A Regulatory Framework for Management of Groundwater in a Drying South-West Climate: Introductory Literature Review

Version 1, 24 July 2013

Outline of the project

1. The south west of Western Australia has experienced a significant decline in rainfall over recent decades. It is likely that climate change caused by anthropogenic greenhouse gas commissions has contributed substantially to this decline. Climatic changes in the south west have increased pressure on groundwater resources, both directly (through reduced recharge of aquifers) and indirectly (through increased extraction as a substitute for surface water).

2. This one year research project will identify the challenges to groundwater management posed by the drying south west climate. It will review the regulatory and management responses of the Western Australian government to these challenges and compare them with responses to comparable challenges in Australia and internationally. Building on this analysis, the project will go on to identify desirable objectives of a groundwater regulatory framework in a drying climate and options to achieve those objectives.

3. The purpose of this project is twofold: to contribute to the immediate program of Western Australian water law reform in 2013-14, taking into account national water policy; and more broadly, to develop understanding of regulatory approaches to managing groundwater under drying climatic conditions.

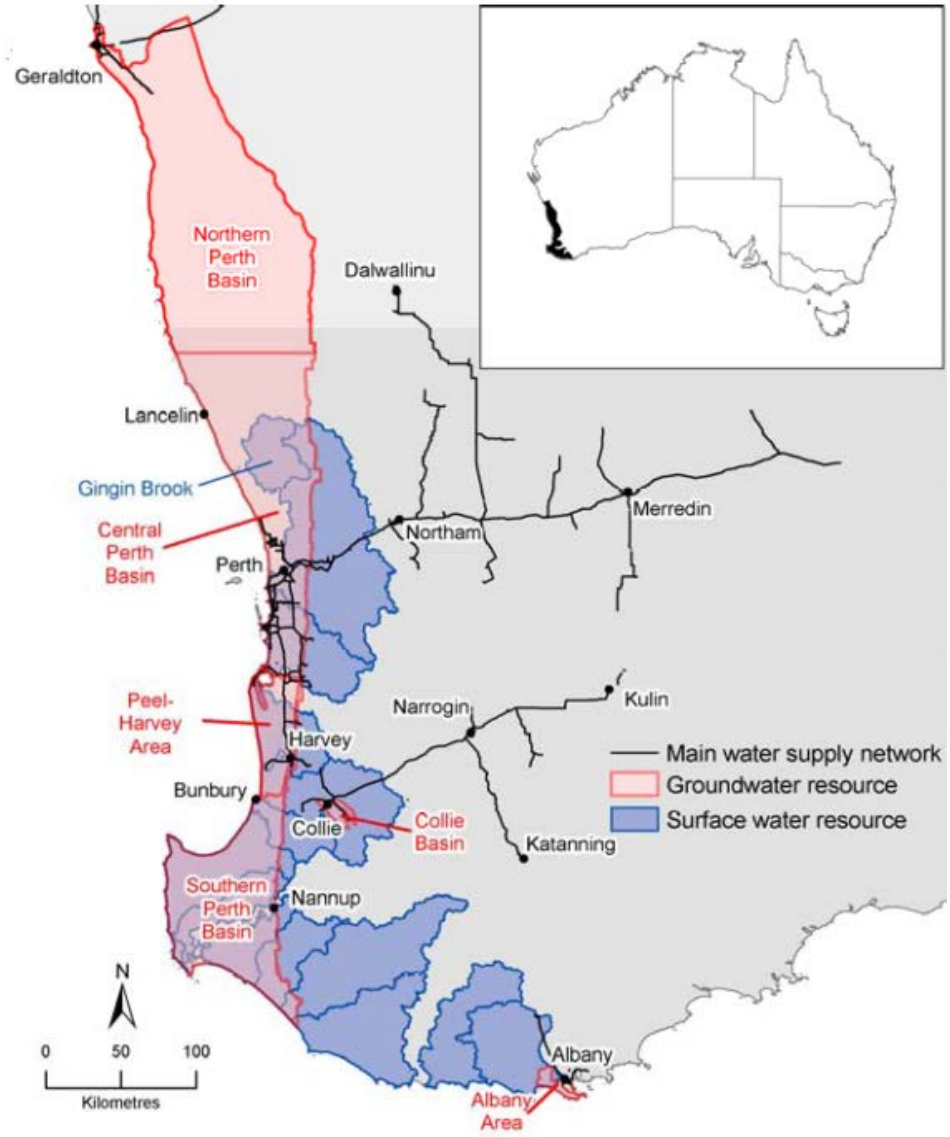
4. While the project will focus on management of groundwater resources, it will do so in the broader context of groundwater-surface water connections and the links between water resource management and water supply planning.

