Water in mining and industry

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Key messages

- Mining, manufacturing, and other industries use about 20% of all water consumed in Australia. They use water in cities and in some fully or over-allocated rural systems, placing them under the same pressures as other users to use water more efficiently.
- Water efficiency improvements have been made by adopting new technologies, more efficient processes, incorporating reuse, and recycling and finding alternative sources of water.
- Mining is a large industrial water use that is growing fast, and uses water in remote areas where it often 'self-supplies'. It discharges large quantities of water to the environment, requiring risks to water quality to be managed.
- Coal seam gas is an industry set to expand on a massive scale in Queensland and northern New South Wales. It poses several water management challenges, including potential impacts on surrounding aquifers and their water users, and the safe treatment, disposal, or use of the saline water that is extracted.

General industrial water use

Before considering mining water use in detail, it is worth outlining some of the general features of industrial water use, of which mining is part. Manufacturing, mining, food processing, electricity, and gas supply and other industries consumed 2840 GL of water in 2008–09: about 20% of total Australian water consumption for that year.[1] Water is typically a very small fraction of total input costs for industry, and considerable value is created, so industrial uses tend to have very high gross value added per gigalitre consumed compared with agricultural uses. The gross value added from mining is comparable with that from manufacturing industries. Where competition for water is resolved through an open water market, industrial uses should be competitive given that water is a low proportion of input costs and high gross value is produced. The marginal cost of securing additional water for a marginal increase in productivity should be low for industrial users. The critical question, though, is the effectiveness of the water market and whether industrial uses face other impediments to water access, particularly as they require reliable supplies of water (i.e. high-security entitlements).

In some rural areas, industries are located in fully utilised systems (e.g. the Hunter Valley or the Murray–Darling Basin) where there are no new water licences available for industry to expand or where the total licensed extraction is actually being reduced. Industrial water use is often not favoured in these situations and can come under community pressure.[2] Growing industry water needs could be met by purchasing entitlements from the water market but the high-security entitlements that industry requires are a very small proportion of total entitlements and are infrequently traded, limiting the ability of the water market to meet the need. Alternative solutions might be to purchase sufficient lower security entitlements to meet industry needs or to allow industry to transfer lower security entitlements to high-security entitlements at suitable exchange rates.

Many industries use urban water supplies on which restrictions for household use have been placed in recent years, raising expectations that industrial users should also curb consumption. The commercial and industrial sectors use 20 to 30% of total urban water supplies and have become more water efficient in several ways.[3] They have adopted new technologies that use less water, reduced pressure, and flow rates (e.g. lower flow rate washing processes), and they use alternative supplies of non-potable water such as rainwater, groundwater, and stormwater. Some users have developed fully integrated water management by reusing and recycling water as much as possible between uses within the site and minimising any discharge of wastewater to the environment.

The Foster's brewery at Yatala, between Brisbane and the Gold Coast, is an example of an industrial water user that has increased its efficiency through a range of measures.[3] The brewery

Cockburn Sound, Western Australia. Photo: CSIRO.

had been using the measures to reduce water use, supplied by Gold Coast Water, with usage falling from 1010 ML in 2005–06 to 840 ML in 2007–08. It then doubled its brewery capacity with only a 15% increase in water consumption. Water efficiency measures included treating wastewater from the brewery to recover pure water and use it for cleaning, steam, and cooling. The water treatment also reduces salt discharge to the environment by using reverse osmosis as part of the process. Sludge is dewatered to recover further water, and water consumption was reduced by implementing more efficient industrial washing processes.

Increases in water efficiency allow businesses to demonstrate their social responsibility and establish reputations as good corporate citizens. With water prices set to double in some urban areas and industry's requirements for highly reliable supplies, improved water efficiency can be driven by direct financial incentives.

