Groundwater policy and governance

Groundwater Governance
A Global Framework for Action

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Groundwater Governance - A Global Framework for Action

Groundwater Governance - A Global Framework for Action (2011-2014) is a joint project supported by the Global Environment Facility (GEF) and implemented by the Food and Agriculture Organisation of the United Nations (FAO), jointly with UNESCO's International Hydrological Programme (UNESCO-IHP), the International Association of Hydrologists (IAH) and the World Bank.

The project is designed to raise awareness of the importance of groundwater resources for many regions of the world, and identify and promote best practices in groundwater governance as a way to achieve the sustainable management of groundwater resources.

The first phase of the project consists of a review of the global situation of groundwater governance and aims to develop of a Global Groundwater Diagnostic that integrates regional and country experiences with prospects for the future. This first phase builds on a series of case studies, thematic papers and five regional consultations.

Twelve thematic papers have thus been prepared to synthesize the current knowledge and experience concerning key economic, policy, institutional, environmental and technical aspects of groundwater management, and address emerging issues and innovative approaches. The 12 thematic papers are listed below and are available on the project website along with a Synthesis Report on Groundwater Governance that compiles the results of the case studies and the thematic papers.

The second phase of the project will develop the main project outcome, a Global Framework for Action consisting of a set of policy and institutional guidelines, recommendations and best practices designed to improve groundwater management at country/local level, and groundwater governance at local, national and transboundary levels.

Thematic Papers

- **No.1 -** Trends in groundwater pollution; trends in loss of groundwater quality and related aquifers services
- **No.2 -** Conjunctive use and management of groundwater and surface water
- **No.3 -** Urban-rural tensions; opportunities for co-management
- **No.4 -** Management of recharge / discharge processes and aquifer equilibrium states
- **No.5 -** Groundwater policy and governance
- **No.6 -** Legal framework for sustainable groundwater governance
- **No.7 -** Trends in local groundwater management institutions / user partnerships
- **No.8 -** Social adoption of groundwater pumping technology and the development of groundwater cultures: governance at the point of abstraction
- **No.9 -** Macro-economic trends that influence demand for groundwater and related aquifer services
- **No. 10 -** Governance of the subsurface and groundwater frontier
- **No.11 -** Political economy of groundwater governance
- **No.12 -** Groundwater and climate change adaptation

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GROUNDWATER GOVERNANCE: A Global Framework for Country Action
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Thematic Paper No. 5: Groundwater Policy and Governance

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1 Introduction

Governance is an immense conceptual construct, encompassing a suite of precepts, principles, ideas, theories, contexts, objectives, and practices. The FAO/ GEF project "Groundwater Governance: A Global Framework for Country Action" is a comprehensive attempt to understand and articulate this notion in its entirety—as applied to the particular subject of groundwater.

The present paper, whose focus is the *policy aspect of groundwater governance*, proceeds from the following set of basic understandings:

- Groundwater is far-and-away the largest source of freshwater in a world where many regions worry about critical shortages
- In the recent past, the study and management of water in general, and groundwater in particular, have benefited from a more well-rounded, more forward-looking, and more comprehensive set of principles and tools
- Non-technical, "soft" approaches to managing water have accepted the centrality of understanding modes of governance. The present water crisis—insofar as the growing lack of access to potable water and water for agricultural and industrial use can be described in such alarming terms—is "mainly a crisis of governance," the Global Water Partnership proclaimed at the turn of the current century (Mukerjee and Shah, 2005).
- Ultimately, principles of governance (which are reviewed and elaborated in this paper)—to the extent that they are appropriate—can result in the development and implementation of effective policies, and
- Such policies can yield a set of practices for "responsible groundwater use," including equity, sustainability and efficiency considerations.

PART 1: BASELINE

2 Policy Framework

2.1 Context

Over the past two generations—and especially since the pioneering 1972 UN Conference on Human Environment and then the 1977 Mar Del Plata UN Conference on Water—public attention has been drawn to the significance of water as the key to human sustenance. Always present implicitly, historically water was perceived as an ingredient for agriculture, transportation, industry, and human development. But when water was studied explicitly, it was typically by hydrologists, civil engineers, and chemists who sought to know its properties, characteristics, and potential for irrigation and power. And nearly always, visible water—that is, surface water—was the main subject of inquiry.

Water science, or more generally, water studies came to be synonymous with investigations of the world's rivers, lakes, oceans, and glaciers. With the convening of the International Geophysical Year (1957-58), and then of the International Hydrological Decade (IHD; 1965-74), these resources were subjected to intensive study. Scientists from both sides of the Cold War divide joined to map river and irrigation systems, estimate water budgets, calculate potential hydrokinetic power, compile glossaries, and propose research protocols. By the end of the IHD and with the 1975 creation of the UN's International Hydrological Programme (IHP), physical scientists had considerably increased general knowledge of the geography, mechanics, and composition of the planet's surface water (Varady, et al. 2008).

But there remained large gaps in our understanding of the role of water in society-at-large and its interconnectedness to the Earth's environment. It was not until the advent in the late 1980s and the subsequent acceptance of the notion of (environmental) sustainability that water became recognized explicitly as a critical resource and core value. Along with sustainability came a number of corollary precepts that have gained currency:

- Integrating water management within other aspects of socioeconomic development is indispensable (*viz.* IWRM, or Integrated Water Resources Management; Rogers and Hall, 2003)
- "Context matters," as Elinor Ostrom (1990) has written, and one-size-fits-all solutions are illusory
- The involvement of nonstate actors and diverse stakeholders such as communities in decisionmaking is a component of most successful resource-management approaches (Biermann and Pattberg, 2008)
- Expertise should be harnessed across a full spectrum of disciplinary approaches, including the social sciences and law
- Communities of practice, such as those among government authorities, scientists, and water users are catalysts for effective management of resources (Ross and Martínez-Santos, 2010)
- Hegemonic, equity-related, ethical, and other political motives are key factors in national, international, and transboundary matters (Gerlak et al., 2010)
- Governance and the globalization of water governance have become increasingly prominent elements of the management discourse (Varady et al., 2009)
- The change in thinking about environmental governance is most clearly visible in the new attention that market-based approaches have received (Agrawal and Lemos, 2007; Barraqué, 2004), and,
- "Demand-side" management of water and other resources is as critical as supply augmentation in attempting ensure sustainability across future generations (Hutchinson, et al., 2009)
- Beyond financial and hydrological considerations, key obstacles to improved management include extensive institutional and territorial fragmentation in a sector with numerous stakeholders at different levels; and strong spillovers in other policy areas such as agriculture, spatial planning, and energy (OECD, 2011).

During this same period of transition from a top-down, technophysical, and present-centric orientation to a more bottom-up, holistic, future-oriented one, another realization became manifest: that in spite of what our eyes were telling us, the vast majority of world's freshwater was not above the ground, but below it. An early proponent of this revisionist view was the International Association of Hydrogeologists (IAH), which was established in 1964 by hydrologists who were convinced of the distinctiveness and importance of groundwater. Although some irrigation-intensive regions of the world like the Punjab in India

and Pakistan had begun shifting from river water to groundwater by the 1960s, the amount of groundwater on the planet was not well understood and vastly underestimated. Now we know that—if polar ice and glaciers are not included in surface water amounts—groundwater systems hold as much as 98 percent of the total freshwater on Earth (Foster and Chilton, 2003). And in developing countries, especially, exploitation of these below-the-surface sources has been accelerating rapidly since 1970, accounting for half of India's agricultural water use and as much as two-thirds in parts of China (Giordano and Villholth, 2007).

2.2 Existing legal frameworks for groundwater allocation and management

It is evident to students and observers of governance that national and international laws are critical instruments for designing and implementing public policy. In fact, confronting the on-the-ground challenges of actually implementing groundwater governance requires close attention to the legal frameworks that prevail in a given context.

As with surface water use, groundwater use is highly dependent on a host of legal institutions, such as:

- Existing formal and customary rights regimes
- Legislation that specifies access, allocation, and quality
- Regulations that control planning and zoning
- Laws and statutes that protect recharge areas, potable water sources, riparian corridors and habitats, and endangered species
- Enforcement directives
- Pricing and use regulations
- Mandates for public participation and transparency, and
- International treaties, agreements, and protocols

By shaping public policy, these legal instruments wield tremendous influence on the nature and details of governance within a nation's boundaries and beyond (Nanni et al., 2006; Nanni et al., 2004; Eckstein, 2011; McCaffrey, 2011). Thematic Paper No. 6 in this series, "Legal Frameworks for Groundwater Governance," offers far greater detail on this subject and we have relied on the working outline for this paper (Mechlem et al., 2011).

3 Current Definitions of Groundwater Governance – a Typology

Consider the simple term 'governance': a review of definitions provided by 12 respected sources[7] offers up some three dozen keywords[8], each of which has a place among the elements defining governance. Contributing to the fuzziness of the idea, each set of authors appears reluctant to assert unequivocally: "governance *is*. . . ." Instead, they dance around the subject, employing such phrases as: "governance *describes/is described as/emphasizes/encompasses/ is about/is an arena in which/is characterized by/refers to/relates to. . . .*"

For the World Bank (1991), governance is, simply put, "the exercise of political authority and the use of institutional resources to manage society's problems and affairs." The definition is pithy, but it lacks the richness that has propelled governance to the fore of so much discussion. For the purposes of this paper, we like the direct and nuanced definition of governance provided by Saunier and Meganck in their *Dictionary and Introduction to Global Environmental Governance* (2007). Below, we have adapted their statement to serve as our working definition:

> Groundwater governance is the process by which groundwater is managed through the application of responsibility, participation, information availability, transparency, custom, and rule of law. It is the art of coordinating administrative actions and decision making between and among different jurisdictional levels-–one of which may be global.

To this definition, Saunier and Meganck add a useful thought formulated in 1995 by the Commission on Global Governance, "Governance is the sum of the many ways individuals and institutions, public and private, manage their common affairs." Importantly, governance implies a <u>process</u> by which societies govern (Lautze et al., 2011).

[7] Batterbury and Fernando 2006, Biermann and Pattberg 2008, Beall 2005, Hyden et al. 2004, Knueppe 2011, Linton and Brooks 2011, Nowlan and Bakker 2010, Ostrom 2005, Rogers and Hall 2003, Ross and Martínez-Santos 2010, Theesfeld 2008, and Turton et al. 2006.

[8] Accountability, allocation, authority, civil society, coherence, conflict, decisions, decisionmaking, duties, formal, influence, informal, institutions, laws, levels, markets, mitigation, models, networks, nonstate actors, objectives, officials, outcomes, politics, polycentric, principles, private sector, regulation, relationships, rights, rules, scale, security, stewardship, sustainability, tradeoffs, users.

