



18/05/2017

To: the NSW Department of Planning and Environment

This is a submission to the Narrabri Gas EIS.

Artesian Bore Water Users Association of NSW Inc. (ABWUA) objects to this project. The EIS asks more questions than it answers.

We find it amazing that Santos, in their Foreward, state that " In addition, the project is not located within a major recharge zone of the Great Artesian Basin." ABWUA commissioned a report by SoilFutures Consulting Pty Ltd into the recharge systems and petroleum and gas licenses. (SoilFutures, 2015) (appendix 1 - http://abwua.com.au/Portals/37/Documents/GAB-Report-Second-Edition_Final10032015.pdf)

This report clearly states that:

- In NSW, the main occurrence of recharge > 30mm is in the east Pilliga between Coonabarabran and Narrabri.
- Only 0.2% of the GAB has effective recharge of 30 – 79mm/yr.
- Both of the Pilliga and the northern Surat gas fields or licence areas occur in the very limited critical recharge (>30mm) areas of the GAB.

Santos are very careful with their wording but even though they qualify their statements with 'main' it is obvious that the NGP is situated above the GAB recharge. As it is a critical recharge area that should be considered a 'main' recharge area. Santos do not say the NGP is not above the recharge area, they just try to downplay the extent.

Other proof of the location of the GAB recharge in relation to the Narrabri Gas Project (NGP) is various and comprises maps used by both Queensland and NSW State Governments and the Australian Federal Government. Other resources are listed in the reference section of the report which is attached. (appendix 1) Please consider those reports and articles part of this submission and read it in its entirety.

The Pilliga stretches across half a million hectares of National Park, State Forests and State Conservation areas. In an area this big there are no big rivers that flow out of the woodlands. It is designed to act as a big sponge to recharge the GAB.

Other findings in the report include:

- Excessive draw down of pressure heads in the recharge zone of the GAB associated with gas extraction, has the potential to reduced pressure heads on artesian waters across much of the GAB, and potentially stopping the free flow of waters to the surface at springs and bores.

- Draw down of many hundreds of metres is reported in Ransley and Smerdon (2012) for the northern Surat basin coal seam gas fields where coal seams are being dewatered to release gas.” **Santos claim “0.5m drawdown”. This is unsubstantiated and any modelling is totally contradictory to what has been found in practise in Qld and other gas fields around the world. The argument of ‘that is a different company or area’ doesn’t fly. Santos has encountered greater drawdown in Queensland but when trying to obtain groundwater level data off their website you get an error message. There is no data available. People near Chinchilla have experienced a drawdown of 10 metres. (appendix 2)**

<http://www.couriermail.com.au/extras/qweekend/fff/features/pdfs/239.pdf?nk=b0e010168540675d750f07fdc4f3c6d8>

A factsheet prepared by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development states: “This can be as much as several hundred metres of drawdown. It may take up to five years of pumping to lower the water pressure to the required level for gas to be released. Pumping continues at the rate necessary to maintain water pressure at the target level until gas production declines to non-economic levels.” **(appendix 3)**

<http://www.iesc.environment.gov.au/system/files/resources/2ba90930-f3f1-471d-8e94-85ca8edefdce/files/fact-sheet-connectivity.pdf>

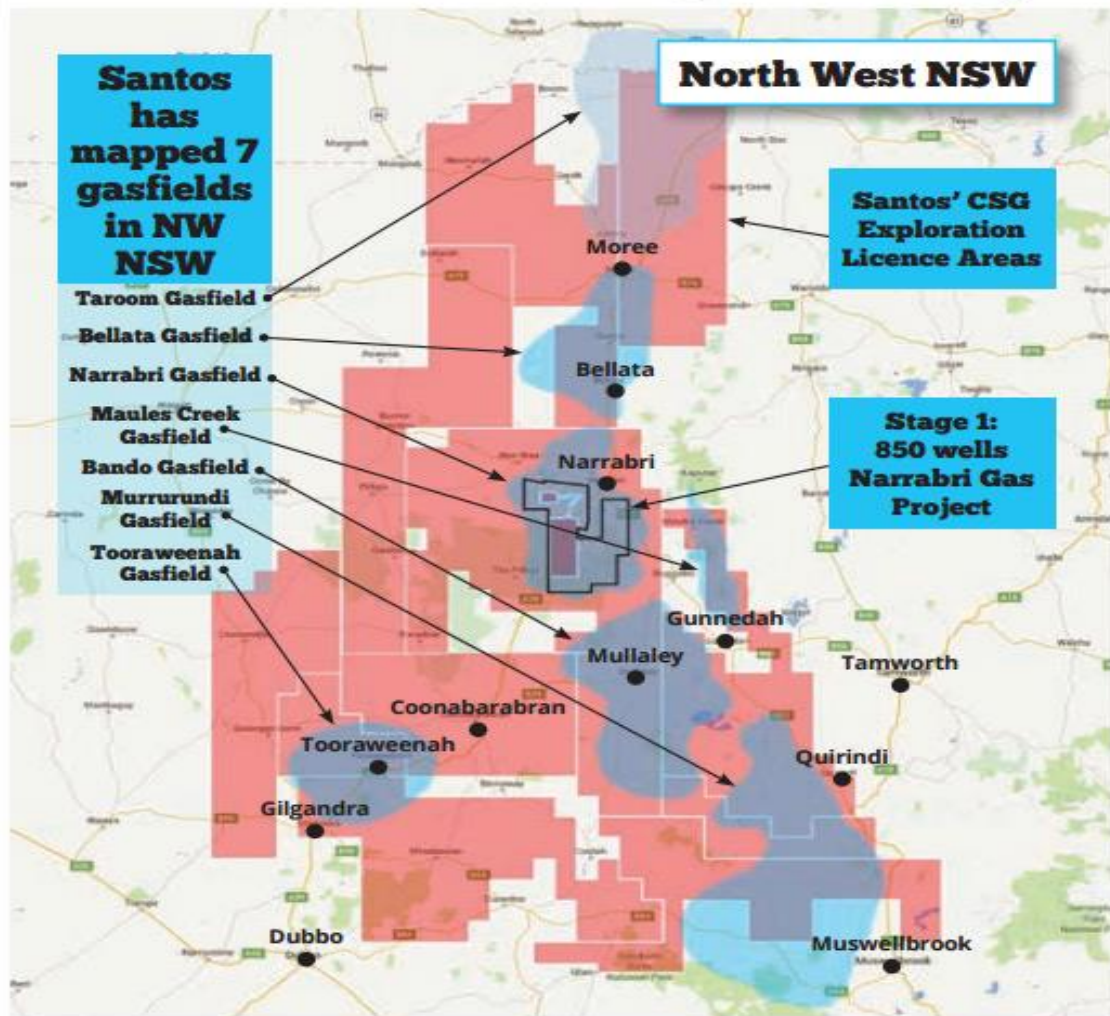
If this drawdown occurs on private property who pays to lower the bores that are now dry?

- **Other queries arising from the forward of the EIS:**

“Due to the geology of the deep coal seams, hydraulic fracturing will not be needed to extract the gas and Santos is not seeking approval to use this technology.” **Why did Eastern Star Gas need to frack when they owned the licence? Does the fact ‘Santos is not seeking approval to use this technology’ mean they will never frack no matter what? A change of management or shareholder pressure will never mean fracking is on the table? Will it be written into any sale contract that the purchaser can’t frack? What legal stipulation will ensure they don’t change their mind?**

“The EIS found the project will have minimal risk of impact on agricultural and domestic water sources”. **Queensland has shown this is not the case. Broadacre Farming and agriculture can not co-exist. Does Santos still stand by this claim when they extend into their neighbouring PEL’s and find a different type of landuse such as broadacre, intensive and irrigated farming. If Santos don’t plan to expand into the surrounding PEL’s they currently hold that have expired why have they not extinguished them?**

The threat of Coal Seam Gasfields has not gone away!



The Narrabri Gas Project in the Pilliga is Santos' Trojan Horse to access the farming country of our region.

Santos should be explaining the extent of their future plans and these should be treated cumulatively.

The Narrabri Gas Project Environmental Impact Statement – factsheet from the Santos NGP webpage
Water and the Narrabri Gas Project

+ The water extracted is not the water accessed by local agricultural or community bores and is not from the Great Artesian Basin. It comes from coal seams much deeper underground (500-1200 metres) and is salty. **Our bore is 820 metres. I believe that is between 500-1200 metres. It was capped and piped under GABSI so the Department of Water obviously believes it is Artesian water.**

+ Geologically, the rock formations in this area isolate those coal seams from the water used by farmers and the community. **The GAB consists of intricate layers of rock, aquifers and other geological formations which all work together to form the structure. There is not enough known about the GAB to ensure Santos' assertions are correct. In fact most research will say**

the opposite.

- + The Government assesses water sources and then sets sustainable extraction limits. The Project is projected to extract an average of 1.5 gigalitres of water per year. This equates to about 1% of the sustainable extraction limit of the water source targeted
- + All of the water extracted will be licensed by the Government, as is the case for any other user. **GAB water licenses in NSW are for stock and domestic purposes, town water use and some irrigation. There has only been one sale of GAB water in NSW in 2009. These licenses were purchased for feedlot and tourism (Moree Bore Baths) purposes. With this precedent Santos should be paying for their water, especially as it is considered a waste by-product.**
- + The water extracted will be desalinated so the majority can be reused for purposes like irrigation. **Desalination removes salt and some other chemicals which are attached to the salt. It does not remove all heavy metals and chemicals.**
- + The salt remaining after the treatment process will be disposed of in accordance with environmental regulations, **If Santos has a plan for this salt why is it not in the EIS?**

ABWUA has been instrumental in the continuation of GABSI. Through continued lobbying GABSI has been renewed and it was announced last week that the federal government has renewed GABSI for phase 5.

Information on GABSI is available at <http://www.water.nsw.gov.au/water-management/water-recovery/cap-and-pipe-bores>

"Great Artesian Basin Sustainability Initiative

The Cap and Pipe the Bores program is part of the Great Artesian Basin Sustainability Initiative (GABSI), jointly funded by the Australian and NSW governments. GABSI phase 1 was implemented between 1999 and 2004 with \$25 million funding. Phase 2 built on this with \$32 million funding from July 2004 until June 2009. DPI Water has targeted remaining free flowing bores through the Cap and Pipe the Bores program under GABSI phase 3, which finished in June 2014.

Some of the savings made under GABSI include:

Achievements

In the past, up to 95 per cent of artesian water was being wasted through evaporation and seepage. Today, the Cap and Pipe the Bores program has improved water supply through the following achievements:

- saving 78,500 ML of water every year
- supplied approximately 4.2 million ha with permanent, reliable, efficient and strategically located watering points
- controlled 398 free flowing bores
- removed over 10,000 km of bore drains
- installed 18,000 km of piping
- improved water use efficiency and reduced water wastage
- improved water quality for stock and domestic use
- increasing artesian pressure, increasing access to water
- reducing salt discharge by 62,800 tonnes every year
- reducing greenhouse gas emissions by 41,600 tonnes every year
- assisted land managers to achieve more sustainable property and stock management.

Increases in artesian bore pressure are being observed in many areas as a result of capping and piping. The program is achieving many other landscape benefits such as improving biodiversity conservation and feral animal control.”



Why when all these savings are applauded as benefits to the environment can Santos even threaten to undo all the good work done? Millions of dollars of both the State and Federal government (\$118.9m Frontier Economics 2016) and the individual landholders (no figures available but at least double including trust and private bores) stands to be wasted. GABCC figures quoted in the Frontier Economics Report (see below) state that to replace all 34,591 estimated bores in the GAB will cost approximately \$5b (2016 \$). Who will pay to repair all these, plus the exponential increase in well numbers due to CSG wells when they reach the end of their useful life?

It has become evident from the Queensland experience that Santos WILL cause a lowering of the water table. This is incontestable as they dewater the aquifer to get the gas – they have said that.

They have no answer to what they propose to do with the salt they will bring to the surface. Something GABSI was designed to do was reduce the salt brought to the surface.

The water saved by GABSI will be treated by Santos as a waste by product that becomes a problem to dispose of.

Current status of GABSI

Barnaby Joyce announced last week an extra \$8m in federal funding for GABSI 5.

[http://minister.agriculture.gov.au/joyce/Pages/Media-Releases/\\$8-million-top-up-to-support-water-management-in-the-Great-Artesian-Basin.aspx](http://minister.agriculture.gov.au/joyce/Pages/Media-Releases/$8-million-top-up-to-support-water-management-in-the-Great-Artesian-Basin.aspx)

The Office of Water has stated that bores that impact on springs will be focussed on. 20 – 30 of these bores will be done in the next 3 years.

The government can't afford to cap less than 250 bores still uncapped in NSW alone. Who will ever be able to cap thousands of bores when Santos has long gone and they all need recapping. 7% of bores fail initially, 30% within 20 years and 100% within 100 years. Bores do not last 'forever' as stated by Santos. Concrete and metal do not have a perpetual lifespan. This damage is permanent. Over time it will be like a pincushion with rusting pins. Who is liable for capping them? Will it be the landowner? Farmers around the NGP have been told that once they accept payment from Santos they are liable for any problems into the future.

A report was commissioned by the Australian Government and Great Artesian Basin Jurisdictions titled "Economic output of groundwater dependent sectors in the Great Artesian Basin" by Frontier Economics (Frontier, 2016) (appendix 4) In table 1 it states that the combined value of industries dependent on GAB water resources in NSW is as follows: livestock, irrigated agriculture and urban water totals \$1132.3m, mining and CSG \$576m annually. **Livestock, agriculture and the provision of water to towns is sustainable into the unending future. Mining and CSG have a limited lifespan and will leave irreparable damage and costs forever. Is a short term benefit worth the long term, permanent pain? Instead of replicating the report in this submission we ask you to consider all the information in the report as part of our submission.**

Make good is another joke of the CSG industry. How do you fix the GAB which covers 22% of Australia and is Jurassic water? Where do you get the water to replace the 'dewatering'? Where do you put the poisonous, chemical laden water you take out? Where do you get the water to 'refill' it? Re-injection has caused problems the world over with increased seismic activity and earthquakes in re-injection areas.

ABWUA has commissioned a report into the Stygofauna population in the Pilliga. Due to the time consuming task of data collection and analysis this report is not yet completed. We will forward a copy of the report as an annexure to this submission when we receive it.

Dr Peter Serov has previously completed a report for a private individual which I can not include but details are as follows:

ABC

Ancient stygofauna could halt Santos' Pilliga coal seam gas project

By Catherine Clifford and ABC Online staff

Updated 12 Jul 2013, 11:42pm



PHOTO: [Stygofauna are blind, colourless and they've been around for millions of years.](#) (Supplied)

A microscopic collection of worms and mites could play havoc with Santos' biggest coal seam gas project in the New South Wales Pilliga State Forest.

The ancient, subterranean creatures that live deep in an underground aquifer are only one millimetre long and thinner than a human hair.

They are known as stygofauna and they play an important role in filtering and determining the quality of groundwater.

The new evidence about the stygofauna is contained in one of 1,800 submissions to the Federal Government opposing Santos' plans to drill 18 gas wells in the Pilliga State Forest near Narrabri.

Santos had estimated the project could supply 25 per cent of New South Wales' gas needs.

The Government will now use its recently-passed "water trigger" laws to determine if Santos can go ahead with the drilling.

Hydro-biologist Dr Peter Serov, who found the two new species of stygofauna, says the creatures could be at risk because they are extremely sensitive to changes in water quality.

"There needs to be a lot more rigorous sampling and monitoring of both water chemistry and biodiversity across the region to determine what the ultimate ranges of these species are and what their environmental requirements are at this point in time," he said.

Blind, clear, subterranean creatures



PHOTO: [There are calls for more research to be done on the stygofauna.](#) (Supplied)

Dr Serov says stygofauna are highly specialised organisms that have been around for hundreds of millions of years.

"They are a group that have adapted over millions of years to occupy a very, very specialised niche," he said.

"Initially all of them would have been surface invertebrates, but due to the vast changes that the environment of Australia has gone through... they have colonised the subterranean environment and over time they've developed their own body forms to actually live exclusively in this situation."

"They have no colouration, they're usually totally clear or white, they have no eyes, they have specialised sensory organs that enable them to determine whether they're going up or down," Dr Serov said.

But Santos groundwater expert, Dr Peter Hancock, says he wants to know just where the tiny animals were found.

He says they may not exist in the deep aquifers that coal seam gas wells drill down to.

"The deeper coal seam aquifers are unlikely to have stygofauna in them. It's the shallow alluvial aquifers that are most likely to have them," he said.

But retiring New England Independent MP, Tony Windsor, who introduced the water trigger laws, says the scientific process must go ahead before the coal seam gas company moves in.

"We don't fully understand the scientific nature of some of these groundwater systems and until we do at a scientific level, I think the political process should step back and the industry process should step back until we get the science right and then make the decision," he said.

<http://www.abc.net.au/news/2013-07-12/4815736>

Using science but on a practical level. Why is water in the GAB not stagnant and dirty. It is underground and moves infinitesimally slowly. There must be something that keeps it clean. I believe this is the stygofauna so it is vitally important. I also believe that taking this water out of the aquifers and running it through the reverse osmosis plant will destroy the stygofauna. Therefore the delicate balance will be destroyed. Re-injection will put too much water in, too fast, with no stygofauna to sustain the delicate balance.

Australia is the driest inhabited continent on the planet. How can we allow an industry that states 'that to get to the gas it dewateres the aquifer'. Our most precious resource is being treated as a toxic byproduct.



The GAB is 22% of Australia. Is it worth the risk?

Water and air are the most valuable things on this planet. How can we risk them?

Sonya Marshall

Secretary ABWUA

NB: **BOLD lettering is submission and** non bold is quotes or information from reports or other sources.





power struggle

Story Leisa Scott

Photography Russell Shakespeare

The coal seam gas industry is fuelling huge growth in the Queensland economy – but it's also creating a lot of negative energy for farmers out west.

You can see it, shimmering. Coal seam gas, the new gold of the west. The lifeblood of Queensland's revenue stream, the "clean, green" answer to our energy needs. It wriggles like a heatwave, this methane, as it rises from the Jurassic-era Surat Basin into the light.

The thing is, it really shouldn't be shimmering here. Not out of the water bore on Col Davis's feedlot near Chinchilla, about 300km west of Brisbane. For five years this bore has watered 2000 head of cattle without a hiccup. Now it gurgles like an underground demon before gushing water – and gas.

Davis is a pragmatic bloke, as evidenced by the rudimentary bandaging of the fingers he injured on a plough recently. Just a few bits of foam rubber wrapped around the digits, all held together by gaffer tape. He's not one to jump at shadows. He knows this area has always been prone to gas in bores. But he's never had a problem with this bore. Until a gas company started drilling a couple of kilometres away.

It's the doubt. That's what's got Davis fired up. Doubt over the safety of the water, the fate of his cattle, the chances of selling "a gas farm". It's one thing – galling as it was – to be told multinational gas companies have every right to come onto farmers' land to drill. It's quite another to meddle with a bloke's livelihood.

Davis sets the gas alight, sending flames roaring into the air. "The government has got to realise that we're still living in this country," he says. "And if they want us to get along with these gas companies, they've got to be able to make good on the things we lose."

Gas companies are part of the landscape out west now, all along the Warrego Highway beyond Roma and points north and south. Their trucks dominate country byways, their workers book out motels and stimulate local economies. The place is booming. Over the years, big and small coal seam gas explorers arrived, punctured the earth, came up with bugger-all and left. But in the past decade, the exploratory, political and economic planets aligned, giving birth to the CSG industry in the resource-rich Surat and Bowen basins. It's been on steroids ever since, bolstered by a Queensland domestic supply policy that mandates 15 per cent of energy be sourced from gas, and pumped up on the world stage by a government-backed export industry out of Gladstone that will turn CSG into the more transportable liquefied natural gas (LNG). Even the head of the Queensland Resources Council (QRC), Michael Roche, told a May conference that final investment decisions were soon to be made in a "remarkably short space of time for projects of such magnitude".

Set to emerge with solid plans this year are GLNG, a teaming up of Australia's Santos and Malaysia's Petronas; Queensland Curtis LNG, run by Queensland Gas Company, a wholly owned subsidiary of Britain's BG Group; and Australia Pacific LNG, a joint venture between Australia's Origin and the US's ConocoPhillips. Not far behind is the partnership of Royal Dutch Shell and PetroChina, which has just paid \$3.5 billion to command the resources built up by Brisbane-based Arrow Energy. More mergers are expected as the CSG/LNG companies gear up for export from 2013, but these big four will together account for the lion's share of the \$40 billion the industry is expected to spend setting up in Queensland.

Some of that will be spent on sinking gas wells – up to 40,000 of them in the state by the time the industry, with its 30-odd-year lifespan, reaches full production. Right now, there are about 2500. As miners march across the countryside with their plans for a well every 750 to 1000 metres, they're moving closer to the coast and encroaching on some of Australia's most productive farms. And the tension is building.

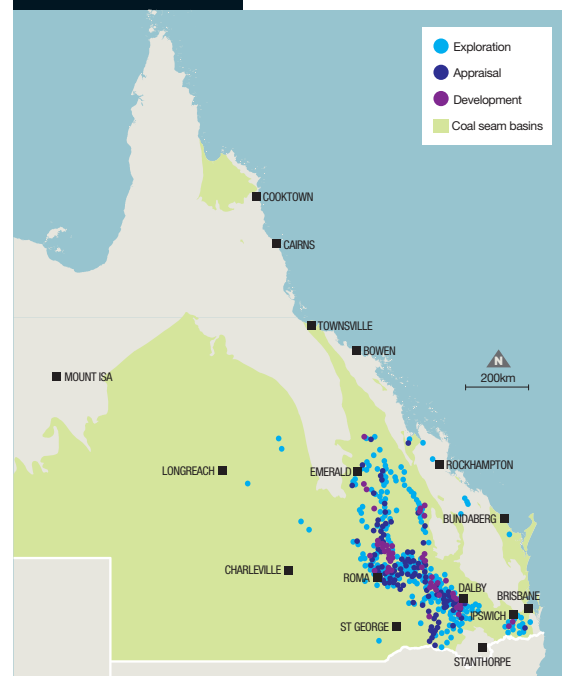
Peter Shannon has watched it unfold. About five years ago, locals started coming to the Dalby solicitor's office with documents gas companies wanted signed. They were complex, so he called the Brisbane legal firm he consulted on such matters. It couldn't help. Conflict of interest: it was working for one of the gas companies. So he tried another. No good. "Almost every significant firm in Queensland is tied up acting for an energy company," Shannon says. "They're very proud members of the QRC, making loads of money from the explosion of the industry and very much entwined with its future."

So he learned about CSG himself. He got a copy of the Petroleum and Gas Act (2004), the "innovative legislation for an innovative industry", as Mines Minister Stephen Robertson heralded it to an enthusiastic Queensland Parliament. The more he read, the crankier Shannon got. More clients came in with concerns about a drilling process that requires the removal of hundreds of thousands of litres of groundwater to access the gas. He downloaded more reports, bothered senior government bureaucrats (those who hadn't left for a lucrative job in the gas fields), burned the midnight oil.

He emerged with strong beliefs. That farmers have been trampled in the rush to rip CSG out of the ground in a money grab by the state to plug its gaping \$1.7 billion deficit. That the legislation is flawed and biased towards mining companies. That the volume of water to be pulled out of aquifers to meet the newfound export demand was not understood by the draughtsmen of the 2004 Act and is poorly

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On the front line ... Katie and Scott Lloyd (right) at a well on their Chinchilla property; (below) the extent of Queensland's coal seam gas plans; and (previous page) Col Davis burns off gas at a bore on his Chinchilla feedlot.





understood now. And that – just as BP was not prepared for a worst-case scenario when its oil rig fell apart in the Gulf of Mexico – the cash-strapped state government is diving into a grand experiment before the science is clear.

“It’s just mind-blowing. There’s no attempt to genuinely appraise the negative side of the industry,” says Shannon, also a farmer. “To me, you can’t make informed decisions about anything until you’ve looked at the pros and cons.”

So what are the farmers worried about? For a start, it’s the quantity and quality of their vital bore water tapped from the Great Artesian Basin; salinity from the brackish CSG water; the degradation of the productive land that provides grains, pulses and cotton to domestic and export markets. They also fear the consequences of “fracking”, a controversial mining method in which water, chemicals and sand are forced into the ground under great pressure to release gas trapped in the rock. In the Rocky Mountains in the United States, fracking has been blamed for contaminating

underground water, forcing a congressional hearing and an ongoing \$US1.9 million government study.

Shannon’s pessimism wasn’t helped by the recent Kingaroy groundwater contamination scare involving underground coal gasification – a nascent industry compared with the juggernaut that is CSG. Traces of a known carcinogen, benzene, and the toxic chemical toluene were found in water bores outside Kingaroy. “The Great Artesian Basin – we muck around with that, and we send all our people from the country into the cities,” he says. “I am convinced there needs to be a moratorium until the industry can prove it’s not going to stuff the whole show up.”

RICH, BLACK SOIL CLINGS TO THE BOOTS OF Greens Senator Bob Brown as he follows Dalby farmers Wayne Newton and Andrew Rushford to a neighbour’s boundary. Under a leaden sky, they drape themselves over the fence and stare out at the laser-levelled field – and the gas well in a corner of it. Taking up about a hectare, the inner perimeter of which is fenced and strewn with “danger” signs, the well consists of a drill head about 2m high, a generator and computer system. Large pipes – one for water, one for gas – emerge from the drill head and disappear underground. Those pipes crisscross below the Western Downs cropping country, linking every one of the wells with a processing facility. Some of the gas will keep our power stations whirring; the rest will be whisked to Gladstone via a yet-to-be-determined number of pipelines, converted to LNG and sold overseas, bringing an \$850 million annual windfall in royalties for state coffers. Or, as Premier Anna Bligh puts it, “for more schools and hospitals”.

It’s an impressive figure, but these farmers and Senator Brown are more interested in other numbers. “If we get to the 40,000 wells, they’re talking up around 350,000 megalitres a year coming out of our aquifers, so that’s two-thirds of Sydney Harbour coming out of the Great Artesian Basin annually,” says Rushford. Newton adds that the amount of water drawn from the basin by farmers and townships is regulated and, at the moment, fully allocated. “This is just going to blow that because the mining companies are totally exempt from all rules of water restrictions. They can go their hardest.”

The Great Artesian Basin is iconic here. Tapping into millions of years of underground water opened the inland up for multi-state farming now worth about \$3.5 billion annually. People are touchy about it. Farmers were appeased six years ago when a government/industry report said the targeted underground source of CSG – known as the Walloon Coal Measures – was not hydraulically connected to

the basin’s aquifers. Further research has shown that it is. This has thrown up many questions for farmers. Is their good water going to be polluted slowly by bad? Or drained away? And will the chemicals used in fracking seep into the water system? And the salt that comes with the water – up to 200,000 tonnes a year – what’s to become of that? Answers have been inadequate and piecemeal, the farmers say – and these are members of the Basin Sustainability Alliance, a group that mines minister Robertson agrees comprises “moderates” who accept CSG could play a role in the region.

“The reporting systems are just terrible,” says Rushford. “There’s really no accountability. The P&G [Petroleum and Gas] Act has not kept pace with development, and now they’re trying to legislate to catch up.”

Farmers generally turn to their traditional support base, the Liberal National Party, to lobby for them. But the Coalition backed the CSG legislation and has annoyed many constituents by being less than rowdy about the issue. Which is how Australia’s best-known greenie, the politician they’ve yelled at on the telly for years, came to be standing in this field listening to their concerns. And why Brown is now ferried to the Newtons’ house, where pikelets and egg and lettuce sandwiches are laid in front of 50 concerned farmers who want to know what he can do about the CSG industry.

Brown doesn’t sugarcoat it. “When it comes to the rapid onslaught of CSG here, you are up against it,” he tells the crowd. “The mining corporations ... will use up the honesty, the humanity, the willingness of good folk in rural and regional Australia to want to give and take – they will take that and then they will take more and ride over the top.” It’s not even a green industry, he says, despite the government’s hype. Methane is 20 times more potent a greenhouse gas than carbon dioxide, he argues, although it survives for a shorter time. It’s an argument expanded on by the Queensland Conservation Council, which has asked government ministers to stop saying the CSG/LNG industry will reduce global greenhouse emissions until they can back it up.

The senator has soothing words, though, for a region that makes up a big slab of the slender 2.2 per cent of Queensland used for growing crops. He tells them arable land is diminishing and must be protected. This is a food bowl, he says, with its special soil that enables the planting of winter and summer crops. “Of course, it’s a no-brainer ... but I would say 90 per cent of MPs in Canberra have no idea of the food crisis, globally, that is coming down the line in the very near future.”

Listening are Scott and Katie Lloyd, who ►

run a 3240ha property near Chinchilla. As luck would have it, the young couple's mixed farming land has three mining leases over it: one held by Origin, another by QGC and the other by a pioneer of the gas industry, Ian Sykes. The first two came knocking about ten years ago.

"They'd all of a sudden turn up and say, 'you've got to sign this and you have to sign it now'," says Scott. Most confronting was QGC's plan to build 25 wells and a 10km pipeline out the front of their homestead. The Lloyds got lawyers. "They retreated," says Scott, "but they'll be back. They went to our neighbours and put down 45 wells there." Origin returned last year. "It was very much 'you sign this or it will be a Land Court trip'." Aware such trips rarely left the farmer cheering – and slightly placated by the fact Origin's operations were out of their line of sight – the Lloyds negotiated a deal.

When the drillers arrive, it's like a rock festival. Trucks churn up tracks carrying equipment, Porta-Loos, canteens and enough lights to brighten a stadium. They work 24/7 for two to three weeks. "It's pretty awful," says Scott. "You've got no control over who's on the place, what time they're here. You completely lose control."

Now they're losing water. Farmers don't routinely measure their bore levels, but the Lloyds do. When the industry started arriving, there was talk of trigger thresholds at which miners would have to investigate falls in the groundwater level. So Scott put gauges in to take his own measurements. One bore on the QGC lease has dropped 10m, based on its official standing level when it was sunk in 2003. Another, on the Origin lease, has dropped 4m since Scott's first 2006 measurement. They've notified both companies, which have measured the bores and taken samples. Now they wait.

Such is the process of the "adaptive environmental management regime" (as described by Brown and Shannon) adopted by the government for the CSG industry. Instead of using the precautionary principle of environmental management, which supports knowing the impact of an activity *before* beginning work, the CSG companies will monitor factors such as groundwater levels as they go. If things start going pear-shaped, the government literature says, "any unintended environmental outcomes would be appropriately managed". To many in the bush, it's a bit like locking the gate after the horse has bolted.

Exasperating the farmers further is the fact that trigger thresholds were only set in May, six years after the legislation touting them was introduced. There's no telling how much water was sucked out of the aquifers in the interim. Shannon reckons the thresholds were only set after lobbying by the community: "And you



know how complicated it was? Five metres for one type of aquifer, two metres for another."

