COMPARATIVE GROUNDWATER LAW AND POLICY PROGRAM
WORKSHOP 2:

GROUNDWATER SCIENCE, POLICY, PARTNERSHIPS, AND MARKETS

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DISCUSSION PAPERS[1]

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INTRODUCTORY NOTES

These short papers are intended to help stimulate discussion and provide some background to the variety of approaches that different jurisdictions take to key groundwater issues ("what we know"), each of which is much more complex and multi-faceted than these papers can fully explore. We also present a condensed series of questions to focus our discussions in relation to each topic ("what we need to know"). We hope that these papers serve as a bridge over the Pacific in relation to terminology and perspective, and an entry point into more detailed dialogue.

In these papers, we discuss various aspects of groundwater **law**, **policy** and **management**. Each of these involves different actors and approaches to dealing with groundwater planning or groundwater problems. To ensure that our discussions are clear about these differences, we propose the definitions that follow. In doing so, we acknowledge that there are many areas of overlap in common usage, and that each of these terms is capable of having multiple meanings in different contexts. Nonetheless, we think it is valuable to ensure that we operate on the basis of a common understanding of these terms for the purposes of clear discussions:

- **Law** refers to formal rules and regulations made by **legislatures** or **courts**;
- **Policy** refers to:
    - the formulation of broad objectives about groundwater management by **government agencies** (which law may express through rules); and
    - the statements or practice of **government agencies** in relation to implementing law (for example, exercising functions like groundwater licensing/permitting) or spending money to pursue particular objectives (for example, establishing non-statutory incentive programs for farmers to use groundwater more efficiently);
- **Management** refers to **on-ground actions** taken by **private parties** or **government agencies** that relate to groundwater, for example, decisions made by groundwater users about how much groundwater to use, where and when to use it, and the purpose for which it will be used; or decisions made by agencies or user groups to establish and use groundwater monitoring systems. Some of these decisions may require permission from government agencies, which those agencies will consider granting pursuant to law and policy.

This **glossary** below is included as a brief guide to differences in water-related terminology between Australia and the U.S.; the "translations" are necessarily approximate. Note also that individual states may use terminology that varies from that presented here.

United States term	**Australian term**
Endangered Species Act	*Environment Protection Biodiversity Conservation Act*
Exempt well	*Private right; stock and domestic right*
Interstate compact (e.g. Rio Grande Compact)	*Interstate agreement* (e.g. Murray-Darling Basin Agreement)
Permit/permitting (of groundwater use)	*License/licensing* (of groundwater use)
Water marketing	*Water trading*
Water right; under the western U.S. prior appropriation doctrine, a right to extract water that developed earlier is "senior" to, and more reliable than, a "junior" right that developed later	*Water entitlement*; an Australian water entitlement (whether to groundwater or surface water) has the same reliability as all other entitlements in its class. The time that the right was developed does not affect its reliability.
Well	*Well* or *bore*

DISCUSSION PAPER 1

– GROUNDWATER AND THE SCIENCE-POLICY INTERFACE –

How can we ensure that policy and management better reflect hydrological and ecological knowledge about groundwater? How can we ensure that science and technology better reflect the limitations and needs of policy and management? And how should policy allocate the cost burden of gathering scientific information about groundwater?

I. WHAT WE KNOW

Traditionally, water law has developed around drastic simplifications of hydrologic science, and in complete isolation from ecological science. As demands for water increase, and science and technology advance, **science-based principles that were unfamiliar at the time that many present laws and policies were first established are increasingly employed in water law and policy** in Australia and the western U.S. For example, the groundwater policies of many states within the western U.S., like Kansas, Washington, Idaho, and Montana, now legally recognize surface water and groundwater as interconnected sources and use the same system to allocate both surface and groundwater supplies. Australian groundwater policy also aspires to recognize these connections. Better understanding and appreciation for science are also seen in state policies and regulations that require applicants for new groundwater diversions to prove that the source basin can sustain increased pumping.

Yet the relationship between science and policy—and scientists and policy-makers—is not always comfortable, despite attempts to bring the two together. Indeed, the **two broad fields are characterized by fundamental differences in approach and world-view**, some of which are particularly amplified in the context of groundwater issues. Key differences relate to the influence of public concerns; temporal and spatial scales; the ability to deal with complexity, change, and uncertainty; the desirability of challenging the status quo; and the adoption of objective versus subjective approaches.

Scientists produce knowledge based on observation, models, and testing hypotheses, striving to be objective. They express findings based on evidence, using probabilities, avoiding definitive or absolute statements, and often using specialized language that is not easily understood by the lay public. The production of scientific knowledge is fundamentally iterative: new information builds on old; sometimes these cycles of knowledge-building are short, but sometimes years or decades are required to answer scientific questions. The subject matter of scientific inquiry is by its nature extremely complex, and it sometimes focuses on extreme or outlier situations as particularly interesting. To many scientists, the value of scientific knowledge is not determined by the perceptions of the general public about its value. Scientists have a personal stake in overturning established scientific knowledge and challenging conventional assumptions.

Policy and policy-makers differ fundamentally in relation to each of these factors. Policy-makers are driven by social values that are subjective by nature. They seek to appeal to the public and the regulated community using narrative, persuasive techniques and simple language. Short political cycles ensure that policy-makers focus on short-term impacts of decisions. Policy and law involve path dependence that often renders them unable to quickly adjust to new information. Law or policy complexity is generally seen as undesirable (though sometimes unavoidable), since it can lead to difficulties in implementation and communication to the regulated community and the general public. Certainty is highly valued in the context of law and policy, since the general public and the regulated community make decisions in the expectation that current laws and policies will generally continue. Policy-makers in democracies must respond to the demands, views, and values of the majority. They make policy with a view to covering the most common situations, and sometimes find it difficult to deal with "extreme" or unusual situations. Policy-makers have a personal stake in avoiding "making waves".

Groundwater issues tend to amplify some of these fundamental differences:

- Information about groundwater is often subject to a high degree of uncertainty (*see* Paper 2 about uncertainty for further discussion of this point).
- The impacts of decisions about using groundwater will sometimes be felt only decades or even centuries into the future, and in any case, multiple political cycles into the future.
- Groundwater systems are very complex and differ radically in their nature from place to place, making general policy prescriptions more difficult (for example, "safe yield" principles struggle to deal with fossil groundwater bodies).
- The general public often has little understanding of groundwater-related terminology or even groundwater systems themselves, or their value.
- There is sometimes a mismatch between the impacts of using groundwater on a localized minority and the more widespread benefits for the majority of the groundwater-using activity (mining being an example of this mismatch).

Practical guidance for managing the relationship between science, on the one hand, and law and policy, on the other hand, could prove useful. Few could dispute that science has a clear and direct role in groundwater law, policy and management, since the task of allocating resources relies fundamentally on accurately understanding the resources available and the impacts of using them. In this vein, key issues are **how to ensure that scientists seek to answer the kinds of questions that will assist in better allocating resources**, and that these **findings are relayed to decision-makers in a way that ensures they are understood and taken up**. This may require scientists to make the inferences needed to transfer scientific information into legal or policy decisions, and to use metrics and measures that are easily understood by lay people, which relate to values that are important from a policy perspective (*see* also Discussion Paper 3 on communication). Several authors point out that **increased cooperation between scientists and policy-makers** would help to make scientists aware of the questions that policy-makers need addressed, and help policy-makers understand that scientists cannot always provide exact and consistent information.

Principles of adaptive management have become an important way in which law and policy can adapt to changing scientific information—both increasing information, and information about changing conditions. Such principles seek to transform policy-making into an iterative process that relies on feedbacks between monitoring systems and decision-making. Adaptive management, in a stronger form, also helps address uncertainty by allowing experimentation that hopefully reduces the degree of uncertainty in the science. Some water management planning statutes require plans to include a monitoring component, and require that plans be reviewed regularly. Some water entitlements issued under Australian water laws are capable of being permanently reduced in response to changing climatic conditions. Finally, some types of Australian water entitlements (though rarely groundwater entitlements) are expressed as shares in a consumptive pool (which may change), rather than as rights to take a volume of water in absolute (and static) terms.

Another important characteristic of the relationship between science and policy is **the degree to which scientific and political processes are separate, for the purposes of making clear the influence that each has on decisions about water**. For example, the Australian federal Water Act creates an independent water science organization, the Murray-Darling Basin Authority, to formulate a legally binding water management plan to cap water extractions, which is then provided to a federal political decision-maker, who may then make policy-based changes (though some question how separate the science and politics are in practice). Alternative ways to maintain separate political and scientific processes are to ensure that scientists, rather than politicians, lead government science agencies; and to establish systems under which scientists review and evaluate policies or decisions that are justified by scientific findings.

At a more operational level, the science-policy interface becomes particularly evident itself when **policy-makers are sometimes required to make decisions based on the "best available science"** (BAS). While BAS is employed in multiple state and federal jurisdictions, including Australia's National Water Initiative and the European Union Water Directive Framework, there remains no clear or consistent articulation of the term or guidance on how to apply it. Indeed, the phrase can be problematic in several ways. Some suggest the "availability" of science is generally determined by the information providers rather than the needs of policy and decision-makers, and should be linked to the meaning of "best" when assessing its relevance. Further, it can sometimes be difficult to determine what information qualifies as "science". The U.S. Endangered Species Act defines "best" as information that is collected by established protocols, properly analyzed and peer-reviewed before release to the public. Ultimately, courts often defer to agency discretion in determining what constitutes BAS.

Some scholars propose a process of "**best evidence synthesis**" that they suggest could improve the integration of scientific information into water policy and decision-making by empowering an interdisciplinary group to address a defined question using the following principles:

- Create and support a cooperative process that enables interdisciplinary teams to produce shared knowledge that meets the needs of all users;
- Articulate a clear management or policy question and translate it into research questions and supporting hypotheses;
- Define the knowledge needs in terms of its properties (scientific, supporting and indicative);
- Create an a priori and case-specific hierarchy of 'best' information (well-established theories, peer-reviewed published and unpublished literature, expert opinion);
- Develop study designs and analyses that are appropriate for the hypotheses being tested;
- Clearly state assumptions, define terms, and identify uncertainties and associated risks;
- Build in revision as uncertainties, limitations and inconsistencies are addressed over time;
- Ensure a record exists of the decision-making process;
- Communicate research methods, supporting rationale, results and management applications via the peer-reviewed literature and through reports or other formats as preferred by the management and policy audience.[2]

The science-policy interface also raises the practical question of **how policy should allocate the cost and burden of obtaining and interpreting groundwater science** between: (1) government agencies, which hold groundwater in trust for the public (and by implication, taxpayers, which fund government budgets and ultimately own the resource, at least in most states), and

[2] Darren S. Ryder, Moya Tomlinson, Ben Gawne, and Gene E. Likens (2010). "Defining and Using "Best Available Science": A Policy Conundrum for the Management of Aquatic Ecosystems", *Marine and Freshwater Research* 61: 821-8.

(2) groundwater users, who benefit from using a common resource. Resolving this question is intimately related to ensuring that sufficient high-quality groundwater information is available to support effective management. It is also a particularly contentious question, given that collecting groundwater information tends to be much more expensive than collecting information about surface water. Relevant to this question is the fact that groundwater information can sometimes be open to different scientific interpretations, leading to the potential for "**combat science**" (also called "duelling models"), where one stakeholder alleges his or her model is superior and should be used instead of another.

Generally speaking, water pricing does not presently allow for recovering management costs. This can threaten the financial sustainability of water management, particularly where subsidies from government budgets are not secure or sustainable. Australia's National Framework for Improved Groundwater Management (1996) encouraged jurisdictions to employ **groundwater user charges** or **"user pays"** approaches to enable groundwater to be managed as an economic commodity, potentially increasing its capacity to be more equitably managed and allocated. The Framework suggested that **funds paid by water users should be used to recover direct management costs**, such as the costs of licensing; **and indirect costs**, such as the costs of formulating policy, where this was "realistic". It further recommended making transparent any subsidies where recovering indirect costs was unrealistic; and increasing public awareness of the value and vulnerability of groundwater. These recommendations have not been fully adopted.