4 Groundwater Governance, Policy and Management

4.1 What are the distinctions?

The present essay, one of ten thematic papers in the GEF Groundwater Governance project, addresses the topic of policy. For our purposes, it is essential to distinguish among a number of fundamental, interrelated terms and concepts: governance, management and, of course, policy. A survey of recent literature on these notions—which as noted have gained prominence in the discourse on natural resources and water—reveals what appears at first glance to be a cacophony of terms struggling to converge to a coherent concept

Management: The term 'management' is perhaps easier to grasp intuitively than its more layered and ambitious cousin 'governance.' We tend to think of management as the "nitty-gritty of day-to-day operations" that emphasize the results of decisions (Linton and Brooks, 2011). Other similar notions are: "approaches, models, principles, and information used to make decisions" (Bakker, 2007, cited in Nowlan and Bakker, 2010); "regimes based on institutions, laws, cultural factors, knowledge, and practices" (Solanes and Jouravlev, 2006); or purposeful activities that enable the accomplishment of goals and objectives (de Loe and Kreutzwiser, 2005; Pahl-Wostl, 2007), with a common caveat, "by definition, based on conflicting interests" (Wolf, 2007). All these definitions share a concern for routine, practical, and effective ways to achieve predetermined objectives.

Policy: Oddly, as popular and well-ingrained as the idea of 'policy' has become, working definitions are hard to come by. The current edition of the Merriam-Webster Dictionary (2011) defines policy as "a definite course or method of action . . . to guide and determine present and future conditions." The UN's Food and Agriculture Organization (FAO, 2011) favors an even simpler phrase, "a set of decisions which are oriented towards a long term purpose or to a particular problem." The simplicity and succinctness of FAO's definition captures the centrality of the vital term, "decision." For many, including the present authors, policymaking is synonymous with decisionmaking, and not just by public-sector institutions but by any and all sectors of society, at any level, with a stake in governance.

Once policies have been formulated, putting them in place requires instruments, tools, rules, protocols, and other procedures. These may include laws, sets of rights, registrations, permits, and regulations (especially regulations that allow those regulated to choose among alternative ways of complying); economic incentives and disincentives such as subsidies, taxes, tradable pollution permits, and pricing structures; and civil-society actions such as those that motivate voluntary actions or behavioral changes (Theesfeld, 2008: 6). In this paper we consider policies to encompass all types of decisions used by state and nonstate entities.

4.2 How do these concepts relate to natural resources, water and groundwater?

The three concepts discussed above all allow for interpretation and application to nearly any sector of society or government. The elements of educational governance, agricultural governance, and natural resources governance, for example, are broadly similar and accordingly the definition we have adopted for governance is equally valid for each of those domains. Our operational definitions of management and policy also are easily applicable to multiple processes.

For our purposes, policies aimed at groundwater management are a subset of policies targeting water management more generally, and those in turn are nested within still broader policies for managing natural resources and the environment. Leaving aside the important difference that water and environment are less easily commodified as natural resources, the management of all three require analogous approaches.

Not surprisingly, therefore, distinctive features of water governance and groundwater governance are specific to the resource. Given the particular nature of watercourses, repositories, flows, quality, and distribution, managers and decisionmakers encounter diverse forms of water—from natural bodies such as streams, lakes, ponds, and aquifers, to engineered structures such as canals, barrages, hydropower dams, and treatment plants. Given the fluid, fugitive nature of water and natural fluctuations in the availability of the resource, water resources require active management (FAO, 2011: 4). Current thinking holds that effective governance of such complex systems must involve integrated management. It also should have available infrastructure in the form of well-functioning technical, economic, judicial, social, institutional, and administrative structures (Clifton et al., 2010: ix; Knueppe, 2011: 68). In addition, observers agree that good water and groundwater governance entails responsible resource use, leading to environmental and economic sustainability; sensitivity and adaptation to geography and

environment, customs, cultures, political systems, and prevailing practices and paradigms; strong stakeholder participation and social acceptance; equitable access to water; fair distribution of costs and benefits; and attention to preferences and to winners and losers (Knueppe, 2011: 68; Linton and Brooks, 2011: 607; Nowlan and Bakker, 2010: 7; Solanes and Jouravlev, 2006: 7-8; van der Gun and Lipponen, 2010: 3430). It is noted that often no universally applicable, measurable and normative definitions exist for above-mentioned notions that good groundwater governance is supposed to lead to—e.g., the difficulty of applying the sustainability concept of because of its multi-interpretability and close relationship with concepts like equity and fairness (UNDP, 2011).

The governance of groundwater basins presents a special condition not present in river systems—e.g., relative to rivers, upstream-downstream considerations are often much smaller as the flow component of groundwater systems is often limited. As Elinor Ostrom (2010) stated recently, “I got started doing my dissertation on groundwater in the early 1960s and didn’t know I was studying the tragedy of the commons.” It’s likely that all groundwater policymakers and managers now recognize that the water contained in aquifers and other subterranean basins is a classic common property resource (see also the section on ecological principles).

4.3 Existing modes of groundwater governance, policy and management

Experts who have studied groundwater use around the world tend to agree that too little is known about the institutions and policies that govern the use of these resources (Mukherji and Shah, 2005). Nevertheless, innovative approaches to groundwater management have been developing in many parts of the world over the past decade (Gooijer et al., 2009). These approaches, the most notable of which we review briefly in the present section, feature a variety of instruments to manage groundwater (Theesfeld, 2010; Kemper, 2007).

In the past decades, the classical governmental approach towards groundwater resources management has been based on a plan-and-control and engineering-centered approach. In many countries, groundwater management decisions are made and interventions planned in (partly decentralized) governmental entities such as ministries and departments dealing with water resources, agriculture, mining, rural development and, increasingly, departments on urban development and spatial planning and the environment. Often, strongly connected specialist research institutes like geological surveys participate in this approach by providing the necessary data and expert knowledge to develop policies and inform decisions.

The issues that groundwater resource managers must deal with differ depending on the level of groundwater development in their mandated area (Tuinhof et al., 2002). In recent decades, many countries appear to have followed a similar incremental and changing institutional path from initial development to groundwater management. At first, when there is still a need to increase groundwater use in a region and the potential to do so, their work focuses on identifying usable groundwater volumes and supporting supply side interventions enabling initial access to the groundwater resources. As the level of groundwater abstractions increases, negative consequences may become manifest like falling groundwater tables. To sustain groundwater use in such stressed aquifers, interventions need to be developed that slow down or even reverse aquifer depletion, including the management of groundwater demand and the conjunctive use of surface water. Also, allocation issues then become more prominent due to the rising scarcity. To conserve the productive capacity of aquifers requires constant monitoring of groundwater quantity and quality and includes aquifer protection. Resulting from the notion of the importance of environmental sustainability, some forward-thinking groundwater resources managers have begun to include the management of groundwater-dependent ecosystems as part of their management activities. Aquifer protection policies like those operationalized through the Groundwater Directive of the European Union Water Framework Directive oblige the member states to take measures to avoid aquifers being contaminated by land use activities.

The classic groundwater resource manager’s tool-kit consists of a wide set of assessment and planning, controlling, and behavior-changing instruments, and is based on the existence of various institutions (Tuinhof et al., 2002; Kemper, 2007; Theesfeld, 2011). The tool-kit includes (but is not limited to):

- technical instruments (surveying, groundwater quantity and quality monitoring and modelling, other diagnostic analyses, sustainable aquifer yield estimations)

- managerial and planning instruments (IWRM-plans, land use and spatial planning, environmental impact assessment, groundwater protection zoning, clear definition of responsibilities and roles of various groundwater resources management entities)
- regulatory instruments (groundwater property and usufructory rights, well licensing and registering, drilling accreditation, water legislation, groundwater caps, bans on hazardous human activities with risks of groundwater contamination)
- economic instruments (groundwater pricing, environmental taxes, tradable rights and groundwater markets) and behavior-changing instruments (training, information sharing).

Moench et al. (2003) argue that this classic approach presumes an ability to identify and quantify the nature of interactions and to clearly define the boundaries of systems. It also presumes that for social institutions (like rights systems and regulatory organizations), sufficient organizational capacity is available so that implementation can occur in a planned and integrated manner.

It needs to be noted that this formalized type of groundwater management is a relatively recent institutional phenomenon. Certainly in the United Kingdom, it was not until the Water Resources Board was formed in 1964 that groundwater became an explicit part of national water policy. In the United States, state water laws had a different set of inception points in the 20th century as water scarcity became manifest, as in other post-industrial countries. However, this does not imply that before the 20th century groundwater management was totally non-existent in these or other countries. Nor does it mean that there was a total absence of governmental interference.

Many historical and more recent examples exist where bottom-up approaches towards water management have been working well. Most of these approaches have been in the field of surface water irrigation but groundwater examples exist as well. Some of the historical case studies described in section 7 and the ancient remnants of rather complicated water infrastructure like qanat systems in former Mesopotamia or related to ancient Indian cultures in South America indicate that complicated systems of more formal or informal (ground)water management must have been existent throughout human civilization. Extensive work by the Ostrom school managed to distill various factors that foster or limit such approaches like the level of salience, homogeneity of users groups and the existence of effective conflict resolution mechanisms.

5 Principles that have been applied in Water Governance Models

Since the 1990s, following larger trends in development, the more centralized, state-led development model for water resources has been replaced by a model of "good governance" that emphasizes sustainability, neo-liberal and market approaches, and decentralization (Varady et al., 2008; Batchelor, 2007; Moriarty et al., 2004; Cook and Sachs, 1999; Conca, 2006). This shift in governance has been referred to a "scalar reconfiguration of state power in favor of regionalization and localization" (Harriss et al., 2004: 2). Today, environmental governance increasingly features multi-partnerships representing more hybrid forms of governance across governments, markets, and communities (Agrawal and Lemos, 2007; Andonova et al., 2009), characterized by new mechanisms, institutions, and types of actors (Auer, 2000; Biermann and Pattberg, 2008). In water governance this approach is reflected by more innovative mixes of local, regional, national and supranational bodies that incorporate both the public and private sectors as part of management regimes (Feitelson, 2000). Some argue that these diverse trends have resulted in a "more fuzzy, Mobius web-like system" that may be more flexible and adaptive but is also less subject to control and less predictable (Gupta, 2011:8). In the process, certain conceptions of what good groundwater governance entails have emerged in both the disciplinary literature and in practice, as we outline below.

5.1 Political and institutional principles

Groundwater governance often includes community involvement, which enables some degree of self-governance along with more formal, instrumental approaches that emphasize laws, regulations, and pricing schemes requiring more government involvement (Schlager, 2007; Giordano and Villholth, 2007: 3). The institutions, or "rules of the game" (North, 1990) within which stakeholders act define the instruments, processes, and organizational context of governance (Kemper, 2007).

However, diverse political and institutional obstacles constrain sustainable water management including "sector fragmentation, poverty, corruption, stagnated budgets, declining levels of development assistance and investment in the water sector, inadequate institutions and limited stakeholder participation" (UNESCO, 2006). The OECD has also pointed out major water governance "gaps" due to limited capacity at the local level, unclear allocation of roles and responsibilities, paucity of transparency, lack of strategic planning, weak economic regulation, and poorly-drafted legislation (OECD, 2011). Overall, good governance of transboundary aquifers can be pursued by establishing the appropriate scales of interest-articulation and decisionmaking, and involving an assortment of nonstate actors as well as formal state agencies (Linton and Brooks, 2011).

