Using Coal Seam Gas produced water in irrigated agriculture in northern NSW

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What is coal seam gas and how is it produced?

Coal seam gas (CSG) is a form of natural gas (95-97% methane) which is trapped in coal seams by water and ground pressure. Gas is stored within the coal seam along fascia or cleats in the coal, and is held there by the pressure of overburden and water.

Water is removed during extraction of CSG, reducing the hydrostatic pressure in the coal seam which results in the release of the gas **(Figure 1)**. The water and gas are pumped to the surface where they are separated. The quantity and quality of this water (referred to as produced water) varies considerably according to the hydrogeological setting, age and depth of the coal seam.

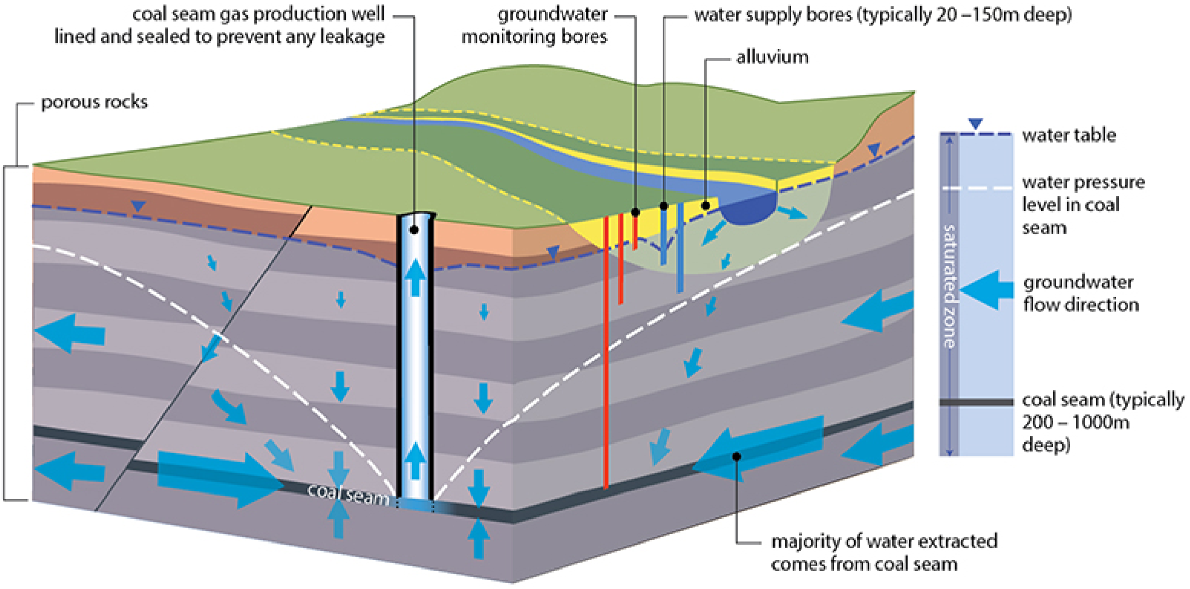

Figure 1: Schematic diagram of groundwater flow in the vicinity of a coal seam gas production well (Image: NSW Office of Water 2017)

A critical issue for the development of the CSG industry in NSW is the management of produced water. All gas exploration, assessment and production activities in NSW require a licence issued by the NSW Environment Protection Authority. These licences include legally enforceable conditions to prevent pollution and safeguard the environment and the community, including conditions relating to the appropriate management and disposal of the produced water.

Produced water could potentially be reused in agriculture, grazing, forestry, and industrial and mining operations. However produced water is of poor quality making beneficial reuse unlikely without treatment.

CSG locations in NSW

The Gunnedah Basin in the Namoi Catchment and the Gloucester Basin, which straddles both the Manning and the Karuah River Catchments **(Figure 2)**, have the greatest defined reserves of CSG in NSW.

