Social research to improve groundwater governance: literature review

Michael Mitchell, Allan Curtis, Emily Sharp & Emily Mendham
Cover photos: Left and middle: Groundwater pump and irrigated vineyard in McLaren Vale (Willunga Basin) region, South Australia (Joseph Guillaume, ANU); Right: Release of groundwater stored in a farm dam to irrigate a cotton crop in Namoi region, New South Wales (David Pannell, UWA)
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Introduction

Australia relies heavily on groundwater resources that account for over 30% of the water consumed in Australia. Groundwater is crucial to the survival of irrigated agriculture, other industries, urban areas, and to ecosystem functioning in many parts of Australia. Yet groundwater management and governance remains an understudied topic by comparison with surface water. In an attempt to redress this imbalance, the Australian government supported establishment of the National Centre for Groundwater Research and Training (NCGRT).

The NCGRT is coordinating the efforts of almost 200 researchers to explore key questions related to groundwater in Australia – including a basic understanding of groundwater processes, how groundwater interacts with surface water, vegetation, and the environment, and how to improve management of the resource through policy, decision support and stakeholder engagement.

Research is organised across the five programs listed below:

- Program 1: Innovative Characterisation of Aquifers and Aquitards
- Program 2: Hydrodynamics and Modelling of Complex Groundwater Systems
- Program 3: Surface Water - Groundwater Interactions
- Program 4: Groundwater-Vegetation-Atmosphere Interactions (GVI)
- Program 5: Integrating Socioeconomics, Policy and Decision Support

These research efforts have been enhanced by the establishment of six ‘Super Science’ groundwater monitoring sites across Australia, including the Namoi basin in northern New South Wales (NSW) and the Willunga basin south of Adelaide in South Australia. A major focus of the integrated program relates to the Namoi and Willunga basins, as well as case study sites along the Lachlan and upper Murrumbidgee Rivers in NSW, Gnangara basin in Western Australia and other urban and peri-urban areas across Australia.

All environments have been and are being modified by human activity. Changing human behaviour is therefore essential, especially when these activities deny opportunities for future generations to live off and enjoy our planet. However, changing human behaviour is often difficult to accomplish. This is the essence of the rationale for research examining the social dimensions of natural resource management (NRM).

Even the term ‘management’ does not convey the extent of the difficulties and complexities in how society interacts with the environment. In the groundwater context, write Mukherji and Shah (2005, p. 339), the term ‘management’ can imply expert-driven processes derived from ‘mathematical model-building exercises’ of hydrologists and ‘the formulation and implementation of groundwater laws’ by water managers. The term ‘governance’, they suggest, represents a paradigm shift in thinking towards more inclusive approaches that take into account concerns of hydrologists, other experts, policy makers, groundwater users and other stakeholders. They emphasise that the current

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1 A similar argument has also been put by Dietz, Ostrom and Stern (2003), when introducing the term adaptive governance in place of adaptive management ‘because the idea of governance conveys the difficulty of control, the need to proceed in the face of substantial uncertainty, and the importance of dealing with diversity and reconciling conflict among people and groups who differ in values, interests, perspectives, power, and the kinds of information they bring to situations.’
water crisis is ‘mainly a crisis in governance’ (Mukherji & Shah, 2005, citing the Global Water Partnership’s 2000 Framework for Action). Governance involves the interactions between social structures, processes and traditions that determine how power in society influences how decisions are made, how responsibilities are exercised and who has a say in all of this, and how (Lockwood, Davidson, Curtis, Stratford & Griffith, 2010, p. 987).

As with many other NRM arenas, the management and governance of groundwater is complex because causes and effects are often uncertain; effective intervention often requires substantial effort over a considerable period of time; it is often difficult to link an intervention with change in resource condition; and in many instances, no single actor is capable of addressing these issues on their own. That is, we are often dealing with ‘wicked problems’ (Allan, 2008; Rittel & Webber, 1973). Behavioural change may occur with the development of new technologies, but there are many examples of technological solutions that have not been widely implemented because they were not socially acceptable (Pannell, Marshall, Barr, Curtis, Vanclay & Wilkinson, 2006). It is also clear from Australian and international experience that land and water degradation frequently result from deficiencies in governance arrangements. That is, our societies have been unable to establish effective formal and informal arrangements to make and implement sound decisions (Lockwood et al., 2010). This is especially apparent in the management of Australia’s Murray-Darling Basin’s water resources where governments have over-allocated surface and groundwater resources for irrigation; then belatedly introduced an inadequate cap on extractions and failed to prevent that cap from being exceeded; and more recently have unsuccessfully attempted to implement reforms that would enhance ecological outcomes by further reducing allocations to irrigation. Groundwater governance also has its own challenges, including those related to compliance when the resource is largely invisible and the interconnections with surface water are poorly understood or mapped.

Social research in NRM typically focuses on the role of human and social capital in the maintenance or improvement of environmental condition (Curtis & Lefroy, 2010). As Webb and Curtis (2002) explain, the skills, abilities and wellbeing of the population form human capital – our individual abilities to contribute to our own and other’s satisfaction (Castle, 2002, p. 335), while social capital refers to the social relations, networks, trust and norms that arise between people when they interact, and which can then lead to further benefits (Sobels, Curtis & Lockie, 2001, building on the seminal conceptualisation by Putnam). For social researchers, a key assumption is that ‘wicked problems’ are best addressed by engaging stakeholders in processes that involve dialogue, learning and action – that is, by engaging and building human and social capital.

Drawing upon theory and empirical studies, social researchers can identify principles and practices that will enhance groundwater governance. For example, social researchers have developed principles for effective stakeholder engagement (Aslin & Brown, 2002), empowering and proactive social impact assessment (Burdge, 2004; Dale, Taylor & Lane, 2001; Howitt, 1989); inclusive and collaborative approaches for regional NRM governance (Lockwood et al., 2010); implementing adaptive management at the regional scale (Allan, Curtis, Stankey & Shindler, 2008); and evaluation of NRM programs (Curtis, Race & Robertson, 1998). Of course, there are many other aspects of social research that can support improved groundwater governance, including knowledge of innovative institutional arrangements (Gunningham, 2007) and ways social norms can support innovation (Minato, Curtis & Allan, 2010).
As the group leading social research in the NCGRT one of our first challenges was to identify and document existing social research related to groundwater governance in Australia. We reviewed the international literature because we expected the body of literature in Australia to be small and because we expected to learn from overseas experiences and analysis. Our objective was to establish a sound footing for social research in the NCGRT. That is, we wanted to identify what had been accomplished and make some judgements about the quality of that research; and identify gaps and other opportunities for future social research in the NCGRT. Part of our motivation was to identify worthwhile topics for doctoral and post-doctoral research within the NCGRT. The latter objective has been accomplished, in part at least. For example, doctoral students and post-doctoral fellows within our team are now engaged in research examining aspects of trust, risk perception, social learning, resilience thinking, the landholder adoption of recommended management practices and institutional arrangements for collaborative management of groundwater. Additional research opportunities related to occupational identity, social norms and the social construction of the concept of sustainable yield have also been identified.

This literature review therefore sets out to address three aims:

1. Provide an overview of the current literature related to social dimensions of groundwater governance;
2. Identify areas where social researchers can contribute to knowledge; and
3. Provide a sound foundation for social research within NCGRT’s work.

In accomplishing these tasks we faced a number of challenges. Firstly, what was the scope of our review? Given the focus of the NCGRT on Australia, and of Program 5 on rural/regional contexts, we have placed greater emphasis on literature related to agriculture in the arid and semi-arid climatic regions of developed nations than on other agricultural or urban water supply contexts. A second challenge was to develop a sound process for the identification and analysis of research outputs (reports, papers, book chapters and books). Our response to this challenge is explained in the section on literature search methods below. The third challenge was to develop a coherent structure for the review summary or report. Our approach has been to organise the literature into themes that summarised the key areas of research being addressed. These themes were identified iteratively, beginning with an initial mind-mapping exercise from topics identified in the literature, then progressively synthesising the number down to five themes (power and influence; social impacts of water reform; community self-regulation; stakeholder engagement; and farmer decision-making – as shown in Figure 2 on page 10). A final challenge concerned the timeframe for the review, and whether the literature database established for the review should be maintained and the review document updated. We began the review in early 2010 and continued to identify and review additional articles until early 2011. At this stage there is no intention to update the review document. Our expectation is that subsequent publications by NCGRT doctoral students and post-doctoral fellows will include literature reviews that build on and update this review. Readers seeking a full list of the most relevant publications identified during the literature search can contact Michael Mitchell at mimitchell@csu.edu.au.

The literature review is structured as follows. We begin by explaining our literature search methods and introduce the themes we have chosen to focus on and the five research papers we highlight for
each. The rest of the review is organised according to the five themes. As part of our efforts to make judgements about the relevance and quality of the research reviewed, we have prepared brief summaries of a limited number of papers, highlighting a key paper in each theme. For each theme we also identify some important opportunities for further research. The key gaps and issues arising are presented in the concluding summary.

**Literature search methods and overview**

**Literature search methods**

While ‘groundwater’, ‘ground water’ and ‘aquifer’ are useful terms to identify groundwater related research, there were no particularly useful terms to narrow results to those publications focused on the social dimensions of groundwater governance. We therefore employed a combination of initial keyword searches, followed by snowball searches using the papers and authors identified, and backed up by keyword searches of specific journals. At the same time, we were also undertaking searches of the academic and grey literature for the NCGRT case study areas we are involved in (the Namoi catchment in NSW and the Willunga Basin south of Adelaide in South Australia). All the relevant literature was recorded into an EndNote database, which facilitated subsequent sorting in terms of relevance.

**Step one: initiating the literature search and sorting method**

The literature search began by identifying and compiling publications already included in the authors’ literature databases that were specifically related to groundwater. These publications were then classified into three broad categories based on a quick preliminary assessment of their perceived relevance to the social dimensions of groundwater governance (i.e. – 1 – most relevant; 2 – moderately relevant; and 3 – peripherally or not relevant). An additional related category was also created for publications that related to social dimensions of water governance but did not relate to groundwater specifically. This classification of the literature was undertaken using the group facility in the EndNote software program. Using this facility meant that as further literature was found, it was easy to quickly scan publications and classify them.

The first keyword search was undertaken using the Informaworld database, and used the following keywords: ‘groundwater’ in title/article AND ‘social’ AND ‘sustainability’ in all fields. This was intended to be a test, but the result was suitably focused (although it may not have revealed all of the publications in the database related to social dimensions of groundwater governance). All ten results were recorded into the EndNote database. Half of these publications were assessed as being most relevant. Two of these publications were later identified as being based on empirical research (Mustafa & Qazi, 2008; Sagala & Smith, 2008) as further explained below.

**Step two: snowball searching**

The next stage involved a range of snowball searching strategies, including:

1. reading papers to identify other relevant papers the author has cited;
2. for particularly useful papers, using journal database facilities to identify other papers that had cited the article; and
3. undertaking searches for literature by specific authors.

As each additional paper was entered into the EndNote database, a note was included to explain the method used to source it.

A clear limitation of this strategy is the possibility that the literature uncovered may be focused around a dominant mass of work – i.e. the literature predominantly used by the bulk of those writing in the area. While identifying this dominant literature set is useful and important, we anticipated that there may be work by social researchers who happen to draw on a case study related to groundwater that has not been picked up by this predominant group (e.g. Budds, 2009; Crow & Sultana, 2002; Shriver & Peaden, 2009), and that this work could offer interesting and/or alternative insights and perspectives. For this reason, we also undertook searches of specific social science journals, as discussed in Step 3 below.

**Step three: organising the ‘most relevant’ publications**

Once a substantial body of literature had been found (i.e. over 100 items), we undertook a re-evaluation of how we had prioritised publications into the categories described at step one. Through this process, we categorised over half of the literature reviewed as ‘relevant’, a quarter as ‘less relevant’ and the remainder as being of ‘minor relevance’. At the time of writing (October 2011), there are over 250 publications identified as ‘most relevant’, over ‘120’ as ‘less relevant’ and around 90 categorised as being of ‘minor relevance’. It became clear that we needed a way to further prioritise these ‘most relevant’ articles, and we identified four criteria to do this:

1. **Evidence of empirical social research (SR):** We prioritised those studies that showed evidence of original empirical research that used social research methods and created a new category for these ‘SR’. This meant we could separate these empirical studies from the many other papers we deemed to be most relevant. We described those other papers as offering useful social analysis or providing a useful overview or background to a particular issue.

2. **Underpinned by social theory:** We examined the publications to identify whether the research was underpinned by social theory. This criterion was particularly helpful when selecting a set of ‘best’ articles for in-depth review.

