Redefining CSG "Waste" Water: New Opportunities for Managed Aquifer Recharge

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Despite calls for increased gas exploration and development, water impacts by coal seam gas (CSG) projects are a continuing concern for many. Apart from fears about hydraulic fracturing, key tensions relate to the quantity of water co-produced with the gas. Some projects in Queensland, Australia, have been required to conduct aquifer injection trials with the CSG produced water: essentially, government-mandated Managed Aquifer Recharge (MAR). MAR is usually associated with other types of excess surface water. Aquifer injection of CSG produced water is potentially a key opportunity for the process. Despite this, the issues around injection of CSG produced water have not been considered in the developing policy frameworks for MAR. This article suggests that further research in respect of the regulatory frameworks governing aquifer injection in the CSG industry could guide regulatory reform not only relating to the CSG industry but also in respect of MAR projects generally.

Introduction

In 2009, I was discussing the newly established CSG industry's issues with water extraction with an American friend who is a geologist. At the time, these issues were making media headlines. He casually remarked that they should reinject the CSG produced water underground. His remarks seemed to make sense to my non-scientist's ears. This would reduce surface disposal impacts and address the drawdown of aquifers associated with the CSG industry. He could not have then known that his words would prove to be prophetic because this is exactly what some CSG operators have been required to do since then. Although, we know now that it was simpler said than done. Apart from the practical, technical and economic issues relating to such a process, how aquifer injection of CSG produced water would and should be governed,[1] in an already complicated regulatory framework, had not yet been considered.

CSG projects have developed since then into a multibillion dollar industry in Australia. However, a significant issue for the industry continues to be the management of water that is co-produced by these projects along with the gas. A key issue involves the quantum of extraction of groundwater as well as how to manage the co-produced water after extraction.[2]

CSG development in Australia appears to be undergoing a resurgence. The release of the Australian Energy Market Operator's report in March 2017 warned there would be energy shortages in New South Wales, Victoria and South Australia in the coming years with Queensland following thereafter.[3] It

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[1] The term "governed", rather than "regulated", is used to acknowledge that what is relevant here is not simply the rules mandated by a government, that is, "regulation", but "governance" which is defined by World Development Report team 2017 as the broader "process through which state and nonstate actors interact to design and implement policies within a given set of formal and informal rules that shape and are shaped by power": World Bank, *World Development Report 2017, Governance and the Law* (2017) <http://www.worldbank.org/en/publication/wdr2017>.

[2] Gary Bryner, "Coalbed Methane Development in the Intermountain West: Producing Energy and Protecting Water" (2004) 4 *Wyoming Law Review* 541.

[3] Australian Energy Market Operator, *Gas Statement of Opportunities for Eastern and South Eastern Australia* (March 2017) <https://www.aemo.com.au/Media-Centre/2017-Gas-Statement-of-Opportunities-released>.

advised that additional production of gas for domestic markets would be required.[4] In response, the Prime Minister Malcolm Turnbull immediately called on State governments to loosen restrictions on CSG exploration and development.[5] Since then, the Queensland Palaszczuk Government opened a further 400 square kilometres of land in the Surat and Bowen Basins for gas development.[6] These events reveal that there is now more than ever a need for research which considers governance of CSG projects, in particular, mechanisms relating to water impacts.

Water law generally governs water use. However, the produced water from CSG projects has traditionally, and legally, been considered a waste rather than a water resource.[7] In other words, this water is not "water" in the sense governed by water governance frameworks, it is something outside of this framework: a "waste". How we govern this "waste" water is generally through environmental protection regimes and the existing resources industry framework generally and not water frameworks.

The technical advances in water resource management relating to sewage, stormwater and excess surface water involving aquifer injection known as Managed Aquifer Recharge (MAR) are now being used in the resources industry. In a nutshell, MAR involves replenishing aquifers with excess surface water through a managed process. Augmentation of existing aquifers can represent a highly effective means of water storage that can mitigate the extensive environmental and efficiency issues of surface dams. It is used to augment traditional supplies as well as restoring over-exploited aquifers.[8] However, the "waste" water produced by the resources industry has not been generally considered by scholars within the emerging policy framework relating to MAR. As a "waste", produced water if injected, is usually governed within the resources and environmental protection legislation. MAR using CSG produced water is oftentimes referred to as simply "aquifer injection" even though it is essentially a similar process. As is often the case, technological advances precede the need for governance change. New scientific and technological understandings challenge how we view certain issues; such as, what we consider a "waste" and what we consider "water".[9] This is a case in point where advances in energy resource extraction have unexpectedly impacted on water resources and the environment. The boundary line between gas resource activities and water-related activities has been blurred.

Some jurisdictions have implemented moratoriums or bans in respect of unconventional gas[10] development particularly where resources are predominantly shale gas rather than CSG.[11] However,

[4] Australian Energy Market Operator, n 3.

[5] Adam Gartrell, James Massola and Nick O'Malley, "Malcolm Turnbull Calls Energy Crisis Talks amid Gas Shortage Blackout Warnings", *Sydney Morning Herald*, 9 March 2017 <http://www.smh.com.au/federal-politics/political-news/malcolm-turnbull-calls-energy-crisis-talks-amid-gas-shortage-blackout-warnings-20170309-guualc.html>.

[6] See the media statement by the Queensland Minister for State Development and Minister for Natural Resources and Mines, Dr Anthony Lynham, *Palaszczuk Government Opens More Land for Domestic Gas Supply* (6 September 2017) <http://statements.qld.gov.au/Statement/2017/9/6/palaszczuk-government-opens-more-land-for-domestic-gas-supply>.

[7] Robert Beck, "Current Water Issues in Oil and Gas Development and Production: Will Water Control What Energy We Have?" (2010) 49 *Washburn Law Journal* 423, 432; see also definition of "waste" in *Environmental Protection Act 1994* (Qld) s 13.

[8] John Ward and Peter Dillon, "Principles to Coordinate Managed Aquifer Recharge with Natural Resource Management Policies in Australia" (2012) 20 *Hydrogeology Journal* 943.

[9] For commentary in respect of opportunities relating to produced water from oil and gas production to alleviate water scarcity, see Measrainsey Meng, Mo Chen and Kelly T Saunders, "Evaluating the Feasibility of Using Produced Water from Oil and Natural Gas production to Address Water Scarcity in California's Central Valley" (2016) 8 *Sustainability* 1318. This is similar to the "rethinking" that has occurred in relation to sewage; see Janice Gray and Alex Gardner, "Legal Access to Sewage and the 'Reinvention' of Waste Water" (2008) 12 *Australasian Journal of Natural Resources Law and Policy* 115.

[10] For an explanation of the different types of unconventional gas, please refer to the glossary.

[11] An unconventional gas moratorium has been in place in Victoria since 2012 and has been extended to 2020, see the Media Statement by the Premier, Daniel Andrews, *Victoria Bans Fracking to Protect Farmers* (30 August 2016) <https://284532a540b00726ab7e-ff7c063c60e1f1cafc9413f00ac5293c.ssl.cf4.rackcdn.com/wp-content/uploads/2016/08/160830-Victoria-Bans-Fracking-To-Protect-Farmers.pdf>. In New South Wales, there are restrictions on gas exploration within areas important for horse breeding and viticulture as well as within 2 kilometres of residential areas, see Department of Industry, Resources and Energy, *Protections and Controls*, New South Wales Government <http://www.resourcesandenergy.nsw.gov.au/landholders-and-community/coal-seam-gas/the-facts/protections-and-controls#_restricted-areas>; the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (NSW) cl 9A: <http://www.legislation.nsw.gov.au/#/view/EPI/2007/65/part2/cl9a>;

where CSG development is well-entrenched, such as Queensland, Australia, and various States in the USA, the impacts of that development are issues that require consideration.

The focus of this article relates to the unavoidable extraction of water during CSG production, termed "CSG produced water", and the application of this produced water using aquifer injection, rather than issues around hydraulic fracturing (or fracking) or other water use by CSG projects. The article highlights that an investigation of the governance of MAR involving CSG produced water, two activities not often contemplated together, could reduce the environmental impacts of CSG extraction and solve a number of current issues facing energy and water security. First I provide an overview of the process of CSG production and how water is inextricably linked to the extraction of this resource. The issue of excessive "wastewater" production in CSG projects along with the inherent conflicts with other users is then presented as well as a summary of what usually happens to the CSG produced water. This discussion is followed by an analysis of the literature highlighting the governance issues relating to CSG extraction and produced water in both Australia and the USA. A description of MAR and a summary of the current literature relating to MAR is then presented so that its applicability to aquifer injection projects using CSG produced water can be considered. The article concludes with recommendations for further research.

BACKGROUND

CSG Projects and CSG Produced Water Generally

A basic understanding of the geology and hydrogeology relating to CSG and the process of extraction is necessary before CSG project water issues can be fully appreciated.

Coal and CSG formations occur in strata where sedimentary organic material over time has been covered by further sedimentary layers. CSG is generated within the coal deposits through thermogenic (heat-driven) and/or biogenic (microbe-driven) processes.[12] Generally, the process of transformation is described as occurring in six stages from peat, to lignite, to sub-bituminous coal, to bituminous coal, then anthracite coal and finally graphite.[13] The process of sedimentation produces alternating permeable aquifers (such as sandstone and the coal measures) and impermeable aquitards and aquicludes (siltstone and mudstone). Subsequent uplift halts the sedimentary process and erosion of the exposed layers results in water intrusion which then travels through the permeable aquifer layers.

The CSG binds to the "coal reservoirs by absorption and adsorption on or within macromolecular nanopores, pores, cleats and/or fractures" and is usually found in a water-saturated condition.[14] The water can be the product of the peatification and coalification process or from recharge through the permeable aquifer (but it is usually the latter).[15] In some areas, the same formation supplies good quality potable water. Shallow coal deposits can be mined; however, the deeper formations are now being utilised for their methane production.[16] In Australia, coal seams are generally from 200m to 1km

the CSG exclusion zones map at <http://www.planning.nsw.gov.au/Policy-and-Legislation/Mining-and-Resources/~/media/79E0A0BFF29946B0A1FFD7065CC70187.ashx>; France has also instituted a ban on unconventional gas exploration and development see International Energy Agency, *Energy Policies of IEA Countries, France, 2016 Review* (2017) 105 <https://www.iea.org/publications/freepublications/publication/Energy_Policies_of_IEA_Countries_France_2016_Review.pdf>.

[12] All Consulting and Montana Board of Oil and Gas Conservation, *Handbook on Best Management Practices and Mitigation Strategies for Coal Bed Methane in the Montana Portion of the Powder River Basin* (2002) <http://bogc.dnrc.mt.gov/PDF/BMPHandbookFinal.pdf>; H Rodney de Bruin et al, *Coalbed Methane in Wyoming* (Wyoming State Geological Survey, 2004) <http://sales.wsgs.wyo.gov/coalbed-methane-in-wyoming/>; Romeo M Flores, *Coal and Coalbed Gas: Fueling the Future*, (Elsevier Science, 2013), 218.

[13] Chantelle A Rebello et al, "Understanding Coal Seam Gas Associated Water, Regulations and Strategies for Treatment" (2016) 13 *Journal of Unconventional Oil and Gas Resources* 32, 34.