For the Lloyds it's a worrying time, with their 5000 head of cattle totally reliant on groundwater and summer coming on. "I don't know how our little bit of data is going to stack up when you're dealing with these big guys," says Katie. "I'm just worried they're going to fob us off." Still, they are being paid. For allowing the wells on site and access to their land for the next 20 to 30 years, the Lloyds will receive more than \$50,000 annually. Katie knows that's not to be sneezed at, but says she'd give it all back right now if it meant she could just stop worrying.

Cash flows are relative. A few weeks after I meet the Lloyds, Arrow Energy finalises its multibillion-dollar sell-out to Shell and PetroChina. The managing director, Nick Davies, leaves with a little over \$30 million.

CATTLE ARE CHEWING THEIR WAY THROUGH

high green fields of luceana as we chopper over Santos's Fairview CSG field in the Bowen Basin north of Roma, a further 260km west of Dalby. It was desalinated CSG water that created this 234ha of protein-rich fodder, and graziers pay Santos to bring their cattle to feed. Soon, Santos will put small reverse-osmosis desalination plants near wells on graziers' properties so they'll be able to grow luceana on their own land.

Sam Claas, Santos's area manager, points out the Chinchilla white gum plantation, the first approved by the government for CSG water.

One million hardwoods have been planted using chemically rebalanced water that's trickle-fed at an average rate of one megalitre an hour. That's fast going, but those gas wells pull out a lot of water. Claas tells how one well gave up no gas for an entire year. Just water. "So you've got to have deep pockets and big testicles," he says. "It's how the dewatering process works ... now that well has produced more than 11 billion cubic feet of gas, more than any CSG well in the country by a long way."

He loves this work, you can tell. It's a big boy's dream: pipelines run for kilometres, massive compressor stations grind away and depots teem with heavy machinery. The sheer investment and logistics of the place are staggering. But the job of getting to full production in this Bowen Basin region is slightly easier than that of rival leaseholders in the Surat Basin, for three reasons: Santos owns much of this land; it is used more for grazing than intensive cropping; and the locals have lived with conventional gas production – by Santos – for more than 40 years.

"I don't envy them trying to do business [in the Surat Basin]," says Claas. "It's all so new for those Downs people. It's always the fear of the unknown that upsets people."

The fear of things happening too fast is another, and the Queensland Government's approval process for these multibillion-dollar projects has come in for heavy criticism. Veteran conservationist and former Queensland Greens federal candidate Drew Hutton says the policy



**These
are our
homes, our
investments
– why aren’t
we treated
fairly?**

Fighting back ...
“Blockie” Michael
Bretherick (left) from
Tara; (below) Dalby
farmer Wayne Newton.



of declaring all big four projects of “state significance” quarantines them from rigorous environmental assessment and shuts out public scrutiny. He points to GLNG and Queensland Curtis LNG receiving conditional approval despite the Coordinator-General, Colin Jensen, citing severe shortfalls in their Environmental Impact Statements. Among 1200 conditions, Jensen sent the companies back to study how

much of an impact all the planned projects – not just their own – would have on groundwater. Jensen has since resigned. So concerned was the federal Environment Minister, Peter Garrett, about the effects on groundwater and other issues that last month he postponed making his call on the projects until mid-October. Just who will hold the pen over that decision after this weekend’s election is wide open.

Claas reckons Santos is answering all the questions Jensen raised, has excellent bore monitoring processes, and is even investigating, with others, the chances of reinjecting treated CSG water into the Great Artesian Basin: “If we do that for 20 years, we believe we can inject enough to have a positive impact on the aquifer for 40 years.” He has a hard-headed reason for believing the kinks will be ironed out and the CSG industry will flourish in the Surat and Bowen basins for the next 30 years. “They’ve got to. I honestly don’t think the government’s going to say, ‘Oh no, forget the CSG industry’.” Anna’s made plenty of promises about jobs and there’s no money in the bank. I mean, here’s a few billion bucks in revenue. Regardless of what people think, I just don’t think she’s going to stop it.”

It’s not a line you’ll hear from Stephen Robertson. In his richly toned parliamentary office, the minister emphasises that while the industry is “a great opportunity for Queensland”, the government feels the farmers’ pain and is not “blinded by the dollar signs”. Wrecking the Great Artesian Basin is not an option. He is adamant that, at the end of the EIS process, if companies cannot satisfy the Coordinator-General’s conditions, their projects will not go ahead. It is possible, he says, that CSG mining could be knocked on the head in the Surat Basin but allowed in the Bowen Basin. But there’ll be no moratorium – Robertson says the requirement for companies to meet the Coordinator-General’s conditions acts as a de facto safety net.

Robertson admits some companies have not been methodically monitoring water bores and says he has “left them under no misapprehension about my expectations of them improving their performance”. The government has some work to do, too. Catch-up legislation to improve water issues is being drafted and as a result of concerns about the industry monitoring the industry, the Queensland Water Commission this month became the arbiter on issues such as groundwater drawdown, the problem affecting the Lloyds.

It may take a little while longer for the Lloyds to hear anything, though. The commission – which will also conduct random testing – is still “ramping up”, says Robertson.

The government is so depleted of hydrologists and other experts after they took off for the mining boom that recruitment teams are “out there at the moment” with a \$9 million kitty trying to entice some back to bureaucracy.

OUT TARA WAY, THEY CALL ROBERTSON THE

Honourable Minister for Mining Companies. They don’t believe a word he says. “Wouldn’t know a CSG mine if he fell over it,” says local Scott Collins. “It’s just get in, refill the government coffers, nudge, nudge, wink, wink.” The industry, he says, “was signed, sealed and delivered ages ago”.

Robertson might see the setting of 1200 conditions as a positive sign of the government’s environmental stewardship, but Collins sees it from another angle. “If you need all those guidelines, doesn’t that say it’s dodgy and it shouldn’t be done?”

Collins lives on a 43ha block outside Tara, about 300km west of Brisbane, in an unserviced bush estate. Many of the residents live in rough-and-ready homes on pensions; they landed here, he says, “for a bit of peace and quiet, to listen to the birds”. Now QGC is on their doorstep wanting to sink wells throughout the scrub. Noise, health and traffic concerns are bigger issues here than groundwater, and that opens up a volatile new front on the CSG battleground.

“These are our homes, our investments – why aren’t we treated fairly?” asks Collins’s neighbour, Mike Bretherick. He figures it’s because the residents are not economic powerhouses. But they can organise. He’s formed a lobby group, set up a website. Collins has taken to accosting QGC workers he bumps into in town. Someone else threatened a gas worker, prompting police action. Other residents are trespassing onto wells to take gas levels and film covert videos. And the blockades have already begun.

“I am totally committed to harass, to blockade – I will blockade them out, I will blockade them in,” Bretherick says. “We will obstruct and it will go on and on. I had a QGC man sit in that seat and very eloquently bully me. Told me I had no rights, this was their land and they were going to drill here.” He narrows his eyes. “I can tell you now,” he says, slowing down to emphasise each word, “they ... will ... not ... come ... in ... here.”

He may be right. He certainly looks serious. Or perhaps Robertson is right when he says relations will improve with better communications. One thing is clear: this brave new world of gas is fuelling as much doubt and suspicion out west as it is money and excitement. And if we’re not careful, it could explode in our faces. ■

June 2014

Connectivity between water systems

What is connectivity?

When groundwater is extracted from an aquifer there are potential impacts on other water resources, depending on the duration and rate of extraction, and the connectivity (or degree of connection) between the water resources.

Connectivity refers to the degree of hydraulic interaction between aquifers, between different parts of the same aquifer, and between groundwater and surface water systems. It depends largely upon the lithology of geological strata, and their integrity and spatial continuity. Fractures, faults and open or inadequately-sealed boreholes can form preferential flow paths that also affect connectivity. The degree of connectivity and the rate of water flow between aquifers and water systems are strongly influenced by local and regional hydraulic pressure. As groundwater and surface water systems are dynamic, these gradients can change with time (Australian Government, 2014).

Connectivity can be considered in the context of groundwater flow paths. For example, groundwater flow in shallow aquifers is often constrained by local catchment boundaries. However, coal seam gas extraction occurs largely from deep coal seams that occur 300 metres or more below ground. At this

depth, groundwater flow paths are more regional in nature, and impacts of groundwater extraction and depressurisation can spread beyond local catchments, subject to the connectivity between individual strata.

Connectivity is normally described as varying between low and high. Where there is high connectivity, water bodies are connected in such a way that there is a high transfer rate of water between them.

This fact sheet explains the significance of connectivity in managing the impacts of coal seam gas development and coal mining.

What creates connectivity?

Connectivity between two water systems is a function of both the permeability of individual geological formations, and hydraulic pressure which creates a driving force for water flow. Permeability includes both the interconnection between pores at a fundamental level within the rock (primary porosity – created as a consequence of the rock's deposition) and fractures and joints in rock bodies (secondary porosity – created by tectonic forces after the rock was formed) (Fetter, 1988).

The main geological formations of interest in coal seam gas development and coal mining are sedimentary layers that can have both

primary porosity and secondary porosity. Also of interest, particularly in coal mine dewatering, are sand and gravel alluvial aquifers that underlie the floodplains of rivers. These aquifers can have high levels of primary porosity, and enable high levels of connectivity between groundwater and surface flows (Figure 1).

The connectivity between water bodies can be increased by deteriorated or

inappropriately constructed bores that provide a direct link between different aquifers, and by fracturing of strata in relation to underground coal mining. In coal seam gas areas, connectivity may also be increased through inappropriately conducted hydraulic fracturing (to establish coal seam gas production wells) and fracturing of strata in relation to subsidence from coal seam gas depressurisation.

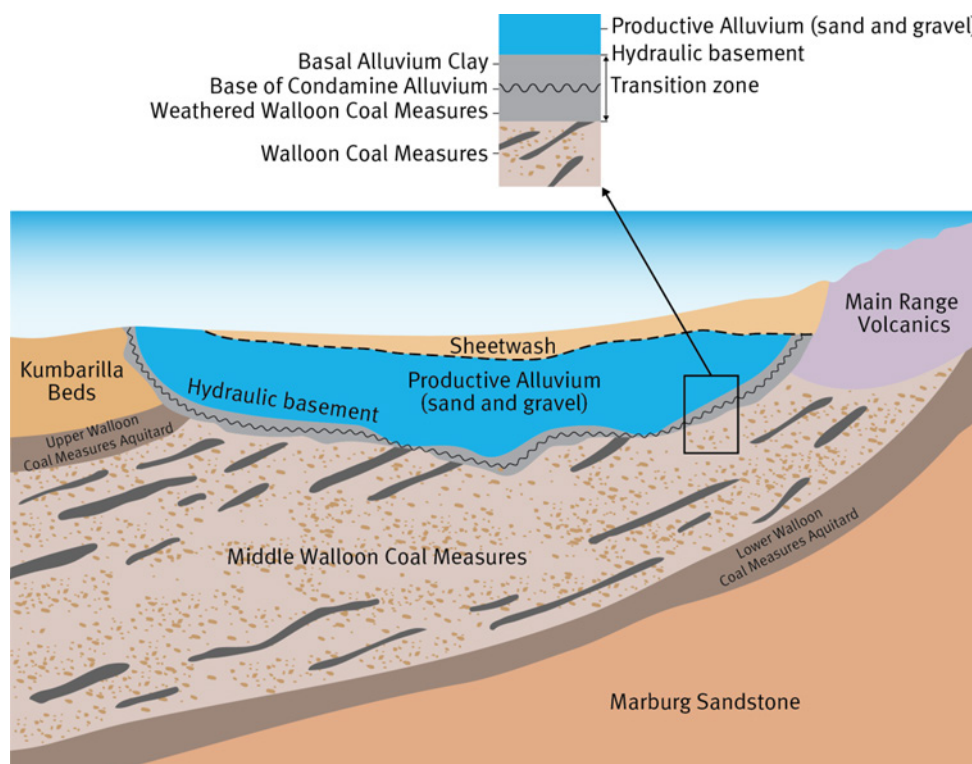


Figure 1. In the Surat Basin, Queensland, the Walloon Coal Measures are a major source of coal seam gas. In a part of the Basin they closely underlie the alluvial aquifers of the Condamine River, which are a major source of groundwater supply. Reduced pressure in the coal measures may enable leakage from the alluvial aquifer. The thickness and permeability of an intervening transition layer influences the degree of connectivity between the two units.

Source: QWC, 2012.

Coal seam gas development and groundwater extraction

Coal seam gas development involves the construction of production bores into suitable coal seams, and extraction of groundwater from the coal seams at rates sufficient to lower the pressure within them and enable gas to be released. This gas is then pumped to the surface along with the groundwater.

Gas-bearing coal seams are typically located at depths of more than 300 m below ground. For gas to be released from coal seams, the water level in the coal formation is typically lowered to within 35 m to 40 m of the uppermost coal seam by pumping groundwater from the seam.

This can be as much as several hundred metres of drawdown. It may take up to five years of pumping to lower the water pressure to the required level for gas to be released. Pumping continues at the rate necessary to maintain water pressure at the target level until gas production declines to non-economic levels.

Coal mining and groundwater extraction

Coal mining involves the excavation and removal of coal from beneath the ground, which can occur by either:

- open-cut mining (removing the ground surface to then extract the coal), or
- underground mining (excavating coal seams from under the surface; this is

commonly done in Australia at present by using the 'longwall' mining method).

If an open cut mine extends below the watertable, the watertable has to be lowered by extracting groundwater to enable work to proceed. This is often achieved through the use of strategically located dewatering bores.

Groundwater that is not extracted by dewatering bores, and flows into and collects in a mine, must also be removed, and is referred to as interception.

Connectivity implications

During coal seam gas development, the extraction of groundwater from the coal seams does not actually 'dewater' the coal seams or adjoining aquifers (they remain fully saturated, but under less pressure). However, the pressure reduction can impact on connected aquifers (Figure 1).

Groundwater interception and extraction for open cut mine dewatering lowers the groundwater level in the vicinity of the mine. A conceptual model of potential groundwater drawdown at adjoining open-cut coal mines is provided in Figure 2.

Underground mining also requires groundwater extraction, which can affect overlying aquifers and streamflow. In addition, planned collapse of longwall mine voids and subsequent fracturing of overlying strata can enhance vertical connectivity.

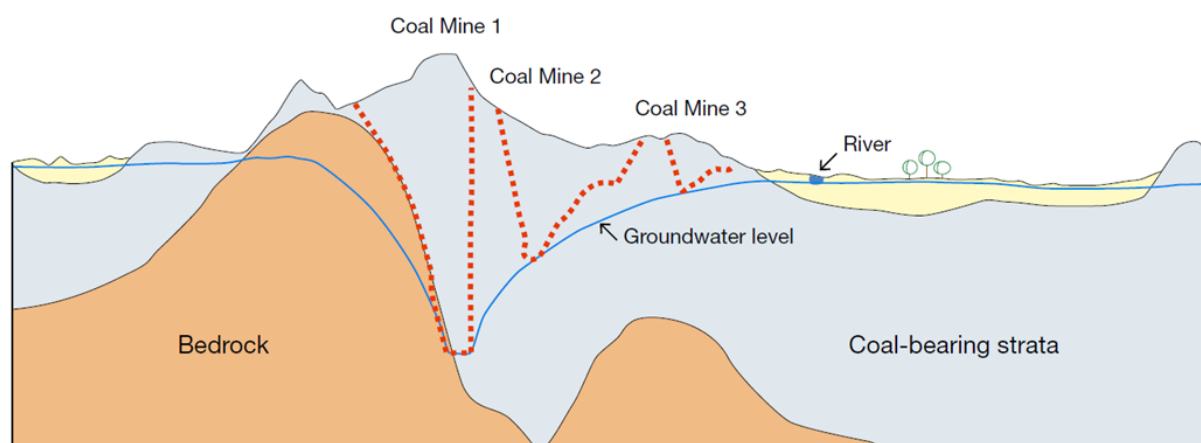


Figure 2. Conceptual cross-section of proposed coal mines and potential groundwater drawdown. Dewatering of aquifers has led to a drawdown of the groundwater level in the vicinity of the mines. This drawdown extends beyond the extent of the mines, and may impact on the adjacent river.

The extent to which the impacts of the extraction of groundwater may extend into adjoining water systems will depend largely on the duration and rate of interception and extraction, and the degree of both lateral and vertical connectivity of local aquifers. Impacts can include:

- increased leakage between aquifers, which may also allow migration of salts from saline to fresh aquifers and flow from water supply aquifers (Figure 1)
- reduced flow to springs and streams, and increased leakage from streams to groundwater
- compaction of strata, which may contribute to land subsidence
- reduced groundwater levels in other production bores in the area, which may increase the cost of groundwater access for other users, and may even prevent access.

Assessing connectivity

Connectivity between aquifers can be assessed using a range of methods including:

- groundwater level monitoring – to determine the direction and potential rate of groundwater flow (the latter also requires measured or assumed rock properties)
- aquifer tests – to determine aquifer hydraulic parameters, and to detect and analyse responses in adjacent aquifers
- geochemistry – to identify potential flowpaths between aquifers
- surface geology – by inspecting outcropping strata to assess primary porosity and degree of fracturing
- laboratory studies – including permeability tests on rock samples
- geophysics – using aerial (e.g. magnetics), surface (e.g. seismic) or down-

hole techniques to identify rock properties and geological structures

- numerical models – to simulate flow conditions under current conditions and how these may change under different scenarios.

Connectivity between groundwater and surface water can be assessed using the following methods:

- groundwater and surface water level monitoring - to identify hydraulic head differences and subsequently the potential rate of flow using measured or assumed rock properties
- stream gauging – to detect differences in stream flow rates between stations, and identify possible losses to or gains from groundwater
- geochemistry and temperature monitoring – to detect flow between surface water and groundwater systems
- water balance assessment – to estimate bulk flow between surface water and groundwater
- numerical models – to validate water balance assessments, simulate flow conditions and identify how these may change under different scenarios.

Ideally, multiple methods should be used for any assessment of system connectivity. Numerical models in particular are frequently used to analyse and/or simulate groundwater flow conditions, including connectivity, and rely on any other available connectivity information in their development. They are valuable tools for validating connectivity

interpretations and illustrating how this affects the migration of depressurisation and groundwater level drawdown between aquifers.

The connectivity between water resources controls the manner in which impacts may move between those resource systems. It is a fundamental property that needs to be considered whenever impacts are being assessed. It can be difficult to quantify, particularly within large regional groundwater systems and its quantification is one source of uncertainty in any assessment.

Future directions: knowledge gaps and strengthening the science

Specific modelling of individual coal mines and coal seam gas borefields is often required to predict how extraction may impact on local water resources, with a particular emphasis on groundwater systems, and to develop appropriate operating conditions. This process would benefit from further research and continual improvement in the following areas:

- understanding the influence of fractures and faults, and representing these features within groundwater models
- the role of aquitards in modifying or controlling flow and how the varying properties of these geological units can be simulated in models
- methods for estimating aquitard permeability and/or aquitard leakage at large scales

- the extent to which hydraulic properties and connectivity may change during coal seam gas development and coal mining operations
- the advantages and disadvantages of various groundwater modelling approaches
- interaction of the physical hydrology with dependent ecosystems, and how these ecosystems are impacted by changes in both groundwater and surface flows.

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Economic output of groundwater dependent sectors in the Great Artesian Basin

A REPORT COMMISSIONED BY THE AUSTRALIAN GOVERNMENT
AND GREAT ARTESIAN BASIN JURISDICTIONS BASED ON
ADVICE FROM THE GREAT ARTESIAN BASIN COORDINATING
COMMITTEE

August 2016

Economic output of groundwater dependent sectors in the Great Artesian Basin

Executive summary	v
1 Introduction	1
1.1 Purpose and scope of this report	1
1.2 The GAB	1
1.3 Structure of this report	7
2 Historical role of GAB groundwater	8
2.1 Introduction	8
2.2 Role in Indigenous life and culture	8
2.3 Early development of the GAB	8
2.4 Maintaining the GAB	9
2.5 Challenges	9
3 Economic value of GAB water using activities	12
3.1 Stock use	14
3.2 Irrigation use	17
3.3 Energy and Earth Resources	21
3.4 Urban Water use	30
3.5 Other industries (including tourism)	34
4 Investment in water infrastructure in the GAB	38
4.1 Private On-farm investment	38
4.2 Public investment — GABSI	39
4.3 Value of investment	40
5 Concluding comments	42
Appendix 1: Agricultural data issues and the alignment of GAB to ABS regions	44
Appendix 2: Water licence information	52
References	55

Economic output of groundwater dependent sectors in the Great Artesian Basin

Figures

Figure 1: GAB water use from coal seam gas production in Queensland (ML/yr)	viii
Figure 2: Regions of the GAB	2
Figure 3: Land use across the Surat region	3
Figure 4: Land use across the Central Eromanga region	4
Figure 5: Land use across the Western Eromanga region	5
Figure 6: Land use across the Carpentaria region	7
Figure 7: Environmentally valuable sites in the GAB	11
Figure 8: The location, number and size of feedlots throughout Australia	16
Figure 9: Operating mines, new mining infrastructure and mineral processing centres	22
Figure 10: Australia's gas facilities	23
Figure 11: NSW CSG wells	24
Figure 12: CSG in SE Queensland	26
Figure 13: CSG in central Queensland	26
Figure 14: Associated water from coal seam gas production in the Surat Basin	27
Figure 15: Total tourism expenditure in 2007-08	36
Figure 16: NRM regions	45
Figure 17: NSW and Queensland SA4 regions	46
Figure 18: South Australian and Northern Territory SA4 regions	47

Tables

Table 1: Values dependent on GAB water resources (\$ million per year)	vi
Table 2: GAB Water licences and estimated use	12
Table 3: Estimated GAB stock water use	14
Table 4: Livestock in GAB regions, 2013-14	15

Table 5: Gross value of livestock industries in GAB regions (\$ million), 2013-14	15
Table 6: GAB irrigation water access licences	17
Table 7: Value of GAB irrigated agricultural output	21
Table 8: Queensland mining output that is GAB-dependent	25
Table 9: South Australian mining output that is GAB-dependent	28
Table 10: Estimated value of GAB-dependent mining	29
Table 11: GAB Urban water licences	31
Table 12: Licence Volumes for Local Water Utilities Access Licences in the NSW GAB	31
Table 13: Populations Queensland towns relying on GAB water for urban supply	32
Table 14: GAB Urban water licences and estimated value	33
Table 15: Key tourism and recreation sites supported by the GAB	34
Table 16: Tourism Indicators 2013-14	36
Table 17: GAB bore depth and estimated replacement cost (\$ million)	38
Table 18: Government funding over the phases 1-3 of GABSI (nominal \$ million)	40
Table 19: Water efficiency investments outside of GABSI	40
Table 20: Estimated government investment by Basin jurisdiction (real \$ million 2016)	41
Table 21: Values dependent on GAB water resources (\$ million per year)	42
Table 22: Livestock in GAB SA4 regions, 2013-14	48
Table 23: Gross value of livestock industries in GAB SA4 regions (\$ million), 2013-14	48
Table 24: Gross value of livestock industries in GAB NRM regions (\$ million), 2013-14	49
Table 25: Gross value of crop industries in GAB regions (\$ million), 2013-14	50
Table 26: Gross value of Agricultural Production in GAB NRM regions (\$ million), 2013-14	51
Table 27: Access Licences and water requirement, GAB NSW	52
Table 28: Water licences and entitlement volumes, GAB Queensland	53
Table 29: Water usage volumes, GAB South Australia	53
Table 30: Estimated NT GAB extraction volumes	54

Executive summary

The Great Artesian Basin (GAB) is a highly valuable water resource which provides locationally diverse benefits and opportunities. The waters of the GAB have:

- been an intrinsic part of social lifestyle and cultural values developed and maintained by Indigenous Australians in arid landscapes
- provided opportunities for the development of low-rainfall areas of Australia through secure access to water
- created economic value through a range of uses including livestock and domestic consumption, irrigation and industrial/mining.
- supported the quality of life and development of more than 120 towns and settlements and economic activity
- sustained infrastructure, lifestyles and local cultures in sparsely populated outback regions
- played host to unique groundwater dependent ecosystems at naturally occurring springs.

Arguably, most of the economic activity in GAB regions is dependent on access to GAB water resources. Without GAB water, economic development in many areas would not have been able to occur. It is also hard to imagine much of the town/urban water use and domestic water use in GAB regions being possible without access to GAB water. In many localities, alternative water supplies are prohibitively costly and total reliance on surface water would significantly reduce liveability. In other areas, such as eastern regions and the far north, other water sources are available and we are unable to differentiate the contributions of GAB water and these other sources of water to regional economic activity.

We estimate that the consumptive use of GAB water is integral to at least \$12.8 billion of production annually (Table 1). The provision of drinking water through domestic bores and town water supply has been essential to the development of GAB regions. The non-consumptive benefits of GAB water resources include groundwater dependent ecosystems.

The consumptive water uses by stock (pastoral and intensive), irrigation, and mining, electricity and gas industries are all of high economic value (Table 1). The use of the GAB water resource provides economic value-add to regional resources (land and minerals), and underpins much of the economic activity and employment across the GAB region. For example:

- *Stock:* There are over 14 million beef cattle for meat production and over 11 million sheep and lambs in GAB regions. Annually the gross value of beef production alone is in excess of \$4 billion and sheep contribute a further \$600 million.

- *Irrigation:* While high levels of sodium render untreated GAB water unsuitable for irrigation in many locations, it provides a valuable supplement to surface water for irrigated fodder and horticultural production in some areas. It is estimated that irrigated production using GAB water is valued in excess of \$60 million annually.
- *Energy and Earth resources:* Mining, gas and other opportunities are dispersed across the GAB regions and are valuable economic uses of GAB water. The total value of mining output dependent on GAB water is estimated to exceed \$6 billion annually. In addition, coal seam gas (CSG) which is produced by pumping groundwater to release gas from coal seams in the Surat Basin (a sub-basin of the GAB) has grown quickly to \$1.7 billion in 2014-15 and could increase further.

The distribution of this production between the GAB jurisdictions (NSW, Queensland, South Australia and the Northern Territory) depends on the location of the companion inputs to production such as grazing land and mineral deposits. Table 1 below sets out the estimated distribution.

Table 1: Values dependent on GAB water resources (\$ million per year)

Sector	NSW	Qld	SA	NT	Total
Estimated annual value of output that is dependent on GAB water resources					
Stock	1094.5	3004.4	105.1	463.7	4667.7
Mining	568.3	2980.7	2801.7	0	6350.7
CSG	7.7	1693.4	0	0	1701.1
Electricity	0	0.1	0	0	0.1
Irrigated Agriculture	30.4	27.7	0	0	58.1
Urban water	7.4	34.0	1.8	0.1	43.3
Total Value of output	1708.3	7740.3	2908.6	463.8	12821.0
Other values related to GAB water resources (noting environmental values could not be monetised)					
Tourism expenditure	100.5	311.0	150.0	163.0	724.5 (per year)
GABSI Infrastructure expenditure	118.9	148.0	13.8	0.0	280.7 (asset total)
Private Infrastructure investment					5000-15000 (asset total)

Source: Frontier Economics analysis

This report examines the direct economic activity of those sectors dependent on GAB water resources. There are also second- and third-round economic effects

related to these sectors. For example, up and down-stream industries that provide inputs and process outputs of the sectors (i.e. farm supplies, mechanics, processors), and the local economy servicing the people working in all these industries. Hence, it could be argued that all of the economic activity in GAB regions is dependent on access to GAB water resources where other water sources are not available.

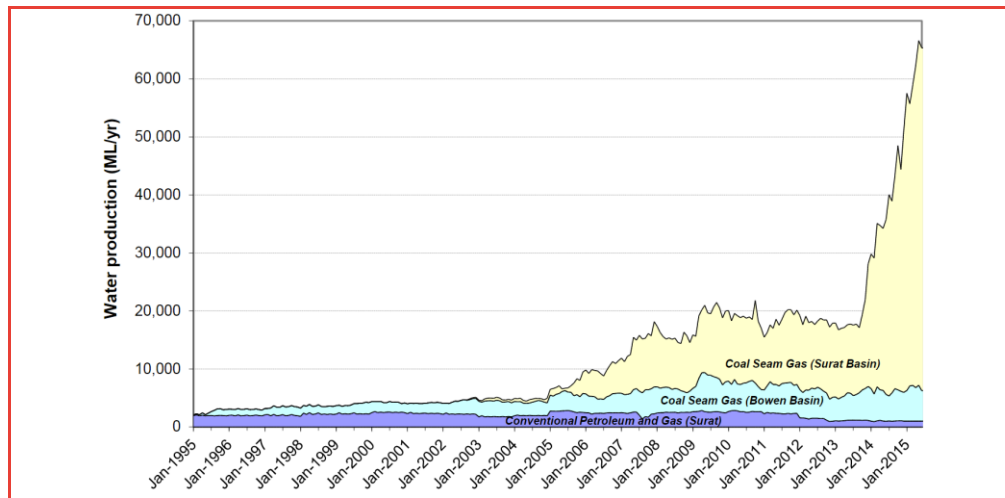
Significant public and private funds have been dedicated to develop and protect this resource to support its economic, social and environmental values. On-farm investment has been significant with 34,951 bores across the GAB. The vast majority of these bores are less than 200 metres deep, however some bores are deeper than 1200 metres.

The Great Artesian Basin Sustainability Initiative (GABSI) and related state and Territory water planning initiatives have entailed significant effort to manage the GAB water resource to reduce water extractions and maintain or increase pressure. Government funding for GABSI has exceeded \$280 million in total (in 2016 dollars). These initiatives have achieved significant reductions in stock and domestic water usage by the pastoral sector, while maintaining or increasing the economic output of the sector. This has been possible because investments have targeted water savings, thereby reducing inefficient usage (uncontrolled bores and open drains).

Looking forward, GAB management will be challenged by new or increased water demand from new or expanding industries:

- The information available on GAB water resource use is limited, with much of the stock and domestic use estimated.
- There are limited opportunities to reallocate water use between existing uses and from existing to new uses. Water trading is hampered due to the challenges associated with hydrologically complex groundwater resources.
- Producing gas resources necessarily involves taking water as a by-product [associated water] which can be significant. The volumes taken tend to diminish over time. There is thus a high degree of uncertainty associated with volumes and reliability over time. In recent years, growth in GAB water volumes extracted by CSG in Queensland's section of the Surat Basin (Figure 1) has increased significantly.

Figure 1: GAB water use from coal seam gas production in Queensland (ML/yr)



Source: DNR 2016, p. 62.

1 Introduction

1.1 Purpose and scope of this report

This report provides an overview of the economic output of groundwater dependent sectors in the Great Artesian Basin (GAB).

The report intent is to provide clarity around current and future water use and users in the GAB and the value of the industries or sectors dependent on GAB water. It is anticipated that the analysis will inform the work of identifying future policy, funding options and incentives for the continued renewal and replacement of the GAB water infrastructure. It will also help inform the development of a new Strategic Management Plan for the GAB.

The report will be a useful resource for GAB stakeholders, particularly the Great Artesian Basin Coordinating Committee (GABCC). The economic value of GAB water was identified by the GABCC as a significant gap in the knowledge of the Basin to inform planning and management decisions within the GAB. The report will help the GABCC achieve an improved understanding of the economic activity within the GAB and allow the committee to provide more informed advice to GAB governments.