3. **Quality and peer-reviewed:** We prioritised studies that had been published in peer-reviewed journals. An unfortunate finding is that a lot of potentially useful research in Australia has not appeared in peer review journals. Of most use are publications that appear in peer-reviewed journals that are based on much more detailed publicly available reports, such as Syme, Nancarrow and McCreddin (1999), based on Nancarrow, McCreddin and Syme (1998). We also used a combination of journal impact factors, Australia’s ERA rankings of journals, and our professional judgement to identify journals that publish high quality social research related to NRM, such as Society and Natural Resources, Local Environment, Journal of Environmental Management, Geoforum, World Development and Ecology and Society.

4. Another factor we assessed was the **social context**. We were keen to have a broad geographical spread of studies from across the world while also paying attention to how the social context for each study might inform the social research agenda and case study
contexts in the NCGRT. We were therefore particularly interested in literature that focused on groundwater used for irrigated agriculture.

Being aware of the limitation of snow-balling search methods, and the dearth of publications that were based on sound social empirical research methods, we employed an additional search process to target specific social science and geography journals. This turned out to be an effective search method as a combined search for keywords ‘groundwater’ ‘ground water’ and ‘aquifer’ resulted in only a few articles per journal.

**Step four: an Excel spreadsheet**

As our database of literature expanded, we recognised the benefit of using an Excel spreadsheet to organise the ‘most relevant’ literature in multiple ways; i.e. by topic, geographical location, date, type of publication and whether and what type of social research methods were used (see Figure 1 for examples of the notes for two publications). We were later able to select and further organise the articles labelled SR in the spreadsheet according to the themes for this report, and whether qualitative (QL), quantitative (QT) or mixed social research methods were used. This further classification helped in the allocation of articles we reviewed according to our respective strengths.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>2004</td>
<td>2009</td>
</tr>
<tr>
<td>Whether and what type of social research methods were used</td>
<td>SR – QL – rapid appraisal &amp; workshop</td>
<td>SR – QL – survey &amp; interviews</td>
</tr>
<tr>
<td>Type of publication</td>
<td>jnl article - GW jnl</td>
<td>jnl article - geog jnl</td>
</tr>
<tr>
<td>Geographical location</td>
<td>Middle East – Jordan</td>
<td>Asia - South Asia - India - Rajasthan</td>
</tr>
<tr>
<td>Key topic being addressed</td>
<td>Management/rules - stakeholder participation</td>
<td>Management/rules - community mgmt</td>
</tr>
</tbody>
</table>

**Figure 1: Examples of the notes used in the Excel database of ‘most relevant’ publications**

This exercise revealed two key characteristics about the collection.

1. A limited number of articles relating to Australia.

To ensure that we had not overlooked articles relevant to Australia we undertook a specific search of the Australian Public Affairs - Full Text (APA-FT) database for all articles that had ‘groundwater’ or ‘ground water’ or ‘aquifer’ mentioned in any field, and examined the literature identified. Only ten additional publications were identified as ‘most relevant’. We also undertook similar searches of specific Australian journals and searches for articles by key authors (e.g. Syme, Nancarrow, Bjornlund), including their individual list of publications, and the authors that had cited their articles. These searches did not add any significant additional peer-reviewed publications to our ‘most relevant’ list.
2. A limited number of publications that satisfied all of the four criteria listed in Step 3 above.

Few of the publications identified met the first two criteria as most were only peripherally related to social research. In many instances the research discussed was part of a larger integrated project where the social research was a minor element. In other instances there was little attempt to embed the research activity within the context of social research methods or theory. Our search of social science and geography journals was able to rectify this situation to a degree.

**Step five: developing a ‘map’ of the existing literature**

Identifying themes based on research topics was an important part of the review process. Our initial method was to ‘map’ the literature into themes or broad categories based on the major focus of articles reviewed. We used the topics we had identified when populating the Excel spreadsheet to identify titles for themes. Some of these used the language from titles of publications (e.g. ‘scarcity and conflict’; ‘framing disputes’) while others were drawn from our knowledge of the wider literature (e.g. ‘power & interest groups’; ‘farmer perspectives/ decision making’). We thought it was important to identify themes and sub-themes where social research has made a substantial contribution to the NRM literature (e.g. engagement, adaptive management, adoption by landholders).

Over time we created several iterations of this visual cognitive or mind map before settling on that shown in Appendix 1 (based on 98 ‘most relevant’ publications). Seventeen key themes were identified as a series of central circled notes, from which another 37 sub-themes were identified, and connections were also drawn from each of these sub-themes to other key themes and sub-themes. Some examples of the 17 themes include:

1. the ‘sustainable use debate’ – about what sustainable use of groundwater means (e.g. Alley & Leake, 2004; Shriver & Peaden, 2009; Sophocleous, 2000);
2. ‘self-regulation’ of groundwater use (e.g. López-Gunn & Cortina, 2006; Schlager & López-Gunn, 2006; Wester, Hoogesteger & Vincent, 2009) – often closely linked with questions about groundwater ‘ownership’ (e.g. Burchi & Nanni, 2003; Kuper, et al., 2009; Wagner & Kreuter, 2004) and the application of Ostrom’s (1990) principles and the notion of groundwater as ‘common property’ (e.g. Ross & Martinez-Santos, 2010);
3. stakeholder engagement in general (e.g. Dreelin & Rose, 2009; George, Tan, Baldwin, Mackenzie & White, 2009; Kastens & Newig, 2008); and
4. ‘transboundary GW governance’ – management of groundwater systems that traverse political boundaries (e.g. Feitelson, 2006; Morris, Mohapatra & Mitchell, 2006; Smith, 2002).

A limitation of the themes identified through this mapping process is that they do not make explicit the policy and practice implications of groundwater management. This limitation stems from the decision to prioritise publications that included evidence of original research. While we extended our

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2 Half of the 20 most useful articles (i.e. Birkenholtz, 2008, 2009; Bluemling, Pahl-Wostl, Yang & Mosler, 2010; Bolin, Collins & Darby, 2008; Budds, 2009; Henriksen & Barlebo, 2008; Mustafa & Qazi, 2007; Shah, et al., 2009; Shriver & Peaden, 2009; Zhang, Wang, Huang & Rozelle, 2008) were found as a result of these specific searches.
map to include publications that provided useful social or political analysis, we did not include reflective or insight articles that recommended or reviewed particular policies or practices (e.g. Mohapatra & Mitchell, 2009; Nevill, 2009; Theesfeld, 2010; Turral & Fullagar, 2007). The map therefore focused on issues, often leaving the policy implications implicit or unidentified.

To limit the number of themes to a more manageable amount, we grouped themes using the map, and highlighted themes that were relevant for our NCGRT case study research projects in the Namoi and Willunga Basin areas of NSW and South Australia respectively. Initially ten themes were identified including topics of ‘groundwater trading’ (relevant to the Namoi case study) and ‘participatory approaches to decision support systems’ such as modelling (relevant to the Willunga Basin case study). We then combined themes, eventually reducing their number to the five themes introduced below. For example, the ‘sustainable use debate’ and ‘transboundary issues’ became part of the theme related to ‘power and influence’ and the theme on ‘groundwater markets and trading’ became a subset of the theme on ‘social impacts of water reform’.
Social dimensions of groundwater governance: a thematic review of the literature

Introduction to themes and publications highlighted for each theme

Five themes have been identified for this review:

1. Power, influence and ‘sustainable yield’;
2. Social impacts of water reform;
3. Community self-regulation;
4. Stakeholder engagement; and
5. Farmer decision-making.

The order of the themes became apparent once a substantial first draft of the review was completed. As depicted in Figure 2, there is a trend in the themes from those that are more general, towards those that are of more specific interest to groundwater governance issues in an agricultural context. The first theme provides the unifying theoretical context and an important part of the explanation of the potential contribution of social research to groundwater research. From this basis we emphasise theoretically sound and empirical research, such as theoretical approaches to justice used to examine water reform impacts (e.g. Syme et al., 1999), and theories around the role of social capital, social norms and collective action to improve opportunities for self-regulation (López-Gunn & Cortina, 2006; Mustafa & Qazi, 2007; van Steenbergen, 2006; López-Gunn, 2003).

Figure 2: Thematic structure of literature review

It is important to appreciate the role that power and influence can play in groundwater management and policy implementation. This also helps to explain the increasing emphasis on ensuring that there is effective stakeholder engagement in the design and implementation of groundwater reforms and policies. There is a growing interest in providing scope for genuinely collaborative approaches over consultative approaches that are often ineffective or even counterproductive. Examples of
collaborative approaches include modifying the use of modelling techniques to enhance collaboration, participation and social learning (e.g. Henriksen & Barlebo, 2008; Zellner, 2008).

The final theme is about understanding farmer decision-making and appreciating the knowledge and perspectives that groundwater users have of the system they depend upon (e.g. Birkenholtz, 2008; Clark & Brake, 2009). This is an important topic given that NRM outcomes in Australia continue to be shaped by the actions of a relatively small number of rural landholders. Engaging and building the capacity of these individuals to take sound decisions to enhance sustainability represents cutting edge research where we would like to make a difference.

While identifying themes, we also grouped papers to correspond with these themes, aiming to select one paper for in-depth review that could provide a focus for each theme. The initial selection occurred early in the process when there were ten themes. One basis for the process of selection was the four criteria described at step three above. The other basis was to draw on our individual research strengths with a view to establishing a strong footing in the field of groundwater governance. The resulting five papers are the best examples on a particular theoretical aspect of individual interest, even if we found that they were lacking in some aspects of quality. So, for example, our interest and expertise in the notion of trust led to the selection of Diwakara (2006) as the paper highlighted for review under the third theme on self-regulation, even though there were other papers that we would consider of better quality under that theme. On the other hand, the papers selected for the first, second and third themes (i.e. Budds, 2009; Syme et al., 1999; and Henriksen & Barlebo, 2008, respectively) represent the best quality papers we could identify for those themes. The contexts for these papers are wide-ranging. Budds (2009) examines a case study of groundwater irrigated agriculture in a semi-arid region of Chile; Syme et al. (1999) is focused on a number of Australian case studies, some of which are groundwater related. The Henriksen and Barlebo (2008) paper examines irrigated agriculture in Denmark. Bekkar, Kuper, Errahj, Faysse and Gafsi, (2009) was selected for the final theme on farmer decision-making because, at the time, it was the only paper we had identified where the researchers actually went out into the field to survey and interview farmers.

Theme 1: Power, influence and ‘sustainable yield’

Many of the papers that explore how power and influence is exerted within society do so in situations of conflict over groundwater as a resource, especially where there are conflicting interpretations of how that resource can be used sustainably. Many of the papers grouped under this theme were based on sound use of social research methods underpinned by social theory (e.g. Birkenholtz, 2008, 2009; Bolin et al., 2008; Budds, 2009 – all using political ecology to frame their investigations), setting them apart from the bulk of the literature we identified during our review. The papers grouped under this theme illustrate the potential contributions of social research to improving groundwater governance. Such a case is made most convincingly by Budds (2009), the paper we have highlighted for this section. Her paper demonstrates that hydrological assessments that ignore social dimensions risk reinforcing existing power structures and can thus directly undermine efforts to resolve conflicts over groundwater management.

Included under this theme are research papers exploring groundwater systems that traverse national, state and even local jurisdictional boundaries, such as in Israel and Palestine (Feitelson, 2006; Fischhendler, 2008) and in North America (Smith, 2002). There is considerable focus on these
cross-boundary contexts given that they comprise the most notorious and difficult to resolve conflicts over groundwater use. Much of the analysis in these papers is focused on legal and policy developments and recommendations (e.g. Kemper, Mestre & Amore, 2003; Klawitter, 2007; Mohapatra & Mitchell, 2009; Morris et al., 2006).

‘Contested H2O: Science, policy and politics in water resources management in Chile’ – J. Budds

The paper by Budds (2009) relates to La Ligua river basin, a groundwater dependent agricultural region north of Santiago in central Chile. As in many other newly industrialising economies around the world, agricultural practices in Chile have been undergoing a transformation away from annual crops for domestic supply to permanent fruit plantations for export. This phenomenon has driven the expansion of plantations in the upper reaches of La Ligua basin, and increased pressure from agribusiness to obtain rights to access groundwater. Chile’s 1981 Water Code possibly represents the most extreme case of treating water as a commodity, with water rights governed by private law, and the role of government confined to administration, with only limited regulatory powers introduced to the Code in 2005 (Budds, 2009, p. 421).

