potentially major impacts on the Basin's water resources .

The potential impact on surface water in the Belyando River catchment as a result of the groundwater interference of the mines, is also poorly understood by both the Queensland and Federal Governments responsible for protecting water resources. A companion report on the impacts on surface water by the proposed Galilee coal mines will be released in the near future.

Environmental Impact Statements and other formal assessment documents prepared by Galilee Basin mine proponents for the five mines which have so far been assessed, predict that up to 870 gigalitres (GL) of groundwater will need to be removed from mine pits and underground workings for coal to be extracted. Dewatering projections for all nine mine proposals could total 1,343GL – over 2.5 times the volume of water in Sydney Harbour. ¹

The nine coal mines proposed for the Galilee Basin would see over 34 open cut pits and 15 underground mines along a 270 kilometre north south strike to produce over 300 million tonnes of coal per annum at full production. Open cut coal pits for Galilee Basin mines will dewater regional aquifers long after mining ceases and will continue to draw groundwater due to evaporation that will raise salinity of the water in the void well beyond usable levels. While Adani's Carmichael mine would operate for 90 years and other Galilee Basin mines for 30 years or more, all of these mines are expected to have impacts on local and regional water resources that will extend beyond the productive life of the mines, for generations to come.

Longwall mining has historically caused land subsidence that increases the risks of aquifer fracturing, which has the potential to impact on the water resources in the Great Artesian Basin (GAB). Though the mechanisms are very poorly understood, the fracturing of aquifers constraining the GAB water from flowing eastward, together with the volume of water from mine dewatering operations, poses a grave risk that significant volumes will be caused to flow out from GAB recharge aquifers. Waratah Coal's EIS for the China First mine reveals that the Rewan Formation aquitard, which separates the Clematis Sandstone aquifer – long considered a GAB recharge aquifer for the Central Eromanga region – from regional aquifers, will be directly affected by the mines, and risks being fractured by one or more of the underground mines proposed for that project. The thickness, permeability and integrity of the Rewan Formation is critical in controlling whether or not the proposed mining will impact on the GAB.

Coal mines require large quantities of water to use for dust suppression and coal washing. Based on the documents produced for Environmental Impact Assessment of the proposed mines, we have estimated that the peak water demand of the five Galilee mine proposals for which assessment documents have been prepared, is between 50 and 70 billion litres a year (GLpa), of which more than 60% will be sourced

¹ The nine mines referred to in this report are those listed in Table 1. Other mining leases and mining exploration projects are also granted or underway in the Galilee Basin.

from local watercourses and groundwater. This has the potential to cause significant impact on local groundwater dependent ecosystems and fundamentally alter the dynamics of groundwater-surface water interaction.

Groundwater is an essential resource for pastoralists and domestic and town water supplies precisely because of its reliability. Groundwater supplies water for the 1000 or so people of the former Jericho Shire (now part of the Barcaldine Regional Shire) and the 180,000-240,000 cattle pastured on properties in the Shire. The high likelihood of significant impacts to the region's groundwater resources by proposed Galilee Basin mines has been acknowledged in the various assessment documents prepared for the mines. This fact has also been implicitly acknowledged by of the mine proponents who have offered to negotiate "make good" agreements with neighbouring landholders to provide alternative water supplies should groundwater no longer be available once mining begins. Despite this risk, a summary of the impacts of all of the proposed projects, and the implications for other water users, has not yet been prepared or attempted. This is the first report which has compiled publicly available information in an attempt to assess and review the likely cumulative impacts of the mines on the regions groundwater resources. A more detailed and rigorous assessment, based on additional data collection and modelling is urgently required in order to safeguard against potentially irreversible impacts.

John Graham, Central Queensland grazier



Impacts outlined in this report

- There are a number of aquifers in the Galilee Basin at potential risk from the proposed coal mining operations. Groundwater from these aquifers is currently utilised by towns and landholders for stock and domestic use. Based on the available yield levels, if operating bores were in operation every day for half of the year, groundwater usage in and around the mine lease areas would be in the order of 5GLpa.
- A majority of the almost 200 operating bores within the mine lease areas are expected to become increasingly inoperable after mining commences. A further 300 bores, within 20km of the mine lease areas, are at risk of being affected by a groundwater drawdown cone that will extend for at least 10 km from the mines. With cumulative drawdown, the compounding impact may extend for a much greater distance to the north, south and west of the mines.
- The close proximity of the approved Alpha mine and the proposed Kevin's Corner, China First and South Galilee mines will lead to significant overlap between their cones of groundwater drawdown, leading to compounded impacts on the area's groundwater levels, in particular, an expanded cone of depression much larger in extent than what would occur for each individual mine.
- The mine proponents acknowledge in their documentation that three of these mines, Alpha, Kevin's Corner and China First, will result in a combined 5m drawdown contour that will extend for an area 30km by 100km, elongated north-south. If more mines are approved the total area affected will be larger.
- Depression of groundwater in the vicinity of the South Galilee mine proposal has been estimated to eventually be up to 70m below pre-mining levels. The proponents acknowledge that: "Groundwater levels in neighbouring bores immediately adjacent to the mine will never recover completely, but will rise up to between 10 to 20m below pre-mining levels".²
- Mine proponents for the South Galilee and China First mines have asserted that groundwater impacts on the closest townships of Jericho and Alpha do not require mitigation. However, these assessments have been made in isolation and no cumulative impact modelling has been undertaken by either proponent to evaluate groundwater drawdown impacts on the water supply bores for these two towns.
- Both the Alpha and the Carmichael mine proposals are expected to interfere with surface water, and connected aquifers. The Carmichael mine proposes to extract a significant amount of water from the Carmichael River, and may also cause, during the mine's most intensive phase, a drawdown of between 30 and 60m in the groundwater table in the vicinity of the Carmichael River, which is known to be partly fed by groundwater discharge.
- The cumulative impact of these surface water diversions and/or extractions together with a potential reduction of groundwater discharge into these important waterways, is not fully understood or explained in the EIS for the Carmichael mine.
- Two important springs, one a GAB discharge spring and therefore a listed endangered ecological community, may be impacted by the Carmichael mine which is proposed to continue operating

² AMCI Investments Pty Ltd, 2012b. p 91

for 90 years, and continue impacting on local water resources and springs long after mining ceases. GAB discharge in this area may be fed by shallower, more localised groundwater flow systems. These shallow systems could be very important for local ecology, and they may also have some interconnection with underlying, larger groundwater flow systems.

- Despite denials from coal mine proponents, there is a significant likelihood that the Galilee Basin mines will impact on the Great Artesian Basin.
- In their advice on the proposed mines, the Independent Expert Scientific Committee raised concern that there is no impervious barrier between the proposed mining operations and the GAB, and also stressed that “there was not enough information to make an assessment as to the integrity of the Rewan Formation as an aquitard in this area to restrict connection with the Great Artesian Basin. In the absence of this assurance, it would be necessary to highlight the risks posed to the Great Artesian Basin (GAB) from the current proposal, as well as future proposals.”³
- Despite recently published research that suggests the Warang and Clematis sandstones are not GAB aquifers, they may provide water to the overlying units in the GAB by way of upwards leakage – as they are under artesian pressure⁴ - and therefore should be protected from impacts. A hydrogeological connection is understood to exist between the Clematis Sandstone and the overlying GAB aquifer, the Hutton Sandstone. There is therefore a possibility that mine dewatering in the Galilee Basin will have impacts on GAB aquifers.

Eucalypt woodland in coal mine lease area



³ IESC Advice on the Kevin's Corner mine proposal. Not yet publicly available, but quoted in the Queensland Coordinator General's report on the project.

⁴ CSIRO, 2012.

Where to from here?

Mine proponents are required to seek both groundwater and surface water licences for their water interference and use. In their EIS documentation, they have indicated that they intend to source a substantial portion of their water needs from recycled groundwater, obtained from the dewatering process, as well as on-stream and off-stream storages replenished during the high flows of the summer months.

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) was recently amended to make water resources a matter of national environmental significance, in relation to coal seam gas and large coal mining development. Any future assessments of developments in the Galilee Basin will therefore require federal oversight to ensure the protection of the region's water resources. It is, however, too late to apply these provisions to the Alpha mine which has already received EPBC Act approval.

To interfere with water in the Great Artesian Basin requires an entitlement. There are no entitlements available from the Clematis Sandstone, so mine proponents would have to obtain their permits from the Queensland State reserve of unallocated water. An attachment to Queensland's *Great Artesian Basin Resource Operations Plan 2007* notes that: "There is no new water available from either the general reserve or the State reserve in management areas that are heavily allocated." This limitation on GAB entitlements may go some way to explaining why coal mine proponents in the Galilee Basin have attempted to avoid admitting that their operations will interfere with water recharging into the Great Artesian Basin.

The Galilee Basin has been identified by the Independent Expert Scientific Committee as a priority sub-region for completion of a bioregional assessment on the impacts of coal seam gas and large scale coal mining on the region's water resources. However this assessment is unlikely to be completed before the Queensland and Commonwealth Governments conclude their statutory roles in assessing the Alpha, Kevin's Corner and China First mines, and possibly also the South Galilee and Carmichael mines. A regional water balance model, modelling the cumulative impacts of all of the proposals has been recommended by the Queensland Coordinator General, but the community of water users dependent on the regional aquifers of the Galilee Basin and the nationally important Great Artesian Basin need more than post-approval studies: they need their water resources protected now.

1: Introduction

The Lock the Gate Alliance commissioned this report, which seeks to estimate the potential impacts the proposed mines in the Galilee Basin may have on groundwater resources including water storages, agriculture and town water supplies. This report includes estimates and analyses of;

- Water consumption of proposed mine projects;
- Predicted life cycle impacts of mine dewatering on groundwater;
- The possible impacts of mining consumption and dewatering on agriculture and town water supplies.
- Investigation of the potential impact of Galilee Basin mines on water resources in the Great Artesian Basin.

Between 2007 and 2012, 120 applications were lodged under the Queensland Mineral Resources Act 1989 for coal Mining Leases in Queensland covering an area of approximately 6,000 square kilometres (km²).⁵ This is a substantial increase over the previous five years that saw 87 coal Mine Lease applications covering approximately 1,500 km².

A large area of these new applications for coal mines are for just nine leases or projects in the Galilee Basin, the last remaining major coal province yet to be developed in Queensland. These nine Mining Leases have been lodged by five companies covering an area of over 3,500 km².⁶

The location of these proposed and potential mining projects is shown in Figure 1.

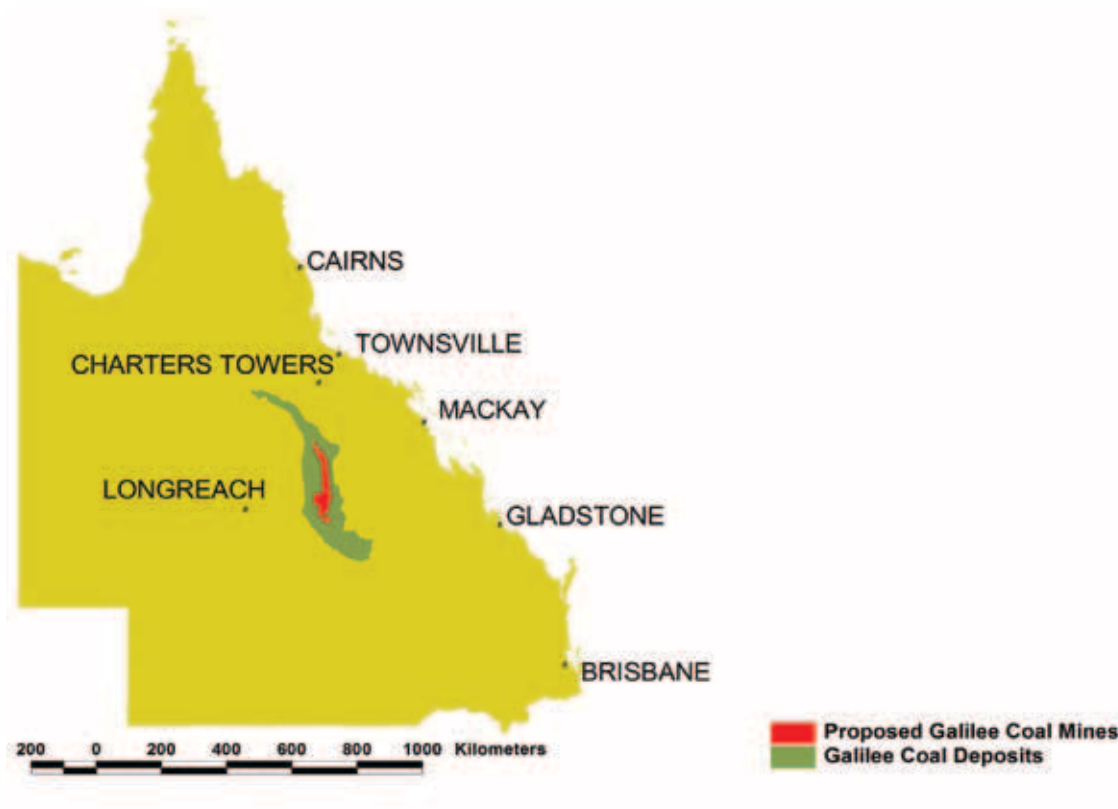


Figure 1: Proposed coal mine projects in the Galilee Basin⁷

⁵DERM, 2013

⁶Ibid

⁷QGIS data

In all, 86 Exploration Permits for Coal (EPC) have been issued for the Galilee Basin and a further 31 applications are pending (see appendix 1). For the purposes of this report, we focus on the mining proposals for which production capacity has been estimated, as listed in Table 1 and shown in Figure 2, though not all of these are the subject of Mining Lease applications, or development applications. Though no production capacity is available, we have also included Vale's Degulla proposal due to its proximity.

Table 1: Coal Mining applications and projects for the Galilee Basin

Name	Principal Holder	Mining Lease Status	Sub Status	Project Area (Ha)	Proposed Capacity (Mtpa)
Alpha	GVH Hancock Coal Pty Ltd	ML App.	EPBC Act Approval	53,513	30
Alpha West ⁸	Waratah Coal Pty Ltd	EPC	No EIS	82,363	20
Carmichael	Adani Pty Ltd	EPC	SEIS Lodged with QCG	52,348	60
China First	Waratah Coal Pty Ltd	ML App.	Qld EIS complete; Federal EIS not.	75,659	40
China Stone ⁹	Macmines Pty Ltd	EPC	EIS in preparation	23,565	45
Degulla ¹⁰	Vale Pty Ltd	EPC	No EIS	28,183	-
Kevin's Corner	GVH Hancock Galilee Pty Ltd	LM App	SEIS Lodged with QCG	37,381	40
North Alpha	Waratah Coal Pty Ltd	LM App	No EIS	104,892	40
South Galilee	Alpha Coal Pty Ltd	LM App	SEIS Lodged with QCG	30,822	17
Total				488,726	312

Assessing the likelihood that any of these coal projects will be approved by the regulators, or indeed will be progressed by the proponents, is beyond the scope of this report. Nevertheless, an analysis of the likely impacts of those Galilee Basin projects for which Environmental Impact Statements (EISs) have been prepared in furtherance of consent under the Federal Environmental Protection and Biodiversity Conservation Act, or those for which such documents are in preparation, will be undertaken in this report. These mines would be the largest black coal mines in Australia, with combined expected annual coal extraction of over 312 million tonnes (Mt) a year if all proceed to full capacity, as shown in Table 1.

Based on estimates by Mudd (2008), black coal mining operations use an average of 300 litres of water for every tonne of coal extracted.¹¹ When applied to the estimated coal extraction of the Galilee Basin coal projects this amounts to over 93 GLpa. Coal developments in the Galilee Basin are going to be large in scale, with significant tributaries to the Burdekin Catchment dissected by mines along a strike of almost 300km.¹² The footprint of the mine projects would occur within headwaters of two of the largest water catchments in Queensland, the Burdekin and Coopers Creek. The location and current status of the projects in the Galilee Basin is shown in Figure 2.

⁸ No Mining lease application or development proposal initiated, but for plans see DEEDI 2012

⁹ No Mining lease application, but a development proposal has been initiated. See Macmines Austasia Pty Ltd, 2012

¹⁰ No Mining lease application or development proposal initiated, but the project has been reported in the press and Vale are now seeking to sell it. See for example Elisabeth Behrmann, 2011 and Steel Guru, 2010

¹¹ Mudd, 2008. See Table 3.

¹² IESC, 2012.

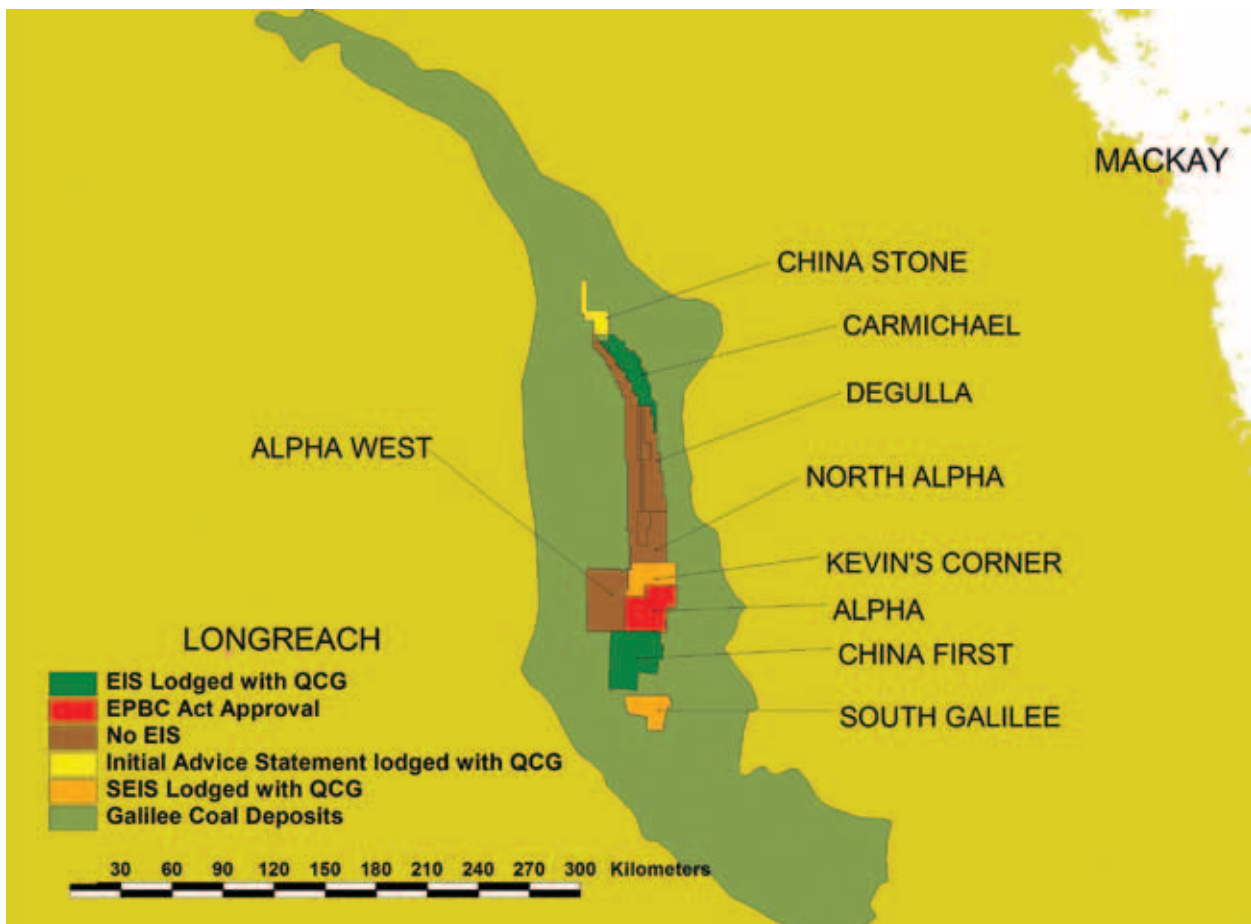


Figure 2: Proposed Galilee coal mines and their status.¹³

The Galilee coal projects are controversial, due in large part to the scale of the projects and their potential impacts on water resources. For example, the then *interim* Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining (IESC)¹⁴ raised concerns regarding the potential impacts of the proposed Alpha mine on the Great Artesian Basin (GAB) and regional surface and groundwater resources of the Galilee Basin.¹⁵ The mine has since been approved by the Federal Environment Minister. Mine proposals also include water course alterations which are likely to impact on local wetlands, including potential habitat for listed threatened species. The cumulative scale of the proposed mines has the potential to cause significant impact in the Burdekin catchments, as well as ground and surface water hydrology in the region.

The IESC also raised concern over the inadequacy of information presented by the Alpha mine proponent on hydrogeological and groundwater model parameters, uncertainties, confidence and transparency and associated risk assessments. It also raised concerns that too little information had been provided by the mine proponent to make an assessment as to the integrity of aquitards in the region to restrict connection with the Lake Eyre and Great Artesian Basin.

¹³ QGIS data

¹⁴ IESC was established as a statutory committee in 2012 by the Australian Government under the Environment Protection and Biodiversity Conservation Act 1999 (Cth) in response to community concerns about coal seam gas and coal mining. It provides scientific advice to decision makers on the impact that coal seam gas and large coal mining development may have on Australia's water resources. An interim committee operated from late 2011.