Water in mining

Use of water in the mining industry shares many of the characteristics of other industrial uses but it has some distinctive features that make it worth considering in further detail. The mining sector is a large industrial user that is growing rapidly. Mining includes mineral extraction (including coal), petroleum, gas, and quarrying. Most water is used in arid or semi-arid regions where water is scarce and there are few competing users such as agriculture and towns. The sector can be the largest water user and even a key water supplier. The industry mostly supplies itself with water that is often regulated separately from the water entitlement system or water supply utilities that provide for other users. Much of the water is extracted to dewater mines or is a by-product of extraction and can be acidic and contain toxic amounts of metals or other pollutants. It is often discharged to the environment, with controls placed on its quality, but in arid regions the discharges may be sufficient to detrimentally alter the natural flow regime. Alternatively, extracted water is disposed of in evaporation ponds.

As the world's population grows, migrates towards cities, and improves in standard of living, the demand for Australian minerals and metals will increase. There has been exponential growth in the production of most Australian metals and coal products since the 1950s. By far the highest production level in the sector is for coal, which since 1994 has almost doubled production from 456 Mt/year[4] to approximately 815 Mt/year in 2008.[5] Iron ore also has a very high production rate, having grown from 129 Mt/year in 1944 to approximately 340 Mt/year in 2008.[5] Increasing production has used up most of the higher-grade ores so that the industry is increasingly accessing ores of lower quality, which require greater volumes of water to be used per tonne of metal produced. Both the increasing production and declining ore quality make continuing access to water a critical business imperative for the industry.

Water use by the mining industry has been relatively steady, as reported by the Australian Bureau of Statistics (ABS) water accounts, consuming 592 GL in 1993–1994 and 508 GL in 2008–2009. The ABS figures and some case studies suggest that water use efficiency in mining has improved greatly since 1994,[6] although to account for the exponential growth in production, efficiency would need to have improved dramatically to maintain steady use. It is believed that there is under-reporting of use, because some enterprises do not report all uses, such as water used in tailing dams.[5]

There are strong prospects for further growth in iron ore extraction in coming decades and exponential growth of the burgeoning coal seam gas industry, which is also a major water user. Demand for water by the mining sector is therefore likely to increase, with projections ranging from 810 GL/year to 940 GL/year use by 2020[7] for Western Australia alone.[8]

Water is used by the minerals industry for operational activities that include:[9]

- transport of ore and waste in slurries and suspension
- separation of minerals through chemical processes
- physical separation of material such as in centrifugal separation
- cooling systems around power generation
- suppression of dust, both during mineral processing and around conveyors and roads
- washing equipment
- dewatering of mines.

Drinking-quality water is required to support towns that have developed in remote areas to house mining staff.

Water is favoured in mineral processing because it is a low cost and low energy way of transporting materials between processes – including disposing of, or storing, waste materials. It is a very efficient medium for supplying chemicals and mixing materials and it is an essential ingredient for some chemical processes. It is also the most convenient medium for gravitational and centrifugal separation of minerals from host rocks.

Mines that go beneath the water table are dewatered by pumping, which draws-down the water table in the surrounding landscape. This can reduce the water available to other users and reduce the discharge to streams and other groundwater-dependent ecosystems. The water from dewatering must be discharged safely to rivers, lakes, or storages and may need to be treated to remove acidity or high metal concentrations (see Chapter 5). In 2008–09, the mining sector had a regulated discharge to the environment of 37 GL; over 90% came from the coal industry – mainly from large open cut mines that extend below the water table.[1] Coal is by far the largest user in the mining sector because of the huge mass of product mined.


Black Flag Lake near Kalgoorlie, Western Australia.
Photo: Bill van Aken, CSIRO.

Water is critical for low production, but high value, products such as gold where water is needed to transport and process very low grade ore. Over 250 ML of water is required to produce a tonne of gold, but the price of gold is so high that it still represents a value added of $80 000 per ML of water used.[10] At the other extreme, petroleum companies use relatively low volumes of water over short periods for drilling and they produce water as a by-product of extraction that needs to be disposed of safely.