In this paper, Budds (2009) critically examined an outsourced hydrological assessment study undertaken for a government agency seeking to provide a scientific basis for decisions that would limit groundwater extractions in La Ligua basin. The hydrological assessment was criticised because of the assumptions behind the modelling used, and the input data used as the basis for the water allocation decisions recommended. The results of the assessment were found to be fundamentally flawed, and their effect was to maintain the privileged upstream access to groundwater by agribusiness estate plantations at the expense of most groundwater users who were peasants located downstream. In particular, the modelling failed to incorporate data about the widespread illegal use of groundwater, an amount that was estimated to be almost twice that of actual legal extractions (i.e. 13,859 compared with 7,508 litres per second – Budds, 2009, p. 425). Not surprisingly, illegal groundwater use is predominantly by peasants. The wealthier and better educated farmers upstream were better able to secure rights to groundwater, including an additional 1,547 litres per second they had sought prior to the hydrological assessment, and which was secured as a result of the assessment.

Rather than seeing bio-physical sciences as being ‘producers of purely technical and neutral assessments of environmental processes’, Budds (2009, p. 419) analysis shows that the bio-physical sciences can be used for socio-political purposes. This conclusion fits within a broader argument that the sciences are inherently politicised, and that not all science should be viewed as unquestionably authoritative. A similar conclusion has recently been made in the context of competing models used to resolve groundwater use conflicts in Christchurch, New Zealand, with similar calls that scientific assessments need to be undertaken with greater attention to the social context as part of a rethink of the role of science in the policy process (Weber, Memon & Painter, 2011, pp. 56-57). Budds’ research also makes an important contribution to the practice of research with a political ecology lens. She shows that case studies often focus more on the ‘politics’ and less on the ‘ecology’ – or in Budds’ case, hydrology. In her study, it was vital to have a thorough understanding of the hydrological aspects of the case study in order for her criticisms to have validity.
**Human influence on the environment and how NRM issues are perceived**

A fundamental premise is that all environments have been modified by humans (Vitousek, Mooney, Lubchenco & Melillo, 1997) leading to an increased appreciation that our landscapes are socially constructed (Greider & Garkovich, 1994). There is already a wide body of research exploring ways that environmental issues are socially constructed (e.g. Kalof, 1998), including the issue of water scarcity (e.g. Mehta, 2001; Mustafa, 2007). Such literature does not necessarily have to lead to a denigration of ‘realist’ scientific epistemology in favour of relativism in a world of multiple realities (Williams, 1998). An appreciation of multiple worldviews is, however, essential to understand how scientific information is communicated and taken up by policy makers and other end users (e.g. Moore, et al., 2009). As Budds’ (2009, p. 419) research reminds us, this is also why social scientists argue that they need to be involved from the outset of integrated research. That is, social scientists have the knowledge and skills to make distinctive contributions to problem definition and the development of sound methods, including through participatory processes that link research efforts with those in broader society who need the research, who will benefit from the research, and without whom the research findings may have little relevance (Redclift, 1999, p. 271).

The way in which issues in NRM have been socially constructed was apparent to us from the outset of our search of the groundwater literature. We were struck by the diverse terminology used for groundwater over-exploitation (Custodio, 2002), with a strong preference by most for the term ‘intensive use’ (Llamas & Martinez-Santos, 2005; Llamas & Custodio, 2003; Mukherji, 2006) as a means to circumvent the politically-loaded notion of what constitutes sustainable use of groundwater (Llamas, Martinez-Santos & de la Hera, 2006; Rogers, 2006). In particular, the notion of ‘sustainable yield’ with reference to groundwater has changed over time, leading to alternative notions of ‘safe yield’ or ‘acceptable yield’ (Sophocleous, 2000; Alley & Leake, 2004; Evans, 2010), with direct implications for management strategies (e.g. Seward, Xu & Brendonck, 2006 – who call for more adaptive approaches).

**A better understanding of conflicts over groundwater**

Studies that focus on conflicts arising because of competition over scarce water resources illustrate the impact of the different stakeholder perspectives on groundwater resources. Some authors have focused on clarifying the nature of these conflicts, as in a study from Mexico by Ruelas-Monjardin, Chavez-Cortes and Shaw (2009). To resolve a conflict, it is often necessary that stakeholders involved first identify and acknowledge that there is a conflict, and then build their capacity and strategies to manage and resolve the conflict (Margerum, 1999, p. 158). In some cases, government efforts to reform water use can create conflict because of inadequate appreciation of alternative constructions of knowledge about groundwater, leading to calls for the use of participatory approaches that encourage social learning (Bekkar et al., 2009; Birkenholtz, 2008; Brugnach, Dewulf, Henriksen & van der Keur, 2011).

A useful approach for clarifying conflicts is to examine how opposing parties frame the dispute, as exemplified in a study in the US by Shriver and Peaden (2009). In this case, the dispute involved landowners selling their unused groundwater to supply water deficient cities outside the area via a pipeline. Opponents downstream argued that such action would severely undermine aquifer

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3 We are indebted here to literature searches undertaken by Stu Roberton for the NCGRT.
sustainability, and have major and irreversible flow-on impacts for environments and communities downstream. Both sides in the dispute were able to rely on scientific expert advice to bolster their claims. The framing analysis organised the opposing positions around a set of themes so that the opposing positions could be more clearly presented and understood. This clarity helped reduce misinformation, ambiguity and mistrust, as well as identify the kinds of new scientific evidence that would help to resolve the conflict. The study suggested that even in situations of unresolved conflict between different stakeholder groups, bringing them together to discuss their different perceptions can help clarify what scientific evidence is needed, and rebuild trust in the scientific process.

Bolin et al. (2008) investigated a similar case study context to that of Shriver and Peaden (2009), but used the context to explore issues of scale in political ecology. Their analysis focused on the array of groups opposing a pipeline that would pump water out of an upstream aquifer to serve towns in a separate catchment. Bolin et al. (2008) make a practical contribution to the understanding of a particular groundwater conflict, as well as a theoretical contribution about the importance of scale to political ecological research. In the Bolin et al. study, opposition was galvanised when it became apparent that the transfer of water would have impacts well beyond the local scale. This study also demonstrated that insufficient attention is often paid to the temporal scale, and there is a tendency to focus on short-term technical fixes to difficult problems that require resolution at much longer time scales.

Managing groundwater across boundaries

Issues of power and influence also shape groundwater governance at national or international transboundary scales (e.g. Mitchell, 1998; Mustafa, 2007; Sneddon & Fox, 2006). This is clearly the case in the water-scarce groundwater-reliant arid regions in the western states of the USA, and in the Middle East. In the case of Israel and Palestine, water adds yet another dimension to the conflict between these nations (e.g. Feitelson & Fischhendler, 2009; Klawitter, 2007), but even within the nation of Israel, a disparity of power and influence undermines effective groundwater management (Feitelson, 2006). These disparities emanate in part from the historical advantage of landholders who had secured water rights early on, and the continuous and escalating pressures that this advantage provides to them over others. The disparities become entrenched as advantaged landholders organise to protect their interests, and through the political connections they exploit.

Despite the considerable focus on transboundary issues in the groundwater literature, our search identified very few examples of empirical social research, as opposed to policy or legal commentary. One study (Smith, 2002) used a survey of key informants to identify the extent of groundwater competition between states in the United States, and between the US and its neighbours. The survey updated information Smith had acquired 15 years prior in the context of the potential need for federal government intervention in groundwater management. In the USA, a legal precedent existed for federal intervention in transboundary groundwater management, but Smith (2002, p. 490) found that federal intervention had not occurred because of an increasing trend to devolve responsibilities for NRM from federal to state governments, and to the private sector. While Smith does not provide details on the kinds of items he included in the survey, it seems that the focus is on fact finding. The survey of these key informants could have been extended to elicit their expert opinion on how to improve groundwater management in transboundary contexts, including their thoughts on how and why some areas were able to take more cooperative action to resolve
conflicts. Brief mention was made of one example involving the Great Lakes basin where five US states and a Canadian province (Manitoba) took their own measures to control inter-state competition, but no details were provided.

By contrast, Dreelin and Rose (2009) focused on eliciting expert opinion about how to improve groundwater governance in the Great Lakes state of Michigan. Their survey, exploring the role of science in water policy-making, also included workshops to increase the participation of these experts in improved groundwater governance. Strategies to improve transboundary groundwater management involving the Great Lakes states are developed and recommended in papers by Morris et al. (2006) and Mohapatra and Mitchell (2009). These are well-researched policy analyses, but do not directly engage stakeholders, even though their recommended approaches involve the creation of collaborative management approaches.

Scope for further research

Our review suggests there is considerable scope for social research to contribute to improved groundwater governance, and the following themes provide an opportunity to explore these in more detail. From the discussion above, however, a clear issue arises in relation to how sustainable yield has been conceptualised. There have been advances and changes in thinking related to the concept of sustainable yield (Sophocleous, 2000; Alley & Leake, 2004; Evans, 2010), leading to an appreciation that conflicting interpretations of the concept result from ideas about how knowledge is constructed (Seward et al, 2006, p. 474). Building on previous studies that have examined social construction of other NRM phenomena (e.g. Kalof, 1998; Goldstein, 2007; Mustafa, 2007), it would be timely to undertake an examination into how key experts and other stakeholders in the groundwater industry socially construct the concept of sustainable yield, and the impact this has on the allocation of groundwater resources for environmental and social benefits.

Theme 2: Social impacts of water reform

Australian state and federal governments have implemented a series of water reforms over the past 20 years in response to increasing water scarcity and concerns about environmental degradation. These reforms have led to changes in how both surface and groundwater are regulated and managed. For example, the federal National Water Initiative, agreed upon by the states and federal government in 2004, is meant to achieve ‘a nationally compatible, market, regulatory and planning-based system of managing surface water and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes’ (National Water Commission, 2009, p. 2).

Water reforms are intended to lead to productivity gains and more effective management, and to provide greater certainty for water users. However, these water reforms have the potential to negatively impact on people. Many irrigation-dependent communities and landholders have faced, or will face, large reductions in water availability as a result of efforts to address over-allocation and return surface and groundwater systems to more sustainable levels of extraction. As a result of reduced water allocations, individuals may face increased uncertainty and management challenges related to production decisions, reduced profitability, and higher operating costs (Stubbs, Storer, Lux & Storer, 2010). In turn, rural communities may experience reduced populations, employment opportunities, consumer spending and support for service industries. In many communities impacted by reform processes, disquiet often surfaces in regard to the perceived lack of fairness and
social justice involved in reductions of water availability. For example, the October 2010 release of the Murray Darling Basin Authority's *Guide to the Basin Plan* instigated widespread protests in irrigation-dependent communities.

We have identified Syme et al. (1999) as a key paper in this theme because of its solid theoretical foundations related to the concepts of fairness and justice, and its rigorous empirical research in the water reform context. We link this paper to research that examines how fair decision-making processes, social impact assessments and alternative institutional arrangements may lessen the social impacts of water reform processes. We then examine the features of water markets as a key element of reform, and highlight findings about the equity and impact of water markets on the wider community. We conclude our review of this theme by describing the scope for future research examining the social impacts of water reform.

*‘Defining the components of fairness in the allocation of water to environmental and human uses’ – G.J. Syme, B.E. Nancarrow and J.A. McCreddin*

Syme et al. (1999) summarised seven research studies that sought to develop theories of justice, equity and fairness in water allocation decisions. The research was initiated in response to water reforms implemented by the Australian government. Syme et al. (1999) employed questionnaires and action research. The objective was to develop a set of principles related to justice, equity and fairness that could be used to assess the social impacts of water reform, increase the likelihood of long-term community acceptance of water allocation decisions, and lessen the likelihood of unexpected impacts.

After discovering that existing equity and procedural justice theories were inadequate to explain public evaluation of water allocation decision-making, Syme et al. developed a set of fairness principles and a fairness heuristic that could be used to judge the justice of such decisions. These fairness principles were tested and further developed in their subsequent studies. Syme et al. found that the public considered both distributional and procedural justice when deciding whether water allocation processes were fair. Additionally, the public assessed fairness at two levels: 1) situational – relating to specific water allocation decisions; and, 2) universal – relating to overarching principles. Syme et al. concluded that most of the community can have at least some of their fairness principles met when water allocation processes address both situational and universal aspects of fairness. The research also showed that the public supported the rights of the environment, community’s rights to have a say in allocation decisions, and adherence to principles of procedural justice in the decision-making process. There was also strong support for these principles being applied in ways that took into account each community’s unique context.

The Syme et al. research demonstrates the value of multiple studies that enable researchers to build their understanding of theory and methods over time. The methods used were consistent between studies and the samples used seem adequate, representative of their respective populations and drawn from a variety of locations and contexts. The survey instruments used in the six studies included some items which were the same across all surveys. This allowed for direct comparison of findings across time and locations, enhancing the credibility and impact of findings. This paper is also important because it is one of few studies in Australia to examine social aspects of water reform processes and water allocation decision-making. Most studies in the water management context described as ‘socio-economic’ have a strong focus on economic measures and indicators. However,
the series of studies in this paper show that non-economic values, and factors other than market efficiency, are important to the community in reform processes.

