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Understanding coal seam gas associated water, regulations and strategies for treatment

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ABSTRACT

The coal seam gas (CSG) industry is globally of potentially great importance economically. This study exemplifies the complex relationship between land use and management, groundwater impact and associated water treatment especially in relation to Queensland where a significant increase in the amount of gas extracted over the past 6 years has occurred. In order to effectively manage the environmental impact of the CSG industry it is necessary to appropriately understand the nature of the gas deposits, methods for gas collection, the physicochemical composition of the by-product associated water and the technologies available for water remediation. Australia is mainly considered arid and semi-arid and thus there is a need to not only beneficially reuse water resources but also protect existing ground water reservoirs such as the Great Artesian Basin (GAB). This paper focussed primarily on the Surat Basin located in Queensland and northern New South Wales. The mechanism for CSG formation, relation to local geological features, extraction approach and the potential impact/benefits of associated water was discussed. An outline of the current legislative requirements on physical and chemical properties of associated water in the Surat Basin was also provided, as well as the current treatment technologies used by the major CSG companies. This review was of significance in relation to the formulation of the most appropriate and cost effective management of associated water, while simultaneously preserving existing water resources and the environment.

Introduction

Gas industry

Conventional gas sources have been exploited in Australia for several years, and in 2013–14, 24 million tonnes of liquefied natural gas (LNG) was exported from Western Australia, the Northern Territory and Queensland with a combined revenue of A$16.4 billion (http://www.appea.com.au/oil-gas-explained/, 2015). Unconventional resources such as coal seam gas (CSG) have more recently emerged, and now represent an important part of the Queensland economy in terms of an energy resource for domestic consumption and export (Van Voast, 2003; Baker and Slater, 2008; Kinnon et al., 2010). The CSG industry has been operating in Queensland since the early 1990's, with commercial production commencing in 1996 (Kinnon et al., 2010). There were approximately 600 production wells drilled in Queensland in 2010–11 and annual gas production has evolved from 2 Petajoules (PJ) in 1997–98 to 234 PJ in 2010–11 (Queensland's Petroleum Exploration, 2011). The potential for CSG extraction in Queensland is due not only to the relatively shallow depths at which the gas is present, but also the large quantity available, with approximately 64% of the proven and probable reserves found in the Surat Basin (Papendick et al., 2011). The Surat Basin (Fig. 1) is located along Eastern Australia, within the southern section of Queensland and northern New South Wales, occupying an area of approximately 300,000 km^2 (Brakel et al., 2009).

It is predicted that the Surat Basin alone contains an estimated 33,000 PJ in methane reserves (Queensland's Petroleum Exploration, 2011). The key geological feature of the Surat Basin is the Walloon Subgroup, which is a series of volcanolithic sandstones, coal, mudstones and siltstones with a maximum thickness of about 250 m (Baker and Slater, 2008). The Walloon Subgroup is found at depths of approximately 200 to greater than 800 m, which is amenable for CSG to be extracted relatively easily (Papendick et al., 2011; Scott et al., 2007). Coal seams found in the Walloon Subgroup are geologically predictable and found in large quantities (Papendick et al., 2011; Rice and Claypool, 1981). Other gas

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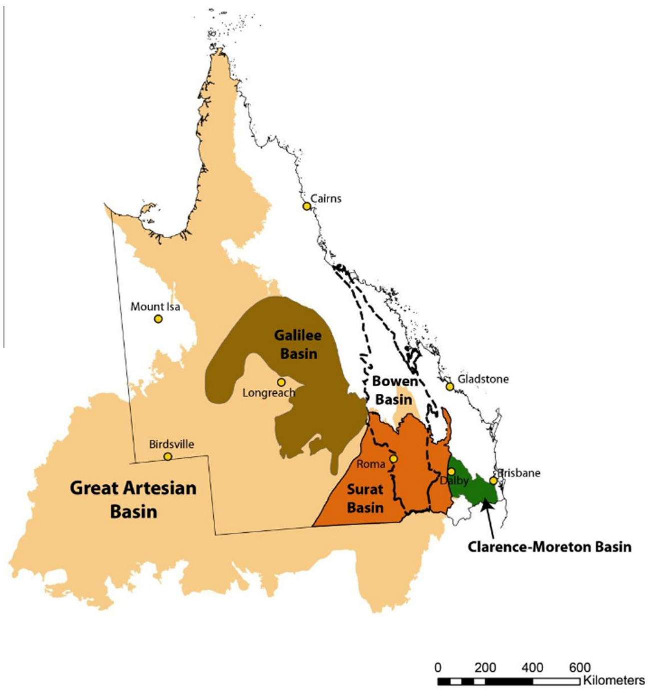

Fig. 1. The extent of the Surat Basin.

resources in Queensland include the Bowen, Galilee, and Clarence–Moreton basins (Wilkinson, 2011).