II. WHAT WE NEED TO KNOW

1. What are the **major groundwater issues where there is currently a disconnect** between science and policy?

2. **How much consultation takes place between policy-makers and the scientific community** (within an organization as well as between organizations) regarding new information about groundwater? What are key barriers to such consultation? What kinds of processes and fora could **facilitate communication** between scientists and policy-makers to ensure that scientists are addressing the key needs of policy-makers and to allow data to be more easily translated to support groundwater management?

3. What **disciplinary expertise is currently underutilized** in groundwater management? How can greater interdisciplinary collaboration be encouraged? Can law or policy help?

4. How should policy-makers **determine when they need additional information** (that is, how should they evaluate the cost and value of additional information)? When should law or policy use a **simple rule of thumb** for making a decision rather than a requirement to collect detailed scientific data?

5. How well do groundwater law, policy, and management currently incorporate principles of **adaptive management**? What could be done to increase the use of adaptive management?

6. What mechanisms or processes could be implemented to **diffuse the potential for "combat science"** and avoid wasting time and resources on lengthy disputes about interpreting scientific information?

DISCUSSION PAPER 2
– GROUNDWATER AND UNCERTAINTY –

How should uncertainty about hydrological and ecological knowledge about groundwater be incorporated into policy?

I. WHAT WE KNOW

Uncertainty attaches to many aspects of groundwater conditions and management in the form of factual and scientific uncertainty, uncertainty or risk associated with future resource availability and conditions, and the costs and benefits associated with different management regimes. Managers often operate in the absence of full information about the physical characteristics of aquifers (e.g., extent, storage volume, etc.), groundwater hydrology (e.g., connections between surface water and groundwater systems, recharge rates, quality fluctuations, etc.), the relationship of groundwater to ecology, the effects of current levels of groundwater use, the expected future conditions of groundwater systems and alternative resources, and future levels of groundwater demand. As a result, there is often a great deal of uncertainty regarding the costs and benefits of management options—and indeed, how these costs and benefits should be valued. In addition, individual groundwater users face the risk that their rights or entitlements will not receive a full allocation of water because of unfavorable climatic conditions or competition from other users. At a high level, jurisdictions adopt **different law and policy tools to help policy-makers and individual groundwater users deal with these uncertainties.** At the same time, **law and policy can contribute to uncertainty**. At the science-policy interface, a key question is how uncertainty in hydrological and ecological knowledge should be communicated to policy-makers and stakeholders (*see* Discussion Papers 1 and 3 on the science-policy interface and communication).

Legal and policy presumptions are a key tool responding to uncertainty about the physical characteristics of groundwater systems:

> Colorado, for example, presumes that all groundwater is connected, but water users who believe that their groundwater is separate can rebut the presumption. Other states [like Wyoming], by contrast, often start with a presumption that surface water and groundwater are legally separate and require surface water users to establish that groundwater withdrawals are materially interfering with their use, or vary the presumption depending on whether a current surface water user is objecting to an established groundwater right or someone is seeking a new groundwater permit. Yet others, like Oregon, assume material connection in certain factual settings (e.g., where a groundwater well is within a set distance from a surface waterway).[3]

In Australia, the National Water Commission recommends that "unless and until it can be demonstrated otherwise, surface water and groundwater resources should be assumed to be connected".[4]

Adaptive management principles deal with uncertainty by allowing for revisions in the law or regulation when new information becomes available (*see* Discussion Paper 1 on the science-policy interface).

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[3] Barton H. Thompson, Jr. (2011). 'Beyond Connections: Pursuing Multidimensional Conjunctive Management', *Idaho Law Review* 47: 265-307.

[4] National Water Commission (2009). *Australian Water Reform 2009: Second Biennial Assessment of Progress in Implementation of the National Water Initiative*, Canberra, ACT: National Water Commission.

The **precautionary principle** is a further policy (and sometimes legal) principle used to deal with uncertainty. A definition of the precautionary principle, which is often included in Australian legislation, states that "if there are threats of serious or irreversible environmental damage, lack of full scientific certainty as to measures to address the threat should not be used as a reason for postponing such measures". A stronger form of the precautionary principle urges policy-makers and managers to err in favor of protecting the environment, including by using law and policy. The precautionary principle speaks particularly to the groundwater context, since a variety of groundwater problems, such as subsidence, seawater intrusion, contamination by pollutants, and loss of unique groundwater-dependent biodiversity are often irreversible. Indeed, a New South Wales state policy adopts as a guiding management principle that "[w]here scientific knowledge is lacking, the precautionary principle should be applied to protect groundwater dependent ecosystems". However, as is common in relation to such statements, no guidance is provided on precisely what is required to act in accordance with the principle. In the 2010 *Alanvale* case, a Victorian tribunal cited the precautionary principle in upholding a water authority's decision to refuse to issue a license for groundwater extraction, where there was uncertainty about the impacts of climate change on the groundwater source—a rare example of the principle being used in the context of litigation over groundwater.

In addition to dealing with scientific and factual uncertainty, to varying degrees, groundwater law and policy provide tools to **minimize the cost of uncertainty associated with the security of groundwater rights and entitlements**. The risk of receiving less than one's full entitlement to water is an inherent quality of water entitlements and allocation schemes, which law acts to distribute. There are many examples of legal mechanisms designed to allocate (and possibly reduce) risk in a way that minimizes the cost of uncertainty. As noted in Discussion Paper 5 on water trading, markets reduce the cost of uncertainty by increasing the flexibility of the property right and allowing risk to be shifted to those who are better-equipped to bear the burden of this risk, or more in need of the right. Other legal mechanisms employed to manage uncertainty, or allocate risks borne by groundwater users include:

- **groundwater mitigation exchanges** and **augmentation planning** (which require new groundwater pumping to be offset by supplementing the source with water from an outside system);
- **aquifer and surface storage** (which allow water to be stored in times of surplus and recovered in times of scarcity);
- **capping basins** (which involves prohibiting further groundwater pumping from fully-allocated basins);
- **call mechanisms** within the U.S. prior appropriation water allocation system (a security tool under which a senior water right holder may prevent a junior user from pumping that would reduce the amount available to the senior, to which he or she has a legal right);
- **water right insurance** (a less common mechanism that provides title insurance for water acquisitions); and
- **carry-over** (which involves allowing a groundwater right/entitlement holder to delay the use of a water allocation until a future water accounting period); and
- **water right pooling** (a stakeholder-driven strategy, in the U.S., and a standard feature of Australian water allocation frameworks, which spreads the risk of unfulfilled water deliveries across a broad set of individuals).

Rather than minimizing uncertainty, **sometimes groundwater law and policy contribute to uncertainty**. This uncertainty can be introduced through **unclear or ambiguous principles**.

For example, under California water law, pumping groundwater from “subterranean streams flowing in known and definite channels” requires a state-issued permit, but pumping “percolating groundwater” does not. Unfortunately, there is no “bright line” test for determining whether a particular body of groundwater is a subterranean stream. Definitively settling this question requires litigation, the absence of which leads to uncertainty about whether groundwater permitting requirements apply. Standards designed to protect groundwater supplies from overexploitation can be similarly unclear, particularly where those standards move beyond relatively simple concepts like safe yield. Australia’s 2007 Water Act prohibits pumping groundwater from the Murray-Darling Basin beyond an “environmentally sustainable level of take”, defined as a level of diversion that does not compromise any of four factors—key environmental assets, key environmental outcomes, the productive base of the resource, and key ecosystem functions. However, the Act gives no guidance on what some of these terms mean, nor how to prioritize “key” elements as against those that may be compromised.

Law can also contribute to uncertainty for groundwater users when **rights to groundwater are not readily quantified**. This is the case in states of the western U.S. (such as California) that require court adjudication to settle groundwater rights. Groundwater rights that are limited to the volume of “reasonable use”, which is common throughout the western U.S., are also, by nature, uncertain (at least in theory), since the reasonable use standard changes with time. In both Australia and the western U.S., some types of groundwater uses are exempt from regular licensing or permitting processes, meaning that they are largely unmonitored and not quantified. Activities that are commonly exempt from such requirements include mining, oil and gas activities, forestry plantations, and stock and domestic bores. In the western U.S., groundwater impacts of large-scale development projects can also remain unquantified because many states, like Montana and Washington, exempt such projects from regulatory review. These unmonitored and unquantified uses cannot effectively be controlled, and as a result, they may erode the security of other water rights, increasing the uncertainty associated with water allocations available under those other water rights.

As one of the most recent concerns of groundwater laws and policies, **groundwater-dependent ecosystems** (“GDEs”) pose particular challenges for law, policy and management in terms of uncertainty. GDEs have received relatively little scientific attention in the U.S. and Australia compared to surface water ecosystems, and comprehensive assessments are needed to reveal the types of ecological services provided by GDEs, sources of threats to those services, types of indicators that might be used to estimate the health of GDEs, and systems by which to value and prioritize the protection of GDEs. Australian water law and policy at the national and state levels often requires that GDEs be considered in determining sustainable aquifer yields, which are generally set out in water allocation plans. However, some postulate that the significant scientific uncertainty surrounding the water requirements of GDEs has contributed to the fact that most Australian water allocation plans do not consider GDEs. If this explanation holds, it appears to contrast with the requirements of the precautionary principle (discussed above), which would appear to require that measures to protect GDEs not be postponed in the face of credible threats of irreversible damage to them. One approach proposed in response to this lack of scientific information is the establishment of strategic monitoring systems, which are designed to test hypothesized relationships between hydrological alteration and ecological responses for various types of groundwater bodies.

Research on GDEs in the U.S. and Australia is beginning to receive more attention. Australia’s National Groundwater Action Plan has invested millions of dollars in studies and reports related to GEs, including a National GDE Atlas. In the U.S., in 2007, the Nature Conservancy developed a methods guide to identifying data inputs needed to characterize the types and locations of GDEs, and how GDEs requirements can be integrated into conservation planning. The U.S. Forest Service has recently incorporated the guide into its groundwater resource management plan (groundwater being a new management emphasis for the agency) and is testing the methods in a pilot grazing plan on Oregon Forest Service lands. The study is intended to inform federal groundwater management on a nation-wide scale.

Scientists face particular challenges in **assessing uncertainty about groundwater information for the purposes of advising policy-makers**. Several different approaches to assessing uncertainty are available. A simple sensitivity analysis approach produces a range of estimates around a "true" value, without assigning probabilities to various points in the range or producing a distribution of value. More sophisticated approaches, such as Monte Carlo analysis and expert elicitation can often provide a more useful and appropriate characterization of uncertainty, but they also can cost more money or increase the complexity of the analysis.

II. WHAT WE NEED TO KNOW

1. What are the **major sources of scientific uncertainty** that currently undermine effective groundwater management? What steps could be taken to reduce these sources of uncertainty?

2. How should scientists **assess uncertainty regarding groundwater information**, and especially, about management (e.g. in predicting the effects of different management strategies)?

3. What does the **precautionary principle** mean with respect to groundwater management? What kind of measures should groundwater managers and policy-makers adopt to embody this principle so as to address threats to groundwater systems? More specifically, how should **risks related to water availability** be allocated between human and ecological users of groundwater? What other principles could guide the adjustment of allocations for water rights or entitlements verses allocations to meet environmental water requirements?

4. In areas that are the subject of a great deal of uncertainty (e.g. water requirements of GDEs), and a great need to collect more information, how can **groundwater information be collected strategically**, rather than in an ad hoc way, to fill unmet management needs?

5. Other than the law and policy tools and principles listed in this discussion paper (e.g. adaptive management, precautionary principle), what mechanisms are available to **manage the problem of uncertainty and reduce the cost of uncertainty**?

DISCUSSION PAPER 3
– GROUNDWATER AND COMMUNICATION –

How can we best communicate to stakeholders the nature of groundwater problems—as they relate to water supply, cultural and ecological requirements—to motivate action?
What information should be presented, to whom, in what form, by whom, and in what forum?

I. WHAT WE KNOW

Stakeholder participation and substantial local involvement in groundwater management are well established across the western U.S. and Australia. **Local stakeholder "buy-in"** is a central theme of success stories in governing groundwater for a host of reasons: local expertise in relation to environmental and cultural conditions can inform local-level management plans; and cooperation between stakeholders and managers can increase the effectiveness of essential management activities. More philosophically, some argue that stakeholders should be able to define their own management goals, and implicitly, acceptable levels of impacts of groundwater pumping in their region.