**Fair decision-making processes**

The importance of fairness-based decision-making processes has also been illustrated in research investigating the development of a water sharing plan (WSP) for groundwater resources in the Namoi Valley of New South Wales from 2000. Using open-ended questions within a survey of groundwater licence holders in the WSP area, Kuehne and Bjornlund (2006b) found that irrigators described the WSP development process as frustrating, unfair, confusing and leading to considerable uncertainty. The sources of frustration primarily arose from two controversies. First, conflict regarding the method of entitlement reduction (i.e. based on cuts across the board to all licence holders or based on an irrigator’s history of extraction) led to deterioration of relationships between the government and irrigators. Second, several years of delays in actually implementing the plan led irrigators to criticise the consultation process. Irrigators suggested that had a fair and effective consultation process been initiated early in the WSP development process, the timeframe of the entire process could have been shortened and conflict minimised.

In a survey of the general public in a regional district facing proposals to export groundwater from the region to urban areas in Western Australia, Nancarrow, Kaercher, Po and Syme (2003) found that there were numerous potential sources of conflict in the community regarding fair decision-making processes. The research found two distinct groups within the regional community. One group supported allocation decisions which would emphasise regional development. The other group supported a wider use of water, including to meet environmental needs and uses outside of the region. Nancarrow et al. suggested that water allocation decisions would need to satisfy the concerns of both of these groups for the decision to be fair.

Discourse analysis may help identify competing ideologies in decision-making processes. Butteriss, Wolfenden and Goodridge (2001) used this technique to analyse media output related to pesticide use in cotton crops in the Namoi Valley, New South Wales. They state that discourse analysis deconstructs the content of communication forms to reveal underlying assumptions and ethical positions. By using discourse analysis to identify and appropriately respond to differing ideologies in decision-making processes, facilitators are better positioned to enable and progress decision-making conversations toward consensus (Butteriss et al., 2001).

**Lessening social impacts of reform**

Governments may be able to lessen the impacts of water reform by implementing options identified in socio-economic assessments, and through the use of alternative institutional arrangements, such as conjunctive use of surface and groundwater. Baldwin, O’Keefe and Hamstead (2009) argue that socio-economic assessments have been underutilised in water reform processes. Baldwin et al. conducted interviews and focus groups and analysed the content of water sharing plans in eleven case studies across Australia to better understand how socio-economic assessments have played a role in water planning decisions. They found several faults with the assessments, including: many were conducted mainly for compliance purposes; many primarily used secondary data (e.g. financial statistics, water consumption figures); and, many simply mapped current water use and/or only considered the economic impact of proposals. Baldwin et al. suggest that comprehensive studies
using primary data and integrating social variables (e.g. community well-being, social cohesion and fairness) have the potential to provide better information about trade-offs and possible impacts to communities. In doing so, transparency, community confidence and credibility of decisions could be increased (Baldwin et al., 2009).

Conjunctive use arrangements have also been suggested as a way to reduce water reform impacts and conflict between water users (de Wrachien & Fasso, 2002; Schlager, 2006). Conjunctive use manages surface and groundwater as a connected resource. Schlager (2006) noted that implementation of alternative institutional arrangements for groundwater can be costly and can meet with considerable resistance from affected users. However, Schlager argues that water users are more likely to accept groundwater policy reform when alternative water sources are available. She proposed that conjunctive management could direct use to the source which was more abundant in a particular year. Conjunctive use might also provide future opportunities for groundwater storage to provide alternatives to surface water storages (Schlager, 2006).

In contrast, Fullagar, Allan and Khan (2009) provided a cautionary note in their review of a failed conjunctive use scheme in New South Wales that operated from the late 1970s to the late 1990s. Fullagar et al. argued that groundwater and surface water should not be allocated as a single resource when there is institutional separation of groundwater and surface water. In the case of New South Wales, independent groundwater and surface water institutions prevented accounting across resources and led to over-allocation of groundwater.

Adaptive management approaches may also lessen the social impacts of water reforms through the coordination and collaboration of water users. Ross and Martinez-Santos (2010) used four case studies in Australia and Spain to explore whether Ostrom’s (1990) design principles for common property management are relevant to adaptive groundwater governance. They concluded that scaling up Ostrom’s self-management principles presents challenges such as user heterogeneity, cross scale coordination and collaboration, and monitoring and enforcement. However, flexible processes, such as adaptive management, allow collaboration between water authorities and groundwater users and encourage transparent and inclusive rule-setting processes (Ross & Martinez-Santos, 2010). This, in turn, may lessen impacts of reform because institutional and management arrangements may better reflect local resource and user characteristics.

Earlier research by Kromm and White (1984) investigated resident preferences for potential adjustment policies related to use of the Ogallala aquifer in western Kansas, USA. This research showed that some adjustment issues in industrialised societies have changed little over time and context. Kromm and White found that irrigators preferred adjustment solutions that provided options to increase water use efficiency rather than limiting uses or availability of water. Further, local and regional-level management was preferred for adjustment policies related to water use efficiency, but state-level management was preferred for enforcement of more general regulations. These findings are consistent with more recent calls for community self-regulation of groundwater resources with centralised government acting as a regulatory backstop (e.g. Baldwin, 2008; Birkenholtz, 2009; van Steenbergen, 2006).

In their review of groundwater ownership and private property rights, Burchi and Nanni (2003) stated that a key challenge in groundwater governance is finding the right balance between private ownership of water and regulation by government. Community self-regulation of groundwater may
lessen the social impacts of water reform processes because it acknowledges local resource conditions and community contexts. Additionally, it may also help decision-making processes in situations of over-allocation. Self-regulation forces water users to own the problem and take responsibility for resolving it (Burchi & Nanni, 2003). These authors suggest that community self-regulation can be a viable option where there is strong government and strong private property rights. Australia features a strong central government at state and federal level, and has emphasised secure water entitlements through the introduction of water markets and pricing reform, so this alternative form of governance may be worth further investigation. See Theme 3 for further review of research related to this topic.

**Water markets**

As noted above, water markets have been a key feature of Australian water reforms. Water market trading has aimed to allow water to move from inefficient, low value uses to higher value, more productive uses (Turral & Fullagar, 2007). In addition to facilitating structural change, water markets have also been cited as a way for landholders to gain greater flexibility in production decisions and to manage risks associated with water supply (Frontier Economics, 2007). In Australia, there are markets for both water entitlements (i.e. perpetual entitlement to receive an annual allocation of water) and water allocations (i.e. the right to use a specified volume of water during a given season). However, much of the Australian research undertaken has been directed at surface water markets because groundwater markets are less developed.

Considerable water market research has been undertaken in Australia and internationally in regard to: market participation rates and drivers (Bauer, 2010; Cai, 2008; Loch & Bjornlund, 2010; Morrison, Durante, Greig & Ward, 2008; Sharma & Sharma, 2004; Wheeler, Bjornlund, Shanahan & Zuo, 2009; Zhang et al., 2008); volumes of water traded (Bjornlund, 2006b); water market net benefits, externalities and economic consequences (Bell, 2002; Diwakara & Nagaraj, 2003; Peterson, Dwyer, Appels & Fry, 2005; Qureshi, Connor, Kirby & Mainuddin, 2007; Thompson, Supalla, Martin & McMullen, 2009; Young & McColl, 2009); levels of market success in promoting economic efficiency (Bjornlund, 2006a; Contor, 2010); equity versus efficiency trade-offs (Msangi & Howitt, 2007; Rawal, 2002); alternative economic instruments (Koundouri, 2004; Young & McColl, 2003); and how water trading impacts irrigation industries and communities (Frontier Economics, 2007).

Bjornlund (2004) contended that markets promote sustainable farming practices, increase productivity, develop new employment options and allow farmers to remain in local districts after selling unviable properties. Similarly, Wichelns and Oster (2006, p. 124) suggested that society could gain from ‘acknowledging the importance of market forces...’ They argued that the costs to society to support sustainable irrigation through public funding and incentive programs for farmers may be greater than the benefits accrued. They suggested water markets provide an arena that allows pricing structures to reflect the value of water in alternative uses, which may include non-agricultural use.

However, concern has continually been raised about the social impacts of water markets and trading. For example, Tisdell and Ward (2003) argued that water markets distribute the resource on the basis of individual costs and benefits rather than those of the community. Furthermore, research in irrigation areas has repeatedly shown that many of these communities do not view water markets, on their own, as fair or acceptable processes for allocating water (Frontier Economics,
Research has also shown that economic variables are of less importance than fair decision-making processes in public acceptance of water allocation decisions (Syme & Nancarrow, 2006; Syme et al., 1999), and that not all irrigator management actions are profit-oriented (Kuehne & Bjornlund, 2006a, 2008; Kuehne, Bjornlund & Cheers, 2007, 2008). Syme et al. (1999) concluded that, even though Australian water reform processes emphasise market mechanisms, social acceptance of water reform requires a balance between market-based policy instruments and fairness-based decision-making processes.

The papers reviewed above describe concerns about the implications of water markets, and suggest ways to lessen the social impacts arising from those reforms. Water markets, as a key element of Australian water reforms, may help move water to more productive uses and encourage efficiency. However, concerns have been raised about the equity of markets and the impacts on the wider community. Alternative institutional arrangements and the use of adaptive management, fair decision-making processes, and socio-economic assessments which focus not only on economic but also on social indicators may lessen these social impacts.

**Scope for further research**

There is considerable scope for further social research regarding the social impacts of water reforms. Existing research provides evidence of community concerns about the operation of water markets, and the fairness of decision-making processes involved in water allocation. Syme, Nancarrow and partners provide a strong foundation for research examining community perceptions of fair and just decision-making processes. Researchers from this group have also explored social values in a groundwater management context. However, there is considerable scope to expand on this research in other locales.

As noted by Baldwin et al. (2009), existing socio-economic assessments lack quality and a focus on economic indicators and values. The social science discipline has strong social impact analysis (SIA) theory and method which could be integrated into future research efforts. There is also scope to compare long-term and short-term social impacts, explore how communities have adapted to previously implemented reforms, and predict adaptation responses to future reforms. It may also be valuable to conduct comparative case studies of allocation decision-making processes which have or have not offered compensation to landholders as part of structural adjustment packages. Such research could determine if and how compensation may lessen both short and long-term social impacts of water reform.

Finally, considerable research has been undertaken in Australia in relation to drivers of and barriers to participation in water markets and trading. However, much of this research has been directed at surface water markets. It may be useful to undertake similar research in a groundwater context for comparison. For example, landholder decisions regarding groundwater use do not always mirror decisions taken in regard to surface water. Therefore, are decisions about buying and selling groundwater on temporary or permanent water markets driven by the same factors as those in surface water markets? Additionally, because many farmers consider both groundwater and surface water allocations when making decisions about water use, it appears to be important to consider how this ‘conjunctive use’ influences their participation in both surface water and groundwater markets.
Theme 3: Community self-regulation: role of social capital, trust and norms

This theme explores opportunities for community self-regulation of groundwater, defined by Wester, Sandoval and Hoogesteger (2011, p. 889) as ‘the collective management of groundwater by water users’ (see also López-Gunn, 2003). Other similar terms used include local (Kumar, 2000; van Steenbergen, 2006), community-based (Yamamoto, 2008) and participatory management (Sandoval, 2004), but these latter terms can be used for both self-regulation and for local participation in decision-making by external regulators (e.g. Chebaane, El-Naser, Fitch, Hijazi & Jabbarin, 2004; Taylor, de Loë, Kreutzwiser & Bjornlund, 2009), as discussed under the next theme on stakeholder engagement. The emphasis in self-regulation is autonomy, but such an outcome is inherently predicated on having a collaborative agreement between those regulated and an external regulator (López-Gunn & Cortina, 2006).

There is increased interest in exploring the potential for community self-regulation given the trend to devolve responsibilities away from centralised authorities (e.g. Wilder & Lankao, 2006), problems associated with increased privatisation (Bluemling et al., 2010) and the difficulties government agencies face in regulating groundwater use and preventing over extraction. These difficulties stem from the nature of groundwater as an ‘invisible’ common pool resource, that in turn inspired Elinor Ostrom’s (1965) doctoral research that formed the foundation for her highly referenced work on governing the commons (Ostrom, 1990). Much of the literature we identified explores constraints on community self-government and cases where external efforts to promote the practice were ineffective. For example, Lopez-Gunn and Cortina (2006) working in Spain, described a range of challenges created by conflict between community-based organisations promoting self-governance and external authorities; Wester et al. (2011, p. 889) described the difficulty faced by an external authority in Mexico attempting to promote improved self-governance by raising awareness of the damage caused by over-extraction. Among other reasons, the process did not adequately account for the social and economic drivers on over-extraction; and Ross and Martinez-Santos (2010) confirmed Ostrom’s (1990) suggestion that self-regulation is more likely to work for smaller scale systems than larger ones.