Accountability and representation are the cornerstones of good governance; accountability entails legislative, legal, and social responsibilities, as well as remedies. Critical features are the primacy of the rule of law, maintained through an impartial and effective legal system with the ability to implement legal accountability; a high degree of transparency and accountability in public and corporate processes; and a participatory approach to service delivery to assure effective public services. Good water governance also relies upon a viable, strong and well-informed, pluralistic civil society. Institutional pluralism involves the development of a partnership between civil society and government based on dialogue, consultation and collaboration and promoting dialogue, consultation and networking within civil society. In addition, good governance entails sets of rules that enable the institution to perform its role efficiently and effectively.

Some call attention to additional institutional aspects of groundwater management, such as the need for consistent policies, legislation and legal frameworks, strategic management planning, and resource administration capacity (Foster and Loucks, 2006; Pandey et al., 2011; Puri et al., 2001). Increasingly, the institutional and political aspects of governance also include active public participation and stakeholder involvement to help ensure greater accountability (Kemper, 2007:167; Foster and Loucks, 2006; Engle and Lemos, 2010; Pandey et al., 2011; Gleeson et al., 2011; Taylor et al., 2010; Eckstein and Eckstein, 2005; Nowlan and Bakker, 2010). Participation of the stakeholders demands good, symmetric, transparent and reliable information to facilitate cooperation (Llamas, 2004; Llamas and Martínez-Cortina, 2009; Giordano and Villholth 2007; Megdal and Scott, 2011; Puri et al., 2001: 21; Mukherji and Shah, 2005). Learning, sharing, and co-producing knowledge is a key aspect of governance (Engle and Lemos, 2010; Gerlak, 2007; Megdal and Scott, 2011; Cash et al., 2006; Pandey et al., 2011; Hoff, 2009; Ostrom, 2011; Wilder et al., 2010; Pahl-Wostl, 2009). So too are monitoring (Foster and Loucks, 2006; Pandey et al., 2011; Taylor et al., 2010; Ostrom, 1990, 2002) and conflict resolution mechanisms (Ostrom, 1990, 2002; Theesfeld, 2008, 2010; Wolf, 2007; Pena and Solanes, 2003) deemed important institutional elements or groundwater governance.

Good governance also calls for a close match between the scale of ecological processes and the institutions that govern groundwater resources (Cumming et al., 2006). Problems of biophysical fit can result in non-compliance with groundwater governance (Cohen and Bakker, 2010). Given the broader trends in environmental and water governance toward multi-partnerships and hybrid approaches, it is also important to build capacity across the multiple and diverse governance scales (Kerr, 2007). In addition, interplay between both formal and informal institutions, and across and within scales is seen as important institutional and political elements of governance (Lebel et al., 2005; Young, 2002). In particular, the degree of centralization or decentralization of governance will shape on-the-ground outcomes (or groundwater governance outcomes).

Increasingly, resiliency research has emphasized the need for institutional capacity to adapt to uncertainty and change in order to be resilient within a social-ecological system (Folke et al., 2005; Gallopin, 2006; Young, 2009; Dietz et al., 2003). For water governance, this might mean flexible governance mechanisms that can help stakeholders to anticipate and adapt to various uncertainties and changing circumstances (Drieschova et al., 2008; Drieschova et al., 2011; Drieschova and Fischhendler 2010; Wolf, 2007; Batchelor, 2007; Pahl-Wostl, 2007; Pahl-Wostl et al., 2008; Huntjens et al., 2010). In the realm of groundwater governance, institutional adaptation and flexibility have been gaining greater attention (Knueppe, 2011; Clifton et al., 2010; Ross and Martínez-Santos, 2010). More adaptive approaches also are likely to better integrate community and instrumental groundwater governance approaches (Giordano and Villhoth, 2007: 3).

5.2 Sociocultural considerations including historical evolution

The concept and existence of water have affected sociocultural beliefs, norms, and values throughout history. Many of the world's religions hold a special place for water, viewing it as a source of spiritual purification. Hinduism, one of the oldest continuously-practiced religions, assigns a powerful cleansing power to water. Hindus believe that all water is sacred, with rivers, namely most notably the Ganges, having special significance. In Buddhism, another venerable religion, water is used in funerals and offered to attending monks and the corpse. The Judeo-Christian tradition also features water prominently. The Torah, the guiding text Judaism, prescribes ritual washing to maintain a state of ritual purity. Similarly, Christians are dipped in water three times during a baptism ceremony to signify their connection to Christ. And the Sharia of Islamic law includes provisions on water management that require social sharing of water's benefits and burdens (Tvedt and Oestigaard, 2009).

An understanding of groundwater systems—though limited, especially in eras with much less means to assess and study groundwater systems—also shaped mythical perceptions on groundwater. The use of phrases considering groundwater (and freshwater in general) as being gifts of God or of Mother Nature are verbal examples of such perceptions. For a long time even up to the present, many people assume that groundwater is held in underground seas and/or rivers. Until the 17th century, the prevailing belief was that groundwater would move in a direction opposite to what we know now, thus from the bottom of the sea to the mountains through mysterious underground channels, from where springs would emerge (Margat, 2008).

As a necessity, water relates to daily life in many ways beyond the religious and spiritual. As the world population has grown, more attention has been given to the water sources essential for human life. In 2010 two respected publications widely read by general audiences—*National Geographic* and *The Economist*—published special issues on water to bring attention to the challenges associated with meeting increasing worldwide demands for water (*National Geographic*, 2010; *The Economist*, 2010). Groundwater was not overlooked. That large, developing-world cities, such as Dhaka, Beijing, Tripoli, and Katmandu, rely exclusively on groundwater was noted, as was the significant decline in groundwater tables in many parts of the world. Concerns about lack of access to clean water and sanitation and the changes in diets associated with rising income levels, along with associated differences in embedded water, were discussed.

As water demands increase relative to supplies, leading to increased reliance on groundwater, there will be a greater focus on groundwater governance. The explicit integration of sociocultural principles into groundwater governance can result in the development and implementation of effective policies. These policies can yield a set of practices for 'responsible groundwater use' including equity, sustainability, and efficiency considerations.

Scholars of water-resources management argue that a major paradigm shift in management is underway, from a historically strong emphasis on engineering and technical solutions to a focus on integrated management that also highlights the importance of culture and social learning (Pahl-Wostl et al., 2008a). The Global Water Partnership (2000) emphasizes that effective governance based on principles of equity, efficiency, and diverse knowledge integration is as important for dealing with

water resource management problems as technical solutions. Recent literature and evidence-based analysis on water governance also shows that technical, institutional, and financial solutions to the so-called “water crisis” often may be known. The implementation and adaptation of these solutions on the ground to develop place-based policy responses remains challenging (OECD, 2011). Groundwater governance is intimately linked to the development and implementation of norms and principles that promote change in the behavior of actors across each scale at which groundwater is managed (Pahl-Wostl et al. 2008b). Contemporary focus on finding transitional governance approaches to help society move from current unsustainable governance paradigms to future governance paradigms that are more sustainable, hinge on the strong interdependencies and synergies between formal and informal institutions that are embedded in their cultures (Pahl-Wostl et al., 2008a; Pahl-Wostl et al., 2008b). Institutions—the formal and informal rules that provide the framework for the behavior of human beings—include codified laws and regulations as well as the socially-shared rules and norms that develop through social interaction and shared learning (Pahl-Wostl et al., 2007).

Sociocultural principles are deeply lodged within governance—even if until recently they have remained largely ignored in the dominant management literature—as ‘good’ governance relates to a regulatory system that shows qualities of accountability, transparency, legitimacy, public participation, justice, efficiency, the rule of law, and an absence of corruption (Pahl-Wostl et al., 2008b). Hassan (2004) introduces the notion of an ‘integrative ethic of water management’ that supports the cooperation of different users, policymakers, financial agencies, and professionals to exchange information and to achieve trust while promoting accountability and transparency. The need for difficult choices to be made regarding rates of water consumption, wasteful practices, and recycling stresses the importance of considering the role of culture in groundwater management.

The role of culture in governance has recently risen to an important focus of study. This follows the recognition that culture is critical to understanding barriers to changing practices and the adoption of technologies and new management strategies, and to successfully exchanging experiences between developed and developing countries (Pahl-Wostl et al., 2008a). The concept of social learning—a learning process that requires collective action and conflict resolution, and which requires people to learn about their interdependences and differences and to deal with them constructively—is emerging as key to effective water management. The integration of social learning into governance implies a major shift to a style of governance based on collaboration, adaptation, and ongoing learning in a complex and always changing world (Folke et al. 2005; Pahl-Wostl et al., 2007; Pahl-Wostl et al., 2008a; Wilder et al. 2010).

A very important aspect of governance is the idea of social inclusion. As water is absolutely essential for human survival, deliberate exclusion of people from access to it is universally considered as inhuman and *in extremis*, even a crime. Social inclusion in governance also means that policies are developed such that they include evaluation of interests of all groups within a society and that all groups are treated with a same level of fairness. A special case of social inclusion is gender mainstreaming, which has been propagated since the conceptualization of IWRM and which has improved the access and control of women over water resources in many areas. Another dimension of social inclusion is to target marginalized groups like people below a certain poverty level. Lifeline drinking-water tariffs (often even free of any charge) and preferred allocation of scarce groundwater resources to the vulnerable during emergency situations are examples of such policy targeting.

Historically, public policy on water has tended to focus primarily on only one level: local, basin-scale, national, or global. In recent years, however, water has been subject to the globalization phenomenon that has characterized politics and economics (Varady et al. 2008; 2009). Going even further, recognition is growing of multi-scale, polycentric governance models that appreciate that a large number of stakeholders in different institutional settings contribute to the overall management of a resource (Pahl-Wostl et al., 2007). Thus multi-level governance based on partnerships across scales represents a more hybrid form of governance that integrates government agencies and diverse stakeholders (Pahl-Wostl et al., 2008b). The OECD defines multi-level governance as the explicit or implicit sharing of policy-making authority, responsibility, development and implementation at different administrative and territorial levels. Evidence from the implementation of the OECD Multi-level Governance Framework “Mind the Gap – Bridge the Gap” in 17 OECD countries and 13 Latin American Countries suggests that all face common coordination and capacity gaps when designing and implementing water policy, regardless of their institutional setting (unitary, federal) and water challenges (scarcity or not). Regarding issues related to groundwater governance, these gaps are of several types, including administrative, information, policy, capacity, funding, objectives, and accountability gaps (OECD, 2011).

The need for collaboration is crucial at this point in time because interdependence between government bodies and stakeholders is increasing as government budgets decrease and the efficacy of traditional command-and-control management is reduced. Furthermore, Pahl-Wostl et al. (2007) contend that the combination of top-down and bottom-up formation of institutional arrangement may in fact lead to greater acceptance across the wide range of stakeholders involved in the governance process. Recognizing the need for adaptive co-management of complex social-ecological systems, such as groundwater, Folke et al. (2005) emphasize integrating dynamic social learning opportunities within a cooperative management framework; they also stress the importance of networks, leadership, diversity, and trust for accumulating experiences and collective memory that can be used to effectively cope with surprise and disturbance, such as drought.