Mines in arid regions rely heavily on groundwater of variable quality. Possible conflicts in use in these areas are with Indigenous access to water (see Chapter 2) and water-dependent ecosystems. The mining industry provides its own infrastructure to supply water in remote areas, so water provisions tend to be part of the development approval for the mine itself, rather than being a licensed extraction under a water sharing plan. Elsewhere mining occurs in fully utilised systems such as the Hunter Valley, Murray–Darling Basin or parts of the South West of Western Australia where water use can also be part of the development approval outside of water sharing plans, even though there are other water users and water supply utilities. It is not clear whether it is justified to keep mining water use separate from other water use entitlements, but in fully allocated regions this separation may hinder mining companies from participating in water trade.[2]

The pressures on water supply for mining foster the same adaptive strategies that industries in general have used to manage water scarcity, including incentives to improve water use efficiency through using more efficient processes and new technologies. Dry or near-dry processing technologies have been applied to several products such as gypsum, phosphate, and uranium. However, they introduce new challenges (e.g. dust generation and dispersal) and are an active area of research.[10,11] The level of reuse and recycling of water is growing, both among processes within a single site, and with other water users (e.g. Newcrest Mining in the Cadia Valley now uses treated town wastewater[12]). The mining industry is often able to use lower quality, alternative sources of water, and some separation processes are more effective using highly saline water.

Mining industry water use was less susceptible to the millennium drought across southern Australia, largely due to the majority being in northern Australia, its greater reliance on groundwater, and the relatively small fraction of the resource that it uses. Dry conditions can actually reduce the amount of mine dewatering, thus reducing costs. Individual mines were affected by the drought and some, such as the Newcrest mine mentioned above, turned to alternative sources. The impacts of climate change are likely to be similar to those of the drought. Mines in southern Australia are likely to experience lower water availability, more severe droughts, and full allocation of water to users. There is less chance of reduced water supply to mining in northern Australia under climate change.

Water and coal seam gas development

New coal seam gas developments in Queensland and New South Wales present major challenges concerning the large volumes of brackish groundwater that will be abstracted from the coal seams as part of the process. These are part of broader public concerns regarding the conflict of mining development with agricultural land use and lifestyle values of the affected regions. Worldwide, a new technology to extract methane from deep lying coal beds has led to unprecedented development in areas previously not viable for economic exploitation. Queensland holds exceptionally large reserves of coal seam gas. The extracted gas will be cooled and compressed

Dump truck and bulldozer moving waste rock at the Ranger Uranium Mine, NT. Photo: Paul Peter.

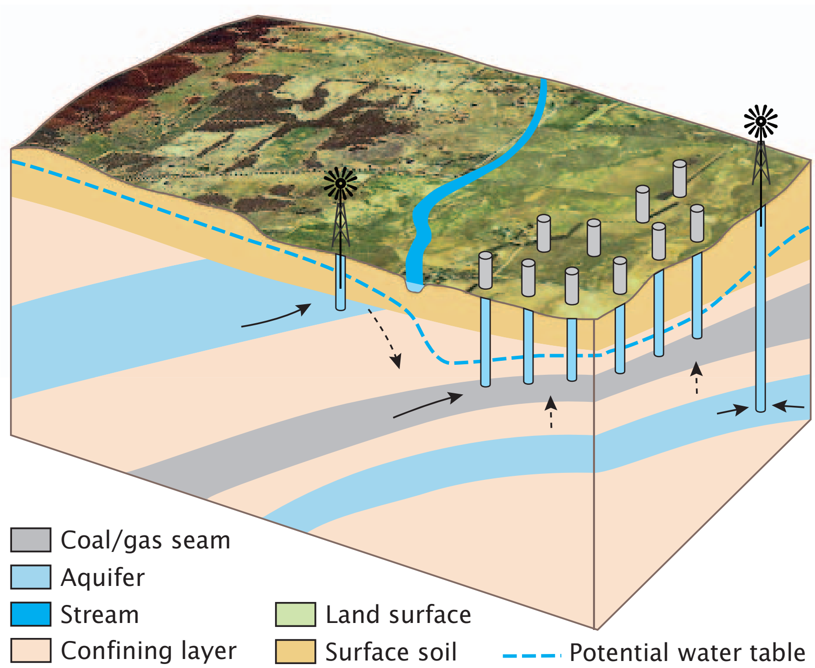


***Figure 10.1**: Schematic block diagram of coal seam gas production. Many wells are drilled into the coal beds that hold the gas, extracting water and gas to the surface. Interactions with the hydrology of adjacent and overlying aquifers that are used by others are of potential concern. A network of pipes is used to transport the gas and water to a treatment plant from where gas is piped to the coast, liquefied, and exported.*