5. Aspects of the National Water Initiative, such as regulatory reforms to achieve sustainable levels of groundwater extraction, are relevant to this project. Consistent with the research goals of the National Centre for Groundwater Research and Training, the project will involve assessment of how relevant aspects of the National Water Initiative could best be implemented in a Western Australian context.

6. For the purposes of the project, the relevant groundwater resources are those identified in the CSIRO's South-West Western Australia Sustainable Yields Project. These

groundwater resources, which are found from Geraldton in the north to Albany in the south, are identified in Figure 1.

Figure 1: Water Resources in the Project Area [1]



[1] Reproduced from CSIRO, 'Water yields and demands in south-west Western Australia: A report to the Australian Government from the CSIRO South-West Western Australia Sustainable Yields Project. ' (CSIRO, 2009) V.

Purpose of this introductory literature review

7. The purpose of this introductory literature review is to identify some of the research that has already been undertaken in this area and flesh out some of the issues that could usefully be considered in the course of the project. It is a preliminary review undertaken early in the project, and has substantial gaps that will be filled over the course of the project.

South-west groundwater resources

8. The south-west is heavily reliant on groundwater. Annual groundwater use in the south west is estimated to be about 850 gigalitres (GL), which is about 74 per cent of all water used (2009 estimate).[2]

9. Uses of south-west groundwater include:

   – *Public water supply*: about half of Perth's public water supply,[3] and all of the public water supply for Bunbury and Busselton, is from groundwater;

   – *Garden bores:* there are around 176,000 homes with domestic garden bores in the Perth-Peel region (2009 estimate);[4]

   – *Irrigated agriculture:* there are self-supplied groundwater irrigation schemes in the Gingin area, in peri-urban parts of Perth, and in coastal areas at Myalup, Jindong, Margaret River and the Scott Coastal Plain.[5]

   – *Mining and industry:* for example, around 20 GL is abstracted annually from the Yarragadee Aquifer for mineral sand mining and processing at the Eneabba mines.[6]

[2] CSIRO, 'Groundwater yields in south-west Western Australia: A report to the Australian Government from the CSIRO South-West Western Australia Sustainable Yields Project' (December 2009) 74.
[3] In 2011/12 water supplied into the Integrated Water Supply Scheme consisted of 46 per cent groundwater: Water Corporation, *2012 Annual Report*, 6.
[4] CSIRO, above n 1 55.
[5] Ibid 33. To take one example, vegetables produced in the Wanneroo area using groundwater from the Gnangara system occupied 1037 hectares and provided at least 25 per cent of state production in 2005-6: Gnangara sustainability strategy taskforce, 'Gnangara Sustainability Strategy Situation statement' (January 2009) 47.
[6] CSIRO, above n 1 74.

10. Groundwater also has an important role in supporting groundwater-dependent ecosystems, which include wetlands, terrestrial ecosystems and stygofauna in limestone caves.[7] There are four Ramsar wetlands in the project area: Forrestdale and Thomsons Lakes; the Peel-Yalgorup System; the Becher Point Wetlands; and the Vasse-Wonnerup System.[8]

Impact of the drying south-west on groundwater resources

11. It is clear from the literature that the south-west of Western Australia has experienced a significant reduction in rainfall in recent decades, together with other climatic changes such as lower rainfall intensity and rising average temperatures.[9]

12. It has been suggested that the south west of Western Australia has experienced amongst the greatest impact on divertible water resources in the world.[10] This is supported by evidence of the marked reduction streamflow to Perth dams. Streamflow has now declined to the extent that the average flow to Perth dams from 2006-2012 was some 80 per cent less than the average flow from 1911-1974.[11]

    - It is important to appreciate that the relationship between rainfall and streamflow is not linear. Reduction in runoff is disproportionately larger than the reduction in rainfall because runoff is more likely to occur where rain falls on soil that is completely saturated.[12] According to a 2008 State Government report, "in parts of SWWA a 10 per cent reduction in rainfall has caused a 50 per cent reduction in streamflow".[13]