Associated water

Australia is prone to drought, with 70% of the Australian continent receiving less than 500 mm of rain annually and as such it is classed as arid or semi-arid (Wolfe, 2009). Therefore, the sustainability of water resources is of major concern. One of the greatest challenges faced by the CSG industry is the substantial volume of water produced during the gas extraction process known as CSG associated water. CSG associated water is typically brackish in character which does not allow it to be used for most large scale applications without being treated due to a high salinity and variable pH (Hamawand et al., 2013; Millar et al., 2014). In addition, the associated or produced water, has a highly variable chemical composition, and as such a universal treatment method is not available (Nghiem et al., 2011). This latter variability is significantly enhanced when comparing the northern and southern ends of the Surat Basin, due to the sheer size of this aquifer system, spanning over numerous geological compositions (Surat Gas Project Environmental Impact Statement Groundwater Impact Assessment, 2012). Similar variation in the composition of coal seam gas water has been found in samples from the US. For example, Dahm et al. described an extensive study of several thousand wells from the Rocky Mountain area and found a substantial range of salinities ranging from a few hundred mg/L total dissolved solids concentration to in excess of 35,000 mg/L (Dahm et al., 2011). Rice reported that the Ferron coal seam gas fields also exhibited major changes in water quality between individual wells (Rice, 2003). Reasons for the disparity and complexity of the associated water were outlined by Pashin et al. and included geological and hydrodynamic factors (Pashin et al., 2014). To aid selection of treatment options for the range of coal seam gas water types produced, Plumlee et al. developed a software program which took into account a large selection of operational parameters and options for beneficial reuse (Plumlee et al., 2014). Knowledge of the associated water characteristics in Australia is not as comprehensive compared to the US. Kinnon et al. reported analysis of coal seam water from the Bowen Basin in Queensland, and generally the total dissolved solids content was less than 10,000 mg/L (Kinnon et al., 2010). The dominant dissolved species were sodium, chloride and bicarbonate with minor amounts of alkaline earth ions, potassium, fluoride, aluminum and iron.

In theory, the availability of associated water should represent an opportunity for local communities due to the potential for beneficial reuse. However, public perception has been shown to view CSG mining as a threat to water supplies (Sherval and Hardiman, 2014). Tan et al. proposed that this latter viewpoint was partially due to a lack of information regarding the relationship between CSG mining operations and aquifers (Tan et al., 2015). Vink has also emphasized the dangers of misinformation inhibiting the development of the CSG industry and the need to accumulate data into one resource (Vink, 2014).

Consequently, it would be useful to gain a better understanding of the pertinent issues that encompass the geological aspects, extraction, legislation, reuse and treatment of associated water. There is a need to improve the management of the associated water produced in the coal seam gas industry, not only in Australia but in other areas of the world such as the US (Vance and Ganjegunte, 2010). This research focused in particular upon the Surat Basin, as it is the major CSG region on the Eastern coast of Australia. The aim of this paper was to facilitate water conservation in Australia and to guide appropriate management practices for the anticipated quantities of associated water.

Geology and stratigraphy

The Surat Basin is composed of sedimentary rocks from the Jurassic to Cretaceous periods (Exon, 1976) and is part of the Great Artesian Basin (GAB), which encompasses approximately one-fifth of Australia (Bekesi et al., 2012). There are a number of groundwater systems located within the GAB and these include the Condamine Alluvium (up to 150 m thick), the Kumbarilla Beds (100–200 m thick) and the Walloon Coal Measure (100 and 500 m thick). Underlying these systems are the Hutton Sandstone/Marburg Subgroups (120–180 m thick) and the Precipice Sandstone systems (Surat Gas Project Environmental Impact Statement Groundwater Impact Assessment, 2012). The Condamine Alluvium is situated west of the Surat Basin, while the Clarence–Moreton Basin lies to the east, they are connected by the Kumbarilla Ridge (Exon, 1976). The key lithostratigraphic units of the Surat Basin include the Kumbarilla Beds (comprising of Mooga, Gubberamunda and Springbok sandstones) overlying the Walloon Coal Measures, and the Walloon Coal Measures overlying Hutton/Marburg Sandstone (Exon, 1976). The groundwater systems of these geological formations are complex and aquifers potentially interconnected. Younger Tertiary basalts cap the Walloon Coal Measures and Hutton/Marburg Sandstone to the east of the Condamine Alluvium (Exon, 1976). The Kumbarilla Beds are described as restricted outcrop (visual exposure of bedrock) (Exon, 1976). The Hutton/Marburg Sandstone is made up of sandstone with interbedded siltstone, shale and mudstone (Exon, 1976). The Walloon Coal Measures are comprised of fine to medium grained, labile, argillaceous sandstone, siltstone, mudstone and coal, with minor calcareous sandstone, impure limestone and ironstone, and coals (located within the upper 75% of the geological sequence) (Exon, 1976). The geological sequence of the Surat Basin was deposited over time from the late Triassic, 206–227 million years ago (Ma) to the early Cretaceous, 99–144 Ma while the Walloon Coal Measures were predominately deposited from the Early Middle Jurassic to the Late Jurassic (197–145 Ma) (Scott et al., 2007; Exon, 1976).