Maximizing the benefits of local stakeholder involvement in groundwater management requires effectively attracting, engaging and informing stakeholders on complex issues, like groundwater-surface water connections and trade mechanisms. Effectively communicating groundwater issues can help attract and ensure the **ongoing commitment of stakeholders** to engagement about groundwater management. **Improving upon what are frequently low levels of public understanding** about groundwater issues is also important, particularly to ensure environmental views are heard. In addition, in some cases, public awareness is a precondition to the NGO community developing interest in groundwater issues—one reason given for the low levels of NGO interest in groundwater issues in Australia. In turn, NGO involvement is a valuable "check and balance" on the implementation of policy, and a precursor to becoming involved in valuable groundwater partnerships (*see* Discussion Paper 4 on partnerships).

Approaches to communicating about groundwater vary significantly by agency. Common approaches include providing online or paper data, condition reports, newsletters or brochures setting out:
- (a) **visual information** about how groundwater systems work, in general, or under different climatic conditions, including by using conceptual models;
- (b) **observed data** about groundwater quality and levels at monitoring wells over time using **graphs or maps**; and
- (c) **predictive information** about groundwater conditions, sometimes using **scenario modeling** tools and conceptual models.

These approaches are discussed in more detail below.

Conceptual models of groundwater systems are designed to represent hydrogeological settings and explain the dynamics of various processes and interrelationships that underpin system mechanics. Scientists use models to "predict responses to disturbances to water regimes, identify appropriate predictor and response variables for statistical analysis, and help develop detailed hypotheses that can be tested in monitoring."[5] Once models have been developed, stakeholders

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[5] Moya Tomlinson (2010). *Environmental Water Requirements of Groundwater Systems: A Knowledge and Policy Review*, Canberra, ACT: National Water Commission.

may offer insights about the extent to which groundwater models accurately represent local conditions. A useful conceptual model was developed by the European Water Framework Directive (EWFD), using "3-D cutaways" and "vertical cross-section" graphics to illustrate groundwater pressures on hydrogeological systems in Britain and Ireland (*see* examples in Figure 1). The images emphasize the interconnection and interdependencies between groundwater, surface waters, and ecosystems. The website www.wfdvisual.com houses hundreds of groundwater-related images.

Stakeholder discussions can help inform the efficient development of conceptual models. A series of studies was conducted by environmental engineers and communications researchers in Refugio County, Texas in the context of groundwater management planning. The studies used stakeholder focus groups in which a moderator facilitated discussions about issues facing the basin, for example, a city proposal to export water from the region and its potential impact on county groundwater supplies. Specialists observed the communication dynamics between stakeholders in response to the technical models presented, and analyzed the discussion for the range of values that were sought to be protected and preferences about allocating risk. The studies suggest that evaluating stakeholders' communication processes can help to tailor environmental conceptual models to address stakeholder concerns while also increasing the efficiency with which modeling tools are developed.

Some states, like California and Arizona, use **scenario modeling** as a way to predict anticipated costs and tangible impacts of specific groundwater management proposals. For example, the Sonoma Valley groundwater management plan (GWMP) assesses the benefit of different management options by modeling them under a range of different water availability scenarios, taking into account projected changes in demand. The results are presented as quantified changes in groundwater storage and levels to 2030 for each scenario. The plan anticipates (but does not quantify) changes in extraction costs, quality degradation, streamflow, and environmental conditions. Similarly, the Eastern San Joaquin Basin GWMP describes a process of modeling groundwater elevations and groundwater salinity based on a no action (status quo management) scenario, projected to 2030. The plan then considers a wide range of management options related to groundwater quantity, including options relating to surface supply, groundwater recharge and demand reduction. For each option, it compares the cost per acre-foot of water, infrastructure requirements, land requirements, effectiveness, and operation and maintenance requirements.

Graphics and maps are particularly important in helping stakeholders assess the impacts of prior decision-making (particularly those which are concealed within an aquifer) and potentially apply that information to future management considerations. As an example of a retrospective illustration, a Kansas study published maps that show changes in the lengths of perennial streams after the advent of intensive groundwater pumping (*see* Figure 2) and rapid changes in aquifer levels before and after major groundwater-dependent development occurred (*see* Figure 3). In Arizona, the U.S. Geological Survey recently presented new maps and interactive graphics created to explain possible effects of groundwater pumping and artificial recharge on the Verde Valley watershed. The report emphasized the need for water managers to obtain more information on the timing of proposed groundwater pumping and recharge effects on surface water and evapotranspiration; and illustrate how mapping efforts could help extrapolate such impacts (*see* Figure 4).

Graphics can also be used to show more general information about how groundwater systems work. Victoria's Goulburn-Murray Rural Water Corporation uses an interactive visualization with a time slider to demonstrate the impacts of pumping groundwater in different types of aquifers, in different climatic conditions (*see* http://www.g-mwater.com.au/water-resources/ground-water). Australia's National Water Commission has recently published a graphics-rich booklet designed to simply communicate basic information about groundwater, such as its basic nature, place in the water cycle, important processes, connections with ecosystems, and the impacts of extraction (*see* Figure 5, and http://www.nwc.gov.au/publications/topic/groundwater/groundwater-essentials).

It seems likely that different methods of communicating water information to the public and stakeholders may affect perceptions of groundwater management problems, desire for action, and preferences for the kind of action sought. However, there is **limited research about what information to convey, and how to convey it**, to communicate groundwater issues most effectively to either interested stakeholders or the general public, and the strengths and shortcomings of current efforts, such as those set out above. At face value, a key shortcoming of much groundwater communication (using any of the methods set out above) is that it contains **little interpretation about the ecological, economic or socio-economic impacts** of changes in groundwater management. In addition, there is **no established metric or system for valuing groundwater**, particularly in ecological settings. Such a metric would provide a clear basis for communicating the importance of groundwater and help decision-makers and the public appreciate the consequences of different groundwater policies.

Communicating uncertainty to stakeholders and policy-makers is a frequent challenge faced by scientists in the management of natural resources, and particularly so with groundwater, where uncertainty can characterize many aspects of its management (*see* Discussion Paper 2 on uncertainty and methods of assessing it). To communicate effectively, scientists should communicate uncertainty in a manner that **does not overwhelm the recipient or lead them to disregard or misinterpret the information**. However, there appears to be no universal, standardized practice for communicating and visualizing uncertainty in groundwater information. The practice of scientific bodies in other contexts can be instructive—the Intergovernmental Panel on Climate Change provides one such example. It suggests that uncertainty should be described using a common language and graphical approaches and that uncertainty assessments should be "up front" and not buried in appendices. A major issue is whether to report uncertainty as "error bars," statistical deviations, or ranges (on the one hand) or as probability distributions (on the other hand).

Groundwater communication occurs in a range of fora. Much information is freely available on agency websites and in reports. In some cases, water managers that involve stakeholders in planning and operational aspects of groundwater management (*see* Discussion Paper 4 on partnerships) also include an education and outreach component to improve understanding of groundwater issues and facilitate interaction between stakeholders, experts, and water managers. This was the goal of the Colorado Rocky Flats Superfund remediation effort, where several federal, state, and local agencies formed a coalition to address major groundwater pollution within a nuclear weapons development and disposal site. A central project component involved scientists educating a range of stakeholder groups and engaging them in cleanup and coalition activities. The collaboration led to regular communication between agencies and stakeholders, accelerated technical studies, an expedited cleanup, and considerable savings in taxpayer money. Similarly, California regional water boards hold regular stakeholder workshops to discuss hot topics within regional water management and present informational policy briefings which include the opportunity for public comment. Many of these workshops are also webcast and allow comments to be posted remotely.

In Australia, Dow Chemical has been part of an enduring communication forum, the Altona Complex Neighbourhood Consultative Group, along with other chemicals manufacturers, local residents groups and regulators. The Group was established in 1989 to facilitate open discussions with the community, using newsletters and meetings, about environmental performance issues (including groundwater contamination issues) at the largest site of chemical manufacturing industry in the southern hemisphere. The Altona Complex also uses direct telephone lines between the Complex and local schools to advise of emergencies, and a 24-hour telephone hotline that residents can use to report environmental nuisances.

II. WHAT WE NEED TO KNOW

1. What **kinds of communication techniques** (for example, particular approaches to presenting graphs, maps, or visualization tools; meeting styles) have proven most helpful in effectively attracting public involvement in groundwater issues, maintaining stakeholder participation, and ensuring a good level of understanding of groundwater issues?

2. Would **valuation information** be valuable in communicating the importance of groundwater-related issues and solutions to the public and policy-makers (e.g., the value of protecting groundwater-dependent ecosystems or eliminating overdrafts)? If so, how should issues and solutions be valued (e.g., in economic terms, in flows of ecosystem services)?

3. The cost of proposed groundwater management decisions or reform efforts can be an important point for discussion by stakeholders. How should the **costs of failing to control groundwater pumping** be calculated and communicated? At what scale would this exercise be most informative and useful?

4. (Referring also to Discussion Papers 1 and 2) How should scientists convey **uncertainty about groundwater information**, including the impacts of groundwater pumping, to stakeholders, policy-makers and managers, in a way that informs policy development and public understanding but avoids raising undue concerns?

5. Would groundwater management benefit from **greater public education**? If so, how can improved public education be achieved?

III. EXAMPLES OF GROUNDWATER GRAPHICS

Figure 1: Three-dimensional conceptual models illustrating groundwater – surface water connectivity in rural and urban settings, available from http://www.wfdvisual.com/

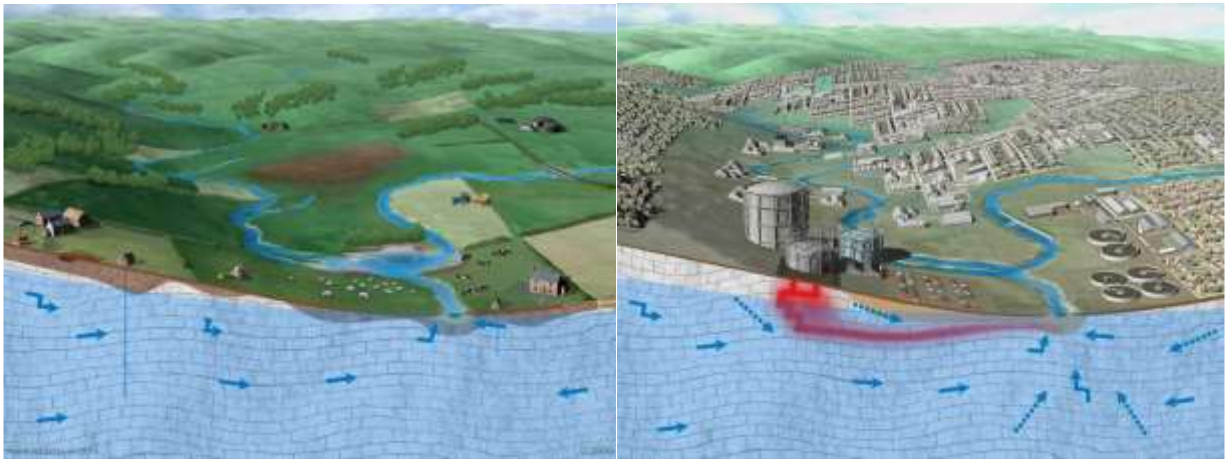


Figure 2: Major perennial streams in Kansas, 1961 versus 1994 (Sophocleous, 2002, adapted from Angelo, 1994).