[7] Ibid 41.
[8] Australian Government, *Australia's Ramsar Sites* <http://www.environment.gov.au/water/publications/environmental/wetlands/pubs/ramsar.pdf>.
[9] Indian Ocean Climate Initiative, *Western Australia's Weather and Climate: A Synthesis of Indian Ocean Climate Initiative Stage 3 Research* (Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology, 2012); CSIRO, above n 1; R P Silberstein et al, 'Climate change and runoff in south-western Australia' (2012) 475 *Journal of Hydrology* 441.
[10] Silberstein et al, above n 8, 442.
[11] See Water Corporation, Streamflow to Perth Dams 1911-2012 <http://www.watercorporation.com.au/water-supply-and-services/rainfall-and-dams>.
[12] Gaia Nugent, Jane Chambers and Peter Speldewinde, *Adapting to climate change: a risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels. Supporting document 1: Literature review* (National Climate Change Adaptation Research Facility, 2013) 10.
[13] Department of Agriculture and Food, *Climate Change, Vulnerability and Adaptation for South West Western Australia 1970 to 2006* (WA Agriculture Authority, 2008) 37.

13. The reduction in streamflow has had an important indirect impact on groundwater resources, namely that extraction of groundwater increased substantially to compensate for the reduction in surface water resources. For example:

    - extraction for public water supply from the Gnangara groundwater system expanded substantially to approximately 142GL in 2008,[14] in part due to reduced availability of surface water[15]

    - there was a rapid increase in the number of private bores in response to water use restrictions imposed in the late 1970s.[16]

14. Reduced rainfall and higher temperatures also have a direct impact on groundwater systems by reducing net recharge,[17] with consequential impacts on water-dependent ecosystems.[18] As net recharge is used as one measure of how much water may be sustainably extracted from an aquifer, the project could explore whether climatic impacts on net recharge have been quantified for particular systems in the south west, and how this has affected water allocation planning and licensing decisions.

15. Reduced rainfall has also had some impact on groundwater quality through lowering the watertable and exposing 'potential acid sulphate soils'. Potential acid sulphate soils are widespread in coastal areas in south west Western Australia. Exposure of these naturally occurring soils to air can cause a reaction that produces sulphuric acid. This has occurred in Perth due to prolonged drought.[19]

---

[14] E J Roberts James H Skurray, David J Pannell, 'Hydrological challenges to groundwater trading: Lessons from south-west Western Australia' (2012) 412-413 *Journal of Hydrology* 256, 258.
[15] Bryson C Bates and Graeme Hughes, 'Adaptation Measures for Metropolitan Water Supply for Perth, Western Australia' in Ludwig Fulco Pavel Kabat, Michael van der Valk, Henk Van Schaik (ed), *Climate Change Adaptation in the Water Sector* (Earthscan, 2009) 198.
[16] Water and Rivers Commission, *Water Facts 12* (August 1998), Department of Water <http://www.water.wa.gov.au/PublicationStore/first/10256.pdf>.
[17] McFarlane et al, 'Climate change impacts on water yields and demands in south-western Australia', *Journal of Hydrology* 475 (2012) 488-498.
[18] O Barron et al, 'Climate change effects on water-dependent ecosystems in south-western Australia' (2012) 434–435 *Journal of Hydrology* 95; Department of Water, 'Gingin surface water allocation plan methods report: supporting information' (38, 2011) 9-11 (example of impact on surface water ecosystems through loss of connection with groundwater).
[19] J Angeloni, R Watkins and S J Appleyard, 'Arsenic-rich groundwater in an urban area experiencing drought and increasing population density, Perth, Australia' (2006) 21 *Applied Geochemistry* 83; S. Clohessy, S. Appleyard and R. Vogwill, 'Groundwater acidification near the water table of the Superficial aquifer, Gnangara Mound, Swan Coastal Plain, Western Australia' (2013) *Applied Geochemistry* .

Is the drying climate caused by human-induced climate change?

16. The cause of the drying climate is relevant to groundwater management because it informs assessments of whether the drying trend is likely to continue. This in turn informs regulatory and policy responses (e.g. approaches to water allocation planning).