Challenges remain in terms of effectively integrating sociocultural principles, including equity, culture, social learning, and cooperation into existing groundwater governance regimes. In considering any arrangements that impact the interests of individuals and communities in regard to their use of water resources, The Food and Agriculture Organization of the United Nations (FAO, 2011) identifies three core principles that should be considered: security, sustainability, and equity. However, balancing the three principles is a key challenge for policy- and decisionmakers as concerns for security tend to outweigh considerations of sustainability and equity. Water resources play a crucial role in terms of basic needs and livelihoods and thus gender and social equity factors must be taken into account in policymaking. Thus, hard decisions about water resource allocation (and increasingly more frequently, re-allocation) under conditions of water scarcity must be perceived as fair by all stakeholders and water users involved (FAO, 2011).

Institutional and cultural arrangements further complicate water management decisions as holders of water rights under informal, customary arrangements may reject becoming involved in formal water tenure arrangements. In the 1980s, for example, Douglas Merrey and his associates were recognizing the critical role of *izzat* (Islamic honor) in decisionmaking for irrigation systems in Pakistan and northern India (Merrey and Wolf, 1986). And a recent case study from Bukhara, Uzbekistan, highlights how water governance is affected by sociocultural considerations, such as underlying traditions and ethics of water use. In Bukhara, the historic role of water magistrates illustrates how sharing water has been organized, both institutionally and ethically, in many regions. Although an oasis in a water-short region, Bukhara became a brilliant metropolis because of an elaborate irrigation system used by the population for daily social exchanges. Bukhara is a good example of the importance of social organization in water management, in this case via irrigation (Fried, 2008).

5.3 Economic principles

Economics is concerned about the allocation of scarce resources. Microeconomic principles tell us that the price of a good or commodity should relate to supply and demand. The supply or availability of a good for consumption will depend on the costs of production. The demand will depend on the willingness and ability to pay for the good. In an ideal or typical setting, the price signals associated with markets will equilibrate supply and demand and result in an efficient allocation of resources, whereby goods are distributed to their highest valued uses.

Water, however, is not a typical economic good (Ostrom, 2002). From a societal perspective, it is necessary for life. All require some access to water for basic existence, yet ability to pay for water depends on the purchaser's income or financial resources. Physical access to groundwater requires the ability to extract the resource, but, absent restrictions, one person's access does not prevent another from tapping into the same aquifer. Rather than seeing water exchanged through a typical market mechanism, wherein multiple buyers and sellers act as economic agents, water is often distributed to customers in a community by a monopoly provider. It may be distributed to agricultural users through a cooperative irrigation association. Alternatively, groundwater users may own and operate their own extraction wells. For many, groundwater may not be the only source of water and its use may or may not be subject to regulation.

Pricing or price signals can assist in the allocation of all types of water, not only groundwater. However, where markets are nonexistent or imperfect, pricing may not accurately reflect the costs and benefits of supplying and consuming the good. Measuring the economic benefits or value of groundwater is important to sustainable management of its quality and quantity but is difficult to accomplish (EPA 1995, GWMATE Briefing Note Series Note 7 2004; Gorlach and Interwies, 2003). Understanding all the costs associated with water provision is likewise important but challenging (Mukherji and Shah, 2005). Significantly, around the world water prices rarely reflect full the costs of water provision, and do not typically assign any cost of the water molecules themselves (Megdal, 2005).

As water demand has increased relative to supply and water sources have become polluted, recognizing the scarcity of this essential resource is important. Measuring fully the economic implications of groundwater provision is difficult due to the absence of key data (Koundouri, 2004a, 2004b). The quantity of groundwater in storage, which depends on groundwater recharge as well as extraction rates, often is not known. The water quality impacts of contaminant intrusion are difficult to measure. Groundwater use itself often is not measured, making it impossible to connect economic payment with utilization. Where water is priced, water prices incorporate the known and measurable costs of water provision, such as construction, operation, maintenance and administration of the water extraction and distribution system. Yet, these costs may not fully reflect the costs of water extraction, such as instances where electricity rates are subsidized for certain users (Mukherji and Shah, 2005). Water prices rarely include consideration of the third party and environmental impacts of groundwater use (Foster, 2006). For example, water extracted by one user can result in higher pumping costs to the nearby well owner. Those pumping groundwater rarely have to pay the costs of environmental degradation due to declining water levels. And while water pricing should assist in allocating water to highest valued uses, the ability to pay is, of course, a critical consideration. Water that is needed for essential functions, such as cooking and cleaning, should be affordable. Indeed, in places where water is metered and priced, regulatory policies often take into account such considerations.

Water in cities and towns is often sold by monopoly providers, resulting in the customer having only one supplier available. Without regulatory oversight, the monopoly provider could take advantage of its single-seller position and charge high prices for water. Hence, there is the need for some process for overseeing and setting water rates, whether the water provider ownership is public or private (Megdal, 2012). The actual and potential roles for the private sector in water provisions are multi-faceted and a topic of debate (Morrison and Gleick, 2004). As access to capital becomes more important to provision of clean, reliable water services, the role of the private sector and public-private partnerships is likely to grow.

As the competition for water increases, many are interested in facilitating more trading opportunities for water. Market-type mechanisms are seen as having the potential to match demand with available supplies. (For a sampling of analyses, see Garrido, 2011; Thompson et al., 2009; Plagmann and Raffensperger, 2007; Raffensperger et al., forthcoming; Zhang et al., 2007/2008; Zetland, 2011). Water transactions depend on the seller of the water possessing the right to in fact engage in the transaction (Hildering, 2004, legal paper that is part of this effort).

Economic considerations are fundamental to other policy options, such as groundwater extraction levies and conservation programs. Although difficulties abound, more attention to identification and measurement of economic factors influencing supply and demand, as well as the economic analysis of alternative policies, will be important to effective groundwater governance (GWG Thematic Paper 9, “Macro-economic trends that influence demand for groundwater and related aquifer services” 2012).

5.4 Ecological principles

Physical characteristics of groundwater systems partly determine consequences of human use. This necessitates the application of ecological principles in order to manage groundwater resources sustainably.

In many parts of the world, groundwater resources are ubiquitously available in large volumes of good quality. Developing access to these resources is in such places rather simple and cheap, and often does not entail large governmental coordination or support. Mukherji and Shah (2005) mention that these intrinsic hydrological advantages of groundwater give rise to several scale-neutral socio-economic benefits, making it a favored grass-roots level source. That groundwater sources tend to be more reliable and predictable than surface water sources often yields significantly higher economic returns per cubic meter of water used for irrigation. This adds to the preference for using groundwater (van der Gun and Lipponen, 2010). As a consequence, in many parts of the world (especially rural areas) groundwater use consists of the accumulation of numerous local groundwater development decisions by individuals, each with distinctive needs and preferences.

In addition, aquifers are conducive and diffusive systems. The first characteristic results in the physical consequence that effects of interventions in the aquifer may propagate through it (even crossing administrative or any other human perceived boundary) while the second characteristic dampens this effect with time and distance to the location of the intervention. Additionally most aquifers are not isolated physical systems but an integral part of hydrological cycle process and indivisibly connected to other water (and land) systems. Groundwater systems are replenished from infiltrating precipitation, infiltrating rivers and lakes and

irrigation return flow. On the other hand groundwater discharges in these surface water bodies and in the sea and transpires through groundwater table dependent vegetation. Hence, effects of interventions in groundwater systems not only propagate through aquifers, but into the linked systems as well and vice versa (Acreman, 2004; Custodio, 2002). A result is that humans, by interfering with these systems (e.g. by groundwater pumping), may affect other locations. In turn, this can disrupt others users' ability to employ the groundwater system, thus causing so-called externalities. This insight has led to more holistic management and recognition that the scale of management should fit the scale of the physical systems. The insight also prompted the cause-no-significant-harm principle (sic utero tuo ut alienum non laedas), i.e., "use your own groundwater resources without harming that of another."

In some cases, groundwater is a renewable resource. As the aquifer is connected to surface water systems and to the land surface, it has the ability to be replenished with passage of time. This renewability is depending on the level of connectedness with these systems and with the availability of water in these systems such as filled rivers and excess precipitation (Foster and Loucks, 2006). Groundwater resources in aquifers without this connectedness and replenishment, or in aquifers where the rate of abstraction exceeds the rate of replenishment, are assumed to be non-renewable and get mined. Mining of such natural resources appears to violate the narrow physical definition of sustainability, which is usually interpreted by hydrogeologists and groundwater resources managers as the ability to continue pumping without aquifer exhaustion. Such practices may, however, be justifiable from a broader definition of sustainability that reconciles the use of the non-renewable resource with "sustainability of human life" (van der Gun and Lipponen, 2010). In this case, so-called non-sustainable groundwater use may be necessary to sustain livelihood options or even immediate human survival when no other water source is present.

A salient question is how to save groundwater resources for future generations. Groundwater mining requires a successful exit strategy, implying that by the time the groundwater resource is substantially depleted, society will have used it to advance economically, socially, and technically so as to enable future generations to develop substitute water sources at an affordable cost. Additionally, it is important to know how to deal with the environmental sustainability of ecosystems that are groundwater-dependent. The bottom line is that sustainability has many dimensions and interpretations and that decisionmaking to achieve sustainability often includes tradeoffs between these different notions. As the level of connectedness and hence renewability is often strongly dependent on aquifer depth, different types of governance including sustainability considerations are suggested for different depths of the aquifer (Lopez-Gunn and Jarvis, 2009).

As groundwater systems are often linked to and nested within other physical systems with various feedback mechanisms at different scales since aquifers often contain high level of heterogeneity and anisotropy, its system behavior is only predictable to a limited extent. Furthermore because of its subsurface nature and the inherent difficulty of monitoring groundwater systems are characterized by inadequate information or so-called epistemic uncertainty (Millman and Ray, 2011). Often even the boundaries of the systems remain fuzzy (Theesfeld, 2010). Because of the vastness of the systems, negative consequences of aquifer overexploitation and contamination appear after a certain time lag (Theesfeld, 2010). The impact of excessive withdrawals, for example, can initially be largely invisible (Linton and Brooks, 2011). The open access nature of the vast groundwater systems, allows groundwater use to be distributed and to consist of large numbers of independent of sometimes even unknown groundwater users (Linton and Brooks, 2011).

With climate and global change, groundwater balances in many areas will change bringing in another level of uncertainty (Green et al., 2011). Hence groundwater systems could be defined as complex adaptive systems characterized by self-organization, adaptation, heterogeneity across scales and distributed control (Pahl-Wostl, 2007). As relevant data on the status of the aquifer are commonly limited, as many abstractors are involved and as impacts are not easily detected and commonly emerge with a delay, there are substantial uncertainties and risks that have to be taken into account in managing non-renewable groundwater resources (van der Gun and Lipponen, 2010). These characteristics require the application of risk-based and adaptive approaches to be able with constant changing conditions and unexpected consequences.

While aquifers are much less vulnerable to anthropogenic pollution than surface water bodies, when aquifers become polluted, contamination is persistent and difficult to remediate as a result of their large storage, long residence times and physical inaccessibility (Foster, 2006). Some aquifers hold a natural attenuation capacity and are able to partially degrade contamination substance. However some of the derivatives of such processes may be equally toxic and/or mobile as the original pesticide compounds themselves (Foster and Chilton, 2003). This irreversible characteristic of aquifer systems plus the limited ability to

predict its system behavior justify the use of the precautionary principle which generally implies that there is a social responsibility to protect the public from exposure to harm, when scientific investigation has found a plausible risk. Only after further research findings proof that no harm will occur, protective measures can be relaxed.