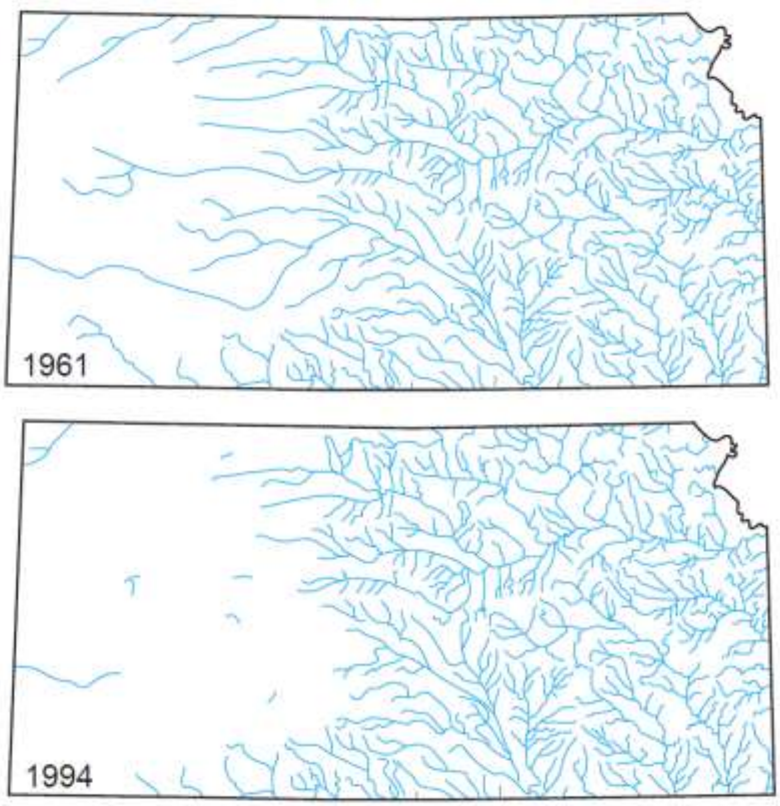


Figure 3: Water level changes in the High Plains aquifer (a) predevelopment to 1980; (b) 1980–1995 (Sophocleous, 2002).

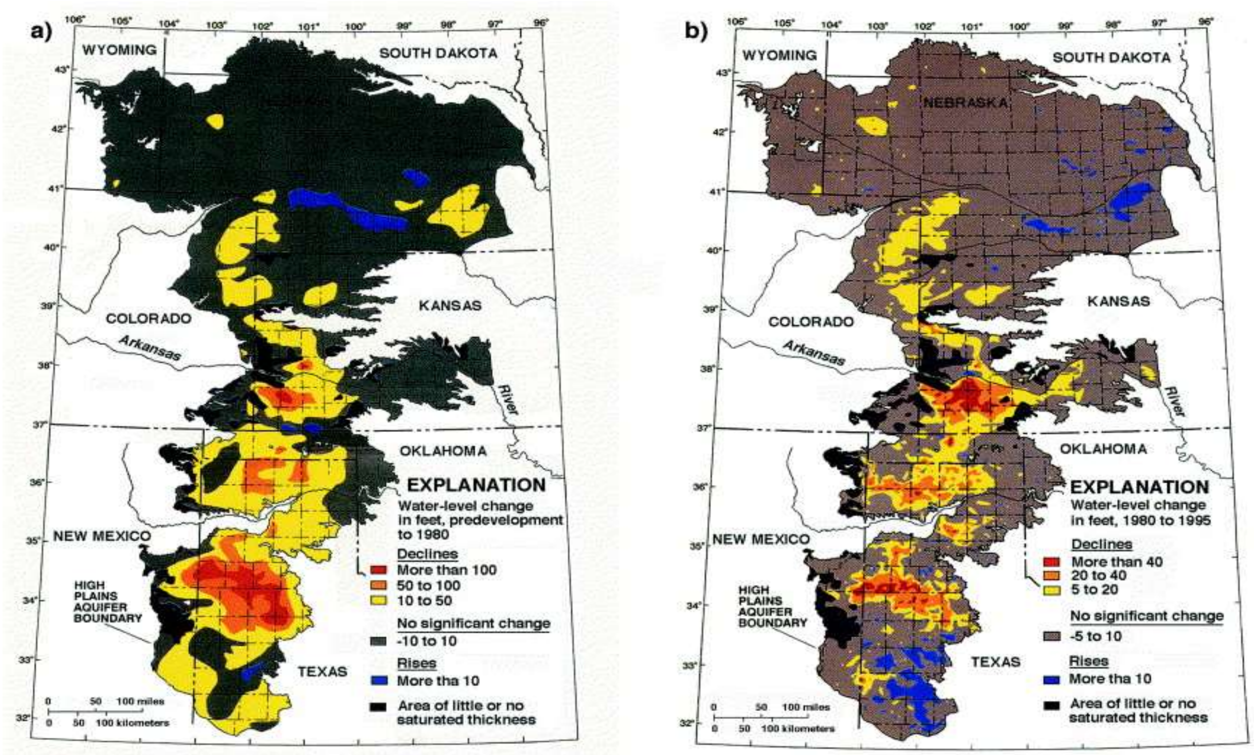


Figure 4: Depletion response to proposed aquifer pumping in Verde Valley watershed after 10 years (left image) and 50 years (right image) (USGS, 2000).

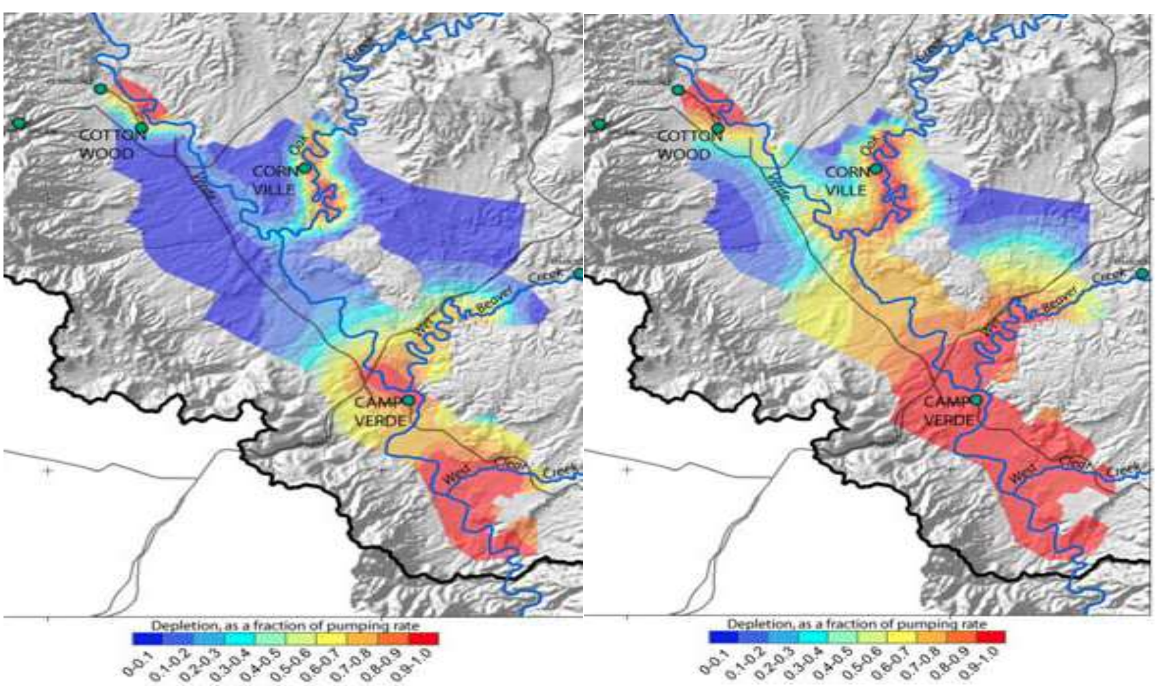
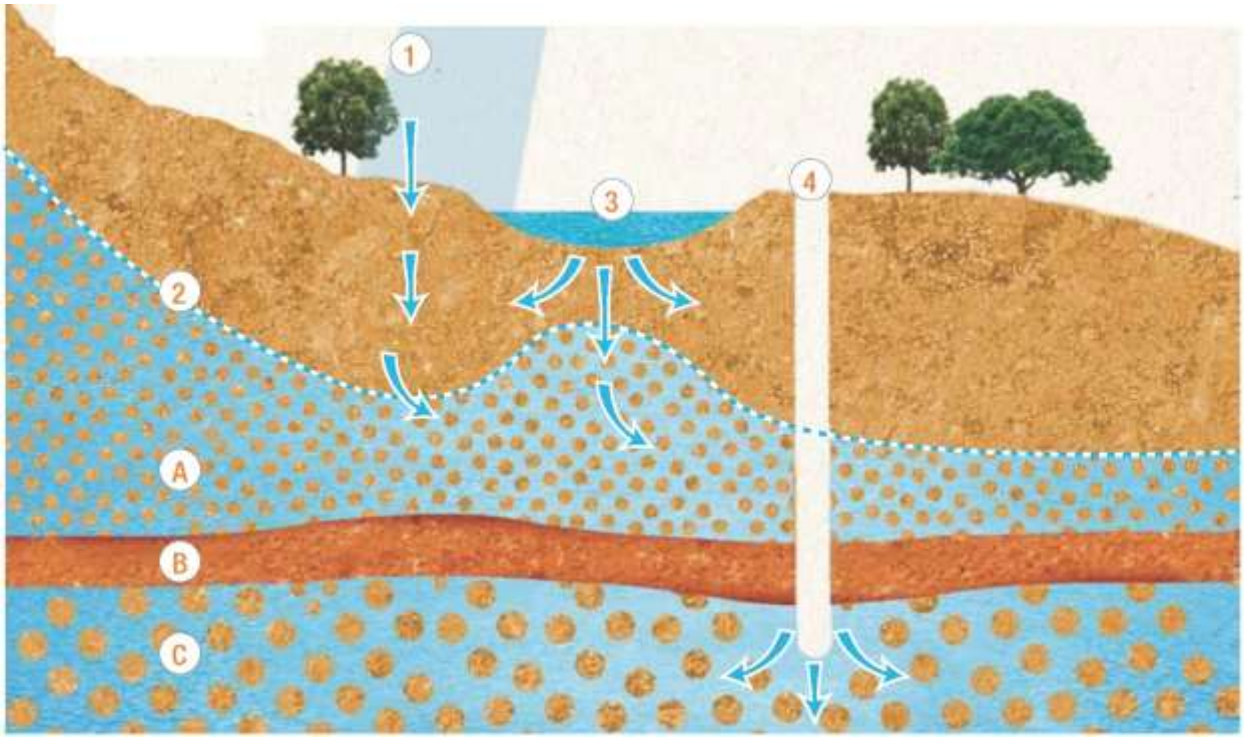


Figure 5: Groundwater recharge figure (1. Precipitation; 2. Watertable; 3. Stream / river; 4. Managed aquifer recharge well; A. Unconfined aquifer; B. Impermeable layer; C. Confined aquifer), from National Water Commission, *Groundwater Essentials* (2012).



DISCUSSION PAPER 4
– GROUNDWATER AND PARTNERSHIPS –

How can the private sector, public interest NGOs, and agencies across government contribute to gathering information and building groundwater tools for use in policy or management, including tools to monitor and model groundwater resources and dependent ecosystems? How can groundwater management move beyond merely consulting stakeholders to forming enduring partnerships that contribute to *implementing* groundwater policy, as well as formulating it?

I. WHAT WE KNOW

Water policy and management literature has much to say about stakeholder consultation, often in the context of government agencies seeking public input on permitting/licensing decisions, or formulating water management plans. In some cases, stakeholders are the primary parties involved in formulating policy. Much less discussed is how a variety of types of partnerships that connect one or more agencies, businesses, and NGOs can **contribute more actively to implementing groundwater policy or undertaking management**. There is evidence of innovative groundwater partnerships in a number of jurisdictions. Such partnerships can offer benefits by **increasing the expertise and human and other resources** available for groundwater management, and lending **broad-based legitimacy** to potentially controversial policy and management approaches.

In the western U.S., natural resource management commonly involves varying interest groups that work simultaneously—and sometimes collectively—on related planning, implementing, and monitoring efforts. In groundwater quantity and quality management, many states rely heavily on the contributions of partnerships comprised of public and private interest groups, individual and associated water users, and all levels of government. Groundwater-related partnerships are also found in several Australian states, though they appear to be less common in groundwater quantity management than in the western U.S. However, groundwater quality concerns, particularly salinity, have spurred the creation of a network of local and regional land and water management groups across Australia.