It is important to note that this project encountered significant data challenges, which meant that it was not possible to fully isolate the economic value derived directly from GAB groundwater from the other water resources available in the geographic basin.

1.2 The GAB

The GAB is one of the largest underground freshwater reservoirs in the world. It underlies approximately 22% of Australia – occupying an area of over 1.7 million square kilometres beneath arid and semi-arid parts of Queensland, New South Wales, South Australia and the Northern Territory. Approximately 70% of the GAB lies within Queensland.

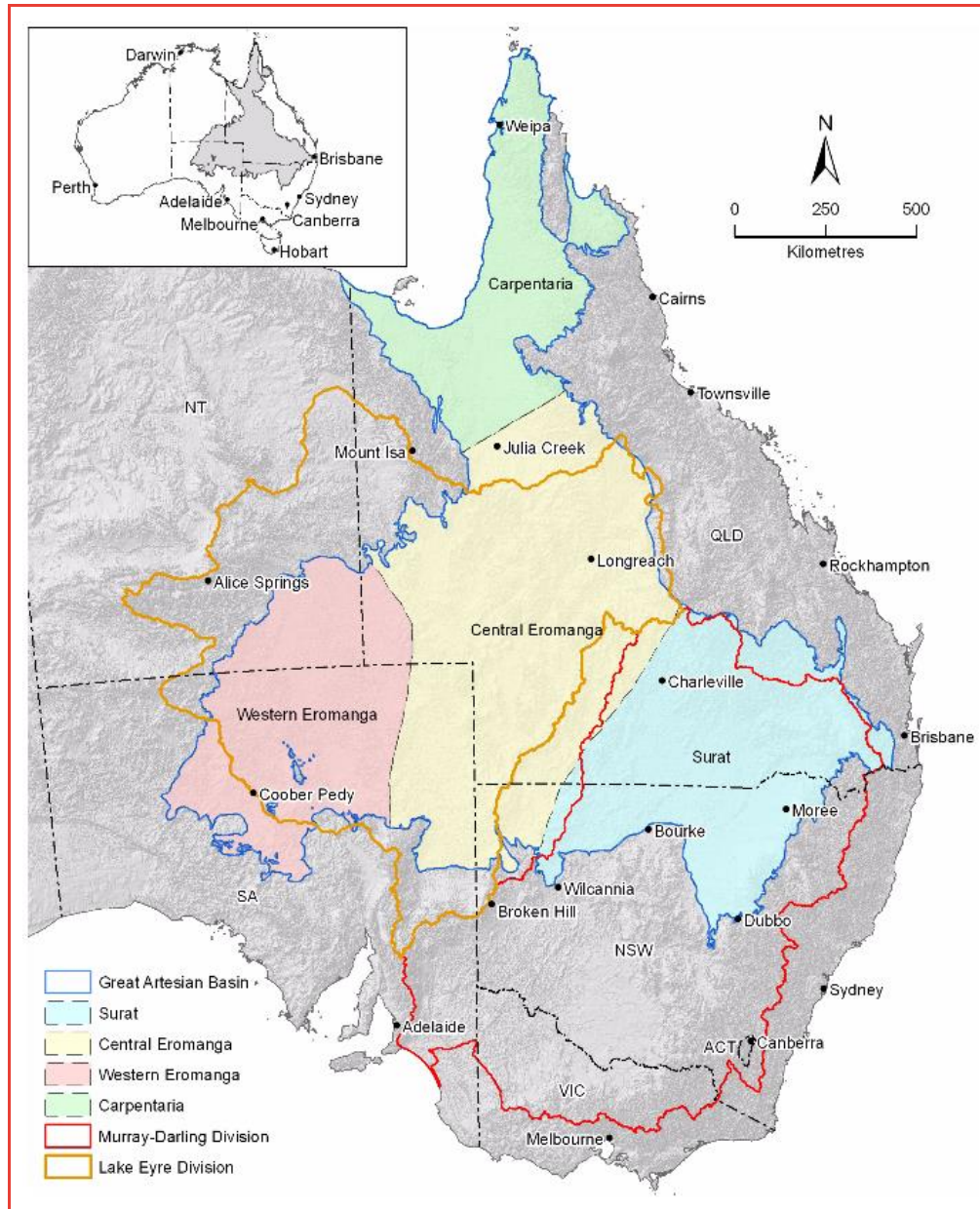
The GAB has been divided into four assessment regions (Figure 2):

- **Surat** — The Surat region is bounded by the Great Dividing Range to the east and the Eulo and Nebine ridges to the west.
- **Central Eromanga** — The Central Eromanga region is bounded by major geological structures including: the Birdsville Track Ridge and Toomba Fault to the west, the Euroka Arch to the north, and the Great Dividing Range and the Eulo and Nebine ridges to the east.
- **Western Eromanga** — The Western Eromanga region is bounded by major geological structures including: the Birdsville Track Ridge and Toomba Fault

to the east, the Northern Flinders and Willoran ranges to the south, and several older geological basins to the west and north-west (e.g. the Arckaringa, Pedirka, Warburton and Amadeus basins).

- **Carpentaria** — The Carpentaria region is bounded by major geological structures including: the Euroka Arch to the south, and the Great Dividing Range to the east of the Carpentaria Basin and to the west of the Laura Basin.

Figure 2: Regions of the GAB



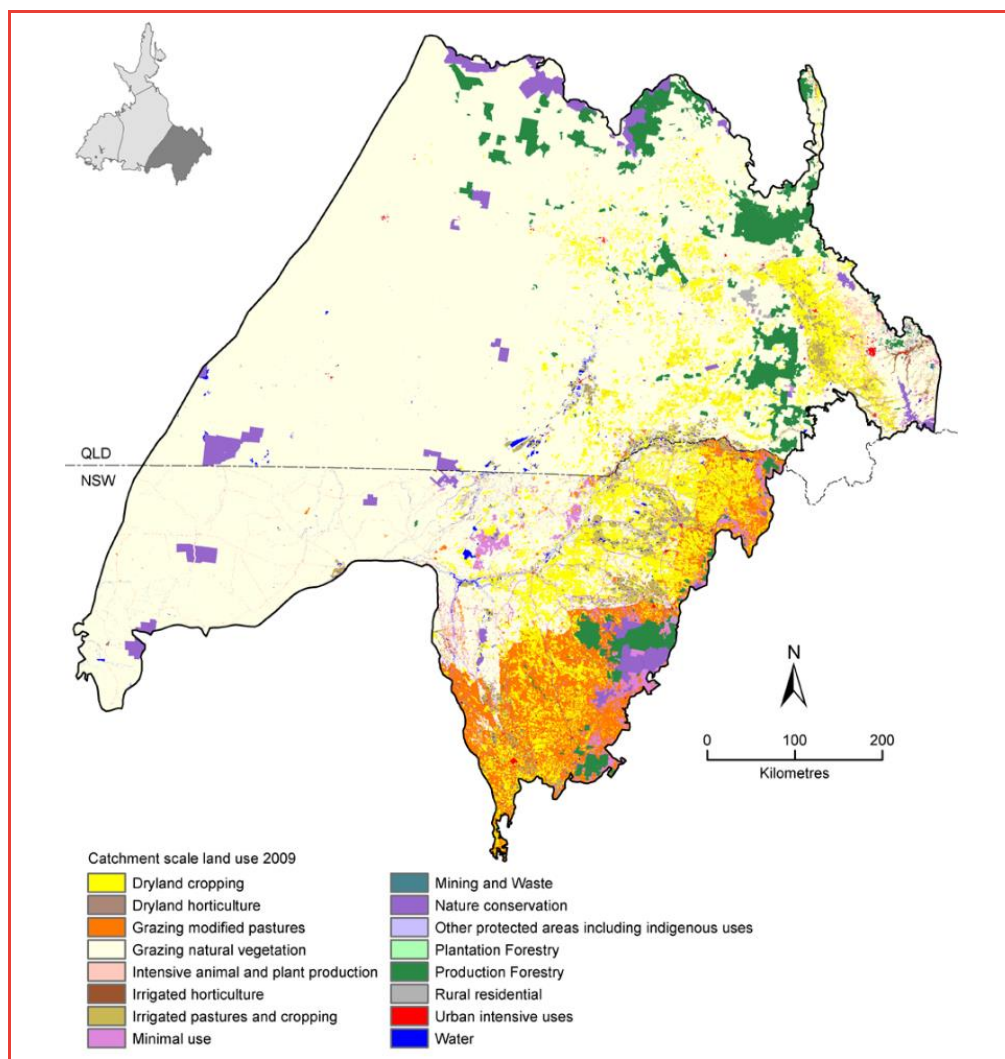
Source: Smerdon et al 2012.

Surat region

The Surat region occupies an area of 440,000 km² of south-eastern Queensland and north-central New South Wales. The Surat Basin in southern Queensland encompasses the Maranoa, Toowoomba and Western Downs regional council areas. Across the border in NSW, the basin extends south as far as Dubbo. As noted in the Surat Basin Regional Planning Framework (2011):

The Surat Basin is renowned for agriculture and quality food production, and energy resources for both domestic and international consumption. These sectors represent the foundations of both population and economic growth, and are vital in securing the quality of life within local and regional communities such as those found in the Surat Basin...While the Surat Basin has, and will retain, a strong and traditional agricultural foundation, it also contains more than six billion tonnes of proven thermal coal reserves which are largely undeveloped and suitable for power generation, both domestically and abroad. The area also has significant reserves of coal seam gas (CSG). CSG is predominantly methane gas, which is also suitable for domestic power generation and export to international markets as liquefied natural gas (LNG).

Figure 3: Land use across the Surat region

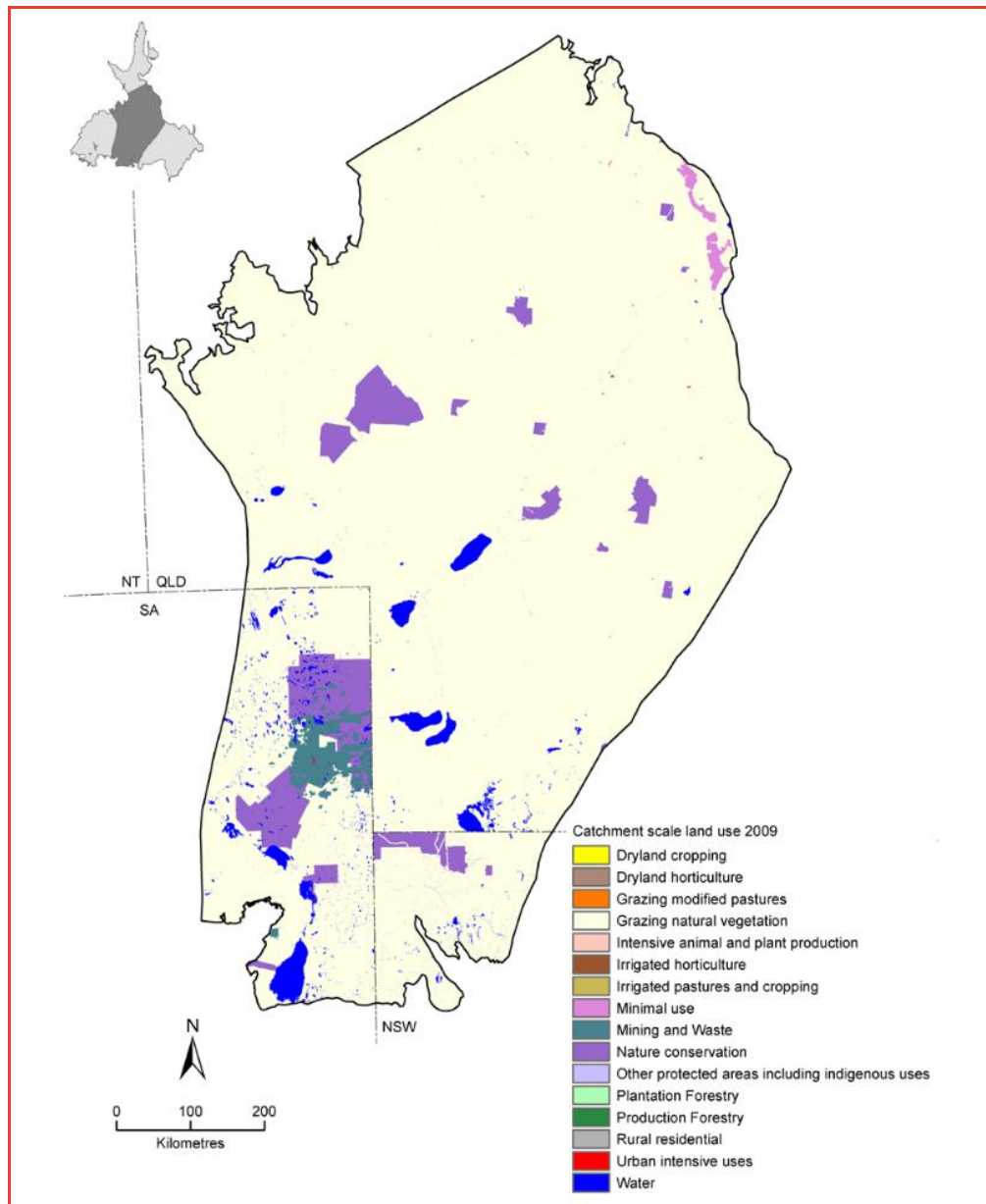


Source: Smerdon and Ransley 2012a.

Central Eromanga region

The Central Eromanga region occupies an area of around 690,000 km² roughly covering the central part of the GAB. It covers parts of Queensland, the Northern Territory, South Australia, and New South Wales. In Queensland and South Australia, the Eromanga Basin has been explored and developed for petroleum production.

Figure 4: Land use across the Central Eromanga region



Source: Smerdon and Ransley 2012b.

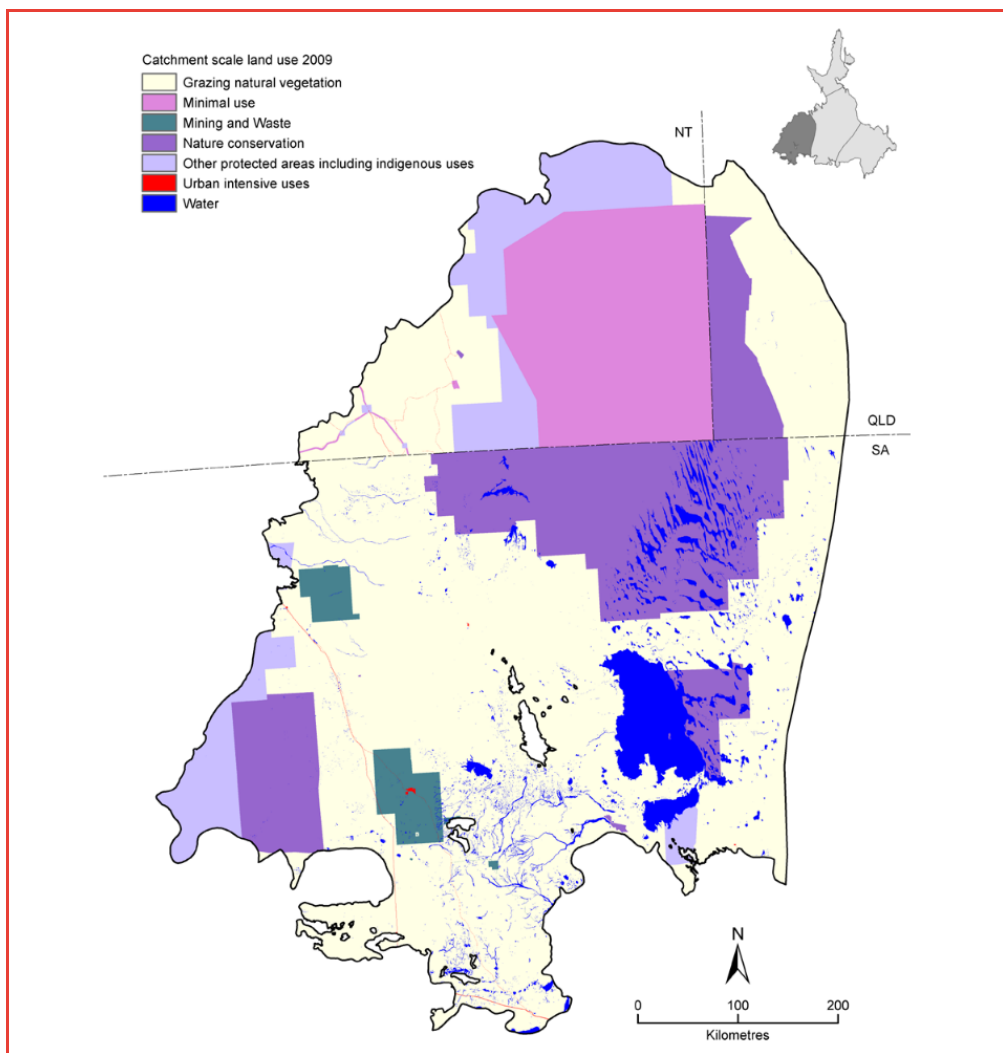
Western Eromanga region

The Western Eromanga region occupies an area of approximately 370,000 km² and includes the western margin of the GAB.

The Western Eromanga region is centred on the sparsely populated areas of far north-east South Australia, the south-west corner of Queensland and the south-east corner of the Northern Territory. The South Australian portion of the Western Eromanga region includes the Local Government Area of Coober Pedy, while the Queensland portion falls within the Shire of Diamantina. Parts of the western margin of the region also fall within Aboriginal freehold lands of the Maralinga Tjarutja and the Anangu Pitjantjatjara peoples.

Pastoralism is the predominant land use in the region, primarily being beef cattle with some sheep.

Figure 5: Land use across the Western Eromanga region



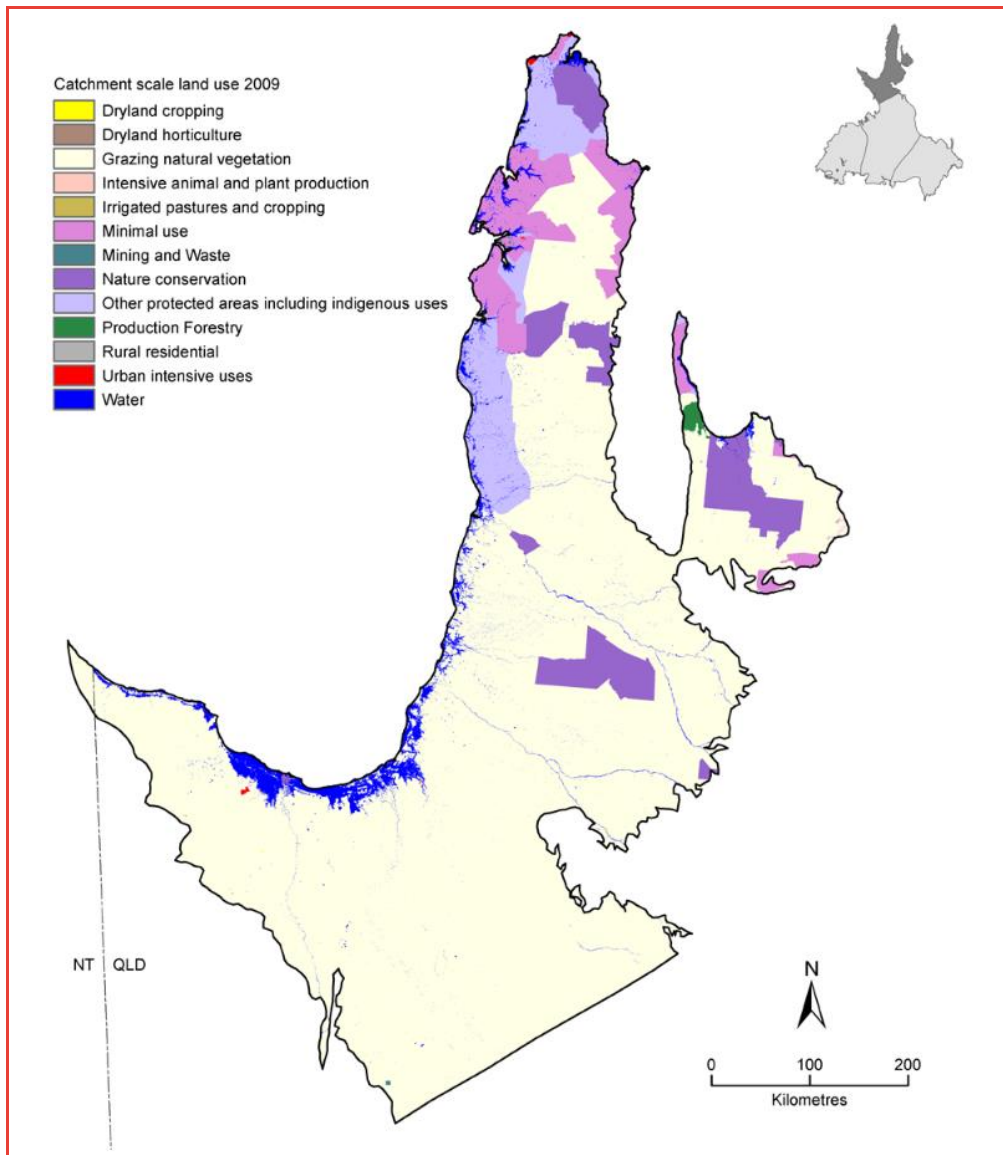
Source: Smerdon, Welsh and Ransley 2012a.

Currently, the main users of water in the GAB in the Western Eromanga region are spring discharge and associated wetlands, pastoralism, the mining and petroleum industries, wetlands, and town and other domestic water supplies. As a collective, the pastoral industry is currently the largest non-environmental user of groundwater in the Western Eromanga region, with bores mainly located in areas south and west of Lake Eyre. However, the biggest single entity extractor of groundwater in the Western Eromanga region is the Olympic Dam mining operation, located just outside the southern extent region. Groundwater for this operation is extracted from two borefield areas within the region located near Lake Eyre South, permitted through a special licensing agreement under the Roxby Downs (Indenture Ratification) Act 1982 (SAALNRMB, 2009).

Carpentaria region

The Carpentaria region occupies an area of 250,000 km² almost entirely within northern Queensland and a small portion of the Northern Territory where the region meets the Gulf of Carpentaria. It includes the Laura Basin (just north of Cooktown), the Carpentaria Basin and the Karumba Basin.

Figure 6: Land use across the Carpentaria region



Source: Smerdon, Welsh and Ransley 2012b.

1.3 Structure of this report

The remainder of this report is structured as follows:

- Section 2 provides information on the historical role of GAB groundwater.
- Section 3 examines the economic value of key GAB water using sectors.
- Section 4 considers investment in water infrastructure in the GAB.
- Section 5 provides concluding comments and observations.

2 Historical role of GAB groundwater

2.1 Introduction

In order to contextualise the role of the GAB in groundwater dependent sectors today, it is first helpful to understand how the role of the GAB has evolved historically in contributing to the economic, social/cultural and environmental values of the GAB region.

2.2 Role in Indigenous life and culture

The first people to make use of GAB water were Indigenous tribes for whom it was critical to survival. Indeed, there is evidence that the GAB sustained Aboriginal people for thousands of years prior to European settlement.

The natural springs of the GAB provided a critical source of fresh water, and supported valuable food sources including birds, mammals, reptiles, crustaceans and insects, creating an abundant hunting ground for local tribes. The plants and trees around the artesian springs were used for food, medicine, materials and shelter. The springs provided semi-permanent oases in the desert and supported trade and travel routes which evolved around them.

The springs also played a key part in the spiritual and cultural beliefs of Aboriginal people. Ceremonies and other events were held at spring wetland areas which remain precious cultural and sacred sites. Numerous Creation stories feature a connection to groundwater.

2.3 Early development of the GAB

The springs also sustained life for drovers along the stock routes before the first bores were drilled.

European discovery of GAB groundwater occurred in 1878, when a shallow bore near Bourke in New South Wales produced flowing water. Further discoveries followed quickly—in 1886, at Back Creek east of Barcaldine, and near Cunnamulla, the following year. By 1899 some 524 bores had been sunk. Most bores were allowed to flow freely onto the ground, running into open drains to water stock because the infrastructure to control this flow was not developed.

The discovery and use of water held underground in the GAB opened up thousands of square miles of country away from rivers in inland New South Wales, Queensland, and South Australia, previously unavailable for pastoral activities.

This heralded the arrival of the so-called ‘Artesian age’ where the GAB became an important water supply for cattle stations, irrigation, and livestock and domestic usage. Thousands of kilometres of bore drains from the GAB underpinned the

development of many rural communities, providing water for a host of activities. The early settlers used bore water to run steam trains, finally making it possible to travel through the desert in relative speed and safety. Farmers sunk bores on their properties to provide a reliable water source for life on the stock routes. (GABCC 2008).

Bore water was used to clean wool before it was sold overseas. This boosted the value of fleece, and saved money on transport since farmers were no longer paying to ship dirt. (GABCC 2008).

Many inland towns relied on bore water for their everyday needs. Since the 1960's, bore water has been used for the mining of copper, gold, lead, zinc, uranium and silver, as well as oil and gas, and tourists travel from all over the world to explore the incredible landscapes of the GAB region. (GABCC 2008)

The role that GAB water resources have played in the development of areas of inland Australia has also made it culturally significant to non-indigenous Australians as embodied in Banjo Paterson's Song of the Artesian Water (December 1896).

2.4 Maintaining the GAB

Ongoing concerns about groundwater extraction and in particular falling artesian pressures due to inefficient water use and the related natural resource problems, such as erosion around bores and weed invasion, drove the development of a Strategic Management Plan (SMP) for the GAB in the late 1990s. The SMP was agreed to in 2000 and is the first whole-of-basin management plan adopted by GAB jurisdictions. In 1999, the Great Artesian Basin Sustainability Initiative (GABSI), a joint programme between the Australian government and state GAB jurisdictions (New South Wales, Queensland, South Australia and the Northern Territory), was introduced to provide for capping of uncontrolled bores and piping of open bore drains. The GABSI aims to better manage the water by controlling its use, and most importantly, by minimising wastage. The program is now in its fourth phase (GABSI 4) and is due to end in 2016-17 unless further extended.

2.5 Challenges

Water has historically been extracted from the GAB at a greater rate than recharge. Many bores were unregulated or abandoned, and a large proportion of the water drawn from the Basin was lost to seepage, and evaporation from bore drains. Even though technologies, practices and regulations have improved, these problems persisted for many decades.

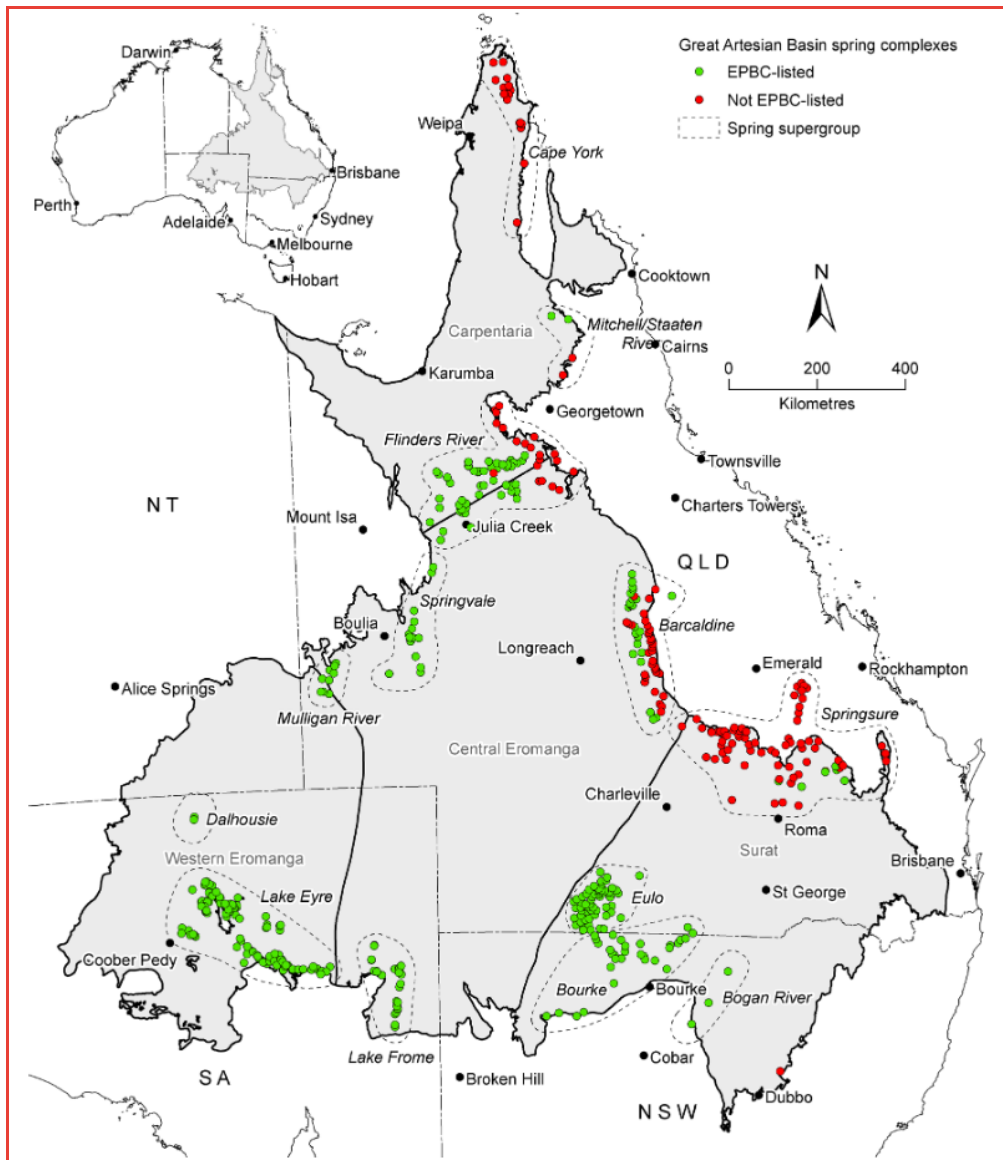
Infrastructure investment, to address this issue of losses and to maintain aquifer pressure, has also brought the challenge of funding that infrastructure maintenance which, if not done, risks the loss of the benefits from investment to date.

There are further challenges posed by newer industries of CSG and shale gas production and also climate change.

While this study focuses on the economic uses of groundwater in the GAB (see section 3), it is important to also recognise other significant values which need to be protected. The Aboriginal cultural values of groundwater-dependent sites remain poorly understood by many non-Aboriginal people. Planning for the future use of GAB water needs to recognise these cultural values. For example, the Water Sharing Plan for the NSW GAB Groundwater Sources acknowledges that access to traditional sources of GAB water may be necessary for continuing Indigenous cultural practices. South Australian and Queensland water management also identifies and protects Aboriginal cultural values. The urgency of these tasks is elevated by the current development pressures placed on the GAB.