Because of the vastness of the characteristics of groundwater systems it is costly and (but not impossible) to monitor groundwater abstraction (and even more difficult groundwater pollution) and to exclude potentially new groundwater appropriators or polluters. Combined with the above-mentioned physical characteristics of diffusivity, conduciveness, slow attenuation rates and sometimes limited renewability, additional groundwater development and land use may rival existing uses. These combined features put groundwater system in the category of common property resources which makes them vulnerable to over-exploitation and/or under-management (Ostrom, 1995).

Generally, humans put a high value on groundwater resources as they get abstracted and consumed or used as a production factor in agriculture or industrial activities. The aquifer is hence traditionally values because of its provisionary service. However, the systems-based approach in research led to the understanding that groundwater often plays an important role to sustain marine, aquatic and terrestrial ecosystems on which humans depend (Bergkamp & Mackay, 2007). Hence increasingly, the notion of the importance to reserve some groundwater for nature plays part in groundwater management decisions. This eco-system approach broadens the notion of sustainability. Van der Gun and Lipponen (2011) argue that the key question then is not whether the development of a particular groundwater system is sustainable, but rather whether the complex of natural resources (to which that groundwater system belongs) allows and supports sustainable socio-economic development and preservation of desired environmental conditions in the region.

5.5 Approaches by institutions to apply principles

United Nations Development Program (UNDP: In 1997, UNDP adopted good governance principles that emphasize participation, rule of law, transparency, responsiveness, consensus orientation, equity, effectiveness and efficiency, accountability, and strategic vision (UNDP, 1997). For the UNDP, governance can no longer be a closed system and includes the state, but transcends it by taking in the private sector and civil society. The state creates a conducive political and legal environment. The private sector generates jobs and income. And civil society facilitates political and social interaction - mobilizing groups to participate in economic, social and political activities. The state’s task is to find a balance between taking advantage of globalization and providing a secure and stable social and economic domestic environment.

Importantly, these principles reflect broader principles discussed above and reflect an evolution in the nature of the approaches adopted as well as the scope of actors involved in water governance. Following on UNDP principles, a number of other organizations in the past decade have adopted similar good governance approaches, including the Global Water Partnership (GWP) (Rogers and Hall, 2003) and UNESCO (2009).

IWRM: Advanced by the Global Water Partnership (GWP), integrated water resource management (IWRM) is an important element of water governance that has emerged in the past two decades. IWRM is a process that promotes coordinated development of water, land and related resources to best maximize social and economic welfare without compromising the sustainability of vital ecosystems (GWP, 2000). It is seen as an alternative to top-down, sector-by-sector management and serves to promote many of the governance principles outlined above. IWRM calls for physical, sectoral, and organizational integration (Kidd and Shaw, 2007), which may result in new institutional arrangements to provide formal coordination in decisionmaking for water allocation and management (Bressers and Kuks, 2004). Central to the implementation of any institutional development is the presence of sufficient human and institutional capacity (Jaspers, 2003). There are four important principles of IWRM:

1) Water as a finite and vulnerable resource: In the context of groundwater, this calls attention to the vulnerability and limits to the resource (Foster and Skinner, 1995; Foster et al., 2005, Vrba and Zaporozec (eds), 1994).

2) Participatory approach: Stakeholder involvement in planning and management decisions is an essential element to IWRM (GWP, 2004). Bringing in more diverse stakeholders make help to make water management decisionmaking more equitable (UNEP, 2006; GWP, 2007). It may also help to support adaptation and learning, and help management systems respond better to uncertainties and change (Folke et al., 2005; Pahl-Wostl, 2007).

3) The important role of women: This includes the involvement of women as an ethical value (Aureli and Brelet, 2004) and calls attention to gender awareness and rural women as water users (Asmaal, 2004).

4) Water as an economic good: This is in line with the Dublin Principles (1992) and represents greater attention to economic efficiency in water governance. For groundwater, the economic value of water is seen as important in making allocation decisions between competing and different water sectors, and helping to guide decisionmakers in the prioritization of investment (Taylor et al. 2010: 60).

Millennium Ecosystem Assessment: On June 5th, 2001, Kofi Annan, Secretary General of the United Nations, launched the Millennium Ecosystem Assessment (MA), an international initiative to respond to the ailing environmental conditions of the globe (Tawfik, 2009). The main goal is to draw public decisionmakers' attention to the necessity to protect the environment in order to maintain economic activity as well as human well-being**.** It is designed to meet the needs of decisionmakers and the public for scientific information concerning the consequences of changes on human well-being and options for responding to those changes. The MA is a multi-scale assessment consisting of interlinked assessments undertaken at local, national, regional and international levels.

The MA introduced a new framework for analyzing social-ecological systems that has had wide influence in policy and scientific communities. The MA used a new conceptual framework for documenting, analyzing, and understanding the effects of environmental change on ecosystems and human well-being. It viewed ecosystems through the lens of the services that they provide to society, how these services in turn benefit humanity, and how human actions alter ecosystems and the services they provide (Daily and Matson, 2008). The MA utilizes a broad definition of 'ecosystem services' (MA, 2005):

- Provisioning services like food, *freshwater* and fiber
- Regulating services like climate and flood regulation
- Supporting services like soil formation and nutrient cycling
- Cultural services like spirituality, aesthetics, education and recreation

Freshwater is fundamental to life and contributes to all the major benefits provided to people, both directly and indirectly, from ecosystems. Freshwater ecosystems include groundwater systems along with permanent and seasonal surface and geothermal sources.

PART 2: DIAGNOSIS

6 Assessment of Governance, Policy and Management Practices – What have we found?

Part 2 provides a descriptive diagnosis of groundwater governance based on what has been published in academic literature. At this stage no normative framework was used to perform the diagnosis. Instead, a more narrative discourse on groundwater governance is assumed to be a more appropriate tool to reach the objectives of this project.

Moreover, this diagnosis is based solely on papers and scientific work that directly address the issue of groundwater governance. This topic is truly innovative and, as such, few papers have yet been produced on it. Therefore, this diagnosis covers a wide array of papers and studies on the diverse subjects of groundwater, surface water, and more general natural resource management, as well as papers applying theoretical approaches to the subject of natural resources governance and policymaking.

The case studies described below demonstrate a great diversity of settings and governance issues. Case studies are drawn from developed and transitional countries, with different climates and stages of socio-economic development, and exhibiting variation in the level of groundwater dependency. The case studies were chosen to present a wide and varied look at diverse governance issues such as participation, the subsidiarity principle, use of diagnostic tools, data and information, the role of global or bridging organizations, the role of scale, market mechanisms, and many others. The well-studied case of the Arizona aquifer is described in somewhat greater detail than the others and is also included as an example of an aquifer's ecosystem services.

We highlight some illustrative case studies to better describe the scope of groundwater governance around the world today. Based on our review of the broader case study literature, we outline a set of barriers and opportunities in Section 6. We conclude with an overview of the evolution of successful and unsuccessful paradigms, models, instruments, methodologies with respect to groundwater governance in Section 7.

7 Lessons learned from Illustrative Case Studies

7.1 Domestic and transboundary case studies

Some studies of groundwater management in South Asia call attention to self-regulation as a governance model (Shah, 2000; van Steenbergen and Shah, 2003, 12 in Llamas and Custodio). For example, in Saurashstra in the State of Gujarat, India when government efforts failed to adequately address the over-exploitation of groundwater and subsequent declines and coastal groundwater salinisation, some local community members began to harvest excess rainwater during the monsoon for aquifer recharge. Based on informal rules, and inspired by a local spiritual Hindu leader, the grassroots movement grew fast. The early adopters acted as change nucleus, inspiring neighbouring farmers in nearby villages, and operating as an open and inclusive network. Although the initial focus was on increasing water supply, some demand side practices were adopted as well. The social cohesion in the villages and in the religion helped to ensure greater compliance. The movement received public recognition from the Government of Gujarat (GoG) resulting in a pluralistic co-existence of formal governmental groundwater legislation and informal movement norms and rules. Technical backstopping from the GoG and locally working NGOs also served to improve effectiveness. Financial support from merchants of a nearby diamond industry originating from these rural areas gave another boost. This case can be seen as a public-private partnership 'avant la lettre' with cooperation between governmental departments, citizens, communities, religious-based community based organizations, NGOs and the private sector.

Groundwater management strategies in India can be contrasted with those in China (Mukherji and Shah, 2005). Since the 1950s, both countries, facing high population density and embracing food self-sufficiency and an agriculture-based economy, have relied on groundwater irrigation for their immense agricultural productions (Siebert et al., 2010). This has led to overexploitation with consequent groundwater table declines in large parts of their territories. In some instances groundwater markets have emerged to allocate groundwater to those without functioning wells. Generally, despite the existence of IWRM plans and groundwater legislation in India today, there is poor governmental implementation and enforcement. A recent World Bank study (Garduño et al, 2011) concludes that the weakest element in the Indian groundwater governance chain is the institutional capacity at central and state levels. The study adds urban groundwater and groundwater contamination as urgent issues. In contrast, China's groundwater management has been much more centralized and successful in implementation and enforcement. Each Chinese village features a governmental agent paid from villager's taxes with the responsibility to plan and manage its irrigation. Such officials provide guidance for price setting mechanisms in groundwater markets. Differences between the Indian and the Chinese experience suggest the roles that both the macro-development path (Shah, 2007) as well as the overarching political regime play in the shape and scope of the groundwater governance. It also shows challenges associated with IWRM in areas of the world where the rate of institutional capacity adaptation lags behind social change.

Further west in Spain, we can come to understand how past practices and policies influence and constrain present groundwater governance (Llamas, 2007).Traditionally, with a strong governmental bias towards surface water infrastructure, Spain has one of the highest number of surface reservoirs per capita and large volume of interbasin river water transfers. This is in large part due to past failures associated with groundwater dependence for public water supplies (i.e., 19th century groundwater-fed khanat system failure to provide water to Madrid). As a result, groundwater has been part of a stereotyping hydromyth assuming that groundwater use always lead to the depletion of the source making it an unreliable. Groundwater came to be used largely in rural areas where farmers were not served by surface water systems. Considered to be private property attached to land endowments, the landowner could pump as much unless a third person was affected. However, intensive groundwater use (partly promoted by the government in the '50 and '60s) led to

hazardous situation. The Spanish Water Code of 1985 turned groundwater resources under the public domain. For the already existing groundwater users usufructory rights were automatically granted based on the rate they had historically be using but under the condition of getting registered. Every new groundwater abstraction would require a permit by the corresponding water authority. Yet, many Spanish groundwater abstractions go unregistered today. In part this is because the government lacks the capacity and resources to carry out the enforcement. But it is also because of the historic notion of groundwater as private property, which hinders registration and licensure. The 2001 National Water Plan appears to challenge the old paradigm of surface water infrastructure development. For the first time, it has provision that strongly supports the management of groundwater resources. It states that no Ebro River water can be transferred to any overexploited aquifer before intensive groundwater research has been carried out and alternatives thoroughly evaluated. Furthermore, it fosters the formation of groundwater user communities and the educating the general public on groundwater.