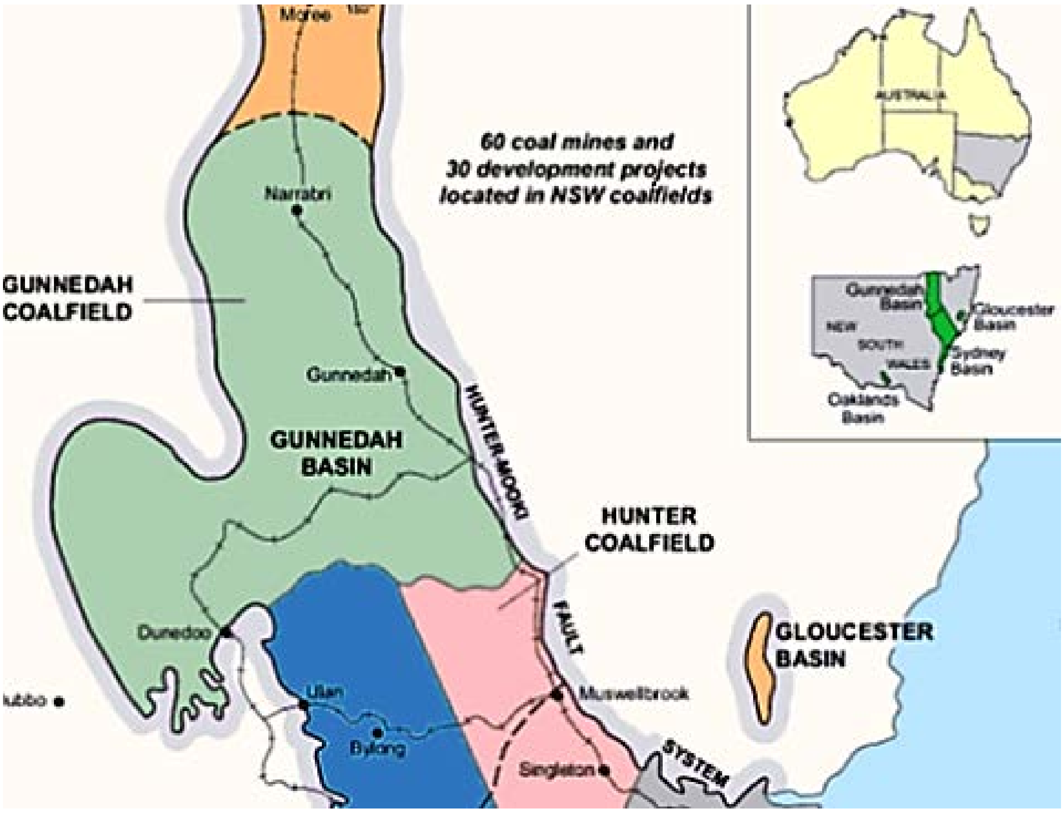

Figure 2: Localities of the major coal bearing basins in northern NSW with CSG potential (Image: NSW Planning & Environment, Resources & Energy 2017)

The Namoi Catchment covers an area of 42,000 km^2. Gas reserves have been identified in the lower part of the Namoi Catchment in the geological formation known as the Gunnedah Basin covering approximately 29,300 km^2 or 2,930,000 ha **(Figure 2)**.

The catchment is characterised by highlands in the east and south and a broad floodplain in the west. Soils are dominated by lithosols, chromosols, and vertosols (Isbell 1996) with surface textures being sandy loam, clay loam or clay, respectively.

About 40% of the total Namoi Catchment is used for grazing livestock, while large areas are used for dryland cropping and horticulture. Other land use includes forestry, nature conservation areas, and irrigated cropping. Mining activities, including the Narrabri Gas Project, currently occupy less than 0.1% of the Namoi Catchment.

The Gloucester Basin is located just north of the Hunter Valley between the townships of Gloucester and Stroud, and covers an area of approximately 350 km^2 (35,000 ha). The terrain is mostly undulating with relatively low slopes. Some steep slopes are found at the edge of the subregion in bordering mountain ranges.