17. Peer-reviewed scientific papers have proposed a number of possible causes for reduced rainfall in south west Western Australia, including land-cover change[20], multi-decadal variations[21] and human-induced climate change.[22] The latter study, cited with approval by McFarlane et al in a recent paper,[23] suggests that anthropogenic forcing contributes to about 50% of the observed rainfall decline.[24]

18. Consistent with this conclusion, the Intergovernmental Panel on Climate Change suggested in 2007 that reduced rainfall in the south west of Western Australia 'is probably due to a combination of increased greenhouse gas concentrations, natural climate variability and land-use change.'[25]

19. The Indian Ocean Climate Initiative, a research partnership between the WA Government, CSIRO and Bureau of Meteorology, was established in 1997 to investigate the causes of the changing climate in WA and develop projections of the future climate in WA. Its latest briefing paper for policy makers, published in 2012, is perhaps the most recent, authoritative statement on this issue. It states that:
    - *Rainfall reductions in SWWA can be explained by major changes in global atmospheric circulation and temperature.*
    - *The strength of the subtropical jetstream decreased by 17% between the periods 1949 to 1968 and 1975 to 1994.*

[20] A J Pitman et al, 'The impact of land cover change on the climate of south west Western Australia' (2004) 109 D18 *Journal of Geophysical Research* 109.
[21] W J Cai, G Shi and Y Li, 'Multidecadal fluctuations of winter rainfall over southwest Western Australia simulated in the CSIRO Mark 3 coupled model', (2005) 32(12) *Geophysical Research Letters* L12701.
[22] W J Cai and T Cowan 2006. 'The SAM and regional rainfall in IPCC AR4 models: can anthropogenic forcing account for southwest Western Australian rainfall reduction', (2006) 33 *Geophysical Research Letters* L24708.
[23] Don McFarlane et al, 'Climate change impacts on water yields and demands in south-western Australia' (2012) *Journal of Hydrology* 488, 489.
[24] W J Cai and T Cowan, above, n 22.
[25] O F Parry et al (ed), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2007) 510.

- *Significant warming south of 30° S [a line a little north of Jurien and Kalgoorlie] over these periods has reduced the temperature gradient between the equator and South Pole, particularly over the Indian Ocean.*
- *As a result, the stability of the atmosphere increased in winter and in other seasons over the period 1950 to 1999 in regions important for the formation of storms affecting SWWA. The net result has been fewer storms impacting on SWWA, and a downward trend in rainfall in the region…*
- *The observed patterns of large-scale atmospheric change associated with SWWA rainfall reductions are consistent with what would be expected in an atmosphere influenced by increasing greenhouse gas concentrations.*[26]

20. The Western Australian government has accepted this advice, acknowledging that climate change due to increased levels of greenhouse gases in the atmosphere 'has contributed substantially to reduced rainfall...in the south-west.'[27]

Groundwater regulation and management in a drying climate: challenges and responses

21. It is likely that research on regulatory and management challenges and responses will need to be drawn from a combination of articles in relevant legal and policy journals, in addition to analysis of government reports, relevant legislation, case law, parliamentary materials, law reform papers, water allocation plans and policies and interviews with government officers.

22. There are two related but distinct areas of research: research on 'water resource management' and research on 'water supply management'. Water resource management, in a groundwater context, is concerned with direct management of groundwater extraction and activities that affect groundwater quality, whereas water supply management concerns measures to ensure that community water needs are met.

23. The following table provides some examples of the challenges and responses in these two areas. A number of the responses have been adopted in Western Australia.

[26] Indian Ocean Climate Initiative, above, n 9, 9-10.
[27] Western Australian Government, *Adapting to our changing climate* (October 2012), 6 (quoted words) and 1 (acknowledging the link between increased levels of greenhouse gases, global climate change and reduced rainfall across southern Australia).

Table: Water resource management and water supply planning: examples of challenges and responses in a drying climate

	Challenge	**Possible Response (examples)**
Water resource management	Return overallocated groundwater systems to sustainable levels of extraction	• Amend water allocation plans and water licences[28] • Direct water purchasing[29]
	Avoid further overallocation due to continued drying trends	• Express water entitlements as a share of the consumptive pool of a water resource[30] • Incorporate climate change scenarios into water allocation plans[31] • Incorporate climate change scenarios into integrated land/water/biodiversity planning[32]
	Ensure that groundwater is used efficiently in fully allocated systems.	• Encourage trading in water entitlements
Water supply management	Bring on new sources of supply while addressing environmental impacts[33]	• Build 'carbon neutral' desalination plants • Increase recycling of storm and waste water • Managed aquifer recharge
	Increase the efficiency with which the public water supply is used. [34]	• Restrict household sprinkler use • Provide education on waterwise gardens • Require water-efficiency 'star-ratings' for products