¹⁵ IESC, 2012

Assessing the likely cumulative impact of the proposed Galilee coal mines is hampered by the number of proposals that have yet to prepare EIS documents and the inadequate assessments produced to date. One of the final reports for the Alpha project noted that “all areas continue to have gaps and errors in the information that is of relevance to condition setting.”¹⁶ The area that came under particular criticism was groundwater. The Federal Environment Department’s Recommendation Report for the Alpha project stated that “the assessment of groundwater impacts both during and post mining has not been completed to an adequate level of reliability, and should be resolved before operational approval.”¹⁷

The cumulative surface and groundwater impacts of the proposed mine projects have not been assessed and a regional water balance has not been estimated, but mine approvals are proceeding regardless. The IESC is now a statutory body, and is conducting a bioregional review of the Lake Eyre Basin, which would encompass the proposed Galilee Basin mines, but it seems unlikely this will be completed prior to further approvals being issued. Irreversible impacts on surface and groundwater in the region are a likely consequence of all of these mines proceeding. The regional cumulative impacts should be adequately assessed before any further approvals for coal mine proposals in the Galilee Basin are considered by government authorities.

The level of projected water use for these projects and the need to source a significant amount of water from outside of the Galilee Basin led the Queensland government to request mining companies proposing to mine coal in the Galilee Basin to pay an estimated \$2.6 billion¹⁸ “upfront” for SunWater to proceed with the construction of the 374GL Connors River Dam near Moranbah, and a dedicated pipeline to provide to service the projects.¹⁹ In June 2012, Sunwater announced that the Connors River Dam would not proceed due to a lack of interest in providing this funding.²⁰ Due to the high water demand of the mines and the shelving of the Connors River Dam project, some water is expected to be required to be piped from either the Burdekin Falls or Fairbairn Dams, which together store 3,161GL of potable water.

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) was recently amended to make water resources a matter of national environmental significance, in relation to coal seam gas and large coal mining development. This means that such developments will require federal assessment and approval to ensure the protection of water resources. It is too late for such an assessment to be carried out for the Alpha mine, which has already received EPBC Act approval. However, an assessment of the other major proposed mines and a regional, cumulative assessment of the impacts the mines together on groundwater and surface water could still be conducted. We consider that such an assessment is of vital importance, given the potential scale of impacts on water resources, and the likelihood of consequences that are irreversible.

¹⁶ RPS Australia East Pty Ltd, 2011. p 1

¹⁷ SEWPAC, 2012.p 5

¹⁸ Andrew Fraser, *The Australian*, 2011.

¹⁹ See Queensland Coordinator General, 2012a.

²⁰ SunWater, 2012.

2: Background

2.1 The Galilee Basin Geology

Central Queensland's Galilee sedimentary Basin covers an area of about 247,000km². It forms part of the Great Artesian Basin Eastern Recharge Zone (see figures 4 and 6) and underlies the Eromanga sedimentary Basin.

The Galilee Basin is connected to the Bowen Basin by the Springsure Shelf and is overlain by the Eromanga Basin, and in places Tertiary basalts. Within the basin, coal is known to exist in the Permian aged Bandana Formation. Seams can reach up to 10 metres thick with coal of moderate ash, low sulphur, low moisture sub bituminous to bituminous thermal coal.

So far, proposed coal mining projects are restricted to the eastern Galilee Basin: they are shown in red, in Figure 3, in the context of other regional geological basins.

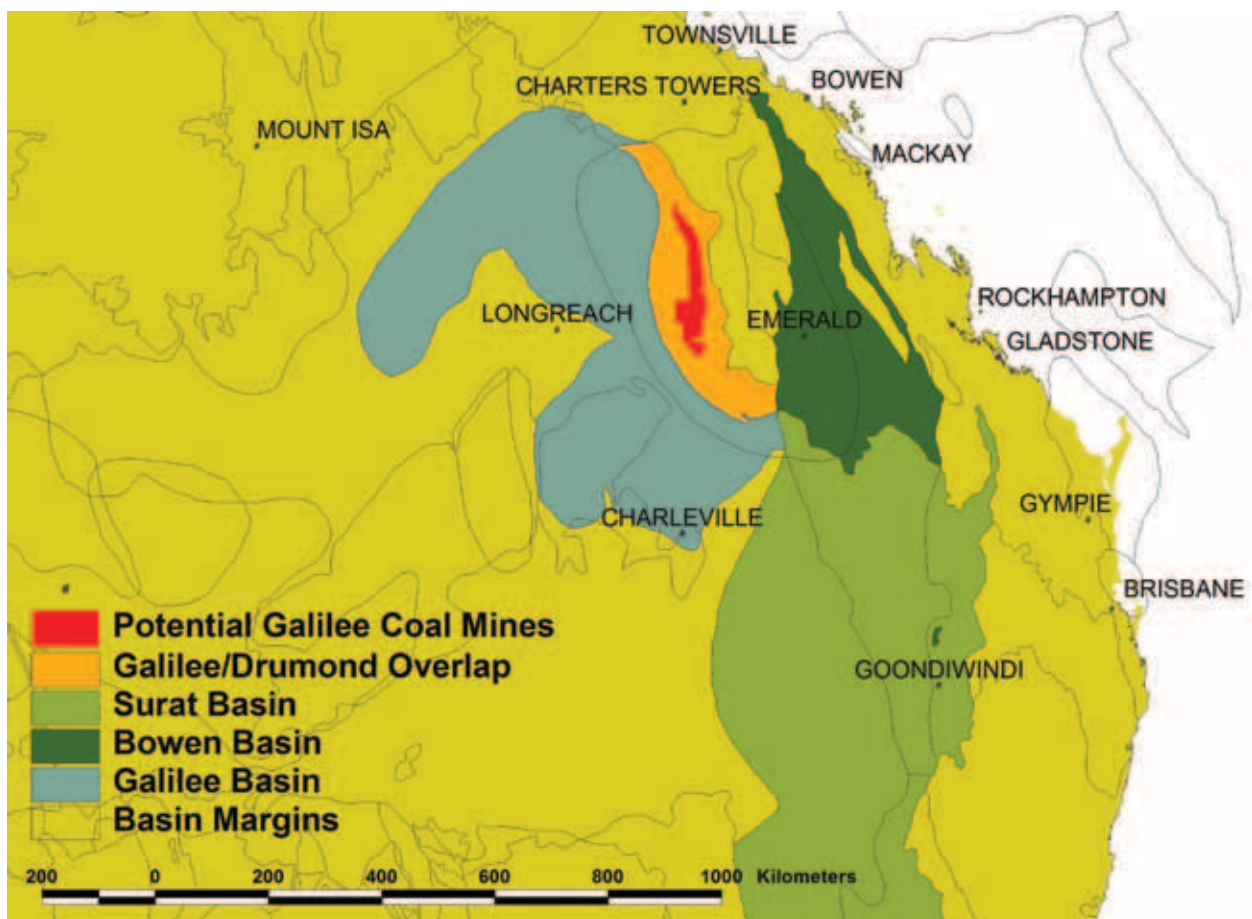


Figure 3: Galilee and surrounding geological basins²¹

²¹ QGIS data

2.2 Water demand of Galilee coal projects

A major strategic concern for the mining industry is the use and management of water resources. Of concern is the quantity of water consumed, the quality of water discharged and competition between mining and other sectors such as agriculture and rural towns. Much of this concern is informed from historical legacy sites and mine accidents.²²

Accurate estimation of water consumption volumes for proposed coal mines is complicated by the practise of on-site recycling of as much water as possible from tailings dams back into the coal preparation plant. Based on review of the assessment documents prepared for the five most advanced Galilee Basin mine proposals, we have estimated that the total net peak water demand of these five mines is likely to be approximately 50-70GLpa, of which 24-34% will be required to be sourced from an off site source. However, it has been difficult to be definitive about the scale of water demand for each project, as several have changed their demand estimates in successive assessment materials.

Table 3 presents data on the proponent's estimates of their water requirements for the 5 proposed mines in the Galilee Basin.

Table 3: Annual peak water demands of Galilee mine projects according to their proponents

Mine	Peak water demand (ML)	Peak imported water demand (ML)
Alpha Coal	10,772	8,236
Kevin's Corner	8,347-9,273	3,529
South Galilee Coal Project	3010-7,325	3,000
China First	17,750	2,500
Carmichael	10,000-24,500	All local sources
Total	49,879 - 69,620	17,265

The peak water demand of the Alpha mine is estimated by the proponent to be 10,772ML/annum in year 30. This is made up of 6,904ML for coal handling and washing, 3,279ML for dust suppression, 389ML for mine infrastructure area and 200ML in potable water.²³ GVK Hancock proposes using groundwater from either dewatering or from other water supply bores in the early stages of mining prior to the completion of the external water supply pipeline for an estimated 8236ML at peak demand. However, no assessment of groundwater availability for the project water supply has been undertaken to date.²⁴ In addition to mine dewatering, GVK Hancock proposes to extract 2,838MLpa of groundwater from 50 bores over the 30 year Alpha mine life and assumes that with the operation of the bore field seepage into the pit would be negligible.²⁵

²² Mudd, 2008. See also some examples of this in section 2.4.1 of this report.

²³ Hancock Prospecting Pty Ltd, 2011e. p 48

²⁴ RPS, 2011. p 11.

²⁵ Parsons Brinckerhoff, 2011b.

Waratah Coal estimated in their 2011 Environmental Impact Statement that the water demand for the China First mine could total 17,750MLpa, including the long wall and open-cut mines and coal washing. Of this, 4,550 ML is specified to be “clean water,” meaning not recycled from underground extraction.²⁶ Of the total water demand, 13,200MLpa is raw water required for open cut mine dust suppression and coal handling and preparation plant (CHPP), which includes coal washing. Waratah’s EIS however, estimated that re-use of water from the coal washery would mean that the net raw water requirement for the mine, to be drawn from groundwater during dewatering, would total 4,689MLpa.²⁷

According to the Environmental Impact Statement prepared for the South Galilee mine, over the life of the mine operation the total water demand ranges between approximately 3,010MLpa and 7,325 MLpa.²⁸ The EIS estimated that runoff yield would contribute between 1,250MLpa and 2,210MLpa of this. Groundwater inflows to underground and open-cut pits would contribute up to 5,932MLpa, and, once an external water supply is operating, raw water requirements vary from approximately 656MLpa to 1,258MLpa.²⁹

As with other mine proposals, there are apparently contradictory estimates of the water consumption for the Carmichael project. The appended “Preliminary Water Balance” of the Environmental Impact Statement estimates that the “raw water supply requirements” for the project “may be” between 4-10GL, which already is a large margin of uncertainty. Yet the “Water Resources” chapter of the same EIS states that during operation, the Carmichael mine offsite water supply infrastructure will extract up to 20GL of flood water, 2GL of in-stream storage water and up to 2.5GL of groundwater per annum which indicates a total water requirement of 24.5GLpa.³⁰

Water demand for the mine will be satisfied by extraction of water at Belyando River and North Creek flood harvesting stations, extraction from North Creek and Obungeena Creek in-stream storages, and extraction of water from seventeen boreholes in the Highland sub-artesian declared area.³¹

The annual water demand for the proposed Kevin’s Corner mine was estimated by the proponent to be a maximum of 8,347MLpa. During the estimated peak 8,347 ML net annual water demand, 90% or about 8,236ML would be for the mine operations and 111ML would be potable water. Raw water would be stored on-site in two dams and potable water will be treated at a packaged water treatment plant. Net water demand is dependent on the ability to recover water from the tailings dam and groundwater from mine dewatering.³²

GVK Hancock is negotiating with SunWater Ltd for the supply of water for the Kevin’s Corner mine.³³ Letters of intent and commercial arrangements are being finalised to guarantee delivery of water at commencement of construction, and long-term delivery of the balance of the mine water demand. The water will be delivered to a dam on the lease. This water will be suitable for immediate use in the coal preparation plant or pumped to the potable water treatment plant.³⁴ Of course any water supplied offsite will necessarily have an impact on the potential beneficial use of that water in the area it is sourced. Water from either the Burdekin Falls or Fairbairn Dams will require a water allocation or entitlement to be purchased or leased by the mine proponent from an existing water user.

Water Management Plans (WMP) are or will be required for all the Galilee mines within the conditions of their Environmental Authorities or in order to comply with the *Environmental Protection (Water) Policy 2009* whereby environmental values must be identified and protected by achieving associated water quality

²⁶ Waratah Coal, 2011a. p 52

²⁷ *ibid*

²⁸ AMCI Investments Pty Ltd, 2012b. p 108

²⁹ *ibid*

³⁰ Adani, 2012g. p 120

³¹ *ibid*

³² Hancock Galilee Pty Ltd, 2011a. p 73

³³ *ibid*

³⁴ Hancock Galilee Pty Ltd, 2011a. p 73

objectives (WQOs). The WMP then forms part of the Environmental Management Plan (EMP) for the project. To be a credible management tool, WMPs for the individual mines must be based on an assessment of the cumulative impact on regional groundwater and surface water resources.

Separate water licences are required to take or interfere with artesian and sub-artesian groundwater. Galilee Basin mine proponents, however, generally contend that the GAB will not be affected by Galilee coal mines, and so licencing to take and interfere with GAB water would not be required. This contention is challenged and discussed more fully in section 2.5.1.

Currently, no water supply scheme exists to provide water to the Galilee Basin coal projects. Available water resources include local groundwater and surface water over which a small number of farms have water entitlements. Mine proponents are generally required to seek both local groundwater and surface water licences. Most state that they intend to source a substantial portion of their water needs from groundwater obtained during the dewatering process as well as on-stream and off-stream storages replenished during the high flows of the summer months. However, many Galilee mine projects require additional water beyond that available on site. Additional water is available from the Burdekin Falls and Fairburn Dams, but pipelines would need to be built and water entitlements purchased by mine proponents.



Creekline in the Galilee Basin

2.3 Galilee Basin aquifers and aquitards

For many important agricultural production areas, groundwater is the most reliable available source of freshwater. The aquifers that host groundwater are also the primary buffers against drought for both human requirements, and agricultural production.³⁵ Pastoralists and other water users in the dry tropics, like the Galilee Basin area, rely on groundwater bores.

It has been well established that the coal mining operations proposed for the Galilee Basin will affect local supplies of groundwater, but an overview of the extent of these impacts from the various projects proposed for the region has not been provided to water users and governments.

There are a number of aquifers in the Galilee Basin potentially at risk. These include unconfined Quaternary and Tertiary alluvial/sediment aquifers, Cretaceous sedimentary rock aquifers, Jurassic sandstone aquifers and Permian sedimentary rock aquifers.³⁶ In the Galilee Basin, locally important volumes of water are produced from units more traditionally considered as confining units or aquitards. Hydrological consultants RPS reported that it is common to find records of bores screened in water-producing zones within the Westbourne, Moolayember and Rewan Formations.³⁷ Regionally, the Permian Betts Creek beds and the Aramac Coal Measures (and their equivalents) yield sufficient groundwater to be classified as water-bearing sediments.³⁸ In these cases, the groundwater is produced from the coal seams and interbedded sandstones, varying in thickness from less than 10cm to more than 21m.³⁹

A conceptual cross section of the major hydrostratigraphic units is shown in Figures 4 and 6. Within the Eromanga Basin sequence, the most significant groundwater resources are in the Hutton Sandstone, the Hooray Sandstone and the Cadna-owie Formation aquifers⁴⁰ with the Hutton Sandstone the main Jurassic sandstone aquifer.⁴¹

Typically, thick regional confining units such as the Moolayember Formation and the Rewan Formation, inhibit hydraulic connection between the Hutton Sandstone and the targeted Permian coal measures of the Galilee Basin, meaning that water does not flow or exchange between aquifers where these formations prevent it. However, these confining rock formations thin toward the Maneroo Platform (east of Longreach) creating an area where the Hutton Sandstone and Permian coal measures are in relatively close contact.⁴² Indeed, the Moolayember Formation, Clematis Sandstone and Rewan Formation are not present between the Hutton Sandstone and the Permian coal measures along the northern edge of the Maneroo Platform.⁴³

RPS (2012) therefore recommended that the Hutton Sandstone and the overlying Hooray Sandstone/Cadna-owie Formation aquifer system be monitored if depressurising the Permian coal measures occurred.⁴⁴

Figure 4 is drawn from the Supplementary EIS for the proposed Kevin's Corner mine, and shows a schematic section of these main geological layers, including aquifers and aquitards, in relation to the targeted Permian coal measures (labelled A, B, C and D).

³⁵ Siebert, et al, 2010

³⁶ AGL, 2013. p 23

³⁷ RPS, 2012. p 11

³⁸ RPS, 2012. p 11

³⁹ *ibid*

⁴⁰ RPS, 2012. P11

⁴¹ AGL, 2012. p 28

⁴² RPS, 2012. p 111

⁴³ RPS, 2012. p 370

⁴⁴ *ibid*

2.3.1 Permian Sediments – the Bandana Formation

The targeted coal seams are located in the Permian sediments within the Bandana Formation and the older Colinlea Sandstone. These Permian units contain both economic and sub-economic coal seams named alphabetically A through F, with the A seam being uppermost.⁴⁵ The Bandana Formations host the A and B seams and the Colinlea Sandstone hosts the target C and D seams.⁴⁶

Aquifers exist within the coal seams under confined conditions in the B-C and C-D sandstones and the C and D coal seams, and also the base of the D coal seam.⁴⁷ Drilling by GVK Hancock reveals that groundwater inflows are relatively low until the D coal seam is intersected, at which point high rates of ground water flow are encountered. Consultants for GVK Hancock identify the sandstone unit directly below the D seam and above the E seam (D-E sandstone) as a target of aquifer depressurisation, and the overlying sandstone (B-C sandstone and C-D sandstone and C and D coal seams) as needing to be locally dewatered in order for mining to occur safely.⁴⁸ In other words, the Colinlea Sandstone will be depressurised, and water removed from the aquifer layers between the coal seams.

For the proposed Alpha and Kevin's Corner mines, mining is proposed to directly occur within four major aquifers in the Permian strata.⁴⁹

2.3.2 Colinlea Sandstone

The Colinlea Sandstone is underlain by sediments of the Joe Joe Formation, described as mudstone, labile sandstone, siltstone, shale and has been identified by GVK Hancock as the bottom confining unit of the Colinlea Sandstone aquifer.⁵⁰ The Colinlea Sandstone is divided into northern and southern parts by the east-west trending Barcaldine Ridge, located near Barcaldine. The northern part of the basin is subdivided by the Maneroo Platform and its easterly components, the Beryl Ridge, into the eastern Koburra Trough and the Western Lovell Depression.⁵¹

The Colinlea Sandstone in its western most extent ends at Maneroo Platform along the western boundary of the Galilee Basin. It does not outcrop but pinches out into the Drummond Basin, below the Hutton Rand Monocline. Unlike the Great Artesian Basin (GAB) units, which discharge via springs in the south western portion of the GAB, the Colinlea Sandstone pinches out below the GAB and therefore may supply water to the overlying GAB if the pressures and permeability permit.⁵²

2.3.3 Rewan Formation

The Rewan Formation separates the aquifers proposed to be dewatered during mining, from the Clematis Sandstone. The Clematis Sandstone is a permeable aquifer which may have a hydraulic connection with overlying hydrostratigraphic layers, including those classed as GAB aquifers (e.g. the Hutton Sandstone). Hence, the integrity of the Rewan Formation as an aquitard has major implications for cross-aquifer hydraulic and hydrochemical impacts of mining. The thickness, permeability and integrity of this layer

⁴⁸ URS, 2012c. p18

⁴⁹ *ibid*

⁵⁰ URS, 2012c. p18

⁵¹ URS, 2012c. p 17

⁵² *ibid*

⁵³ *ibid*

will be crucial controls on whether there is an impact on overlying aquifers. It is known that the Rewan Formation is heterogeneous –containing a range of different sedimentary horizons, including patches of sandy material, with potentially relatively high permeability.

The thickness of the combined aquitards are likely to be highly variable, particularly near the edge of the basin. The base of the Rewan Formation is located some 30-50m above the uppermost Bandana Formation A seam coal ply, and is taken to have an average thickness of 175m.⁵⁵ Senior (1973) suggests the thickness of the Rewan Formation in this area is only 130m. The South Galilee mine proponent suggests the combined thickness of the aquitard is around 250m. The Rewan aquitard has a vertical hydraulic conductivity in the order of 1×10^{-4} to 1×10^{-3} m/day, based on previous investigations during an early phase of GAB groundwater modelling (Audibert, 1976).