[14] Flores, n 12; Colby Barrett, "Fitting a Square Peg in a Round (Drill) Hole: The Evolving Legal Treatment of Coal Bed Methane Produced Water in the Intermountain West" (2008) 38 *Environmental Law Reporter News & Analysis* 10661, 10663.

[15] Romeo M Flores, *Coalbed Methane in the Powder River Basin, Wyoming and Montana: An Assessment of the Tertiary-Upper Cretaceous Coalbed Methane Total Petroleum System* (US Geological Survey Digital Data Series DDS–69–C, 2004) 7 <http://pubs.usgs.gov/dds/dds-069/dds-069-c/REPORTS/Chapter_2.pdf>.

[16] Barrett, n 14, 10662.

deep.[17] In the USA, they are typically no more than 1.6km deep.[18] As the CSG forms onto the surface of the coal particles, the coal seam is therefore both the source and the reservoir for the gas.[19] "Conventional" methods of drilling whereby a well is drilled into the reservoir to release the gas are not possible because the gas resource is adsorbed throughout the seam. As the CSG resource occurs over relatively large areas, multiple wells are drilled into the coal seam and the water must first be extracted, depressurising the coal measures so that the gas can be pumped out.

The quality and quantity of the produced water depends on the geology and hydrology of the target formation as well as the underlying and overlying units and will change over the life of a project.[20] It is often related to the depth of the coal seam with younger shallower coals being more porous and therefore having higher water content.[21] Barrett explains that as "coals mature and consolidate, their porosity decreases, and water is driven into the surrounding strata" and "the net effect … is a general salinity gradient that increases with depth, and a water to coal ratio that decreases with depth".[22] In Australia, the southern coalfields are considered "dry" and the ratio of water to gas increases northwards.[23]

The chemical composition of the produced water also depends on the depositional environment of the coal, the thermal maturity of the coal, the flux of freshwater into the formation from surrounding formations and the time of residence of the water.[24] Characteristics generally associated with produced water are high salinity and high total dissolved solids (TDS), a high sodium absorption ratio ("SAR" or sodicity) and high alkalinity.[25] TDS is the total amount of salts or mobile charged ions dissolved in the water and usually includes sodium, potassium, magnesium, calcium, strontium, barium, iron, aluminium, bicarbonate, chloride and sulphates.[26] The variable nature of produced water means that universal treatment methods are not available.[27] Although, to give perspective to this article, the water quality in the Walloon Coal Measures which is the source of CSG in the Surat Basin in Queensland Australia varies from fresh or potable to saline.[28]

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[17] John Williams Scientific Services Pty Ltd, *An Analysis of Coal Seam Gas Production and Natural Resource Management in Australia Issues and Ways Forward* (Australian Council of Environmental Deans and Directors, 2012) <https://www.aie.org.au/AIE/Documents/Oil_Gas_121114.pdf>.

[18] 5,000 feet; All Consulting, *Coal Bed Methane Primer, New Source of Natural Gas – Environmental Implications, Background and Development in the Rocky Mountain West* (February 2004) 10 <http://www.all-llc.com/publicdownloads/CBMPRIMERFINAL.pdf>.

[19] Office of Groundwater Impact Assessment, *Underground Water Impact Report for the Surat Cumulative Basin Management Area* (2016) 5 <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0007/345616/uwir-surat-basin-2016.pdf>.

[20] Michael J Day and Arthur P O'Hayre, "Regulation and Development of Coalbed Methane. Management of Produced Water in Coalbed Methane Operations. Paper 12A" (2002) 4 *Rocky Mountain Mineral Law Foundation Institute* 1; Graeme J Millar, Sara J Couperthwaite and Cameron D Moodliar, "Strategies for the Management and Treatment of Coal Seam Gas Associated Water" (2016) 57 *Renewable and Sustainable Energy Reviews* 669.

[21] Barrett, n 14, 10663.

[22] Barrett, n 14, 10663.

[23] PJ Davies, DB Gore and SJ Khan, "Managing Produced Water from Coal Seam Gas Projects: Implications for an Emerging Industry in Australia" (2015) 22 *Environmental Science Pollution Research International* 10981, 10982.

[24] Davies, Gore and Khan, n 23; Rebello et al, n 13.

[25] John Veil, *US Produced Water Volumes and Management Practices 2012* (Groundwater Protection Council, 2015) <http://www.gwpc.org/sites/default/files/Produced%20Water%20Report%202014-GWPC_0.pdf>; Rebello et al, n 13.

[26] Millar, Couperthwaite and Moodliar, n 20, 672.

[27] Rebello et al, n 13; Department of Environment and Heritage Protection, *Coal Seam Gas Water Management Policy* (Queensland Government, 2012) <http://www.ehp.qld.gov.au/assets/documents/regulation/rs-po-csg-water-management-policy.pdf>; C Stephen Herlihy, "Trading Water for Gas: Application of the Public Interest Review to Coalbed Methane Produced Water Discharge in Wyoming" (2009) 9 *Wyoming Law Review* 455, 461.

[28] Klohn Crippen Berger, *Hydrogeological Assessment of the Great Artesian Basin – Characterisation of Aquifer Groups Surat Basin* (2016) 30 <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0008/1039454/gab-hydrogeological-surat.pdf>. The average salinity of the Walloon Coal Measures is 3,000 mg/L; see Office of Groundwater Impact Assessment, n 19, 35. For a detailed analysis of further water quality parameters see Chantelle Rebello et al, "Coal Seam Water Quality and the Impact upon Management Strategies" (2017) 150 *Journal of Petroleum Science and Engineering* 323; the salinity of the Fort Union Formation in the Powder River Basin, Wyoming averages between 1000 and 1,350 mg/L; see David Copeland and Megan L Ewald (eds), *Water Associated with Coal Beds in Wyoming's Powder River Basin: Geology, Hydrology, and Water Quality* (Wyoming State Geological Survey Exploration Memoir, No 2, 2008).

The Problem of CSG Produced Water

CSG projects in Australia and in the USA, have been perceived as directly competing with agriculture and pastoralists for water resources due to the quantum of water co-produced along with the CSG. This is unsurprising as often the gas resource is located very near or is itself a groundwater source. The CSG resources in the Surat Basin, Queensland are located within the Great Artesian Basin (GAB). The Walloon Coal Measures which is the source of the CSG, is itself a GAB aquifer and is a groundwater source for agriculture,[29] and underlie the Condamine Alluvium which is the largest allocated groundwater source in Queensland.[30] In parts of the Rocky Mountains West, such as the Powder River Basin in Wyoming and Montana, the CSG reserves are also located within main potable water sources.[31] The Fort Union Formation is the source of the CSG as well as the main potable water source for the town of Gillette Wyoming as "the coal measures transmit more water than the sandstones".[32] There are approximately 14,000 permitted non-CSG water wells and more than 36,000 CSG wells were drilled in the Powder River Basin.[33] Ninety-five percent of the world's freshwater sources, excluding glaciers, is groundwater and these sources supply half the drinking water in the USA.[34] Therefore, any industry which impacts on this resource will be controversial.

While extraction of conventional oil and gas and other types of unconventional gas also produce water, the quantities of produced water for these other types of petroleum and gas are normally much smaller.[35] Therefore the disposal of CSG produced water creates unique practical and environmental issues. As the quality of this produced water varies widely from drinkable to hazardous (principally in terms of TDS, SAR and electrical conductivity), management practices in respect of the disposal of the water also vary.[36] Furthermore, the co-production of water along with the gas is a substantial economic issue for the industry. As CSG wells produce less gas than conventional wells,[37] the cost of disposal of the co-produced water is a significant expense in any project, and an additional factor influencing management practices.

The quantities of water involved in CSG extraction are immense. The production of water is greatest in the initial stages of pumping prior to accessing the CSG and the amounts reduce as the CSG recovery increases until the quantum of gas recovery becomes uneconomical (see Figure 1 below). Estimates in respect of the production of water associated with the Queensland CSG industry have varied (from 140 GL/y to 300 GL/y)[38] for the peak producing years. Although the most recent assessment sets the figure at

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[29] Office of Groundwater Impact Assessment, n 19; see also Brian Towler et al, "An Overview of the Coal Seam Gas Developments in Queensland" (2016) 31 *Journal of Natural Gas Science and Engineering* 249, 263.

[30] Sue Vink et al, *Scoping Study: Groundwater Impacts of Coal Seam Gas Development – Assessment and Monitoring* (22 December 2008) Centre for Water in the Minerals Industry, Sustainable Minerals Institute, University Queensland, 8 <https://www.researchgate.net/publication/43515035_Scoping_Study_Groundwater_Impacts_of_Coal_Seam_Gas_Development_-_Assessment_and_Monitoring>.

[31] Day and O'Hayre, n 20; Tom Myers, "Groundwater Management and Coal Bed Methane Development in the Powder River Basin of Montana" (2009) 368 *Journal of Hydrology* 178, 180.

[32] All Consulting, n 18, 20.

[33] Karl G Taboga, James E Stafford and James R Rodgers, *Groundwater Response in the Sandstones of the Wasatch and Fort Union Formations, Powder River Basin, Wyoming* (Report of Investigations 74, 2017) 2 <http://www.wsgs.wyo.gov/products/wsgs-2017-ri-74.pdf>.

[34] Thomas F Darin, "Waste or Wasted? Rethinking the Regulation of Coalbed Methane Byproduct Water in the Rocky Mountains: A Comparative Analysis of Approaches to Coalbed Methane Produced Water Quantity. Legal Issues in Utah, New Mexico, Colorado, Montana and Wyoming" (2002) 17 *Journal of Environmental Law & Litigation* 281, 295.

[35] International Energy Agency, *Golden Rules for a Golden Age of Gas – World Energy Outlook Special Report on Unconventional Gas* (2012) 34 <http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf>.

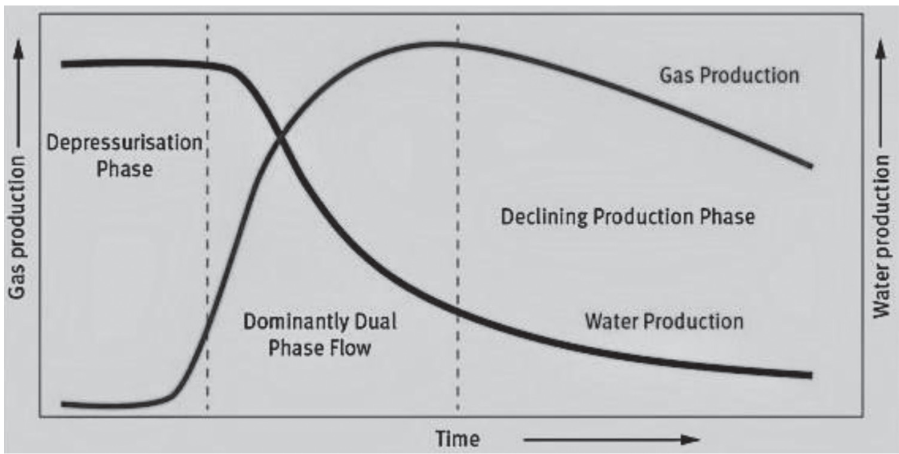
[36] Herlihy, n 27, 461.