Our focus under this theme is different. Recognising that self-government by its very nature requires community self-organisation, we are interested in research that explores how to strengthen this opportunity by building and engaging existing community capacity for self-organisation. ‘Social capital’ is one term popularly used to capture this capacity, referring to the social relations, networks, trust and norms that arise when people interact, providing benefits to the parties that interact (Sobels et al., 2001). We have selected the limited examples of groundwater related research that explore aspects related to social capital, and in particular, the role of trust and social norms.

The concept of social capital has been taken up with great fervour by international development agencies, including the World Bank, because of its perceived potential to alleviate poverty (Grootaert & Van Bastelaer, 2002) by enabling collective action through facilitating greater inclusion, cohesion and cooperation in mutually beneficial relationships (Grootaert, Narayan, Woolcock & Jones, 2004; Sorensen, 2000). Following from this, collective action, or working together to address common needs, is suggested to be a vital component of stable, self-regulation of common pool resources (Ostrom, 1990) such as groundwater. In other words, social capital enables collective action, which in turn enables community self-regulation of common pool resources.
In this section, we highlight the paper by Diwakara (2006) because it is one of few papers to investigate trust and social capital in a groundwater management context. We present commentary on the theoretical approach and methods used, the paper’s key findings, and the limitations of the study. We also provide further context to this research through the work of Shah (2000), Tewari and Khanna (2005) and van Steenbergen (2006), linking the latter to a brief discussion on the role of social norms in community self-governance. We then link these papers to Mustafa and Qazi’s (2007) empirical examination of social capital in common pool resource management in a Pakistani context, and some suggested attributes of common pool resource management that may contribute to success or failure of self-governing arrangements (Schlager, 2002). Finally, we consider the potential for community self-regulation in Australia through a study of community self-regulation in Queensland (Baldwin, 2008) and Bell and Park’s (2006) work examining the benefits of alternative forms of governance in Australian water management.

“Determinants of trust and cooperation: Case study of self-managed tubewell organizations in North Gujarat, India’ – H. Diwakara

Diwakara (2006) examined whether socio-economic and demographic differences between individuals influenced levels of trust and cooperation in farming communities using groundwater for irrigation in India. Diwakara used an economic development perspective to argue that social capital improves performance of informal and formal institutions, and holds communities together to achieve collective action to improve their livelihoods. The study drew on work prepared by the World Bank’s Social Capital Thematic Group to define social capital’s components as: groups and networks, trust and solidarity, and collective action and cooperation (Grootaert et al., 2004). These constructs, and the influence of socio-economic and demographic variables on them, are measured through a survey of 150 households in the Indian state of Gujarat. The households are members of groups self-organised to access irrigation. In this setting, self-organisation is described as a being a necessity because of over-exploitation of groundwater aquifers. The survey was analysed using ordered-probit analysis.

Diwakara (2006) measured the socio-economic variables of age, caste, education level, income and household size, finding that these have varying levels of influence on the study’s trust and cooperation measures. Overall, the results indicated that young people and individuals from medium-sized households and households with lower education levels were more likely to trust others. Caste and ethnicity did not play a significant role. However, Diwakara provided limited interpretation of these findings, making it difficult to understand how the economic and demographic variables which significantly influenced trust and cooperation in this study did or did not reflect any unique characteristics of the case study location. Further, Diwakara did not extend his discussion to include implications of these results for groundwater use and self-organisation of groups in the study area, or for groundwater management more generally.

It may be that the coarseness of the measures used (i.e. items from the General Social Survey or Integrated Social Capital Survey developed by the World Bank), and a lack of conceptual clarity of key concepts, may have limited the interpretation of results. Because the conceptual underpinnings of the paper are unclear, they do not provide a transparent foundation for the measures employed. Further, the study does not provide a clear and differentiated definition of each high-level construct of trust, collective action and cooperation. The study also does not give a clear indication of what the
author considers to be the key elements of each key construct or how the measures employed by the study 'tap' each of these elements. Finally, Diwakara’s analysis compared individual independent variables (i.e. socio-economic and demographic variables) with individual dependent variable items (e.g. ‘own welfare’), but then made claims that the socio-economic variables influenced the key constructs (e.g. trust) at the scale-level. However, data from item-level correlations or regressions did not support claims at scale-level. The data presented suggest that socio-economic variables influence aspects of each construct, but not necessarily the construct itself.

Although the Diwakara study has important limitations, well-designed and analysed research exploring the role of trust in common pool resources management, and NRM more generally, does exist. Such research provides future social studies of groundwater management with a rich pool of potential construct scales and conceptual foundations to draw upon. For example, de Vos and van Tatenhove (2011) described the evolution of trust relationships between fishers and government through the development of co-management arrangements in the Netherlands. They concluded that development of co-management arrangements was inevitable and necessary in building trust between fishers and government, but this trust was later eroded when new discourses, actors and rules began to enter the relationships. In their analysis, the authors specifically defined trust and described how they used this definition in their analysis of qualitative interviews and secondary documents. The strength of this study lies in its clear conceptual underpinnings – something Diwakara’s study lacks. The clearly defined conceptual constructs allow the authors to draw useful insights about the progression of uncertainty in fisher-government relationships, and relate the associated implications back to their conceptual understanding of trust as being based in uncertainty.

However, the findings from Diwakara’s (2006) study may be more meaningful when given further context through two other recent studies from Gujarat where the Diwakara study was located. Tewari and Khanna (2005) described irrigation reforms that began in Gujarat in the 1980s. Like much of the literature we found relating to community self-regulation, the paper focused on government-based initiatives establishing farmer cooperatives, or water user’s associations, for participatory irrigation management (PIM). The authors described how the government established credible institutions through collaboration with local NGO’s. The authors concluded that transferring the economic and administrative management of irrigation to farmer cooperatives brought positive socio-economic changes, such as increased household income and a reduction of migration from villages, to the area.

In a paper describing a social movement to address over-exploitation of groundwater in a specific region of Gujarat, Shah (2000) provided an alternative viewpoint. Shah suggested that NGO and government-based initiatives, such as those described by Tewari and Khanna, are ineffective and limited in their area of influence. While Tewari and Khanna suggested that government-initiated farmer cooperatives address groundwater scarcity through pricing structures set by the cooperatives, Shah described these initiatives as insufficient. Shah criticised government action, stating that groundwater regulation has not been rigorous, and that policy instruments, such as using electricity pricing to indirectly influence amounts of water pumped from tubewells, have been misused to appease vocal pumping lobbies. Shah, instead, credited social movements as a source of broad, collective values among irrigators and the collective response to problems of groundwater exploitation. Shah explained how strong leadership by spiritual leaders and the communities’
adherence to a religious movement were important drivers in initial experimentation and development of practices and methods to recharge groundwater. What began as a religious movement of spiritual devotion to a leader advocating water conservation had become a popular movement spread by word-of-mouth and motivated by rational, technical and economic logic. Shah suggested that social capital propelled the movement that initiated the techniques to augment recharge, and that simply adopting groundwater recharge techniques without this social capital would be ineffective.

The research by Shah suggests that: 1) government-based initiatives may be ineffectual because different arms of government work against each other to nullify benefits (e.g. cheap electricity provided to encourage development versus water pricing designed to conserve water); and, 2) NGO initiatives may be ineffectual because their domain is small. Therefore, methods to drive awareness and innovation to augment groundwater recharge may be more successful when tapping into the existing social capital of a region, in this case, through spiritual and religious institutions.

These conclusions were re-examined by van Steenbergen (2006) who noted the role of what he called ‘informal’ norms in a range of studies in South Asia, the Middle East and North Africa where local management of groundwater has been promoted. In the South Asian context, there has been a proliferation of privately constructed wells, giving greater control to individuals over the collective interest. He noted that in Pangju, Pakistan and Nellore, India that the most effective means to control this excessive private development occurred through the use of informal norms. The informal norms he describes equate with so-called ‘injunctive’ social norms that build on moral imperatives (Minato et al., 2010, p. 383), imposed through collective expectations, and when violated, through collective sanctions (van Steenbergen, 2006, p. 383). Yamamoto (2008) used a case study of groundwater irrigation in Japan to describe the role of similar ‘injunctive’ social norms. Van Steenbergen (2006) also referred to the well recharge movement analysed by Shah (2000), noting how the movement changed social norms and behaviours.

Other studies of social capital and community self-regulation

Erosion of existing social capital by well-intentioned government schemes has been analysed by Mustafa and Qazi (2007). Their research was situated in the highlands of the Balochistan province in Pakistan and described the impact of the transition from a traditional ‘karez-based’ irrigation scheme to a modern groundwater extraction regime. The existing regime of underground, gravity-fed channels was a passive system in which water supply varies with changes in groundwater. The change from this system to tubewells with electric or diesel pumps began in the 1970s as part of a larger project to modernize and develop agriculture.

To analyse the impact of the irrigation transition, Mustafa and Qazi used a survey of 147 households in seven villages with different mixes of karez systems and private and group-owned diesel/electric tubewells. Mustafa and Qazi argued that the introduction of tubewells has eroded social capital because tubewells: 1) accentuate economic power differentials because they tend to benefit richer, bigger landholders; 2) remove incentives for owners to participate in community water management; and 3) are a source of intra- and inter- community conflict because tubewells developed near karez systems negatively impact the karez water supply. Mustafa and Qazi acknowledged that the electrification and development efforts have increased productivity and encouraged a switch to high-value crops. However, they argued that the benefits accrue to a few
larger farmers at great environmental costs and loss of social equity. Mustafa and Qazi suggested that the karez system should be restored, and viewed as an ecologically and socially sustainable regime supporting the social capital constructed around the technique.

The papers reviewed above suggest that social capital, developed or maintained through self-organised farmer groups, government-initiated cooperatives, and/or religious movements, facilitates community self-regulation. Schlager (2002) provided a further description of the attributes of resources and their users that support the emergence of self-governing arrangements. In her paper, Schlager also challenged the traditional tragedy of the commons and bio-economic models, which suggest that individuals act rationally with perfect information to maximize their individual welfare at the expense of others and the common pool resource. Schlager argued that the underlying premises of these models in individual decision-making and perfect rationality does not account for why people cooperate in different contexts. Schlager then suggested that these models have informed government policy but the resulting regulations haven’t necessarily protected resources, livelihoods and existing social capital.

Schlager (2002) argued that self-organised groups of resource users can develop irrigation management systems which achieve better outcomes than government systems or regulation. Schlager argued that the principles developed by Ostrom (1990) explain what resource conditions and user attributes contribute to successful collective action among irrigators. One of these principles states that the rights of water users to devise their own institutions should not be challenged by external government authorities. Schlager therefore recommended that government should enable irrigators to self-organise.

Community self-regulation in Australia

Given the benefits of community self-regulation of common pool resources like groundwater, what are the prospects for self-regulation in Australia? There are few examples in the research literature of attempts at developing self-regulating arrangements in an Australian groundwater context. However, Baldwin (2008) details a case study of the Lockyer Valley in Queensland, where irrigators attempted to initiate a system of co-management of groundwater with government through a water planning process. Baldwin used 33 interviews with irrigators, Landcare/catchment management staff and other government stakeholders to explore the water-related values and interests of participants. This was followed by a workshop at an irrigators’ meeting which sought to find where agreement existed on topics such as sustainable water management and self-management. However, the description of methods and analysis contains little detail, so it is difficult to evaluate the validity of the results.

Baldwin found that there are differences between irrigators and government/catchment management staff in decision-making styles and beliefs about how to achieve sustainable groundwater use. However, all participants agreed that better information was needed about aquifer behaviour. The findings also indicate that irrigators valued long-term sustainable use, economic viability, fairness and a sense of community. However, Baldwin fails to define what constitutes ‘value’, so it is left to the reader to decide whether the values elicited by the interviews are indeed values, or something else like norms or goals. Baldwin (2008) concluded that groundwater management should reflect Ostrom’s principles and use values-based rules developed by stakeholders and enforced by government. Baldwin did not elaborate on ways to translate values
into rules, or how the values expressed by participants in the research related to specific Ostrom principles.

Bell and Park (2006) also commented on water planning processes, using development of the New South Wales water-sharing plans to detail the failure of collaborative arrangements in that state. The paper is not groundwater-specific and does not describe a situation of community self-regulation. However, it highlights issues with government devolution of power more generally, and therefore may provide some insights into the potential success of community self-regulation.