[28] See SKM, 'Review into the management of overallocated groundwater resources in the Gnangara mound groundwater management area: case studies and options' (Consultancy study undertaken for the Department of Water, February 2009).
[29] James Horne, 'Australian water policy in a climate change context: some reflections', (2013) 29.2 *International Journal of Water Resources Development* 137, 143.
[30] Council of Australian Governments, *Intergovernmental Agreement on a National Water Initiative* (2004) 5-6 [28].
[31] Water allocation plans are available at Department of Water, *Allocation Planning* <http://www.water.wa.gov.au/Managing+water/Allocation+planning/default.aspx>
[32] See draft Gnangara Sustainability Strategy and related materials: <http://www.water.wa.gov.au/sites/gss/otherPubs.html>.
[33] See Bryson C Bates and Graeme Hughes, above n 15.
[34] Ibid and Water Corporation, *Water Forever: Towards Climate Resilience* (October 2009).

24. Of course, each response to one challenge has the potential to raise further challenges. For example, efforts to return overallocated systems to sustainable levels of extraction can raise difficult questions as to how to best share declining water resources between consumptive use and dependent ecosystems.

25. The focus of this project, at least initially, will be on water resource management as this is more directly relevant to the research goals of the National Centre for Groundwater Research and Training.

Responses by other jurisdictions to comparable challenges

26. In the first instance the project will consider regulatory and management approaches in other Australian jurisdictions with groundwater resources that have experienced a drying trend. While further investigation is required, this may include Victoria, New South Wales, South Australia and Queensland.[35]

27. On the international front, the work of the Intergovernmental Panel on Climate Change provides a starting point in identifying comparator jurisdictions.[36] It identifies the western USA, southern Canada and the Africa's Sahel region (as well as Australia) as having suffered from intense and multiannual droughts.[37] Of these regions, possible comparator jurisdictions include Arizona and California.

    – Arizona has experienced a drying trend and intense competition for groundwater resources.[38] Prospective areas to investigate are Arizona's approach to groundwater recharge and recovery and the mechanisms it has sought to use to return areas experiencing over-extraction to 'safe yield'.[39]

    – Due to growth in population and water demand California's groundwater resources are under also considerable pressure.[40] While its laws for groundwater

[35] See Bureau of Meteorology, *Trends in Annual Total Rainfall 1970-2012*< http://www.bom.gov.au>; see also Climate Change Commission reports on climate change impacts for different Australian regions: <http://climatecommission.gov.au/resources/commission-reports/>.
[36] O F Parry et al, above n 25.
[37] Ibid 180.
[38] US EPA, 'Rate of Precipitation Change in the United States 1901-2011, <http://www.epa.gov/climatechange/science/indicators/weather-climate/precipitation.html>; Bonnie G Colby and Katharine L Jacobs (eds), *Arizona Water Policy: Management and Innovations in an Ubanizing, Arid Region* (Resources for the Future, 2007), Chapter 1.
[39] Ibid.
[40] Department of Water Resources, *California Water Plan: Update 2009* (Bulletin 160-09), 2-7.

management are very different to Western Australia's, there may be lessons to be learned. For example, if the project does consider approaches water supply management, consideration could be given to California's legislation that requires the responsible department to prepare, consult on and regularly update a state-wide water supply plan.[41]

Objectives of a groundwater regulatory framework in a drying climate, and options to achieve those objectives

28. A number of journal articles have considered water laws in a climate change context, and some touch on the issue of groundwater management under drying climatic conditions.[42] Some of the common themes in these articles are that regulatory frameworks should ensure that:

    – climate change impacts are taken into account in water resource planning

    – there is scope to manage adaptively, while recognising that this may need to be balanced against the need for well-defined water rights

    – mechanisms are available to address over-exploitation of water resources

    – economic incentives promote efficient water use

    – water managers have sufficient technical capacity and human resources.

29. These articles also stress the need for 'integrated water resource management', which has been defined as:

    a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant

[41] Cal Water Code §10004 -10013.