[37] All Consulting, n 18, 16.

[38] Office of Groundwater Impact Assessment, Queensland Water Commission, *Underground Water Impact Report for the Surat Cumulative Management Area* (2012) <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0007/345616/uwir-surat-basin-2016.pdf>; Klohn Crippen Berger, *Forecasting Coal Seam Gas Water Production in Queensland's Surat and Southern Bowen Basins – Technical Report* (Queensland Department of Natural Resources and Mines, September 2012) <https://www.klohn.com/rd/technical-papers/forecasting-coal-seam-gas-water-production-in-queenslands-surat-and-southern-bowen-basins-technical-report/>.

65 GL/y increasing to about 110 GL/Y in the next three years with the average water extraction predicted to be 70 GL/y.[39] In New South Wales, while exploration is extensive, production of water is minimal as the industry has not yet reached an operational phase.[40] Estimates with respect to the USA also vary. However, production of water in the Wyoming portion of the Powder River Basin for 2007 was approximately 101 GL/yr.[41] During 2008 production of water as part of CSG extraction for the entire USA was estimated at 180 GL.[42] The International Energy Agency (IEA) puts this latter quantity in perspective by noting that it is the same quantity as the "annual direct water consumption of the city of San Francisco".[43]

FIGURE 1. Typical gas and water flow in coal seam gas production taken from the Queensland Water Commission, Office of Groundwater Impact Assessment.[44]



In addition to the competition for the water resource and the immense quantities involved, estimates in respect of how long it would take to recharge the relevant aquifers (or naturally reverse the impacts of extraction) are a key concern. The GAB, in which the Walloon Coal Measures are located, is one of the largest groundwater systems in the world.[45] Klohn Crippen Berger explains that the larger the system the larger the response time for groundwater to move through the system (for both stress and recharge events).[46] For the GAB, they estimate that the response time could be hundreds to thousands of years.[47] Myers notes with respect to the Powder River Basin in Wyoming that it will take more than 200 years for the basin to recover even though drawdown of the entire basin may only indicate a metre or less.[48] Although others suggest that following the end of CSG production in the Powder River Basin it will take 800–1,500 years to

[39] Office of Groundwater Impact Assessment, n 19, 88.

[40] Production of water in the Sydney Basin at Camden was only 4.8 ML in total in 2012, see NSW Department of Primary Industries, Water, *Managing Coal Seam Gas Produced Water* <http://www.water.nsw.gov.au/water-management/groundwater/water-and-coal-seam-gas/managing-coal-seam-gas-produced-water>.

[41] Copeland and Ewald, n 28, 154.

[42] International Energy Agency, n 35, 35.

[43] International Energy Agency, n 35, 35.

[44] Office of Groundwater Impact Assessment, n 19, 6.

[45] Klohn Crippen Berger, n 28, i.

[46] Klohn Crippen Berger, n 28, iv.

[47] Klohn Crippen Berger, n 28, iv.

[48] However, he also notes that studies with respect to reinjection of produced water indicate that the water levels could recover more quickly using MAR: Myers, n 31.

recharge the aquifer.[49] Further, in 2017 the Wyoming State Geological Survey concluded that groundwater level responses remain unpredictable post CSG production.[50] Scholars have highlighted that this water is generally non-renewable as it is water from aquifers that are considered "fossil aquifers".[51] Any extraction of water from fossil aquifers requires a very high level of justification. Many fear that the other existing competing users of this water, such as agriculture, will feel the impacts of the industry long after it has left.

What Usually Happens to Produced Water from CSG Projects?

How the CSG produced water is treated depends on the water quality characteristics and the quantity that is produced as well as the topography of the land where the water is extracted. The issue here is whether the water is wasted (disposed of in ways that prevent its further use) or beneficially used by other water users (thus minimising extraction that would occur elsewhere).

In Queensland, Australia, where most CSG production occurs, historically evaporation ponds had been used as the primary management option, although the practice came to be recognised as presenting significant ecological risks.[52] In 2012, the *Environmental Protection Act 1994* (Qld) (*EP Act*) was amended as part of the Greentape Reduction reforms[53] to restrict the use of evaporation dams in connection with CSG activity.[54]

The Queensland Government announced in July 2011 that aquifer injection would be its priority for management of CSG water. It stated that "reinjection to the coal seam, or treatment and injection to a stressed aquifer, is the first priority management option of this water where feasible".[55] However, a change of government in 2012 and a further review resulted in a change in policy so that aquifer injection was not elevated as a priority but rather placed as an equally preferred option for beneficial reuse of the produced water. The *Coal Seam Gas Water Management Policy 2012* requires that CSG produced water be first beneficially reused (through injection, release or substitution of other water by either the environment, existing or new water users and industries) and, second, treated and disposed of in a way that avoids and then minimises and mitigates impacts on the environment.[56] Previous disposal methods (not including evaporation ponds) would be transitioned.

Government policy aside, what does generally happen to the CSG produced water in Queensland? Conditions in environmental authorities (EAs) issued under the *EP Act* can provide us with a clue as to the current practice in Queensland. Standard conditions included in the EAs often allow for CSG produced water to be used for drilling, well-hole and stimulation activities, dust suppression, construction, irrigation, domestic and stock watering, landscaping and revegetation, research and development as well as industrial purposes such as coal washing, power stations and water treatment facilities. The CSG produced water may also be transferred to third parties for many of these purposes. Specifically tailored conditions often allow treated CSG produced water to be released into specific watercourses. EAs will also explicitly note the dams permitted as part of a project. Further, all operators have had to conduct feasibility or pilot aquifer injection studies. By reviewing the current EAs issued in respect of

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[49] Bryner, n 2.

[50] Taboga, Stafford and Rodgers, n 33, 15.

[51] National Research Council et al, *Management and Effects of Coalbed Methane Produced Water in the Western United States* (National Academies Press, 2010) 188.

[52] Davies, Gore and Khan, n 23.

[53] By the *Environmental Protection (Greentape Reduction) and Other Legislation Amendment Act 2012* (Qld).

[54] The amendments require an operator to evaluate best practice environmental management for managing the CSG water and consider alternative ways for managing the water. Only when this evaluation reveals that there are no other feasible alternatives for managing the CSG water would evaporation ponds be permitted.

[55] Queensland Department of Employment Economic Development and Innovation, *Surat Basin Future Directions Statement – Final Report* (July 2011) <http://www.cabinet.qld.gov.au/documents/2011/may/surat%20basin%20future%20directions%20final%20report/Attachments/Surat%20Basin%20future%20Directions%20final%20report.pdf>.

[56] Department of Environment and Heritage Protection, n 27.

the four main CSG producers in Queensland, it becomes clear that many storage ponds, albeit named as "regulated dams" and "low consequence dams", remain. Table 1 below provides a snap-shot of specifically authorised dams, aquifer injection trials and authorised watercourse release for the four main operators in Queensland.

TABLE 1. Snapshot of some of the authorised CSG produced water disposal options in Queensland.

Operator (principal or first holder)	Environmental authority (EA)	Specifically authorised CSG produced water disposal methods
Santos CSG Pty Ltd	Roma Shallow Gas Project Area EA EPPG00898213 dated 19 September 2017	Two regulated[57] dams greater or equal to 400ML with a maximum total area of 90ha, 28 regulated dams smaller than 400ML in size with a total area of 305ha and 3,161 non-regulated dams with a total of 790ha (A1). Evaporation dams may be used for the evaporation of CSG produced water concentrate (which is the result of a reverse osmosis water treatment process) until 1 January 2019 (H7)
		Treated CSG produced water injection trial is authorised but limited to 180 days for the injection activities at the Emu Park 1 well (13 wells) (BE1–BE3) not exceeding 180ML over the duration of the trial (BE9) and not exceeding 24ML per day (BE10).
Santos TOGA Pty Ltd	Fairview Arcadia Project EA EPPG00928713 dated 19 September 2017	Five regulated dams greater or equal to 400ML with a maximum total area of 250ha, 43 regulated dams less than 400ML in size with a maximum total area of 270ha and 4,910 low hazard dams being in total no more than 1,229ha in size (A1)
		Release of treated CSG produced water is authorised to the Tributary of Hutton Creek (maximum 5.1ML per day) and the Tributary of the Dawson River (maximum 18ML per day) until 17 May 2024 (B14–B35)
		Release of CSG produced water to the Dawson River (B30-B39)
		Aquifer injection of CSG produced water or brine is authorised into the Timbury Hills Formation or CSG depleted source formations (BE2–BE25)
QGC Pty Ltd and Australia Pacific LNG Pty Ltd (AP LNG)	Ruby Project Area EA EPPG00797813 dated 27 November 2017	406 non-regulated dams with a maximum area of 406ha and 20 regulated dams, 6800ML in total capacity and 91ha maximum total area (condition A1)

[57] The term "regulated dam" refers to a dam classed as within the significant or high consequence category as assessed using the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures, prepared by the Queensland Department of Environment and Heritage Protection from time to time. The current version of the manual is available at <https://www.ehp.qld.gov.au/assets/documents/regulation/era-mn-assessing-consequence-hydraulic-performance.pdf>.

TABLE 1. *Continued*

QGC Pty Ltd	Woleebee Creek Project Area EA EPPG00903513 dated 15 September 2016	1,450 non-regulated dams with a maximum total capacity of 7200ML and 700ha and 23 regulated dams with a maximum capacity of 8,800ML in total and 223ha (condition A1)
		Fluid injection trial requires a stage 1A injection management plan prior to progressing to stage 1B field tests (B18 and B19). However, stages 2 and 3 field and full-scale injection are not authorised (B20).
QGC Pty Ltd	Bellevue Project Area EA EPPG00611313 dated 7 November 2017	49 non-regulated dams each with a maximum capacity of 189ML and 18ha and 12 regulated dams with a maximum capacity of 1,005ML and 16.5ha (condition A1)
Arrow Energy Pty Ltd	Dalby Expansion Project EA EPPG00972513 dated 9 May 2017	22 regulated dams (condition A1)
		Treated CSG produced water may be discharged to Wilkie Creek (B15–B404)
		Aquifer injection trial (BE2) limited to a period of 180 days followed by a six-month recovery period (BE4)
CH4 Pty Ltd (Arrow Energy)	Moranbah Gas Project EA EPPG00935413 dated 21 September 2017	17 regulated structures up to 400 ML (condition A1b)
		CSG produced water may be discharged into the Isaac River (G1–G7)
AP LNG	Spring Gully EA EPPG00885313 dated 8 February 2017	48 regulated dams and 600 low consequence dams for storing CSG produced water (condition A1). 10 existing dams are noted which include two evaporation ponds of 68ML each (condition C1)
		Treated or good quality CSG produced water (RO permeate) may be discharged to Eastern Gully and Tributary to Eurombah Creek (B5) up until 31 March 2020 (B2)
		Aquifer injection of treated RO permeate into three wells targeting the Precipice Sandstone is authorised (B41).
AP LNG	Combabula Development Area EA EPPG00853213 dated 31 August 2017	30 regulated dams and 1,850 low consequence dams (condition A1), including seven evaporation dams (conditions C29 and C30).
		Aquifer injection of treated CSG produced water is authorised into the Precipice Sandstone using 21 wells (B52).
		Treated CSG produced water may be released to an unnamed tributary of Yuleba Creek (B70)