Partnerships in the context of groundwater management arise with a variety of motives. Many **states delegate significant responsibility to water stakeholders at the local or regional level to formulate plans or rules**, which then sometimes undergo the further step of state approval. These local-state or local-regional partnerships offer a means to capitalize on local knowledge of groundwater issues, increase the managerial workforce at the community or watershed level (particularly at the monitoring stage), and provide incentives for stakeholders to support management action by affording them a larger role in the decision-making process. In Victoria, stakeholder planning groups are comprised of government appointees, over half of which must be involved in agriculture. In California, local agencies and stakeholders assume primary responsibility for producing non-binding groundwater management plans (GWMPs) and integrated regional water management plans, which consider groundwater in the context of surface water, flood management, and ecological resources. The state is involved only in an advisory capacity, or as a project funder, primarily using state bond funds. Formulating Idaho's Eastern Snake Plain Comprehensive Aquifer Management Plan involved establishing a technical committee, to which major stakeholders sent representatives. They assisted with the modeling effort, and helped ensure local buy-in to the model results. Undeniably, broad stakeholder involvement takes time. Some GWMPs that cover large areas report up to 6 years of consensusbuilding and negotiation with tens of stakeholder groups. However, broad stakeholder involvement brings multiple perspectives to help meet multiple objectives, and can help avoid conflicts that have the potential to derail groundwater management efforts. Their involvement also helps to ensure that plans and programs are consistent across agencies, avoiding potential inter-governmental conflict, which can be particularly problematic in the groundwater sphere, when jurisdictional boundaries are blurred and may overlap.

Other regional water management schemes are designed to unify smaller stakeholders as a means to **increase the region's funding and bargaining power** needed to acquire new water rights and infrastructure. In Colorado, water "authorities" are sophisticated, quasi-governmental groups that advise their member constituents (municipalities, sanitation districts, etc.) as to how they can obtain renewable water resources in a fully-appropriated basin. The authorities frequently partner with the state to carry out the necessary negotiations to secure new water rights, build infrastructure, and transport and store water for the benefit of their members.

Many coalitions form in **response to funding made available to particular interests**. For example, partnerships have formed in Oregon, Idaho, California, and Colorado in response to the 2008 Farm Bill, under which the U.S. Department of Agriculture provides several conservation programs that can be used to help farmers and ranchers increase water use efficiency. With emphasis on water conservation and quality enhancement, one farm bill program—the Agricultural Water Enhancement Program—expressly invites "partners or groups" (comprised of NGOs, Indian tribes, agricultural associations and/or state or local governments) to submit conservation proposals pertaining to a specified area, like a watershed. In return for five years of federal funding, the partner/group, often a NGO, designs the proposed conservation plan with oversight from the local Department staff; engages with participants; locates funding to help cover the costs required from the producers; and monitors and evaluates the program. Program analysts have found that the good working relationships between federal agencies, NGOs, and participating farmers are imperative to achieving program objectives. Discussion Paper 5 on aquifer storage and recovery (ASR) describes landholder-government partnerships to undertake ASR.

Non-profit organizations play a number of roles in groundwater management efforts. NGOs often collaborate with agencies and contribute resources to developing modeling, monitoring, and water banking tools. For example, the Deschutes River Conservancy has played a critical role in the **implementation** of Oregon's Deschutes Groundwater Mitigation Program (a form of water bank) by carrying out conservation activities, such as piping and lining canals, which make water available for mitigation. By contrast, the state of Washington authorized the **private sector** to develop and operate groundwater mitigation banks in Yakima County, though the Department of Ecology oversees market activity.

A partnership between the Environmental Defense Fund and Southwestern Energy illustrates how such alliances can be effective during the **regulatory and policy-development** stages. The organizations worked together to establish groundwater recharge standards for hydraulic fracturing projects in the Ogallala Aquifer, Texas. In Montana, Trout Unlimited is in the process of establishing a private non-profit corporation, Montana Aquatic Resources Services (MARS), designed to administer a statewide in-lieu fee program that would collect and disburse mitigation fees to preserve, enhance, and restore aquatic resources (*see* Discussion Paper 7 on mitigation programs). Where practical, MARS will use program funds (obtained from groundwater permitted fees) for projects in partnership with other entities to enhance resource benefits while carrying out mitigation mandates required by the federal Clean Water Act, as well as those specified within the project standards. The establishment of another mitigation program in Walla Walla, Washington, was driven by stakeholder engagement. Stakeholders sought to localize groundwater management and protect senior water rights in the face of impending federal mandates to deliver water to imperiled fish species. The mitigation program was born from a collaborative process that involved forming a NGO that eventually assumed program administration, oversight by the state water agency, and an emphasis on educating basin water users.

The Australian Landcare movement is a well-known and celebrated example of partnerships relating to groundwater quality. It involves community groups, business, NGOs and multiple levels of government **jointly implementing a broad range of natural resource policies**. Community Landcare groups formed during the 1980s to tackle water and land management issues, triggered by broad-based community concern about increasing groundwater salinity in Victoria and Western Australia, caused by irrigation and vegetation clearing. The now widespread movement of around 4,000 local groups was formally established in 1992 as a joint national initiative of the Australian Conservation Foundation (an environmental NGO) and the National Farmers Federation. Later, regional umbrella groups were established by statute (for example, Catchment Management Authorities in Victoria) to coordinate the activities and strategic direction of multiple local Landcare groups, with state government assuming an advisory role, and with funding contributed by local groups along with local, state and federal governments.

NGO partnerships also **contribute to developing groundwater monitoring tools, as well as facilitating regular monitoring activities**. A partnership between The Nature Conservancy and the U.S. Forest Service is developing an inventory and monitoring protocol for groundwater-dependent ecosystems on Forest Service lands. As one component of the Forest Service groundwater resource management program, *TNC's Methods Guide* identifies a variety of data inputs needed to characterize the types and locations of GDEs at a coarse scale across the landscape. These methods are being developed and tested within a grazing management plan revision in Oregon, and are intended to inform a federal groundwater permitting policies protocol a nation-wide scale. In Arizona, volunteer "citizen scientists", coordinated by The Nature Conservancy and the U.S. Bureau of Land Management, have mapped the spatial extent of surface water flows in a portion of the San Pedro River over more than a decade. The San Pedro is affected by baseflow reductions, which are thought to be due to increased groundwater pumping from wells near the river and changes in riparian vegetation. The data collected shows year-to-year variability in flow length, which indicates changes in local groundwater conditions. In Victoria, groundwater license holders double as "citizen scientists" when they return groundwater sample bottles to the Goulburn-Murray Rural Water Corporation, under a voluntary program in which the Corporation supplies the bottles in order to gather data on groundwater salinity trends.

NGOs also **balance and complement agency operations** by seeking multiple benefits from state water management efforts. For example, The Nature Conservancy collaborated with water managers from Colorado, Nebraska, and Kansas to implement an interstate conservation plan that would protect particular groundwater-dependent ecosystems in the Republican River Basin. The states' central motive was to fulfill surface water deliveries required by their interstate water compact by buying and retiring connected groundwater rights. The Nature Conservancy's primary objective was to ensure the plan augmented the flow of the Arikaree River, a tributary of less economic value to the delivery effort (because it was only connected to the mainstem in the winter), but of higher value to groundwater-dependent species.

A different, and more **controversial partnership** between The Nature Conservancy and the U.S. Forest Service involves an effort to restore river flow using a version of a practice known as "buy and dry." In southern Arizona, The Nature Conservancy has been pursuing an effective strategy of buying agricultural lands along the San Pedro River, placing conservation easements on the properties, then re-selling the land with drastically restricted groundwater pumping rights. The collaborative effort has received mixed reactions from those who resist permanent retirement of agricultural land and others interested in protecting streamflow (*see* also Discussion Paper 8 on buybacks).

II. WHAT WE NEED TO KNOW

1. **Which groundwater management roles or issues** especially benefit from partnerships (e.g. modeling groundwater systems, monitoring groundwater-dependent ecosystems, implementation, etc)? Are some types of decisions better left to a single entity (i.e., for purposes of efficiency, clarity, other)?

2. How can water managers **optimize the use of partnerships in different stages** of groundwater management? At what stages are partnerships more or less productive?

3. How is the **usefulness of partnerships affected by the degree of controversy** attending a groundwater management issue? Can partnerships contribute to productive policy development or implementation in particularly controversial areas, for example, managing the groundwater impacts of coal seam gas/coalbed methane development?

4. What **barriers exist to forming partnerships** (e.g., agency-agency; business-agency; business-NGO; NGO-agency; etc.) in groundwater management?

5. To what extent can partnerships form help solve the problem of **institutional capacity** within government agencies (e.g., shortages of staff and skills)?

DISCUSSION PAPER 5
– GROUNDWATER TRADE –

What principles should govern water transfers that enable: (1) a person who pumps groundwater to sell their right/entitlement to a purchaser who will pump groundwater or surface water from a different location (or vice versa), *or* (2) a person who pumps surface water to switch to groundwater (or vice versa)?

I. WHAT WE KNOW.

In parts of Australia and the western U.S., water managers have established market-based institutions to facilitate the trading of groundwater rights or entitlements as a way to distribute water in heavily allocated systems. Water markets (or "trading regimes") are particularly effective management tools in water-scarce regions because they increase the **flexibility** inherent in a water right/entitlement and enable water users to more quickly respond to changes in climate and commodity prices. Additionally, water markets **encourage efficient, high-value water use** between competing interests. "Unlike administrative allocation methods, water markets provide for the compensation of those who 'lose' from the transfer of water resources . . . [and] allow for the reallocation of risk to those who are best able to bear the risk of uncertainty."[6] While markets are well established in many surface water systems throughout the western U.S. and Australia, groundwater trade regimes have emerged at a slower pace and in fewer regions.

In Australia, groundwater trade can occur for both water entitlements (buying/selling shares to water), known as "**permanent trade**", and water allocations (buying/selling water allocated to an entitlement), known as "**temporary trade**". All jurisdictions in Australia have legislation that enables groundwater trading; however, market activity is minimal or non-existent in the Australian Capital Territory, Tasmania, and the Northern Territory. Groundwater trading in Queensland and Western Australia consists almost entirely of temporary trades. In New South Wales, Victoria and South Australia, there are developing markets in temporary and permanent groundwater trading. A majority of Australia's groundwater trade has occurred in regions of New South Wales with large alluvial aquifers, large license numbers, and high levels of water scarcity. The steep **rise in surface water trade in recent years may suggest a similar fate in the activity of groundwater trade**, particularly in drought years. (Surface water entitlement volume trade increased by 75% between 2007-08 and 2008-09, then by another 20% between 2008-09 and 2009-10; and seasonal allocation volume trade increased by 41% and 22%, in those years, respectively.)

Several states in the western U.S. also have some form of active groundwater trade. Market frameworks vary widely and are initially informed by the state groundwater regime (whether states prioritize security for groundwater rights acquired *first in time* under prior appropriation; associate groundwater rights with overlying property ownership; allow unlimited pumping of *reasonably used* groundwater; etc.). Where states have not assumed authority over groundwater trade in a general sense, as in California, **markets are commonly operated and further regulated at the county level**. In Arizona, groundwater trade primarily occurs within regulatory management jurisdictions called Active Management Areas (AMAs) that encompass only 13 percent of the state land area, but comprise about 85 percent of Arizona's total water use. On lands outside of AMAs, groundwater pumping is minimally restricted (subject only to the

[6] Jonathan H. Alder (2008). 'Water Marketing as an Adaptive Response to the Threat of Climate Change', *Hamline Law Review*, 31: 730.

reasonable use doctrine), but can only be traded if bought or sold in conjunction with the overlying property. Many other groundwater markets in the western U.S. are specifically implemented to serve as administration mechanisms for **mitigation water that is used to offset new groundwater pumping** in fully allocated basins (*see* Discussion Paper 7 on groundwater mitigation). For example, Oregon's Deschutes Water Bank Alliance is a cooperative water bank between the Deschutes River Conservancy, irrigation districts, and municipal water suppliers. The bank facilitates new groundwater pumping (mostly for municipal supply and development) by retiring corresponding surface water rights, with additional agreements to designate water to benefit environmental flows and endangered species.