Overall, there is not a lot of data on the thickness, extent and permeability of the Rewan formation, and so pathways for connection with overlying/underlying hydrostratigraphic layers may exist that are not currently known

2.3.4 Clematis Sandstone

The Early to Middle Triassic age Clematis Sandstone, which can be up to 130 m thick, consists of medium to coarse-grained quartzose to sublabilite, micaceous sandstone, siltstone, mudstone and conglomerate. According to RPS, The Clematis Sandstone aquifer is tapped by more than 100 water bores in the Galilee Basin and outcrops through the younger sediments in a similar pattern to the Moolayember Formation.⁵⁶

The upper Triassic sandstones in the sedimentary sequences, the Clematis and Warang Sandstones, are of continental origin, and contain aquifers, which have previously been considered to form part of the GAB.⁵⁷ The Clematis Sandstone and Warang Sandstone were deposited in fluvial sedimentary environments. The Clematis Sandstone is overlain by the Moolayember Formation, which consists of mudstone and siltstone and was deposited in fluvial, lacustrine, deltaic and shallow marine environments.⁵⁸

Despite recently published research that suggests the Warang and Clematis sandstones are not GAB aquifers, they may provide water to the overlying units in the GAB by way of upwards leakage – as they are under artesian pressure. The older geological units in the Galilee Basin either do not contain aquifer sequences, or contain reservoirs with different hydraulic characteristics and groundwater with different hydrochemistry and high to very high salinities, indicating a distinctly different hydrogeological system from the GAB.⁶⁰

⁵⁴ AMCI Investments Pty Ltd, 2012b, p 35

⁵⁵ Op cit. p 18

⁵⁶ RPS, 2012

⁵⁷ Habermehl, 1980

⁵⁸ GABCC, 2010. p21

⁵⁹ CSIRO, 2012.

⁶⁰ GABCC, 2010. p21

2.4 Mining methods proposed for Galilee coal mines

2.4.1 Longwall mining

Eleven underground mines are currently proposed for the Galilee Basin. The China First mine involves the construction of four, nine million tonnes per annum longwall underground mines.⁶¹ Adani's proposed Carmichael mine includes three underground longwall working areas. The Kevin's Corner mine proposes to extract the majority (695Mt) of its run-of-mine (ROM) coal from three longwall mines.⁶² The South Galilee proposal would include one longwall underground mine.⁶³

Impacts on groundwater aquifers are common in longwall mining operations due to subsidence-related fracturing.⁶⁴ Although overlying aquifers may be protected to some degree from the impact of mines (such as drainage of water towards mines) by a confining zone, fracturing and subsidence cause substantial changes to the physical structure and permeability of the subsurface, which can propagate upwards. These changes have in other localities (such as NSW) manifested at the surface, causing irreversible environmental impacts such as streambed cracking, drainage of surface and shallow aquifers to deeper levels, and geochemical changes such as sulphide oxidation.⁶⁵

For example, damage to creek systems in the Hunter Valley creeks including Eui Creek, Wambo Creek, Bowmans Creek, Fishery Creek and Black Creek has been associated with subsidence due to longwall mining.⁶⁶ Damage has occurred as a result of loss of stability, with consequent release of sediment into the downstream environment, loss of stream flow, death of fringing vegetation, and release of iron rich and occasionally highly acidic leachate. In the Southern Coalfields of NSW, substantial surface cracking has occurred in watercourses within the Upper Nepean, Avon, Cordeaux, Cataract, Bargo, Georges and Woronora catchments, including Flying Fox Creek, Wongawilli Creek, Native Dog Creek and Waratah Rivulet. The usual sequence of events has been subsidence-induced cracking within the streambed, followed by significant dewatering of permanent pools and in some cases complete absence of surface flow.⁶⁷

The most widely publicised subsidence event in the Southern Coalfields was the cracking of the Cataract riverbed. In 1994, the river downstream of the longwall mining operations dried up.⁶⁸ Water that re-emerged downstream was notably deoxygenated and heavily contaminated with iron deposits; no aquatic life was found in these areas.⁶⁹ In 1998, a Mining Wardens Court Hearing concluded that 80% of the drying of the Cataract River was due to longwall mining operations. Reduction of the surface river flow was accompanied by release of gas, fish kills, iron bacteria mats, and deterioration of water quality and instream habitat. Periodic drying of the river has continued, with cessation of flow recorded on over 20 occasions between June 1999 and October 2002.⁷⁰ At one site, the 'Bubble Pool', localised water loss up to 4 ML/day has been recorded.⁷¹

⁶² Queensland Coordinator General, 2013. p2

⁶³ SEWPAC - Office of Water Science, 2012.

⁶⁴ See for example McNally and Evans, 2007; Booth, 2006; DIPNR 2003; ACARP 2001, 2002 and 2003; and Everett *et al*, 1998;

⁶⁵ Booth, 2006; McNally and Evans 2007

⁶⁶ <http://www.environment.nsw.gov.au/determinations/LongwallMiningKtp.htm>

⁶⁷ <http://www.environment.nsw.gov.au/determinations/LongwallMiningKtp.htm>

⁶⁸ ACARP 2001, 2002

⁶⁹ Everett *et al*, 1998

⁷⁰ DIPNR, 2003

⁷¹ *ibid*

Longwall mining is known to cause deformation and enlargement of existing fractures, the creation of new fractures, and bedding plane separation. As a result, conditions can change from confined to unconfined, causing water quality changes and greatly enhanced leakage of water from upper aquifers into lower aquifers.⁷² Longwall mining causes changes to the hydraulic properties of the strata, such as porosity, permeability, hydraulic gradients, groundwater levels, and groundwater flow paths.⁷³ If such changes were to occur in the Galilee Basin, there may be serious impacts on aquifers overlying the targeted coal seams, right to the surface.

GVK Hancock acknowledges that groundwater will flow into the underground mine workings of the Kevin's Corner project, through the floor and walls and from sediments above the underground workings as fracturing develops due to the collapse of strata in the longwall mining panels.⁷⁴ This fracturing creates voids or spaces underground known as goafs. The inflowing water into the goafs is expected to come from Tertiary sediments, the sediments of the B-C and C-D sandstone and C and D coal seams in the Bandana Formation, and locally from passive depressurization of sub-E sandstone.⁷⁵ Refer to Figure 4 to see the a cross-section of these units.

Waratah Coal acknowledges that the likely subsidence level in the north-western section of the China First project due to long wall mining is estimated to be 3.27m. Cracking of the overlying geology is therefore likely. The cracking may result in rapid infiltration of rainfall into the aquifers surrounding the mine, potentially increasing rates of flow into the goafs requiring dewatering.⁷⁶

The Longwall Mining Report which formed part of Waratah's SEIS states that "Underground longwall activities will have some degree of impact to these aquifers through subsidence and tensile fracturing. There will be marginal overall impact to all aquifers and any inflow through tensile fracturing has been calculated and can be used as a guide... Considerably more research into tensile fracturing is required before confident predictions can be made."⁷⁷ Nevertheless, the proponent is seeking approval from the Federal Minister for the Environment, despite an absence of any confident basis to make predictions about the degree of fracturing, and its impact of overlying strata.

AMCI suggest that deep fracture networks can extend upwards to a height of about 0.6 to 0.67 times the longwall width (350m at South Galilee). This means the South Galilee mine could create a fracture extending to a height of 210-235m above the mine, which is only proposed to be 150m below the surface.⁷⁸ In short, deep and surface cracking caused by the mining operation could propagate through the entire subsurface from the mines upward. In the EIS for the South Galilee mine, AMCI-Bandanna downplays the impacts of this cracking, claiming the cracks would be filled by sediment after heavy rain and floods "which would tend to reduce the permeability of the fractured zone and thus reduce potential for related impacts."⁷⁹ This is a highly questionable assumption - only in cases where the in-filling sediment is extremely fine grained and stable, would increased fracture permeability be mitigated.⁸⁰

⁷² Booth et al, 1998.

⁷³ Booth, 2002.

⁷⁴ URS, 2012c. p 63

⁷⁵ *ibid*

⁷⁶ Waratah Coal, 2011c. p 246

⁷⁷ Engeny, 2013a. p 8

⁷⁸ AMCI Investments Pty Ltd, 2012b. p 85

⁷⁹ *ibid*

⁸⁰ Pers. Comm. Dr Matthew Currell. School of Civil, Environmental & Chemical Engineering. RMIT University Melbourne.

Madden *et al* indicate that increased lateral fracturing and connectivity within the same strata can be another consequence of subsidence, and in some situations may result in the diversion of stream flow and shallow groundwater away from the streams and the catchment of origin.⁸¹ This potential impact is however not canvassed in the Environmental Impact Statements prepared for the mines.

AMCI-Bandanna have suggested that the water table will be lowered in response to mining and dewatering in the immediate vicinity of the mines, and the shallow water table may drop substantially.⁸² AMCI-Bandanna's modelling also suggests that after mining is over, the water table will recover, but to a different elevation than observed pre-mining level due to the permanence of the fractured zone above the longwall panels.⁸³ Long-term groundwater level recovery is dependent on connection to recharge, and the ability of water to flow to and from the impacted area. Some studies have suggested that although groundwater levels in the surface zone can recover from fracturing by longwall mining, groundwater levels in the lower fractured/caved zone may never recover at all.⁸⁴

Longwall mining will have a significant impact on regional groundwater in the Galilee Basin. Five aquifers have been identified within the proposed mining area. These aquifers are found within successive formations at depths beginning with the Base of Tertiary sandstone, A-B Sandstone, C-D Sandstone, D-E sandstone and sub E sandstone. The Galilee Basin mine proponents have accepted that this groundwater impact will occur, and that this will have an effect on water uses in the local area. Should this impact extend to dewatering aquifers that are part of, or recharge the GAB through the fracturing of the overlying Rewan Formation, these impacts will have a far broader impact. The risk that this could occur has not been adequately addressed by any of the mine proponents, nor has the risk that longwall mining may have impacts that reach the surface and therefore affect shallow aquifers, streams and groundwater dependent ecosystems.



Clermont Mine, Bowen Basin Queensland

⁸¹ Madden *et al*, 2009.

⁸² AMCI Investments Pty Ltd, 2012b. p 85

⁸³ *ibid*

⁸⁴ Booth, 2003.

2.4.2 Open cut pits

At least 34 open cut coal pits are currently proposed for the Galilee Basin mines. The Alpha open cut mining operation alone will extend along a 24km strike, divided into four pits.⁸⁵ China First project proposes to mine two 10Mtpa open cut pits.⁸⁶ The Kevin's Corner project will mine 2 open cut pits (20km² and 4km²) along an initial strike of 6.5km.⁸⁷ The China Stone project would include a 3km long open cut pit. The South Galilee mine would comprise four open cut pits, with a total strike length of approximately 14km.⁸⁸ Adani intends to build a large coal mining complex with 21 open cut pits with an overall workable length of approximately 58 kilometres and a total area of over 100km².⁸⁹ The combined strike length of open cut operations in the proposed mining area is therefore well over 100km long. It is our hypothesis that since the mines form a continuous belt aligned approximately NNW-SSE, a regional drawdown cone will develop stretching for the full length of the proposed open cut mines, having a major regional impact on groundwater. This cumulative impact has yet to be properly assessed.

The final voids from the open cut coal pits will have substantial long-term cumulative environmental impacts. For example, the China First EIS states, "The open voids are likely to significantly alter the hydrological regime of the aquifer they intersect as they act as artificial sinks for groundwater."⁹⁰ The open voids will continue to receive groundwater inflows and be subject to evaporation, after the mine finishes production, which will result in a long term depression in the water table in the local mine area.⁹¹

The final void water level for the proposed Kevin's Corner mine is predicted to reach a 'pseudo' steady state after 100 years, at 100m below the surface.⁹² However, the time required to reach steady state conditions for such a large feature is a highly uncertain model prediction, and this value could far underestimate the true impact.⁹³ The final void water will deteriorate in quality over time, accumulating salts until it will be unusable when it reaches saline levels 5,000mg/L, the maximum ANZECC 2000 guidelines for livestock and drinking water.⁹⁴ For the proposed South Galilee mine pits, the proponent claims that the salinity of this water will not impact the quality of surrounding aquifers because the void will remain a groundwater sink – that is, it will continue drawing water in from the surrounding aquifers, and turning it saline, but this salt will remain in the void.⁹⁵ The geographical extent of these groundwater impacts could be tens of kilometres.

For the final void of the proposed China First mine, Waratah acknowledges that there will be "major temporal and spatial effects" on groundwater, "which would result in a high level of impact to groundwater users."⁹⁶ The Kevin's Corner SEIS acknowledges that after 300 years, the groundwater contours will be altered permanently by the effect of evaporation from the final mine void, which acts as if the water is being pumped from the void.⁹⁷ The SEIS also acknowledges that the much larger Alpha Coal void will permanently alter the long-term groundwater flow patterns of the area.⁹⁸ The groundwater modelling undertaken for this SEIS predicts a permanent lowering of the water table in the area, because the rate of evaporation of water from the open final void will exceed the rate of groundwater flowing into it.⁹⁹

⁸⁵ Hancock Prospecting Pty Ltd, 2012. p 69

⁸⁶ Waratah Coal, 2011a. p 5

⁸⁷ Hancock Galilee, 2011a. p 32

⁸⁸ AMCI Investments Pty Ltd, 2012a. p 39

⁸⁹ GHD, 2012. p 5

⁹⁰ Waratah Coal, 2011b. p 72

⁹¹ AMCI Investments Pty Ltd, 2012a. p 85

⁹² URS, 2012c. p xvi

⁹³ Bredehoeft and Durbin, 2009

⁹⁴ *ibid*

⁹⁵ AMCI Investments Pty Ltd, 2012b. p 91

⁹⁶ Waratah Coal, 2011b. p 72

⁹⁷ Hancock Galilee, 2012. p 26

⁹⁸ *ibid*

⁹⁹ AMCI Investments Pty Ltd, 2012b. p 89

Waratah Coal attempted to model the cumulative impact of the drawdown that would be caused by its own mine proposal in conjunction with the Alpha and Kevin's Corner mines. They found that a groundwater drawdown of 5m would be experienced over an area 30km wide and over 100km in length along a north-south axis. On the western side, this impact zone crossed into the GAB formations, and affected the availability of groundwater in the whole surrounding area.¹⁰⁰ An extension of this modelling to include the South Galilee proposal and other proposed mines in the area has not been undertaken. The large area of impact predicted from simultaneously assessing three mines demonstrates that there is a need for a full regional cumulative assessment of the proposals on groundwater resources. This was a finding recommended by the Independent Expert Scientific Committee, and has also been requested by concerned parties and stakeholders.



Alpha mine, Galilee Basin

Photo courtesy Greenpeace/Andrew Quilty

¹⁰⁰ AMCI Investments Pty Ltd, 2012b, p 89

2.5 Queensland groundwater regulation

Queensland water legislation regulates artesian (groundwater that flows naturally to the surface if tapped by a bore) and sub-artesian (groundwater that does not flow naturally to the surface if tapped by a bore) water separately. The majority of Queensland's artesian water exists within the GAB, from which artesian water and sub-artesian water connected to artesian water are managed under the *Water Resource (Great Artesian Basin) Plan 2006* and the *Great Artesian Basin Resource Operations Plan 2007*. An authorisation to take sub-artesian water is required in:

- a sub-artesian area declared under Schedule 11 of the *Water Regulation 2000*.
- a groundwater management area established under Schedule 4, Schedule 10, Schedule 14 or Schedule 15A of the *Water Regulation 2000*, or
- a groundwater management area or sub-artesian management area established under a water resource plan, or
- a sub-artesian management area under a wild river declaration.

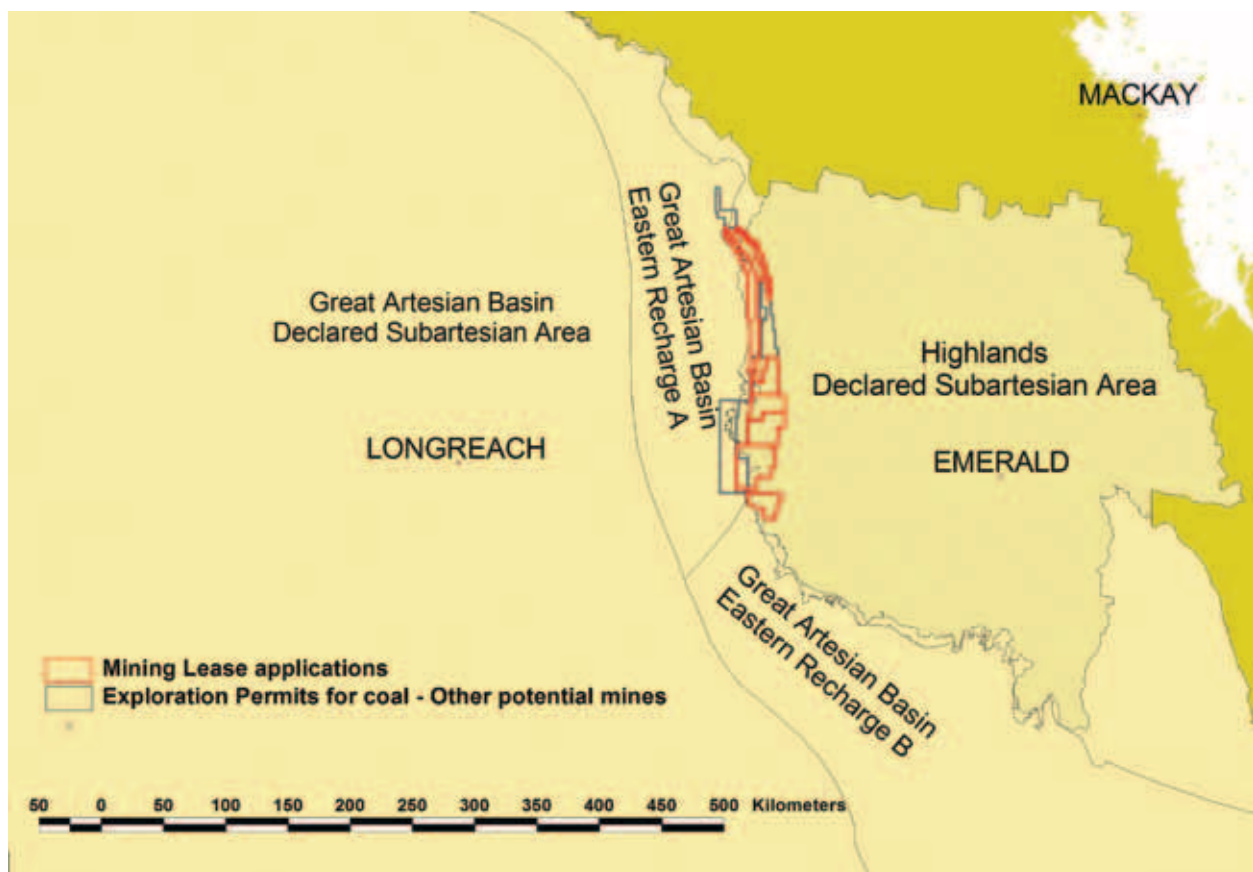


Figure 5: Declared sub artesian areas and GAB Queensland Eastern Recharge areas A and B.¹⁰¹

As shown in Figure 5, the proposed Galilee Basin mines are within the Water Regulation 2000 Schedule 11 declared sub-artesian area called the Highlands Groundwater Management Area and therefore they require an authorisation to take or interfere with sub-artesian water.

¹⁰¹ QGIS data.

2.5.1 Great Artesian Basin Plan

In 2010, the total annual extraction of water from the GAB was estimated at over 600GL, with Queensland water users accounting for almost 70% of this use, an estimated 450GL.¹⁰² Currently, a few coal mines in the Surat Basin require dewatering and extraction of GAB water for dust suppression and processing and their usage is included in this total.¹⁰³ The current entitlements for mining, including quarrying, from the GAB in Queensland amount to about 17GL a year.¹⁰⁴

All the proposed Galilee Basin mines fall outside of the GAB. However, as outlined in section 3.1, it is likely that mine dewatering will have consequences for GAB aquifers, which we believe would require the mine proponents to obtain an entitlement to take or interfere with GAB water.

Under section 11 of the *Water Resource (Great Artesian Basin) Plan 2006*¹⁰⁵ a person may not take or interfere with sub-artesian water other than for domestic purposes or under a water entitlement in a GAB management area. However, no general reserve entitlements are available for GAB water from the Clematis Sandstone in the Barcaldine North, unit 3 management area, which is the closest to the proposed Galilee Basin mines (See Schedule 5, *Water Resources (Great Artesian Basin) Plan 2006*). Thus, a water entitlement to interfere with GAB water could only be granted from the Queensland State reserve. If a project is of State or regional significance, and water is available, up to 10GL can be granted from State reserves.

Section 8 of the *Water Resource (Great Artesian Basin) Plan 2006 (Qld)* provides that:

“Water is to be allocated and managed in a way that seeks to achieve a balance in the following outcomes -

- (a) to protect the flow of water to springs and base flow to watercourses that support significant cultural and environmental values;
- (b) to provide for the continued use of all water entitlements and other authorisations to take or interfere with water;
- (c) to reserve water in storage in aquifers for future generations;
- (d) to ensure a reliable supply of water from the plan area;
- (e) to make water available for new users.”

Attachment C of the *Great Artesian Basin Resource Operations Plan 2007*¹⁰⁶ notes that in light of Section 8 of the Plan: “There is no new water available from either the general reserve or the State reserve in management areas that are heavily allocated.”