TABLE 1. *Continued*

AP LNG	Ramyard/Woleebee EA EPPG00672313 dated 23 May 2016	One regulated dam (noted as an evaporation dam- Ramyard Pilot Pond (C19)) of less than 400ML with a maximum size of 9ha (condition A1). Although condition C24 forbids evaporation dams for CSG activities.
AP LNG	Condabri Development Area EA EPPG00853013 dated 23 May 2016	30 regulated dams and 695 low consequence dams (condition A1).
		Treated CSG produced water may be released to the Condamine River from 1 January 2015 to 31 December 2040 not exceeding 2.3GL per annum (B2–B23).
		Stage 1 injection management trial must be developed (B62) and stage 2 aquifer injection into the Gubberamunda, Hutton and Precipice Sandstone formations via three injection wells are authorised for 12 months (B64–B66).
AP LNG	Walloons Development Area EA EPPG00968013 dated 10 August 2017	30 regulated dams and 1,130 low consequence dams (A1)
		Treated CSG produced water may be released to the Condamine River until 31 December 2040 (B2–B28)
		Reverse osmosis permeate or blend of reverse osmosis permeate and raw CSG water may be injected into the Gubberamunda formation for a period of 12 months after phase 1 and phase 2 injection management plans have been developed (B77–B101)

The table shows clearly the unavoidable problem of co-production of huge amounts of water. The fact that Queensland continues to have many structures that look and seem like the banned "evaporation ponds" points to the difficulty of translating a legal mandate into physical compliance: an "implementation gap" as described by Daniel Farber.[58] While the CSG produced water is waiting to be treated, beneficially reused by third parties, used in aquifer injection or discharged to streams, the fact remains: it still needs to be stored somewhere in structures that are physically identical to evaporation ponds.

Since January 2015, AP LNG has proceeded to the operational stage for its two aquifer injection projects using treated CSG produced water at Reedy Creek and Spring Gully.[59] Its 2015–2016 Groundwater Report states that over 8GL of CSG produced water has been injected to June 2016 (15% of the CSG produced water at Spring Gully and 83% of the CSG produced water at Reedy Creek).[60] The project operator was required and authorised to undertake aquifer injection via its environment

[58] Daniel A Farber, "The Implementation Gap in Environmental Law" (2016) 16 *Journal of Korean Law* 3.

[59] Australia Pacific LNG, *2015–2016 Groundwater Assessment Report* (2016) 109 <https://www.aplng.com.au/content/dam/aplng/compliance/management-plans/2015-2016_Groundwater_Assessment.pdf>.

[60] Australia Pacific LNG, n 59.

permits at the federal and State levels.[61] Increased water levels have been observed 75kms from the Reedy Creek bore field and are attributed to the injection project.[62] Other trials have been explored by the other main gas producers.[63] The Roma Managed Aquifer Recharge Study by Santos and CSIRO and URS Pty Ltd aimed at exploring the potential of using produced water to augment the potable water supplies of the Maranoa Regional Council in Queensland.[64] A field of wells would inject up to 20ML/day of treated produced water into the Gubberamunda Formation.[65] The Coal Seam Water Monitoring and Management Annual Report 2015 published by Santos GLNG in March 2016 states that it is assessing the feasibility of this project.[66]

In the United States in 2012, 93% of all produced water from onshore oil and gas wells (for both conventional and unconventional gas) was injected into disposal wells.[67] For the lower quantity and quality produced water from the unconventional gas deposits in the San Juan Basin in New Mexico and Colorado and the Uinta Basin in Utah, disposal is predominantly via deep bed injection wells which dispose of the water well below potable water sources.[68] In contrast, where the produced water is high in quality and quantity such as in the Powder River Basin in Wyoming and Montana and the Raton Basin in Colorado and the Marcellus Basin in Pennsylvania, disposal methods are predominantly surface discharge and infiltration impoundments.[69] Although, certainly in Wyoming, there have been many projects that discharge the water through aquifer injection into both deeper disposal wells as well as shallower formations that are potable and agricultural water sources.

Often it is difficult to measure how much CSG produced water is actually beneficially used by other water users and how much is essentially wasted. In Queensland, this information, should be included in the annual returns to the regulator, although these figures are not generally made available to the public. If it is voluntarily reported, it is often published as general aims, goals or broad calculations by the separate operators. In other jurisdictions, such as Wyoming, it is possible to estimate such figures given that water licences are required for both water produced along with the CSG as well as its later beneficial use for other activities, although not for injection. Even so, in Wyoming there is no duty to put the CSG produced water to a further beneficial use.[70] Buccino and Jones quoted former Wyoming Governor Dave Freudenthal as stating in 2004 with respect to the Powder River Basin that, "if we don't do something soon, we're going to have more stock ponds than cattle".[71] If the CSG produced water cannot be immediately beneficially reused by other water users, treating the water and storing it via aquifer injection seems to make a lot of sense. This is particularly so where the source aquifers are under stress and take a very long time to recharge naturally.

[61] The Commonwealth approval 2009/4974 dated 21 February 2011, the Queensland EA's EPPG00853213 dated 18 February 2016 and EPPG00885313 dated 11 December 2015.

[62] Australia Pacific LNG, n 59.

[63] Millar, Couperthwaite and Moodliar, n 20, 674 and 684.

[64] Davies, Gore and Khan, n 23, 10994.

[65] Santos GLNG, *CSG Water Monitoring and Management Plan, Summary Plan- Stage 2 Revision 2* (October 2013) 28 <http://waterportal.santos.com/media/pdf1833/131009_santos_glng_stage_2_cwmmp_revision_2_summary_plan.pdf>..

[66] Santos GLNG, *Coal Seam Water Monitoring and Management Annual Report 2015* (2016) 25 <http://www.santoswaterportal.com.au/media/pdf1891/santos_glng_cwmmp_annual_report_2015.pdf>; as at the date of writing this article, the company was yet to publish its 2016 or 2017 Annual Reports.

[67] Veil, n 25, 10.

[68] Day and O'Hayre, n 20, 11.

[69] Dr Christopher S Kulander, "Surface Damages, Site Remediation and Well Bonding in Wyoming – Results and Analysis of Recent Regulations" (2009) 9 *Wyoming Law Review* 413, 429–430; Sharon Buccino and Steve Jones, "Controlling Water Pollution from Coal Bed Methane Drilling: An Analysis of Discharge Permit Requirements" (2004) 4 *Wyoming Law Review* 559, 560.

[70] Neal Joseph Valorz, "The Need for Codification of Wyoming's Coal Bed Methane Produced Groundwater Laws" (2010) 10 *Wyoming Law Review* 115.

[71] Buccino and Jones, n 69, 560, citing Associated Press, *Freudenthal: Coal-bed Water Quality Must be Addressed* (Casper Star Tribune, 12 April 2004).

Current Iiterature with Respect to Governance of CSG Produced Water – Australia and the USA

The Paris based IEA in 2012 produced the special report *Golden Rules for a Golden Age of Gas*[72] cautioning that the successful development of unconventional gas resources hinges on addressing environmental and social impacts. One of the "Golden Rules" addressing environmental impacts formulated in that report is to "treat water responsibly". The report posits:

> It is the responsibility of regulators to set and enforce appropriate standards based on local factors, including the availability of freshwater supplies and options for disposal, without diminishing the operators' ultimate responsibility for operation in accordance with evolving best practice standards.[73]

The next section explores the views of scholars and other commentators as to whether the regulators have set and enforced appropriate standards for CSG projects in respect of water resources in Australia and the USA, both major CSG producing jurisdictions.

Australia

Issues around the management of CSG produced water have sparked many criticisms of the governance regime relating to both water and CSG projects in Australia. Davies, Gore and Khan remark that as a relatively new industry, the short-term and long-term risks that CSG produced water may have on the environment are not fully understood and that questions as to how to manage water-related impacts remain unresolved.[74] In a similar vein, Hancock and Wolkersdorfer highlight:

> The outcome of this "learning period" is that massively complex, restrictive, and probably unworkable licensing conditions have been imposed on CSG operators. These are generally recognised by the industry as being interim measures designed, at least in part, to allow the industry to commence as it gathers the data that will allow rational redevelopment of pre-existing groundwater uses and policies.[75]

Scholars have highlighted specific flaws in the CSG industry practices and regulatory framework. Well integrity and spills, a lack of peer-reviewed monitoring programs, the management of the effects of aquifer drawdown and the cumulative effects on surface water ecosystems have been the separate subject of academic commentary.[76] After noting the different water treatment activities of the four main CSG producers in Queensland (Arrow Energy, QGC, AP LNG and Santos), Rebello, Couperthwaite, Millar and Dawes have highlighted that the "legislative requirements are not consistent between the CSG operating companies".[77]

In addition, the adequacy of the regulatory regime in Queensland relating to CSG projects generally (including the management of CSG produced water) has been questioned. Comino, Tan and George highlight that there is a major flaw in the current regulatory approach to CSG projects in Queensland in that there is an "absence of a risk assessment and management approach that integrates water allocation and mining decision-making and considers the cumulative impacts of proposed and existing development

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[72] International Energy Agency, n 35.

[73] International Energy Agency, n 35, 46.

[74] Davies, Gore and Khan, n 23, 10996.

[75] Stephen Hancock and Christian Wolkersdorfer, "Renewed Demands for Mine Water Management" (2012) 31 *Mine Water and the Environment* 147, 153.

[76] Davies, Gore and Khan, n 23; John Williams Scientific Services Pty Ltd, n 17; Michael Walton, "The Queensland CSG Industry: Miners versus Farmers: Do the 2010 Water Act Amendments for Underground Water Management Ease the Tension?" (2013) 32 *Australian Resources and Energy Law Journal* 19; G McGregor, J Dunlop and S Rogers, *Coal Seam Gas Water Use Proposals in the Queensland Murray–Darling Basin: Impacts on Aquatic Ecosystems; Assessing Cumulative Impacts of Coal Seam Gas Water Releases to Stream* (Healthy Head Waters Coal Seam Gas Water Feasibility Study Activity 9 Task 4, Queensland Department of Science, Information Technology, Innovation and the Arts, 2013) available through the Queensland Government library at <https://www.qld.gov.au/environment/library/>.