The dominant land use in the Gloucester Basin is the cultivation of forage crops and improved pastures for livestock, particularly dairy and beef cattle. Soils are mainly kurosols (62%) and rudosols, with some ferrosol soils (Isbell 1996) also present.

CSG produced water

One of the key environmental concerns with the emerging CSG industry is the management of the produced water. The quantity and quality of produced water varies from area to area and also varies during the life of the coal seam gas well, but is typically characterised by high salinity and sodicity.

Use of treated CSG produced water for irrigated agriculture will be constrained by:

- modest volumes of water available
- variable and seasonal irrigation demand
- the need for a distribution system
- short-term supply of water (CSG projects generally have a production life of less than 20 years, and volumes of water are likely to peak at just three years)
- the effect of the quality of the treated water on soils and crops

Water quantity

The volume of CSG produced water varies during the early, plateau and decline phases of the coal seam gas well **(Figure 3)**.

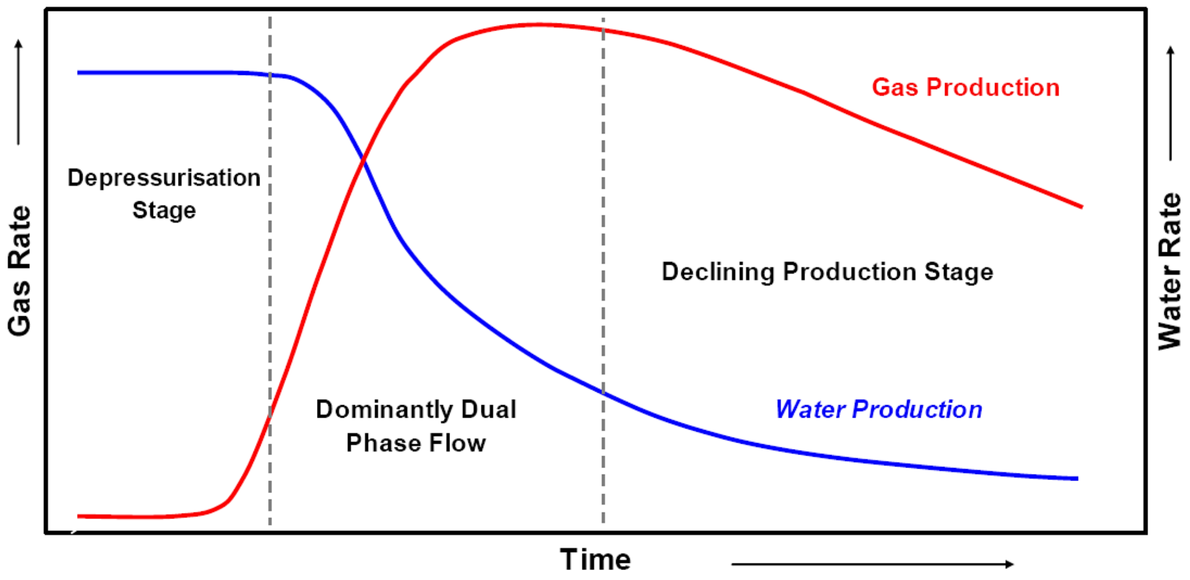

Figure 3: Stylised production curves of gas and produced water from coal seams during life of gas well (Source: QWC 2012)

The long-term supply and seasonal availability of water needs to be investigated to determine its viability for irrigation use. Research on the volume of produced water during the three phases of well or field operation **(Figure 3)** will help determine the treatment, reuse and disposal options for CSG produced water.

In NSW, the period in which the water yield declines to low production levels has been typically less than three years. In Queensland low yields occur generally after a much longer period and even these low yields are typically above the initial yields of wells in NSW.

The volumes of CSG produced water in Queensland are anticipated to be up to 196,000 ML per year when the CSG industry reaches mid-size. Coal deposits in NSW however are older and drier, with water yield expected to be much lower than in Queensland. Heavily investing in irrigation infrastructure for short-term availability may not therefore be economically feasible in NSW.