¹⁰² GABCC, 2010. p86

¹⁰³ Op cit. P90

¹⁰⁴ ibid

¹⁰⁵ <http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/W/WaterReGABP06.pdf>

¹⁰⁶ http://www.nrm.qld.gov.au/wrp/pdf/gab/gab_rop.pdf

2.6 Environment Protection Biodiversity Conservation Act 1999

Sections 24D and 24E of the Commonwealth Environment Protection Biodiversity Conservation Act 1999 (EPBC Act) make water resources a protected matter for coal seam gas extraction and large coal mining. These sections came into force on 22 June 2013, and transitional arrangements mean that the Alpha Coal mine, which has an approval under Part 9 of the Act already, is saved from having water resources added as a controlling provision for the purposes of its assessment under that Act.

At the time of writing this report, it appears that all other proposed Galilee Basin coal mines will have a significant impact on water resources and should therefore have water resources included as a controlling provision. It is hoped that if and when this occurs, more rigorous and comprehensive assessment of the impact these mines will have on groundwater and surface water resources will be undertaken before the Commonwealth concludes its statutory role in assessing them.



Emus in a Galilee Basin river channel

3: Groundwater impacts of Galilee Basin mine proposals

Groundwater in the area of the proposed coal mines is encountered in all geological formations, although it is primarily the Quaternary, Tertiary and GAB sediments that provide groundwater resources in region.¹⁰⁷

The following Eromanga and Galilee basin aquifers have been identified as in close contact with the Permian coal measures and at risk of being impacted by depressurisation of the coal measures:

- Jurassic age Hutton Sandstone;
- Late Triassic to Early Jurassic age Warang Sandstone;
- Triassic age Clematis Sandstone;
- Triassic age Dunda beds; and
- Late Carboniferous to Early Permian Jochmus Formation (upper Joe Joe Group).¹⁰⁸

In short, the mines will affect regionally significant aquifers and although it has been frequently claimed that the aquifers that will be dewatered by coal mining proposed in the Galilee Basin are geologically separated from the GAB, some impact cannot be ruled out, without a more rigorous regional assessment being conducted.

The EIS for the South Galilee mine found that groundwater within the Hutton Sandstone aquifer may be influenced by depressurising the Permian coal measures. The absence of normally thick confining sequences in the proposed mining area means that the overlying Cadna-owie Formation/Hooray Sandstone aquifer systems are also stratigraphically in closer proximity to the Permian coal measures than in the central Eromanga Basin.¹⁰⁹ In areas where the Moolayember Formation, the Dunda beds and the Rewan Formations are thin or absent, depressurisation of the Permian coal measures may potentially impact regional aquifers or water-bearing sediments.¹¹⁰ In spite of average thicknesses for the aquitards and connection between aquifers and the targeted coal seams cited by the various Galilee mine proposals, there appears to be insufficient information to assess the thickness of the aquitards across the total mining area. This is of significant concern, as it is essential data on which to assess whether the aquitards will be effective in preventing groundwater exchange between the depressurized targeted coal seams and overlying aquifers.

Figure 6 is drawn from the China First SEIS and shows a conceptual model of the groundwater flow systems under the impact of mining. This concept diagram indicates that the flow of groundwater from the Clematis Sandstone may be re-directed away from the GAB and eastwards towards the area of coal mining. The fracture zones created by longwall mining have the potential to induce discharge from the Clematis sandstone into the depressurised Bandana and Colinlea Formations.

¹⁰⁷ AMCI Investments Pty Ltd, 2012a. p 32

¹⁰⁸ RPS, 2012. p 12

¹⁰⁹ AMCI Investments Pty Ltd, 2012a. p 32

¹¹⁰ RPS, 2012. p 12

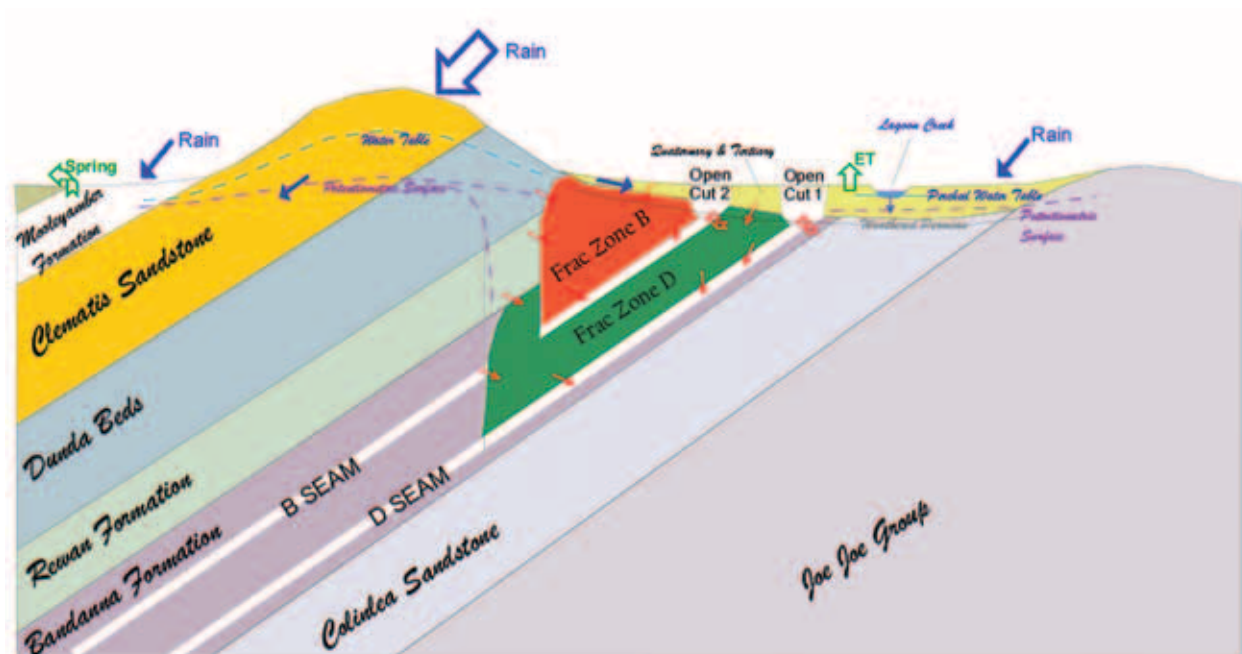


Figure 6: Conceptual hydrological model showing fracture zones of China First longwall mining and north east groundwater flow from Clematis Sandstone – Copy of Figure 3.6 from Heritage Computing, 2013. p8

The very high likelihood of significant impacts to groundwater by proposed Galilee Basin mines has been acknowledged in the assessment documents submitted by the mine proponents. A number of proponents have offered to make agreements with neighbouring landholders to supply “make good” water, should groundwater no longer be available once mining begins. However, a regional assessment of the impacts of all of the proposed projects together, and the implications for other water users, including groundwater dependent ecosystems, has not yet been conducted and should be carried out urgently.

It is also the contention of this report that it is not possible with the current information available to be certain that coal mining in the Galilee Basin will not affect water resources of the GAB. Significant local impact on both ground and surface water resources closer to the mining area itself are also likely to occur as described above, and the cumulative magnitude of these local impacts cannot be made without a regional assessment.

Conditions have been imposed by the Queensland Coordinator General for the Kevin’s Corner mine including:

- A system of ‘trigger levels’ is required to be instigated, to monitor any change in water levels in the Rewan and Clematis and give early warning of any induced flow from the GAB.
- Regional ground and surface water modelling is required to be conducted to look at cumulative impacts on both types of water.
- Groundwater monitoring (levels and quality) is to be instigated prior to mine operation; results to be made public.¹¹¹

These are conditions of mining approval and will not prevent impacts. Monitoring induced flow from the GAB, providing regional hydrological modelling and providing groundwater levels to the public will merely identify and quantify the impacts caused. They cannot prevent them from occurring.

¹¹¹ QCG 2013.

3.1 Impacts on the Great Artesian Basin

The GAB occupies approximately 1,711,000 km², covering much of Queensland and South Australia and extending into the Northern Territory and New South Wales. This large subterranean aquifer is an essential domestic and agricultural resource for many regions where permanent surface water is scarce.¹¹² The GAB stores approximately 8.7 million GL of water, some of which is estimated to be nearly two million years old.¹¹³ The GAB itself is approximately 100 to 250 million years old, and was formed by the layering of sandstone aquifers between impermeable layers of silt and mudstones.¹¹⁴ The GAB is Australia's largest artesian groundwater basin, extending to sub-surface depths of up to 3,000 metres¹¹⁵ and comprises the Eromanga, Surat and Carpentaria sedimentary basins and parts of the Bowen and Galilee Basins.¹¹⁶

Groundwater recharge occurs mainly along the eastern margins of the Basin, where the main sandstone aquifers outcrop in upland areas which experience high rates of rainfall. The western part of the Galilee Basin is a major recharge zone for the GAB. Recharge occurs via direct infiltration of rainfall, with additional contributions by leakage through surficial sediments overlying the aquifers, leakage from intersecting rivers and alluvial groundwater systems and, in some areas, infiltration through overlying aquitards. The eastern recharge area follows the course of the Great Dividing Range, extending from Dubbo in the south to Cape York in the North.¹¹⁷

The confining aquifers of the GAB are bounded by the Rewan Group at the bottom and the Winton Formation at the top.¹¹⁸

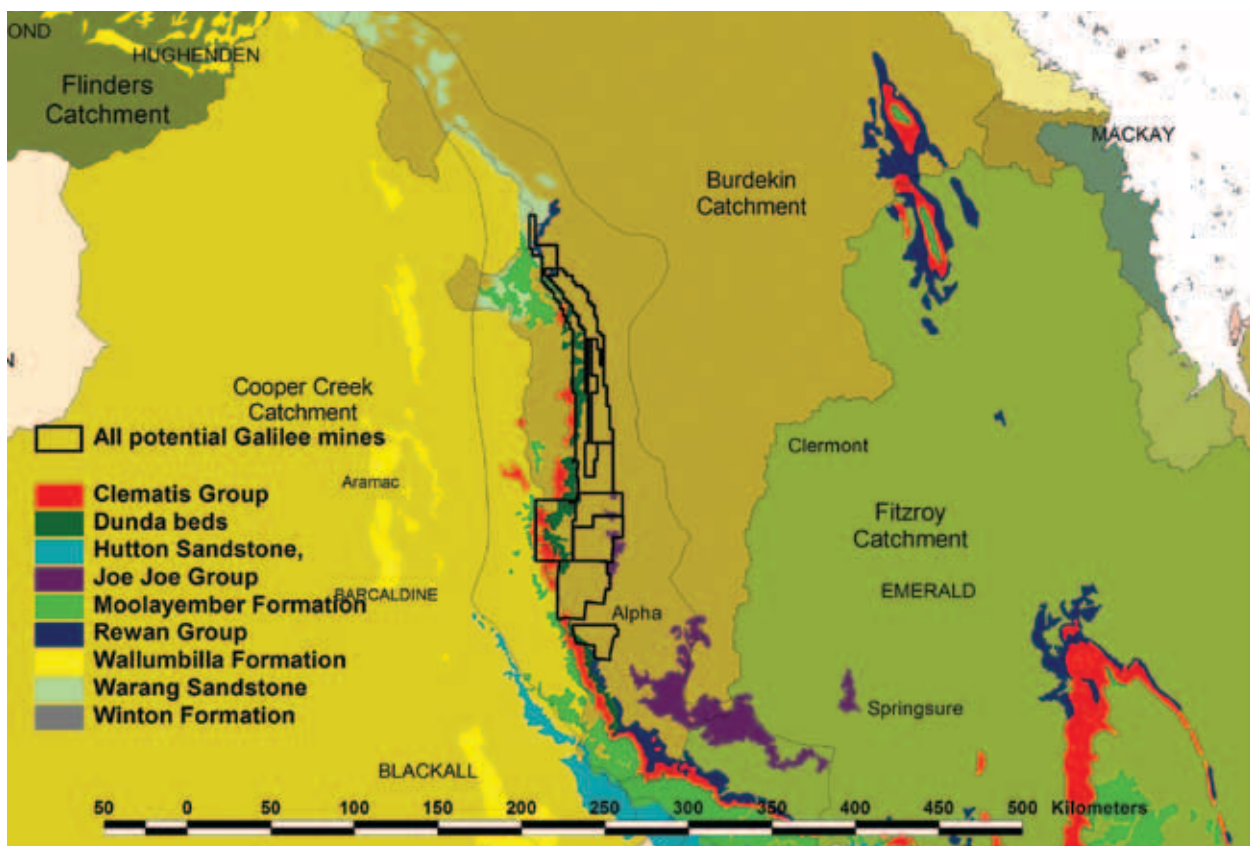


Figure 7: Surface geology showing Colinlea, Clematis and Hutton Sandstone outcrops, GAB Eastern Recharge Zone, Rewan/Dunda aquitards and other important aquifer outcrops in relation to proposed Galilee coal mines.¹¹⁹

¹¹² Ponder, 2002.

¹¹³ Noble et al, 1998.

¹¹⁴ Ponder, 2002.

¹¹⁵ Geoscience Australia, 2008.

¹¹⁶ Geoscience Australia, 2008, p73

¹¹⁷ Op cit. p76

¹¹⁸ Waratah Coal, 2011c, p22

¹¹⁹ QGIS data

As has been outlined previously, the Hutton Sandstone, Clematis Sandstone and Rewan Formation overlay the Permian coal measures targeted by the Galilee mine proposals which overlays the Permian Joe Joe Group. The Rewan Formation together with the Dunda Beds are categorized as aquitards which underlie and confine the Clematis Sandstones from the targeted Permian coal measures. It is therefore the Rewan/Dunda aquitard that is being relied upon by Galilee mine proponents to protect against mine-induced impacts on the GAB. Figure 7 shows the surface outcropping and recharge beds of regional aquifers and the Clematis Sandstone and Rewan/Dunda aquitard, overlain with the outline of mining lease applications for the proposed Galilee Basin mines.

The main threat posed to the Rewan/Dunda aquitard by coal mining is from underground longwall mines that cause fracturing and subsidence of the overlying sediments. While aquifers that are separated from longwall panels by aquitards may be somewhat insulated against hydraulic connection and leakage into underground mines, fracturing and deformation of such low permeability units can still occur, enhancing the likelihood of hydraulic connectivity between aquifers.¹²⁰ Only one page of the 120 pages of the China First SEIS Longwall Report is devoted to the GAB. The SEIS asserts, as other mine proponents have done, that the connection between mining targets and overlying units, particularly the Clematis Sandstone, is protected from longwall tensile cracking by the 100-175m thick aquitards of the Lower Triassic Dundas Beds and Rewan Formation. Waratah Coal also asserts that the Colins Formation, which will be subjected to dewatering, is vertically separated from the underground mines to the east by between 200 and 400m.¹²¹

Waratah Coal maintains that the separation distances between the underground mines and the Clematis Sandstone would prevent any impact by underground longwall mining on the Clematis Sandstone. However, this is contradicted by a subsequent admission that “The aquitard beneath the Clematis Sandstone aquifer will mostly remain unaffected, except in the eastern areas of underground longwall mine number 4, mining the ‘B’ seam horizon.”¹²² This demonstrates that the aquitard beneath the Clematis Sandstone will in fact be affected by at least one longwall mine. Even if this effect is supposedly localised, the impact on overlying strata will be highly dependent on the degree of subsidence and fracturing, which is difficult to predict quantitatively at this stage.

The Clematis Sandstone crosses the south-western corner of the South Galilee mining lease, and dips to the west into the GAB. At its closest point, it lies about 2km from the western limit of proposed underground mining and about 7km west of the western limit of proposed open-cut mining. The AMCI groundwater report for its South Galilee mine proposal suggests that “The results demonstrate that the maximum drawdown under the Clematis Sandstone is in the order of 5 m”.¹²³ Impacts on the Clematis Sandstone and the corresponding potential for impacts on the GAB are as a result of coal mining activities proposed in the Galilee Basin.

The federal Department of Sustainability, Environment, Water, Population and Communities’ (SEWPAC) Recommendation Report for the Alpha coal mine criticised assumptions by the Galilee mine proponents that the mines would not interfere with GAB water.¹²⁴ Indeed, mine proponents do predict some level of impact on the GAB, it’s just that this information is embedded in complex and contradictory assessment documentation, and requires significant critical review to bring to light. GVK Hancock state in their groundwater report for the Alpha mine that “Regional groundwater modelling predicts that the cone of depression [of groundwater drawdown] will extend westward to the Rewan Formation outcrop, but that *drawdown in overlying GAB aquifers will not be extensive*” (our emphasis).¹²⁵

¹²⁰ Booth, 2002.

¹²¹ Waratah Coal, 2013a. p 8

¹²² *ibid*

¹²³ RPS Aquaterra, 2012. p iii

¹²⁴ Alpha Coal mine Recommendation Report, August 2012. Obtained through Freedom of Information.

¹²⁵ Hancock Prospecting Pty Ltd, 2011d. p 51

The Queensland Coordinator General has also acknowledged the risk of groundwater draining via geological fault structures from the Clematis Sandstone through the Rewan Formation to the aquifers of the Bandanna Formation and Colinlea Sandstone in which targeted Permian coal measures occur.¹²⁶

The assessment documents for the proposed Galilee Basin mines appear to indicate a potential impact on the GAB without fully assessing these impacts. For example, the groundwater assessment for Waratah's China First mine states that "...the mine's footprint is designed to pass beneath the GAB's basal aquitard but it is not certain whether or not it will lie beneath the GAB's basal aquifer."¹²⁷ This again underscores the need for further regional assessment of the impacts on groundwater. The uncertainty in regard to likely impact, and the importance of the GAB as a national water resources would suggest that substantial additional assessment is required before any mining is allowed to put this crucial water resource at risk. Mine proponents have not satisfactorily demonstrated that significant impacts on this nationally significant resource will not occur.



Ensham mine, Bowen Basin

¹²⁶ Queensland Coordinator General, 2013. p viii

¹²⁷ Heritage Computing Pty Ltd, 2013. p 4

3.2 Scale and impact of mine dewatering

All of the Galilee Basin mines propose to take substantial volumes of groundwater in order to dewater underground mines and open cut pits. The scale of proposed mine dewatering in the Galilee Basin means that permanent changes are expected to groundwater levels, flow direction, hydrochemistry, recharge and discharge mechanisms of regional aquifers and potentially GAB aquifers.

The uncertain, and sometimes contradictory estimates of groundwater ingress by mine proponents indicates that further modelling, supported by collection of field data for calibration purposes is required to properly assess this issue. One document suggests that up to 100GL of groundwater will enter pits over the 30 year life of the mine¹²⁸ and that cumulative groundwater ingress is estimated to be up to 240GL for Kevin's Corner and Alpha mines together (between 104GL and 241GL).¹²⁹ According to an earlier report prepared for the Alpha SEIS, simulations suggested the cumulative inflow volume into just the Alpha pits varied between 658 and 1150GL over the 31 years of mining activity.¹³⁰ The cumulative inflow volumes into the Kevin's Corner underground mine and into the Northern and Southern Kevin's Corner open cut pits were estimated in the same document to be in the ranges 4844-7150GL, 60-123GL and 169-348GL respectively.¹³¹

Projected groundwater ingress estimates for the other three proposed mines seem low in comparison with the GVK Hancock's predictions for the Alpha and Kevin's Corner mines. Projections by Adani for its Carmichael proposal suggest that by the year 2067, over 125GL of groundwater will flow into its open cut pits, and over 112GL into its underground workings by 2047. For South Galilee, the estimated dewatering volume required is 147GL¹³² and for the China First mine, the estimate is up to 127.3GL, which also seem low compared to GVK Hancock's predictions. Waratah Coal acknowledges that the models on which its estimates are based assume no pre-drainage or evaporation, so their figures are likely to be higher in reality.¹³³ The Carmichael EIS suggests that increased vertical hydraulic conductivity due to longwall cracking would lead to increased inflows up to an order of magnitude higher than the estimates it provides.¹³⁴

Based on the above projections, the overall estimated volume of groundwater ingress into the five Galilee mines with completed environmental impact assessments could be between 700GL and 9,253GL over the life of the mines. The huge variation of estimates is confusing and ultimately fails to provide an accurate basis on which to assess the mines' impact on a cumulative, regional scale.

Through extrapolation of the modelling and estimates provided by the assessment reports for the five Galilee mines that have been assessed, we have conservatively estimated the overall potential removal of groundwater for Galilee mining proposals to be in the order of 1,354GL (see Table 4).