[77] Rebello et al, n 13, 37, 41.

at regional and sub-regional levels".[78] Instead, assessment processes focus on specific projects and although a cumulative management area has been designated for parts of the Surat and Bowen Basins, the management regime in place is not equipped to address impacts before they occur.[79] As production impacts are considered after petroleum authorities are granted and production commences, commentary suggests that the regulatory system in place jeopardises the precautionary approach.[80] The efficacy of the "make good framework" in place to mitigate water extraction impacts in Queensland has been questioned,[81] as has the authenticity of the adaptive management approach adopted by the Queensland Government.[82]

The Queensland Competition Authority (QCA) was directed by the Queensland Government to review the regulation of the CSG industry in June 2013.[83] In its 2014 report, *The Coal Seam Gas Review*, the QCA also noted that the regulatory framework relating to the CSG industry was developed in haste responding to the rapid growth of the industry and that in many cases specific CSG regulatory requirements were added to the general requirements in the resources sector which created a framework that was "confusing for government, industry and the community".[84] It also noted that the costs of unconventional gas projects in Australia (which centre on CSG) are 20% to 30% higher than in North America or East Africa.[85] Generally with respect to the regulation of the industry, the QCA found that there were regulatory duplication[86] and inconstancies between regulatory requirements,[87] excessive reporting requirements and recommended that outcomes-based requirements replace the existing prescriptive regulations.[88] The QCA made various specific recommendations with respect to the regulatory regime generally. Relevantly, it noted that there were three government agencies that managed CSG water use and it recommended consolidation of governance into a single government portfolio.[89]

In 2014, the National Water Commission (NWC) reported on the regulatory frameworks for use of water by the mining and unconventional gas industries. It noted that the growth of these industries and their increasing level of coexistence with other land uses had exposed weaknesses in water planning

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[78] Maria Comino, Poh-Ling Tan and David George, "Between the Cracks: Water Governance in Queensland, Australia and Potential Cumulative Impacts from Mining Coal Seam Gas" (2014) 21 *The Journal of Water Law* 219; McGregor, Dunlop and Rogers, n 76.

[79] Comino, Tan and George, n 78.

[80] Poh-Ling Tan, David George and Maria Comino, "Cumulative Risk Management, Coal Seam Gas, Sustainable Water, and Agriculture in Australia" (2015) 31 *International Journal of Water Resources Development* 682; Comino, Tan and George, n 78; Nicola Swayne, "Regulating Coal Seam Gas in Queensland: Lessons in an Adaptive Environmental Management Approach?" (2012) 29 EPLJ 163.

[81] Ron Janjua, "Mitigating Water Impacts in Coal Seam Gas Extraction: Is Queensland's "Make Good" Framework a Suitable Regulatory Model?" (2017) 25 *Water Law* 211.

[82] Swayne, n 80; and Jessica Lee, "Theory to Practice: Adaptive Management of the Groundwater Impacts of Australian Mining Projects" (2014) 31 *Environmental and Planning Law Journal* 251.

[83] See "Minister's Direction Notice under the *Queensland Competition Authority Act 1997* (Qld), s 10(e)" in Queensland, *Queensland Government Gazette*, No 30, 14 June 2013, 294.

[84] Queensland Competition Authority, *Coal Seam Gas Review – Final Report* (January 2014) 1 <http://www.qca.org.au/getattachment/aaaeab4b-519f-4a95-8a65-911bc46cc1d3/CSG-investigation.aspx>.

[85] Queensland Competition Authority, n 84.

[86] Such as between the Queensland Department of Energy and Water Supply and the Queensland Department of Environment and Heritage Protection regulating the use of produced water in public drinking water sources, although recent regulatory amendments have now eliminated this duplication. In 2014 the *Electricity and Other Legislation Amendment Act 2014* (Qld) amended the *Water Supply (Safety and Reliability) Act 2008* (Qld)(Water Supply Act) where the regulation of CSG produced water in the *Water Supply Act*, Pt 9A was excluded so that it could be solely regulated under the *Environmental Protection Act 1994* (Qld).

[87] For example, the overlapping health and safety requirements under the *Workplace Health and Safety Act 2011* (Qld) and the *Petroleum and Gas (Production and Safety) Act 2004* (Qld).

[88] Queensland Competition Authority, n 84, 2.

[89] Queensland Competition Authority, n 84, 7, 73–76; the 2016 Independent Review of the Gasfields Commission highlighted that there was a need for clear and readily available information including a memorandum of understanding about the respective roles of the different government agencies involved in the regulation of CSG activities; Robert P Scott, *Independent review of the Gasfields Commission Queensland and Associated Matters*, (State of Queensland, Department of State Development, July 2016) ch 8 <https://www.statedevelopment.qld.gov.au/resources/report/gasfields-commission-review-report.pdf>.

instruments to assess the suitability of such projects.[90] Echoing the academic commentary, the NWC also stated that lack of data and data sharing constrained effective governance of water resources.[91] Furthermore the NWC highlighted that “separate baseline assessments undertaken for EIS’s and shadow arrangements developed through approval decisions do not allow integrated allocation and planning decisions for all users. … In some cases, governments have developed alternative arrangements where water for mining and unconventional gas is completely outside the water entitlement framework”.[92] The NWC stressed that it considered that all water extraction (from all users) should be explicitly accounted for in the water plans and that proponents should be required to obtain a water licence or entitlement prior to beginning operations.[93] Given that in Queensland, all extraction of water as part of petroleum, gas and mining activities falls outside of the water accounting framework with no volumetric controls,[94] these comments highlight the flaws in the Queensland regulatory framework.

Successive “Underground Water Impact Reports” for the Surat Cumulative Management Area[95] have been issued by the Office of Groundwater Impact Assessment Queensland in 2012 and 2016.[96] These reports summarise the impacts on the groundwater resources within the area. The 2016 report found that there are “long-term declining trends which pre-date CSG development … [which] reflects below-average rainfall over much of the recharge area over the period 1990–2011 and increased water extraction for agriculture and other non-CSG purposes”.[97] It also highlights the contribution of CSG activities on this declining trend where there is significant CSG development.[98] The report predicts that there would be 91 bores within the area that are likely to be affected by CSG extraction within the next three years[99] and 459 bores are predicted to be affected by CSG water extraction in the long term.[100] Consequently, the report quantifies and highlights the competition for the water resources between non-resources users and CSG producers and the resulting decline in those resources.

In summary, the current literature in respect of CSG produced water in Australia notes that the legislative regime is as yet unprepared to adequately manage water-related impacts of CSG projects. Legislative requirements are complex, restrictive and appear to lack uniformity across projects. A further criticism of the regulatory regime in place in Queensland is that the method of assessment fails to adequately address cumulative impacts of projects on a regional level and there are questions as to the application of the precautionary approach and adaptive management. Many scholars have also called for water use by resources projects to be rolled-in to the water accounting and planning process. Finally,

[90] National Water Commission, *Water for Mining and Unconventional Gas under the National Water Initiative* (Australian Government, 2014) 2 <https://web.archive.org/web/20160302162506/http://nwc.gov.au/__data/assets/pdf_file/0008/37691/Water-for-mining-and-unconventional-gas-under-the-National-Water-Initiative.pdf>.

[91] National Water Commission, n 90.

[92] National Water Commission, n 90; RPS Australia East Pty Ltd, *Onshore Co-produced Water: Extent and Management,* (Australian Government, National Water Commission, Waterlines Report Series No 54, 2011) 33 <https://web.archive.org/web/20120227203643/http://www.nwc.gov.au/__data/assets/pdf_file/0007/18619/Onshore-co-produced-water-extent-and-management_final-for-web.pdf>.

[93] National Water Commission, n 90; this recommendation was similarly put forward by Dr Rebecca L Nelson in her chapter, “Unconventional Gas and Produced Water” in *Australia’s Unconventional Energy Options* (Committee for Economic Development in Australia, 2012) <https://www.ceda.com.au/CEDA/media/ResearchCatalogueDocuments/PDFs/15347-cedaunconventionalenergyfinal.pdf>; Productivity Commission, *National Water Reform, Productivity Commission Draft Report* (Australian Government, 2017) 75-81 <http://www.pc.gov.au/inquiries/current/water-reform/draft>; Council of Australian Governments, *National Groundwater Strategic Framework 2016-2026* 10-11 <http://www.agriculture.gov.au/water/policy/nwi/national-groundwater>.

[94] *Petroleum and Gas (Safety and Supply) Act 2004* (Qld) ss 185, 188; *Mineral Resources Act 1989* (Qld) s 334ZP; *Water Act 2000* (Qld) s 808.

[95] A geographic area that is managed collectively by a government agency, the Office of Groundwater Impact Assessment, in order to address cumulative impacts of multiple CSG projects.

[96] Office of Groundwater Impact Assessment, Queensland Water Commission, n 38; Office of Groundwater Impact Assessment, n 19.

[97] Office of Groundwater Impact Assessment, n 19, 70.

[98] Office of Groundwater Impact Assessment, n 19, 70.

[99] Office of Groundwater Impact Assessment, n 19, xiii.

[100] Office of Groundwater Impact Assessment, n 19, xiii.

the intense competition between the CSG industry and other water users for diminishing groundwater resources has been highlighted suggesting an important area for research and reform.

USA

While fracking and groundwater contamination continue to be controversial,[101] the extraction of and subsequent management of produced water from unconventional gas extraction is also an issue in the USA. So important in fact, that it has been cited as having been a handbrake on the entire industry in 2005.[102] It has become the flashpoint for criticisms of the entire water governance framework for the industry. These criticisms highlight that the framework was developed in the 1950s to deal with conventional oil and gas production which produces water that is vastly inferior in terms of quality (and quantity) compared to the water extracted in the production of CSG.[103] In short, the governance framework has been viewed as "out of date".

Criticisms of the governance frameworks have been raised relating to the extraction of the groundwater in the first place and the differing permit requirements between States.[104] In respect of the Rocky Mountain States, although water is a valuable commodity, only Colorado and Wyoming[105] require a water right to extract prior to drilling and none of the States require the water to be beneficially re-used after extraction.[106] It has been suggested that each State's approach to produced water in particular with respect to issues of quantity, is inextricably linked to the quality of the produced water. Where the quality is poor, it is more likely to be viewed as a waste and not require extraction permits.[107] However, it is also suggested that there is a movement away from treating produced water under a by-product waste model (centring on disposal) to a groundwater resource model (that focuses on treatment and beneficial re-use).[108] Efforts relating to options for beneficial re-use of the water appear to be growing.[109] Darin warns that this paradigm change will challenge each State "to rethink how it deals with produced CBM [CSG] water in a manner that best serves the purposes of western appropriation water law".[110]

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[101] See TW Merril and DM Schizer, "The Shale Oil and Gas Revolution, Hydraulic Fracturing, and Water Contamination: A Regulatory Strategy" (2013) 98 *Minnesota Law Review* 145; Inessa Abayev, "Hydraulic Fracturing Wastewater: Making the Case for Treating the Environmentally Condemned" (2013) 24 *Fordham Environmental Law Review* 275; Dennis C Stickley, "Expanding Best Practice: The Conundrum of Hydraulic Fracturing" (2012) 12 *Wyoming Law Review* 321; Julie Murphy, "Coal Bed Methane Wastewater: Establishing a Best Available Technology Standard for Disposal under the Clean Water Act" (2006) 14 *Southeastern Environmental Law Journal* 333; Michael N Mills and Robin B Seifreid, "What Is Fracking Wastewater and How Should We Managed It?" (2013–2014) 28 *Natural Resources and Environment* 9.

[102] It has been suggested that the continued growth of CSG production in Wyoming USA was under threat due to (among other things) an inadequate regulatory system for CSG development, including water management and disposal and that there was a decrease in CSG production possibly due in part to water management issues see Melinda Benson et al, *Water Production from Coalbed Methane Development in Wyoming: A Summary of Quantity, Quality and Management Options – Final Report* (Ruckelshaus Institute of the Environment and Natural Resources, University of Wyoming, 2005) <http://www.uwyo.edu/haub/_files/_docs/ruckelshaus/pubs/2005-cbm-water-final-report.pdf>; see also Rebecca W Watson and Holly J Franz, "Produced Water: Water Rights and Water Quality: 'A 'Meeting' of the Waters'?" (2006) 52 *Proceedings of the Rocky Mountain Mineral Law Fifty-Second Annual Institute* § 12.01, § 12.02 and Anne MacKinnon and Kate Fox, "Demanding Beneficial Use: Opportunities and Obligations for Wyoming Regulators in Coalbed Methane" (2006) 6 *Wyoming Law Review* 369, 371.