Since the **transferability of groundwater** is a product of the legal structure of the instrument traded, some jurisdictions have created or reformed water license properties to support increased groundwater trade (among other policy objectives). For example, the primary type of groundwater traded in Arizona is a "Groundwater Extinguishment Credit", which is created by retiring one of the three other types of groundwater rights and can only be traded within designated trade zones. These **groundwater credits** are marketable assets for landowners because the credits enable groundwater pumping for "assured water supply" (a demonstration of water availability often required to support new development), and can also be used for water stored within aquifer recharge projects. In Australia, most states are contemplating whether or not to "**unbundle**" their water license system, so that the right to access groundwater (a "water entitlement") is separated from the right to use the resource, and is defined in terms of some portion of the entitlement per year (a "water allocation"). The decision in New South Wales to move to an unbundled water license system significantly contributes to the fact that it has the highest trade activity in the country (along with the nature of irrigation businesses, which have varying seasonal demands).

Some states, like Nevada, California, Oregon, and Nevada use **groundwater banks** to facilitate groundwater transfers and administer underground storage. In the western U.S., the majority of groundwater market transactions that occur outside of a water bank are bilateral trades between a single seller and single buyer. **Buyers and sellers can incur significant expenses in identifying trading partners** and limited information is typically available to assist in negotiating a transaction price. Market participants that have invested resources in obtaining market information often have a strategic advantage in price negotiations. As a result, large price differences within a market are often attributable to differing levels of price information between trading partners.

In both Australia and the U.S., water trading has become an increasingly popular avenue through which water **rights and entitlements change hands to benefit the environment**. A major difference in the two countries' approaches involves the role of water trusts and conservation organizations. In the U.S., groups such as the Freshwater Trust and the Arizona Land and Water Trust, are well established and have been closely involved with water right acquisition processes (especially in surface water transactions), as well as attempts to establish environmental benefits, despite common institutional and administrative barriers. In Australia, that same process has largely been government-driven, where large volumes of entitlement water have been traded to the Commonwealth Environmental Water Holder and other government environmental water managers for ecosystem and water supply restoration (though this has not yet occurred with groundwater entitlements). In the U.S., **water user associations**, such as irrigation districts, are also folded into large scale trade programs that aim to replenish water supplies (*see* Discussion Paper 8 on buybacks). While environmental water transactions have continued to diversify in strategy and ecological contexts, they are limited in extent. Moreover, water traded into some regions has produced significant **water quality and other environmental concerns**, like increased salinity and changes in the spatial distribution of groundwater discharge and recharge.

A variety of considerations arises in developing groundwater trade schemes, including specifying trading zones among which trade is permitted; developing economically and institutionally efficient trading rules; establishing administrative systems for processing and registering trades; establishing sustainable aquifer yields (the "caps" in cap-and-trade) in water management plans; determining environmental requirements of the system; (re)structuring groundwater rights or licenses to be easily transferred; and designing effective monitoring systems. Identifying **acceptable zones**[7] **that define groundwater trade boundaries** is complicated by the fact that multiple jurisdictions may trade water from the same aquifer. Australia's National Water Initiative advocates that boundaries be drawn as large as possible, based on evidence of hydrologic connectivity; institutional factors, such as transaction efficiency may also be taken into consideration. Hydrologic connectivity is particularly important in jurisdictions that allow **"source switching"**, in which a surface water user is allowed to switch to groundwater pumping, or a groundwater pumper switches to surface water use. Where there is insufficient information describing aquifer recharge, or the lag time between extracting groundwater and in-stream impact is long, source switching without close monitoring may result in unanticipated source depletion and negative impacts to third parties (addressed further below).

Although commonly practiced in the western U.S., some rural areas discourage or prohibit trades that **export groundwater from a basin** for fear of diminished return flow and detriment to local water-dependent economies. Moreover, government tax revenues may shrink if farmers fallow land or non-profit entities purchase water rights or secure long-term water leases (*see* Discussion Paper 8 on buybacks). As a result, some county ordinances in California require those wishing to export groundwater to go through an environmental review process to obtain a transfer permit. "The very low number of permit applications suggests, however, that this process is more useful as a deterrent than as a screening mechanism. High up-front costs and the likelihood of negative public opinion guiding the decision process are both factors discouraging parties from filing."[8] Restricting market activity by zone or basin boundaries can reduce the economic value of the water right and stifle potential trade within aquifer storage programs (*see* Discussion Paper 6 on aquifer storage and recovery).

Even where entitlements are traded within basin boundaries, the issue of **third-party impacts** arises. Because groundwater resources are collective in nature, increased groundwater extraction at one location (resulting from a trade) can increase drawdown beyond that location, potentially reducing the security of supply to groundwater-dependent ecosystems and groundwater users outside the transaction. To reduce potential adverse effects on third parties, some western U.S. states and local agencies attach strict **mitigation and monitoring requirements** to groundwater transactions. Glenn County, California has articulated rules for determining whether pumping activity associated with a transfer should be curtailed. It employs a multi-party monitoring framework for transfers, and requires that third parties be at least as well as off as they would be

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[7] Note that the use of the term "zone" here is more generalized than that with which the National Water Initiative has proposed as Australia's trading terminology; which includes "planning areas," "groundwater systems," and "trading zones".

[8] Ellen Hanak (2003). *Who Should Be Allowed to Sell Water in California? Third-Party Issues and the Water Market*, San Francisco, California: Public Policy Institute of California.

without the transfer (a common “no harm” principle). Oregon employs special enforcement-monitoring agents called water masters, however, water master districts typically cover too large an area to maintain comprehensive monitoring records. Transfers that are either controlled by a single water right holder or have clear ecological benefits often require less monitoring to ensure compliance; whereas more complex transfers linked to biological outcomes are sometimes monitored by the Oregon Water Trust.

II. WHAT WE NEED TO KNOW.

1. How should law and policy manage trades that could **adversely affect third parties or groundwater-dependent species and ecosystems**? Should such transfers be strictly prohibited (employing a “no harm” rule), or permissible, but only if mitigated in some way, or should some level of impact be allowed without mitigation?

2. Do the transactional and hydrologic **complexities of inter-basin groundwater trading** outweigh the potential benefits related to increased market activity? What kinds of groundwater policies would allow **groundwater to be exported** from basins while protecting local users and providing opportunities to address other externalities?

3. What principles should apply to determining the **circumstances in which to permit source switching or groundwater-surface water trade**?

4. A groundwater market must employ **effective monitoring systems** to ensure that a transferor reduces his or her pumping by the volume transferred. To what extent are such systems implemented in practice?

5. How should public policy safeguard against the effects of activating formerly unused entitlements (often referred to as “**sleeper,” “dozer,” or paper entitlements**) through trade?

DISCUSSION PAPER 6
– AQUIFER STORAGE AND RECOVERY –

What kinds of frameworks should guide trade and market-based instruments in the context of aquifer storage and recovery—a management mechanism in which one who owns a right to artificially store groundwater can sell the right to recover that water to someone else (or recover the water and sell it to someone else)? How can other market-based instruments be used in the ASR context?

I. WHAT WE KNOW.

Aquifer storage and recovery (ASR)[9] refers to the process of storing surplus surface water within groundwater basins, then later recovering that water for use during times of water scarcity. Aquifers with available storage capacity are most commonly "recharged" either by injection or infiltration. The **infiltration** approach involves spreading water on a land surface or streambed and allowing it to percolate down into the aquifer below. It is a relatively low-cost recharge method, but requires sufficient land area with porous surface characteristics. **Injection** wells require greater investment, but allow for "storage of large quantities of water in deep, confined aquifers in areas where there is insufficient room for infiltration ponds or conditions are not favorable for recharge and storage of large volumes of water in shallow, unconfined aquifers."[10] After recovery, the water may be used for potable, environmental, industrial, agricultural, emergency supply, and a variety of other uses. A related conjunctive management strategy is **"in lieu" storage**, which refers to a strategy of using additional surface water "in lieu" of groundwater, thereby storing the equivalent volume of groundwater in an aquifer without developing any additional storage infrastructure.

ASR is used in several key contexts: (1) In many cases, ASR is a substitute for surface storage. (2) Related to this, ASR is proposed as a mechanism for permitting reoperation of major dams in order to allow greater environmental flows and increased water provision. (3) ASR is used sometimes to allow groundwater pumping to continue while protecting against salt water intrusion or other problems of overdrafting. (4) ASR also is used as a means of putting recycled water into use for domestic and other purposes—a practice that has been in use for decades in some parts of California and in other areas, but which is still generally regarded as an emerging practice.

In particular, escalating costs and environmental permitting requirements associated with surface reservoirs, as well as declining availability of land and suitable sites, have driven water managers to explore ASR. Compared to surface reservoirs, ASR is **relatively less expensive** and can involve **fewer environmental impacts**: aquifers provide natural storage space rather than requiring construction of expensive storage facilities; while water is stored within a basin, the basin serves as a natural distribution system and thereby obviates some of the need to construct additional conveyance facilities (depending on the location from which the source surface water is transferred); water stored underground is not lost to evaporation as it is from surface reservoirs; and groundwater serves as an emergency supply in the event of disruptions to surface water systems.

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[9] The term is here used synonymously with managed aquifer recharge (MAR), a term which is more common in Australia.

[10] Walter Burt and Jeff Barry (2011). 'Advantages, Challenges, Applications & Approaches for Expanding ASR in the West', *The Water Report* 91.

Aquifer storage presents significant opportunities in Australia to increase access to groundwater where appropriate and increase overall water reliability. Some states, like Queensland and Western Australia, have also begun developing ASR law and policies using a **risk-based approach**, with guidance from the national level. However, the overall practice of ASR is relatively under-utilized due to the uncertainty of the impact of recharged water on native groundwater resources (and the quality of stored water after it is recovered), and a host of unique regulatory challenges, including those pertaining to **water right and entitlement trade** within the context of ASR. Substantial opportunities exist to develop state law and policy frameworks for ASR, building on existing national guidelines, and potentially to explore the use of ASR in conjunction with other types of new groundwater policy tools, like mitigation schemes (*see* Discussion Paper 7) to safely allow increased groundwater pumping in basins where the available groundwater supply is fully allocated.

Since aquifer storage technology has been **active in the U.S. for over 40 years**, many states have extensive experience in developing ASR projects and considering relevant policies. ASR was initially developed to augment municipal water supply, often by bolstering the storage capacity of surface reservoirs and using a larger percentage of annual runoff. More recently, ASR has expanded to provide water for agriculture, industry, and environmental water supplies. For example, regions in Washington use ASR water to combat forest fires; South Carolina reserves ASR water to ensure supplies in case of hurricanes; Iowa stores supplies for the event that floods reduce the quality of surface water supplies and render them unsuitable for use; and Colorado uses ASR to augment streamflow and support migratory fowl species. Arizona uses ASR as a means to make use of its entire Colorado River allocation supply, much of which is transported through the Central Arizona Project and released into recharge basins near central Arizona's urban centers.

Market-based instruments, in the form of incentive programs, can be used to encourage the take-up of ASR programs. In Arizona, ASR provides opportunities for innovative public–private partnerships, in which rural landowners may be able to enter into **incentive-based agreements** that would allow recharge facilities to be placed on their lands in return for financial and physical benefits. The Marana High Plains Effluent Recharge Project benefits from such an agreement. The Project was constructed in 2002 as a collaboration between the Bridle Bit Ranch, the Pima County Regional Flood Control District, the U.S. Bureau of Reclamation, Arizona Water Protection Fund, Cortaro-Marana Irrigation District, and the Town of Marana. The Ranch, which provides land for recharge ponds, benefits from a more dependable water supply and higher groundwater levels; riparian zones that benefit migratory birds are supported by effluent conveyed from the town's treatment plants to the recharge ponds; and the project creates recharge credits that are used to offset pumping in other areas (*see* Discussion Paper 7 for a broader discussion of offset/mitigation schemes).