Monitoring has shown that groundwater drawdown from mining is conical, diminishing with distance from the centre of extraction – in this case the mines. However, the spatial radius of influence of a drawdown cone is always significantly greater than the target area of dewatering. For example, modelling indicates that groundwater drawdown impacts for the Alpha mine alone may be experienced at distances up to 20km from the mine, elongated along the open cut pit length in a north-south direction.¹³⁵ One of GVK Hancock's assessment documents states that "The water table is predicted to recover over a period of ~250-300 years after the start of mining. Water levels in mine pit lakes will equilibrate at about 280mAHD, and the regional water table will show a cone of depression with almost radial flow towards the mine pit lakes."¹³⁶

¹²⁸ URS, 2012a.p xiv

¹²⁹ ibid

¹³⁰ Hancock Coal Pty Ltd, 2011. p v1

¹³¹ Hancock Coal Pty Ltd, 2011. p v1

¹³² RPS Aquaterra, 2012. P ii

¹³³ Waratah Coal, 2011c. p 246

¹³⁴ ibid

¹³⁵ Hancock Prospecting Pty Ltd, 2010. P 13

¹³⁶ Hancock Coal Pty Ltd, 2011. P v1

Table 4: Stated, estimated and predicted mine dewatering by proposed Galilee mines

Mine	Status	open cut pits	L-wall mines	Total cost -Mt (estimate)	Peak Coal Mtpa	Mine life	Max dewater (GL)	Stated max dewater (GL)	GL/Mt total coal
Alpha	Approved	4	0	2600	30	30	100	100	0.038
Alpha North	Proposed	Yes	Yes	3480	40	?	190,03 (est)	-	-
Alpha West	Proposed	?	?	?	20	?	98.29 (est)	-	-
China First	SEIS	2	4	3684	40	30	127.3	127.3	0.035
China Stone	Initial Advice Statement	1	4	1800	45	40	98.29 (est)	-	-
Carmichael	EIS	21	3	8300	60	90	355	355	0.043
Degulla	Proposed	?	?	?	30	?	98.29 (est)	-	-
Kevin's Corner	SEIS	2	3	4300	30	30	140	140	0.033
South Galilee	EIS	4	1	1179	17	55	147	147	0.125
Totals [average]		34	15	25343	312	-	1354.2	869.3	[0.055]

The depression in the water table in the vicinity of the proposed South Galilee mine has been estimated to eventually be up to 70m below pre-mining levels.¹³⁷ Post mining simulation of aquifer recovery suggested that long term groundwater aquifer levels may recover to around 10-20m below the pre-mining levels, with about 80% of that recovery occurring within about 30 years of the cessation of mining.¹³⁸ The South Galilee mine proponents acknowledge that: "Groundwater levels in neighbouring bores immediately adjacent to the mine will never recover completely, but will rise up to between 10 to 20m below pre-mining levels".¹³⁹

Simulations by Waratah Coal suggest that the China First mine drawdown effects will be up to approximately 30km from the mine during the mine's life.¹⁴⁰ A similar cone of groundwater depression will develop as a result of the GVK Hancock Coal projects. The close proximity of the respective mines will lead to significant overlap between the cones of groundwater drawdown leading to compounded effects of the groundwater level.¹⁴¹

These are significant impacts, and are also likely to be highly uncertain. The transient response of groundwater systems to long-term drawdown, and subsequent recovery behaviour are inherently difficult to predict. An accurate knowledge of the storage co-efficient, transmissivity and volume of water in storage are needed to properly assess this through calibrated groundwater modelling.¹⁴²

¹³⁷ AMCI Investments Pty Ltd, 2012b. p 85

¹³⁸ AMCI Investments Pty Ltd, 2012b. p 89

¹³⁹ Op cit. p 91

¹⁴⁰ Waratah Coal, 2011c. p 245

¹⁴¹ Waratah Coal, 2011a. p 72

¹⁴² Bredehoeft and Durbin, 2009

Because drawdown propagates through aquifers and cannot be confined simply to the area being dewatered, there is significant likelihood that regional impacts will occur far outside the area of the individual mines. Dewatering drawdown cones are predicted to elongate north and south within the more permeable sandstone units of the Colinlea Sandstone. The cumulative impact of adding the additional mine dewatering will result in deeper drawdown in regions where the drawdown cones of individual mines overlap, further impacting on recovery.¹⁴³

As has already been cited, Waratah Coal modelled the cumulative drawdown of the proposed China First, South Galilee and Alpha mines, but noted that “there is incomplete knowledge of the geological detail and mining sequence for the other projects.”¹⁴⁴ The predicted cumulative impact of the three mines on groundwater will result in “a broad elongated cone of depression that is about 30km wide and over 100km in length along a north-south axis. The eastern limit of drawdown is well defined, as it is controlled by outcropping geology and the erosion of coal measures. There is predicted in this assessment to be some expansion of the drawdown to the west, including a small tongue crossing the GAB geological boundary in the area where the GAB rocks are hidden by Quaternary cover.”¹⁴⁵

As Waratah Coal only modelled the cumulative impacts for three mines, each additional mine will presumably add to the cone of depression with the likely result of encroachment to the GAB aquifers and the springs. Waratah’s assertion that “The expansion to the west is not substantial and considered unlikely to impact on the GAB aquifer or the GAB springs”¹⁴⁶ is not able to be tested without a regional groundwater flow model that includes impacts from all mines.

There is a lot of uncertainty in the assessment reports around the length of time groundwater will take to recover from mine dewatering, and the degree to which recovery will occur, if at all. Assessment documents for GVK Hancock Coal admit this uncertainty is in part due to uncertainty in predictions of drawdown levels.¹⁴⁷ Even under the best case scenarios, Waratah Coal could not predict when the groundwater aquifers would recover and suggested that in some instances groundwater levels will never recover from mining.¹⁴⁸

The Queensland Coordinator General acknowledged that: “The data suggests that mining will locally dewater the groundwater resource, and that there will be little or no recharge to replenish ‘mined’ groundwater. This has implications for long-term sustainable yields for mine use, and for local groundwater users with bores constructed within the D-E sandstone or strategically higher sediments.”¹⁴⁹

The effects of aquifer depressurisation (extraction of groundwater which decreases aquifer pressures) has been described in other mines to extend for many kilometres from the mine and cause major impacts on aquifer piezometric levels, water temperature and land subsidence.¹⁵⁰

The proposed Kevin’s Corner mine SEIS suggested there is very little mitigation possible for the potential impacts of groundwater aquifer drawdown. Coal companies are therefore proposing to enter into “make good” agreements with affected landowners to ensure future water supply. GVK Hancock documentation suggests the potential for the use of available groundwater to supplement surface water resources

¹⁴³ Op cit. p 26

¹⁴⁴ Waratah Coal, 2013b. p 3948

¹⁴⁵ *ibid*

¹⁴⁶ *ibid*

¹⁴⁷ Hancock Coal Pty Ltd, 2011. Pv1

¹⁴⁸ Waratah Coal, 2011c. p 246

¹⁴⁹ QCC, 2012b. Alpha Coal Project. p 64

¹⁵⁰ Fernando and Nag, 2007.

impacted by one or more of the projects, including the artificial recharge of registered springs,¹⁵¹ - a highly questionable mitigation measure - and have suggested they could obtain this water from the sub-E sandstone aquifer.¹⁵² GVK Hancock proposes to depressurise the underlying D-E sandstone¹⁵³ and the sub-E sandstone for the Alpha mine.¹⁵⁴ Nevertheless, URS suggest that the sub-E sandstone will still be fully saturated and therefore consider the sub-E sandstone away from the immediate mining area, as a potential source of make-good water.¹⁵⁵

The mine proponents propose developing alternate water supply agreements with landholders who will potentially be impacted by mine dewatering. Landholders are being offered an alternate water supply of comparable yield and quality. It is expected that this may include strategies such as lowering pumps within an existing borehole or supplying pumps with a greater capacity and drilling new bores to a greater depths where groundwater is not yet affected by mining operations.¹⁵⁶

Cattle north of Belyando River crossing



¹⁵¹ Hancock Galilee Pty Ltd, 2012. p 28

¹⁵² URS, 2012c. p 179

¹⁵³ Hancock Prospecting Pty Ltd, 2011d. p 10

¹⁵⁴ In groundwater "potentiometric surface" is a synonym of "piezometric surface" which is an imaginary surface that defines the level to which water in a confined aquifer would rise were it completely pierced with wells

¹⁵⁵ URS, 2012c. p xvii-xviii

¹⁵⁶ Hancock Prospecting Pty Ltd, 2010. p13

3.3 Impacts on groundwater discharge

Groundwater and surface water are connected through the hydrological cycle and therefore impacts on one can, and often do, affect the other.¹⁵⁷

Groundwater may become surface water through discharge to springs and drainage into rivers, lakes and wetlands. Conversely, surface water bodies may seep into the ground and recharge the aquifers, e.g. when flood water percolates through the unsaturated zone to the saturated zone.¹⁵⁸

This means that there are risks that the mines will impact both ground and surface water, and ecosystems that depend on them. The Alpha coal mine is one example where groundwater surface water interaction is likely to be impacted by mining. The Alpha EIS acknowledges the possibility of Colinlea and Bandana Formation groundwater discharging into Lagoon Creek, particularly if fracturing of the overlying sand beds occurs due to longwall mining.¹⁵⁹ This risk appears to be exacerbated by the proposed diversion of Lagoon Creek for the mine development.¹⁶⁰ Similarly, previous cases have been documented in NSW where longwall mining has induced major impacts on surface water, including drying up of streams and cracking of their beds.¹⁶¹

Proponents of the South Galilee mine suggest that groundwater discharge to streams is virtually zero, but leakage from stream systems into groundwater is about 2ML/day. According to the modelling undertaken for the proponent of the mine, these components of the water balance did not change with time during the mining and post-mining simulations (i.e. there is no additional induced flow from surface water streams as the depth to water table is typically 10m or more).¹⁶² Unless the streams are completely isolated from any groundwater inflow (which is generally only the case for ephemeral streams), and there is no hydraulic connection with any aquifer, the lowering of a water table near a stream will always increase the hydraulic gradient, and therefore increase the driving force for increased leakage of surface water to groundwater.¹⁶³

The potential impacts of the Carmichael mine proposal on groundwater discharge into the Carmichael River and into springs may be significant. An assessment of the water chemistry of the Carmichael River and nearby groundwater resources showed that it is likely that the surface water of the Carmichael River is influenced by the nearby groundwater aquifers, particularly in the dry season.¹⁶⁴

Further monitoring undertaken for the Carmichael mine EIS found that groundwater discharge to the Carmichael River may be occurring upstream of the proposed mine, but the EIS was not able to determine clearly the degree to which the river is fed by direct discharge from groundwater into the river itself, or from the upstream Doongmabulla Springs, which are GAB discharge springs.¹⁶⁵ Figure 8 shows the proximity of Doongmabulla Springs to Carmichael and the other coal leases of the Galilee Basin, and other important wetlands in the region.

The EIS stated that during the period of most intensive mining and impact, after about 60 years of the proposed 90 year life of the mine, drawdowns of between 30 to 60m would occur in the groundwater table in the vicinity of the Carmichael River. The proponent has acknowledged that this will result in a reduction in the flow of the River.¹⁶⁶

¹⁵⁷ Winter *et al*, 1999:

¹⁵⁸ Siebert, *et al*, 2010.

¹⁵⁹ Hancock Prospecting, 2010c. p22

¹⁶⁰ SEWPAC - Office of Water Science, 2012.

¹⁶¹ See for example ACARP 2001, 2 002, 2003; Everett *et al*, 1998; DIPNR 2003

¹⁶² AMCI Investments Pty Ltd, 2012b . p 88

¹⁶³ Winter *et al*, 1999

¹⁶⁴ Adani Mining Pty Ltd, 2012g. p 31

¹⁶⁵ Adani Mining Pty Ltd, 2012g. p 78

¹⁶⁶ Adani Mining Pty Ltd, 2012h. p34.

3.3.1 Springs

Doongmabulla Springs are a group of permanent artesian, fresh water springs about 8km west of the proposed Galilee Basin mines. Doongmabulla Springs are part of the Barcaldine spring supergroup, a regional cluster of springs associated with the GAB, on the eastern margin of the GAB Eastern Recharge.¹⁶⁷ The Recovery Plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin, of which Doongmabulla Springs are an example, notes that habitat critical to the survival of the endangered plant *Eryngium fontanum* can be based on permanent spring-fed wetlands with a groundwater source from the GAB within a 5km radius of Doongmabulla and Edgbaston/Myross Springs.¹⁶⁸ The Environmental Impact Statement for the Carmichael mine states that the most intensive phase of the mine will lead to "Loss of a small area of vegetation, including species of conservation significance, along the outer boundary of the [Doongmabulla Springs] wetland as the volume of flow from the spring declines."¹⁶⁹

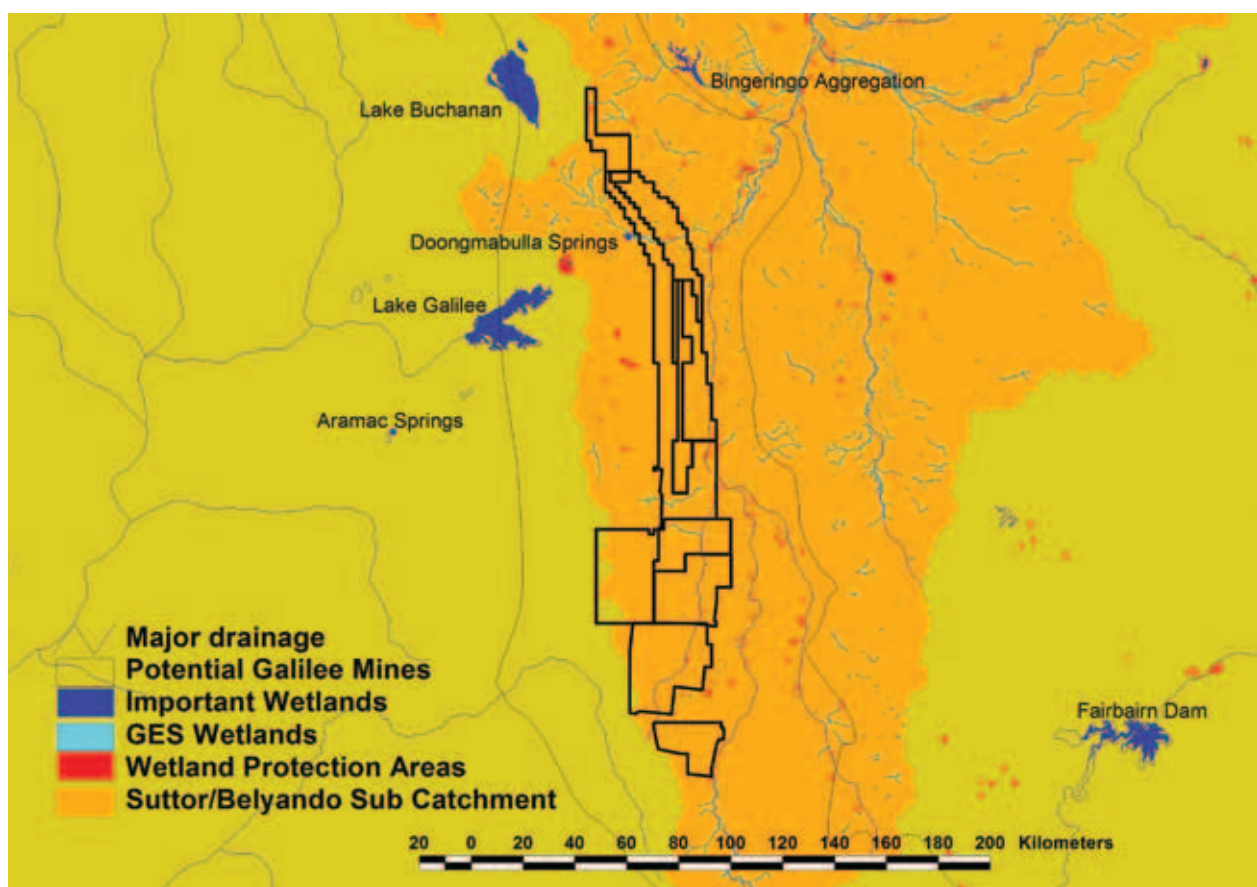


Figure 8: Galilee main drainage features including wetlands, springs and Wetland Protected Areas¹⁷⁰

The spring complex is located near the junction of three third order streams, Cattle Creek (in the south), Dyllingo Creek (in the centre) and Carmichael Creek (in the north). These watercourses converge within a kilometre of each other to form the Carmichael River. Much of this flow proceeds directly to the Carmichael River, contributing to its base flow.

¹⁶⁷ Adani Mining Pty Ltd, 2012g. p 88

¹⁶⁸ Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin. Department of Environment and Resource Management (Qld). 2010

¹⁶⁹ Adani Mining Pty Ltd, 2012h p35

¹⁷⁰ QGIS data

The mapped geology in the vicinity of the Doongmabulla Springs complex suggests that all of the springs are likely fed by groundwater from the Clematis Sandstone aquifer which in the case of most of the springs discharges through the overlying Moolayember Formation and/or Quaternary alluvium.¹⁷¹ This is consistent with the Australian Wetlands Database, which describe Doongmabulla Springs as “derived from faults allowing water to flow from thin confining beds of the Great Artesian Basin aquifer”.¹⁷²

There are two further springs around 10km south of Carmichael mine proposal, to the north of Mellaluka. These springs are identified as non-GAB Eastern Desert Upland springs typically associated with outcropping Dunda Beds. The springs are mapped around 10km east of the nearest area of Dunda Beds outcrop and the geology typically dips from east to west making it more likely that the springs are associated with older Permian units and/or near surface Quaternary/Tertiary units.¹⁷³

The EIS for the Carmichael mine identifies that the Mellaluka Springs are likely to experience 0.7 to 0.8m drawdown due to mine dewatering at the peak intensity of the mine’s operation, in its sixtieth year and there is admission that “Further assessment of the ecology and hydrogeology of the springs themselves and of the area between the springs and the proposed mining area is required to better understand the potential for impact in this area.”¹⁷⁴ After the mine, which is proposed continue for 90 years, finishes operating, Adani predict the mine will result in a drawdown of 5m at Mellaluka Springs.¹⁷⁵



Carmichael River channel

¹⁷¹ Adani Mining Pty Ltd, 2012g. p 88

¹⁷² *ibid*

¹⁷³ Adani Mining Pty Ltd, 2012g. p 89

¹⁷⁴ Adani Mining Pty Ltd, 2012g. p113

¹⁷⁵ Adani Mining Pty Ltd, 2012g. p 118

3.4 Impact on aquifer recharge and cross-formation flow

Groundwater recharge is highly variable and difficult to estimate with certainty. It generally does not occur as a flat percentage of rainfall, and particularly in semi-arid areas it is events of high rainfall intensity that are often required for recharge to occur.¹⁷⁶ One reason for this is that the hydraulic conductivity of unsaturated material is low relative to the hydraulic conductivity of the same material when saturated. During rainfall events below a particular intensity, water either runs off via the surface drainage system, or is lost through evapo-transpiration resulting in no deep drainage or recharge.

In a study on groundwater recharge in the Great Artesian Basin intake beds, rainfall in excess of 200mm per month in the area of the beds was found to be required before significant recharge events occurred, and diffuse recharge following "average" rainfall events, occurred at a rate of up to 3mm per year.¹⁷⁷ The EIS for the proposed South Galilee mine calculated the recharge to the groundwater at the South Galilee area is in the range 1 to 20mm/year or about 1% to 4% of the annual rainfall.¹⁷⁸

A review of bore hydrographs for GVK Hancock Coal's proposed Kevin's Corner mine did not indicate an obvious increase in groundwater levels in most bores that could be interpreted as effective aquifer recharge in response to wet season rainfall, but it did find this occurring at one bore, located above the A coal seam. The shallow sandstone and the A-B sandstone both recorded groundwater levels with an increasing trend over 2010 which coincided with significant wet season rainfall over the 2009/2010 and 2010/2011, which indicates that recharge is occurring there.¹⁷⁹

As has previously been noted, in their work for GVK Hancock, URS could not definitively determine where recharge to groundwater in the formations in the vicinity of the proposed Alpha and Kevin's Corner mines was occurring. This may mean that recharge to the aquifers within the proposed mine site occurs as a result of diffuse recharge along the Great Dividing Range.¹⁸⁰ As a general rule, recharge tends to take place in areas where the topography is high relative to surrounding areas, and where sediments are more permeable (often also adjacent to topographically elevated areas).¹⁸¹ There is thus significant likelihood that recharge occurs on the Divide.

If this is the case, according to a company commissioned by the Queensland Coordinator General to review the hydrological impacts of the Alpha mine, it is more likely that there will be impact on the GAB aquifers from the mine. The consultant explained that this was because recharge from the west "is derived either from discharge from the GAB strata, or vertical infiltration from the surface through the GAB beds and the basal Rewan Formation into the underlying Colinlea Sandstone. In either case, the potential for impact on the GAB exists. The source and mechanism of recharge needs to be resolved."¹⁸² In their advice on the proposed mines, the IESC were similarly concerned that there was no impervious link between the proposed mining operations and the GAB, stressing that "there was not enough information to make an assessment as to the integrity of the Rewan Formation as an aquitard in this area to restrict connection with the Great Artesian Basin. In the absence of this assurance, it would be necessary to highlight the risks posed to the Great Artesian Basin from the current proposal, as well as future proposals."¹⁸³

¹⁷⁶ De Vries and Simmers, 2002

¹⁷⁷ Kellett *et al*, 2003.

¹⁷⁸ AMCI Investments Pty Ltd, 2012b. p 50

¹⁷⁹ URS, 2012c. p 37

¹⁸⁰ URS, 2012c. p 41

¹⁸¹ Toth, 1963

¹⁸² RPS, 2011. p 8

¹⁸³ IESC, 2012

¹⁸⁴ Adani Mining Pty Ltd, 2012g. p88

¹⁸⁵ Adani Mining Pty Ltd, 2012g. p137

Adani acknowledge that for the Carmichael mine project, the predicted post-closure cone of influence extends to the west, and includes areas where the Triassic-age Dunda Beds, Clematis Sandstone and/or the Moolayember Formation are mapped at outcrop. Hence, there is the potential for groundwater levels to remain lower than pre-development levels after the cessation of mining activities and for a reduction in flow of water to the west in the Clematis, as a result of changes to the groundwater flow field.