A case of climate change adaptation and groundwater governance in East Anglia in the UK reflects implementation of IWRM principles and connections to the larger regional European Union Water Framework Directive. As one of England's most productive agricultural areas, farmers and food processing industries depend on groundwater irrigation and groundwater for drinking water supply. Groundwater resources are managed by the Environmental Agency (EA, an executive non-departmental Public Body responsible to the English Secretary of State for Environment, Food and Rural Affairs) through a first-come first-served licensing process (most recently with a 12-year validity) and with a drought allocation prioritization of drinking water first, then environment and irrigation. Although it is difficult to comprehend why the EA would initiate climate change adaptation processes when most picture an often green (and wet) England, the stark reality is that currently the available groundwater is completely allocated, mostly to the politically powerful groundwater-dependent farming/food processing sector. Future droughts and groundwater loss would mean huge economic losses for the region. As a result, the EA initiated Water Abstractor Organisations providing local groundwater stakeholders participation in policy and policymaking. In a participatory fashion, the following adaptive measures were developed: reduction of licenses' time-limit to 6 years, changes in land practices to reduce groundwater contamination, more efficient irrigation techniques and on-farm winter water harvesting. This case demonstrates how an IWRM-based approach increasingly took environmental needs into account and how the regulatory authority used public participation as an instrument to further improve its IWRM-capacity.

In Africa, the countries which share the North Western Saharan Aquifer System (NWSAS), recently agreed to begin an incremental process toward joint management under the supervision of the Observatoire du Sahara et du Sahel (OSS). Shared by Algeria, Tunisia and Libya, exploitation of the aquifer has occurred faster than it gets replenished in this arid area. Hence this aquifer system is non-renewable and with the current abstraction rates the groundwater resources are mined. This has meant negative consequences for these countries internally and represents potential risk of conflict across states. The first step has been a joint technical fact finding study with sharing of the countries' data in a central database maintained by OSS. With technical backstopping of OSS, a numerical groundwater flow model was built and the effects of agreed future use scenarios were calculated. While this was mainly a technical exercise, OSS and the UNESCO-IHP and IAH Internationally Shared Aquifers Resources Management Program continued to raise awareness on the necessity to manage these resources at policymaking and political level and it was agreed to start a consultation and dialogue mechanisms to keep each other informed. This case suggests the importance of an incremental approach towards more cooperation and the use of a neutral bridging organization (OSS) in the case of a transboundary aquifer. It also reveals the role of agreed data and models to base further dialogue on factual information and using ISARM as a Community of Practice to share their learning with and learn from other similar areas in the world.

Groundwater management in South Africa illustrates the role of legal and institutional change and decentralization in governance (Knüppe, 2011). Since its democratization in 1994, South Africa has undergone fast socio-political changes, including reform of its water law. The National Water Act (NWA) of 1998 provides for basic access to water and calls for management of water resources based on principles of equity, efficiency and sustainability. One important instrument in this law is the so-called Ecological Reserve stating that before any abstracted water is allocated for human use, the environmental requirements of the particular resource where the water is taken from should be determined and reserved. The National Water Resource Strategy and the Guidelines for Groundwater Resources Management provided the methodological and scientific basis for the NWA and is strongly based on the IWRM-approach. The process is decentralized with Department of Water Affairs (DWA) exercising overall responsibility and regional offices in nineteen water management areas and catchment management agencies at the more local scale. The formulation of water users associations guarantees participation from users at grass-root level.

The changes have been deemed to be only partially successful. According to local experts, there are several reasons for this. First, groundwater sources are relatively undervalued by both average citizens who consider it to be a poor man's source, and water engineers and policy makers who have historically worked with large-scale surface water structures. Second, human expertise to deal with groundwater resources is lacking across all management levels and reflects a relative absence of hydrogeological and socio-economic data to make informed decisions. Provisions to control groundwater abstraction and pollution are weak or even non-existent at more local levels (Pietersen et al., 2011) so are provisions for the establishment of aquifer management organisations. Third, despite the institutional reform, groundwater is still being decided upon fragmentarily in different state departments. Furthermore, the assignment of responsibilities, roles, tasks and resources between the various DWA scales is unclear. This is also confirmed by a recent World Bank study on South African Groundwater Governance, which concludes that at the national level technical, legal and institutional provisions are basically reasonable but weak for cross-sector policy coordination (Pietersen et al., 2011). Bottom-up movements towards public participation are poorly recognized nor enabled by the groundwater managers and governmental agencies. Finally, the ecosystem services of aquifer are rarely recognized despite the existence of the Ecological Reserve. These factors suggest the challenges associated with institutional and legal reform and the realization of equitable, sufficient, and sustainable groundwater management.

An interesting case study is that of the arid and strongly groundwater-dependent state of Arizona in the U.S. Aside from drinking water quality and discharge standards, which are established at the federal level, the individual states have the discretion to establish their own groundwater rights and management systems (Megdal, 2012). Statewide, groundwater accounts for about 40 percent of total water extractions/diversions (Arizona Water Atlas, accessed 18 December 2011) With its adoption of the 1980 Groundwater Management Act (GMA), Arizona became a national leader in managing groundwater in the areas designated as Active Management Areas (AMAs) (Colby and Jacobs, 2007). These areas were identified statutorily due to extant groundwater mining. Groundwater rights and permitting regulations were established for the major water using sectors – municipal, industrial and agricultural – with each sector having to abide by conservation programs established by the Arizona Department of Water Resources every 10 years. Key to the GMA was the establishment of statutory management goals for each of the AMAs as well as a program of assured water supply, whereby new municipal developments are required to show they have legally, physically and continuously available water supplies for 100 years. Use of groundwater must be consistent with the management goal, which for most of the five AMAs is the attempt to reach safe-yield, meaning long-term withdrawals of groundwater do not exceed natural and artificial recharge. The natural terrain, economies and water resources of the five AMAs differ, and there is some ability to customize regulations in recognition of the differing conditions. A statutory framework for recharge and recovery has allowed water to be banked for future use and groundwater recharge to serve as a treatment mechanism for Colorado River water in lieu of the construction of costly treatment plants.

Arizona's GMA is hailed as a progressive approach to groundwater regulation and has allowed for significant innovation and variation in water user approaches to meeting the state-established regulations (Colby and Jacobs, 2007). However, after 30 years of experience, the water management challenges remain substantial. Even in the large AMA regions, where safe yield is the management goal, there are areas where localized draw-down of water tables is a concern. The assured water supply framework allows for groundwater to be pumped to depths as low as 1,000 feet (303 meters) below land surface, provided most of that groundwater is replenished with surface water supplies. However, the Central Arizona Water Conservation District, the agency responsible for replenishment, does not have long-term renewable water supplies under contract to meet the projected replenishment obligation. Among the related concerns, therefore, is the future cost of replenishment. There are no penalties for non-achievement of the management goals, and many small wells are exempt from regulation. Although about 80 percent of Arizona's approximately 6.5 million people live in an AMA, some of the non-AMA areas of the state are facing projected imbalances in water supply and demand (WRDC, 2011). The difficulties and data gaps associated with quantifying the water needs of water-dependent natural systems (Nadeau and Megdal 2011) and lack of legal recognition of environmental water needs (Megdal et al. 2011) result in lack of policies addressing the water needs of nature . Although the 1980 Groundwater Management Act provided a strong foundation for groundwater management, much work remains. The experiences of Arizona indeed point to the complexities associated with groundwater management in growing, semi-arid regions where groundwater is a crucial part of the water supply.

7.2 Groundwater in emergency situations

One particular issue of groundwater governance relates to groundwater in emergency situations. Emergency situations are defined here as those natural hazard like floods and droughts and man-made hazards like violent conflicts that significantly affect the functioning of societies and hence adversely affect human life. Immediately after physically securing an endangered population, the priority of emergency relief mostly considers drinking water distribution since existing drinking water supply systems are often rendered dysfunctional. Ignorance and professional bias by the relevant authorities and emergency relief NGOs and the lack of information on the presence of high yielding aquifers with safe groundwater limit the ability of the (ad-hoc) emergency sector to include simply exploitable, locally available and non-affected groundwater resources as a relief solution. Instead, complicated emergency water supply systems based on transfers of large volumes of water from elsewhere are often developed.

Under UNESCO International Hydrogeological Programme(VII), a Working Group IHP project on *Groundwater for Emergency Situations (GWES)* was established. The main project outcome are methodological guidelines for the identification, investigation, development, management of strategic groundwater bodies to be used in emergency situations resulting from extreme climatic, hydrological and geological events and in case of conflicts and to formulate principles of groundwater governance policy in emergency situations (Vrba, 2011). Within the GWES project, various project proposals with 'groundwater solutions' have been developed for a number of disaster events in India, State Orissa (flood and storm), Pakistan (flood), Somalia (drought) and Haiti (earthquake) after assessments by teams of local and international groundwater experts.

What is of relevance to governance is that in emergency situations commonly practiced general principles of equity, sustainability and efficiency are hardly valid or get very different meanings. The actors and related economic, social, ecological and scientific/technical activities and the needed policy response for emergency groundwater resources even differ between the different phases of an disaster event (preparedness, warning, impact/relief and rehabilitation). E.g. groundwater abstractions rights may need to be temporally overruled to facilitate the allocation of groundwater resources to drinking water supply. Sustainability policies cannot strictly adhered to as providing water to safe human life now is more urgent then managing groundwater resources to sustain future human life or to sustain natural systems on which people depend less directly. Of great importance is to include groundwater resources in national disaster risk reduction and preparedness plans and the emergency relief plans and operations. With climate change, the frequency and intensity of

disaster events are expected to increase in many areas of the world. Hence, the relevance of groundwater governance for emergency situations.

7.3 Groundwater use going global

The final case study considers the whole earth and looks at groundwater resources as a global common property resource. Globalization has caused water use impacts to reach global dimensions and countries across the globe are thought to be linked through so-called water teleconnections (Hoff, 2009). As an illustrative example, India's groundwater overexploitation is assumed to have contributed significantly to the recent sea level rise (Konikow, 2011). The main groundwater teleconnection is through the international trade and transport of groundwater-irrigation based food and (increasingly important) bio-fuels. From a global perspective, this virtual water transfer appears to be sustainable as it saves about 300-450 km3 of water annually as food is grown in areas with relatively high water productivities and imported by countries with low water productivities.

Although land-acquisitions by multi-national companies have been common in recent history, there are increasing concerns related to the large-scale land acquisitions by countries lacking arable land and/or water resources to sustain their national food security. Since 2004, more than 2.5 million hectares have been leased and/or sold in Africa to governments and some companies of the Gulf States, China, Libya, India, and South Korea (Cotula et al., 2009). It has been argued by some that water is the hidden agenda behind many of these land acquisition deals (HLPE, 2011). Cases are observed where the intensive agricultural production rates on these land acquisitions have lead to negative environmental externalities such as water mining and nutrients loss and making its local sustainability questionable. Additionally, cases are known where governments stopped respecting the non-formalized local and traditional land and water use rights. Several governments (such as Tanzania, Ethiopia, Mozambique, Cambodia) have made efforts to identify 'available' land which is only non-formally entitled to local people through traditional rights and that can be 'allocated' to investors. With climate and global change, about 20% more water than today is needed to meet the food demand in 2025 (Hanjra and Qureshi, 2010) and hence this search for land plus water is not likely to stop. The global groundwater governance community (basically led by human rights community) have only recently started to address these issues of global groundwater governance.