[103] Barrett, n 14; Darin, n 34; Benson et al, n 102, 2.

[104] Victor Flatt and Heather Payne, "Curtailment First: Why Climate Change and the Energy Industry Suggest a New Allocation Paradigm Is Needed for Water Utilized in Hydraulic Fracturing" (2014) 48 *University of Richmond Law Review* 829. See also National Research Council et al, n 51, 187.

[105] Although it has been suggested that with respect to Wyoming, this is largely a reporting matter and does not lead to an adjudicated right: see Watson and Franz, n 102; Christopher L Thorne and William H Caile, "Produced Water Extraction from Oil and Gas Wells: Implications for Western Water Rights" (2012–2013) 27 *Natural Resources and Environment* 16.

[106] Valorz, n 70, 116.

[107] Darin, n 34.

[108] Barrett, n 14.

[109] Watson and Franz, n 102; Day and O'Hayre, n 20.

[110] Darin, n 34, 341.

Scholars have also highlighted the issues relating to drawdown of the potable water resource in the Powder River Basin due to CSG production.[111] Myers notes that during 40 years "full CBM [CSG] development will pump about 124,000 ha-m of water from the Fort Union coals and inter-burden in the PRB, or about 36% of the total recharge simulated for the entire model domain".[112]

The environmental impacts of disposing of vast quantities of produced water have also been highlighted by scholars.[113] This issue is particularly acute in Wyoming and Montana where the CSG produced water is of a higher quality than the other States and in far greater quantities.[114] The higher than normal stream flows cause stream bank erosion, disruption to existing ecosystems, and damage to downstream crops.[115] Most States exclude unconventional gas production and other dewatering activities from their waste statutes so that its disposal on land does not generally require permitting.[116] Unsurprisingly, where the quality and quantity of the produced water are high and surface disposal is used significantly,[117] commentary focuses on the efficacy of the current surface disposal and the opportunity for other beneficial uses.[118] Recommendations for improvement in respect of the regulation of surface disposal in Wyoming include increased monitoring of disposal permits, increased resourcing for management agencies, tighter regulation with respect to off-channel and in-channel reservoirs (or holding ponds that are outside or within drainage channels) and suggestions that aquifer injection should be encouraged.[119] The discharge limits for surface disposal to waters have been criticised for aligning with the water quality parameters of the ultimate receiving waters rather than the uses and the water quality criteria of the water body at the discharge point.[120] Day highlights that an effluent limitation guideline based on a zero discharge would fail to account for the loss of other beneficial uses.[121] Although, others recommend a zero-discharge effluent limitation which would result in all produced water being disposed of by injection or evaporation.[122]

Even though overall, most produced water[123] is injected into disposal wells which lie deep below potable aquifers,[124] there is a lack of regulatory mechanism for injecting high-quality (treated or otherwise) produced water into high-quality aquifers in the USA.[125] Scholars are now highlighting the opportunity

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[111] J Benjamin Winburn, "The Coal Bed Methane Boom: The Push for Energy Independence Raises Questions about Water and the Rights of America's Homesteaders" (2006) 19 *Tulane Environmental Law Journal* 359, 371; and National Research Council et al, n 51, 123, Ch 5 of that report generally; Bryner, n 2, 546.

[112] Myers, n 31, 190.

[113] Abayev, n 101; Winburn, n 111, 371; National Research Council et al, n 51, 135, Ch 5 of that report generally; MacKinnon and Fox, n 102, 373; Samuel S Bacon, "Why Waste Water? A Bifurcated Proposal for Managing, Utilizing and Profiting from Coalbed Methane Discharged Water" (2009) 80 *University of Colorado Law Review* 571, 573.

[114] Herlihy, n 27.

[115] Herlihy, n 27, 463.

[116] Watson and Franz, n 102, citing Darin, n 34, 306, fn 111. Although, Buccino and Jones note that "Courts have explicitly found that pollution that reaches navigable waters by way of infiltration into groundwater triggers an obligation for an NPDES permit", citing *Idaho Rural Council v Bosma*, 143 F Supp 2d 1169, 1180 (D Idaho, 2001); *Friends of Santa Fe County v LAC Minerals, Inc*, 892 F Supp 1333, 1357 (D NM, 1995); *Sierra Club v Colorado Refining Co*, 838 F Supp 1428, 1433 (D Colo, 1993); see Buccino and Jones, n 69, fn 31.

[117] And where deep bed aquifer injection is largely unavailable.

[118] Buccino and Jones, n 69; Abayev, n 101.

[119] Buccino and Jones, n 69.

[120] Day and O'Hayre, n 20.

[121] Day and O'Hayre, n 20, 16.

[122] Murphy, n 101.

[123] For both conventional and unconventional gas extraction.

[124] In the San Juan Basin in New Mexico and Colorado they are typically over 3,000m deep.

[125] Barrett, n 14, 10683.

to recharge depleted aquifers with good quality produced water.[126] As noted above, in Wellington, Colorado, as well as Gillette, Wyoming, produced water from oil and CSG production respectively has been used to recharge aquifers that are the town potable water supplies.[127] Reinjecting produced water (treated or otherwise) into depleted coal seams has been recommended to replenish lost storage and thereby reducing groundwater drawdown and mitigating the hydrological impacts of CSG dewatering.[128]

A report in 2005 by the Ruckelshaus Institute of Environment and Natural Resources which was prepared for the Office of the Governor of the State of Wyoming made recommendations with respect to the management of CSG produced water in that State.[129] The report stated that the challenges faced by "CBM [CSG] development in Wyoming, including water management and disposal, [were] likely [to] have been due to inadequate and sometimes confusing regulatory framework for CBM [CSG]".[130] Recommendations included incremental adjustments to the CSG water management regulations such as strengthening monitoring and enforcement, speeding up and reinforcing the regulatory agency's planning and permitting program, implementing data sharing, identifying and fixing regulatory gaps and considering adopting multi-stakeholder and/or industry-formulated Best Management Practices for CSG.[131] Alternatively, it was recommended that a comprehensive review of the CSG regulatory framework be undertaken either through a "CBM [CSG] coordinator" or a "CBM [CSG] Management Act".[132]

The economic issues relating to the management of produced water and the costs and benefits of the CSG industry generally to the States have also been raised. The 2006 "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin, Phase One" commissioned by the US Department of Energy in conjunction with the Wyoming Governor's Office, found that if disposal requirements were restrictive or made excessively onerous, increased costs would eliminate or severely limit the industry.[133] Stewart noted that there are economic benefits in respect of produced water which include augmenting traditional water supplies and reducing costs associated with disposal.[134] Other scholars have highlighted that the overall market potential of CSG produced water has not been fully evaluated in any study nor has an adequate cost/benefit analysis of the industry been fully canvassed.[135]

In summary, current literature in respect of CSG produced water in the USA highlights that the current regime was developed on a waste disposal model for produced water but that the assumption that the water is a waste is rapidly changing. Environmental issues relating to surface disposal options have been highlighted along with the absence of any legislative requirements to beneficially re-use the water. More comprehensive regulation in respect of the extraction and accounting for the quantities produced have been recommended along with a suggestion for streamlined mechanisms to encourage aquifer injection to augment potable water sources.

[126] Day and O'Hayre, n 20; Myers, n 31; All Consulting and Montana Board of Oil and Gas Conservation, n 12, 29.

[127] Davies, Gore and Khan, n 23; Day and O'Hayre, n 20; Benson et al, n 102.

[128] Myers, n 31, 193.

[129] Benson et al, n 102.

[130] Benson et al, n 102, 52.

[131] Benson et al, n 102, ix.

[132] Benson et al, n 102, ix.

[133] Interstate Oil and Gas Compact Commission and All Consulting, *A Guide to the Practical Management of Produced Water from Onshore Oil and Gas Operations in the United States* (US Department of Energy National Petroleum Technology Office, 2006) 3 <http://www.all-llc.com/publicdownloads/ALL-PWGuide.pdf>.

[134] David R Stewart, "Developing a New Water Resource from Production Water" (Paper presented at 13th International Petroleum Environmental Conference, San Antonio, Texas USA, 2006) 2.

[135] Benson et al, n 102, 31–32.

MAR AND CSG PRODUCED WATER

One of the developments in water management which provides an opportunity for conjunctive management of surface water and groundwater resources is MAR. MAR is the term given to the collection of techniques used to intentionally augment groundwater supplies[136] and has been defined as "the purposeful recharge of water to aquifers for subsequent recovery or environmental benefit".[137] It is normally achieved "through mechanisms such as injection wells, and infiltration basins and galleries for rainwater, stormwater, reclaimed water, mains water and water from other aquifers that is subsequently recovered for all types of uses".[138] The end use can vary from consumptive uses to environmental purposes.[139] Therefore, aquifer injection of CSG produced water into potable water sources would seem to fit these definitions even if it is merely for the purpose of mitigating environmental impacts. In the case where the recharged water is later recovered for consumptive uses, it fairly meets this description.

Aquifers that lie beneath a layer of clay or other impervious material (known as a "confined" aquifer) require injecting water through a well and infiltration is used in respect of unconfined aquifers, allowing water to seep through a permeable layer.[140] Dillon et al helpfully summarise the different types of MAR projects as including aquifer storage and recovery (ASR), aquifer storage, transport and recovery, vadose zone wells (or dry wells), infiltration ponds, percolation tanks, rainwater harvesting, infiltration galleries and recharge releases.[141]

To date the focus of MAR projects which allow recovery of water for consumptive uses has been centred on sewage, stormwater and excess surface water allocations. However, the process is now being acknowledged as extending to the re-use of water produced during mining and unconventional gas extraction.[142] For example, as already mentioned above, studies conducted on behalf of the Queensland Department of Environment and Resource Management[143] in 2011 concluded that it was technically feasible to recharge the Central Condamine Alluvium with treated CSG produced water through both shallow and deep injection.[144] Monckton et al suggest that, "barring technical and economic constraints, re-injection of treated CSW [coal seam gas produced water] into stressed agricultural aquifers may provide more equitable access to water and broader economic benefits than current location-specific irrigation schemes".[145] The AP LNG projects at Reedy Creek and Spring Gully are now recharging the Precipice Sandstone aquifer, a GAB aquifer used by agriculture.[146] The Roma Managed Aquifer Study in Roma Queensland considered the potential to augment the town water supplies with produced water from a CSG project.[147] The source of drinking water in Gillette Wyoming USA has been augmented by CSG produced water through injection into the sandy aquifer serving the city.[148] In Wellington,

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[136] Peter Dillon, "Australian Progress in Managed Aquifer Recharge and The Water Banking Frontier" (2015) 42 (September) *Water: Journal of the Australian Water Association* 53.