to produce liquefied natural gas, which has about 1/600th of the natural gas volume and is well suited for export to China and elsewhere.[13] Seven new liquefied natural gas (LNG) projects have been announced in Queensland. Together, they could provide over 50 Mt/year of LNG for export and production is expected to rapidly expand to 15 times its current size.[14] Proven and probable reserves have grown from 3600 petajoules (PJ) to over 28 000 PJ in the last 5 years, compared with an annual gas consumption of 213 PJ/year in Queensland for 2010.[15] Coal seam gas has been produced from the Bowen Basin since 1997 and production started growing in the Surat Basin in 2005. Exploration is also occurring in other Queensland basins, northern New South Wales, and Western Australia where there are known coal deposits.

The gas is bound to the coal by the pressure of the surrounding water. It is released from the coal by extracting large volumes of water to lower the water pressure. This poses two water management challenges. Firstly, the depressurisation could affect users of water in surrounding aquifers (Figure 10.1) and, secondly, the released water needs to be disposed of safely.

The water in the coal seam aquifers is not used because it is of poor quality, containing salts and some hydrocarbons associated with the coal and gas, but depressurisation could affect the surrounding aquifers that are used (Figure 10.1). In the Queensland developments, there are concerns over possible interactions with usable aquifers in the Great Artesian, Bowen, and Surat Basins (Figure 10.2). Usable aquifers can occur above or below the coal seams and are used for irrigated agriculture, and stock and domestic water. Removing water from the coal seams could induce leakage from the surrounding aquifers. The extent of that leakage will depend upon the amount of water removed, the distance between the aquifers and whether there are intervening