8 Constraints and Barriers

Our review of the diverse case study literature on groundwater management, as well as our analysis of the more illustrative case studies presented above, leads us to identify a set of broad barriers in terms of groundwater governance.

8.1 Inertia and resistance to change

Within some countries, historical access and ownership rules led to a concentration of power and access to resources in the hands of the few—who also had a key role in institutionalizing rules that protected these rights (Gupta and Lebel, 2010). Hence, individuals, organizations and sectors tend to favor the status quo when it is known or perceived that the new institutional constellation is going to provide less benefits (Cumming et al., 2006). Discourses and rules on the management of water resources at the national level are often influenced by practices at the international level, through development cooperation, development banks and international social movements. These aspects of globalization often foster homogenous rules that may face more national or local resistance (Gupta and Lebel, 2010). Finally, the intensive use of groundwater resources is of relatively recent origin, dating back no more than half-century in most countries (Knueppe, 2011). Institutional capacity is lagging behind the technological development and economic and cultural valuation of the natural resource (Cumming et al., 2006).

8.2 Rent-seeking behavior

In particular governance regimes, groundwater users may form a large part of the electorate. Politicians may fear negative polls as a consequence of trying to implement policies that constrain the perceived groundwater use rights of those users. Populist, electoral motives drive policymakers to abstain from or delay the implementation of such policies (Mukherji and Shah, 2005). Furthermore, mechanisms of patronage result in the formulation of distorted or perverse policies privileging some elites or sectors and to corruption within governmental organizations (Garduño et al., 2010; Cumming et al., 2006).

8.3 Problems of fit

The time scale of issues in groundwater resources systems often exceeds the standard terms of the responsible governmental administrations. Changes in such administrations after elections often pose a discontinuity in groundwater governance arrangements. Also, despite the promotion of system-based and holistic approaches to water resources management, the boundaries and scales of the governmental entities responsible for the management of groundwater resources generally do not align with the physical boundaries and scale of the system (Cash et al., 2006). As well, in general, key aspects of groundwater resource policy and law were formulated at an earlier time, when encouraging exploration was the main goal (Cumming et al., 2006). Slow re-adjustment of those policies and laws renders them unfit the deal current conditions and issues.

8.4 Problems of interplay

Despite the promotion of system-based and holistic approaches to water resources management, the management of groundwater resources is still fragmented and placed in different functional departments. Some functional departments may perceive sustainability issues as outside of their responsibilities (Jouravlev and Solanes, 2006). Cooperation and coordination across departments and functional units is often lacking. The consequent “Silos” policies and isolated lateral planning lead competing and conflicting preferences and decisions and to sub-optimal solutions (Cumming et al., 2006). In addition, because groundwater governance may include the transfer or devolution of tasks and responsibilities from central (capital based) departments to more local (province or city based) governmental entities, this may induce resistance (Theesfeld, 2010) and further problems of interplay.

8.5 Information deficit

In many countries, groundwater resources management is characterized by continuous information deficits, particularly around monitoring and quality (Foster and Chilton, 2003). When the available information is incomplete or incorrect, it becomes harder to realize the significance of the problem. In other instances, too much information of the wrong kind is collected; data gathering and analysis can then become traps that distract members of the organization from truly coming to grips with the key issues (Cumming et al 2006). While technical data and information on groundwater resources is often poor, information on socio-economics and institutional and legal aspects appear to be completely ignored (Mukherji and Shah, 2005; van der Gun and Lipponen, 2010). The knowledge gap is the communication mismatch between the producers and users of information. Often it

is the producers of information that have defined which and how information is being produced and disseminated without taking into account the mind frames of the users of the information (Timmerman and Langaas, 2005). Translation of technical information into understandable information for non-experts is generally weak. Groundwater management often lacks the financial and human resources needed for the investigation of the resource characteristics and functions, especially in developing countries, and as a consequence there are shortcomings in terms of reasonable legal provisions and pricing systems. In many instances groundwater experts are unwilling to share information with the general public (Knueppe, 2011). Sometimes countries are unwilling to share data and information on groundwater resources because of national security arguments.

8.6 Limited mental models and framing of groundwater resources

It is being increasingly recognized by scientists that groundwater resources are complex adaptive systems. To provide sustainable and equitable solution to groundwater-management issues requires a holistic approach based on the knowledge and expertise of many disciplines. However, human actors typically tend to reduce the complexity and dimensions of such complex problems. What may be more appropriately described as a messy problem situation is often compressed into a description of a well-defined problem with simple cause-effect relationships (Pahl-Wostl, 2007). It is an incorrect assumption that there is a single perceived characterisation of the scale and level a phenomenon is working on. The drive to frame issues at a single scale or level comes from the need to both simplify and control (puts it under the sole responsibility of one group (Cash et al., 2006).

However, often groundwater resources systems are still considered to be systems that can be managed by a plan and control and engineering approach. Departments responsible for the management often hold a small diversity of disciplines with a bias on technical sciences and engineering solutions (Pahl-Wostl, 2007). In the traditional groundwater communication, there is a bias on addressing negative consequences of overexploitation instead of addressing the socio-economic benefits of using groundwater resources. Mental models and framing in groundwater resources management are very much determined on the uncertainty and mystical characteristics of the groundwater resources, besides cultural backgrounds and subjective preferences and prejudices (Millman and Ray, 2011). These mental models around groundwater shape perceptions of equity, sustainability and issues of use across borders.

8.7 Lack of sufficient public participation

The involvement of stakeholders in policymaking processes and resource utilization is mostly weak and barely acknowledged by groundwater managers and government agents (Knueppe, 2011). Civil servants are often not trained to deal with processes that include interaction with communities. There are often few regulations in place that recognize the power or mandates of civil society organizations and they are even seen as activist or even illegal interest groups. Often civil society is poorly developed. People do not have the capacity or time to be involved in all nor do they have adequate access to information, which may impede multi-scale participation (Theesfeld, 2010). There is a lack of knowledge on the technical groundwater issues with citizens at grass-root level and in the staffs of NGOs and CBOs. Marginalized and minority voices may be excluded from participation (Garduño et al., 2010).

9 Knowledge gaps: Identifying what we don't know

There are still large areas about which we do not possess adequate information or understanding in the context of groundwater governance. Perhaps the most unknown factor of groundwater governance is the resource itself (Mukherji and Shah, 2005; Villholt, 2006; Theesfeld, 2008). The intrinsic complexity and heterogeneity of groundwater, combined with the relative inaccessibility for monitoring results in cases where many of the groundwater system and aquifer characteristics like its dimensions, storage and conductivity properties and rates of recharge and discharge, are poorly known (Milmann and Ray, 2011). Without these basic data on groundwater quantity and quality, it becomes very hard to estimate socially constructed concepts and indicators like safe yield and groundwater sustainability that are used by those responsible for developing sensible groundwater policies and managing the resource.

Relevant socio-economic information related to groundwater is especially missing (Shah, 2007) and where the administrative capacity to register and monitor the groundwater development by new users, the accumulated groundwater demand is hard to estimate. In many cases it is unknown to those responsible for governing the resource how many people are depending on it and to what extent. Do they depend on groundwater for daily survival as alternatives are simply lacking or does groundwater form an important input factor to sustain livelihoods (e.g. based on groundwater based agriculture)? Additionally, governments are often only able to roughly estimate how their national economies depend on groundwater resources.

In addition, although it is fairly well accepted that more general water sector decisions and policies are likely to highly impact more national and local actions, most countries lack the research capacity to study and determine the causality and dynamics between macro-policies, such as food security, energy security, international trade, and spatial planning, and groundwater policy. Hence important links, trade-offs and possible synergies and opportunities are missed and suboptimal or even decisions counter-acting sustainable, equitable and effective groundwater resources management are taken (UNDP GWP 2011; Shah, 2007).

Finally, the institutional diversity of groundwater governance models is enormous as the small set of case studies in section 5 perfectly illustrate. Yet, we do not have a complete picture of the institutional diversity and management practices in groundwater governance. Groundwater governance studies thus far have only looked at comparisons of just a selected small number of cases and/or focussed on particular governance issues. It is unclear how some the institutional solutions and principles, which are generally advocated to facilitate the implementation of good groundwater governance, work out in practice across a variety of settings. For example, decentralization of groundwater management roles and responsibilities to lower scale organizations is thought to foster context–fit and demand-responsiveness but if economies of scale are missed, the decentralization may ultimately come at a higher cost. Public participation is another solution propagated to facilitate good groundwater governance. However, research on public participation has shown that it is a process with variable success rates because of issues of unwillingness, indecisiveness and inability at all kinds of levels and scales (Meinzen-Dick, 2007). Similarly, the institutional reform of privatizing water utilities that were part of the earlier neo-liberal paradigm on water was originally advocated to be the most promising solution to provide effective and efficient water services. Yet current evaluations of privatizations of governmental water services across the globe show varying levels of success and failure (Budds and McGranahan, 2003; Prasad, 2006). Although it is assumed that eventually the transaction costs of managing water resources will decrease when good water governance practices are applied (UNDP WGF, 2011), we know far less about the transaction costs associated with transitioning to new governance structures and applying broader practices to a more local context.

With groundwater governance being a social construct based on a set of interrelated and sometimes changing principles norms and values, it is assumed that it is, like other institutional changes, path-dependent (Shah, 2007). Countries that currently appear to have a similar groundwater governance status will likely evolve differently because of decisions taken in the past. A groundwater decision taken by a country that appears to be in a context similar to a former context in a different country will likely turn out differently. However, the generally increasing global connectivity between and shared by various groundwater communities of practice may decrease these differences.

Importantly, the knowledge gaps on groundwater governance highlighted here should not serve as an argument to delay action. No situation should be created where there is “paralysis by analysis” (Wade, 2004). Neither should we have unrealistic high

expectations of success of implementations of various groundwater governance mechanisms. Meinzen-Dick (2007) puts it rightly when she states that rather than adopting rigid institutional models and then declaring each of them to be a failure, it is better to make explicit provision for institutional learning and change.

10 Evolution of successful and unsuccessful paradigms, models, instruments, and methodologies

Based on the described case studies and the diagnosis of barriers and opportunities in groundwater governance, this section tries to synthesize the evolution of various groundwater governance paradigms and to determine its level of success. One of the assumptions taken here, as already mentioned earlier in the introduction, is that the paradigms to govern groundwater are nested within those that govern water which are again part of or closely linked to paradigms on how we deal with natural resources in general. This section takes a classical separation of state, market and by collective action paradigms to natural resources.