Adani assert, however, that the topography, groundwater modelling results and the available groundwater level data all suggest that current groundwater flow in Triassic-age units to the west of the site may be towards the east and therefore away from the GAB rather than towards it. Like other Galilee Basin mine proponents, the company maintains that if this eastward groundwater flow direction is confirmed by further monitoring then no impacts on the GAB groundwater resources are expected to occur as a result of dewatering for their project.¹⁸⁷



Belyando River crossing

¹⁸⁶ Adani Mining Pty Ltd, 2012g. p 118

¹⁸⁷ *ibid*

3.5 Town and property impacts

The Queensland Cadastral data for the Isaac, Barcaldine and Charters Towers Regional Government Area (24-3-2013)¹⁸⁸ identifies 168 parcels of land associated with 39 stations¹⁸⁹ within the mine lease areas of the nine proposed Galilee Basin coal mines. Most of these parcels are held as leasehold (155) but 13 are freehold. The stations within the proposed Galilee Basin mines are shown in Table 5.

Table 5: Private land within the proposed Galilee Basin mine lease areas

Name	Freehold	Leases	Regional Government Areas	Stations
Alpha	3	17	Barcaldine	Surbiton South, Hobartville, Wendouree, Burtle
Alpha West	4	10	Barcaldine	Speculation, Mundah, Wendouree, Hobartville, Hotspur, Locharnoch, Milangavie, Spring Creek
Carmichael	0	18	Charters Towers & Isaac	Moray Downs, Mellaluka, Bygana
China First	4	16	Barcaldine	Spring Creek, Kia Ora, Cavendish, Glen Innes (Bimblebox Nature Refuge), Monkland, Lambton Meddows, Cornetop, Toarbee
China Stone	0	8	Charters Towers & Isaac	Moray Downs, Dooyne, Hyde Park
Degulla	0	31	Charters Towers & Isaac	Degulla, Mellaluka, Golspie, Lennox, Alinya, Lestree Downs, Laglan
Kevin's Corner	0	10	Barcaldine Regional	Surbiton, Surbiton South, Forrester, Wendouree, Cudmore Resource Reserve
North Alpha	0	39	Charters Towers, Isaac & Barcaldine	Forrester, Riverview, Surbiton, Cudmore Resource Reserve, Lennox, Degulla, Moray Downs, Mellaluka, Golspie, Laglan, Bimbah East, Doongmabulla, Carmichael
South Galilee	2	6	Barcaldine	Creek Farm, Betanga, Sapling Creek, Chesalon
Total	13	155	3	39

Source: Cadastre fortnightly extract – Isaac, Charters Towers and Barcaldine Regional Government Areas - <http://www.nrm.qld.gov.au/property/mapping/dccdata/>, Alick, 2012.

¹⁸⁸ <http://www.derm.qld.gov.au/property/mapping/dccdata/>

¹⁸⁹ Alick, 2012

Table 6 presents data on the status of existing bores within the 9 proposed Galilee Basin mine lease areas. Of the 227 bores within the proposed mine lease areas, 194 are in use, and 182 of these are sub-artesian.¹⁹⁰ It is expected that all of these groundwater bores will become increasingly inoperable as mining progresses, and the projected groundwater drawdown depression of up to 70m below pre-mining levels develops, depending on their distance from the mine site.¹⁹¹ Mine proponents suggest that long term groundwater levels may recover to around 10-20m below the pre-mining levels.¹⁹² However, the cumulative impacts of additional mines are very likely to increase this groundwater depression, both in depth and spatial area and will likely affect recovery.

Table 6: Bores within the proposed Galilee Basin mine lease areas

Mine	Bores	Operating	Sub-artesian	Artesian	Estimated annual extraction (MLpa)
Alpha	52	47	42	0	470
Alpha West	7	1	1	0	10
Carmichael	19	17	14	3	170
China First	54	43	43	0	430
China Stone	3	3	3	0	30
Degulla	30	29	25	4	290
Kevin's Corner	31	31	31	0	310
North Alpha	14	10	10	0	100
South Galilee	17	13	13	0	130
Total	227	194	182	7	1940

Source: DNRM bore database

Groundwater in the Galilee Basin is used primarily for town water, stock and domestic water supply, and some small scale irrigation, where salinity levels are low. Current groundwater extraction volumes are unavailable for the Galilee Basin due to bores not having flow metres installed.¹⁹³

The proposed South Galilee mine groundwater report suggests bore yields in the area range from 0.01 litres a second to 16 litres a second.¹⁹⁴ Information available from DNRM indicates that average bore yields are typically 1 to 2 litres a second, which could equate to 7.5 to 13 ML/year if it was assumed that bore operation is 10 hours/day for 6 months per year.¹⁹⁵ Using an average bore yield of 10MLpa, it is estimated that currently about 1.94GLpa of groundwater may be extracted from the 194 active bores within the mine lease areas.

¹⁹⁰ DNRM, 2013a.

¹⁹¹ AMCI Investments Pty Ltd, 2012b, p 85

¹⁹³ AMCI Investments Pty Ltd, 2012b, p 89

¹⁹⁴ RPS Aquaterra, 2012, p 27

¹⁹⁵ RPS Aquaterra, 2012, p 27

Table 7 shows the number of bores within 10 and 20km radii of the proposed coal mines, including those in the towns of Alpha and Jericho. Figure 9 is a map showing existing bores in red and their distance in 10km increments from the proposed coal mines.

Table 7: Bores impacted and potentially impacted by groundwater drawdown

Distance from proposed Galilee mines	Bores	In use	Sub-artesian	Artesian	Estimated annual extraction (GLpa)	Alpha town (in use)	Jericho town (in use)
10km	241	159	155	4	1.59	91 (40)	
20km	221	150	149	1	1.5	51 (33)	25 (15)



Alpha township

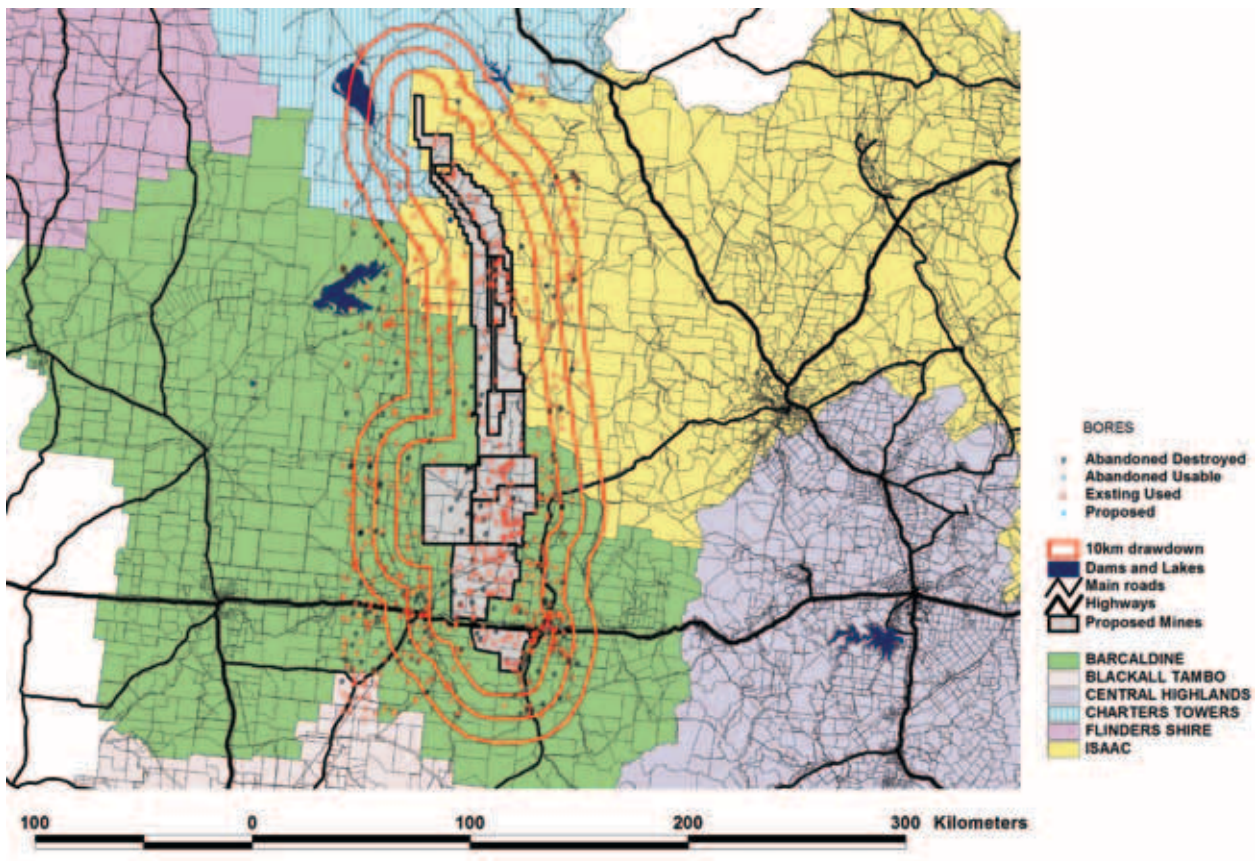


Figure 9: Galilee properties and bores affected by proposed mines at 10km increments from mine areas¹⁹⁶

Adani's Carmichael mine EIS predicts that dewatering will result in declining groundwater levels of more than one metre up to 10km from the mine site and identifies potential impacts on 31 of the 36 registered bores with drawdowns of greater than one metre anticipated for at least five registered bores.¹⁹⁷ These impacts include a 3.6m drawdown of the Clematis Sandstone aquifer to the north of the lease area, a 6.4m drawdown of the Dunda Beds to the south east of the lease area and a staggering 19.8m drawdown of the Permian Sandstone aquifer to the north of the mine lease area.¹⁹⁸

Simulation results by GVK Hancock indicate that the cumulative cone of depression caused by Alpha and Kevin's Corner mines will also extend to about 10km around these mines. In the north-west corner, the outcropping low conductivity Rewan Formation limits the extent of the cone of depression to between 1.5 and 6 km.¹⁹⁹ Based on the predicted cumulative drawdown cones for Alpha and Kevin's Corner mines, 25 DNRM registered bores are at risk within the predicted 1m drawdown contour.²⁰⁰

While over 500mm of annual rainfall is experienced across most of the Galilee Basin groundwater is a key source of reliable water for towns and pastoralists in the Basin. There are 10 groundwater bores installed at the town of Alpha for the town's water supply. The bores source groundwater from unconsolidated Tertiary and alluvial sediments with 87 ML extracted in 2010/11 and 164 ML in 2011/12.²⁰¹

¹⁹⁶ QGIS data

¹⁹⁷ Adani Mining Pty Ltd, 2012g. p 112

¹⁹⁸ Adani Mining Pty Ltd, 2012g. p 113

¹⁹⁹ Hancock Coal Pty Ltd, 2011. p v1

²⁰⁰ URS, 2012c. p 131

²⁰¹ South Galilee Coal Project Section 9—Water Resources p 43

The towns of Alpha and Jericho are part of the former Jericho Shire which has a population of about 1103 (2002 ABS). The Shire has a cattle population between 180,000 and 240,000 head.²⁰² Beef cattle in Queensland consume about 50 litres a day.²⁰³ Total water required for the cattle of the former Jericho Shire is therefore in the order of 4GLpa.

The groundwater report for Waratah Coal's proposed China First mine suggests that the groundwater drawdown beneath the Clematis Sandstone, near the local springs that are near the recharge area, is predicted to be less than one metre 35km southeast at Alpha township, and 20km southwest at Jericho township.²⁰⁴ Predicted impacts on water levels in private bores are expected to also extend up to 10km to the east and south of the China First mine lease.²⁰⁵

The AMCI-Bandanna groundwater report suggests that the drawdown at the Alpha township area and at the town water supply bores as a result of the South Galilee mine is predicted to be less than 1m, mainly due to the influence of the low permeability of the Rewan Formation outcrop limiting the eastern extent of drawdown.²⁰⁶ AMCI, therefore, assert there should be no need for mitigation of water supplies for Alpha and Jericho townships.

However, there is the potential for cumulative impact associated with the proposed South Galilee and China First mines that could add to the groundwater drawdown in the town of Alpha.

The groundwater depression cone may extend further than the predicted 10km from mine pits and longwalls. Dewatering drawdown cones are predicted to elongate north and south within the more permeable sandstone units of the Colinslea Sandstone. The cumulative impact of adding the additional mine dewatering will result in deeper drawdown where drawdown cones overlap and further elongate along strike.²⁰⁷ The overall size and extent of overlapping cones will impact on recovery.²⁰⁸

Based on 10MLpa average yield for operating bores yield, 5GLpa is currently extracted for stock, domestic and town water supplies within 20km of the proposed mine lease areas.²⁰⁹ We have estimated that at least 40 per cent of this groundwater (194 active bores with the mine lease areas) will be inaccessible due to mining activity. Access to at least a further 3GLpa (304 active bores within 20km of the mine lease area boundaries) may also be limited due to drawdown associated with dewatering of mines and evaporation of open cut mine voids once mining has ceased.

The proposed Moranbah to Alpha Pipeline was to bring water from the Connors River Dam to both the Galilee Basin mines and the town of Alpha. This has now been shelved along with the Connors River Dam due to reluctance by mine proponents to furnish the required funds. Make good water by mine proponents for the towns of Alpha and Jericho and landholders cannot be relied upon without firm commitments to pipe water to the area from either the Burdekin Falls or Fairbairn Dams.

²⁰² See <http://www.alphaqueensland.com.au/thetown.html>

²⁰³ Hill, 2012.

²⁰⁴ Heritage Computing Pty Ltd, 2013, p 53

²⁰⁵ Heritage Computing Pty Ltd, 2013, p 60

²⁰⁶ RPS Aquaterra, 2012. P ii

²⁰⁷ Hancock Galilee, 2011b. p 23

²⁰⁸ Hancock Galilee, 2011b. p 26

²⁰⁹ The proposed South Galilee mine groundwater report suggests that average bore yields are typically 1 to 2 litres a second, which could equate to 7.5 to 13 ML/year if it was assumed that bore operation is 10 hours/day for 6 months per year. Based on this, we use a conservative estimate of an average bore yield of 10MLpa which if applied to the 304 active bores within 20 km and 194 active bores within the mine leases, equates to about 5 GLpa of groundwater extracted.

4. Conclusion

The nine coal mines proposed for the Galilee Basin would see over 34 open cut pits and 15 underground mines along a 270 kilometre north south strike to produce over 300 million tonnes of coal per annum at full production.

Clearly, if approved by government regulating authorities, these mines will result in enormous groundwater impacts. While documents lodged with the Queensland Coordinator General by five Galilee mine proponents predict that up to 870GL will be extracted, our research indicates that a total of 1,343GL could be removed from Galilee aquifers if all nine Galilee mine proposals gained approval. Mine proponents admit that this volume could increase by a factor of ten if the Rewan aquitard, which currently separates the proposed mining target from the Clematis Sandstone, is fractured as a result of longwall mining.

The open cut coal pits proposed for Galilee Basin coal mines will dewater regional aquifers. Long after mining ceases they will continue to draw groundwater from the surrounding area and will raise salinity of the water in the void well beyond usable levels. These proposed mines will operate for between 30 and 90 years, and all are expected to have impacts on local and regional water resources that will not recover for centuries, if ever.

Longwall mining operations in the Galilee Basin have the potential to impact on the water resources in the Great Artesian Basin (GAB). There is good reason to believe that aquifers that recharge the GAB to the west of the mining leases are not entirely separated from the aquifers that will be impacted by the coal mines. Indeed, the targeted Permian coal seam is identified as in contact with GAB aquifers to the west of the mine leases. These aquifers may therefore be influenced by depressurising the Permian coal measures with the potential for transmission of hydraulic effects from the mining areas to aquifers that recharge the GAB, causing a change in the amount and direction of groundwater flow in these layers.

Based on the documents produced for Environmental Impact Statements for the mines, we estimated that the peak water demand of the five Galilee mine proposals for which assessment documents have been prepared could be between 50 and 70 GLpa, of which more than 60% will be sourced from local watercourses and groundwater. This has the potential to cause significant impact on local groundwater dependent ecosystems and fundamentally alter the dynamics of groundwater-surface water interaction.

Despite the predicted impacts set out in separate assessment documents of the proposed Galilee Basin mines, mines are being approved without an adequate understanding of their cumulative impacts. To date, no cumulative hydrological impact study has been prepared or published by any government agency. The documents that are meant to dispel concerns of unacceptable impacts of proposed mines have been criticised for their inadequacy with gaps in the requisite understanding of regional aquifers and their interaction with the GAB. Currently, not enough information has been provided either by the proponents or government to make an assessment as to the integrity of aquitards to restrict connection with the Great Artesian Basin.

Groundwater drawdown will significantly reduce the ability for surrounding graziers and towns to supply their water needs. The cumulative drawdown of groundwater may affect bores within 20km of the proposed mine lease areas, which includes the townships of Jericho and Alpha. These bores may no longer be usable or may need to be drilled to greater depths to access the depressed water table. In some cases this will not be possible as mine proponents depressurize deep aquifers, hence promises are being made to supply "make good water."

Unsubstantiated suggestions by the mine proponents that they could artificially recharge regional aquifers has little basis in technical reality, yet seems to have been taken at face value by the Queensland and Federal Governments. Governments have not been sufficiently rigorous in scrutinising mine proponents' claims about the impacts their projects will and will not have on groundwater resources. It is highly likely that regional impacts to deep aquifers will occur due to the need to depressurise these underlying aquifers. Therefore, groundwater may never be available in sufficient volumes at any economic depth to satisfy local landholders' and towns' demand should the Galilee Basin mine proposals proceed. Pipelines from either Burdekin Falls or Fairbairn Dams would thus be the sole viable option.

Any "make good" agreements contemplated by landholders and the townships of Alpha and Jericho should include an ironclad guarantee that such water will be available and that it has been secured in sufficient volumes in perpetuity before signing any agreement, and certainly before any final mining approval is granted and mining activity occurs. There needs to be a high degree of legal certainty that these "make good" agreements are enforceable, or landholders could be left alone grappling with permanent groundwater deficits.

The Federal Government now has a statutory role in ensuring that coal seam gas and large coal mining activities do not irreparably damage water resources. Given the uncertain and sometimes contradictory information in existing assessments, and incomplete assessment of the projects in a regional context, this new legislative trigger provides an opportunity to conduct further assessment and safeguard the high value water resources of the region.

It is clear from this study that a far more in-depth and stronger understanding of the groundwater impact of these coal mine proposals is needed, and that such work must address the cumulative impact of so many very large mines in one location. The assessment and approvals processes for any further Galilee Basin coal mines should be placed on hold until comprehensive studies on the cumulative effects of the Galilee Basin coal mine proposals on groundwater are appropriately investigated. If, as seems possible, the groundwater impacts are irreparable and cause damage to water supplies and ecosystems, then a re-assessment of whether the mines should proceed should be considered.