[137] Peter Dillon et al, *Managed Aquifer Recharge: An Introduction* (Australian Government, National Water Commission, February 2009) <https://web.archive.org/web/20120317050200/http://www.nwc.gov.au/__data/assets/pdf_file/0011/10442/Waterlines_MAR_completeREPLACE.pdf>.

[138] Dillon et al, n 137, 2.

[139] Dillon et al, n 137.

[140] Dillon et al, n 137, 3.

[141] Dillon et al, n 137, 5, and see also Yie Yuan, Michele I Van Dyke and Peter Huck, "Water Reuse through Managed Aquifer Recharge (MAR): Assessment of Regulations/Guidelines and Case Studies" (2016) 51 *Water Quality Research Journal of Canada* 357.

[142] Dillon, n 136, 54.

[143] Now the Department of Environment and Heritage Protection.

[144] Klohn Crippen Berger, *Injection of Coal Seam Gas Water into the Central Condamine Alluvium: Technical Feasibility Assessment – Final Report* (27 July 2011).

[145] David Monckton et al, "Use of Coal Seam Water for Agriculture in Queensland, Australia" (2017) 42 *Water International* 599.

[146] Klohn Crippen Berger, n 28, 56; and Australia Pacific LNG, n 59.

[147] Davies, Gore and Khan, n 23, 10994.

[148] Day and O'Hayre, n 20, 15; All Consulting, n 41, 11; see also US Bureau of Land Management, Buffalo Field Office, *Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project* (2003) 3–54 <https://archive.org/details/finalenvironment02buff>.

Colorado produced water from oil production is used to recharge an aquifer that is the town potable water supply.[149]

Aquifer recharge using CSG produced water has been performed using a variety of techniques. The Reedy Creek Aquifer Project undertaken by AP LNG described above uses injection wells. In contrast, the Powder River Basin Environmental Impact Statement contemplated that most aquifer recharge in Wyoming from CSG projects would occur via infiltration methods.[150] Although, there are plenty of projects in Wyoming that have used injection wells into formations appropriate for stock watering.[151]

Therefore, MAR is proving to be an effective tool for the management of CSG produced water. However, no scholars have addressed the unique regulatory issues when these projects are part of CSG projects.

Current Literature with Respect to MAR

Current literature relating to MAR generally relates to recycling and using excess surface water as the source water which is recovered at a later date. As such, the literature focuses on all four operational stages of MAR: source water harvesting, aquifer recharge, recovery of stored water and end use.[152] From the author's review of the literature, there is no academic research considering governance or regulatory issues in respect of MAR specifically relating to CSG produced water. The first two stages of a MAR project are applicable to CSG projects that dispose of produced water into shallow formations via aquifer injection or infiltration methods. If the aquifer injection or infiltration project involves an underground water source that is also used by other water users, all four stages of a MAR project are in fact occurring. Therefore, much of the literature in respect of MAR will be relevant.

Bennett, Gardner and Vincent argue that MAR is an innovation in respect to water supply which needs to be the subject of regulatory renovation.[153] They note that the current regulatory regime in Western Australia uses provisions that were designed to be used for groundwater extraction rather than recharge and that there are uncertainties in the application of health and environmental legislation to MAR projects.[154] These concerns were echoed by CSG operators in Queensland who have argued that the Queensland regulatory regime is undeveloped and aquifer injection of CSG produced water (in particular into the Central Condamine Alluvium rather than other confined aquifers) could lead to future uncertain legal liability.[155] Reform is not only required in respect of potential future liabilities but also rights to access surface water generally, the legal requirements concerning the quality and quantity of recharged water, rights to aquifer space as well as with respect to the rights to extract recharged water.[156] A MAR proponent currently has little legal or policy security to extract groundwater that it has recharged and scholars suggest that this creates a disincentive to MAR projects.[157]

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[149] Davies, Gore and Khan, n 23, 10994.

[150] US Bureau of Land Management, Buffalo Field Office, n 148.

[151] Such as Anadarko Petroleum's injection wells in Midwest, Wyoming, Pennaco Energy Inc's facilities in its Dow 2 and Sales 14 fields and Inkline and Brinkerhoff extensions and Yates Petroleum Corporations facilities in the Caliente fields.

[152] John Ward and Peter Dillon, *Robust Policy Design for Managed Aquifer Recharge* (Australian Government, National Water Commission, 2011) 6 <https://web.archive.org/web/20141216010235/http://archive.nwc.gov.au/library/waterlines/38>.

[153] Michael Bennett, Alex Gardner and Katie Vincent, "Regulatory Renovation for Managed Aquifer Recharge Using Alternative Water Resources: A Western Australian Perspective" (2014) 24 *Journal of Water Law* 5. See also Yuan, Van Dyke and Huck, n 141, where the authors note that detailed regulations or guidelines in respect of MAR are unavailable in most countries.

[154] Bennett, Gardner and Vincent, n 153; Ward and Dillon, n 8.

[155] See QGC's Stage 2 Water Monitoring and Management Plan s 11 in *Re-injection and Repressurisation Options* at 127 and Arrow's concerns are noted in ARUP, *Assessment of options for using coal seam gas water in the Central Condamine Alluvium: Business Case* (2013) 113.

[156] Bennett, Gardner and Vincent, n 153; Ward and Dillon, n 8.

[157] Bennett, Gardner and Vincent, n 153; Katie Vincent and Alex Gardner, "Managed Aquifer Recharge Using Alternative Water Sources in Western Australia: A New Property Rights Approach" (2014) 23 *Australian Property Law Journal* 36; S Parsons et al, *Progress in Managed Aquifer Recharge in Australia* (Australian Government, National Water Commission Australia, 2012) 72 <https://web.archive.org/web/20160404022030/http://archive.nwc.gov.au/__data/assets/pdf_file/0015/21534/Waterlines-73-Managed-aquifer-recharge.pdf>.

Ward and Dillon note that no Australian jurisdictions have MAR policies that are integrated into catchment management strategies, nor take account of the potential for MAR to augment groundwater supplies and protect aquifers and groundwater-dependent ecosystems.[158] The authors note that effective urban water management requires an approach that co-ordinates management of water quality and quantity; such as, issues relating to water extraction and consumption.[159]

Clear rights in respect of all four operational stages of MAR have not been established in Australia or international jurisdictions.[160] Ward and Dillon have refined "a set of 'robust separation of rights' principles based on secure entitlements, annual allocations and end-use obligations to guide the coordination of policies specific to each of the four operational processes central to MAR schemes".[161] Each of the four operational phases are analysed in terms of allocations and entitlements and recommendations for each stage are made. A sequenced institutional transition from a permit-based system to a tradeable entitlement system is described to stimulate policy design.[162] The authors conclude that in the absence of well-defined entitlements to access stormwater and recycled water, aquifer storage as well as to the recovery of the water, MAR will not achieve its full potential.[163]

Although, institutional constraints are not the only impediment to the implementation of MAR. Kurki et al note that the interaction of multiple stakeholders with diverse interests and responsibilities are also challenges for MAR.[164] They suggest that identifying the beneficiaries and who bears the costs of the scheme is essential.[165] Once technical issues are resolved, Kurki et al suggest that the socio-economic and legislative issues will become more relevant.[166]

Maliva suggests that MAR has not yet been implemented to its full extent due to a lack of understanding on the part of relevant decision-makers[167] as to the economic case for the investment in the technology.[168] Many scholars have noted the economic benefits of MAR.[169] While the economic analysis of any MAR project is dependent on site and water specifics, the system to be implemented as well as end use for the recovered water, Maliva suggests that MAR is usually economically feasible where the water is for potable uses in a water scarce region and the hydrogeologic conditions are favourable.[170] This

[158] Ward and Dillon, n 8; Ward and Dillon, n 152.

[159] John Ward and Peter Dillon, *Robust Design of Managed Aquifer Recharge Policy in Australia* (CSIRO, 2009) <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.476.8268&rep=rep1&type=pdf>; Ward and Dillon, n 8.

[160] Ward and Dillon, n 152, 7, where the authors discuss "property rights" in respect of water quantity; see also Vincent and Gardner, n 157 who highlight shortcomings in current property rights in respect of alternative water sources used in MAR in Western Australia. In respect of the legal nature of rights in respect of groundwater in Australia; see Virginia Newell, "Property Rights in Groundwater?" (1999) 4 *Indigenous Law Bulletin* 4 and Janice Gray and Louise Lee, "National Water Initiative Styled Water Entitlements as Property: Legal and Practical Perspectives" (2016) 33 EPLJ 284 in respect of water entitlements in New South Wales, Australia; and for the nature of water entitlements generally in the USA, see Shelley Ross Saxer, "The Fluid Nature of Property Rights in Water" (2010) 21 *Duke Environmental Law and Policy Forum* 49.

[161] Ward and Dillon, n 8, 943.

[162] Ward and Dillon, n 8.

[163] Ward and Dillon, n 8; this point is also made by Vincent and Gardner, n 157.

[164] Vuokko Kurki, Katko Tapio and Annukka Lipponen, "Managed Aquifer Recharge in Community Water Supply: The Finnish Experience and Some International Comparisons" (2013) 38 *Water International* 774, 786.

[165] Kurki, Tapio and Lipponen, n 164, 786.

[166] Kurki, Tapio and Lipponen, n 164, 786.

[167] Such as water utility managers, water management agency officials and political leaders.

[168] Robert G Maliva, "Economics of Managed Aquifer Recharge" (2014) 6 *Water* 1257.

[169] Kurki, Tapio and Lipponen, n 164, 785, citing K Balke and Y Zhu, "Natural Water Purification and Water Management by Artificial Groundwater Recharge" (2008) 9 *Journal of Zheijang University Science B* 221; SR Barnett et al, "Aquifer Storage and Recharge: Innovation in Water Resources Management" (2000) 47 *Australian Journal of Earth Sciences* 13; Herman Bouwer, "Artificial Recharge of Groundwater: Hydrogeology and Engineering" (2002) 10 *Hydrogeology Journal* 121; P Dillon, "Future Management of Aquifer Recharge" (2005) 13 *Hydrogeology Journal* 313; Shahbaz Khan et al, "Estimating Potential Costs and Gains from an Aquifer Storage and Recovery Program in Australia" (2008) 95 *Agricultural Water Management* 477.