The GAB is also important environmentally and its unique ecosystems are home to a host of native plant and animal species, many of which are not found anywhere else in the world (GABCC 2008). As many of the mound springs have dried up, the communities of native species which depend on the natural discharge of groundwater have been declared as endangered ecological communities under the *Commonwealth Environment Protection and Biodiversity Act 1999* (GABCC 2014). Figure 7 maps environmentally valuable sites in the GAB.

Figure 7: Environmentally valuable sites in the GAB



Source: Smerdon et al 2012.

3 Economic value of GAB water using activities

GAB water resources sustain the lives of more than 180 000 people and 7600 enterprises. Basin water is used in households in more than 120 towns and settlements and on hundreds of properties (GABCC nd).

This report brings together information on the range of economic activities that rely on GAB water resources. The focus of the assessment is on the value of output that is dependent on access to GAB water, and the distribution of this across the GAB jurisdictions.

Arguably most of the output of these areas is due to access to GAB water resources. Without it there might be no towns or industry, except where other water resources are available. The report focuses on primary outputs and their location to inform the future planning for the management and development of the GAB.

The activities undertaken across the GAB regions vary in the nature and extent of their use of groundwater. It is difficult to determine the volume and the use to which all GAB water is applied. In NSW, licences are not granted with particular approved purposes. In Queensland and South Australia, multiple purposes may be listed. In the Northern Territory, stock and domestic water use predominates. Further, the volume of stock and domestic water access across the GAB is generally estimated (not metered) based on regional characteristics (such as stocking rates).

Table 2 below sets out estimated GAB water use / water licence information for the GAB jurisdictions. Further detail is presented in Appendix 2.

Table 2: GAB Water licences and estimated use

Jurisdiction	GAB Estimated Use / Access Licence Volume (ML/yr)
New South Wales	
Stock and Domestic	56,270
Local Water Utility	7,028
Irrigation	76,758
Other uses	11,641
Queensland	
Stock and Domestic	121,759
Local Water Utility	32,057
Irrigation	32,341
Mining, Industrial and Commercial	30,909
Stock intensive (feedlots)	16,098
Gas extraction	65,000

South Australia	
Stock and Domestic ¹	10,438
Local Water Utility ²	1,579
Irrigation ³	115
Mining ⁴	24,200
Industrial and Commercial	934
Co-Produced water	21,900
Bore Fed Wetland	2,025
Northern Territory	
Stock and Domestic	3,150
Local Water Utility	70
Environmental discharge	250

Notes: ¹ Based on the licensed allocation which assumes delivery through a water tight delivery system (ie tank and trough). Under current licence conditions, the water tight delivery system will become mandatory in 2019. ² Includes water supply for mining camps. ³ A single licence lists irrigation as a listed use, and other listed uses include Commercial, Bore Fed Wetland and Domestic. ⁴ Includes Olympic Dam.
Source: Appendix 2.

The relative use of GAB water in different activities has informed the following categorisation of GAB water using industries:

- Stock water use (which support pastoral activities), including stock intensive water use
- Irrigation
- Energy and Earth Resources (including Mining, Electricity and Gas)
- Urban Water and Domestic Use
- Other industries (including tourism).

The following discussion looks at each of these activities. For each activity we examine current patterns of water use, the economic value of the activity, and potential future water use taking into account prospects for the sector.

3.1 Stock use

Stock and domestic¹ water use and licences for intensive stock water use (such as feedlots) support stock industries reliant on GAB water resources. Stock and domestic includes the pastoral beef and sheep industries that rely on GAB water to keep stock watered.

The availability of GAB water is crucial to this sector, as low and unreliable rainfall makes a sole reliance on surface water risky and impractical for the volumes of water required. A key resource management challenge arises because stock and domestic usage of water is generally unmetered.

Intensive lot feeding of stock has become an important use of GAB water in recent years. While lot feeding to finish cattle and other stock is a distinct activity from the pastoral industry, its economic value is incorporated in Australian Bureau of Statistics (ABS) data on livestock industries and so is included in the discussion.

3.1.1 Patterns of water use

The pastoral industry has long been the largest user of GAB water, although much stock and domestic water use is not metered (volume is estimated) (Table 3).

Table 3: Estimated GAB stock water use

Jurisdiction	GAB Estimated Use / Access Licence Volume (ML/yr)
New South Wales — Stock and Domestic	56,270
Queensland — Stock and Domestic	121,759
Stock intensive (feedlots)	16,098
South Australia — Stock and Domestic	11,846
Northern Territory — Stock and Domestic	3,150

Source: Appendix 2.

GAB regions are home to vast numbers of beef cattle and sheep. The most recent ABS data indicates that there are more than 14 million beef cattle for meat production and over 11 million sheep and lambs. Stock numbers fluctuate considerably during drought periods.

The majority of cattle grazing on GAB regions are in northern zones (Queensland, NT and northern areas of NSW), while sheep are more prevalent in the southern zones of SA and NSW (Table 4).

¹ A stock and domestic right is a water right held by rural landowners for domestic, on-farm purposes. Stock and domestic means uses such as household purposes, watering of animals kept as pets, watering of cattle or other stock and irrigation of a kitchen garden.

Table 4: Livestock in GAB regions, 2013-14

Jurisdiction (GAB region)	Livestock - Meat cattle - Total (no.)	Livestock - Sheep and lambs - Total (no.)	Total beef and sheep in region (no.)
NSW	2,292,216	8,449,233	10,741,449
Qld	9,447,571	2,328,966	11,776,537
SA	252,365	260,000*	512,365
NT	2,158,388	-	2,158,388
Total	14,150,540	11,038,199	25,188,739

Note: * This figure was provided by SA DEWNR given the ABS figure of 2,807,084 includes sheep outside of the GAB.

Source: ABS 7121.0

3.1.2 Economic value of the sector

The challenges of accessing agricultural data that is relevant to GAB regions is discussed in Appendix 1 to this report. In this section we attempt to value the sector by using data based on the Australia Bureau of Statistics' SA4 regions that overlay the GAB.

Production

As shown in Table 5, the value of production from these livestock is in excess of \$4 billion annually for beef cattle and \$800 million for sheep (meat and wool). In order to confirm these estimates of economic value of production, the ABS data for NRM regions was also analysed and this found a similar total (Appendix 1).

Table 5: Gross value of livestock industries in GAB regions (\$ million), 2013-14

Jurisdiction (GAB region)	Gross value from livestock slaughtered and other disposals - Cattle and calves (\$m)	Gross value from livestock slaughtered and other disposals - Sheep and lambs (\$m)	Gross value from Wool (\$m)	Total (\$m)
NSW	629.2	207.2	258.1	1094.5
Qld	2864.1	60.4	79.9	3004.4
SA	84.3	11.8*	9.0*	105.1
NT	463.7	0	0	463.7
Grand Total	4041.1	279.4	347.0	4667.7

Note: *Prorated based on the adjustment to the estimated number of SA sheep.

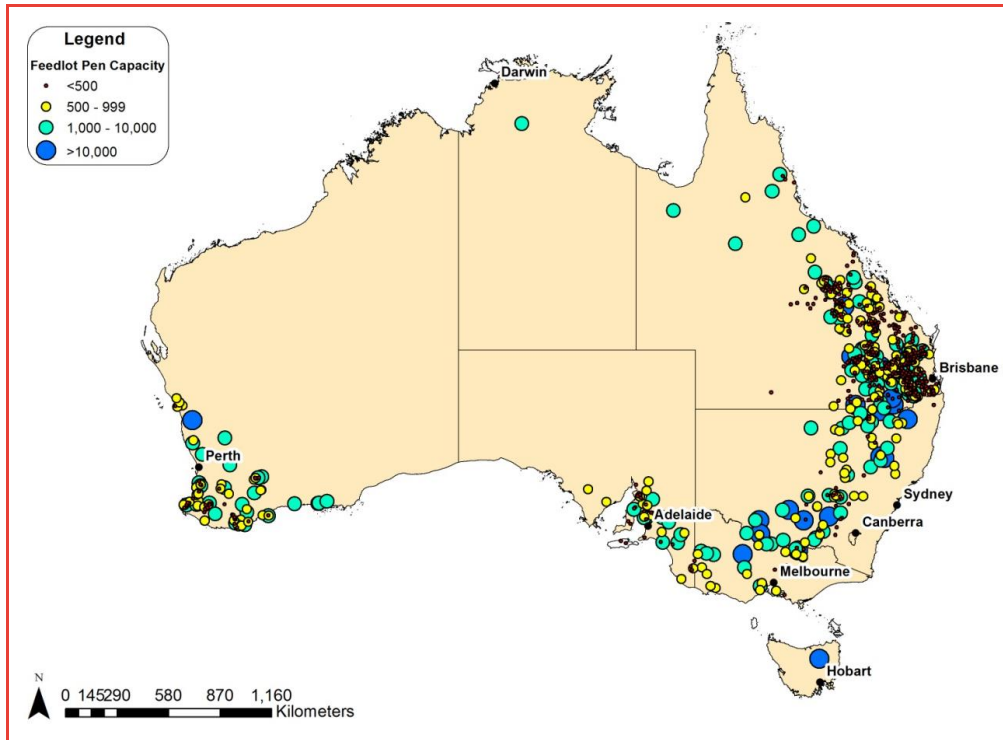
Source: ABS 7503.0

Feedlots

While not reported separately, the gross value of production of feedlots across Australia is significant (\$2.5 billion).

Most of the feedlots in Queensland are in the shires overlaying the GAB (Figure 8). NSW commercial feedlots are predominantly in the Eastern Recharge Groundwater Source.

Figure 8: The location, number and size of feedlots throughout Australia



Source: ALFA 2016

Water is used by feedlots for cattle drinking, effluent management, cooling cattle and dust abatement. (ACIL Tasman 2005). ACIL Tasman (2005) report that other intensive stock industries are important GAB water users too, and use piggeries as an example. Deloitte (2015) notes that where a feedlot relies on GAB water, the water is a crucial element in its function and location.

We understand from the ABS data the value of feedlot output is included in the Queensland total value for cattle slaughtered of \$2.86 billion.

3.1.3 Potential future water use

The future water use for stock purposes is expected to increase in efficiency as free-flowing bores are progressively capped and bore drains are replaced with pipes and troughs.

Efficient water consumption (inclusive of losses) does not mean reduced industry output. In fact, production could be maintained or increased since the improved

Economic value of GAB water using activities

infrastructure reduces losses and provides water in a more controlled way that aids farm management (Moore (1992) notes the value of water quality to livestock productivity and the ability to more effectively control undesirable animal pests and weeds). This more efficient management of GAB water will still support the economic outcomes of stock and domestic water use while using less of the GAB resource.

The increasing use of metering should contribute to improved resource use information. For example, in Queensland, mandated meter installation was completed in the Mulgildie and Eastern Downs management areas in 2007 and in the Gatton-Esk Road Implementation Area in 2010. In addition to the mandated metered entitlements, a number of licences in areas such as the Surat, Flinders, Gulf East, Barcaldine West and Barcaldine North management areas have a condition that requires them to meter their take of water (DNRM 2015).

3.2 Irrigation use

The use of GAB water for irrigation is localised due to water quality issues. Some GAB groundwater has high levels of sodium or other salts, which renders the water unusable for irrigation in some places, while soil condition may also reduce the viability of irrigation. Water quality and sodicity issues can build up over time with regular irrigation. There are also challenges due to isolation from other farmers, agronomic advice and farm technology providers and the distance to potential markets.²

Despite this, a number of different irrigated crop types have been reported using GAB water, including sorghum, lucerne and cotton. GAB water is also used to irrigated limited horticultural crops (such as avocados, mandarins and grapes) though often GAB water is a backup source given both the water quality issues and the higher relative pumping cost compared to using surface water.

3.2.1 Patterns of water use

The table below sets out the volumes of water access licences associated with irrigation water use.

Table 6: GAB irrigation water access licences

Jurisdiction	GAB Access Licence Volume (ML/yr)
New South Wales	76,758
Queensland	32,341

² Pers. comm., Mr Ed Fessey, 14 May 2016.

South Australia	115
Northern Territory	-

Source: Appendix 2.

Queensland

The areas overlying and neighbouring the GAB are important contributors to Queensland's irrigated agricultural area. However, a minimal proportion of this area would use GAB water as the irrigation water source (ACIL 2005).

A current search of the Water Management Database of the Department of Natural Resources and Mines identified total entitlements with irrigation as an approved purpose are 32,341ML per annum spread over 578 licences. In addition to this, there are 154 area-based licences (predominantly in Mulgildie and Clarence Moreton management areas), with irrigable area totalling approximately 5,850 hectares.

Industry contacts suggest that irrigation using GAB water occurs around Goondiwindi.

ACIL (2005) identified that:

- Most irrigation using GAB water is for small areas of fodder production for supplementary feeding of sheep and cattle during dry seasons or to boost fodder quality for particular classes of stock, such as weaner cattle, lambs or dairy cattle.
- Some producers are using GAB water to irrigate lucerne or other crops for sale such as hay, but there are relatively few producers involved. Higher transport costs for fodder from other areas have encouraged the development of these enterprises to supply local markets, especially in western areas of the state.
- There is some limited application for horticulture (tree crops and grapes) in Queensland and typically GAB water is mixed with surface storage water given the high mineral content and high temperatures of GAB water.

Often the GAB entitlement is a backup source given both the water quality issues and the higher relative pumping cost compared to using surface water sources. These other sources could include water captured from overflow and stored on farm dams or publicly owned dams on watercourses (where a water supply charge may apply as well as pumping costs).

NSW

In the past two decades an irrigation industry reliant on GAB water has developed in the Eastern and Southern Recharge Groundwater Sources, where water quality is suitable (NSW Office of Water 2009).

Economic value of GAB water using activities

Parts of these areas have been developed for high volume irrigation extraction at two main locations: North Star – Croppa Creek at the northern end of the Eastern Recharge; and near Narromine at the southern end of the Southern Recharge Groundwater Source. Industry contacts suggested that irrigation occurs around Walgett, Moree, Narrabri, and Coonamble, and that GAB water may be blended with surface water for irrigation.

The NSW Department of Primary Industries identified that irrigation would be the primary use for virtually all of the aquifer access licences in Eastern Recharge, Southern Recharge and the 3 Lower Macquarie zones. The Department suggested that there was no significant irrigation in the other water sources.

Therefore, from the licence data presented in Appendix 2, the volume of GAB access licence entitlement associated with irrigation use is estimated to be 76,758 unit shares (if each unit share is utilised to provide 1ML, this would correspond to irrigation use of 76,758 ML).

SA

A single licence lists irrigation as a listed use to the volume of 115 ML per year.

NT

No irrigation using GAB water is reported in the Northern Territory.

3.2.2 Economic value of the sector

Irrigated production (surface and groundwater)

The gross values of crops that may be irrigated with groundwater are difficult to estimate since ABS data does not differentiate between crops irrigated with groundwater and crops irrigated with surface water. There is also the challenge of aligning ABS data regions to focus on the GAB resource. As discussed in Appendix 1, neither ABS SA4 regions nor NRM regions used by the ABS concord very closely with the geographical boundaries of the GAB. When data from NRM regions is considered, the estimates of production from broadacre crops (such as cereal for grain and seed and others) are much lower (as compared to estimates for meat cattle and sheep which were similar between SA4 and NRM approaches). This suggests that the SA4 estimate for broadacre crops above (in excess of \$4 billion) is not attributable to production reliant on the GAB.

For this reason, an alternative approach is used to estimate irrigated output dependent on GAB water resources (see below).

Estimated irrigated output (groundwater only)

In light of the difficulties using ABS data that aggregates surface and groundwater irrigated production, we have estimated the value of irrigated agricultural

production by considering the volumes of groundwater available that could be applied to different potential crops.

The farm budget (DPI 2012a) for NSW Northern Zone irrigated sorghum (surface irrigation using diesel pump from bore) uses an irrigation rate of 3.8 ML per hectare and suggests a central estimate of yield is 8 tonnes per hectare. An estimate of the on farm value of sorghum can be obtained from daily contract prices, which were around \$180 per tonne in March-April 2016 (Broadbent Grain 2016).

The sorghum farm budget (central estimate) suggest that the NSW irrigation volume licences of 76,758 ML (assuming 1ML per unit share) could produce an irrigated crop valued at approximately \$29.1 million.

If the northern NSW sorghum farm budget (central estimate) is applied to Queensland, it suggest that the Queensland irrigation volume licences of 32,341 ML could produce an irrigated crop valued at approximately \$12.3 million. Using the same farm budget assumptions, the additional area-based licences for 5850 hectares could produce an irrigated crop valued at approximately \$8.4 million. This provides a total potential Queensland sorghum crop valued at \$20.7 million.

The farm budget (DPI 2012b) for NSW Northern Zone irrigated lucerne (surface irrigation of an established stand) uses an irrigation rate of 8.75 ML to achieve 7 cuts of 1.9 tonne per hectare (giving a central estimate for total yield of 13.3 tonnes per hectare).³

The lucerne farm budget (central estimate) suggests that the Queensland irrigation volume licences of 76,758 ML (assuming 1ML per unit share) could produce an irrigated crop valued at approximately \$31.8 million.

If the northern NSW lucerne farm budget (central estimate) is applied to Queensland, it suggests that the Queensland irrigation volume licences of 32,341 ML could produce an irrigated crop valued at approximately \$13.4 million. Using the same farm budget assumptions, the additional area licences for 5850 hectares could produce an irrigated crop valued at approximately \$21.2 million. This leads to a total potential Queensland lucerne farm crop valued at \$34.6 million.

No information on irrigated agriculture in SA and NT that relies on GAB water was identified. Therefore it is assumed that the output of GAB-reliant irrigated agriculture in SA and NT is negligible.

³ The farm budget translates this yield to 320 bales/ha of AFIA Grade A1 (valued at approximately \$8/bale), 106 bales/ha of AFIA Grade B2 (valued at approximately \$6/bale) and 106 bales/ha of AFIA Grade C3 (valued at approximately \$4/bale).

Table 7: Value of GAB irrigated agricultural output

GAB Jurisdiction	Value	Central estimate
NSW	\$29.1-31.8 million	\$30.4 million
Queensland	\$20.7-34.6 million	\$27.7 million
South Australia	-	0
Northern Territory	-	0
Total GAB	\$49.8-66.4 million	\$58.1 million

Source: Frontier analysis

Given that GAB water is known to also be used for higher value crops such as horticulture, the above estimates based on sorghum/lucerne represents a lower bound estimate.

3.2.3 Potential future water use

The Queensland Department of Agriculture, Fisheries and Forestry identifies potential for further significant agricultural development across Queensland (DAFF 2014). In its 2014 Agricultural Land Audit report, it identified that, based on the biophysical conditions, there is potential for future broadacre cropping particularly in the Surat and Surat East management areas, as well as annual and perennial horticulture opportunities in many areas across the state including the Cape and Surat management areas. There is also potential to increase pasture production in many areas across the state, including the south eastern part of the plan area. License applications for additional water indicate demand from the intensive livestock sector.

Research has recently been undertaken on the potential for intensive, irrigated cropping and livestock production along the alluvial floodplains of the Flinders and Gilbert rivers as part of the North Queensland Irrigated Agriculture Strategy where limited shallow groundwater is available.

3.3 Energy and Earth Resources

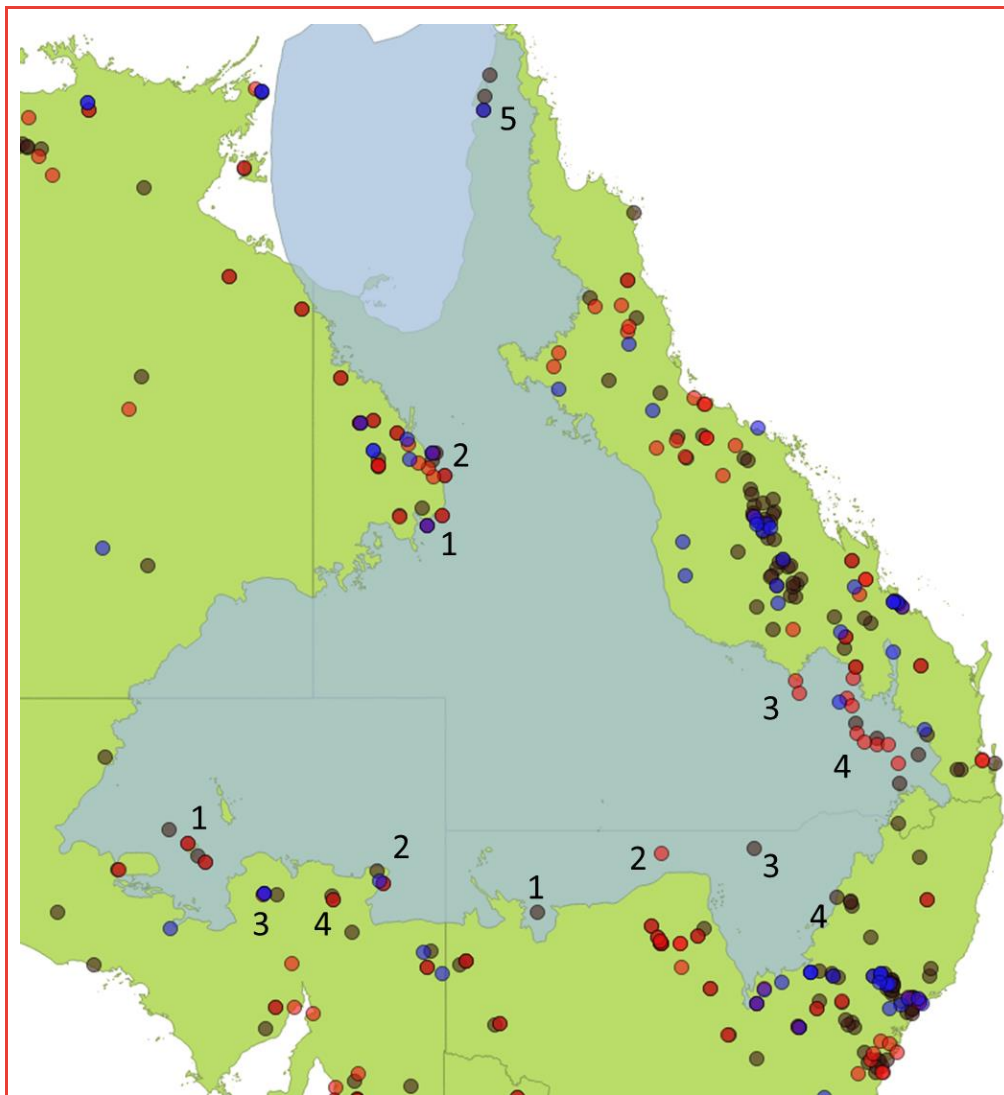
GAB water resources can be used to directly generate electricity by geothermal generation. Earth resources include mineral and ores, as well as coal, oil and gas, the extraction and processing of which involve GAB water resources.

Mining for copper, uranium, bauxite and opals depend on a reliable supply of GAB water. The extraction of oil and gas from the GAB results in the simultaneous extraction of substantial amounts of water as a waste product. Coal seam gas (CSG) is a rapidly expanding industry, and uses large amounts of water for the life of those projects. Opportunities are being explored for using associated water for economic uses.

3.3.1 Patterns of water use

Mining activity is relatively limited in GAB regions as compared to other parts of Australia. The figure below shows the significant exclusion of mining activity over the blue-shaded area of the map which corresponds to the GAB. The figure presents the operating mines (as at February 2015), mineral processing centres (as at February 2014) and new mining infrastructure (as at November 2013). The numbered sites are discussed in the subsection associated with each Basin jurisdiction.

Figure 9: Operating mines, new mining infrastructure and mineral processing centres



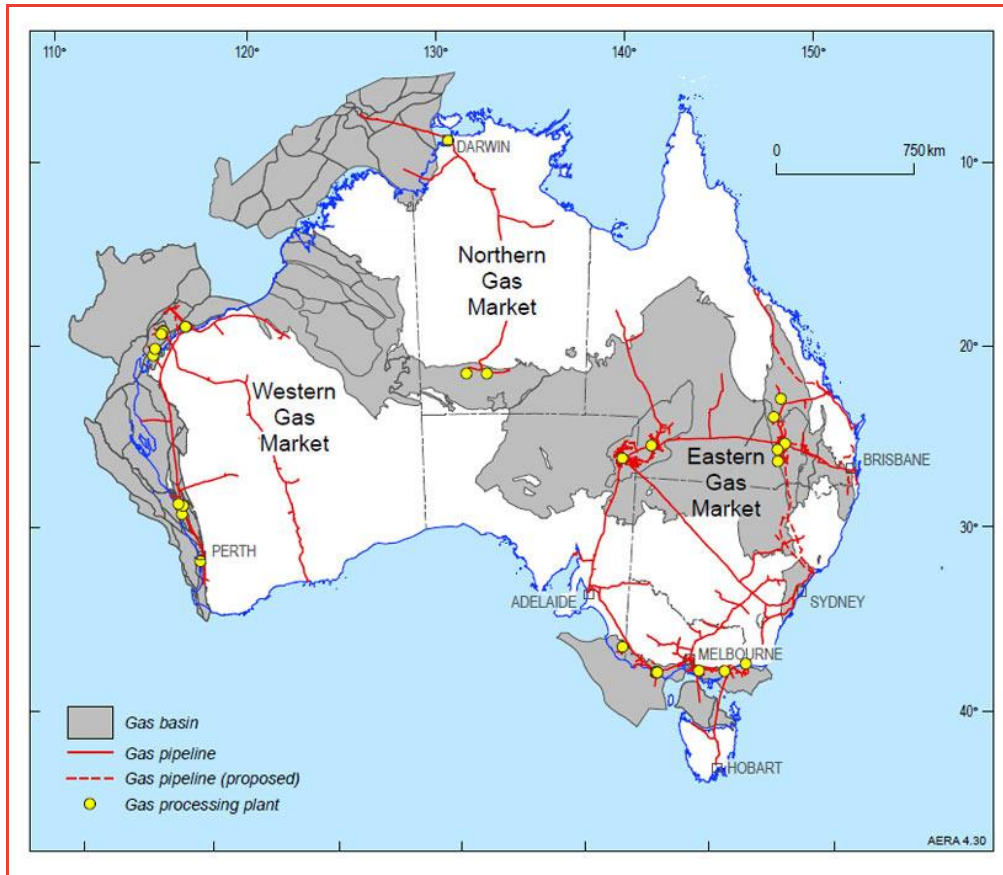
Legend: Brown markers represent operation mines, red markers represent processing plants, and blue markers represent planned developments.

Source: Australian Mines Atlas 2015; Geoscience Australia 2016.

Economic value of GAB water using activities

The distribution of CSG projects is concentrated on the eastern parts of the GAB, in Queensland and New South Wales. The GAB underlies much of the Eastern Gas Market and gas basin (Figure 10).

Figure 10: Australia's gas facilities



Source: Geoscience Australia nd.

NSW

Mine sites that are overlaying the GAB water resource (Figure 9) include:

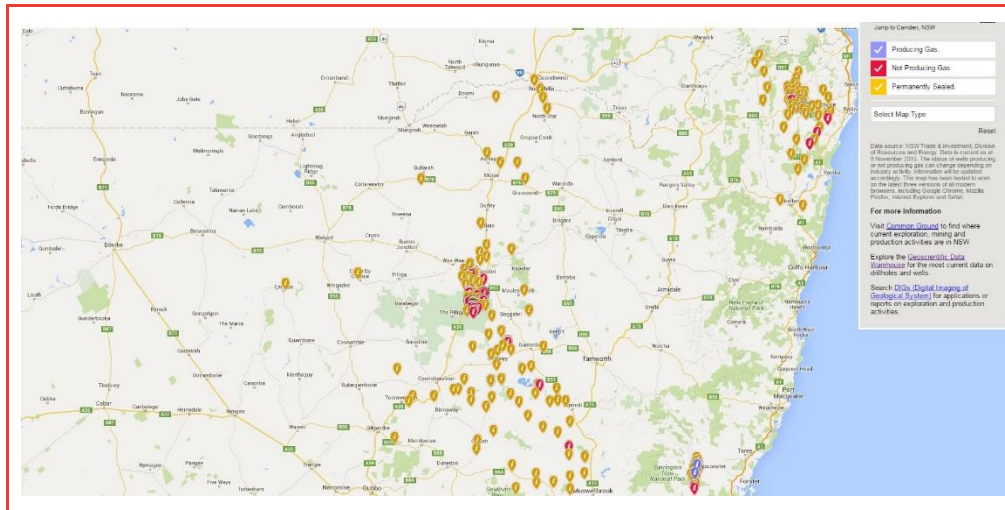
- ❑ NSW 1 — overlaying GAB: White Cliffs (Opal) operating mine.
- ❑ NSW 3 — overlaying GAB: Lightning Ridge (Opal) operating mine.
- ❑ NSW 4 — overlaying GAB: Narrabri (Coal – black)
- ❑ (The Australia Mine Atlas entry for NSW 2 is actually an error in the database for Three Springs (WA))

Mining is a modest user of artesian water in NSW and this is primarily associated with the opal mining in the Lightning Ridge and White Cliffs areas (NSW WSP 2009). Water use for Lightning Ridge varies from year to year, but is in part related to the number of agitators operating and the rainfall, and was 25-173ML per year in the period 1997-2002 (the only time series identified) (NSW DPI 2004).

Production of coal at Narrabri was reported to be 7.2Mt in 2015 (Whitehaven Coal 2016).

According to the NSW Government data mapped in Figure 11, there are no producing CSG wells in the NSW areas of the GAB. However, there is still some reported CSG produced as part of exploration activities around Narrabri, of 0.2PJ in 2014 and 1.6PJ in 2015 (pers. comm., APPEA, 6 May 2016).

Figure 11: NSW CSG wells



Source: NSW DIRE 2015; NSW Government 2016.

Queensland

Mining industries in Queensland use GAB water for both mineral extraction (mining) and mineral processing. Water use is concentrated in the shires of Cook, Monto, Chinchilla and Jondaryan. Mine sites that overlie the GAB water resource (Figure 9) include:

- ❑ QLD 1 — overlaying GAB: Cannington (Lead, Silver, Zinc, Bismuth, Antimony) operating mine and processing plant; Osborne (Copper, Gold) operating mine, processing plant and proposed magnetite development.
- ❑ QLD 2 — parts of the Mt Isa region overlaying GAB: include Eloise (Copper, Gold, Silver) operating mine and processing plant; Mount Margaret (Copper Gold, Uranium, Uranium Oxide) operating; Ernest Henry (Copper, Gold, Magnetite, Iron ore, Iron) operating mine, processing plant and proposed underground copper mine.
- ❑ QLD 3 — overlaying GAB: Fairview (Coal Bed Methane) processing plant; Spring Gully (Coal Bed Methane) processing plant.
- ❑ QLD 4 — overlaying GAB: Commodore (Coal – black) operating mine; New Acland (Coal – black) operating mine; Kogan Creek (Coal – black)

Economic value of GAB water using activities

operating mine; Cameby Downs (Coal – black) operating mine; eight Coal Bed Methane processing plants.