References

- 4T Consultants, 2011a. Coal Mine Groundwater Bore Survey Report. Appendix O. Alpha Coal Project. Supplementary EIS.
- _, 2011b. Bore Survey. Section N. Hancock Galilee Pty Ltd. Kevin's Corner EIS.
- ABC News 24, 2011. Stranded residents may need more food drops. Jan 6, 2011 12:32pm AEDT.
<http://www.abc.net.au/news/2011-01-06/stranded-residents-may-need-more-food-drops/1896216>
- ACARP, 2001. 'Impacts of Mine Subsidence on the Strata & Hydrology of River Valleys - Management Guidelines for Undermining Cliffs, Gorges and River Systems'. Australian Coal Association Research Program Final Report C8005 Stage 1, March 2001.
- ACARP, 2002. 'Impacts of Mine Subsidence on the Strata & Hydrology of River Valleys - Management Guidelines for Undermining Cliffs, Gorges and River Systems'. Australian Coal Association Research Program Final Report C9067 Stage 2, June 2002.
- ACARP, 2003. 'Review of Industry Subsidence Data in Relation to the Influence of Overburden Lithology on Subsidence and an Initial Assessment of a Sub-Surface Fracturing Model for Groundwater Analysis'. Australian Coal Association Research Program Final Report C10023, September 2003
- Adani Mining Pty Ltd, 2012a. Description of the Project. Volume 2 Section 2 Carmichael Coal Mine and Rail Project EIS.
- _, 2012b. Doongmabulla Springs Existing Environment Report. Mine Technical Report for Carmichael Coal Mine and Rail Project EIS.
- _, 2012c. 8. Cumulative Impacts. Volume 2 Section 8 Carmichael Coal Mine and Rail Project EIS.
- _, 2012d. Land Use .Revision 3 .Report for Carmichael Coal Mine and Rail Project EIS
- _, 2012e. Mine Technical Report Mine Water Quality. Carmichael Coal Mine and Rail Project EIS
- _, 2012f. Preliminary Water Balance Carmichael Mine EPC 1690 & 1080. Report for Carmichael Coal Mine and Rail Project EIS.
- _, 2012g. Water Resources. Volume 2 Section 6. Carmichael Coal Mine and Rail Project EIS.
http://www.adanimining.com/Common/Uploads/EISDocuments/75_EISDoc_Water%20Resources.pdf
- _, 2012h. Matters of National Environmental Significance. Section 5 Carmichael Coal Mine and Rail Project EIS.
- AGL, 2013. Underground Water Impact Report ATP529P - Galilee Basin Date: 4 January 2013
- Alick, T & Alick, R, 2012. Atlas of Queensland and Northern Territory Pastoral Stations etc, 9th Edition, Terrence Alick Mapping Service Pty Ltd, Brisbane
- AMCI Investments Pty Ltd, 2012a. Project Description Section 4. South Galilee Coal Project EIS
- _, 2012b. Water Resources. Section 9. South Galilee Coal Project EIS
- _, 2012c. Rehabilitation and Decommissioning. Section 5. South Galilee Coal Project EIS.
- Andrew Fraser, The Australian Newspaper, 2011. Galilee miners will have to build dam. Business section. December 06, 2011 12:00AM.
<http://www.theaustralian.com.au/business/galilee-miners-will-have-to-build-dam/story-e6frg8zx-1226214543153>
- Booth, C. J., 2002. The effects of longwall coal mining on overlying aquifers. Geological Society, London, Special Publications, 198(1), 17-45.
- Australian Groundwater Consultants, 1983. Maranoa Dam Leakage Investigations, Unpublished Report
- Booth, Colin J. "Groundwater as an Environmental Constraint of Longwall Coal Mining." *Materials and Geoenvironment* 50 (2003): 49-52.
- Booth, C.J., 2006. Groundwater as an environmental constraint of longwall coal mining. *Environmental Geology*, Volume 49, Issue 6, pp 796-803
- Booth, C. J., Spande, E. D., Pattee, C. T., Miller, J. D., & Bertsch, L. P. ,1998. Positive and negative impacts of longwall mine subsidence on a sandstone aquifer. *Environmental Geology*, 34(2-3), 223-233.
- Geoenvironment, 50, 49-52
- Bredehoeft, J. and Durbin, T., 2009. Ground Water Development—The Time to Full Capture Problem. *Ground Water* 47(4) 1745-6584
- Bureau of Meteorology (BOM), 2013. Burdekin Fall Dam Storage Levels 2002-2013 L227_BURDEKINFSSStorageVolum(136.3)
- CE3 Consult, 2011a. Groundwater Assessment. Appendix 14, Volume 5 Waratah Coal China First EIS.
- _, 2011b. Surface Water Assessment. Appendix 15, Volume 5 Waratah Coal China First EIS.
- CSIRO, 2012. Hydrostratigraphy, hydrogeology and system conceptualisation of the Great Artesian Basin: A technical report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment <https://publications.csiro.au/rpr/download?pid=csiro:EP132693&dsid=DS5>
- Department of Employment, Economic Development and Innovation (DEEDI), 2012. Central Galilee Basin Exploration and Mining Projects. Queensland Department of Employment, Economic Development and Innovation
http://www.chdc.com.au/documents/Resources/Mines_And_Energy/201203_CentralGalileeBasinExplorationAndMiningProjects.pdf
- Department of Environment and Resource Management. (DERM), 2013. Queensland Department of Natural Resources and Mines, April 2013 Mining Leases data file. <http://mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>
- Department of Natural Resources and mines (DNRM), 2009. Burdekin Basin Resource Operations Plan, Attachment 5. http://www.nrm.qld.gov.au/wrp/pdf/burdekin/burdekin_rop.pdf
- _, 2012a. Annual Report 2011–2012 Queensland's Water Resource Plans: Summary. http://www.nrm.qld.gov.au/wrp/pdf/annual_reports/wrp-annual-report-2011-12.pdf
- _, 2012b. Great Artesian Basin Water Resource Plan Five Year Review. http://www.nrm.qld.gov.au/wrp/pdf/gab/gab_rop.pdf
- _, 2013a. Groundwater Database. v7.
- _, 2013. 120301B Belyando River at Gregory Development Rd> Streamflow Data > Open stations > Burdekin Basin. <http://watermonitoring.derm.qld.gov.au/host.htm>
- Department of Infrastructure Planning and Natural Resources (DIPNR), 2003. 'Hydrological and water quality assessment of the Cataract River; June 1999 to October 2002: Implications for the management of longwall coal mining.' NSW Department of Infrastructure, Planning and Environment, Wollongong.
- De Vries JJ, Simmers I, 2002, 'Groundwater recharge: an overview of processes and challenges', *Hydrogeology Journal*, vol.10, no.5, pp. 5-17
- Elisabeth Behrmann, 2011. Australia's \$32 Billion Galilee Coal Basin Needs Joint Rail, Vale Says. Bloomberg. <http://www.bloomberg.com/news/2011-11-23/australia-s-32-billion-galilee-coal-basin-needs-joint-rail-vale-says.html>
- Engeny, 2011. Mine Development Flood Assessment, Appendix 17, Volume 5. Waratah Coal Galilee Coal Project EIS.
- _, 2012a. Surface Water Impact Assessment of Longwall Mining Subsidence. Technical Report. Waratah Coal Galilee Coal Project SEIS
- _, 2012b. Mine Site Water Management System Technical Report. Waratah Coal Galilee Cal Project SEIS.
- _, 2012c. Mine Site Creek Diversion and Flooding. Technical Report.. Waratah Coal Galilee Coal Project SEIS.
- Evans, R, Roe, P and Joy, J, 2003. Water use and sustainable development in coal mining – A case study from Central Queensland, Paper presented to Minerals Council of Australia's Sustainable Development 2003 Conference, Brisbane, November.

- Everett M, Ross T, Hunt G (eds), 1998. 'Final Report of the Cataract River Taskforce. A report to the Upper Nepean Catchment Management Committee of the studies of water loss in the lower Cataract River during the period 1993 to 1997.' Cataract River Taskforce, Picton.
- Fensham R 2006, 'Spring wetlands of the Great Artesian Basin', paper for the 2006 Australian State of the Environment Committee, Department of Environment and Heritage, Canberra <http://www.deh.gov.au/soe/2006/emerging/wetlands/index.html>
- Fernando, F., and Nag, D. 2007. Management of aquifer depressurization system in Hazelwood mine, Latrobe Valley, Australia. <http://www.infomine.com/library/publications/docs/Fernando2007.pdf>
- Great Artesian Basin Consultative Council, 2010. Great Artesian Basin Resource Study Update. <http://www.gabcc.org.au/tools/getFile.aspx?tbl=tblContentItem&id=412>
- Geoscience Australia, 2008. Assessment of Groundwater Resources in the Broken Hill Region Prepared for the Australian Government Department of the Environment, Water, Heritage and the Arts. <http://www.environment.gov.au/water/publications/environmental/groundwater/broken-hill.html>
- GVK 2011. Project Overview Infrastructure Association of QLD presentation. Paul Mulder, Managing Director – Coal. 1 March. p3. http://www.hancockcoal.com.au/files/120301_IAQ_Breakfast_Presentation1.pdf
- Habermehl, M.A, 1980. The Great Artesian Basin, Australia. BMR Journal of Geology & Geophys. 5, 9-38.
- Hancock Coal Pty Ltd, 2011. Alpha Coal Project And Kevin's Corner Project Regional Groundwater Model Interim Report.
- _, 2010. Alpha Coal Project EIS. Executive Summary. <http://www.dsdlp.qld.gov.au/resources/project/alpha-coal-project/alpha-coal-executive-summary.pdf>
- _, 2010a. Project Description. Section 2. Volume 2. Alpha Coal Project EIS.
- _, 2010b. Surface Water. Section 11. Alpha Coal Project EIS.
- _, 2010c. Groundwater. Section 12. Alpha Coal Project EIS
- _, 2010d. Decommissioning and Rehabilitation. Section 25 . Alpha Coal Project EIS
- _, 2010e. Coal Mine Surface Water. Appendix I. Alpha Coal Project EIS
- Hancock Galilee Pty Ltd, 2011a. Project description. Chapter 2. Kevin's Corner Coal Project
- _, 2011b. Cumulative Impacts. Section X. Kevin's Corner EIS.
- _, 2011c. Surface Water, Chapter 11. Hancock Galilee Pty Ltd. Kevin's Corner Project EIS.
- _, 2011d. Groundwater, Chapter 12. Hancock Galilee Pty Ltd. Kevin's Corner Project EIS.
- _, 2011e. Decommissioning and Rehabilitation. Chapter 26. Hancock Galilee Pty Ltd. Kevin's Corner Project EIS
- _, 2011f. Site Water Management System and Water Balance Technical Report. Appendix M3. Kevin's Corner Project Environmental Impact Statement .
- _, 2012. Interim Cumulative Impact Assessment Report. Appendix O. Kevin's Corner Project Environmental Impact Statement
- Hancock Prospecting Pty Ltd, 2011a. Amendments to the Project Description. Section 2. Alpha Coal Project Supplementary EIS.
- _, 2011b. Revised Description of Project. Appendix C. Alpha Coal Project Supplementary EIS.
- _, 2011c. Coal Mine Surface Water Summary. Appendix I. Alpha Coal Project Supplementary EIS.
- _, 2011d. Coal Mine Groundwater and Final Void Report. Appendix N. Alpha Coal Project Supplementary EIS.
- _, 2011e. Site Water Management System and Water Balance Technical Report. Appendix L. Alpha Coal Project Supplementary EIS.
- _, 2012. Surface Water Summary. Appendix I. Alpha Coal Project Supplementary EIS.
- Henderson, R.A., Davis B. K. & Fanning, C. M, 1998. Stratigraphy, age relationships and tectonic setting of rift phase infill in the Drummond Basin central Queensland. Australian Journal of Earth Sciences: An International Geoscience Journal of the Geological Society of Australia Volume 45, Issue 4, pages 579-595
- Heritage Computing Pty Ltd, 2013. Galilee Coal Project Groundwater Assessment. Appendix. Waratah Coal Galilee Coal Project SEIS.
- Hill, 2012. Water requirements for cattle. Futurebeef. <http://futurebeef.com.au/topics/nutrition/water-requirements-for-cattle/>
- Interim Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining. (IESC), 2012. Alpha Coal Mine, QLD (EPBC 2008/4648) Advice to decision maker on coal mining project <http://www.environment.gov.au/coal-seam-gas-mining/interim-committee/pubs/iiesc-advice-alpha.pdf>
- JBT, 2010. Groundwater Technical Report. Hancock Prospecting Pty Ltd. Alpha Coal Project
- Kellett, JR., Ransley, TR., Coram J., Jaycock, J., Barcaly, DF., McMahon, GA, Foster LM, Hillier JR., 2003 Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland Department of Natural Resources and Mines Technical Report
- McNally G. and Evans R., 2007. Impacts of longwall mining on surface water and groundwater, Southern Coalfield NSW. Report prepared for NSW Department of Environment and Climate Change. eWater Cooperative Research Centre, Canberra.
- Macmines Austasia Pty Ltd, 2012. Project China Stone. Initial Advice Statement. <http://www.dsdlp.qld.gov.au/resources/project/china-stone-coal-project/china-stone-coal-project-ias.pdf>
- Madden, A., Ross, J.B., and Jankowski, J., 2009. Longwall Mining Effects on Deep Groundwater in a Southern Coalfield Catchment, Australia. Hydrology and Water Resources Symposium 30 November-3 December 2009, Newcastle, Australia
- Mudd, G.M., 2008. Sustainability Reporting and Water Resources: a Preliminary Assessment of Embodied Water and Sustainable Mining. Mine Water and the Environment Volume 27, Issue 3, pp 136-144.
- Sinclair Knight Merz (SKM), 2012. Assessing water stress in Australian catchments and aquifers . Technical Report for the National Water Commission. http://archive.nwc.gov.au/_data/assets/pdf_file/0007/23020/Assessing-Water-Stress-in-Australian-Catchments-and-Aquifers-Technical-Report.pdf
- Noble, J.C., Habermehl, M.A., James, C.D., Landsberg, J., Langston, A.C., and Morton, S.R, 1998, 'Biodiversity implications of water management in the great artesian basin'. Rangeland Journal. Vol. 20. pp 275-300.
- NTEC, 2011. Regional Groundwater Report. Alpha Coal Project and Kevin's Corner Project. Section N1. Hancock Galilee Pty Ltd. Kevin's Corner Coal Project EIS.
- Parsons Brinckerhoff, 2010a. Flooding Technical Report. F2. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2010b. Site Water Management System and Water Balance Technical Report. F3. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2010c. Surface Water Quality Technical Report. F4. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2010d. Tailings Storage Facility – Concept Design Report. J2. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2010e. Flooding Technical Report. F2. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2010f. Coal Surface Water Quality Technical Report. Appendix N.. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2010g. Coal Tailing Storage Facility Update Appendix T. Hancock Prospecting Pty Ltd. Alpha Coal Project EIS
- _, 2011a. Flooding Technical Report. Appendix K Hancock Prospecting Pty Ltd. Alpha Coal Project Supplementary EIS
- _, 2011b. Coal Mine – Site Water Management System and Water Balance Technical Report.. Appendix L Hancock Prospecting Pty Ltd.

- Alpha Coal Project Supplementary EIS
- _, 2011c. Surface Water Quality Technical Report. Appendix M. Hancock Prospecting Pty Ltd. Alpha Coal Project Supplementary EIS
- _, 2011d. Coal Mine Tailings Storage Facility Update. Appendix T. Hancock Prospecting Pty Ltd. Alpha Coal Project Supplementary EIS
- _, 2011e. Stream Morphology Technical Report. Addendum E. Hancock Coal Pty Ltd. Alpha Coal Project Supplementary EIS
- Ponder, W.F., 2002, 'Desert Springs of the Australian Great Artesian Basin'. In D.W. Sada, and S.E., Sharpe, (eds), Conference Proceedings, Spring-fed Wetlands: Important Scientific and Cultural Resources of the Intermountain Region, May 7-9 2002, Las Vegas, Nevada. Available from: <http://wetlands.dri.edu/2002/Ponder.pdf>
- Petheram, C., Tickell, S., O'Gara, F., Bristow, K.L., Smith A. and Jolly, P., 2008. Analysis of the Lower Burdekin, Ord and Katherine-Douglas-Daly Irrigation Areas: Implications to future design and management of tropical irrigation. CRC for Irrigation Futures Technical Report No. 05/08 CSIRO Land and Water Science Report 19/08. <http://www.clw.csiro.au/publications/science/2008/sr19-08.pdf>
- Queensland Competition Authority (QCA), 2012. Final Report SunWater Irrigation Price Review: 2012-17 Volume 2 Burdekin-Haughton Water Supply Scheme April 2012 <http://www.qca.org.au/files/W-QCA-SunWaterFinalReport-Volume2-BurdekinHaughton-WSS-0412.pdf>
- _, 2013. SunWater Irrigation Price Burdekin Haughton Scheme. <http://www.qca.org.au/files/W-SunIrrigPrice-Synergies-Burdekin-Haughton-0310.pdf>
- Queensland Coordinator General (QCC), 2012a. Connors River Dam and Pipelines Project Report January 2012 <http://www.dlg.qld.gov.au/assessments-and-approvals/connors-river-dam-and-pipelines.html>
- _, 2012b. Alpha Coal Project. Coordinator-General's Evaluation Report on the environmental impact statement. Queensland Government Printers Brisbane. <http://www.dsdlp.qld.gov.au/resources/project/alpha-coal-project/alpha-coal-cg-report-final-sig.pdf>
- _, 2013. Kevin's Corner project: Evaluation report on the environmental impact statement. <http://www.dsdlp.qld.gov.au/resources/project/kevins-corner-project/kevins-corner-cg-report.pdf>.
- Queensland Department of Natural Resources and Mines, 2013. Mining Leases data file. <http://mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>
- RPS, 2011. Alpha Coal Project Review of Selected Aspects of the EIS Supplementary EIS, SEIS Addendum and other Proponent Responses proposed conditions. Prepared for the Queensland Department of Infrastructure and Planning.
- _, 2012. Galilee Basin Report on the Hydrogeological Investigations. Consultant's report for RLMS and the Galilee Basin Operators Forum. http://www.rlms.com.au/uploaded_docs/RPS_Galilee%20Basin%20Hydrogeological%20Investigations.pdf
- RPS Aquaterra, 2012. Groundwater Assessment and Modelling. South Galilee Coal Project EIS.
- Siebert, S., Burke, J., J. M. Faures, J.M., Frenken, K., Hoogeveen, J., Doll, P., and Portmann, F.T. 2010. Groundwater use for irrigation – a global Inventory. Hydrol. Earth Syst. Sci. Discuss., 7, 3977–4021, 2010 www.hydrol-earth-syst-sci-discuss.net/7/3977/2010/ doi:10.5194/hessd-7-3977-2010
- Sunwater, 2012. SunWater discontinues work on Connors River Dam and Pipelines Project 27 Jul 2012 Media Release, <http://www.sunwater.com.au/about-sunwater/media-room/latest-news/latest-news/2012/sunwater-discontinues-work-on-connors-river-dam-and-pipelines-project>
- Senior, D.A., 1973. Explanatory notes to the Jericho 1:250000 geol map, by D.A. Senior, 1973.
- SEWPAC – Department of Sustainability, Environment, Water, Population and Communities –Office of Water Science, 2012. Supporting Information – Proposed Action: Alpha Coal Project (Coal and Associated Infrastructure), QLD (EPBC 2008/4648). Attachment A: 200612 Alpha coal project supporting information
- SGCP (2012) Site Water Balance Model, Appendix A of South Galilee Coal Project Surface Water Assessment, Appendix F. South Galilee Coal Project EIS.
- Steel Guru, 2010. Vale to tap into Galilee Basin potential. http://www.steelguru.com/raw_material_news/Vale_to_tap_into_Galilee_Basin_potential/162804.html
- Toth, 1963. A theoretical analysis of groundwater flow in small drainage basins. Journal of Geophysical Research 68(16), 4895-4811
- URS, 2011a. Fluvial Geomorphology. Section M. Hancock Galilee Pty Ltd. Kevin's Corner EIS.
- _, 2011b. Flood Hydrology Study. Section M. Hancock Galilee Pty Ltd. Kevin's Corner EIS.
- _, 2011c. Hydraulic Technical Report. Section M. Hancock Galilee Pty Ltd. Kevin's Corner EIS
- _, 2011d. Surface Water Technical Report. Section M. Hancock Galilee Pty Ltd. Kevin's Corner EIS
- _, 2011e. Out of Pit Tailings Storage: Hydrogeology Assessment. Addendum C. Hancock Coal Pty Ltd Alpha Coal Project Supplementary EIS.
- _, 2012a. Groundwater Modelling Report. Hancock Coal Pty Ltd Alpha Coal Project. Supplementary EIS.
- _, 2012b. Cumulative Surface Water Impact Assessment. Hancock Galilee Pty Ltd. Kevin's Corner Supplementary EIS.
- _, 2012c. Groundwater Report. Appendix L. Hancock Galilee Pty Ltd. Kevin's Corner Supplementary EIS.
- _, 2012d. Revised Surface Hydraulic Report. Appendix K. Hancock Galilee Pty Ltd. Kevin's Corner Coal Project Supplementary EIS.
- _, 2012e. Site Water Management (Basis of Design) Report. Appendix M. Hancock Galilee Pty Ltd. Kevin's Corner Coal Project Supplementary EIS.
- Van Heeswijck, A., 2006, The structure, sedimentology, sequence stratigraphy and tectonic of the northern Drummond and Galilee Basins, Central Queensland, Australia: PhD dissertation James Cook University of North Queensland, Smithfield QLD, various pagination.
- Waratah Coal, 2011a. Project Description, Volume 2 Chapter 1 Galilee Coal Project EIS.
- _, 2011b. Cumulative Impacts. Volume 1 Chapter 5. Galilee Mine EIS. <http://www.waratahcoal.com/publications.htm>
- _, 2011c. Groundwater Resources. Volume 2 Chapter 8. Galilee Coal Project EIS.
- _, 2011d. Surface Water Resources, Volume 2, Chapter 9. Galilee Coal Project EIS
- _, 2012. Tailings Storage Facilities Update. Appendix 9. China First Coal Project, Galilee Basin, Supplementary EIS.
- _, 2013a. Longwall Mining Subsidence Report. Volume 2. Appendix 41. China First Project, Galilee Basin
- _, 2013b. Updated Cumulative Impact Assessment. Appendix 42, China First Coal Project, Galilee Basin. Supplementary EIS, Water Resource (Great Artesian Basin) Plan 2006 <http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/W/WaterReGABP06.pdf>
- Winter et al, 1999: 'Groundwater and surface water: a single resource' USGS Circular 1139
- WRM, 2012. South Galilee Coal Project Surface Water Assessment. AMCI Investments Pty Ltd South Galilee Coal Project EIS.