[42] Carl Bruch and Jessica Troell, 'Legalising adaptation: water law in a changing climate' (2011) 36.7 *Water International* 828; Marcella Nanni, 'Legislation as a tool in support of adaptive water management in response to climate change' (2012) 37.6 *Water International* 628; Poh-Ling 'Adaptation measures for water security in a changing climate: Policy, planning, law', T Bonyhady, J McDonald and A Macintosh (eds), *Climate Change Adaptation: Policy and Law* (Federation Press, 2010); Mrittika Basu and Rajib Shaw, 'Water policy, climate change and adaptation in South Asia' (2013) 70(2) *International Journal of Environmental Studies* 175.

> *economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.*[43]

Comment on the value of the project and its place in the literature

30. It appears that this project will make a new contribution to the literature. There is some literature addressing climate change impacts on Western Australia's water resources and adaptation measures that have been adopted in response – especially with respect to metropolitan water supplies.[44] However, there does not appear to be any analysis of Western Australia's regulatory response to date or the future implications of climate change for Western Australian water law and policy.[45]

31. The project has the potential to contribute to the development of water law and policy in Western Australia. Proposals for water law reform are likely to be released for comment in late 2013. Analysis carried out for the project could contribute to the reform process.

32. In order to maximise this contribution, early research could concentrate on areas that are likely to be most relevant to WA water law reform. One prospective 'sub-project' could involve:

    – identifying changes that would be needed for Western Australia to comply with the National Water Initiative and their value in adapting to a drying climate

    – identifying, with reference to past legislative reform in other Australian jurisdictions, legislative options to implement those changes

[43] Global Water Partnership, *What is IWRM?* < http://www.gwp.org/The-Challenge/What-is-IWRM/>.
[44] e.g. Bryson C Bates and Graeme Hughes, above n 15; Department of Agriculture and Food, *Climate Change Vulnerability and Adaptation for South West Western Australia 1970 to 2006* (Western Australia Agriculture Authority, 2008).
[45] Compare Poh-Ling Tan, above n 43 (no discussion of WA water law); Andrew Macintosh, Anita Foerster and Jan McDonald, *Limp, leap or learn? Development legal frameworks for climate change adaptation planning in Australia* (National Climate Change Adaptation Research Facility, 2013) (addresses coastal climate change and bushfire hazards); Carl Bruch and Jessica Troell, above n 42 (a global review); Stuart-Hill Sabine, Roland Schulze, 'Does South Africa's water law and policy allow for climate change adaptation?', (2010) 2.2 *Climate and Development* 128 (South African study); James Horne, 'Australian water policy in a climate change context: some reflections', (2013) 29.2 *International Journal of Water Resources Development* 137 (Murray-Darling focus).

- analysing the suitability of those options in the context of Western Australia's groundwater resources.

33. This sub-project would build on the existing literature concerning the NWI, including articles addressing water pricing, environmental water allocations and trade in groundwater entitlements.[46]

34. In addition to the Western Australian focus, a more generic assessment of regulatory objectives and options for groundwater management in a drying climate has the potential to make a contribution to the international literature in this area. This is an important area of scholarship, given that groundwater is the source of around one third of freshwater withdrawals worldwide.[47]

[46] Alex Gardner, Darla Hatton MacDonald and Vivian Chung, 'Pricing water for environmental externalities in Western Australia' (2006) 23 *Environmental and Planning Law Journal* 309; Alex Gardner, 'Environmental Water Allocations in Australia' (2006) 23 *Environmental and Planning Law Journal* 208; Skurray, James H., E. J. Roberts, and David J. Pannell. "Hydrological challenges to groundwater trading: lessons from south-west Western Australia." *Journal of Hydrology* 412 (2012) 256; James H. Skurray, Ram Pandit and David J. Pannell, 'Institutional impediments to groundwater trading: the case of the Gnangara groundwater system of Western Australia' (2013) 56(7) *Journal of Environmental Planning and Management* 1046; James H. Skurray and David J. Pannell, 'Potential approaches to the management of third-party impacts from groundwater transfers' (2012) 20(5) *Hydrogeology Journal* 879; Fisher, D E, *Implementing the National Water Initiative: A Generic Set of Arrangements for Managing Interests in Water* (2006); National Water Commission, *The National Water Initiative - securing Australia's water future: 2011 assessment* (2011); Karen Hussey; Stephen Dovers, *Managing water for Australia : the social and institutional challenges*; CSIRO, 2007.

[47] Richard G. Taylor et al, 'Ground water and climate change' (2012) 3(4) Nature Climate Change 322.