- QLD 5 — overlaying GAB: Skardon River (Kaolin) operating mine; Ely (Bauxite) operating mine; Weipa (Alumina, Bauxite) operating mine and proposed expansion.

These mines produce significant volumes of a range of outputs (Table 8).

Table 8: Queensland mining output that is GAB-dependent

Mining product	Unit	Output
Copper	t	102,680
Gold	kg	1,412
Silver	t	844
Coal	t	12,836,905
Zinc	t	69,611
Lead	t	196,293

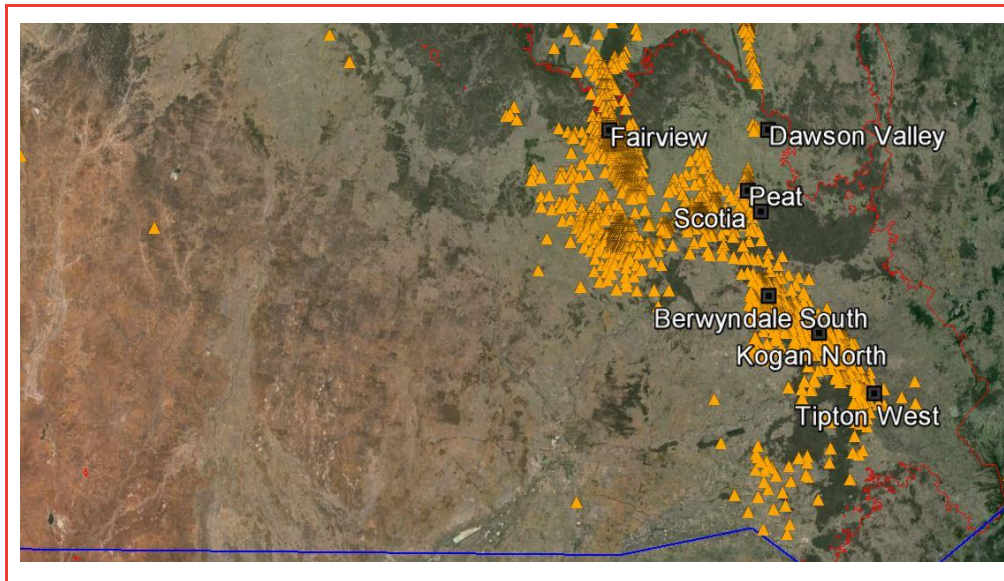
Note: This table aggregates production from the following mines: Cannington, Osbourne, Eloise, Mount Margaret, Ernest Henry, Commodore, New Acland, Kogan Creek, Cameby Downs.
Source: Queensland Government 2016a; Queensland Government 2016b.

Coal seam gas (CSG) is another prominent industry in Queensland that interacts with GAB water resources. The Queensland 5-year review of the GAB Water Resource Plan considered the impacts of the CSG industry on GAB groundwater (DNRM 2012).

The largest concentration of CSG wells in the GAB is in south-eastern Queensland (Figure 12), coincident with the coal methane bed processing plants identified in Figure 9. Each yellow marker represents an active CSG well using the most current available data from state websites (as at April 2016). There are also a number of CSG wells in central Queensland (Figure 13).

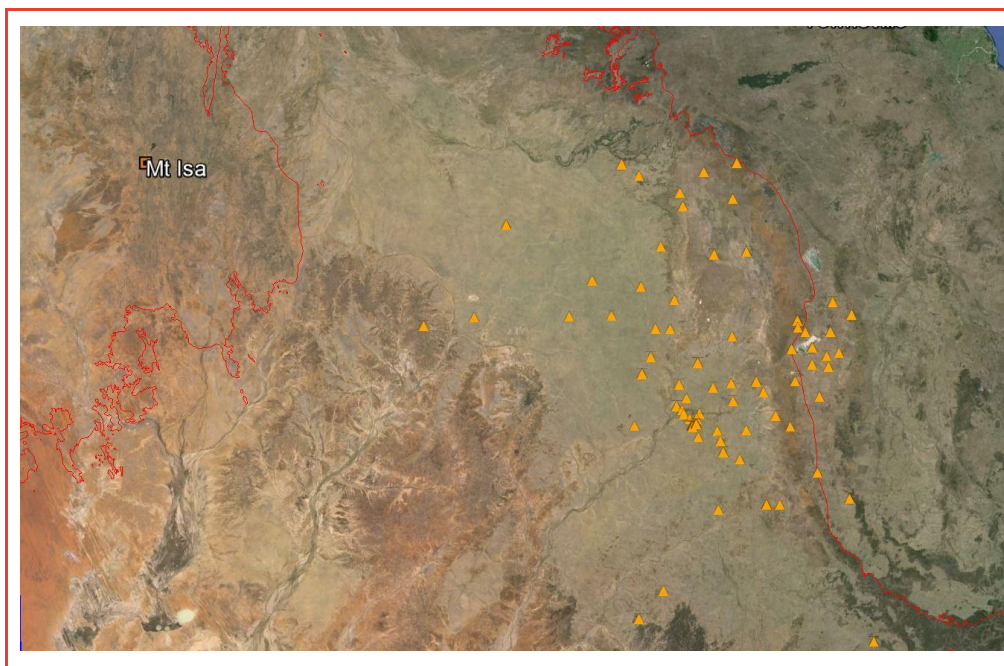
CSG extraction within the GAB area occurs in the Bowen and Surat Basins (although production from the Bowen Basin occurs from formations deeper than those dealt with in the plan). In the GAB, the CSG industry is most intensively developed in the Walloon Coal Measures (a series of volcanolithic sandstones, coal, mudstones and siltstones, extending over wide areas of the Surat Basin) (Kear and Hamilton-Bruce 2011).

Figure 12: CSG in SE Queensland



Source: Queensland Government 2015; Geoscience Australia 2016.

Figure 13: CSG in central Queensland



Source: Queensland Government 2015; Geoscience Australia 2016.

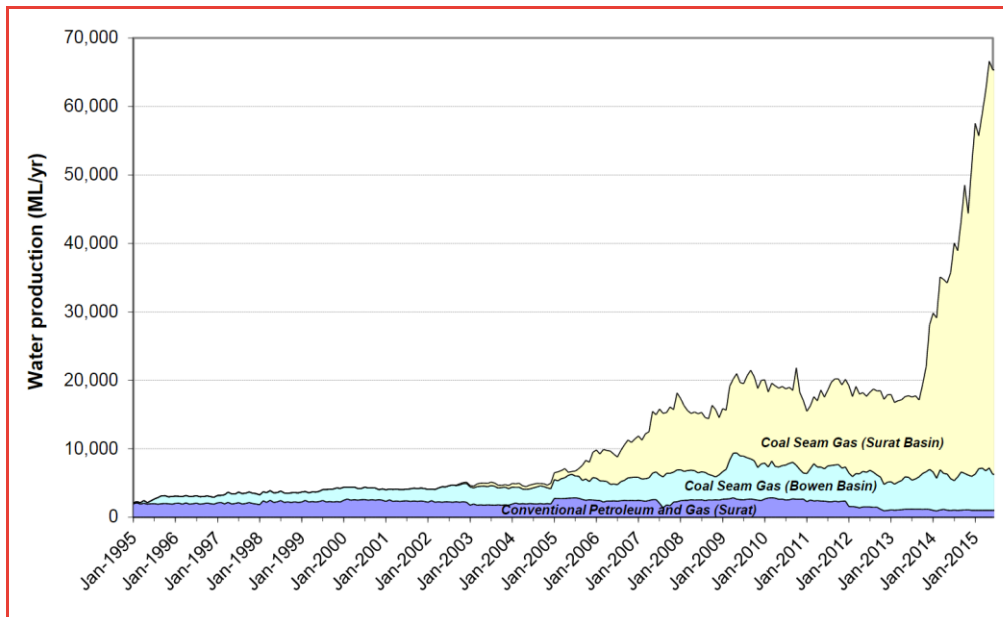
There has been an almost four-fold increase in the volume of associated water production from the Surat Basin from 2005 to 2013 (OGIA 2015). The number of producing CSG wells almost doubled in the first half of 2014 and this has increased associated water extraction significantly (DNRM 2015, p. 30).

This increasing trend has continued. The most recent estimate (July 2015) of water extraction from CSG in Queensland is 64,000ML per year (Figure 14). There is

Economic value of GAB water using activities

also an estimated 1,000 ML per year of water extracted for conventional petroleum and gas. This totals an estimated 65,000ML per year for groundwater extraction associated with Queensland's petroleum and gas developments. This is not managed under the water entitlement framework, rather through a comprehensive regulatory framework that aims to minimise and or mitigate the impacts of mining and gas development on primary producers and the environment. (pers. comm., DNRM, 11 May 2016).

Figure 14: Associated water from coal seam gas production in the Surat Basin



Source: DNRM 2016, p. 62.

Conventional gas production (as opposed to CSG) also occurs in GAB regions. A significant resource for this gas is the Cooper Basin, which underlies the GAB. The Queensland Gas Fields Commission (2015) reports that relatively small volumes of groundwater are extracted as a by-product during conventional gas production. SA DEWNR (pers. comm., 28 July 2016) noted that some Cooper Basin operations in SA currently access GAB water as well as using co-produced water (for example, Santos (2015) report that 1622ML of groundwater was extracted from their SA operations). SA DEWNR also noted that industry is now moving towards using the co-produced water to extract unconventional gas from the Cooper Basin, with this type of extraction is expected to increase in the future.

GAB water is also used for geothermal electricity generation in Birdsville. The plant specification is for water use at 27 litres per second (Ergon 2015), which is 850 ML per year if being continuously operated. The geothermal power station provides 80kW of electricity for customer use which is about 30% of the town's needs.

South Australia

Mines sites that are overlaying the GAB water resource (Figure 9) include:

- SA 1 — overlaying GAB: Cairn Hill⁴ (Iron, Copper, Gold, Iron Ore) operating mine and processing plant; Coober Pedy (Opal) operating mine; Southern Iron- Peculiar Knob (Iron Ore, Iron) operating mine; Prominent Hill (Copper, Gold, Silver) operating mine and processing plant.
- SA 2 — overlaying GAB (or very close): Mount Fitton (Talc) operating mine; Beverly (Uranium, Uranium Oxide) operating mine and processing plant; Four Mile potential uranium mine.
- SA 3 — not overlaying GAB: Olympic Dam (Uranium, Gold) operating mine, processing plant and planned expansion; Andamooka (opal) operating mine
- SA 4 — not overlaying GAB: Leigh Creek (Coal – black) operating mine (now closed)⁵; Mountain of Light (Copper) operating mine and processing plant.

These mines produce significant volumes or a range of outputs (Table 8).

Table 9: South Australian mining output that is GAB-dependent

Mining product	Unit	Output
Copper	t	284905
Uranium Oxide	t	4901
Gold	oz	217555
Silver	oz	1487349
Iron ore	Mt	1.235

Note: This table aggregates production from Peculiar Knob, Prominent Hill, Beverly, Four Mile and Olympic Dam.

Source: SA DSD 2016.

The Olympic Dam underground copper and uranium mine is South Australia's largest mining water user. The primary water supply for the existing Olympic Dam operation is groundwater extracted from Wellfields A and B located in the GAB, about 120 and 200 km north of Olympic Dam, respectively.

⁴ Reported to not use GAB water (IMX Resources 2013).

⁵ Reported to not use GAB water (DEWNR 2013).

3.3.2 Economic value of the sector

Mining

The value of GAB dependent mining outputs was estimated using production data from mines sites that are overlaying the GAB water resource in combination with representative prices for the output commodities. It is important to note that it was outside the scope of the project to confirm that every mine site overlaying the GAB water resource was dependent on GAB water. The Minerals Council of Australia were unable to assist with the provision of this information (MCA, pers. comm., 12 May 2016).

The total value is estimated to be in excess of \$6 billion annually, with the bulk of this from Queensland and South Australian production (Table 10).

Table 10: Estimated value of GAB-dependent mining

Jurisdiction	Estimated value (\$ million)
New South Wales	568.3
Queensland	2,980.7
South Australia	2,801.7
Northern Territory	-
Total	6,350.8

Source: Quantity data from tables above. Price data from Indexmundi 2016a-h, and NSW DIRE nd.

CSG

The Queensland area of the Surat Basin produced 352.8 PJ of CSG in 2014-15 (which was 77% of the state's CSG production) (DNRM 2016).⁶

The value of the Queensland CSG output may be inferred from the Brisbane wholesale gas market where the price was \$4.80 per GJ at the Wallumbilla hub (at the end of March 2016) (AEMO 2016). This suggests that a market price of \$1 693.4 million for the 352.8PJ.

The reported NSW production of 1.6PJ in 2015 would be valued at \$7.7 million if valued on the same basis as above.

⁶ Although CSG production around Fairview and Spring Gully are in areas overlaying the GAB, the CSG extraction is technically Bowen Basin. For the combined Surat/Bowen Basin, CSG production 2014-15 was 408.8 PJ and CSG production for 12 months calendar year 2015 was 631.9 PJ (pers. comm. APPEA, 6 May 2016).

Electricity

The Birdsville geothermal plant provides 520,116kWh. Using a representative electricity tariff of 24.462 cents per kWh (Ergon 2016), this can be valued at a maximum of \$127,000.

3.3.3 Potential future water use

Two instances of increased future water use have been identified for geothermal power generation in Queensland.

- Ergon Energy is expanding the 80 kW plant to completely meet Birdsville's electricity requirements (from 25%).
- Winton Shire Council resolved to design and construct two 150kW geothermal plants which uses GAB water at a temperature of 86°C, and at a flow rate of 72 litres per second (Reneweconomy 2015).

As the CSG industry continues to expand in Queensland, the amount of associated water taken for gas fields is expected to increase (DNRM 2015).

The Surat Basin Regional Planning Framework (2011) identified that:

The Surat Basin will experience rapid growth over the next 30 years in the mining and gas sector due to increasing domestic and international demand for energy resources. However, it is difficult to accurately predict levels of resource demand. Consumption of thermal coal and CSG for power generation and material production will fluctuate with global economic conditions and the emergence of innovative and cleaner technology for energy production may also impact on demand.

The Minister's Performance Assessment Report (DNRM 2015, p.20) notes that the current GAB Water Resource Plan (WRP) does not currently consider the potential magnitude of water that may be taken by potential new industries such as the shale gas industry. Queensland is currently reviewing the WRP and water that may be potentially made available to new users will be re-evaluated using updated hydrogeological and environmental assessments.

In South Australia, GAB water use by gas operations may increase in the future due to the use of co-produced water to extract unconventional gas from the underlying Cooper Basin (SA DEWNR, pers. comm., 28 July 2016).

3.4 Urban Water use

3.4.1 Patterns of water use

Basin water is used in more than 120 towns and settlements across the GAB. Many of these towns rely on GAB water in combination with surface water supplies, while others are wholly dependent on GAB water for urban supplies. For example, although urban water supplies in Queensland represent only 5% of the total water

Economic value of GAB water using activities

use from the GAB, a large proportion of towns overlying the resource rely solely on this supply (Cox and McKay 2006).

GABCC (2012) reports total entitlements for urban use from the GAB was 40 341 ML per annum. Town water includes domestic uses as well as limited commercial and specified industrial uses. Domestic uses include drinking water, bathing, washing, watering gardens and other external uses.

Information provided to this report is broadly consistent with this, identifying 40847 ML of licenced annual use (Table 11). Overall, GABCC (nd) reports that GAB water sustains more than 180,000 people.

Table 11: GAB Urban water licences

Local Water Utility jurisdiction	GAB Estimated Use / Access Licence Volume (ML/yr)
New South Wales	7,028
Queensland	32,057
South Australia	1,692 ¹
Northern Territory	70
Total	40,847

*Note:*¹ This is different to the local water utility licence volume of 630ML/yr since it includes town water use from mining camp licences. The majority of this entitlement was for Roxby Downs (876 ML p.a.), Coober Pedy (475 ML p.a.) and Oodnadatta (32.9 ML p.a.).
Source: Appendix 2.

New South Wales

NSW towns accounted for 7028 ML of entitlement per annum (Table 12). In NSW, at least 42 communities currently source GAB water for town water and domestic supplies.

Table 12: Licence Volumes for Local Water Utilities Access Licences in the NSW GAB

Local Water Utility	Entitlement (ML/yr)	Population
Bourke Shire Council	252	3095
Coonamble Shire Council	1541	4030
Gilgandra Shire Council	2020	4355
Moree Plains Shire Council	925	13429
Narrabri Shire Council	179	14000

Walgett Shire Council	707	7199
Warren Shire Council	740	2900
Warrumbungle Shire Council	264	9808
Brewarrina Shire Council	50	2193
Narromine Shire Council	350	6800
Total	7028	67809

Note: The entitlement (Access Licence Volume) is sourced from DPI Corporate database. The population information is sourced from the web sites of the relevant councils.

Source: Pers. comm., NSW DPI, 6 May 2016.

Queensland

Queensland is the largest user of GAB water for town supply. In Queensland, GAB aquifers supply water for more than 85 towns or settlements. Some 25 towns had an entitlement of less than 100 ML per year, 44 had an entitlement of between 100 and 500 ML per year and 16 had entitlements greater than 500 ML per year. These include Aramac, Barcaldine, Blackall, Charleville, Cunnamulla, Dalby, Longreach, Miles, Millmerran, Mitchell, Quilpie, Roma and St George (ACIL Tasman 2005).

Table 13: Populations Queensland towns relying on GAB water for urban supply

Town	Population
Aramac	299
Barcaldine	1655
Blackall	1588
Charleville	3728
Cunnamulla	1641
Dalby	12,299
Longreach	3356
Miles	1588
Millmerran	1566
Mitchell	1311
Quilpie	574
Roma	6906
St George	3292

Source: ABS Populations Census 2011.

Economic value of GAB water using activities

South Australia

Towns in South Australia accounted for some 1,692 ML of entitlements per annum in 2007. The majority of this entitlement was for Roxby Downs (876 ML p.a.), Coober Pedy (475 ML p.a.) and Oodnadatta (32.9 ML p.a.).

Northern Territory

In the Northern Territory, Power & Water Corp is licensed for 96 ML per year for supply to Finke, but generally extract approximately 60ML per year.⁷ The population of Finke is 162 (ABS Population Census 2011).

3.4.2 Economic value of the sector

Clean, reliable and affordable water and wastewater services are fundamental to life, health outcomes and the economy in urban areas across Australia (WSAA 2015). Infrastructure Australia's recent audit estimated that the urban water sector makes a Direct Economic Contribution of some \$10.6 billion across the economy (Infrastructure Australia, 2015).

Like all urban areas, access to water for regional centres and settlements across the GAB is vital to their continued existence and their quality of life. In this sense water is critical to the ability of these centres to service industries and economic activity in the surrounding regions.

In order to estimate the value of urban water provision dependent on GAB water resources, a representative water tariff can be applied to the volume of licenced urban use. Using a representative tariff of the Longreach region charge of \$1.06 per kL⁸, provides the results in Table 14.

Table 14: GAB Urban water licences and estimated value

Local Water Utility jurisdiction	Estimated Use / Access Licence Volume (ML/yr)	Estimated value (\$ million)
New South Wales	7,028	7.4
Queensland	32,057	34.0
South Australia	1,692 ¹	1.8
Northern Territory	70	0.1
Total	40,847	43.3

*Note:*¹ This is different to the local water utility licence volume of 630ML/yr since it includes town water use from mining camp licences and other sources. The majority of this entitlement was for Roxby Downs

⁷ Pers. comm., NT DLRM, 14 January 2016.

⁸ \$1.06/kL is the charge for the first 300kL of excess consumption above the allowance in the Longreach, Ilfracombe, Isisford/Yaraka areas (Longreach Regional Council 2015).

(876 ML p.a.), Coober Pedy (475 ML p.a.) and Oodnadatta (32.9 ML p.a.).
Source: Appendix 2.

3.4.3 Potential future water use

Additional water supply may be required to support population growth, changes in population distribution, loss of access to surface water, or in response to reduced availability or quality of GAB water at particular sites.

As noted by Infrastructure Australia (2015), growth in the number of properties served by urban water suppliers will generally grow in line with regional population growth. This is likely to vary significantly across the GAB depending on the future growth or contraction of different economic activities (e.g. mining and gas exploration and development).

3.5 Other industries (including tourism)

3.5.1 Patterns of water use

GAB water is also a key input into other economic activities across the GAB.

In particular, many tourist attractions and developments across the Basin rely on artesian water. In some areas, artesian water is used in mineral spas and tourists are attracted by the cultural and natural history of springs that are developed as visitor sites. The tourism industry, includes baths, camel treks, Indigenous heritage sites and the Ghan railway. (GABCC 2008). In NSW and Queensland, flowing and non-flowing artesian bores are used for spa-bath tourist facilities in places such as Moree, Lightning Ridge, Boomi, Mitchell, Bedourie and Burren Junction. (Moree Plains Shire Council, 2001).

A list of the key regions and specific tourism and recreations sites partly supported by the GAB is provided in Table 15.

Table 15: Key tourism and recreation sites supported by the GAB

Jurisdiction	Key tourism and recreation sites
NSW	<ul style="list-style-type: none"> • Moree, various locations - a number of accommodation houses that have access to private artesian spas. • Bourke, Comerio Camel Station - multi-faceted tourist retreat with camel riding, private artesian spas, and a working sheep station. • Pilliga Bore Baths • Burren Junction Bore Baths – also has accommodation and facilities. • Lightning Ridge Bore Baths – has several accommodation houses and Bore Baths.
QLD	<ul style="list-style-type: none"> • Blackall Aquatic Centre - aquatic centre with artesian spa. • Mitchell Great Artesian Spa Complex - Mitchell's major tourist attraction. • Cunnamulla, Charlotte Plains Farmstay - a working sheep and cattle property with bore baths.

Economic value of GAB water using activities

	<ul style="list-style-type: none"> • Ilfracombe Artesian Spa • Bedourie Artesian Spa – 22 person Therapeutic Spa and provides for an aquatic centre (built in 2000) • Cunnamulla Fella Centre – Artesian Time Tunnel, Paroo Shire Council, Eromanga Basin
SA	<ul style="list-style-type: none"> • Wabma Kadarbu Mound Springs Conservation Park – Blanche Cup and The Bubbler mound springs • Witjira National Park – Dalhousie Springs

Source: SKM 2014.

While the tourism sector is not in itself a major consumptive user of GAB water, the ongoing health of the GAB springs is vital to the attraction of these sites as tourism destinations.

3.5.2 Economic value of the sector

It has not been possible to estimate the proportion of tourism that is dependent on GAB water resources directly.

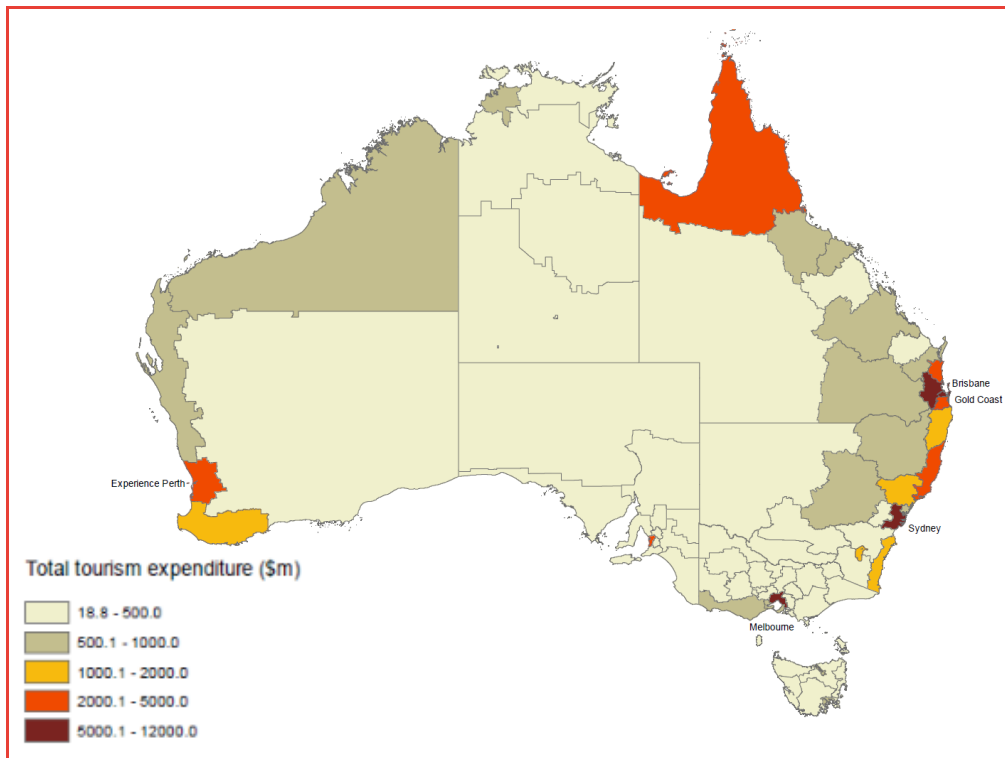
As discussed elsewhere in this report, arguably, most of the economic activity in GAB regions is reliant on access to the GAB water resource. Without the water access, economic development would not be viable where other reliable water sources are not available.

Tourism expenditure in GAB regions is significant, however, small compared to tourism in other regions. This is demonstrated in 2011 report by Tourism Research Australia estimates the economic importance of tourism in Australian regions (Figure 15).

The reporting regions for tourism data do not align well with GAB boundaries. This only region clearly relevant is the Queensland outback. Many other tourism indicator regions include GAB regions and also include significant areas of non-GAB areas (and often with greater population density). However, based on the data underlying the above map, an estimate of the tourism expenditure in areas dependent on the GAB is \$725 million (Table 16).

In the GAB region of Outback Queensland the economic importance of tourism (as a proportion of the regional economy) was found to be 6.5% (TRA 2011).

Figure 15: Total tourism expenditure in 2007-08



Source: TRA 2011

Table 16: Tourism Indicators 2013-14

Region	Total overnight visitors ('000)	Tourism Businesses*	Tourism expenditure (\$m)
Outback Queensland	237	611	311
Outback NSW	347	500	201
Darling Downs	1832	3057	1201
Tropical North Queensland	2317	3643	2752
SA Flinders Ranges and Outback	451	550	300
NT Lasseter	257	9	326
Estimate for GAB-type regions^	765	1141	725

Notes: * 2012-13 since 2013-14 not reported. ^ A conservative estimate includes all of tourism activity in Outback Queensland, and half of tourism activity in Outback NSW, SA Flinders Ranges and Outback, and NT Lasseter. Tropical North Queensland and Darling Down are excluded due to the expectation that most activity tourism activity in these areas is outside of GAB overlaying regions and not reliant on GAB water access.

Source: TRA 2016.

Economic value of GAB water using activities

3.5.3 Potential future water use

Natural springs and environmental tourism depend on GAB water pressure being maintained.

The overall size of the tourism industry is small in most of the GAB area. Although there may be a gradual increase in visitation and spend there is no information expecting a rapid change. At present there are few water-related attractions and water's key role is in sustaining tourism infrastructure.

4 Investment in water infrastructure in the GAB

This study also sought information on the asset value of capping and piping infrastructure in the GAB based on replacement value.

In doing so we have drawn on public information where available and input from jurisdictions.

4.1 Private On-farm investment

There are an estimated 34,591 bores across the GAB (Table 17). The vast majority of these bores are less than 200 metres deep, however some bores are deeper than 1200 metres.

Table 17: GAB bore depth and estimated replacement cost (\$ million)

Bore depth (m)	Number of bores	Estimated replacement cost (\$ million)*
0-200	23507	952.7
200-400	4879	684.7
400-600	1687	459.6
600-800	722	244.3
800-1000	441	198.8
1000-1200	385	201.4
>1200	1162	2011.9
No depth data	1808	73.3^
Total	34591	4826.6

Note: *Estimated replacement cost is based on the GABCC estimate for SA, NT and NSW bores and extrapolated across Queensland bores. ^ Assuming bores with no depth data are 0-200m deep. Source: GABCC 2016; Queensland DNRm, pers. comm., 12 April 2016.

It is estimated, that 87% of bores in Queensland are landholder owned. Since 1954, all artesian bores have had to supply water via fully reticulated water systems. This means that the majority of bores which are for water supply would therefore have surface pipes, tanks and troughs.

The private benefits of capping and piping are wide ranging and significant. CIE (2003) identified potential benefits including:

- The elimination of all costs associated with bore drain maintenance and repairs, such as delving, repairing breakouts and bore drain inspections
- Reduced mustering times and much simplified mustering processes

- Better utilisation of all natural resources on the property through better water distribution
- more flexible and efficient property management — by controlling watering points, properties can be rotationally grazed, improving native vegetation and livestock performance
- having clean water for stock to drink
- having pressure and clean water at the homestead
- ability to better control vertebrate pests, thereby reducing control costs
- reduced costs of controlling weeds which can be spread along bore drains
- increased pumping costs avoided where artesian wells might otherwise turn subartesian
- increased security of water supplies, thereby reducing management anxiety
- improved scope to better manage in times of drought.

4.2 Public investment — GABSI

GABSI funding for phases 1–4 has totalled \$230 million over fifteen years (Table 18). Between 1999-00 and 2012-13, 647 bores have been controlled, 19,178 kilometres of bore drains deleted, and 28,345 kilometres of piping installed. These works have resulted in estimated annual water savings of 204,527ML. These savings are distributed between the states as follows: New South Wales (64,971 ML per year); Queensland (119,217 ML per year) and South Australia (20,338 ML per year) (SKM 2014).

The GABSI has involved extensive funding and facilitation by governments (see Table 17 below), and landholder contributions (both cash and in-kind). For example, in Queensland, during Stage 3 of GABSI alone it is estimated that landholders contributed \$12.8 million in cash and about \$4.7 million through in-kind contributions, across 230 projects (DNRM 2014). Over the 15 years of this program a total of \$53 million dollars and in-kind investment was provided by landholders. In New South Wales, landholder contributions are estimated to have been \$87.1 million⁹. In South Australia, landholder contributions have been \$3.7 million¹⁰.

⁹ Pers. comm., NSW DPI, 31 May 2016.

¹⁰ Pers. comm., SA DEWNR, 9 May 2016.

Table 18: Government funding over the phases 1-3 of GABSI (nominal \$ million)

Funding source	Phase 1 (1999/2000 – 2003/2004)	Phase 2 (2004/2005 – 2008/2009)	Phase 3 (2009/2010 – 2012/2013)	Remaining Phase 3 (2013/2014)	Total
Commonwealth	28.39	39.89	30.95	15.83	115.06
South Australia	1.75	0.20	2.25	1.60	5.8
New South Wales	12.34	15.79	13.00	7.40	48.53
Queensland	13.23	23.88	16.49	6.83	60.43
Total (government)	55.71	79.76	62.69	31.66	229.82

Source: SKM 2014

GABSI built on earlier initiatives that targeted uncontrolled bores, and inefficient bore drains. For example, in Queensland, the GAB Rehabilitation Program was active 1989 to 1998, and the Bore Drain Replacement Program was active 1994 to 2000. Table 18 sets out water savings from water efficiency investments outside of GABSI.