Bell and Park (2006) suggested that the water-sharing plan process in New South Wales failed to devolve power even though a number of participatory governance mechanisms were used. These mechanisms included stakeholder advisory committees formed to involve the community in the decision-making process. Bell and Park argued that even though the government had a desire to engage with stakeholders, they did not want to share power. The participation rhetoric led stakeholders to believe that they would have influence in the decision-making process but they were instead relegated to an advisory role only. Bell and Park stated that an advisory role is not genuine collaborative governance, and that the reluctance to devolve power sidelines networks already in place. Therefore, the legitimacy of the entire process was undermined by the manner in which public participation was handled. Bell and Park suggested that the perceived failure of collaboration in the NSW water-sharing plan process will lead government to feel that the benefits of collaboration do not exceed those produced through arms-length consultation, and community participation will continue to be relegated to advisory input.

The papers cited in this section suggest that effective groundwater management can draw upon existing social capital within communities to develop self-regulating governance arrangements. The papers highlight that governments can erode or enhance social capital through support of community-based initiatives to self-regulate in groundwater contexts. The papers highlight successes and failures of community self-regulation and collaborative governance in both developing country and Australian contexts. The research has also suggested self-governing principles and how government can play a supporting role in community self-regulation arrangements.

**Scope for further research**

The research reviewed in this theme suggests that tapping into the existing social capital in a region can help facilitate successful community self-regulation of groundwater. However, social capital remains a poorly defined concept in the literature with disagreements arising over its definition and measurement. One way forward may be to utilise the rich sources of well-conceptualised studies of trust and norms, both components of social capital that are generally agreed upon. There is the potential to use the best of these studies to create greater conceptual clarity for the overarching concept of social capital and to understand its role in enabling collective action in a groundwater context.

There is also scope to further investigate the concept of collective action as a catalyst for successful community self-regulation. While there is some research from Spain (López-Gunn, 2003) and from developing countries (e.g. van Steenbergen, 2006) to suggest features of collective action which facilitate community self-regulation, it may be useful to explore how these features might apply in the Australian context. Given its role as a pre-cursor to community self-regulation, it may also be
useful to investigate collective action as a process, and explore what impedes or facilitates the occurrence of this process. The literature reviewed in this theme describes how governments can support community self-regulation (i.e. lowering transaction, information and enforcement costs), but can government encourage collective action to develop, or must it remain a grass-roots initiative?

Because there are so few examples of community self-regulation in Australia, further research could be useful to explore the following questions: What does community self-regulation look like in industrialised nations? What is the social acceptability of the concept for farmers, government agencies and the general public? What are the barriers to community self-regulation in Australia and which ones can potentially be addressed? There may also be the potential to explore the applicability of business research investigating the advantages of self-regulation in industry bodies to the community self-regulation context. These studies may give a basis for understanding how pitfalls of self-regulation can be avoided or remedied.

**Theme 4: Stakeholder engagement**

Stakeholder engagement is a broad topic that overlaps with other themes in this review. It is a crucial consideration for effective social impact assessment (Theme 2). Community self-regulation (Theme 3) also sits at one end of a spectrum concerning the extent that stakeholders are engaged in groundwater management decision-making. Indeed, in introducing the terms used for community self-regulation, we identified that the terms ‘local management’ and ‘participatory management’ were used both for cases involving community self-regulation and in cases where the context involved stakeholder input into how decisions were made by external authorities.

The difficulty in drawing a distinction between Themes 3 and 4 is not one of loose-fitting definitions. Rather, it points to a well-established discourse of a typology of stakeholder engagement that classifies different types of participation along a scale. The origins of this discourse are generally sourced to Arnstein’s (1969) ladder of citizen participation, but this ‘ladder’ has been criticised for idealising the ‘citizen control’ top rung of the ladder, potentially disparaging a wider range of types of participation that might also be useful in different contexts (Collins & Ison, 2009; Ross, Buchy & Proctor, 2002). This section therefore uses the notion of engagement or participation as a general, wide-ranging term. We have also decided to adopt the commonly used term ‘stakeholder’ to indicate the range of people who might participate, because the term is intended to encompass those who are influenced by a particular action, organisation or phenomenon, as well as those who influence that action, organisation or phenomenon (Freeman, 1984). So in the groundwater context stakeholders can include experts, policy makers and users (e.g. Zellner, 2008). The implication is that decision-making is not just done by experts and policy makers, but that users are also engaged as key stakeholders.

We begin this section by referring to Taylor et al. (2009) to provide a context, and to explain how this section relates to the previous section. In the groundwater literature, we found a heavy emphasis on stakeholder engagement in modelling processes used for decision support, also referred to as participatory modelling (Martínez-Santos, Llamas & Martínez-Alfaro, 2008), agent-based modelling (Zellner, 2008), integrated assessment modelling (Letcher & Jakeman, 2003) or cooperative modelling (Tidwell & van den Brink, 2008). Our feature paper for this theme is Henriksen and Barlebo (2008) because they provide a thorough example of how stakeholder
engagement can be integrated into decision support systems using adaptive management principles, in this case through the development of a Bayesian Network model.

Next, through the research of Suvedi, Krueger, Shrestha and Bettinghouse (2000), George et al. (2009), and Baggett, Jefferson and Jeffrey (2008), we consider who is involved in stakeholder engagement processes, barriers to participation, stakeholder perceptions regarding appropriate levels of engagement, and how surveys of the broader population may be used prior to stakeholder engagement to improve planning processes. We then use Burke, Sauveplane and Moench (1999) and Emel and Roberts (1995) to discuss the potential for stakeholder engagement within different institutional forms. Finally, we review the overall quality of research regarding stakeholder engagement in groundwater management and suggest how further social research may contribute to improved engagement processes.

**Stakeholder engagement as ‘good’ and ‘nested’ governance**

For most of this literature review, we have focused on issues involving groundwater extractions for irrigation. This section begins with two papers that focus on another groundwater management issue of great concern in some parts of the world: groundwater contamination (see also Kastens & Newig, 2008). Taylor et al.’s (2009) case study builds on an established body of literature related to community-based NRM, but makes an argument to retain a role for government authorities. Their study is one of several (e.g. de Loë & Kreutzwiser, 2005; Ivey, de Loë & Kreutzwiser, 2002, 2006; Prudham, 2004) that were sparked by the notorious case in Ontario of groundwater poisoning in May 2000 which led to seven deaths and over two thousand cases of serious illness. Taylor et al. analysed the governance challenges involved in subsequent efforts to manage investigations aimed at preventing future case of groundwater contamination. The strength of the case study is the way that it has been framed by the broader discourse concerning community-based NRM. In particular, the study focused on the dilemma of finding a balance between allowing greater local autonomy and broader regional outcomes.

Recent literature (e.g. Smiley, de Loë & Kreutzwiser, 2010) has explored the constraints on a ‘purely localised approach to resource management’. Pursuing a similar approach, Taylor et al. (2009) explored the notion of situating locally-based collaborative initiatives within a nested governance structure that promotes collaboration at different levels for different purposes (Margerum, 2007). Also characterised as a polycentric approach (Neef, 2009), a nested approach would enable different types of collaboration at different scales. According to Margerum (2008), this could include local-level collaborative action to enhance community well-being and ecosystem health on the ground; collaboration at an organisational scale to enhance that organisation’s policies and programs – which in Australia might be focused on regional based NRM organisations; and policy-level collaboration, where stakeholders are invited to provide input on broader-level and longer-term policy initiatives. For Taylor et al. (2009), this kind of nested approach was used to balance the benefit of a more flexible approach to investigations into the groundwater system to meet local needs, with the need for consistent groundwater data collection to ensure compatibility with data collected in other local areas.

While the paper does not reach any clear conclusions, its evaluation of process and outcomes against pre-determined criteria for community-based NRM is useful. Regrettably, much of this analysis is based on Taylor’s personal observations while working for the relevant government
agency, even though these observations are backed up by reference to interviews with key informants as part of a 2002 study (de Loë & Kreutzwiser, 2005). Taylor et al. concluded that there are clear benefits from stakeholder engagement in raising awareness, building capacity and in producing contextualised local knowledge about groundwater systems. They recommended that government authorities provide a more effective coordinating role to ensure improved management at broader scales, and greater uniformity in knowledge production across a region. While the government agencies provided terms of reference for data collection related to groundwater, the actual approach adopted in different localities depended on the preferences of individual local consultants employed, compounded by limited oversight at regional levels. A better approach is to ‘nest’ the privileging of flexibility and adaptability through local autonomy within clear guidance that meets policy and management needs at broader scales. Because locally autonomous forms of governance may be quicker to adapt to changing needs and conditions within the local context than traditional forms of regulation (Ross & Martinez-Santos, 2010), adaptive management strategies may be considered a useful approach in such situations. The next paper focuses on the use of Bayesian belief networks as a tool for engaging stakeholders in an adaptive management context, albeit in a non-nested approach.

‘Reflections on the use of Bayesian belief networks for adaptive management’
– H.J. Henriksen and H.C. Barlebo

This research, based on a Danish case study, tested the usefulness of Bayesian belief networks (BNs) as a tool for engaging stakeholders and identifying instruments that could be used against pesticide threats in groundwater management. The paper first details the stakeholder engagement process and then presents interview findings relating to three water managers’ experiences using BNs as a way to engage stakeholders and develop a management model.

Henriksen and Barlebo (2008) argued that integrated water management requires a move to adaptive management in order to acknowledge the uncertainty and complexity in both environmental and social systems. They define adaptive management as a structured process of ‘learning by doing’ that aims to work with stakeholders to develop shared understandings of system(s) and outcomes. The adaptive management process may be used to build a management model that identifies and implements policies and then monitors and evaluates outcomes.

In the case study described, BNs were used as a tool in the adaptive management process. BNs are a type of decision-making tool which has a graphical structure that maps out and quantifies causal links between variables. According to Henriksen and Barlebo, the advantages of BNs include: 1) they can be updated as new information becomes available; 2) they can integrate data from multiple sources and disciplines; 3) they are good at modelling complex problems where there is uncertainty in the data; and, 4) they can be used to easily communicate relationships between variables to stakeholders because the graphical model presents a visual picture. Henriksen and Barlebo go on to argue that BNs are particularly suited to adaptive management and participatory processes because stakeholders are engaged in defining variables and their quantities. This provides opportunities to identify ‘all relevant information and clarify gaps’, and in doing so, acknowledge and include multiple forms of knowledge. In turn, the participatory process has the potential to strengthen relationships among stakeholders and build commitment to management decisions before being implemented.
This paper is valuable because the authors demonstrate how BNs can be used as a decision-making tool that copes with uncertainty and complexity in an integrated water management context. Through their interviews with water managers involved in the BNs development, the authors also discuss the advantages of using participatory processes in decision-making, and outline some of the difficulties in implementation. For example, Henriksen and Barlebo suggested that the participants in both the ‘stakeholder professionals’ and ‘citizen’ groups involved in the study were suspicious of the process used to develop the BNs. Further, the water manager interviews revealed that some stakeholders stuck to pre-formed opinions, or did not feel comfortable voicing their opinions and tended to back the dominant views being voiced.

The authors also discussed the difficulties of organising participation of different groups of stakeholders. In this case study, the two stakeholder groups were kept separate so that the citizen group could ‘develop its own identity without being influenced by the professional stakeholders’. Additionally, only the professional group participated in model development. The citizen group were consulted but not involved in the BNs construction process. Instead, they were relegated to informing other citizens about what was happening, and gathering feedback to present to the researchers. Consequently, the two groups’ different ‘knowledges’ were kept separate and there was little opportunity to develop shared understandings of the problem. These examples highlight that, even when it is a primary focus of the development of management models and solutions, stakeholder engagement can be problematic.

While Henriksen and Barlebo give due consideration to both the merits and difficulties of the BNs development process in this case study, their conclusions about how to overcome the difficulties associated with stakeholder engagement lack the same thoroughness. They concluded that suspicions regarding the BNs development process can be solved by investing more resources and time when introducing the tool, and following established engagement procedures so that participants are comfortable with the process. However, this ignores the difficulties encountered in the engagement process itself. For example, the authors state that one objective of using BNs in stakeholder engagement is to create mutual understanding of issues and a greater awareness of other stakeholder needs and views. Separating stakeholder groups, and only involving some of them in the BN construction process, makes it very difficult to achieve this objective. However, Henriksen and Barlebo note that it was difficult deriving variable quantities for the BNs model even within groups. This suggests that engagement processes may encounter substantial barriers and delays if trying to negotiate many views across groups in the same session.