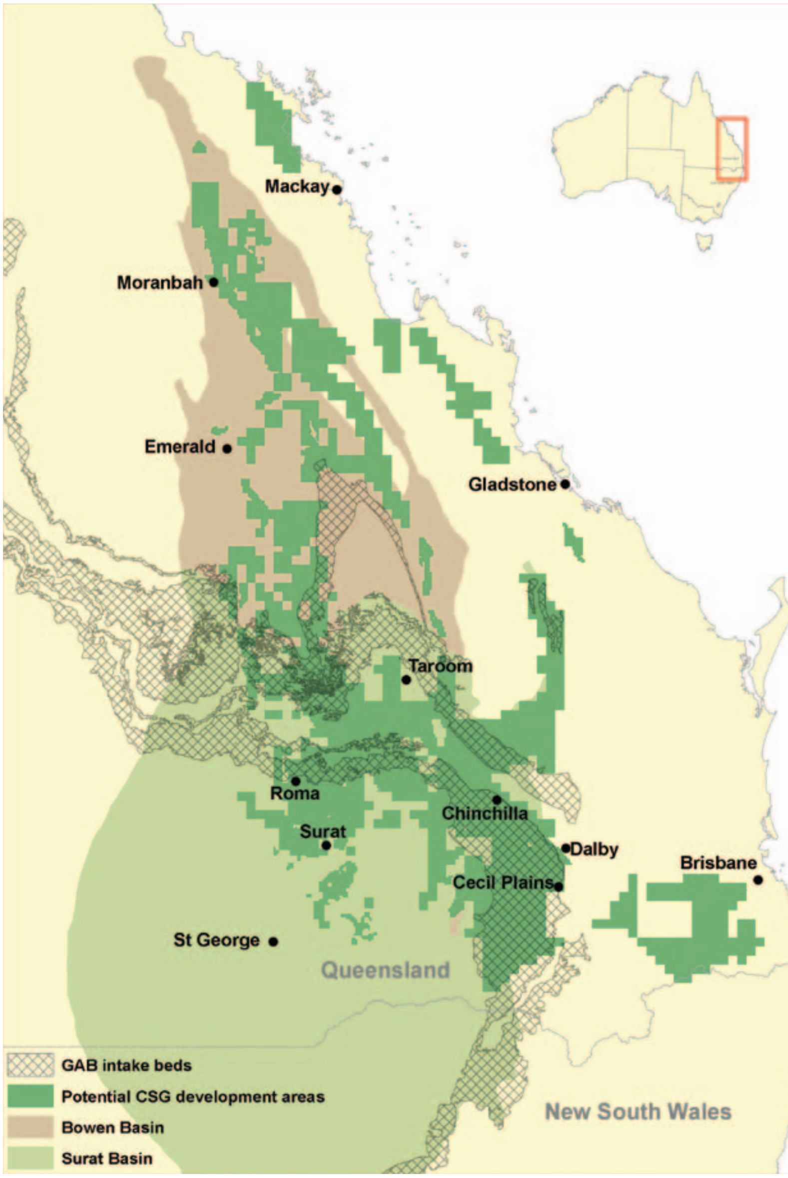
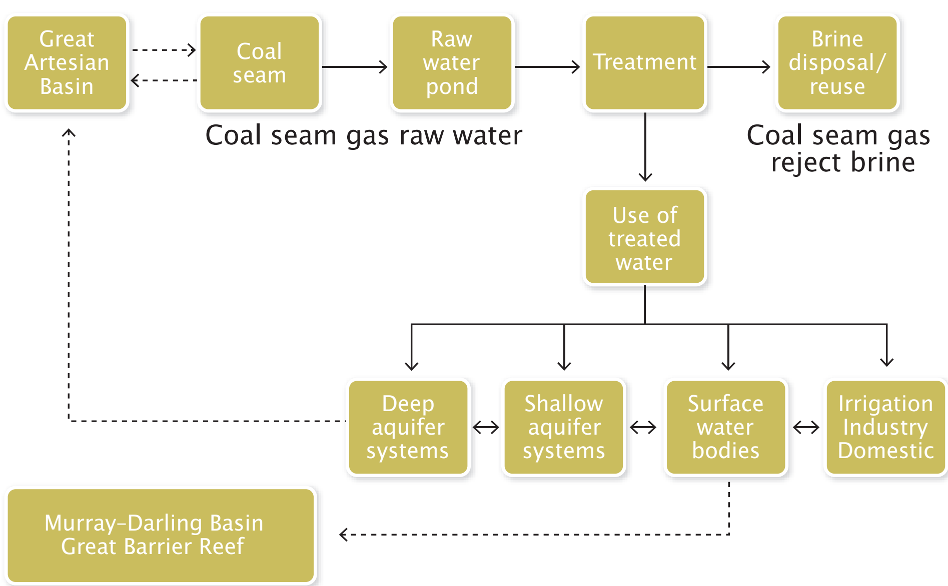