Table 19: Water efficiency investments outside of GABSI

	Flow Saved (ML/annum)
NSW	9,051
Queensland	69,141
South Australia	39,420

Source: SKM 2014; Data request responses from jurisdictions.

4.3 Value of investment

The value of this investment is significant. One approach to estimating this value is the cost of the infrastructure, where recent build cost would approximate replacement cost.

The GABSI investment in each Basin jurisdiction can be estimated by prorating the Commonwealth contributions to GABSI between the Basin jurisdictions in line with their contributions. Given these investments have occurred over an extended timeframe, the expenditure can be compared by inflating these estimates by CPI to obtain estimated funding in 2016 dollars (Table 20).

Investment in water infrastructure in the GAB

Table 20: Estimated government investment by Basin jurisdiction (real \$ million 2016)

	Phase 1	Phase 2	Phase 3	Phase 4	Total
NSW	36.1	39.5	28.0	15.3	118.9
Queensland	38.7	59.7	35.5	14.1	148.0
South Australia	5.1	0.5	4.8	3.3	13.8
Northern Territory	0.0	0.0	0.0	0.0	0.0
Total	280.7				

Source: Frontier Economics analysis

The total cost of surface water infrastructure in the Basin may be extrapolated across all GAB water supply bores using data from the GABSI program as it is likely that water distribution systems put in place are of similar scale, with or without rehabilitation funding.

If this approach is applied to the 34,591 bores across the GAB, rather than the 647 bores controlled under GABSI, then the expected replacement cost of all bores and associated water distribution systems is in the order of \$15 billion dollars.

GABCC data suggests that the replacement cost of the 34,591 bores only is estimated to be nearly \$5 billion (Table 17).

The value of private investment is therefore expected to lie in the range of \$5-15 billion.

5 Concluding comments

The GAB is a highly valuable water resource which provides locationally diverse benefits and opportunities. Arguably, most of the economic activity in GAB regions is dependent on access to GAB water resources. Without GAB water, economic development in many areas would not have been able to occur. It is also hard to imagine much of the town/urban water use and domestic water use in GAB regions being possible without access to GAB water. In many localities, alternative water supplies are prohibitively costly and total reliance on surface water would significantly reduce liveability. In other areas, such as eastern regions and the far north, other water sources are available and we are unable to differentiate the contributions of GAB water and these other sources of water to regional economic activity.

We estimate that the consumptive use of GAB water is integral to at least \$12.8 billion of production annually (Table 21). The provision of drinking water through domestic bores and town water supply has been essential to the development of GAB regions. The non-consumptive benefits of GAB water resources include groundwater dependent ecosystems.

Table 21: Values dependent on GAB water resources (\$ million per year)

	NSW	Qld	SA	NT	Total
Estimated annual value of output that is dependent on GAB water resources					
Stock	1094.5	3004.4	105.1	463.7	4667.7
Mining	568.3	2980.7	2801.7	0	6350.7
CSG	7.7	1693.4	0	0	1701.1
Electricity	0	0.1	0	0	0.1
Irrigated Agriculture	30.4	27.7	0	0	58.1
Urban water	7.4	34.0	1.8	0.1	43.3
Total Value of output	1708.3	7740.3	2908.6	463.8	12821.0
Other values related to GAB water resources (noting environmental values could not be monetised)					
Tourism expenditure	100.5	311.0	150.0	163.0	724.5 (per year)
GABSI Infrastructure expenditure	118.9	148.0	13.8	0.0	280.7 (asset total)
Private Infrastructure investment					5000-15000 (asset total)

Source: Frontier Economics analysis

This report examines the direct economic activity of those sectors dependent on GAB water resources. There are also second- and third-round economic effects related to these sectors. For example, up and down-stream industries that provide inputs and process outputs of the sectors (i.e. farm supplies, mechanics, processors), and the local economy servicing the people working in all these industries. Hence, it could be argued that all of the economic activity in GAB regions is dependent on access to GAB water resources where other water sources are not available.

The GABSI and related state and territory water planning initiatives have entailed significant effort to manage the GAB water resource to reduce water extractions and maintain pressure.

These initiatives have achieved significant reductions in stock and domestic water usage of the pastoral sector, while maintaining or increasing the economic output of the sector. This has been possible because investments have targeted water savings, thereby reducing inefficient usage (uncontrolled bores and open drains).

Developments in the gas industry require additional access to GAB water, and these volumes can be substantial. In recent years, growth in water volumes extracted by CSG in Queensland has increased significantly. This finding is based on data up to July 2015, and no information was available for the following 11 months to establish if the trajectory of high growth had continued.

Appendix 1: Agricultural data issues and the alignment of GAB to ABS regions

The ABS report agricultural data down to the SA4 and NRM level. However, concordance of the boundaries of these regions with the hydrological boundaries of the GAB is poor.

Previous analysis has attributed economic activity in proportion to the overlapping area of the ABS region, however this assumes that the economic activity is evenly distributed across the ABS region. In fact, economic activity is unevenly distributed to the location of population, farms and businesses. The distribution can be more uneven when more specialised economic activities are considered — such as mining, which is highly localised at the mine site.

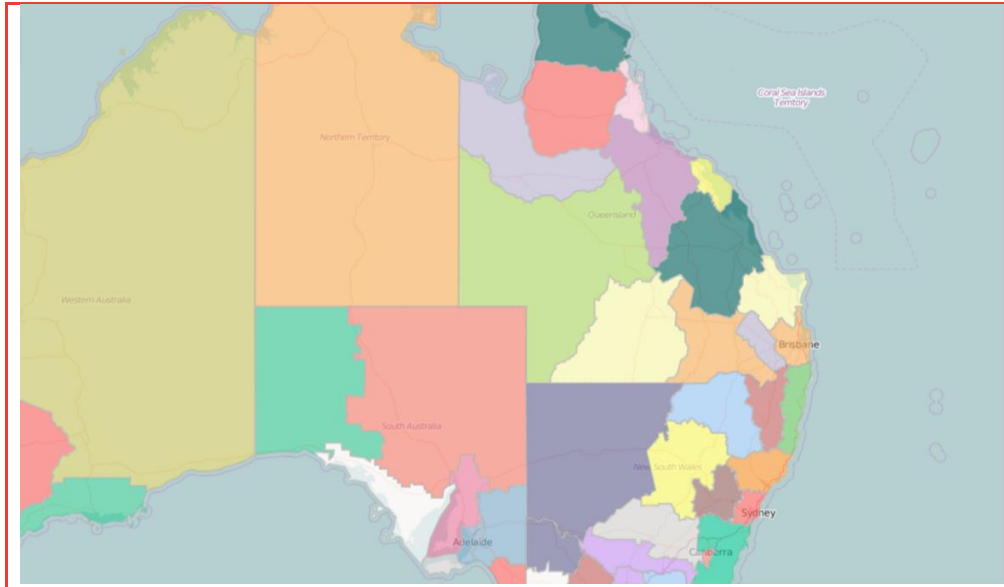
The most accurate measure would be to obtain customised ABS datasets which are matched to GAB regions. This is possible since ABS data is geocoded. It may be possible to obtain such data, however data will not be released if the number of relevant data points drops below the minimum that may jeopardise privacy. The use of customised boundary data would not aid in identification of output from irrigation with surface or groundwater since this much of the irrigation of land overlying the GAB uses surface water.

The NRM regions relevant to the GAB include:

- NSW
 - The GAB is contained within the North West, Central West and Western NRM regions. However, significant amounts of these NRM regions are also outside the area of the GAB.
 - Other NRM regions not associated with the GAB are Central Tablelands, Greater Sydney, Hunter, Murray, Northern Tablelands, Northern Coast, Riverina, South East.
- Queensland
 - The GAB underlies significant areas of the NRM regions South West Queensland, Border Rivers Maranoa–Balonne, Fitzroy, Desert Channels, Southern Gulf, Northern Gulf, and Cape York regions, as well as small areas of Condamine and Burnett Mary NRM regions.
 - Other NRM regions not associated with the GAB are Burdekin, Mackay Whitsunday, South East Queensland, Torres Strait, Wet Tropics.
- South Australia
 - South Australian Arid Lands

- Other areas (Alinytjara Wilurara, Eyre Peninsula, Kangaroo Island, Adelaide and Mount Lofty Ranges, South Australian Murray Darling Basin, Northern and Yorke, South East) are mostly/all outside the GAB
- NT
 - NT — the entire Northern Territory is a single NRM region. The GAB underlies only a small proportion of this region.

Figure 16: NRM regions



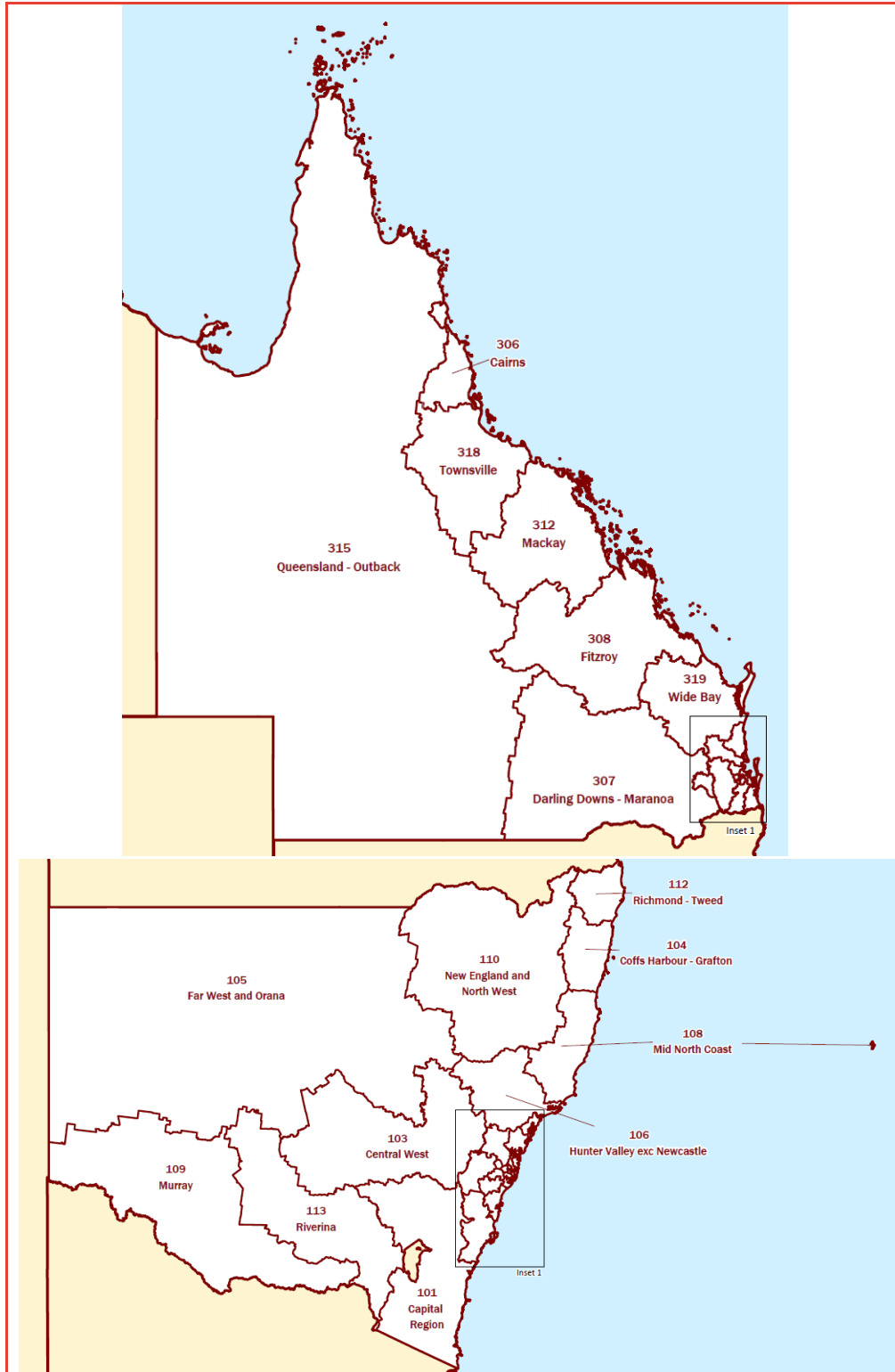
Source: <http://nrmregionsaustralia.com.au/nrm-regions-map/>

The ABS SA4 concordance is similarly problematic. The SA4 regions relevant to the GAB include:

- NSW
 - The GAB underlies significant areas of the SA4 regions Far West and Orana (105) and New England and North West (110).
- Queensland
 - The GAB underlies significant areas of the SA4 regions Queensland – Outback (315), Darling-Downs – Maranoa (307). It also underlies some of Fitzroy (308), and very small amounts of Townville (318), Wide Bay (319) and Mackay (312).
- South Australia
 - SA – Outback (406), although significant amounts of this region is also outside the area of the GAB.
- NT

- NT – Outback (702), although the vast majority of this region is also outside the area of the GAB.

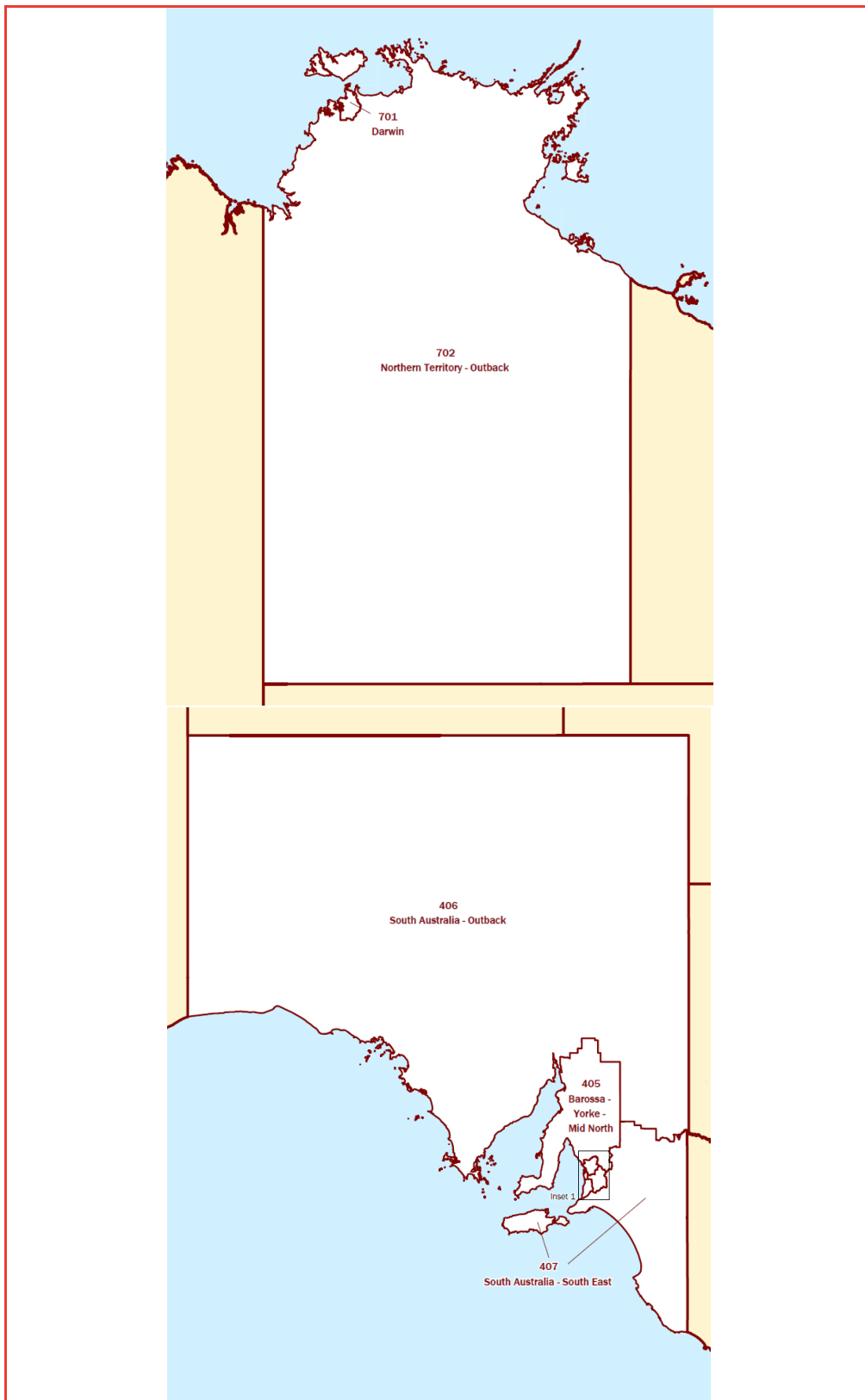
Figure 17: NSW and Queensland SA4 regions



Source: ABS 1270.0.55.001

Appendix 1: Agricultural data issues and the alignment of GAB to ABS regions

Figure 18: South Australian and Northern Territory SA4 regions



Source: ABS 1270.0.55.001

Data on livestock

For livestock industries, the value of production is broadly consistent using ABS SA4 or ABS data for NRM regions (Table 23 and Table 24).

Table 22: Livestock in GAB SA4 regions, 2013-14

GAB region (ABS SA4)	Livestock - Meat cattle - Total (no.)	Livestock - Sheep and lambs - Total (no.)	Total beef and sheep in region (no.)
Darling Downs - Maranoa	2,065,894	748,815	2,814,709
Far West and Orana	748,308	5,491,014	6,239,322
Fitzroy	2,738,238	423	2,738,661
New England and North West	1,543,908	2,958,219	4,502,127
Northern Territory - Outback	2,158,388		2,158,388
Queensland - Outback	4,643,439	1,579,728	6,223,167
South Australia - Outback	252,365	2,807,084	3,059,449
Grand Total	14,150,540	13,585,283	27,735,823

Notes: ABS 7121.0

Table 23: Gross value of livestock industries in GAB SA4 regions (\$ million), 2013-14

GAB region (ABS SA4)	Gross value from livestock slaughtered and other disposals - Cattle and calves (\$m)	Gross value from livestock slaughtered and other disposals - Sheep and lambs (\$m)	Gross value from Wool (\$m)
Qld - Darling Downs - Maranoa	630.5	18.7	25.7
NSW - Far West and Orana	203.7	138.8	167.7
Qld - Fitzroy	823.6	0.0	0.0
NSW - New England and North West	425.5	68.4	90.4
Northern Territory - Outback	463.7	0.0	0.0
Queensland - Outback	1410.0	41.7	54.2

Appendix 1: Agricultural data issues and the alignment of GAB to ABS regions

South Australia - Outback	84.3	127.3	97.2
Grand Total	4041.1	394.9	435.3

Source: ABS 7503.0

Table 24: Gross value of livestock industries in GAB NRM regions (\$ million), 2013-14

GAB region (ABS NRM)	Production from meat cattle	Production from sheep and other livestock
Qld - Border Rivers Maranoa-Balonne	343.04	57.79
Qld - Cape York	25.46	0.06
NSW - Central West	236	300.49
Qld - Desert Channels	495.29	70.8
Qld - Fitzroy	1075.86	33.42
Qld - Northern Gulf	329.04	1.05
Northern Territory	929.7	46.32
South Australian Arid Lands	74.22	80.9
South West Queensland	172.9	28.63
Qld - Southern Gulf	362.38	3.54
NSW - Western	42.47	146.23
Grand Total	4086.36	769.23

Source: ABS 7503.0

Data on irrigated agriculture

The ABS estimates of gross value of crops that may be irrigated with groundwater in the GAB region is presented in Table 25. Caution is required, however, in interpreting this data because much of the production of broadacre crops and hay/silage would be expected to rely on rainfall, or where there is irrigation, from surface water resources. Similarly, it is difficult to ascertain what proportion of the fruit and nut production is reliant on GAB water resources.

Table 25: Gross value of crop industries in GAB regions (\$ million), 2013-14

GAB region (ABS SA4)	Broadacre crops - Total	Fruit and nuts (excluding grapes) - Total	Hay and Silage - Total
Darling Downs - Maranoa	1,113.7	76.4	48.6
Far West and Orana	698.2	1.1	9.7
Fitzroy	277.9	19.9	12.5
New England and North West	1,433.1	11.9	37.8
Northern Territory - Outback	0.1	3.3	7.8
Queensland - Outback	18.3	60.6	5.5
South Australia - Outback	723.9	0.0	8.6
Grand Total	4,265.2	173.2	130.5

Notes: ABS 7503.0

There is also the challenge of aligning ABS data regions to focus on the GAB resource. As discussed above, neither ABS SA4 regions nor NRM regions used by the ABS concord very closely with the geographical boundaries of the GAB. When data from the NRM regions is considered (see Table 26), the data on production from broadacre crops (such as cereal for grain and seed and others) is much lower. This suggests that the high estimate for broadacre crops above (in excess of \$4 billion) is not attributable to production reliant of the GAB.

Table 26: Gross value of Agricultural Production in GAB NRM regions (\$ million), 2013-14

GAB region (ABS NRM)	Cereals for grain and seed (a)	Cotton (b)	Dairy production (d)	Fruit and nuts (excluding grapes)	Grapes	Hay	Nurseries, cut flowers and cultivated turf	Other broadacre crops
Border Rivers Maranoa-Balonne	208.79	475.61	1.89	48.52	7.26	20.82	20.99	44.23
Cape York	0.22			9.15		0.21		0.21
Central West	319.67	188.48	2.18	58.61	2.63	20.46	7.49	50.81
Desert Channels	0.57		0.06			1.68		0.09
Fitzroy	192.17	95.32	9.02	19.32	33.03	13.1	7.41	51.77
Northern Gulf	0.01			44.86	1.1	0.48		0.05
Northern Territory				47.94	8	16.62	0	0.04
South Australian Arid Lands	0.98					0.27		0.16
South West Queensland	0.91				2.15	0.08		
Southern Gulf						3		
Western	10.3	91.06		0.86	0.52	0.15		2.58
Grand Total	733.62	850.47	13.15	229.26	54.69	76.87	35.89	149.94

Source: ABS 7503.0

Appendix 1: Agricultural data issues and the alignment of GAB to ABS regions

Appendix 2: Water licence information

Table 27: Access Licences and water requirement, GAB NSW

Groundwater Source	Domestic & Stock Water requirement (ML/yr)	Local Water Utility Access Licences	Aquifer Access Licences (Share Units)
Eastern Recharge	2,000	0	35,006
Southern Recharge	3,000	3,058	25,908
Surat	28,100	3,318	5,527
Warrego	14,300	252	406
Central	4,900	0	39
GAB Surat Shallow	978	50	5,662
GAB Warrego Shallow	650	0	0
GAB Central Shallow	1,162	0	7
Lower Macquarie Zone 3	520	350	8,264
Lower Macquarie Zone 4	215	0	5,103
Lower Macquarie Zone 5	445	0	2,477
Total	56,270	7,028	88,399
Estimated total irrigation*			76,758
Estimated other uses			11,641

Note: *The NSW Department of Primary Industries identified that irrigation would be the primary use for virtually all of the aquifer access licences in Eastern Recharge, Southern Recharge and the 3 Lower Macquarie zones. The Department suggested that there was no significant irrigation in the other water sources

Source: NSW DPI

Table 28: Water licences and entitlement volumes, GAB Queensland

Main approved purpose	Number of licences/ allocations/ entitlements!	Estimated total GAB water use (ML/yr)
Commercial	31	617
Irrigation/ agriculture	578	32,341
Stock and domestic	5,476	121,759
Stock intensive	248	16,098
Urban (town water supply)	105	32,057
Industrial and Mining	83	30,292
P&G / CSG	(not currently licensed)	65,000
Total licences	6,521	
Total GAB water extracted		298,164

Source: DNRM provided data from Water Management Database.

Table 29: Water usage volumes, GAB South Australia

Use type	ML/yr
Bore Fed Wetland	2,025
Camp Water	948
Commercial	79
Co-Produced Water	21,900
Domestic	915
Industrial	850
Irrigation	115
Mining	24,200
Recreation	6
Stock	9,524
Town Water Supply	630
Total	61,191

Source: DEWNR provided data WILMA Records for the Far North Prescribed Water Resource Area; pers. comm. DEWNR, 6 June 2016.

Appendix 2: Water licence information

Table 30: Estimated NT GAB extraction volumes

Use	Volume (ML/yr)
Stock and Domestic	3150
Environmental discharge	250
Local water supply (Apatula Community)	70

Source: Fulton 2012.

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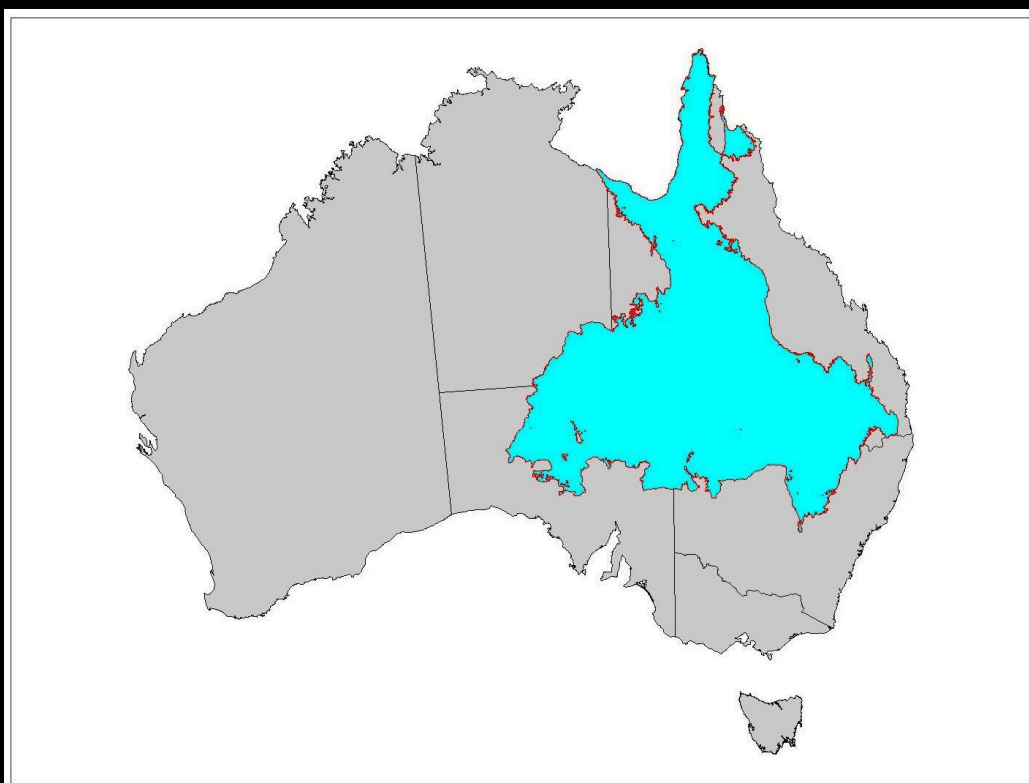
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GREAT ARTESIAN BASIN RECHARGE SYSTEMS AND EXTENT OF
PETROLEUM AND GAS LEASES
SECOND EDITION
WITH RESPONSE TO MINISTERIAL REVIEW



Prepared for
THE ARTESIAN BORE WATER USERS ASSOCIATION

March 2015

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Disclaimer

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The findings and opinions in this report are based on research undertaken by Robert Banks (BSc Hons, Certified Professional Soil Scientist, Dip Bus, Adjunct Research Fellow (UQ) of SoilFutures Consulting Pty Ltd, independent consultants, and do not purport to be those of the client.



Table of Contents

Acknowledgements	1
Disclaimer	1
Preface to Second Edition	3
Executive Summary	4
1. Introduction.....	5
1.1 Background	5
1.2 Brief for this report.....	6
2. Materials and Methods.....	6
2.1 Great Artesian Basin Spatial Data Collection	6
2.2 Manipulation of spatial data.....	7
2.3 Review of Recent Publications	7
3. Results of Analysis of Spatial Data	10
3.1 Recharge areas.....	10
3.2 Gas and petroleum data	14
3.3 Gas/Petroleum license areas and Recharge	15
4. Discussion of results.....	16
5. Concluding Remarks and Recommendations	16
6. References.....	19
Appendix 1: Review of Revised Edition by NSW Minister for Water.....	20
Appendix 2: Summary of Criticisms and Authors Response	23
Conclusion of Response to Review	26



Preface to Second Edition

The First Edition of this report was presented to the NSW Minister for Water by the NSW Artesian Bore Water Users Association on the 7th November, 2014. One of the immediate criticisms of the document was lack of transparent peer review. In response to this a Revised Edition was published with clear peer review references and presented to the NSW Minister for Water on 5th December 2014. The Revised Edition was also presented in person to Mr Troy Grant, NSW Deputy Premier in his offices at Dubbo on 19th December, 2014.

The Revised Edition had wide peer review from both Australian and international hydrogeologists, and scientists. It remained substantively unchanged, but incorporates the results of considered critique and some small changes to maps presented. One significant change in the Revised Edition is that recharge of less than 1 mm has been removed as being substantial or critical recharge within the GAB.

Following the publication of the Revised Edition of this document in 2014, a review of the report was presented to the Artesian Bore Water Users Association by Mr Kevin Humphreys, NSW Minister for Water on 14th February, 2015. Whilst this review does have a NSW DPI Office of Water letterhead, it is neither dated, nor signed and no reviewer is named or acknowledged. Nonetheless, in an attempt to clarify matters raised by the NSW Minister for Water, this Second Edition has been prepared with responses to his review given in Appendices 1 and 2 of this report.

This Second Edition of the document and its predecessors are not attempts to describe the complete hydrogeology of the Great Artesian Basin (which seems to be a common criticism of the first edition), but represents a mapping exercise using the highest quality peer reviewed CSIRO and State Agency spatial data, as well as reviewing the latest peer reviewed and published reports on recharge and connectivity in the GAB. The technical information from these sources is the culmination of hundreds of person years of patient and thorough research on the GAB by well qualified and recognised scientists. The report draws conclusions based purely on the mapping and the review material.



Executive Summary

The Great Artesian Basin (GAB) of Australia extends over 22% of the Australian continent where it is the only reliable groundwater or surface water source. The GAB contains 65 000 km³ (or **115 658** Sydney Harbours) of groundwater which is released under pressure to the surface through natural springs and artesian bores across its extent (QDNRM 2012).

Much of the groundwater held in the GAB is very old, having taken thousands to many hundreds of thousands of years to reach its current position in the basin from the recharge beds which are predominantly around the margins of the basin. Modern recharge is not thought to add significantly to the volume stored in the basin however it provides the crucial pressure head to keep the artesian waters flowing to the surface across this massive expanse of land. In most areas, the bulk of the GAB has a recharge value of less than 0.1 mm/yr.

This report is not an exhaustive review of GAB hydrogeology, yet uses the findings of the most recent and valuable recharge measurement and modeling of recharge. State held data on gas, coal seam gas (CSG), and petroleum production and exploration leases are combined to create a GAB wide data set. This report shows that 80% of the GAB currently has a gas, petroleum or CSG exploration or production license over it.