Henriksen and Barlebo suggest that successful stakeholder engagement can be achieved by adhering to the stakeholder involvement guidelines developed through previous work and used in this case study. However, the engagement difficulties described in this paper suggest that there is scope for further research to address questions relating to which stakeholders should be involved in the model building processes, and in what capacity. Future research could also develop and explore different approaches to including BNs as a tool in engagement processes. It would be useful to then measure which approach most successfully achieved mutual understandings of management problems, and drove stakeholders to reconsider their normal positions and proposed alternatives to management issues.
Potential weaknesses of BNs stakeholder engagement

Not all BN model development processes exhibit Henriksen and Barlebo’s clear focus on stakeholder engagement (e.g. Martín de Santa Olalla, Domínguez, Artigao, Fabeiro & Ortega, 2005; Molina, Bromley, García-Aróstegui, Sullivan & Benavente, 2010). The focus of these papers and the processes they document seem to lie in model outputs rather than the participatory process itself. For example, Molina et al. (2010) describe the development of a BNs decision support system (DSS) for integrated water management in southern Spain. They state that stakeholder engagement was obtained through ‘interviews, surveys, questionnaires and general meetings’ to develop and validate the DSS model. Molina et al. (2010) list collaboration and confidence among researchers, stakeholders and managers as the benefits of stakeholder engagement but seem to present these benefits as by-products of DSS development. The researchers highlight the results of the model simulations rather than the benefits of the stakeholder engagement process. In doing so, this seemingly relegates the main benefits of stakeholder engagement to model validation rather than any of the advantages listed by Henriksen and Barlebeo above.

Who is involved, when should they be involved and at what level of engagement?

The stakeholder engagement process used in the BNs modelling process described above can be time and resource intensive. It may involve only key stakeholders and community members with direct interests or ties to the problem. However, other social research methods, such as telephone, internet or mail surveys, can be used to elicit perceptions of groundwater management issues from a broader population. For example, Suvedi et al. (2000) surveyed 663 members of the general public in Michigan, USA to generate baseline data about public knowledge and perceptions of groundwater. The study found significant differences among urban, rural and farm residents, and between farmers and non-farmers, in their perceptions of the effects of land use on groundwater quality. The differences in these perceptions may indicate where stakeholder engagement processes could encounter difficulties in advancing discussions or reaching consensus in decision-making activities. In this way, findings from surveys of the broader population may be used to centre discussions and activities within a more focused stakeholder engagement process.

Similarly, George et al. (2009) argued that stakeholder analysis can be used prior to water planning to inform and improve processes. In their study, George et al. used a survey to identify stakeholder (i.e. irrigators and industry, agricultural and natural resource managers) needs and opinions about groundwater planning. Through this survey they identified stakeholders’ views on key issues in groundwater management and key barriers to participation in water planning. Importantly, the findings indicate that ignored or undervalued contributions, perceived pre-determined outcomes, and a lack of time available to deal with people and agencies were the three most important barriers to water planning participation.

The timing and level of stakeholder participation may also need to be considered in engagement processes. In an internet survey of 153 water regulators, managers, researchers and customers, Baggett et al. (2008) found no significant differences among groups regarding preferred degrees of public involvement in participatory management. The majority of each group thought that the public should be involved in the scoping and planning phases, but not in the construction and operation phase of water projects. However, significant differences were found in the monitoring and shut down project phases with researchers, but not regulators, managers or customers, supporting public
Participation in these phases. Further, Baggett et al. found that the highest level of support among the groups was for the public to ‘make some decisions’ in the water projects instead of ‘making all decisions’, being ‘consulted’ or being ‘informed’.

**Stakeholder engagement within different institutional arrangements**

Participatory processes of stakeholder engagement may be evident in multiple forms of institutional arrangements. However, some institutional forms may provide more direct pathways or potential for stakeholder engagement than others. For example, Emel and Roberts (1995) compared the effects of a community-organised management regime, a centralised-state regime, and an unrestricted private-property regime on groundwater resources and community sustainability in a part of the Southern High Plains of the United States. They concluded that more than one of these forms of governance may reduce harm to groundwater resources, but advocated that ‘institutions that are regional-scale, democratic, and locally determined seem to offer greater flexibility and representative autonomy in maintaining... the region and its society.’ Because regional scale management may be driven by community members themselves, there appears to be greater potential for meaningful stakeholder engagement within this institutional form.

Similarly, further evidence that local or regional scale management may have greater potential to incorporate stakeholder engagement processes is indirectly provided by Burke et al. (1999) in their paper discussing socio-economic responses to groundwater management. They stated that management and regulatory enforcement in centralised government regimes suffer from variation in conditions, problems and management actions at the local level. Therefore, they argued, legal and institutional structures should reflect this by enabling local communities to devise different forms of action based on local management needs and options.

**Scope for further research**

Our review of research within this theme highlights several opportunities for future social research regarding stakeholder engagement and participatory processes in groundwater management. First, the literature shows that some modelling exercises focus more on model outputs than the stakeholder engagement process itself. This suggests that future social research within groundwater contexts could be used to further examine how both stakeholder engagement and modelling outputs may be improved in modelling processes, including BNs.

Second, there is scope to investigate how social variables may be better measured and integrated in modelling processes. For example, Molina et al. (2010) used socio-economic factors within their model. However, all of the measures they used are economic, instead of social variables such as stakeholder values, beliefs, norms and attitudes.

Third, some research shows significant differences among stakeholder group perceptions of groundwater management. Other research does not. While the studies of Suvedi et al. (2000) and Baggett et al. (2008) cited above cannot be directly compared because they use different survey instruments and stakeholder groups, further social research into public and stakeholder perceptions of water management may provide a bridge between existing studies by confirming, contradicting or adding further depth to their findings. We suggest that improved analysis of the stakeholder groups that are to be engaged would help to improve both an understanding of the range of perceptions and processes of engagement. Such analysis could draw on research into community types focused
around how collective interest have been organised, whether it be focused around a shared locality, a shared experience of being affected by something, a shared interest, activity, or identity, or a shared aspiration to be achieved through collective action (Harrington, Curtis & Black, 2008).

Fourth, much of the quantitative survey research reviewed in this theme based its discussion on findings from relatively small sample sizes. For example, George et al. had a sample size of 20; Baggett et al. had a total sample size of 152, but interpreted findings from group comparisons with some group sample sizes numbering less than 20. Future surveys utilising larger sample sizes would help improve validity and reliability of measures and subsequent findings in groundwater management research.

**Theme 5: Rural landholder decision-making**

Groundwater governance is problematic because causes and effects are often uncertain and separated in space and time; replenishment of aquifers may require substantial effort over a considerable period of time; and in many cases, no single actor is capable of addressing the issues on their own. Rural landholders are important actors in groundwater governance and the impacts of their actions on aquifers are often not readily observed. While the groundwater specific literature is limited, those interested in achieving change in the land use or management practices of rural landholders can gain considerable insights from the large body of literature examining rural landholder adoption of farming and conservation practices.

The adoption of new technologies by rural landholders is often a complex process influenced by the personal circumstances of landholders, their social context, the nature of the specific technology and any intervention that is being made to support adoption (Curtis & Mendham, 2011). A number of specific theories have been developed that focus on some elements of this complex web of factors. It is also important to acknowledge that even the concept of adoption is problematic in that non-adoption may be a sound decision for an individual, and adoption is not always linear in that a new technology may be partly adopted or adopted for a short time and then rejected.

Social-psychology models, such as the Theory of Planned Behaviour (Ajzen, 1991), Cognitive Hierarchy Theory (Vaske & Donnelly, 1999) and Value-Belief-Norm Theory (Stern, Dietz, Abel, Guagnano & Kalof, 1999) focus on the personal circumstances of the landholder and largely assume that other influences are expressed through the variables included in these models. A number of Australian researchers have attempted to develop more holistic models that enable researchers to identify those influences that practitioners can ‘pull’ or influence, and those they need to know about if they are to effectively engage landholders. Perhaps the best summary of this research is provided in the work by Pannell et al. (2006). These authors concluded their extensive review of the Australian and overseas literature by proposing that adoption decisions were influenced by four sets of factors:

1. The personal characteristics of the landholder and their immediate family (e.g. goals, values, attitudes, motivation, attitude towards risk, introversion or extroversion, world views, commitment to place, personal norms, knowledge, occupation, experience, age/ stage in life and succession).
2. The wider social context of the landholder, including prevailing social norms, the presence of local organisations, trust and experience with extension agents and information flows through networks.

3. The nature of the practice or attributes of the behaviour, including the feasibility of the practice, benefits (relative advantage of the practice over existing practices), ease of use or complexity, the extent it fits in with existing systems, the ability to trial the practice to learn and reduce uncertainty, the ability to observe the benefits of the practice, extent of re-skilling required, opportunity costs, time lags, how it has been designed and disseminated.

4. Landholder access to resources (income, group membership, labour, farm equipment).

Drawing on the work of Pannell et al. (2006), Mazur, Curtis, Thwaites and Race (2008) developed a model of the factors affecting adoption and this model is represented in Figure 3. This model illustrates the key points of overlap in the web of factors that can shape adoption decision-making.

The research on landholder decision-making in the groundwater context is limited. As Hammani, Hartani, Kuper & Imache (2009) state, groundwater studies have focused mostly on the resource, rather than the actors who use and manage the resource. Hammani et al. (2009) also identify that few studies in the literature integrate social and biophysical aspects (groundwater users’ behaviour with aquifer dynamics). There have been few studies which link landholders’ groundwater behaviour with the factors influencing decision-making/adoption of practices identified above, such as values and attitudes. A selection of papers that examine one or several factors influencing landholder decision-making in the groundwater context is reviewed in this section. Bekkar et al. (2009) was selected as the best example from the literature reviewed, as it goes some way to link actual behaviour with a number factors that influence decision-making. Additionally, two papers by Albrecht (1990; 1995) were found to link actual behaviour and adaptation strategies with potential influences on adoption (social, personal and farming). Other papers examined in this section explore typologies of landholder/irrigator types. Several papers in this section investigated the importance of local knowledge and highlighted contested knowledges in the groundwater space. The literature review also highlighted a group of papers focusing specifically on pricing mechanisms and examining behaviour from an economic perspective.

The papers reviewed in this section often utilised a mixture of qualitative and quantitative methods, yet in many cases provided limited and poor explanation of the methods, lacked clear conceptual frameworks or a solid grounding in theory, and often lacked thorough interpretation of results. We were not able to find an article that included a comprehensive exploration of landholder adoption taking into account the influencing factors described above and linking it to solid theory and/or a conceptual framework. Albrecht (1990; 1995) and Bekkar et al. (2009) go some way to meeting this test – but Albrecht (1995) calls for a much greater research effort in the area, and the need to undertake further research to determine which farm and personal characteristics are important in determining groundwater behaviour and adaptation decisions. The other papers examined here explore one or several aspects of decision-making, but there is not a collection of papers that together provide a comprehensive understanding of landholder decision-making in the groundwater context. The papers reviewed explored some aspects of the following topics:
Figure 3: Understanding landholder decision-making (Source Mazur et al., 2008, p. 8).
- The personal characteristics of the landholder and their immediate family, and access to resources (values, knowledge, occupation, age/stage in life, attitudes, education, income);
- The wider social context of the landholder (the presence of local organisations, trust and experience with extension agents, institutional arrangements); and
- The nature of the practice or attributes of the behaviour (cost of irrigation technology, access to resources).

‘On the difficulty of managing an invisible resource: Farmers’ strategies and perceptions of groundwater use, field evidence from Morocco’ – Bekkar et al.

Bekkar et al.’s (2009) study links behaviour with values, attitudes, knowledge, context and access to resources. The paper provides a brief exploration of landholder knowledge of aquifer functioning; broad groundwater use strategies; the importance of context and access to resources, including the nature of that access; and farmer attitudes to management of groundwater.

The study examined farmer strategies for groundwater exploitation and perceptions of aquifers and groundwater use in three contrasting situations in Morocco: the Tadla (a large area where surface water supply has been reduced and farmers rely heavily on groundwater); Taroudant in Souss Valley (a small public irrigation scheme where severe drought has seen large areas converted to drip irrigation); and the Berrchid Plain (a private irrigation scheme under urban pressure).

Bekkar et al. (2009) aimed to identify the factors that determine farmer attitudes to the management of groundwater. Groundwater is state property and its use is legally defined, yet this has had little impact on preventing exploitation owing to the rapid development of illegal tubewells, the diffuse nature of access to tubewells (lack of community control) and the subsequent difficulties associated with monitoring and controlling use, limited scientific information about aquifer dynamics and groundwater use, and the importance of groundwater to farmers’ livelihoods.