The Narrabri Gas Project is estimated to yield a maximum of approximately 1,500 ML per year. This is a minor volume of water compared to the current volume of surface and groundwater available for irrigated agriculture in the Namoi Catchment of 472,000 ML per year.

The Narrabri Gas Project could potentially supply sufficient water to irrigate either:

- 150-200 ha of lucerne at 7-10 ML/ha per year, or
- 190 ha of cotton at 7.8 ML/ha per year

Water quality

Studies have shown that there can be considerable variability in the quality of produced water across a basin, while inter-basin variability can be extreme. An indication of the quality of produced water can be determined during the exploration phase for CSG.

Measured total dissolved solids (TDS) of CSG produced water from wells in the Gunnedah Basin range from 0.22 to 17,000 mg/L with a median of ~10,000 mg/L. The range in the Gloucester Basin is from 100 to 6,800 mg/L with a median of ~2,100 mg/L. This water is moderately to highly saline.

Produced water is typically rich in sodium, potassium, barium, strontium, iron, chloride, carbonate and bicarbonate. Sodium occurs in concentrations ranging from less than 150 mg/L up to more than 34,000 mg/L (similar to seawater).

Salt toxicity is likely to be the most serious issue to be managed when re-using produced water. Chloride concentrations range from less than1 mg/L to over 70,000 mg/L (about three times the chloride in seawater).

Median sodium absorption ratios (SAR) of water produced from wells in the Gunnedah (SAR 122) and Gloucester (SAR 38) basins exceed the maximum recommended threshold SAR for irrigation water on all soils with a texture finer than that of sand. Low concentrations of calcium and magnesium magnify the sodic nature of this water.

Predicting ongoing water quality will require projections based on findings in similar CSG wells. Projections will also need to be calculated to the extent to which water supply from multiple wells on one CSG site can be coordinated to provide consistent quality to a water treatment plant.

Treated CSG produced water should be amended to make it more neutral and suitable for use. Untreated CSG produced water is typically strongly alkaline, commonly reaching pH 8-9. Such high pH is highly unusual in Australian streams. When soil pH ($CaCl_2$) is greater than 7.5, calcium can tie up phosphorus making it less available to plants.

Additionally, alkaline soils cause zinc and cobalt deficiencies that lead to stunted plants, poor growth and reduced yields in some crops and pastures. Nitrogen fixing Rhizobia bacteria have very specific pH requirements and a change can adversely affect legume production. The application of water with high pH to already alkaline soils is not recommended.

Natural stream ecosystems require a narrow band of water pH. The release of large volumes of produced water without amended pH into streams could alter natural flow patterns and significantly impact on water quality and the health of rivers and wetlands.

Minor and trace elements pose a further threat to water quality. Depending on the origin of the produced water, unacceptable levels of aluminium, iron, strontium and barium may be present. Heavy metals are typically low in concentration, while organic contaminants such as heavy hydrocarbons are generally at very low levels. Nutrients are generally absent or present at low levels.

Irrigating with CSG produced water

The physical and chemical properties of CSG produced water have significant implications for its use in irrigated agriculture.

The use of untreated water is likely to result in:

- impaired plant growth due to salinity impacts on crops
- specific ion toxicity to plants (particularly sodium and chloride)
- damage to soil structure and permeability because of the high sodium and low calcium-magnesium concentrations
- possible impacts on shallow aquifers.

The suitability of water for irrigation in any particular situation is dependent on water quality and the soil characteristics of the intended site. The effects of salinity and sodicity in irrigation water are very situation specific so general water quality guidelines cannot be provided.

The application of produced water needs to be carefully considered on a case by case basis taking into account several interacting factors:

- water quality
- soil properties
- plant salt tolerance
- climate
- landscape
- irrigation management practices.

Treated CSG produced water

Untreated produced water commonly exceeds indicators of toxicity, scaling, clogging and corrosion hazards, and will require treatment to be suitable for use in irrigation.