Many states in the U.S. use **aquifer storage to provide water for various environmental benefits**. In addition to providing a mechanism to protect groundwater resources from overdraft and water for groundwater banking, ASR is commonly used to boost supply needed for connected surface systems and groundwater and/or surface-water dependent species. For example, The Farmington Program is a large-scale groundwater recharge project in eastern San Joaquin County, California which is jointly administered by the U.S. Army Corps of Engineers and the local water district. An objective of the program is to provide **seasonal or permanent habitat for migratory birds** by seasonally rotating field flooding to create temporary recharge basins (a "percolating-type" ASR system). Permanent spreading basins that could support permanent habitat are designed to protect adjacent lands. The project also aims to reduce overdraft of the basin and prevent the migration of saline water from the west. In Colorado, the Lower South Platte Water Conservancy District uses ASR primarily for stream augmentation and whooping crane recovery. **Market-based instruments also feature in ASR projects for environmental purposes**. Oregon's Klamath River Basin Pilot Water Bank is used to augment federally-mandated levels in the basin to **protect threatened salmon species**. One way in which stream levels are supported is by providing compensation to irrigators who switch from surface water to groundwater use or store their water underground, which can later be released to augment streamflows.

Market-based groundwater banking (which enables a water storer to sell rights to recover recharged water) is a relatively new form of water banking and is sometimes used in ASR schemes to allow access to the stored water by individuals and entities beyond those owning the land overlying the aquifer. Groundwater trading within the context of ASR offers a unique advantage to other types of trading in that it *creates and allocates a new supply* of water, rather than merely reallocating existing sources between users.

Groundwater banking requires a **sound aquifer management system**. A number of U.S. states, like Arizona, New Mexico, Oregon and Washington, have complex frameworks that regulate many elements of an ASR project. Other states, like Colorado and California, have notable experience implementing ASR projects, although they have not established special-purpose legal frameworks for ASR. Property entitlements in relation to ASR are often not clearly defined, leading to a battery of uncertainties that can become especially important in the context of groundwater banking ASR projects, due to the involvement of multiple parties with potentially uncertain rights and liabilities. **Key legal issues** include:

(a) the right to aquifer storage capacity;
(b) the percentage of water that should be "counted" as stored for later recovery;
(c) the acceptable duration of storage;
(d) the zone within which recovery is permitted (e.g. hydrologically connected to the location in which artificial recharge or injection occurred);
(e) the management of impacts on connected surface waters;
(f) the establishment of title to the stored water and prevention of its extraction by third parties;
(g) administration of and authority over importing and exporting surface water to and from the aquifer, and approving transfers of water in ASR projects that involve banking;
(h) liabilities associated with the stored water potentially affecting contaminant migration, dependent species and ecosystems, the land surface, and the aquifer matrix;
(i) accounting treatment of reductions in "natural" recharge caused by "artificially" storing water in aquifers, and liabilities associated with displacing native groundwater;
(j) more generally, the accounting system to be used for the storage and future recovery of water, and institutional arrangements for maintaining it;
(k) monitoring requirements in relation to impacts to groundwater systems and connected surface systems; and
(l) protecting sites that have suitable hydrologic, geologic and geochemical conditions for ASR by prohibiting or requiring a permit for high-risk land uses, including by establishing aquifer protection districts.

Not all of these issues are commonly addressed in existing legal frameworks in western U.S. states. For example, Arizona manages groundwater and surface water as separate systems and its monitoring arrangements do not assess ASR impacts to surface water.

II. WHAT WE NEED TO KNOW.

1. What are the **minimum legal and institutional requirements** for an effective ASR program? More specifically, what **general policy principles** should apply to ASR projects that involve a groundwater banking (that is, trade) component?

2. How would **existing frameworks for groundwater trade need to be modified** to facilitate trade in the context of ASR projects? Can trade be facilitated where property rights in relation to unconventional source waters (e.g. stormwater, recycled water) are unclear?

3. How should market-based instruments like **incentive schemes** be structured to encourage ASR projects, particularly where there are **broader public benefits** beyond increasing water supplies for the storer, for example, improving groundwater quality, preventing overdraft and subsidence, and augmenting flows in connected surface waters? What **unique challenges arise in the planning and implementation of ASR projects with environmental goals**?

4. Should opportunities for ASR be **better integrated into regional and national water policies**?

5. In urban areas, an emerging policy issue is how to **retain land with recharge capacity**, in order to maximize the potential for future development of ASR. Communication between city planners and water agencies is particularly important in this context. In what ways can water managers encourage awareness of this issue (e.g., California will require local groundwater management plans to map recharge areas beginning in 2013)?

DISCUSSION PAPER 7
– MITIGATING THE IMPACTS OF PUMPING GROUNDWATER –

What principles should govern programs that allow a person to extract groundwater that is connected to surface water in an already over-allocated basin, or allow a person to pump groundwater from a depleted aquifer, on the condition that the person takes action to offset the effects of pumping?

I. WHAT WE KNOW

In the U.S., several western states have developed **groundwater mitigation/offset programs** to facilitate increased groundwater pumping without compromising aquifer levels or connected streamflows. In exchange for permission to pump groundwater, the diverter is required to offset the withdrawal by acquiring replacement water from another source ("mitigation water"), which is then used to supplement streamflow or recharge the pumped basin. Unlike general trading schemes that enable greater flexibility in how, when, and who uses a particular water right/entitlement, mitigation programs aim to effect *balanced* water transactions—compensation being the condition to any use at all. Mitigation is particularly **useful in basins that are fully allocated** and capped to further diversions because it enables increased groundwater consumption and groundwater-dependent development to continue, provided the consumer/developer is willing to reimburse the basin's overall water supply.

While Australian states have not employed formal mitigation programs in regular water allocation frameworks to date, they may be well-suited to adopt this approach to "basin-neutral water balance," especially in areas of high water demand where surface and groundwater are managed as a connected system. At present, mitigation programs are restricted to the context of mining impacts on water rights, in the form of "make good" provisions, and some policy support for "offsets" in the more general groundwater context—though without any detailed framework of principles that would apply to such a policy.

It is important to note that there is **no single design prototype** by which groundwater mitigation programs operate most effectively. As illustrated in this discussion paper, basin-specific needs and stakeholder interests in implementing mitigation largely inform the program's regulatory structure, policy frameworks, and degree of complexity.

Since there are **varying impetuses for establishing mitigation programs** (e.g., compliance with related statutory mandates; interest to increase groundwater-dependent development; localize water management and conservation, etc.), states differ in how they determine when groundwater pumping becomes significant enough to require mitigation. Some determine significance with reference to the types of impacts to streams, the time it takes for groundwater pumping to deplete a stream, and the volume of the depletion. By contrast, in Nebraska's Platte River basin, mitigation is triggered when an aggrieved party can show that they suffered an **economic loss** due to the groundwater depletion caused by development or conservation activities initiated since the granting of their water right. Where groundwater pumping affects a legally significant species, **water quality and temperature** can also serve as central factors informing when and how mitigation is required, since groundwater contributions to streams can affect these characteristics. For example, programs in Washington and Oregon aim to ensure mitigation efforts support habitats of anadromous fish species, protected under the U.S. Endangered Species Act, which have in-stream water quality and temperature requirements.

Mitigation water is typically obtained either by retiring existing rights to pump groundwater or by transferring surface water rights to a mitigation purpose (e.g. reassigning the designated use for a water right from irrigation to mitigation). Some programs, such as in Idaho and Colorado, allow applicants to pursue direct exchanges with other entitlement holders who are willing to sell or retire their right, without transacting through a third party institution to purchase a credit. In some states, Colorado and Idaho again being examples, well associations and irrigation districts purchase surface water for mitigation use by their members, **reducing individual transaction costs**. **Mitigation banks and trusts** may also be employed to help applicants find water rights and track collective bank activity. In Walla Walla, Washington, a relatively simple mitigation model is used, under which all mitigation is conducted through a single bank and applicants pay a fixed fee per "**mitigation credit**." By contrast, mitigation in Kittitas County, Washington involves exchanges through multiple privately-operated water banks that negotiate the terms of individual exchanges and determine the market price of mitigation water for the Yakima River basin. The Kittitas system is praised for its active exchange and precision in mapping areas where groundwater pumping is allowed (if mitigated), but criticized for using the program to control development patterns (since the "mitigation suitability areas" were identified based on their aptness for future development).

To ensure the mitigation credit balances the pumping debit, many states mandate a **"bucket for bucket"** or "drop for drop" exchange, which requires that the groundwater pumped is replaced by the same amount of mitigation water. Other states require that more mitigation water be returned than that which was pumped. Oregon's Deschutes Groundwater Mitigation Program operates within a basin that has completely allocated its water rights and allows leased groundwater pumping only if the diverter returns *twice* the amount of mitigation water as was diverted.

Different approaches are taken to ensure that mitigation bears a reasonable **hydrologic connection** to the proposed groundwater diversion. Many states require that mitigation water be applied within the hydrological "**zone of impact**" of the proposed groundwater pumping, which is largely defined by the underlying aquifer characteristics. For example, since Oregon's Deschutes River basin is deep and fed by multiple diverse hydrologic systems, the state most often requires that mitigation water be returned near the point of groundwater pumping to ensure the credit actually balances the debit. In Walla Walla, however, the underlying aquifer is shallow and homogenous, therefore, the program merely asserts a preference that mitigation occur upstream of the diversion site and be used in high-density areas. In Montana, it was proposed that mitigation water be used for specific stream restoration as a means to replenish the basin's most dewatered areas, outside the immediate zone of impact of a particular well (though the state has not yet adopted a mitigation program).

In addition to geographic accuracy, **temporal proximity** is also a key consideration of mitigation effectiveness. Timing issues are particularly important where a municipal water utility seeks a *year-round* groundwater pumping permit, and proposes to mitigate its water use under the permit by buying and retiring a *seasonal* irrigation surface right. Common policy approaches to dealing with mitigation timing are to calculate depletion—and therefore, the requirement to provide an offset—on a monthly, seasonal or annual basis, with annual calculation being the least precise and arguably least desirable in terms of truly neutralizing the effect of the pumping. A further issue arises in relation to temporal proximity—whether a program requires mitigation to occur at the time that groundwater pumping commences, or only when the depletion would be felt, based on hydrologic modeling, as in New Mexico's Middle Rio Grande mitigation program. The latter has been controversial, since it may increase the uncertainty that the mitigation action will in fact occur, on account of businesses failing or replacement water being unavailable, for example,

Depending on the structure and motive for establishing a groundwater mitigation program, a number of institutions may be well suited to **administer the exchange**. State and local partnerships may increase transaction efficiency where state water regulatory agencies are already overburdened. They also present an opportunity to capitalize on local expertise in relation to water markets, water rights, monitoring, etc. Two years after founding the exchange in Walla Walla, Washington, the state partnered with a non-governmental pilot organization to create local management plans; and after another two years, transferred primary administrative duties to the organization.

II. WHAT WE NEED TO KNOW

1. In what capacity would groundwater mitigation be most **effective and practical for Australian** states? Basin-wide mitigation programs to reduce groundwater stress or offsets for only specific types of groundwater uses (e.g., new development, mining developments, etc.)?

2. For any new program, policy must identify how groundwater mitigation will fit into existing management schemes and the **types of entities appropriate to assume administrative duties**. In the U.S., public interest groups are more commonly involved in water management and natural resource administration than they are in Australia. How might a groundwater mitigation program present opportunities to increase involvement of NGOs within the public and private sectors in Australia? What possible benefits and shortcomings stem from sharing managerial duties with local NGO entities?

3. Where there is an **incomplete qualitative understanding** of surface water-groundwater connectivity and/or flow rate data, policy must address whether water managers should be more conservative or allow diversions that compromise the security of established water right/entitlement holders. What kinds of guidelines can states use to evaluate and address this balance? Should these judgments be made at the state or local level? What tools, other than mitigation requirements, can be used to deal with potential effects on established water right/entitlement holders?

4. What types of **enforcement and monitoring mechanisms** could be employed to guarantee that mitigation requirements are met and replacement water is appropriate to return to the streamflow of aquifer? What remedies might exist to address noncompliance or determination that water is being compromised by mitigation efforts?

5. Should it be permissible to use **"fossil" (nonrenewable) groundwater** to offset stream depletions? Should there be other restrictions on source water for mitigation?