Modern recharge concepts are summarised into maps and overlain with the extent of gas and petroleum production and exploration license areas. 9% of the GAB has recharge greater than 0.1 mm/yr. Less than 6% of the GAB provides recharge which pressurises most of the remainder of the basin with recharge greater than 1 mm/yr. Approximately 2.1% of the total area of the GAB provides than 5 – 30 mm/yr recharge to the basin, and only 0.2% of the GAB provides greater 30 - 80 mm/yr of recharge. These recharge values are recognised as very low, despite being the highest in the basin. These very critical recharge areas are rare and widely separated. The main recharge area in NSW is in the East Pilliga Forest between Narrabri and Coonabarabran.

Using a simple spatial overlay, the main recharge zones (> 1mm/yr) of the GAB which provide pressure to the remainder of the GAB are 69% covered with gas, coal seam gas (CSG) leases. Typically CSG production involves dewatering (pumping) of coal seams to allow methane gas to be extracted (the water is a waste product of production called produced water). There is proven downwards connection between sub basins of the GAB and many of its underlying petrochemical rich basins (Surat has 10% connection; Eromanga has up to 50% connection). It follows that dewatering of aquifers under the GAB where proven connectivity exists can ultimately reduce pressure heads in the critical recharge areas of the GAB and reduce or halt water flow at its numerous bores and springs.

This report shows that the proliferation of gas exploration and production licenses on recharge zones appears to have progressed without much consideration of a GAB wide impact on artesian groundwater resources and pressures. Regulation which is GAB wide and transgresses state boundaries should be considered particularly with regard to protection and management of the few and critical recharge areas of the GAB.

Clearly, there are other wide ranging risks to the water supply of the GAB, with many free flowing bores still in existence (which causes local water and pressure depletion), as well as large scale uranium mining in South Australia. None of these other risks have the potential to stop groundwater flowing across entire sub basins within the GAB.



1. Introduction

1.1 Background

This report has been prepared in response to a request from Mrs Anne Kennedy of the Artesian Bore Water Users Association to provide information on the extent and quality of the recharge areas of the Great Artesian Basin (GAB), and the extent of Coal Seam Gas licenses in relation to the recharge areas. The GAB provides the only reliable water resource for 22% of Australia. The community perception is that there is considerable proliferation of both gas and petroleum exploration and production licenses across the GAB. The potential cumulative GAB wide impact of gas and petroleum extraction and dewatering of aquifers (which is general practice in coal seam gas extraction) in recharge zones is largely unknown.

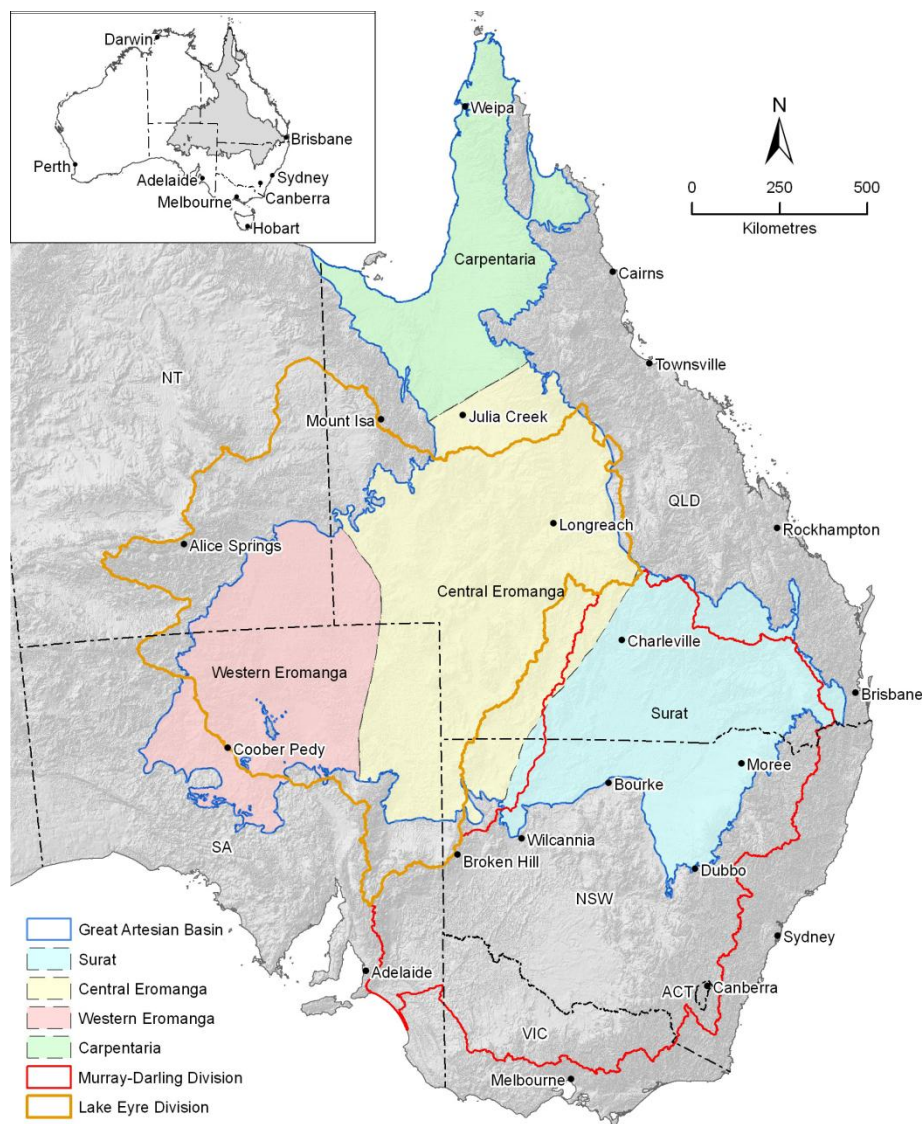


Figure 1: Location of the Great Artesian Basin within Australia



The following description of the Great Artesian Basin (GAB) is given in Ransley and Smerdon (2012).

The GAB contains an extensive and complex groundwater system. It encompasses several geological basins that were deposited at different times in Earth's history, from 200 to 65 million years ago in the Jurassic and Cretaceous periods. These geological basins sit on top of deeper, older geological basins and in turn, have newer surface drainage divisions situated on top of them (e.g. the Lake Eyre and Murray-Darling river basins). In this context – as a groundwater basin – the GAB is a vast groundwater entity underlying one-fifth of Australia.

Discharge from the GAB aquifers occurs naturally in the form of concentrated outflow from artesian springs, vertical diffuse leakage from the Lower Cretaceous-Jurassic aquifers towards the Cretaceous aquifers and upwards to the regional watertable and as artificial discharge by means of free or controlled artesian flow and pumped abstraction from water bores drilled into the aquifers.

For the GAB, like many other semi-arid to arid zone aquifers around the world, the current rate of recharge is significantly less than discharge. Groundwater currently stored in the Cadna-owie – Hooray Aquifer and equivalents is a legacy from higher recharge rates that occurred during much wetter periods in the early Holocene and Pleistocene age (essentially the last 2.6 million years).

The significance of the recharge zones to the GAB is not so much as an immediate water supply to central parts of the basin and natural discharge areas, but that they provide the pressure head (or weight of water) required to drive the water to the surface. Removal of this pressure through water abstraction associated particularly with Coal Seam Gas (where local drawdown of in excess of 1000 m can be experienced around gas fields) risks removing the driving force of many of the free flowing artesian bores and springs in the GAB.

1.2 Brief for this report

The brief provided to SoilFutures Consulting for this report was to undertake the following work;

- 1. Map known recharge areas of the Great Artesian Basin (GAB) using published and as 'up-to-date' as possible information; and*
- 2. to comment on the extent of Gas and petroleum activities within the GAB, particularly with respect to positioning on recharge areas.*

2. Materials and Methods

2.1 Great Artesian Basin Spatial Data Collection

Spatial data for the Great artesian Basin was obtained from the following sources.

Up to date boundary information, historical recharge zone information, and modern raster grid modelling recharge was sourced from Ransley and Smerdon (2012) and downloaded from www.ga.gov.au (Catalogue numbers 75904, 75842 and 76932 respectively).



State data for gas and petroleum exploration licenses and production licenses were obtained from the following sources which are acknowledged as per the download license agreement for each state below:

1. NSW Trade & Investment, Resources & Energy (2014). Petroleum Titles (almost exclusively natural gas and coal seam gas) including production leases and Exploration leases and Applications. Downloaded from <http://minview.minerals.nsw.gov.au/mv2web/mv2>
2. Northern Territory Government (2014). Petroleum Applications (Including natural gas and petroleum) and Granted Exploration licences. Downloaded from http://geoscience.nt.gov.au/GeosambaU/strike_gs_webclient/default.aspx
3. Queensland Department of Natural Resources and Mines (2014). Exploration license leases, production license leases (Predominantly coal seam gas and natural gas). Downloaded from <http://dds.information.qld.gov.au/dds>
4. South Australian Department for Manufacturing, Innovation, Trade Resources and Energy (2014). Exploration license leases, production license leases for both natural gas and petroleum (oil). <http://sarig.pir.sa.gov.au/Map>

2.2 Manipulation of spatial data

The GAB wide datasets for recharge and boundary information were compiled in ArcView 3.3 (A Geographic Information System) as a base layer for an analysis of other mapped data. As the new recharge information was presented essentially as an image, it was categorised into recharge increments and then transformed into a shape file, so that area statistics of different recharge areas could be calculated.

Gas and petroleum lease data for each state was transformed to a common datum (WGS84) and a common projection (Albers Equal Area Conic). The data for each state was then merged into a single shapefile for ease of use.

2.3 Review of Recent Publications

This review is only a brief summary of select, up to date publications relating to recharge and discharge mechanisms and mapping in the GAB. The review helps to establish a model for how to process spatial data later in the report. It is important to note that the recharge calculations undertaken in this report do not include the Carpentaria Basin within the GAB, as this area has its own high recharge areas from overlying regional aquifers which do not affect the rest of the basin.



Ransley and Smerdon (2012) provide a thorough overview of recent research and conceptualization of the GAB. Figure 2 summarises recharge zones and their significance to the GAB. The eastern NSW section of the basin (The Surat Basin) and the Surat Basin extending into Queensland has some horizontal connectivity with the adjacent Eromanga Basin (the largest sub basin of the GAB) to the west.

The Surat Basin has about 10% connection with underlying aquifers. In addition to this, the Surat Basin has minor known discharge into the Gunnedah and Cubaroo formations which form the Namoi River Paleochannel at the northern end of the Pilliga outwash which bounds the Namoi Alluvium. These waters are still relatively fresh and augment irrigation aquifers and possibly surface flows in the Namoi between Narabri and Walgett.

Concern regarding CSG extraction is raised in Ransley and Smerdon (2012) in the following quote. *“CSG production in the Surat Basin targets the Jurassic Walloon Coal Measures. The main CSG producing fields are located in the northern Surat Basin in a broad arc extending from Dalby to Roma. For gas to be harvested, the coal seams need to be depressurised by pumping groundwater from tens of thousands of wells intersecting the Walloon Coal Measures. Drawdowns of several hundred metres will be generated by the depressurisation and significant volumes of groundwater are to be pumped from the Walloon Coal Measures – averaging about 75 to 98 GL/year over the next 60 years (RPS Australia East Pty Ltd, 2011). This process will induce drawdown in overlying and underlying GAB aquifers, the amount of which will depend on the leakiness of the system.”*

Ransley and Smerdon (2012) summarise recharge in the following: *“Wohling et al (2013b) recently mapped recharge. Across the majority of the Surat Basin, recharge is estimated to be less than 5 mm/year, with the exception of portions of the Hutton Sandstone, which have values greater than 20 mm/year in the north part of the region. Similarly, recharge values of up to 45 mm/year were estimated for a localised region on the east side of the Coonamble Embayment. For the remainder of the eastern margin of the GAB, the spatial distribution and values are similar to those reported previously by Kellett et al (2003), less than 5 mm/year, with a trend for increasing recharge in the north of the region, with values up to 45 mm/year. Across the western margin of the GAB, recharge was effectively zero (mean of 0.15 mm/year).”*

Smerdon, Ransley, Radke and Kellett (2012) updated the geological knowledge base for the GAB and also revised the boundary of the GAB. This revised boundary is used in all of the below analyses of recharge and gas and petroleum related activities. They provide detailed information about the geological formations which contribute to recharge of the greater basin.

Recharge mechanisms are discussed in Herczeg and Love (2007) and fall into the following categories:

1. Via direct infiltration to the soil into the outcropping regions of the Jurassic Aquifers
2. Direct recharge through ephemeral creeks and rivers and mountain block alluvial fan systems (very important within the East Pilliga section of the Coonamble Embayment of the Surat Basin)
3. Downward hydraulic movement through aquifers above the GAB aquifers, where conditions permit



4. Upward hydraulic movement from aquifers underlying the GAB aquifers. This is thought to be happening in the Winton Sandstones in the central part of the wider GAB.

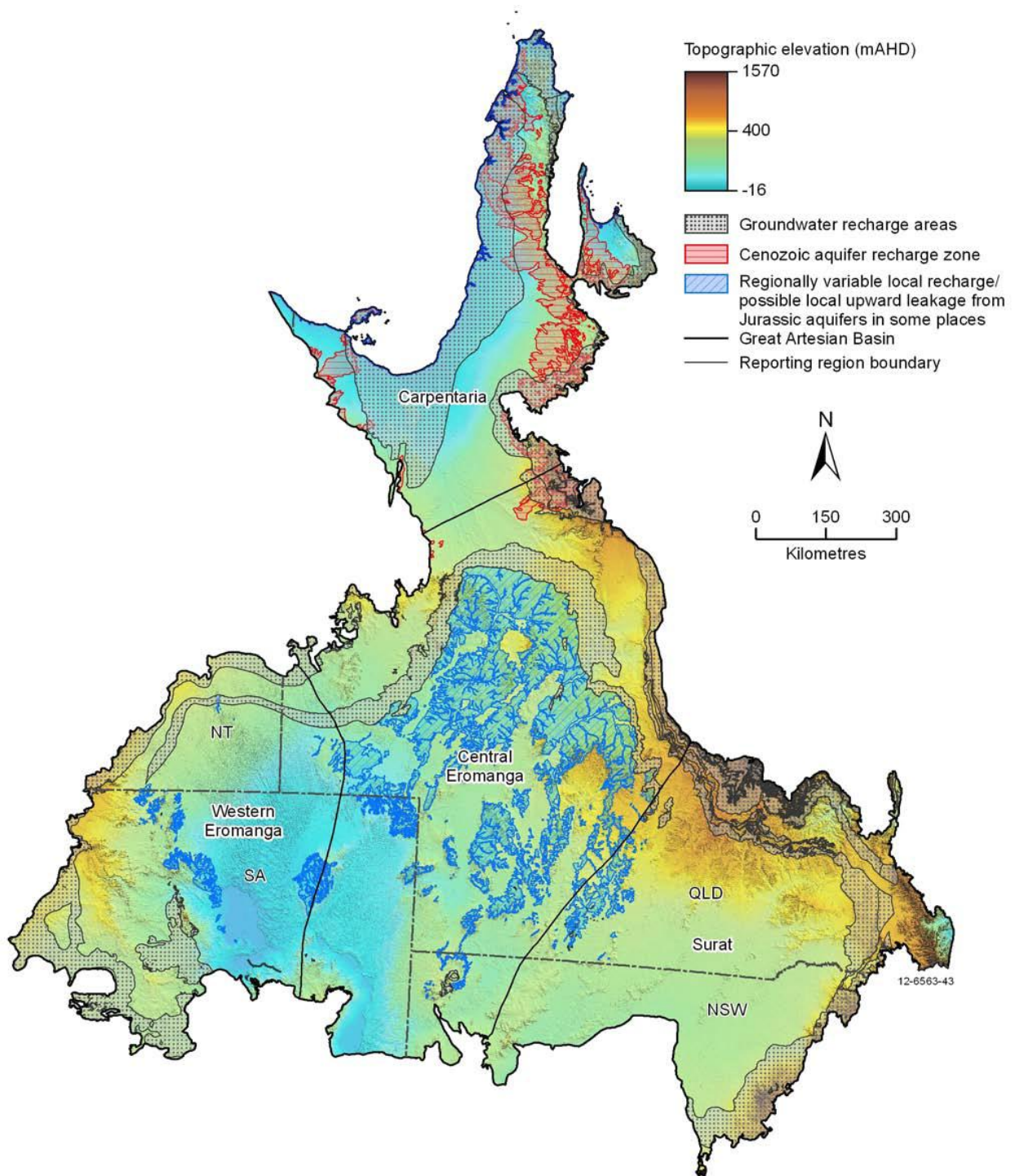


Figure 2: © CSIRO 2012 Hydrostratigraphy, hydrogeology and system conceptualisation of the Great Artesian Basin ▪ 17 Figure 2.2 Digital elevation model with Great Artesian Basin boundary and aquifer recharge zones.



3. Results of Analysis of Spatial Data

This section of the report provides a stepwise analysis of high quality modern spatial data relevant to recharge in the GAB. It shows the process by which areas were modeled and spatial statistics generated.

3.1 Recharge areas

Known mapped recharge areas for the GAB are separated into the Carpentaria basin recharge (not considered in this report), broad recharge associated with the Winton Block (in central QLD) which is thought to be recharged from underlying geology rather than from the surface), and the eastern and western margins of the GAB, which are generally considered to be the main recharge areas.

Figure 3 includes the Winton block recharge area (the central red area of the map), where water is thought to enter the GAB from pressurized aquifers underlying the main GAB aquifer. Surface recharge here is reported as poor (<0.1 mm/yr) No further consideration of these areas is given in this report.

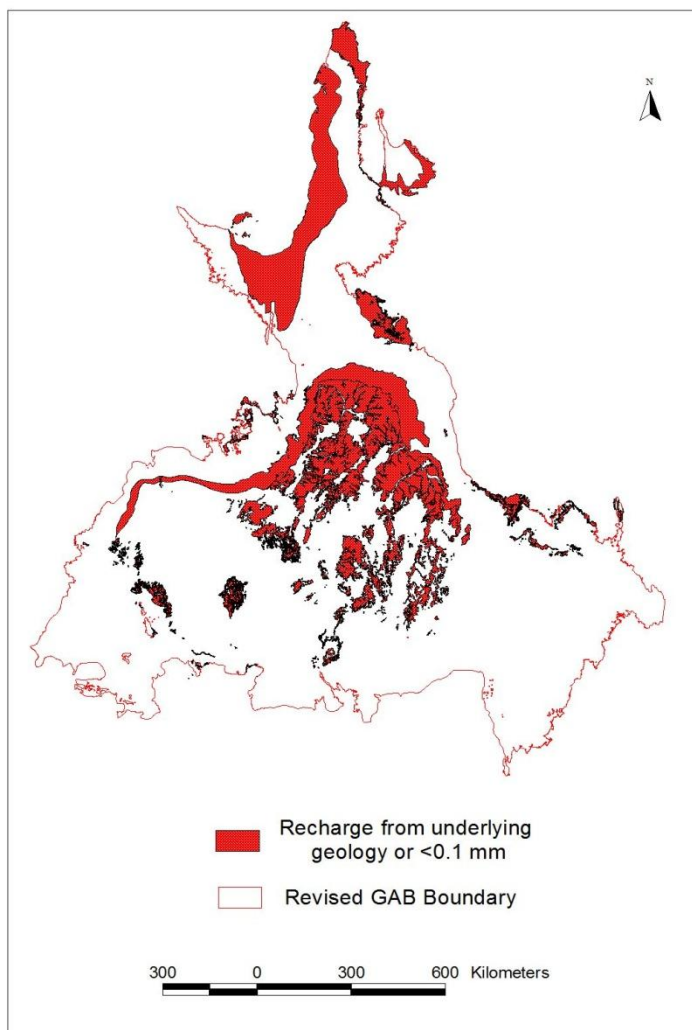


Figure 3: Poor recharge from surface yet likely recharge from underlying aquifers.



Figure 4 Shows known areas of recharge around the margins of the GAB, where recharge is through soil into underlying Cretaceous and Jurassic geologies or through alluvial fan systems which are prominent in the south eastern portion of the basin in the Pilliga Outwash. This figure shows that the total area of GAB marginal recharge (excluding Carpentaria) is 157 902 km² or 9% of the GAB.

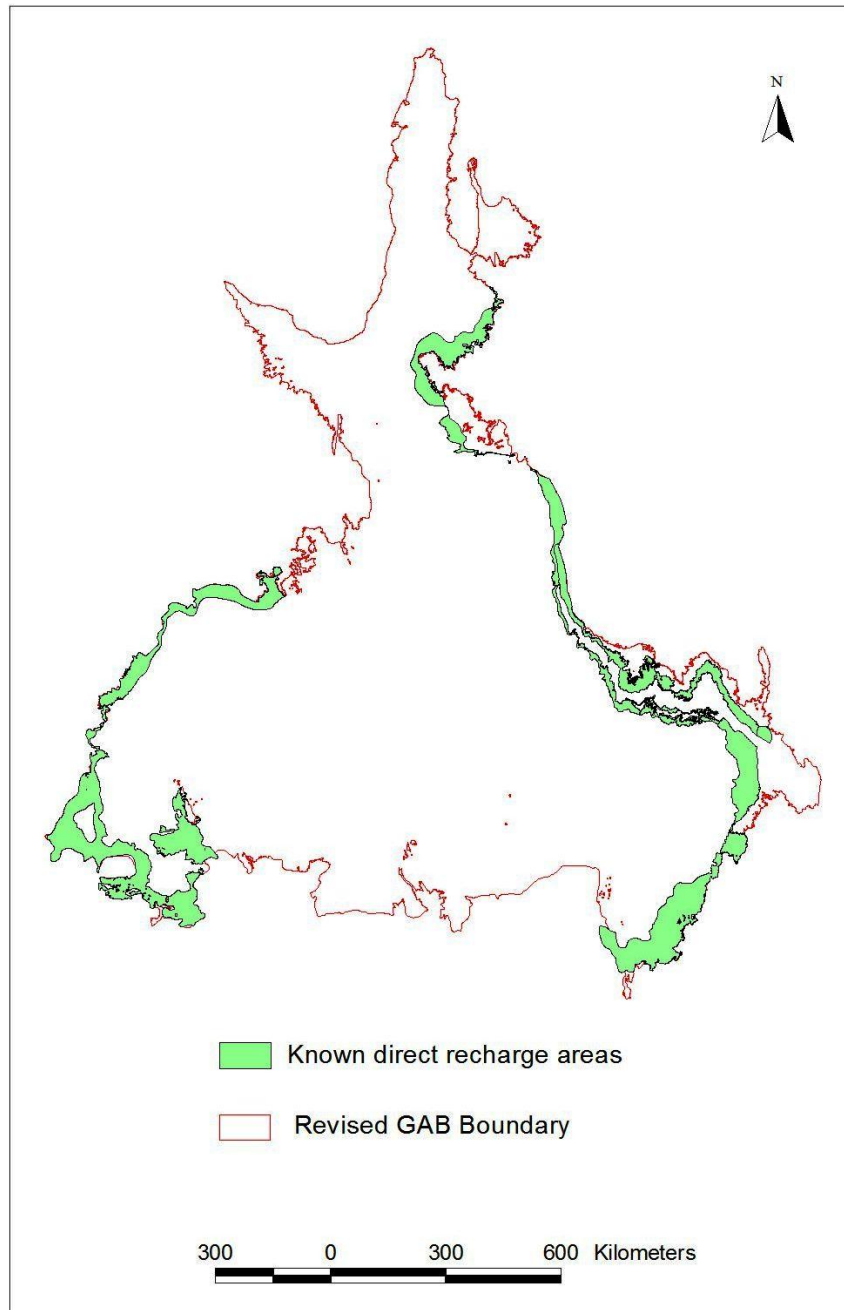


Figure 4: Direct recharge areas – margins of basin on Jurassic and Cretaceous Sandstones

Figure 5 shows the results of recharge measurement and modeling presented in Ransley and Smerdon (2012) and derived from Wohling *et al* (2012), Kellet and Ransley *et al* (2003) and Habermehl *et al* (2009) and are the most up to date assessment of GAB margin recharge available.



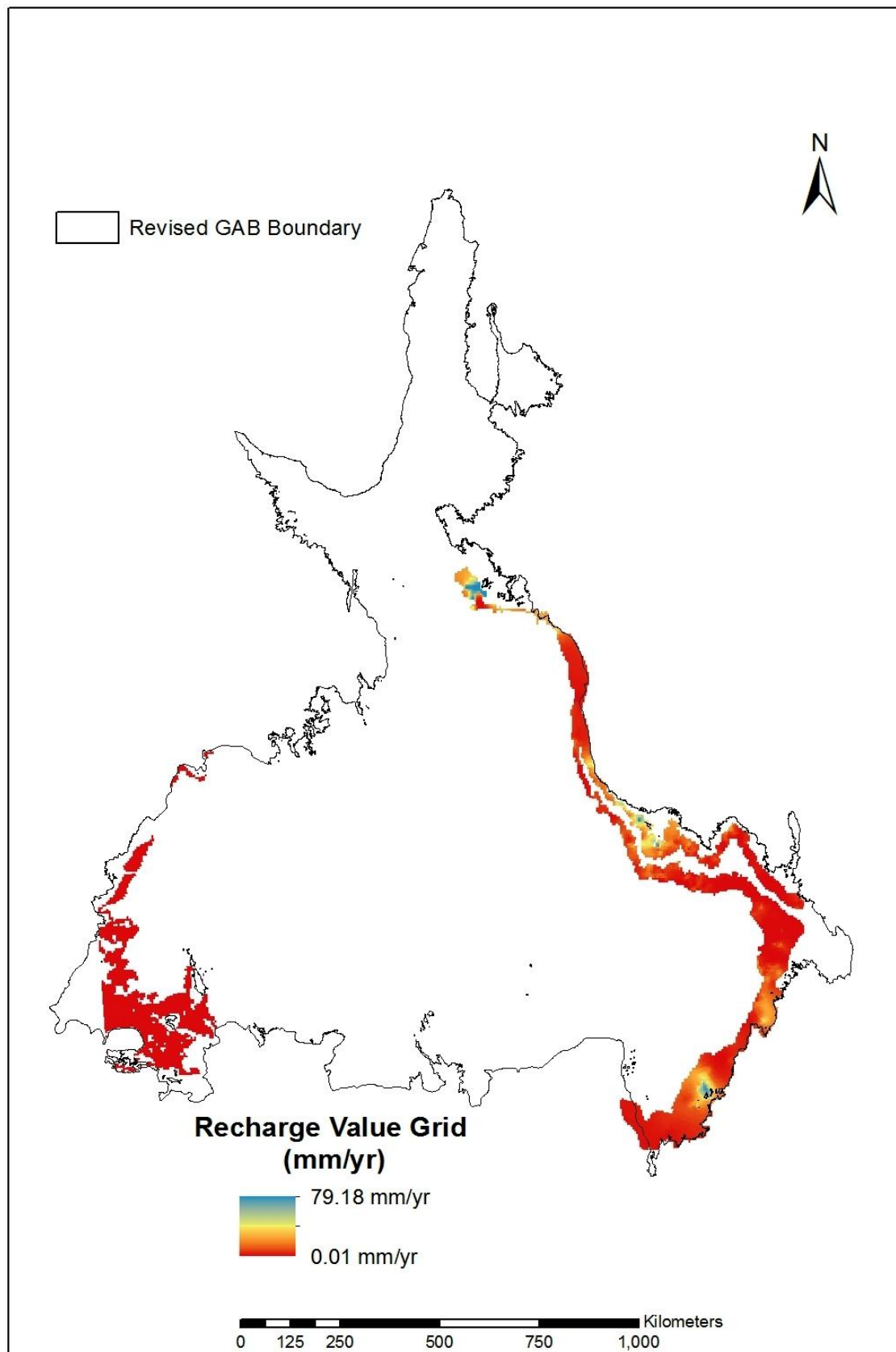


Figure 5: Modern recharge values for the GAB margins (from Ransley and Smerdon (2012))



The recharge categories presented in Figure 5 were machine digitized into the three zones which are presented in Figure 6 below.

Figure 6 shows the following. The area with 1 – 5 mm/yr recharge is 65 064 km², or 3.8% of the GAB. The area with 5 – 30 mm/yr recharge is 37 775 km² (2.1% of the GAB). The area with recharge greater than 30 mm/yr recharge is 2 847 km² (0.2% of the GAB). In NSW the recharge areas of higher than 5 mm/yr and >30 mm are almost entirely contained within the east Pilliga area. The total area with recharge > 1 mm/yr is 102 826 km², or 6% of the GAB.

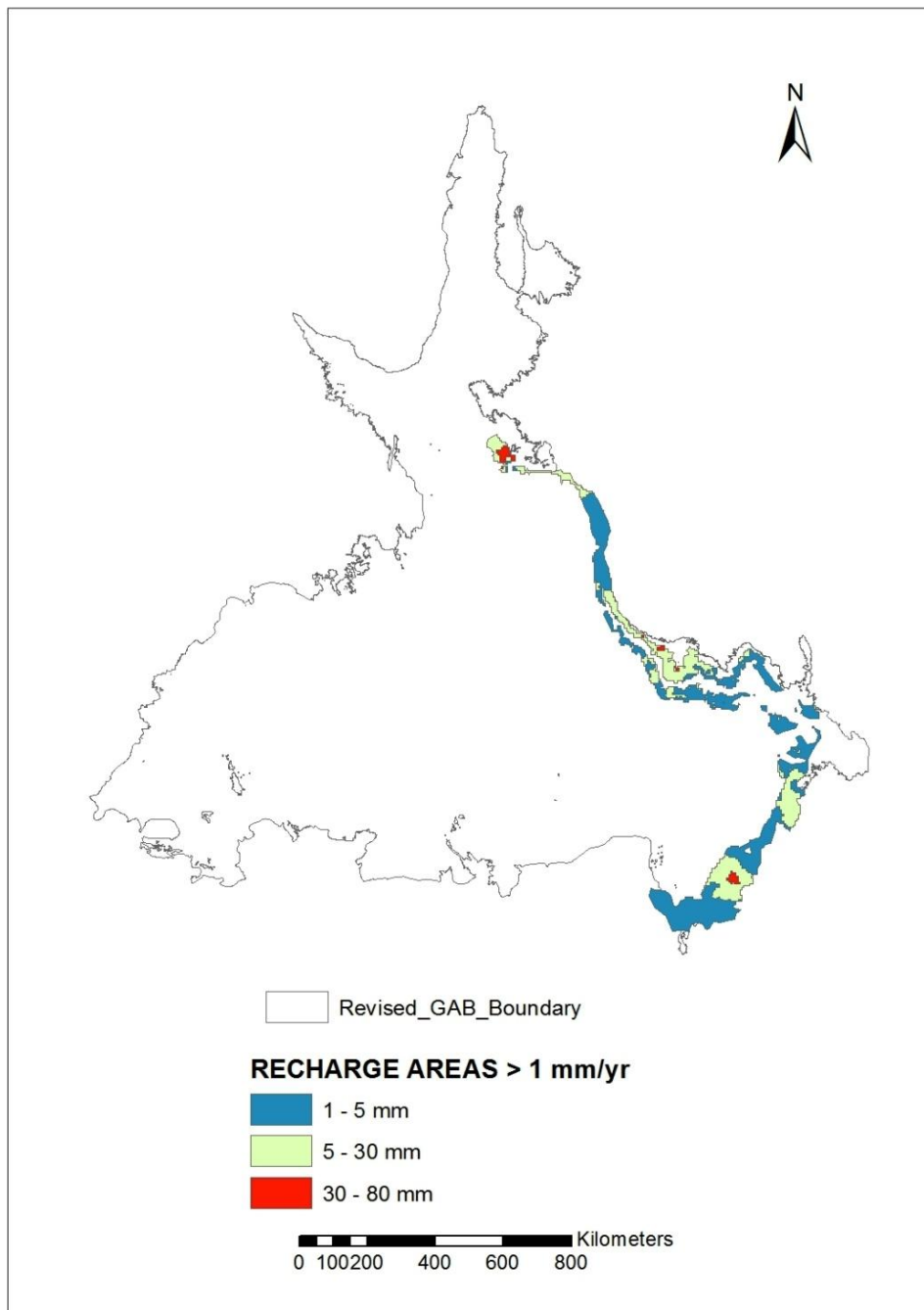


Figure 6: Machine digitised recharge zones from grid data provided in Figure 5.