Appendices

Appendix 1: Galilee Exploration Permits for Coal

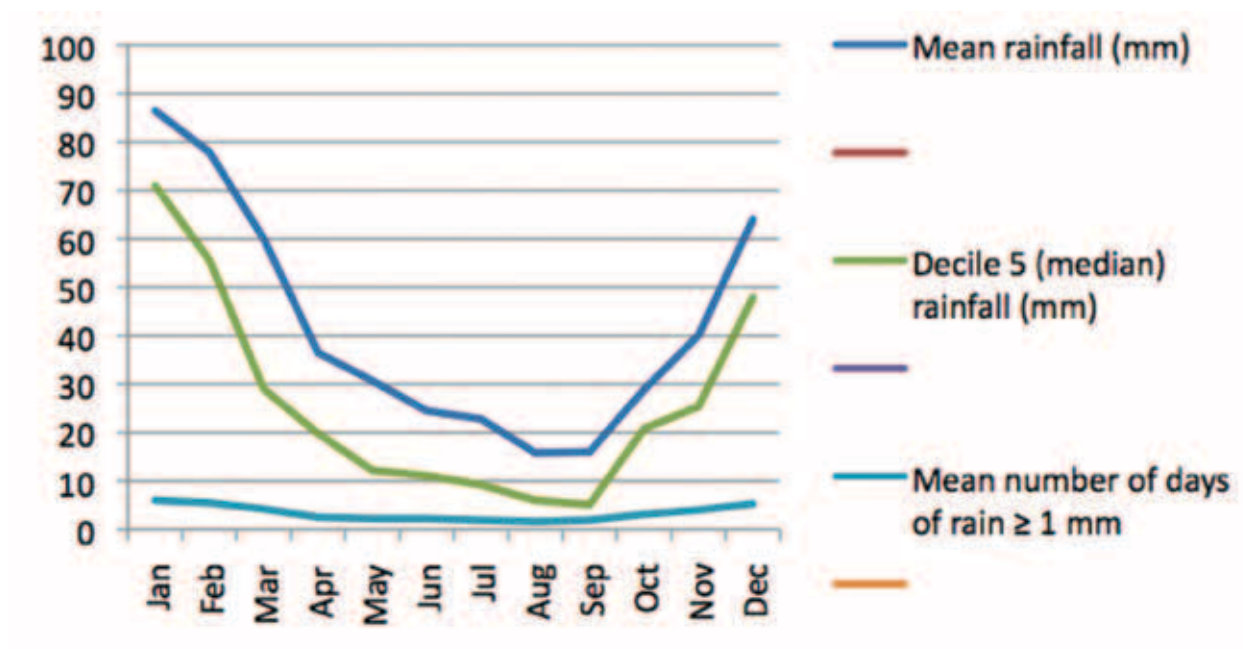
LODGED	GRANTED	PRINCIPAL	TENURE #	STATUS
1-Mar-93	27-Apr-93	LINC ENERGY LTD	526	GRANTED
14-Jan-02	6-Jan-03	XSTRATA COAL QUEENSLAND PTY LTD	771	GRANTED
7-Sep-04	25-Aug-05	VALE COAL EXPLORATION PTY LTD	907	GRANTED
29-Nov-04	29-Nov-05	VALE COAL EXPLORATION PTY LTD	926	GRANTED
15-Jul-05	2-Aug-06	MACMINES AUSTASIA PTY LTD	987	GRANTED
2-Sep-05	25-Sep-07	BHUSHAN STEEL (AUSTRALIA) PTY LIMITED	1002	GRANTED
3-Apr-06	9-Mar-07	WARATAH COAL PTY LTD	1039	GRANTED
3-Apr-06	22-Jun-06	WARATAH COAL PTY LTD	1040	GRANTED
18-May-06	28-Nov-07	ALPHA COAL PTY LTD	1049	GRANTED
18-May-06	29-Oct-07	ALPHA COAL PTY LTD	1048	GRANTED
25-May-06	30-Aug-07	WARATAH COAL PTY LTD	1053	GRANTED
1-Sep-06	10-Jan-08	VALE COAL EXPLORATION PTY LTD	1078	GRANTED
6-Sep-06	2-Nov-07	WARATAH COAL PTY LTD	1080	GRANTED
6-Sep-06	2-Nov-07	WARATAH COAL PTY LTD	1079	GRANTED
1-Nov-06	11-Feb-13	WARATAH COAL PTY LTD	1105	GRANTED
1-Nov-06	25-Feb-11	VALE COAL EXPLORATION PTY LTD	1104	GRANTED
16-Mar-07	17-Apr-08	VALE COAL EXPLORATION PTY LTD	1141	GRANTED
12-Jun-07	21-Oct-08	WARATAH COAL PTY LTD	1157	GRANTED
12-Jun-07	22-Oct-08	WARATAH COAL PTY LTD	1156	GRANTED
12-Jun-07	17-Sep-08	WARATAH COAL PTY LTD	1155	GRANTED
13-Aug-07	18-Dec-08	ALPHA COAL PTY LTD	1180	GRANTED
13-Aug-07	18-Dec-08	ALPHA COAL PTY LTD	1179	GRANTED
13-Sep-07	4-Aug-10	BOWEN ENERGY LIMITED	1187	GRANTED
20-Dec-07	18-Sep-09	HANCOCK KEVIN'S CORNER PTY LTD	1210	GRANTED
7-Mar-08	31-Jan-12	THECHAIRMEN1 PTY LTD	1250	GRANTED
27-Mar-08	28-Feb-11	CLYDE PARK COAL PTY LTD	1260	GRANTED
31-Mar-08	24-Feb-10	QUEENSLAND THERMAL COAL PTY LTD	1263	GRANTED
22-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1280	GRANTED
22-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1284	GRANTED
22-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1281	GRANTED
22-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1285	GRANTED
22-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1286	GRANTED
22-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1283	GRANTED
24-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1289	GRANTED
24-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1290	GRANTED
24-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1288	GRANTED
24-Apr-08	14-Jul-10	WARATAH COAL PTY LTD	1287	GRANTED
30-Apr-08	22-Oct-10	SOUTH QUEENSLAND THERMAL COAL PTY LTD	1293	GRANTED
26-May-08	23-Dec-08	CLIFFS AUSTRALIA COAL PTY LTD	1311	GRANTED
26-May-08	10-Dec-08	CLIFFS AUSTRALIA COAL PTY LTD	1308	GRANTED
26-May-08	28-Apr-10	CLIFFS AUSTRALIA COAL PTY LTD	1306	GRANTED
26-May-08	9-Jun-10	CLIFFS AUSTRALIA COAL PTY LTD	1307	GRANTED
26-May-08	15-Jun-10	CLIFFS AUSTRALIA COAL PTY LTD	1304	GRANTED
26-May-08	3-May-10	CLIFFS AUSTRALIA COAL PTY LTD	1303	GRANTED
26-May-08	24-Feb-10	CLIFFS AUSTRALIA COAL PTY LTD	1310	GRANTED
28-May-08	23-Dec-08	CLIFFS AUSTRALIA COAL PTY LTD	1312	GRANTED
19-Jun-08	31-May-11	IDALIA COAL PTY LIMITED	1410	GRANTED
4-Jul-08	8-Apr-09	CLIFFS AUSTRALIA COAL PTY LTD	1469	GRANTED
7-Jul-08	11-May-10	CLIFFS AUSTRALIA COAL PTY LTD	1476	GRANTED
8-Jul-08	26-Nov-10	MATILDA COAL PTY LTD	1485	GRANTED
8-Jul-08	21-Jan-11	MATILDA COAL PTY LTD	1486	GRANTED
8-Jul-08	18-Jun-10	MATILDA COAL PTY LTD	1483	GRANTED
14-Jul-08	29-Oct-10	MATILDA COAL PTY LTD	1496	GRANTED
31-Jul-08	25-May-10	VALE COAL EXPLORATION PTY LTD	1528	GRANTED
29-Sep-08	21-Oct-10	XSTRATA COAL QUEENSLAND PTY LTD	1588	GRANTED
3-Nov-08		CITATION RESOURCES OPERATIONS PTY LTD	1637	APPLICATION

3-Nov-08		AREA COAL PTY LTD	1638	APPLICATION
3-Nov-08		METROCOAL LIMITED	1640	APPLICATION
3-Nov-08		CARPENTARIA EXPLORATION LIMITED	1641	APPLICATION
3-Nov-08		GOLDEN CROSS OPERATIONS PTY LTD	1642	APPLICATION
3-Dec-08	26-Nov-10	RESOLVE COAL PTY LTD	1663	GRANTED
3-Feb-09	14-Jul-10	ADANI MINING PTY LTD	1690	GRANTED
9-Mar-09	11-Oct-10	EASTERN AUSTRALIA ENERGY PTY LTD	1701	GRANTED
24-Apr-09	29-Jun-11	QLD COAL AUST NO. 1 PTY LTD	1740	GRANTED
7-May-09	26-Nov-10	EASTERN AUSTRALIA ENERGY PTY LTD	1752	GRANTED
12-May-09	29-Oct-10	RESOLVE COAL PTY LTD	1754	GRANTED
22-May-09	28-Feb-11	MATILDA COAL PTY LTD	1762	GRANTED
12-Jun-09	29-Oct-10	QLD COAL AUST NO. 1 PTY LTD	1775	GRANTED
12-Jun-09	29-Oct-10	QLD COAL AUST NO. 1 PTY LTD	1774	GRANTED
1-Jul-09	29-Oct-10	BLACKWOOD EXPLORATION PTY LTD	1802	GRANTED
14-Aug-09	6-Jun-12	ORION MINING PTY LTD	1892	GRANTED
14-Aug-09	24-Jan-11	ORION MINING PTY LTD	1890	GRANTED
17-Aug-09	19-Mar-12	ORION MINING PTY LTD	1893	GRANTED
31-Aug-09	13-Aug-12	BOWEN BASIN COAL QLD AUST PTY LTD	1898	GRANTED
31-Aug-09	8-May-12	BOWEN BASIN COAL QLD AUST PTY LTD	1905	GRANTED
31-Aug-09	8-May-12	BOWEN BASIN COAL QLD AUST PTY LTD	1903	GRANTED
31-Aug-09	29-Jun-11	BOWEN BASIN COAL QLD AUST PTY LTD	1908	GRANTED
1-Sep-09	27-Jun-11	BOWEN BASIN COAL QLD AUST PTY LTD	1918	GRANTED
7-Oct-09	8-Feb-12	MINING INVESTMENTS ONE PTY LTD	1957	GRANTED
2-Nov-09		SCORPION ENERGY PTY LTD	1983	APPLICATION
2-Nov-09		CITATION RESOURCES OPERATIONS PTY LTD	1986	APPLICATION
2-Nov-09	26-Jul-12	MINING INVESTMENTS ONE PTY LTD	1989	GRANTED
3-Nov-09		SPINIFEX RURAL MANAGEMENT PTY LTD	1988	APPLICATION
9-Dec-09	9-Feb-12	SPINIFEX RURAL MANAGEMENT PTY LTD	2020	GRANTED
4-Jan-10	20-Aug-12	SEYMOUR ENERGY PTY. LTD.	2028	GRANTED
1-Feb-10	2-Feb-12	RESOLVE COAL PTY LTD	2050	GRANTED
24-Feb-10	15-Oct-10	SHADFORTH CIVIL CONSTRUCTION PTY LTD	2065	GRANTED
10-Mar-10		BLACKWOOD EXPLORATION PTY LTD	2079	APPLICATION
10-Mar-10	11-Feb-13	BLACKWOOD EXPLORATION PTY LTD	2080	GRANTED
7-Jul-10	23-May-12	REM RESOURCES PTY LTD	2160	GRANTED
7-Jul-10	6-Jun-12	REM RESOURCES PTY LTD	2161	GRANTED
16-Jul-10		SPINIFEX RURAL MANAGEMENT PTY LTD	2166	APPLICATION
3-Sep-10	24-Jan-11	SHADFORTH CIVIL CONSTRUCTION PTY LTD	2215	GRANTED
1-Nov-10		MINERAL & COAL INVESTMENTS PTY LIMITED	2251	APPLICATION
1-Nov-10		GOLDEN CROSS OPERATIONS PTY LTD	2252	APPLICATION
1-Nov-10		QUEENSLAND COAL INVESTMENTS PTY LTD	2255	APPLICATION
1-Nov-10		GUILDFORD COAL LIMITED	2259	APPLICATION
1-Nov-10		ENDOCOAL LIMITED	2262	APPLICATION
1-Feb-11		RESOLVE GEO PTY LTD	2341	APPLICATION
1-Feb-11		ADANI MINING PTY LTD	2344	APPLICATION
1-Feb-11		REM RESOURCES PTY LTD	2345	APPLICATION
1-Feb-11		BLACKWOOD EXPLORATION PTY LTD	2347	APPLICATION
1-Feb-11		ENDOCOAL LIMITED	2348	APPLICATION
30-Mar-11		CIVIL & MINING RESOURCES PTY LTD	2459	APPLICATION
30-Mar-11		CIVIL & MINING RESOURCES PTY LTD	2458	APPLICATION
12-Apr-11	2-Aug-12	GUILDFORD COAL LIMITED	2503	GRANTED
12-Apr-11	22-Oct-12	GUILDFORD COAL LIMITED	2504	GRANTED
1-Jul-11		FAIRWAY COAL PTY LTD	2637	APPLICATION
1-Jul-11		QUEENSLAND COAL INVESTMENTS PTY LTD	2639	APPLICATION
1-Jul-11		ADANI MINING PTY LTD	2642	APPLICATION
1-Jul-11		MINERAL & COAL INVESTMENTS PTY LIMITED	2644	APPLICATION
19-Jul-11		BLACKWOOD EXPLORATION PTY LTD	2689	APPLICATION
18-Oct-11	7-Dec-12	MATILDA COAL PTY LTD	2842	GRANTED
1-Nov-11		COAL FACE RESOURCES PTY LTD	2852	APPLICATION
1-Nov-11		ENDOCOAL LIMITED	2858	APPLICATION
1-Nov-11		QUEENSLAND COAL INVESTMENTS PTY LTD	2873	APPLICATION
1-Nov-11	11-Feb-13	MATILDA COAL PTY LTD	2853	GRANTED

Appendix 2: Rainfall data

- **Site name:** BARCALDINE POST OFFICE
- **Site number:** 036007
- **Latitude:** 23.55 °S **Longitude:** 145.29 °E
- **Elevation:** 267 m
- **Commenced:** 1886 Status: Open
- **Latest available data:** 18 Apr 2013

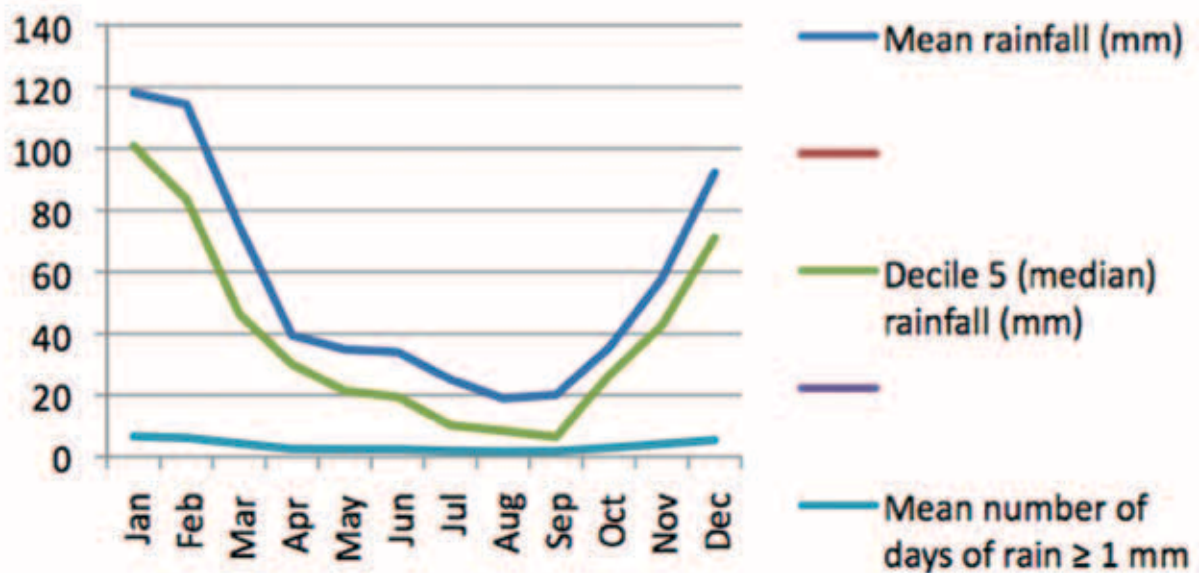
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual	Years	
Mean rainfall (mm)	87	78	60	37	30.7	25	23	16	16	29	40	64	504.4	126	1886
															2013
Decile 5 (median) rainfall (mm)	71	56	29	20	12.2	11	9.2	6	5.1	21	25	48	465.9	126	1886
															2013
Mean number of days of rain \geq 1 mm	6	5.5	4.2	2.5	2.2	2.2	1.9	1.6	1.9	3.1	4	5.3	40.4	126	1887
															2013



Source: <http://www.bom.gov.au/climate/data/index.shtml?bookmark=200&view=map>

- **Site name:** CLERMONT POST OFFICE
- **Site number:** 035019
- **Latitude:** 23.83 °S **Longitude:** 145.64 °E
- **Elevation:** 273 m
- **Commenced:** 1870 Status: Open
- **Latest available data:** 31 Mar 2013

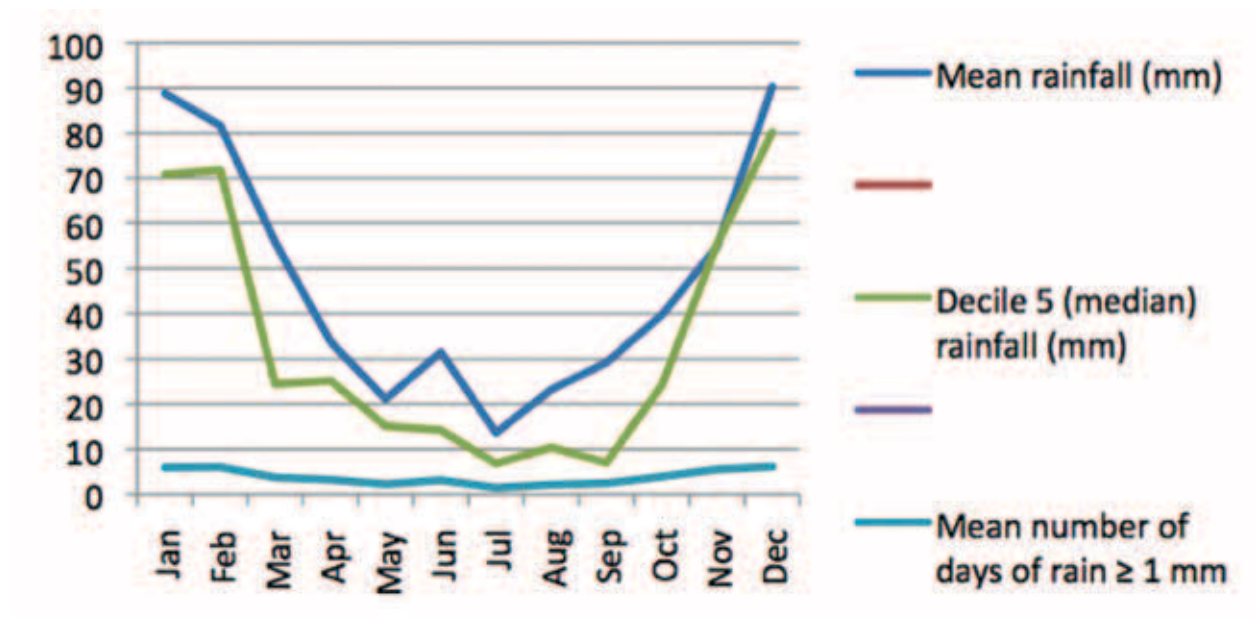
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual	Years	
Mean rainfall (mm)	118	114	75	39	35	34	25	19	20	35	58	92	664.9	126	1870
															2013
Decile 5 (median) rainfall (mm)	101	83.7	47	30	21	19	10	8.4	6.4	26	43	71	628.1	128	1870
															2013
Mean number of days of rain \geq 1 mm	6.6	6.1	4.3	2.5	2.4	2.4	1.9	1.7	1.8	2.9	4.1	5.4	42.1	128	1870
															2013



Source: <http://www.bom.gov.au/climate/data/index.shtml?bookmark=200&view=map>

- **Site name:** EMERALD AIRPORT
- **Site number:** 35264
- **Latitude:** 23.57 °S **Longitude:** 148.18 °E
- **Elevation:** 189 m
- **Open:** 1981 **Now:** Open

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual	Years	
Mean rainfall (mm)	89	82	55.7	34	21	32	14	23	29	40	55	90	567.3	20	1992
															2013
Decile 5 (median) rainfall (mm)	71	72	24.4	25	15	14	6.8	10	7	24	55	80	483.6	20	1992
															2013
Mean number of days of rain \geq 1 mm	5.9	6	3.7	3.2	2.2	3.1	1.4	2.1	2.4	3.9	5.5	6.1	45.5	21	1992
															2013



Source: <http://www.bom.gov.au/climate/data/index.shtml?bookmark=200&view=map>