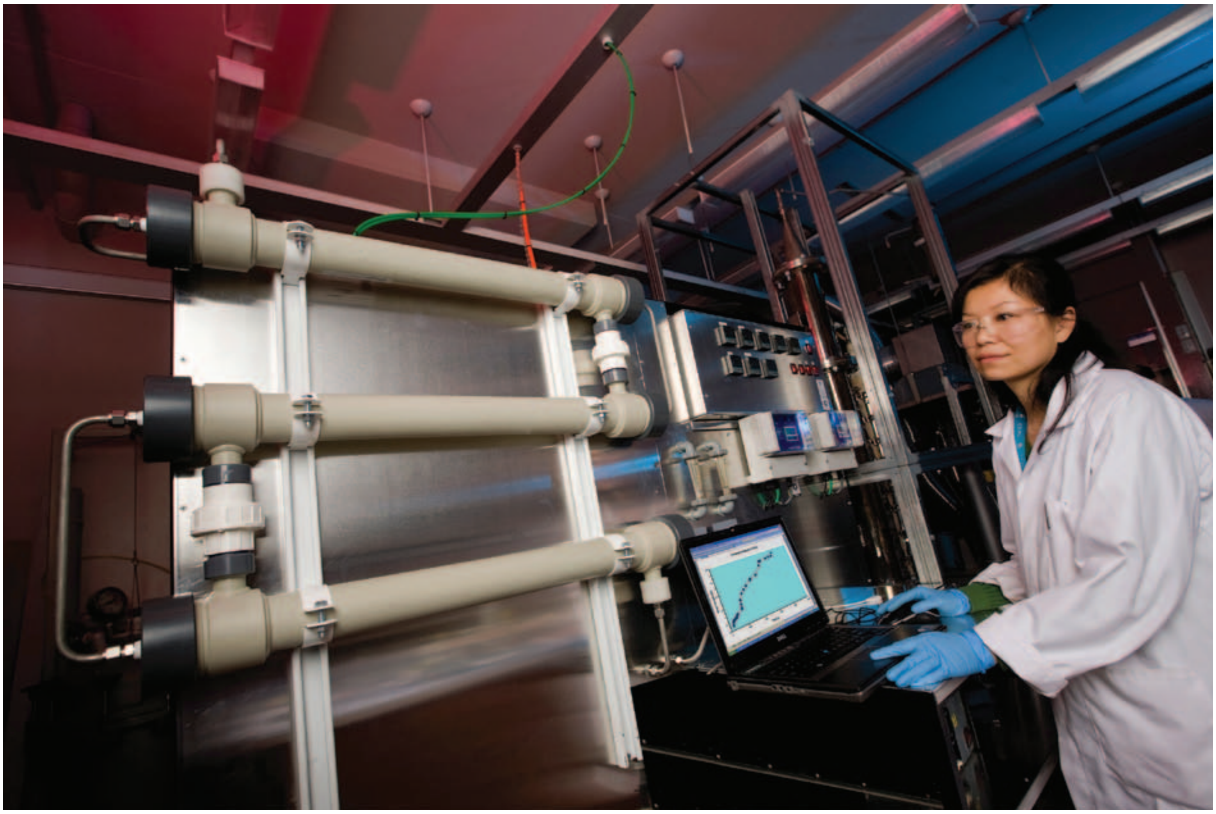
Figure 10.2: Potential coal seam gas production areas[16] in relation to the Surat and Bowen basins and the intake beds of the Great Artesian Basin.

impermeable layers that prevent leakage. Estimates of water extraction were initially predicted to peak at 261 GL/year for a 40 Mt/year industry (with a range of 227 to 419 GL/year), but have now been reduced to a peak of 160 GL/year and may be reduced further as the process proves to be more efficient than expected.[16] This extraction rate compares with an estimated bore discharge of 500 GL/year in 2001 for the entire Great Artesian Basin – a rate that is leading to reductions in artesian pressure. Extraction of gas and water occurs across many wells in each gas field (Figure 10.1), with prospects for 30 000 to 40 000 wells to depths of up to 1000 m below the ground in the Queensland developments. Wells are often laid out on a grid within a few hundred metres of each other.

For some wells part of the extraction process is to hydraulically fracture the coal beds to increase gas output (a process known as fraccing). Fraccing involves pumping large volumes of fluid into the well under high pressure. This opens fractures in the surrounding coal seam, increases hydraulic conductivity, and in turn leads to higher gas production from the well. Fraccing fluid consists of water, sand, and a small amount (<2%) of additives, used to make the fluid gel-like to better suspend the sand. The sand keeps the fractures open after the injection pressure is removed. Additives used in fraccing can include acids, breakers, cross-linkers, gelling agents, iron control, surfactants, pH control, solvents, and stabilisers.[17] Some of the additives are toxic and the fracturing can extend beyond the coal seam if not executed properly, leading to public concerns over pollution of usable aquifers. Fraccing has been applied in more than one million wells in the United States of America since the 1940s.[18] The United States Environment Protection Authority (EPA) reviewed complaints of drinking water bore contamination believed to be associated with fraccing, but were unable to confirm that fraccing contaminated drinking water bores.[19] A recent study found an increase of methane concentrations in drinking water wells near gas wells, which is of concern, but found no contamination with fraccing fluids.[20] The environmental risk posed by fraccing is reduced by recovery of the fraccing fluid. If the coal seams