3.2 Gas and petroleum data

Owing to the complex nature of the gas and petroleum data from the four differing states, it was decided to present both exploration license areas and production license areas on the same map. The data in Figure 7, show that 1.38 million km² (or 80% of the GAB) is taken up with exploration or production licenses associated with gas or petroleum.

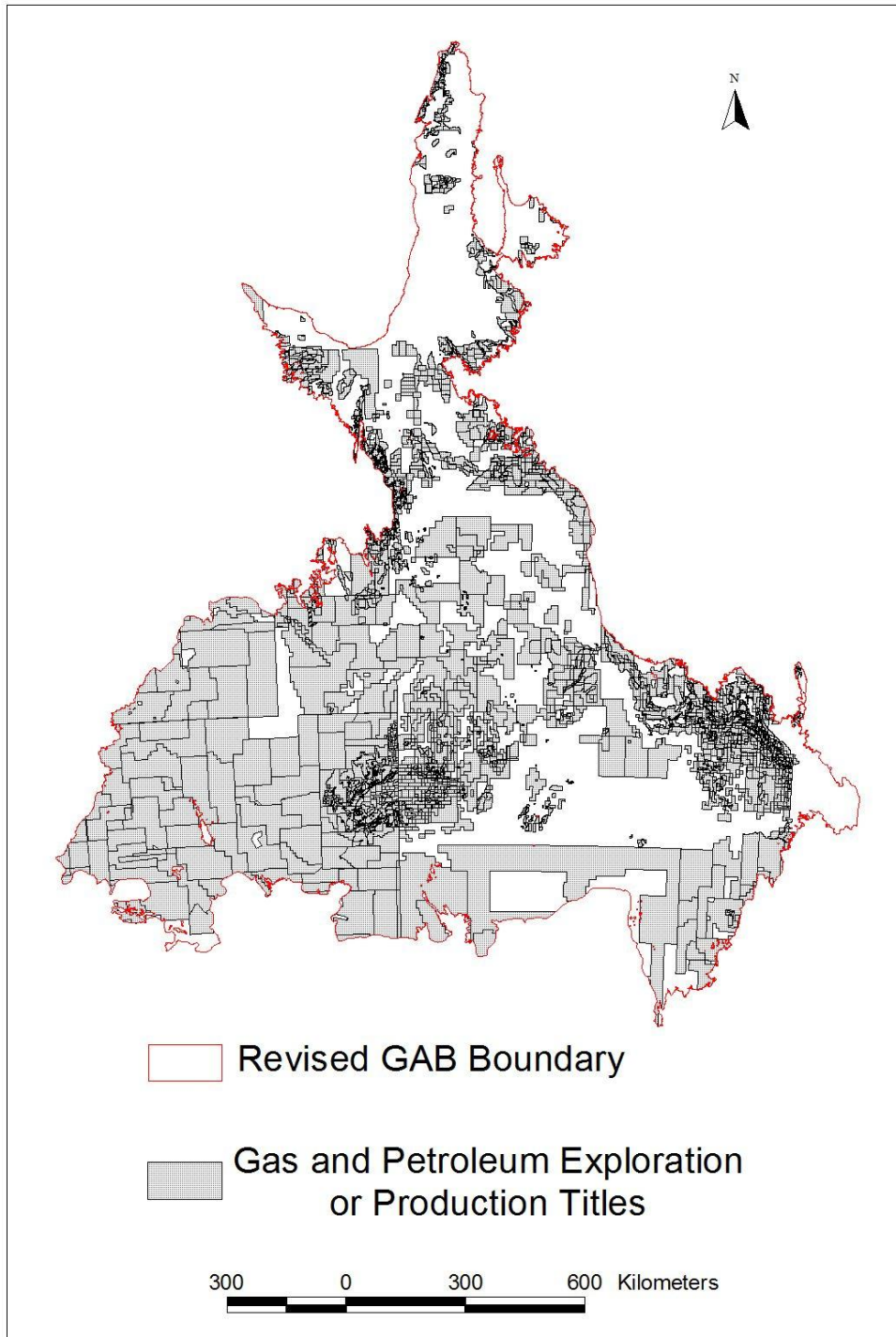


Figure 7: Extent of Gas or petroleum production and exploration licenses in the GAB



3.3 Gas/Petroleum license areas and Recharge

The data from Figure 7 were overlain with the digitised (polygon) version of the Cretaceous and Jurassic recharge zones on the margins of the GAB (Figure 6). Figure 8 shows the extent of gas and petroleum related license areas within the critical recharge zones (>1 mm/yr).

32 326 km² (or 31%) of the critical recharge zone is not covered by any license. 70 590 km² (or 69%) of the critical recharge zone is taken up with either production or exploration leases.

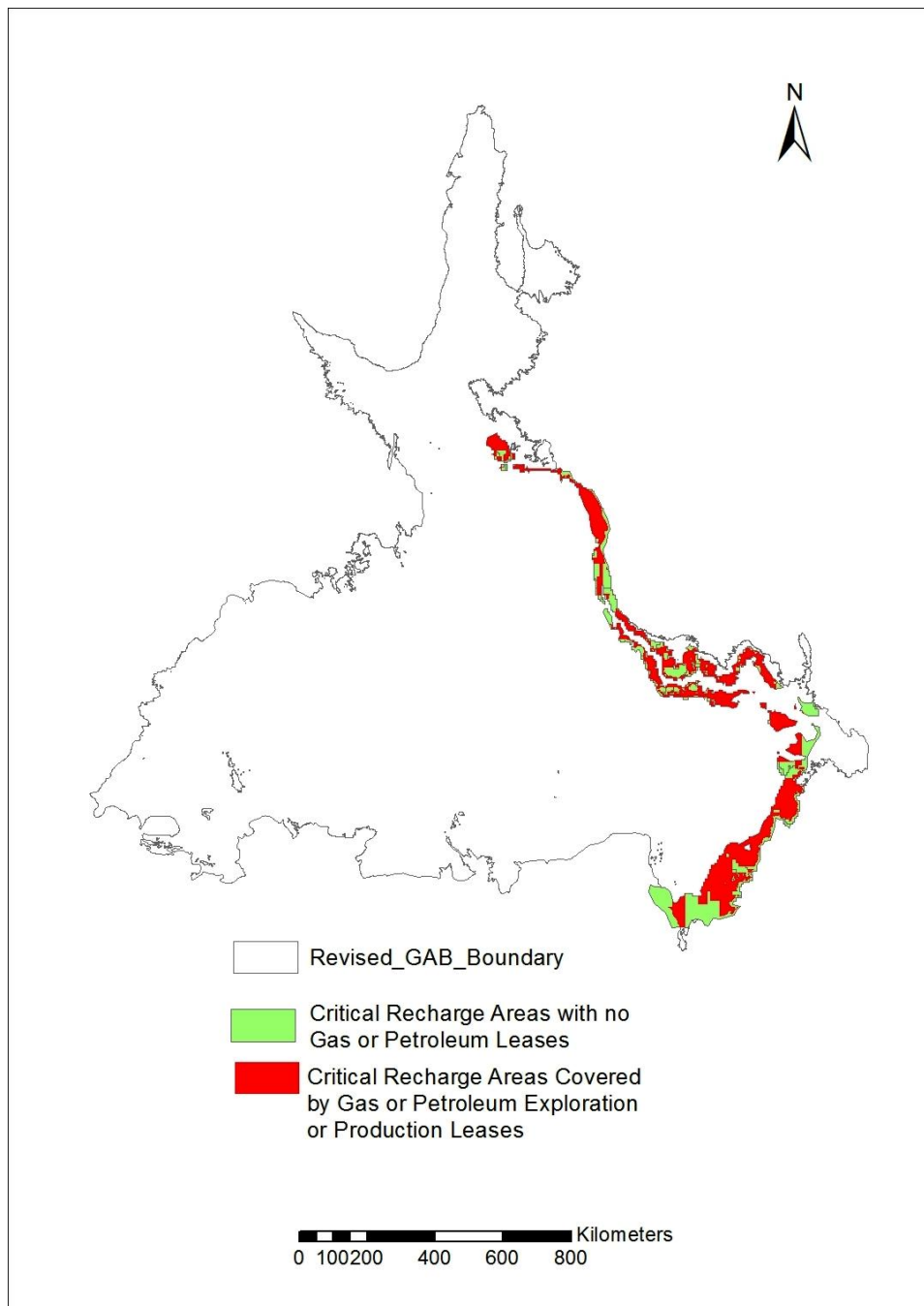


Figure 8: Extent of Gas/Petroleum production and exploration licenses within critical recharge zone (>1 mm/yr) of GAB



4. Discussion of results

The above results show that:

- Recharge along the Eastern Jurassic to Cretaceous margins of the GAB is crucial to providing hydraulic head which drives the whole system.
- Significant recharge to the bulk of the GAB is much more limited in area than previously thought with only 6% of its area providing more than 1 mm /yr.
- Although approximately 30% of the GAB is mapped as recharge, only 6% of the GAB is effective recharge which maintains the pressure head on the bulk of the GAB (excluding the Carpentaria basin).
- Only 2.3% of the GAB has effective recharge of greater than 5 mm/yr.
- Only 0.2% of the GAB has effective recharge of 30 – 79 mm/yr.
- In NSW, the main occurrence of recharge >30 mm is in the east Pilliga between Coonabarabran and Narrabri.
- Draw down of many hundreds of metres is reported in Ransley and Smerdon (2012) for the northern Surat basin coal seam gas fields where coal seams are being dewatered to release gas.
- Draw down of in excess of 1000 m is proposed in the Pilliga in the south eastern Surat Basin (ICSG Forum, 2014).
- Both of the Pilliga and the northern Surat gas fields or license areas occur in the very limited critical recharge (>30 mm) areas of the GAB.
- Excessive draw down of pressure heads in the recharge zone of the GAB associated with gas extraction, has the potential to reduced pressure heads on artesian waters across much of the GAB, and potentially stopping the free flow of waters to the surface at springs and bores.
- Gas and petroleum exploration and production licenses cover 80% of the entire GAB.
- Gas and petroleum exploration and production licenses cover 69% of the critical highest and most critical recharge areas of the GAB.

5. Concluding Remarks and Recommendations

This report clearly demonstrates that a very large percentage of the critical recharge areas of the GAB are covered with gas or petroleum exploration or production licenses. Although individual impact studies may have been carried out or may be carried out for each license on the impact of gas or petroleum extraction from beneath the GAB sediments, it is unlikely that an impact on the whole of the GAB can be assessed in this way.

The GAB covers large areas of Australia's two largest surface catchments, the Murray Darling Basin, and the Lake Ayre Basin and comprises a substantial portion of Australia's agricultural production.



Clearly the area of highest recharge (>5 mm/yr) within NSW is in the Pilliga Sandstones and associated colluvial fans of the East Pilliga. This area is almost completely covered with exploration licenses at this time. Most of the highest recharge areas within QLD are also substantially covered by gas or petroleum licenses for exploration and production.

The GAB is administered from four states which place differing values on its mineral and natural resources. Given that the four states within the GAB have different criteria by which to judge the suitability of a proposal for development, it seems that there is as yet no standard approach to gas and petroleum extraction approvals which cover the whole of the GAB. The current approval or issuing of licenses for both exploration and production in the GAB appears without coordination or regard to recharge. CSG extraction may significantly affect groundwater resources and groundwater resource access within the GAB if bores or springs begin to fail as a result of depressurisation caused by dewatering of recharge zones.

Consideration should be given to a basin wide approach to the management of the GAB with respect to minerals and natural resources, particularly with respect to potentially wide ranging activities such as gas and petroleum production where groundwater from below the GAB is drawn down and produced as an excess or waste byproduct of such development. In particular, serious thought needs to be given to the management of the few critical recharge zones within the GAB and how these might interact with future water supplies.

Recognition of CSG as a water user needs to be given parity with groundwater irrigation users. It needs to be monitored stringently to ensure that the overlying water resource (the GAB) is not affected and the recharge resource is properly managed to maintain hydraulic head.

The concept of the value of land in making development decisions with regard to CSG and mining in NSW has been developed significantly in the past few years. Biophysical Strategic Agricultural Lands (BSAL) were defined to place more rigorous consideration on extractive industry applications in areas of high agricultural productivity, or near special agricultural industry clusters (NSW Government 2013). BSAL areas address the agricultural potential of land only, and do not relate to other landscape functions. Landscape functions such as critical recharge zones to the GAB or other aquifer systems are not considered. A similar approach to delineating high value agricultural lands in Queensland is given in DERM (2012).

The East Pilliga area between Narrabri and Coonabarabran in NSW has Soil and Land Capability Classification (SLC) of between 4 and 6, meaning that there are no contiguous areas of Biophysical Agricultural Land (BSAL) in the area. BSAL is defined as Classes 1 to 3. This means that currently no special consideration which includes landscape function is given with regard to CSG and Mining applications in the critical recharge zone areas of the GAB within the East Pilliga.

A regulative approach which is applied in Germany on a regional scale to manage potential impacts on groundwater is the concept of “*Wasserschutzgebiet*”, or clean water protection area. Despite having relatively high rainfall and low evaporation, Germany predominantly sources its drinking waters and waters for agricultural or industrial applications through groundwater. These legislated groundwater protection zones are in place to protect both



water quality and quantity and all land uses are highly regulated with respect to groundwater and surface activities within sensitive zones. The sensitive zones include recharge areas and areas in proximity to water bores. This approach to recharge has now been modified and legislated for across the entire European Union (EU 2014).

This report establishes that the landscape function of critical recharge is an important consideration community and national land value that is generally not taken into account with regard to mining and CSG activities across the whole GAB. The landscape function of critical recharge to the GAB should be taken into account with regard to these activities. Prolonged deep draw down of aquifers under the GAB (associated with CSG) may eventually lead to a permanent loss of head to large areas of the GAB and as such this needs to be considered a very high risk activity extending far beyond the bounds of an individual gas field or mining activity.

Clearly an approach such as the German/European one, which controls all land use with regard to important recharge zones and other areas within the GAB, may be useful in avoiding potential catastrophic pressure losses. A nationwide management stratagem which includes critical recharge protection and regulates these industries within the GAB may prevent potential degradation of this essential groundwater resource which provides water to 22% of Australia.



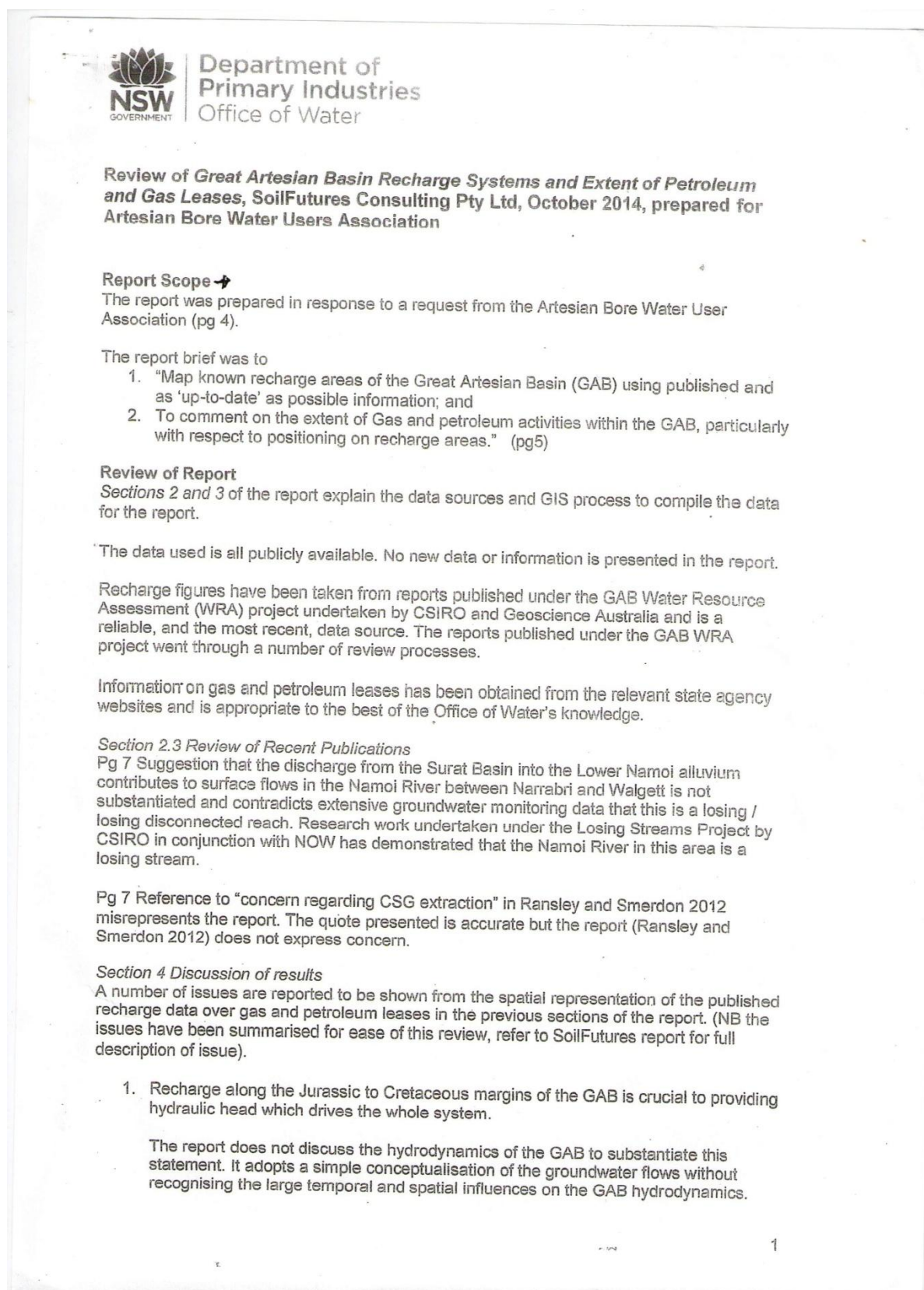
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Appendix 1: Review of Revised Edition by NSW Minister for Water

Below is a copy of the review presented in person to the Artesian Bore Water Users Association by the NSW Minister for Water on 14th February at Coonamble.



There is a significant lag in the transfer of pressure changes in the GAB due to the size of the groundwater system. The magnitude of the pressure impacts also diminish with distance from the applied stress.

As explained in Ransley and Smerdon 2012, groundwater stored in the GAB is a legacy from higher recharge rates that occurred during much wetter periods in the early Holocene and Pleistocene age.

2. Recharge is more limited than previously thought.

Given the recharge figures are based entirely on published data this statement is not supported by the published hydrogeology of the GAB.

3. Points 3 to 5 refer to percentage of "effective recharge which maintains the pressure head on the bulk of the GAB".

A simple model is presented and significant contributions to the hydrodynamics are ignored. Given the area of particular interest to this report are the NSW recharge areas it is of little consequence that contributions in central and northern Queensland are not considered. Expressing this selected recharge as a percentage of the whole of the GAB without including other contributions to the groundwater flow systems distorts the significance of the data. However, the general point that the relative area of the GAB that receives diffuse rainfall recharge is small when compared to the entire GAB is valid.

4. Reference to many hundreds of metres of drawdown in the Surat Basin in Queensland (ie the Walloon Coal Measures) is correctly quoted. Note the Walloon Coal Measures are not present in the Coonamble Embayment of the Surat Basin in NSW.

5. "Draw down in excess of 1000m is proposed in the Pilliga in the south eastern Surat Basin (ICSG Forum, 2014)".

This reference is not available, and this statement could be misleading by suggesting that this level of drawdown is predicted in the GAB in the Pilliga region.

Information provided by Santos in support of development applications for pilot production in the Narrabri Gas Project does confirm that pressure drawdown in the order of 1,000m is predicted expected in the Maules Creek Formation of the Gunnedah Basin at CSG production bore sites. The report does not clarify that the predicted drawdowns relate to the target CSG production zone of the underlying Gunnedah Basin and not the Pilliga Sandstone of the south eastern Surat Basin. Reference to Pilliga in this point is geographic and not associated with the Pilliga Sandstone of the GAB.

6. Reference to "Excessive drawdown of pressure heads in the recharge zone.....potentially stopping the free flow of waters to the surface at springs and bores".

This broad statement is not constrained geographically (eg Qld gas fields or NSW recharge area) nor does it clarify the depth to which the inferred pressure heads relate (Surat or Gunnedah Basin) to enable the context of the implied impacts to be assessed. It again assumes a simple model of the GAB and does not recognise the long response times of regional impacts.



Section 5. Concluding Remarks and Recommendations

This section appears to state opinion and apart from repeating previously noted interpretations does not purport to be presenting information of the GAB.

In the discussion of what should be considered in the management of the GAB the author has not referred to the specific management of the GAB recharge areas within NSW, including:

- all take of groundwater from the GAB has to be accounted for against the extraction limit set by the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008*, and
- the NSW Aquifer Interference Policy sets a minimum impact consideration of 15m of drawdown within the Southern Recharge Groundwater Source and that any flowing bore should not cease to flow.

The reference to the concept of "Wasserschutzgebiet" in Germany appears to misunderstand the typical use of this as a management tool. It is used to declare recharge protection areas around municipal bore fields to prevent contamination from activities in the vicinity of the well heads. It is typically done at the scale of tens to hundreds of metres.

Summary

The conclusions of the report appear to be based on general perceptions rather than a detailed understanding of the hydrogeology of the GAB. It also does not discuss the current NSW planning and policy frameworks under which the GAB and potential impacts to it are managed. A discussion on the current management of groundwater impacts would have been beneficial to the Artesian Bore Water Users Association providing them with a sound basis on which to discuss their concerns on potential impacts of CSG developments on the GAB.

The Office of Water suggests that addressing the matters raised in this review will improve the accuracy and usefulness of the report for the Artesian Bore Water Users Association.



Appendix 2: Summary of Criticisms and Authors Response

<p>Issue: Page 1. No New information is provided in this report</p> <p><i>Response: Although all data presented in this report is public domain, no single agency in Australia has compiled the data in this form to show the extent of petroleum, coal and CSG related activities in the GAB. This is new information – a new map compiled using the best available data.</i></p>
<p>Issue: Page 1: Comment re Namoi being a gaining or losing stream Narrabri to Walgett, using the Losing Streams Project (Lamontagne et al 2011).</p> <p><i>Response: Whilst this is an interesting comment, the study area for this report is a 3km degrading stretch of river starting 12 km from Narrabri. It does not negate or hold in doubt question data also presented in Ransley and Smerdon (2012) which shows that the Namoi alluvial aquifers closer to Pilliga are gaining waters from the GAB.</i></p> <p><i>It also appears from the wording of this that the revised edition of this report (SoilFutures, December 2014) was not reviewed, despite being provided to the NSW Minister for Water on 5th December, 2014.</i></p> <p><i>Lamontagne et al (2011) references a very small and eroding section of the Namoi River where as Ransley and Smerdon (2012) refers to more regional upward pressures into the Namoi Alluvial aquifers near Cuttabri which is between Narrabri and Walgett. There is no conflict here and the findings of Lamontagne et al (2011) needs to be considered in the context of the entire stretch of river mentioned. Clearly the reference quoted in the Ministerial Review is older than the reference quoted in the document.</i></p>
<p>Issue: “Reference to Concern”</p> <p><i>Response: This is a moot point but as one of the reviewers of the report was the author of Ransley and Smerdon (2012) and he agreed that he was expressing concern. Perhaps this is a misunderstanding of scientific language or just semantic.</i></p>
<p>Issue: Bottom of Page 1. “This report does not discuss the hydrodynamics.....”</p> <p><i>Response: The brief for the report did not include this. The does not present a conceptualisation of groundwater flows. It presents maps and creates new maps. There is no argument here and the point is not relevant to the document.</i></p>
<p>Issue: Page 2. Recharge is more limited than previously thought</p> <p><i>Response: Traditionally, the recharge for the GAB has been thought to be 30% of the basin, and that it was significant. The recently published information contained in this report shows clearly that effective recharge (>1 mm/yr) is only 6% of the GAB. 6% is lower than 30% so it is hard to understand what the reviewer is trying to say in this instance.</i></p>



Issue: Page 2 point 3. “A simple model”

Response: *This criticism is misleading.*

Central and Northern Queensland are referenced and mapped with mention of CSG activities and impacts.

The Report does not focus on NSW – it is a GAB wide study referring to some points of interest within NSW.

The final sentence of this criticism negates the previous remarks “the general point that the relative area of the GAB that receives diffuse rainfall recharge is small when compared with the entire GAB is valid” however; the report also refers to the mountain block and alluvial fan recharge which is most common in NSW.

Issue: Page 2 point 4. “Reference to many hundreds of metres of drawdown”...

Response: The criticism says that the statement is correct so why this is mentioned is unknown. The point that this document makes is that there are known connections between the underlying Permian gas rich rocks and the Jurassic/ Cretaceous GAB aquifer and the removal of waters from the Permian rocks may result in drawdown in the Gab aquifer.

Issue: Page 2, Point 5. Reference to CSG forum and comment that this statement could be misleading.

Response: This is clearly referenced and the 1000 m drawdown is clearly available at <http://csgscienceforum.com/contributor-reports/>

The intent of this whole section of the report is to show that

- 1. A 10% connection between the GAB sediments and the Permian and the overlying GAB aquifers exists (established)*
- 2. A drawdown of 1000 m in the Permian layers could well therefore result in a significant loss of water out of the GAB recharge bed area. (Potential)*
- 3. If such a loss happened, and it was say 40 m (which is enough to potentially threaten artesian water pressures at Coonamble, then a recharge rate of 1 – 30 mm/year, will ensure that it takes 1300 – 40 000 years to recover, if only surface recharge is required to refill the space created. (Risk of loss)*

There is no misleading information given in the report and no intent to mislead.

Issue: Point 6, page 2. This broad statement is not constrained geographically.....

Response: The report is about the Great Artesian Basin. It is geographically constrained to the Great Artesian Basin. It is about risk, and it is not intended to provide a hydrogeological model. No such model is proposed. It is the job of the various state and federal agencies to monitor and model the GAB or the part which they have legislative authority over. There are no data or peer reviewed publications currently publically available from these agencies to



show that this has been done.

Issue: “long response times of regional impacts” not recognised.

Response: The document is about risk. Response times are not mentioned because none of the federal or state bodies have published any response times. It is interesting to note that (in NSW) over 30% of artesian bores in the GAB are no longer artesian due to pressure losses. These local effects happened within a 140 year time frame or less.

Even though the minster or his staff has made the comment about response times, he has no furnished any data to suggest a length of time for such a risk scenario to impact on water supplies. Clearly if the impact is in tens to hundreds of years, there is a big problem. If it is to the order of millions of years, it is unlikely to be an issue for the human race.

Issue: Section 5. Page 3. This section states opinion

Response: The conclusions show that there is a risk of dewatering partially connected aquifers with regard to pressure gradients in the GAB.

Note that the title of this section of the report also says “Recommendations”. The recommendations are based on knowledge presented in the report and the experience of the author.

It is the job of a scientist to express a considered and informed opinion.

Issue: Remarks regarding NSW State Policy and lack of inclusion in the report

Response:

- 1. The report is not about NSW, it is about the GAB.*
- 2. The policy of a particular agency is irrelevant to the identification or existence of risk*
- 3. The agency who apparently provided the review has not published anything to do with the risk in the scientific literature so no comment on how risk is proposed to be managed is made.*

Issue: Comment on “Wasserschutzgebiet” is incorrect

Response: Obviously the reviewer has no recent knowledge on European Legislation with regard to groundwater management, not have they made contact with the relevant qualified persons in German Government (such as Dr Gredner, whose details are provided in the acknowledgements section of this document). Dr Gredner would be happy to furnish any information that the NSW Minister for Water Requires in this matter.



Conclusion of Response to Review

The review provided by the NSW Minister for Water, shows that the intent of; and the issues raised in this report have not been clearly understood by the reviewer. Although the minister was furnished with a revised edition of the report in early December 2014, the former version of the report was reviewed. The revised edition of the report was peer reviewed with reviewers acknowledged for their comment. Clearly the NSW Minister for Water chose not to have the Revised Edition reviewed.

The Revised Edition was also presented in person to Mr Troy Grant, NSW Deputy Premier in his offices at Dubbo on 19th December, 2014. The NSW Deputy Premier undertook to pass a copy of the Revised Edition to the Office of the NSW Chief Scientist.

Whilst the NSW Minister for Water has made comments such as those on response times, he or his staff has provided no suggestion as to response times. There are currently no peer reviewed and published data on this relevant to the entire GAB.

Some issues arising such as not using up to date data are incorrect. The suggestion that the Namoi River is a losing stream between Narrabri and Walgett is based on some science done on one 3 km stretch of river published in 2011. The discussion represented about the alluvial aquifers and possible surface recharge to streams was published in 2012. Clearly the regional information quoted is more recent and more regionally relevant than data for a 3 km stretch of the Namoi River.

The main issue raised in the report is that of risk to pressure heads which drive the GAB through extraction of waters in aquifers beneath the GAB which are partially connected to the GAB. There appears to be no dispute on behalf of the reviewer over this issue.

The conclusion of the report is that the highly localised critical recharge areas identified are the only places where the significant recharge waters can get into the GAB. Potential lowering the hydraulic head in these critical areas is therefore important. This is not held in dispute in the NSW Minister for Water's review.

It is the function and responsibility of the State and Federal Agencies that are responsible to manage the GAB to assess this risk and to publish findings on how it can be managed. Unfortunately, "policy" quoted by the reviewer; which may have the intent of risk management; does not explain what science has been done to ensure that the "policy" will be effective.

It was not the role of the author of this document to comment on policy, but available data and publications. A suggestion is given in the conclusions of this report, that a national approach to GAB pressure management which ignores State boundaries may be useful in managing highlighted risks. It does suggest the European model as a potential framework, but this is as far as any reference to policy occurs in the document.