6. What measures could be used to assess the **effectiveness of mitigation programs**?

DISCUSSION PAPER 8
– GROUNDWATER BUYBACKS –

What principles should govern programs under which a government agency or private party purchases and temporarily or permanently relinquishes a right to: (1) pump groundwater, in order to protect the sustainability of the aquifer or connected surface waters; or (2) divert surface water, to facilitate the continued pumping of connected groundwater?

I. WHAT WE KNOW

A key issue in designing policies to reduce groundwater use is how to allocate reductions among groundwater pumpers. Traditionally, Australian systems have favored equal reductions, and western U.S. systems have favored reductions based on the time that a right was established. However, as noted in the report from Workshop 1, there are a variety of mechanisms used to allocate reductions equally among all users, or differently among groups of users, based on priority in time, or economic value. A **"buyback"** scheme is a further approach to reducing source depletion: a party purchases and **temporarily or permanently relinquishes a right** to: (1) pump groundwater, in order to protect the sustainability of the aquifer or connected surface waters; or (2) divert surface water, to facilitate the continued pumping of connected groundwater. A buyback might also involve paying a farmer not to irrigate with groundwater (and not to extract groundwater), rather than buying the water right/entitlement per se. Buyback agreements may take place outside the formal processes for water right changes and trades (particularly in the western U.S.), and provide a potential advantage by **minimizing administrative scrutiny**. As presented within this discussion paper, buybacks relevant to groundwater can be initiated and funded by a government agency, an environmental NGO, or any stakeholder entitled to appropriate some quantity of water.

Australia has well-developed policies for governments systematically to buy back **surface water entitlements** from willing sellers in over-allocated areas, for environmental purposes. Current policy statements suggest that this will be extended to groundwater entitlement holders in areas in which the current level of entitlement exceeds the "sustainable diversion limit" set by the Basin Plan for the Murray-Darling Basin. To assist the transition to reduced water allocations, the Australian Government's AU$3.1 billion (US$3.3 billion) Restoring the Balance in the Murray-Darling Basin Program buys water entitlements from willing sellers. **Australian NGOs** like the Waterfind Environment Fund are also emerging as potential agents of buyback projects, though they are presently focusing on only surface water purchases.

In the U.S., state groundwater buyback programs seem to be directed towards "**hotspots**", for example, as a response to the otherwise economically crippling effects of strict administration of the prior appropriation system (as exemplified by the Idaho buybacks to support spring-fed trout hatcheries on the Snake River, discussed below). **Conservation-oriented NGOs** have considerable experience using buyback strategies to support surface water systems, and are increasingly extending that focus to include groundwater buyback opportunities as conjunctive management becomes more widely recognized throughout the west. The U.S. federal government also plays a significant role in funding and administering a number of **agricultural land-fallowing programs** to provide incentives for irrigators to reduce water consumption—a practice that is not widespread in Australia.

Buyback schemes employ a variety of conversion strategies that can be tailored to different policy objectives. In Australia, buyback programs have been primarily implemented to allow continued pumping without exceeding the sustainable yield established for a particular basin. As a matter of policy, the Commonwealth and State programs plan to purchase water entitlements from water users, rather than compulsorily acquiring water entitlements, where the Basin Plan requires reductions to current extraction levels. The aim of the Restoring the Balance in the Murray-Darling Basin program is to provide more water for the environment, which can be used to protect and restore Basin river systems and wetlands. To date, the program has made purchases through more than 4,100 individual trades. Another scheme, the Achieving Sustainable Groundwater Entitlements program, is jointly administered by New South Wales and Commonwealth agencies and is designed to buy back groundwater entitlements in over-allocated inland areas, though it makes no explicit reference to providing water for environmental use.

Programs that buy back groundwater to **benefit ecosystems and water-dependent species** are increasingly used in the U.S. where fishery and migratory bird species require protection under the Endangered Species Act. For example, initiated by litigation within the Pecos River Basin, New Mexico implemented new buyback policies to augment streamflow under a program known as the Strategic Water Reserve. The state purchases or leases water rights from willing sellers/lessors, **pools the publicly-held water rights**, and commits them to fulfilling contractual delivery obligations to downstream states and benefiting surface water-dependent endangered species. The sale, lease, or donation of groundwater water rights, however, may only be used for the purposes of cessation of pumping or for limited short-term stream augmentation. The Platte River Recovery and Implementation Program aims to restore Platte River flows to 1997 levels by 2019, chiefly to benefit endangered fish and migratory birds, and to prevent the need to list further species. The Program involves Nebraska, Wyoming, Colorado, and the federal government. Each party has adopted a "depletions plan", under which water use activities commenced since 1997, including groundwater pumping, must be **mitigated**. As part of the program, Nebraska's New Depletions Plan seeks to increase Platte River streamflows by phasing in reductions of groundwater use through decreased water allocations or **fallowing presently irrigated acres**, from 2013 to 2019.

In Idaho, the state **contributed to purchasing a business that used groundwater** in order to reduce pumping impacts to groundwater-dependent species. The state was confronted with a scenario in which groundwater pumped for irrigation impacted springs that fed trout hatcheries on the Snake River. Administering water rights based on priority would have had severe economic impacts, shutting down wells irrigating 58,000 acres to benefit spring-dependent trout production with a much lower total value. Ultimately, the state of Idaho and groundwater irrigators purchased the trout hatchery facilities, land, and water rights and will use the water to satisfy the senior rights of adjoining trout producers, and avoid the need to curtail lower-priority groundwater rights for irrigation.

In **hydrologically-connected systems**, reducing groundwater use by purchasing or leasing rights is a common method of fulfilling instream delivery obligations and providing water for surface water and wetland ecosystems (as in the Pecos River Basin, noted above). As a further example, in Idaho's Eastern Snake River Aquifer, groundwater pumping has regularly exceeded basin recharge on an annual basis, which led to on-going litigation between groundwater pumpers and the surface water users that divert water from aquifer-fed springs for irrigation. Initially, the state used federal Farm Bill funding (discussed below) to buy and retire irrigated land in an attempt to augment groundwater sources and fulfill water requirements for endangered species mandates.

When the basin was still not in balance, Idaho's governor organized the Comprehensive Aquifer Management Plan (CAMP) that comprised of state agencies, spring-user stakeholders, groundwater stakeholders, and conservation NGOs. The group aimed to reduce water usage over five years by switching 10,000 irrigated acres to dry-land farming, and implementing aquifer-wide reduction incentives and assistance to farmers to convert to less water-intensive crops.

There are also a number of examples of **U.S. environmental NGOs purchasing groundwater rights** to benefit streamflow and dependent species. The Nature Conservancy has employed a strategy in areas of southern Arizona of purchasing agricultural lands along the San Pedro River (thereby acquiring a right to divert groundwater appurtenant to that property, according to state law) and reselling the property with an attached easement that dramatically reduces the volume of groundwater the buyer is permitted to pump. While this practice, commonly known as "buy and dry", is effective in augmenting streamflow and reducing aquifer depletion, it has received criticism for retiring land available to the irrigation community. As an alternative, Arizona's Land and Water Trust has also bought and sold agricultural land with the purpose of reducing groundwater withdrawal, but often builds in a requirement that water continue to be used for agricultural use. The strategy aims to balance protection of the ecological values of surface and groundwater, as well as its agricultural and ranching communities.

In order to buy back groundwater to benefit surface flow systems, **state laws must recognize** "instream flows" or "environmental purposes" as being a legally permissible use of water. However, several states in the western U.S., including Idaho, Wyoming, and Utah, do not allow transfers of water designated for an instream beneficial use. Montana NGOs like Trout Unlimited devoted 15 years lobbying the Montana legislature and state agencies before surface and groundwater were managed as a single, connected system and "instream flow" was legally recognized as a beneficial use of transferred water.

Several of the examples above reference arrangements by which private landowners (typically large-scale irrigators) agree to **temporarily or permanently reduce water use by fallowing land** in exchange for some form of compensation. These voluntary land-fallowing agreements are often funded by the U.S. Farm Bill Conservation Programs, in which the U.S. Natural Resources Conservation Service (NRCS) offers financial and technical assistance to help willing participants manage natural resources in a sustainable manner. Generally, states, NGOs, or other willing project organizers submit contract proposals to NRCS that describe how the collective will achieve conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land. A common challenge for these large-scale fallowing projects (which may receive up to ten years of Farm Bill funding) is that the project requires well-developed working partnerships between all participating parties, including federal and state agencies, all volunteer landowners, and any participating NGOs. Two programs that are commonly used to reduce groundwater and/or surface water use are the Environmental Quality Incentives Program (EQUIP) (along with its sub-program called the Agricultural Water Enhancement Program, mentioned in Discussion Paper 4 on Partnerships) and the Conservation Reserve Enhancement Program (CREP). From 2003 to 2010, EQIP contracts were arranged in every U.S. state and the annual funding ranged from US$1 billion to US$1.2 billion.

Another related form of irrigation-driven incentive that is common in the western U.S. involves **rotational land-fallowing programs**, in which individual farmers in a group are paid to fallow their land in a cycle, so that no one section of the farm economy is greatly impacted, and long-term agricultural production is maintained. An alternative often preferred to "buy and dry" approaches, these programs focus on balancing sustainability efforts between agriculture and water supplies. Colorado's Lower Arkansas Valley Water Conservancy District, for example, has adopted a "rotational land fallowing program [that] involves removing irrigated parcels from production on a periodic basis, once every three or four years for example, and transferring the associated water to an economically higher-valued use, such as municipal use."[11] For these rotational land fallowing-water leasing programs to be successful, it is important to encourage the participation of the larger ditch companies in a particular region as a means to increase the pool of available water supply and farmland that can be fallowed.

As mentioned above, and in Discussion Paper 5 on groundwater trade, some buyback programs in the western U.S. are criticized for their **effects on third parties**, namely, negatively impacting agricultural economies when farmers idle cropland to sell water. Many rural areas discourage or prohibit trades that export groundwater from the basin for fear of diminished return flow and detriment to local water-dependent economies. Moreover, government tax revenues may shrink if farmers fallow land or non-profit entities purchase water rights or secure long-term water leases. California's widespread use of these buyback agreements for its drought water bank generated notable strife in some agricultural counties.

Recent studies in Murray-Darling Basin report that the third-party effects of surface water buybacks proved lower than anticipated in some regions within the Basin, and that the impact of buybacks on house prices could even be positive. Since farmers are fully compensated, any income losses will be offset by the annuity arising from buyback proceeds. The study also compared the impacts of drought and impacts of buybacks within the Basin, and found that drought impacts were significantly higher than direct buyback impacts in terms of productivity and job retention.

II. WHAT WE NEED TO KNOW.

1. Excessive groundwater pumping can reduce river flows, effectively reversing some of the gains that have been made in buying water back for the environment. What measures can be taken in law and policy **safeguard** the politically hard-won and often expensive **water that has been bought back and dedicated to environmental benefits**, from groundwater pumping, particularly in Australia, which lacks legal tools like "calls" to curtail pumping by junior water users?

2. What **opportunities and barriers exist for environmental NGOs** that wish to become more involved in buyback programs? In Australia, where buybacks are typically government-operated, should governments also fund NGO-driven projects, or should NGOs be responsible for raising funds to cover all of the requisite program costs? More generally, should NGOs be provided with incentives to engage in buybacks, for example tax deductions?

3. Are current funding mechanisms used to buy back water in Australia and the western U.S. sustainable for long-term use? What are **financially sustainable ways to fund buyback**

[11] HDR Engineering, Inc. (2007). *Rotational Land Fallowing-Water Leasing Program – Engineering and Economic Feasibility Analysis*. Executive Summary. Prepared for the Lower Arkansas Valley Water Conservancy District.

programs? Is there a reliable valuation guide by which to quantify the services provided by buyback programs?

4. In relation to **connected stream-aquifer systems**: if protecting surface water flows is a key policy goal, under what circumstances is buying back rights/entitlements to pump connected groundwater preferable to buying back rights/entitlements to divert surface water? How do factors like the value of the end use, the cost of the right/entitlement, and the degree of connectivity influence the answer to this question? What other factors are relevant?