[170] Maliva, n 168, 1275.

point is supported by a feasibility study undertaken for the Queensland Department of Natural Resources and Mines in 2013 which recommended injection of CSG produced water into the Central Condamine Alluvium on the basis of a cost–benefit analysis.[171]

In the USA, groundwater recharge has been used as a water management tool for decades.[172] A report by the Committee on Sustainable Underground Storage of Recoverable Water in 2008 noted that these projects are "among the most complex to implement, unless a state has addressed these issues in a statutory scheme that was created specifically for the regulation of these projects".[173] The Committee recommended that a comprehensive approach was advantageous and at the very least defined property rights in water used for recharge, aquifer storage, and withdrawn water are necessary for MAR projects.[174] Without this framework, "users are less likely to undertake investments in storing water or to exercise restraint in leaving stored water underground".[175]

The same report noted that most legal regimes in the USA also treat separately issues relating to water quantity and water quality, even though the two issues are inextricably linked. Often, these issues are managed by separate departments.[176] In MAR projects, water quantity and water quality issues are linked and a failure to address this in the legislative framework can lead to sub-optimal results. For example, where water quality parameters for protecting aquifers are so rigid that they prevent MAR projects, even where threats to human or environmental health are extremely remote, this can result in the lost opportunity for groundwater augmentation.[177]

Water banking has been developed in Arizona USA in order to store unused surface water allocations from the Colorado River and this program has been highly successful in facilitating aquifer recharge.[178] Megdal, Dillon and Seasholes stress that a precursor for water banking is a robust water entitlement and accounting system.[179] The Arizona Department of Water Resources oversees this regulatory system. Statutory provisions authorising ASR in Arizona were inserted in the mid-1980s (along with refinements in 1994) to that State's *Groundwater Management Act*.[180] The legislative regime already in place involved a complex permitting system which created and quantified groundwater rights in Active Management Areas (which are intensively regulated).[181] A permitting system with respect to recharge projects was introduced that governs the storage facility, the water storage as well as water recovery.[182] The authors explain that "the system of permits, monitoring, reporting and accounting helps maintain the integrity in the process, which is necessary to assure users that the water they bank can be withdrawn

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[171] ARUP, n 155; and Tree Crop Technologies Pty Ltd, *Assessment of Alternative Use Options for Coal Seam Gas Water proposed for Central Condamine Alluvium Recharge Scheme* (Queensland Department of Natural Resources and Mines, 2013), available online through the Queensland Government's library at <http://qldgov.softlinkhosting.com.au/liberty/libraryHome.do>.

[172] Sharon B Megdal, Peter Dillon and Kenneth Seasholes, "Water Banks: Using Managed Aquifer Recharge to Meet Water Policy Objectives" (2014) 6 *Water* 1500.

[173] National Academy of Sciences, Committee on Sustainable Underground Storage of Recoverable Water, *Prospects for Managed Underground Storage of Recoverable Water* (The National Academies Press, 2008) 183; see also Kurki, Tapio and Lipponen, n 164.

[174] National Academy of Sciences, Committee on Sustainable Underground Storage of Recoverable Water, n 173, 218.

[175] National Academy of Sciences, Committee on Sustainable Underground Storage of Recoverable Water, n 173, 189; these sentiments were shared by Ward and Dillon, n 159, vii.

[176] National Academy of Sciences, Committee on Sustainable Underground Storage of Recoverable Water, n 173, 183.

[177] National Academy of Sciences, Committee on Sustainable Underground Storage of Recoverable Water, n 173; Robert G Maliva, "Managed Aquifer Recharge: State-of-the-Art and Opportunities" (2015) 15 *Water Science & Technology: Water Supply* 578, 582.

[178] Megdal, Dillon and Seasholes, n 172.

[179] Megdal, Dillon and Seasholes, n 172.

[180] Megdal, Dillon and Seasholes, n 172.

[181] Megdal, Dillon and Seasholes, n 172; KL Patrick and KE Archer, "A Comparison of State Groundwater Laws" (1994) 30 *Tulsa Law Journal* 123, 132–139.

[182] Megdal, Dillon and Seasholes, n 172.

at a later date".[183] In 1996 the Arizona Water Banking Authority was established which also stores water at recharge facilities, in particular excess water entitlements from the Colorado River for both Arizona and Nevada.[184]

The current literature relating to MAR recommends that it be the subject of regulatory reform and made a part of integrated catchment management strategies which co-ordinate issues with respect to both quantity and quality of water. Scholars recommend clear rights with respect to accessing surface water, recharging aquifers, recovering the water as well as to re-using that water. Scholars suggest that economic incentives and robust water accounting will encourage the use of MAR to augment water supplies. Whether these recommendations apply to aquifer injection projects involving CSG produced water is uncertain.

Conclusion

The need for energy security has enabled CSG projects to flourish. However, the environmental implications of the immense quantities of co-produced water are now apparent and are impacting issues of water security with wider regional implications. It has also been suggested that the issues relating to the management of this produced water have impacted on production of the gas resource itself.

The literature in both the USA and Australia reveals a change in paradigm, considering CSG produced water as a resource rather than a waste. It has been suggested that neither jurisdiction currently enables CSG produced water to achieve its full potential in terms of beneficial re-use. This is particularly so with respect to augmenting aquifers. A criticism in respect of both jurisdictions in this area has been a lack of consolidated governance and comprehensive water permitting and accounting. In other words, we have been applying outdated paradigms in respect of the CSG produced water which have been found wanting.

Technical developments in respect of MAR are proving to be an effective tool for the management of CSG produced water. However, as a new technology, scholars have argued that existing regulatory regimes are ill-equipped to manage this process. MAR has been primarily considered from the perspective of sewage and stormwater disposal rather than in respect of CSG produced water. The governance regime adopted in relation to aquifer injection projects using CSG produced water in Queensland, Australia, is different to that governing MAR projects using other types of water, given the definition of CSG produced water as a "waste" in the *EP Act*. Research which seeks to evaluate this governance framework will not only address a significant issue with regards to CSG development, that is, its water impacts, but also should have broader implications for MAR governance generally.

Science and technology have leapfrogged existing legal frameworks relating to both extraction of CSG and the governance of water and the environment. As already noted, the current governance frameworks for CSG produced water have attracted much criticism as have the current frameworks for MAR projects. The frameworks have generally been seen as sub-optimal having been created in a rushed and reactionary manner to adapt to new technologies and industries. Current research in respect of MAR has recommended regulatory reform so that it is included in integrated catchment management strategies which co-ordinate issues with respect to both quantity and quality of water. MAR projects involving produced water from a CSG project are specific applications of MAR not already considered in the literature or by governments. Nonetheless, they should be included as an integral part of an integrated catchment strategy as they are large extractors and producers of groundwater.

Accordingly, there are tangible advantages in research which seeks to co-ordinate and streamline such projects at this time. Enabling aquifer injection projects involving CSG produced water could lead to a reduction in the environmental impact of the production of vast quantities of "wastewater" (by reducing the aquifer depletion and surface release of treated and untreated produced water). It could also add to the available water supply in a given water basin for potable, agricultural or environmental uses thus addressing water security issues. The research may also lead to a reduction in the regulatory burden faced by CSG projects and therefore reduce their costs, thus promoting alternative energy supplies which

[183] Megdal, Dillon and Seasholes, n 172, 1505.

[184] Megdal, Dillon and Seasholes, n 172, 1506.

are much needed. Therefore, research in respect of the governance of aquifer injection involving CSG produced water could solve a number of current issues facing energy and water security as well as protection of the environment.

It's been many years since my American friend mentioned the possibilities of aquifer injection as addressing the CSG industry's water woes. During that time, there have been numerous CSG projects around the world that have in fact used aquifer injection as a means of addressing water impacts, including in Australia. It therefore would seem an appropriate time to now consider how effectively the existing governance frameworks have facilitated sustainable development of gas and water resources. Especially as there are now calls to relax these constraints. Have there been ecological, economic or social issues that have been addressed or perhaps exacerbated by the governance mechanisms in place for aquifer injection of CSG produced water? Would the scholarly recommendations for MAR projects also be appropriate in the CSG context? Or do aquifer injection projects involving CSG produced water present issues that are singular to that industry? Perhaps the governance framework relating to aquifer injection of CSG produced water in Queensland Australia has lessons that can be adopted more broadly. Now would seem an opportune time to comprehensively answer these questions.

GLOSSARY

An **aquiclude** is "a saturated geological unit of such low permeability that it is incapable of transmitting significant quantities of water under ordinary hydraulic gradients and can act as a barrier to regional groundwater flow' such as "clays, shales and metamorphic rocks".[185]

An **aquifer** is "a layer or layered sequence of rock or sediment comprising one or more geological formations that contains water and is able to transmit significant quantities of water under an ordinary hydraulic gradient" such as "sands, gravels, solutionally weathered limestones and fractured sandstones".[186]

An **aquitard** is a "formation of lower permeability that may transmit quantities of water that are significant in terms of regional groundwater flow, but from which negligible supplies of groundwater can be obtained" such as "fluvial and glacio-fluvial silts and sandy clays, sedimentary rocks with few fractures and fractured crystalline rock".[187]

Coal seam gas (CSG) or **coal bed methane** (CBM) occurs in conjunction with coal seams and is "usually 'dry', being almost entirely methane with very little of the heavier hydrocarbons such as propane or butane and no natural gas condensate".[188] The methane can be in a near liquid state and the water pressure and reservoir pressure hold the gas in place.[189] CSG is the term most often used in Australia and CBM is the term most often used in the USA.

A **confined aquifer** is "contained between two aquitards or aquicludes".[190]

Conventional gas "is a combustible mixture of hydrocarbon gases found alone or with oil in oil fields".[191] Entrapment of the gas is usually structural and extraction is often helped by natural pressure in the reservoir and very little water is displaced in the process.[192] However, the water that is displaced is usually extremely salty, sometimes 10 to 11 times saltier than seawater.[193]

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[185] KM Hiscock and VF Bense, "Ch 2: Physical Hydrogeology" in *Hydrogeology: Principles and Practice* (Wiley-Blackwell, 2nd ed, 2014) 29.

[186] Hiscock and Bense, n 185.

[187] Hiscock and Bense, n 185.

[188] John Williams Scientific Services Pty Ltd, n 17.

[189] John Williams Scientific Services Pty Ltd, n 17.

[190] Hiscock and Bense, n 185.

[191] John Williams Scientific Services Pty Ltd, n 17, 9.

[192] John Williams Scientific Services Pty Ltd, n 17.

[193] Barrett, n 14, 10663.

Groundwater is the water beneath the surface of the ground, which consists largely of surface water that has seeped down, and which eventually drains into rivers, lakes or wetlands.[194]

Hydraulic fracturing or "fracking" is where fluids consisting of water, sand and chemical additives are injected into the formation in order to open or enlarge fractures in the rock and proppant material keep the fractures open.[195]

Produced water (or "associated water") is the water that is extracted (or produced) along with the unconventional gas during extraction.

Shale gas is a natural gas dispersed within source rocks such as shales and carbonates.[196] These deposits are usually found at much greater depths compared to CSG.[197]

Surface water refers to water that is found in rivers, lakes, wetlands, and overland flow such as stormwater and flood water.

Tight gas is a poorly defined category of unconventional gas most often dispersed in low permeability rocks which require large-scale fracturing to extract the resource.[198]

An **unconfined aquifer** "exists when a water table is developed that separates the unsaturated zone above from the saturated zone below".[199]

Unconventional gas includes coal seam gas (or coal bed methane), tight gas, tight oil and shale gas.[200] Large amounts of water of variable quality are produced as part of all unconventional gas extraction.[201]

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194 Macquarie Dictionary online <https://www.macquariedictionary.com.au/>.

195 Joanna Glowacki and Christoph Henkel, "Hydraulic Fracturing in the European Union: Leveraging the U.S. Experience in Shale Gas Exploration and Production" (2014) 24 *Indiana International & Comparative Law Review* 133.

196 John Williams Scientific Services Pty Ltd, n 17.

197 John Williams Scientific Services Pty Ltd, n 17.

198 John Williams Scientific Services Pty Ltd, n 17.

199 Hiscock and Bense, n 185.

200 Veil, n 25, 19.

201 John Williams Scientific Services Pty Ltd, n 17.