Classification of irrigation water based on the level of chloride salts present and the sodium adsorption ratio (SAR) will assist in determining the suitability of the water for different soil types. While highly calcic soils can tolerate a higher SAR, sodic soils will become further degraded if water with a high SAR is applied.

Untreated produced water in the Namoi Catchment contains high TDS and high SAR, and is not suitable for use in irrigation, primarily due to the risk of salinity and sodicity.

Conventional guidelines for managing water quality in irrigation, such as ANZECC (2000), focus on quality issues commonly encountered with surface or production groundwater used for irrigation, emphasising irrigation salinity and sodicity, major ions of concern, and heavy metals and metalloids.

Before an irrigation project is developed for the use of produced water, the planning process should ideally include analysis within the ANZECC framework. Salinity and sodicity problems also need to be considered within the framework of both local and broader catchment issues such as regional water tables, groundwater pollution and surface water quality.

A limitation of the ANZECC system is it does not include guidelines for many of the very specific components of CSG produced water.

A thorough irrigation management plan will be required for the use of produced water to avoid degradation of soil and water resources and negative crop impacts. However there are currently no well-defined guidelines available for various quality measures for CSG produced water.

Soil suitability

The land and soil capability assessment scheme (NSW Office of Environment & Heritage 2012) assesses the sustainability of soil use based on factors such as water erosion, wind erosion, salinity, topsoil acidification, shallow soils/rockiness, soil structural decline, water logging and mass movement.

Soil classes relevant to northern NSW include:

Class 2: very good fertile cropping land with short, low slopes, which can be easily managed

Class 3: capable of supporting most land uses, but more intensive management is needed to avoid moderate degradation from a range of hazards

Class 4: generally not capable of sustaining high impact land uses without specialised management

Class 5: land is characterised as having severe limitations

Class 6: very severely limited land

The vertosol soils of the lower Namoi floodplain and the Liverpool Plains are mostly Class 3 and 4 with narrow belts of Class 2 land along the major drainage lines. If using treated CSG produced water on this land, intensive, specialised management will probably be necessary.

The lighter soils of the Pilliga Plateau in the Namoi Catchment are mostly Class 5, with localised areas of Class 6, and are most likely unsuitable for irrigation with produced water. Much of the land around the Narrabri Gas Project is Class 4 and Class 5 which means highly specialised management practices will be required for any irrigation development.

In northern NSW, vertosol soils of the alluvial floodplains often contain sodic subsoils. Sodic soils are prone to structural decline and require unique management. Where soils have the potential to become sodic, prevention is better than cure as chemical ameliorants for sodicity tend to have only short-term effects.

Appropriate soil survey and assessment is essential to identify areas where soil properties are suitable for irrigation with treated produced water. If applied to soil, treated produced water will require amelioration with calcium in either lime or gypsum form depending on the pH of the soil.

Summary

CSG produced water in northern NSW is of poor quality and low volume and reserves are likely to be short-lived.

CSG produced water is highly saline, high in sodium and contains little if any nutrients. It will require comprehensive treatment for re-use in irrigation. Without treatment it is likely to cause adverse effects in crops and damage to soils. If untreated produced water reaches aquifers or streams it is likely to have a detrimental effect on these water sources and the local ecology.

Any irrigation project proposal to use produced water would be prepared without definitive knowledge of key water parameters regarding quantity and quality and their variability over time as this information is currently unavailable.

Further reading

Primefact 1337 *Farm water quality and treatment*

Primefact 1344 *Interpreting water quality test results*

Primefact 1345 *Salinity tolerance in irrigated crops*

Rengasamy, North & Smith (2010) *Diagnosis and management of sodicity and salinity in soil and water in the Murray Irrigation region*. University of Adelaide SA

Acknowledgements

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QWC (2012) *Underground Water Impact Report for the Surat Cumulative Management Area*. Office of Groundwater Impact Assessment (consultation draft by Queensland Water Commission, May 2012), Queensland Government Department of Natural Resources and Mines, Brisbane, (http://dnrm.qld.gov.au/__data/assets/pdf_file/0016/31327/underground-water-impact-report.pdf)

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