▲ ***Figure 10.3***: *Schematic diagram of water flow in coal seam gas production in Queensland. Water is extracted, treated, and used or disposed of in various ways.*



A membrane testing facility for purification of industrial water. Photo: David McClenaghan, CSIRO.

are separated from high water quality aquifers by aquitards this can lower the environmental risk – thus, a comprehensive knowledge of the subsurface hydraulic properties is essential to assess the risks from fraccing.

To resolve the issues of water extraction and fraccing across several development proposals and thousands of wells requires a good characterisation of basin geology and how it controls groundwater pressures, flows, connections, and quality. This will help answer the critical question of how much leakage will occur between the coal seam beds and usable aquifers. The Queensland Government will complete a groundwater model to asses the cumulative impact of coal seam gas on the Surat Basin in 2011. Groundwater models typically use the hydrogeology (drill logs and groundwater levels), hydraulic properties determined from well tests, and other information such as isotope studies of aquifer interactions and ages of water. Industry also uses groundwater models to predict and minimise environmental impacts. However, the modelling of a regional groundwater system the size of the Surat, Bowen, or even the Great Artesian Basin is a major challenge, especially because of the scarcity of groundwater data in this sparsely populated region. The difficulty in the Great Artesian Basin is that groundwater flow velocities are slow, waters are old and any unforeseen consequences of extraction will take decades or centuries to work through the aquifers. The overriding issue is the uncertainty of the potential cumulative, regional impacts of multiple developments.[21]

The extracted water is considered a waste stream of the production process, and is treated, used or disposed of as a regulated waste under the Environmental Protection (Waste Management) Regulation of Queensland (2000) (see Figure 10.3). As with other extractive industries, treatment must be sufficient to ensure that use or disposal has no environmental impacts. The salinity of the water varies from 200 to more than 10 000 mg/L, and it may also contain some hydrocarbons and metals.[22] Using saline water for irrigation can change soil structure or cause salt to accumulate in the soil. Disposal into rivers may lead to increased river salinities or concentration of metals in organisms.

The majority of the extracted water within the last 10 years was directed to evaporation ponds, but this is not expected to continue because of concerns over leakage of saline waters into soils, aquifers, and rivers.[16] A number of reverse osmosis water treatment plants were built subsequently to remove salt and contaminants from the coal seam water. This effectively provides large volumes of high quality water and a waste stream (about 10% of volume) of highly concentrated salt brine. The treated water is suitable for domestic, industrial, or agricultural purposes. Potential uses include coal washing and dust suppression in the mining industry. Treated water could also be reinjected into groundwater aquifers, but always in consideration of the impacts to those aquifers. Large injection trials and modelling exercises are currently underway to prove the feasibility of this option and the high quality of the reverse osmosis treated water would suggest comparatively low risk. Disposal into rivers, however, is not a preferred use because desalinated water could cause 'clean water pollution' – river water has natural concentrations of salts, ions and nutrients required to support life. Rivers in this environment are ephemeral and the ecology adapted to seasonally dry conditions that would be altered by continual discharge of treated water.

The waste stream of concentrated salts (brine waste) following water treatment needs to be disposed of. Typically evaporation dams are used to store brine and further concentrate the salt. The brine stream may receive further treatment to extract the remaining water and produce commercially usable salts, but the process is currently not economically viable.

Overall, the environmentally sound management of coal seam gas water is a major concern for the industry, governments, and affected communities and may delay the development of the resource.[23] Regulations are actively being developed and governments, industry and communities would all benefit from a good knowledge of the risks involved regarding water extraction and disposal, and agreement in advance of appropriate mitigation measures in case the risks eventuate. This requires a good understanding of the behaviour and characteristics of the groundwater systems and how they will change with coal seam gas operations.

Further reading

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