The conceptual framework used for the study is ‘social representation’. This framework is not clearly articulated in the paper and it is not apparent how the concept informed the methods and discussion of results beyond the decision to measure farmer attitudes, information sources and knowledge. The details of the methods employed are also not clear. Bekkar et al. (2009) used Likert scales with 13 items. While these items are not listed in the paper, they explored attitudes, farmer knowledge regarding physical representation of the aquifer, farmers’ perspectives on the reasons for overdrawing, farmers’ ideas for solutions to overdrawning, attitudes regarding potential for aquifer renewal and ownership of groundwater. The first stage of the study involved creating a farmer typology using semi-structured interviews with government representatives and farmers. The second stage involved interviews with 60 farmers (20 from each region) selected according to the typology developed during the first stage.

Bekkar et al. (2009) found each case study area could be classified according to the:

- Nature of access (collective or individual access to groundwater, either public or private);
- Use of water saving irrigation equipment; and
- Offensive or defensive groundwater use strategies:
  - Offensive strategies included maximising economic profits by obtaining continuous access to groundwater through individual tubewells (installing more tubewells,
planting new crops of high water use and high value, and installing new water-saving irrigation techniques allowing farmers to irrigate more rather than use less water).

- Defensive strategies included maintaining existing levels of water use through existing tubewells, planting less water intensive crops, using water saving techniques.

Defensive groundwater use strategies were most often utilised in areas of collective access to groundwater. In areas where groundwater was individually accessed, offensive strategies were usually adopted, save for those with investment problems. Irrigation saving technologies were adopted by both those using defensive and offensive strategies (i.e. it did not always lead to water savings, but rather more efficient use of water allowing farmers to intensify existing systems). The authors state that most farmers had some knowledge of the physical functions of aquifers, and list the reasons given by respondents for decline in groundwater levels, reasons for renewal and possible solutions. Farmers interviewed felt that whoever had installed the infrastructure had the right to exploit it. Those with private access felt it could be privately exploited, whereas if access was public, farmers felt it could only be exploited by the irrigation agency. Those farmers with defensive strategies were more likely to suggest limits to the volume pumped, while those employing offensive strategies were likely to convert to drip irrigation. The authors explained that attitudes to control of groundwater, and the strategies adopted (offensive or defensive), seemed to relate to existing control. Those with collective access recognised the advantage of access involving government services that was not dependent on their financial means and adopted defensive strategies. Opinion on over-exploitation also seemed to relate to the context, availability and access to the resource. Farmers did not necessarily link over-exploitation with their own practices. The authors reported that those with public access felt sustainable management was possible, while those with private access felt it wasn’t possible (a minority felt only God could control it).

Linking behaviour to values, social characteristics and attitudes

Two studies by Albrecht (1990; 1995) begin to link values, social characteristics and attitudes to groundwater behaviour. Albrecht (1990) explored the adaptations of farmers (N = 700) in the Texas High Plains to the depletion of their primary source of irrigation water, the Ogallala Aquifer. He measured four factors, including the farmers’ positions in relation to the saturated zone, financial condition, farm structure (including property size and off-farm employment), and social and demographic aspects including age, time in farming and education. Albrecht (1990) examined seven possible adaptations (not irrigating, reducing acres irrigated, reducing times crops are irrigated each year, and four different techniques that reduce the amount of water needed). He employed bivariate comparisons and logistic regression and provided a thorough explanation of both. He found those who had smaller farms and less extensive groundwater supplies adopted water conserving technologies that were relatively cheap to implement. Farmers adopting more expensive irrigation technologies (e.g. centre-pivots) had larger farms with a more extensive groundwater supply, and were in a better position to justify a major irrigation investment (Albrecht, 1990).

Three dependent variables were used in the study, including the opinion about the extent of the problem; priority given to agricultural water uses; and the extent to which respondents believe federal or state government rather than individual landowners should make management decisions.
concerning the use of aquifer water. Respondents were given a score based on their responses. Age, education and income were controlled for during regression analysis.

Albrecht (1995) provided an empirical comparison of the views of farmers (n=448) and the non-farm public (n=501) on three critical Edwards Aquifer water issues. He hypothesised that farmer respondents will be less likely to consider water shortage problems to be severe; more likely to give the agricultural uses of water a high priority; and more likely to express opposition to government involvement and control in management decisions regarding the Edwards Aquifer compared to non-farm respondents.

He found the non-farm population was more likely than farmers to believe that the water problems associated with the Edwards Aquifer were severe, while farmer respondents placed a higher priority on agricultural water uses. Farmer respondents were more likely to oppose government involvement in management decisions. Although farmer respondents were significantly older and had lower education attainment and income levels than non-farmer respondents, differences in opinions/beliefs remained significant in the regression models when they were controlled for.

Abu-Madi (2009) used data collected through a survey of 157 farmers to examine the impact of water pricing on agricultural water consumption and farming profitability in Palestine. Abu-Madi (2009) stated that water consumption varied between farms depending on water availability, water price, land area, types of irrigated crops, farmer experience, method of measuring water consumption, technical performance of the irrigation system, and type of irrigation system. He developed a regression model using some of these factors, describing agricultural water consumption as a function of water prices, irrigated land area, farm income, and irrigation frequency. He did not observe significant correlations between farmers’ age, education, type of irrigation system or crops. He concluded that irrigation water prices are perceived as high, making up a large portion of total farming expenses, and that increases to irrigation water prices in the district might jeopardize farming viability.

Zhen and Routray (2002) used a mixture of primary and secondary data sources (agricultural bureau, ministry, household survey, focus group, interviews with key informants, and field observations) to explore farmer awareness of groundwater. They stated that awareness of groundwater plays an important role in management behaviour. All of the respondents believed the water resource was renewable and not exhaustible, leading them to use water more intensively for short-term benefits. Little explanation or interpretation of the study was given.

**Adaptation strategies and groundwater use behaviours**

Several papers explored farmer adaptation strategies and groundwater use without further analysis of factors influencing decisions. Mudrakartha (2007) examined farmer adaptation in response to drought (as an example of decline in groundwater resources) in three semi-arid and arid districts. The study involved 400 households in 20 villages, and ran from 2002-2004 using focus groups, structured questionnaires and unstructured checklists. The paper lists the different strategies adopted by landholders to cope during the drought. Those related to groundwater management included deepening wells or drilling new ones, using savings or selling jewellery to finance adaptations, and the creation of new institutional structures such as joint bore wells created by small or marginal farmers to share access and cost. Those not directly related to management of the
water resource included changing animal husbandry practices, diversification, sale of assets, and migration.

**Knowledge, information sources and landholder decision-making**

Birkenholtz (2008) explored whether conflicting environmental knowledge adversely affects the management of over-exploited groundwater resources. The research involved a survey of 150 farmers in six villages, followed by 78 in-depth interviews with farmers, government technocrats, tubewell drilling firms and local Hindu water diviners. It thus included formally trained through to local expertise. The author argued that the relationship between state and local producers of groundwater knowledge practices was non-linear and porous. State attempts to assimilate, reorganise, plagiarise or disparage local knowledge produced or exacerbated tensions between farmers and state groundwater engineers resulting in further hybridisation of knowledge and the marginalisation of the state as farmers sought out non-state avenues of expertise; and relationships between farmers and the state were further strained because of a lack of visibility of the state. Of the farmers interviewed, none would consult an engineer, 24.5% would consult a diviner, 63.5% a local tubewell drilling firm, while 12% would consult both a diviner and drilling firm. Farmers expressed trust in local knowledge (formed through experience, time spent in the area, and being highly visible); distrust of engineers (who were often expensive, took bribes, were sometimes unreliable); and thought that the government was ambivalent to their plight, and were left feeling they had no choice but to irrigate to survive. The study found that caste differences were important. Members of higher castes, who currently had access to high quality water, wanted a permit and licence system to stop groundwater depletion.

**Pricing and groundwater use behaviour**

Several papers examine water pricing as a way of limiting groundwater use (Blanco-Gutiérrez, Varela-Ortega & Flichman, 2011; Shah et al., 2009; Yang, Zhang & Zehnder, 2003; Zhang, Wang, Huang, Huang & Rozelle, 2010), and the link between energy prices and groundwater use (Shah, Bhatt, Shah & Talati, 2008). While exploring the impact of changing prices on farmer behaviour), these papers fail to consider other factors identified in Figure 3 as important influences on decision-making.

**Farmer typologies**

Kuehne et al. (2008) aimed to examine the non-commercial influences impacting on irrigators’ behaviour, especially the influence of the values they hold toward family, land, water, community and lifestyle. This study investigated whether it is possible to group irrigators according to these values, and then use the subsequent groupings to explore landholder willingness to participate in environmental reforms. The researchers employed a mail-out survey, in depth interviews and telephone interviews in the Namoi Valley at a time when irrigators were responding to large reductions in groundwater entitlements. The authors clustered the irrigators into three groups with differing orientations: (i) investors (profit oriented, 25%); (ii) lifestylers (lifestyle oriented, 25%); and (iii) providers (family-succession oriented, 50%). The authors explored whether the different clusters of irrigators had different intentions and attitudes to water trading. In an earlier study, Kuehne and Bjornlund (2006a) and Kuehne and Bjornlund (2008) used a similar approach to classify farmers on a continuum from investor to custodian, and explored whether these types adopted different
decision-making behaviour (ranging from buying more water, selling or leasing water, selling or leasing land, reducing irrigated area or water use, changing crop types, changing irrigation technology, water efficiency improvements, infrastructure improvements, diversifying away from irrigation or no action). The researchers also compared these actions between those who would be highly affected by changes to groundwater allocations; those whose situation would remain ‘stable’; and ‘inactive’ farmers who had not used their groundwater allocation. However, it is not clear how they identified these categories or linked their qualitative findings to these classifications.

**Scope for further research**

There is much scope for further research examining the mix of factors influencing landholder decisions about land use and management practices that affect groundwater. This research may focus on assessing the ‘adoptability’ of specific land uses (e.g. dryland cotton) or practices (e.g. use of polymers on dams to reduce evaporation); or the extent of behavioural change that can be achieved through a mix of policy instruments (e.g. extension, cost-sharing). It would also be interesting to explore the extent that the groundwater context is really different to the surface water context in terms of the key influences on landholder decision-making. Given the trend towards an increased proportion of rural landholders identifying as non-farmers by occupation, the role of occupational identity in surface and groundwater management would be an important theoretical and applied research topic. There is also considerable scope for research examining the role of social capital and the opportunities to engage or build social capital to support the dialogue, learning and action that is necessary to address some of the more difficult/complex NRM issues in groundwater governance.
Concluding summary

Rather than repeat our earlier summaries, our intention here is to focus on identifying what we see as some of the key research directions for the social researchers in the NCGRT. As a result of this review, our specific research interests and strengths, and in response to contemporary developments in NRM, we have identified five key areas of future research interest and these are briefly introduced below:

1. **Social construction of the concept of sustainable yield**
   This research would explore the extent different groundwater stakeholders have different views of sustainable yield, and that those views shape groundwater management and policy. Our view is that this research should be sited in a particular groundwater context.

2. **Effective co-management of groundwater (and possibly surface water)**
   This research would focus on identifying the institutional arrangements required to achieve effective co-management of groundwater at different scales (i.e. nested governance). Program 5 research examining the feasibility of Managed Aquifer Recovery (MAR) in agricultural landscapes using large flood events is likely to provide a timely and relevant context for this topic.

3. **Risk and groundwater management**
   This research would assess the extent that different stakeholders construct risk differently and how those perceptions of risk influence groundwater management. The expansion of coal-seam gas mining and the public controversy around that industry seems to provide an ideal context for this research.

4. **Occupational identity and groundwater management**
   An increasing proportion of rural landholders identify as non-farmers by occupation. Evidence to date suggests that there are important differences between farmer and non-farmer cohorts in terms of their personal backgrounds and property management styles. This research could draw on identity theory to examine the nature and role of occupational identity in the 21st Century and the implications for groundwater management.

5. **Trust between landholders and management agencies**
   Trust is both an ingredient shaping the success of landholder/agency collaboration and an outcome of effective engagement that can be drawn upon by agencies and their staff in the future. At the same time, trust is easily lost. This research would assess the level of trust and identify key factors affecting landholder trust in agencies and their staff in the groundwater context. This research might also provide an opportunity to explore the efficacy of important contemporary theory (e.g. Values-Beliefs-Norms theory) that focuses on a small range of personal factors to explain behaviour.
References

The following reference list is of all publications cited in the text.

Readers seeking a list of the most relevant publications identified during the literature search can contact Michael Mitchell at mimitchell@csu.edu.au.


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Appendix 1: A mind map of the social dimensions of groundwater governance literature

1 dot (●) represents 1 (of the first 98) most relevant publications identified