Historically, the state has always been involved in developing and managing water resources by providing the engineering capacity. This engineering-based and hydro-centric approach peaked during in the period of Industrial modernity when it was generally believed that with capital and technology one was able to control nature (Allan, 2005). During the hydraulic mission, many governments constructed large water infrastructural works and developed water resource or the benefit of society and economic development. Foster (2006) describes that countries during this phase often go through a process of groundwater under-utilization to a stage of over-exploitation where negative impacts become apparent. Although nowadays this approach is considered non-sustainable, it must be acknowledged that this paradigm has contributed to the economic development of many countries across the world (Mukherji and Shah, 2005; Björklund et al., 2009).

From the 1980's, the human confidence in nature's predictability and controllability was declining. The scientific application of the systems approach to natural systems raised the recognition of limits to growth. Furthermore, neo-liberalism questioned the affordability of state-driven water resources development and other public services provision. In the field of water management, this resulted in a paradigm change towards IWRM, which has been successful in implementing notions of sustainability. Many examples can be found where IWRM has been able to slow down or even reverse negative impacts of groundwater use. However, full IWRM often requires a large institutional restructuring of rights systems, markets and the establishment of aquifer basin authorities with sufficient regulatory power and resources. Only a few (often developed) countries have had the ability to bear the necessary transaction costs. Other countries especially in the development world have continued with the hydraulic mission (Allan, 2005) or take a "clumsy" approach where they incrementally try to install bits and pieces of IWRM (Moench et al., 2003). Groundwater issues that still tend to be under-addressed (even in the counties where a relatively full IWRM approach has been taken) are groundwater quality and groundwater and urban development (Foster and Chilton, 2003).

IWRM's goal to gain full understanding of natural system dynamics can hardly be met in practice because of intrinsic unpredictable character of nature and the limited resources available for the monitoring which is a prerequisite for this understanding. The adaptive water management approach that is currently advocated takes these limitations into account. A more learning-by-doing (and monitoring and evaluating) model forms its basis. The effectiveness of this approach still remains to be proven. The coming decades of climate change will provide a huge test case.

Market solutions towards groundwater resources management appear to applied only limitedly and have been variably successful. In many countries, groundwater rights even changed from originally being private property rights towards usufructuary rights putting the groundwater resource itself under state property (Gupta and Lebel, 2010). Neo-liberalism thinking pushed many countries to privatize their water utilities to some extent (Solanes and Jouravlev, 2006). This has been limited to mostly to drinking water supply companies. Studies from the United States and other parts of the world have indicated that due to the large capital investments needed, coupled with the open access characteristic of aquifers and the economic characteristics of the agricultural sector, make private investors reluctant to develop risky groundwater-based irrigation services to farmers. Water markets are seen as a promising instrument to allocate water sustainably and economically while preserving notions of fairness (Zetland, 2011). The trading of capped groundwater allocations can reduce the cost of limiting water use (Thompson et al., 2009). However, water markets that lack some level of governmental regulations and/or guidance are deemed to behave less well.

There is a large volume of literature on the efficacy of collective action or community-based management of natural resources. Grabert and Narasimhan (2006) note that although success stories are limited, collective action was the only option that did work. Some critics argue that many of these community-based management approaches lack a regional overview, technical knowledge and resources to properly monitor and hence fail to take into account environmental externalities (Blaikie, 2006).

The conclusion is that there is no single paradigm, model instrument or policy that has been generally successful. There are no panaceas (Ostrom, 2007) when it comes to effective, sustainable and equitable governance of natural resources like groundwater. Contexts and historical development paths (Shah, 2007; Solanes and Jouravlev, 2006; Villholth, 2006) determine the applicability and potential success of the various mentioned groundwater governance and management instruments. Groundwater is mostly a local issue and solutions need to be found that are fit to that location including vague and often immeasurable notions like societal culture and the sign of the times. Per definition, as these notions change, paradigms that are social constructs change as well. Secondly, only very few cases are known where groundwater governance have been either fully state, market or collective action driven. Often these three groundwater-governance paradigms have existed and have been practiced simultaneously in some hybrid and nested form all the time. By accepting the complexity of groundwater resources management and recognizing that the different paradigms and approaches all have a role, good groundwater governance practices can be developed.

PART 3: PROSPECTS

11 Significance and options for groundwater governance and policy: operational definitions for the GWG project

Governance, as we have seen, can be defined as “the sum of the many ways individuals and institutions, public and private, manage their common affairs” (Saunier and Meganck, 2007). Under a governance approach, considerable attention is given to the interactions between the variety of policies, decisions and enforcement practices (Tesiman and Hermans, 2011: 64 in in van der Valk and Keenan). In this forward-looking part of the paper we consider prospects for future modes of groundwater governance that will prove to be robust and sustainable. In doing so, we note that groundwater governance occurs in the context of broader governance trends. These trends include macro-economic policies at all levels, the widespread adoption of integrated management, the growing involvement of civil-society and other nonstate institutions in environmental decisionmaking, and the recognition of demand-side management as a complement to traditional supply-side approaches. The implementation of successful policies will require decision-makers and on-the-ground implementers to reassess the classical toolbox for groundwater managers within a broad context.

One of the most pervasive notions of past governance modes has been the overriding prevalence of technical and scientific approaches. Such approaches have of course contributed immensely to our understanding of groundwater systems and provided productive ways to harness their resources. But, at bottom, governance increasingly has come to be seen as a political concept in which the chief constraints are social, institutional, and political (Linton and Brooks, 2011; Burke et al., 1999; Burke and Moench, 2000; Linton, 2010; Espelend, 1998). Viewed in this light, changes in governance—of groundwater resources or indeed of any process—necessarily involve changes in power relations. Accordingly, when such actions as decentralization, public participation, and conservation are proposed, it is unsurprising that these often meet with scepticism and even resistance. A clear lesson is that changes in governance are long-term processes that should be incrementally developed and that are accompanied by high transaction costs.

One characteristic of governance that contributes to high transaction costs is the high degree of interrelatedness, dependency, and mutually reinforcing nature of governance. These features are incapable of standing alone. For example, accessible information means more transparency, broader participation and more effective decisionmaking. Broad participation contributes both to the exchange of information needed for effective decisionmaking and to the legitimacy of those decisions. Legitimacy, in turn, means effective implementation and encourages further participation. Responsive institutions must be transparent and function according to the rule of law if they are to be equitable. These core characteristics represent the ideal; no one society has them all.

Among the tensions generated by the above features of groundwater governance is the question of the locus of policymaking. At one extreme, such policymaking is subject to the broad role of institutions and rules that govern behavior. These may be global or regional and they may involve international treaties. Or they may be national. GWMATE’s (Groundwater Management Advisory Team; 2004) operational experience shows that a decentralised groundwater management with some form of stakeholder participation is the most promising approach. Ideally, our review of the literature suggests that groundwater management and its associated policymaking should be performed at the lowest scale possible, that is, at the local level and so as to fit the context. This context includes culture, religion, the role of the state, specific resource conditions, historic water use patterns, relative capacity of actors, attitudes toward groundwater, existing scientific paradigm, heightened dependencies, and indeed, any variables that affect policy (Ostrom, 1990; Ostrom, 2007).

But in our preference for actions at local scales, we should recognize that such actions are always embedded within higher scale processes, possibilities, and restrictions. Equally important is to have coherence of groundwater policies across all scales. As an example, international lawyers consider international agreements as the most logical instrument to manage transboundary water conflicts. Such agreements are useless when not supported by domestic legislations and local users adhering to it.

Groundwater governance also should be viewed in close relationship with national or even international policies on food security and energy security. With agriculture often being the biggest groundwater consumer and with increasing competition

with biofuels, a country's choices to be self-sufficient can have immense consequences. Optimizing groundwater demand with virtual-water transfer mechanisms often has bigger effects than sophisticated water saving measures. Obviously, the ambition to reduce groundwater demand should be balanced with potentially unwanted loss of agriculture-based livelihoods and economies. Accomplishing such outcomes will entail employing the full arsenal of conventional groundwater policies such as well registration, licensing, monitoring, education, voluntary compliance, and enforcement. But in as noted above—while recognizing that there are no one-size-fits-all modes of governance—such steps should strive to fit local contexts and historical development paths (Mukherji and Shah, 2005; Ostrom et al., 2007; Theesfeld, 2008; Villholth, 2006). As one example of how circumstances differ by region or country, data for 18 countries show great variability in irrigable area equipped with a groundwater source, ranging from a low of 18 percent (Afghanistan) to a high of 97 percent (Saudi Arabia) (FAO Aquastat 2011). Clearly, groundwater policies will vary by region.

In view of the changing understanding of governance—that is, its evolution from a technical process to a socio-political one—it is important to consider overall perceptions of groundwater. Some observers have noted that in many societies, this perception is largely negative (e.g., Knueppe, 2011). To counteract such notions, it is important to inform water users about the value of groundwater and aquifers. Although quantifying the value of groundwater remains elusive, expressing it in monetary units would be most persuasive to decision-makers operating in resource-deficient environments. Such a course would help build support for more forward-looking and sustainable groundwater governance policies. Moreover, UN-system agencies and other organizations can help to harvest and disseminate lessons from the many governments and communities around the world that are trying different approaches to groundwater governance (Moench et al., 2003).

12 Criteria and Considerations for Effective Policy Objectives and Groundwater Governance

In order to avoid what has come to be called “the tragedy of the commons,” some sort of common property regime or “unitization” agreement will have to be established and fostered for groundwater resources as they have been for other open-access resources (Linton and Brooks, 2011; Ostrom, 1994; Agrawal, 2003; Weaver, 2011). Such regimes will require that that resource users and managers develop common rules for exploitation that apply at the scale of the aquifer, something that is bound to be more difficult across an international border. In a different context, Bakker (2007: 447) has advocated recognizing and empowering alternative concepts of property rights, most notably in the form of what she calls “community economies of water.” The principles of governance that we are advocating in this paper would help provide a basis for establishing such regimes. At the aquifer level, Aquifer Management Organisations, comprising representatives of government agencies, water users and other stakeholders, may play important roles in the implementation of planning determinations and management measures (Foster and Loucks, 2006). In the context of international aquifers, it is helpful to think about meditation and conflict resolution and the broader role of national economic or military security issues in negotiations and management (Blomquist and Ingram, 2003).

Under the scope of the broader regime, it is important to consider compliance issues. Groundwater, unlike surface water, is subject to the individual decisions of hundreds or even perhaps thousands of independent users with direct access to the resource. Because of this, top-down control has often proven insufficient in many places and the reason why user communities are often advocated as the most plausible solution to ensure adequate groundwater resources management (Llamas and Martínez-Cortina, 2009: 198). Groundwater governance should be based then on voluntary compliance due to the immensely high transaction costs of rule compliance and enforcement. Voluntary compliance is fostered when the groundwater rules are demand responsive, align with local norms and beliefs, provide for conflict resolution and implicitly assume a common level of understanding of the resource systems its issues and solutions (Theesfeld, 2010).

In addition to Ostrom’s (1990) design principles and formal rules, increasingly scholars and observers are recognizing that sustainable groundwater management depends on a flexible and adaptive management approach. Such an approach should feature strong collaboration between scientists, policy makers, water supply agencies, and water users. This is an effective way to deal with externalities, to bring in the necessary technical knowledge, and to be able to make use of economies of scale that allow affordable monitoring and surveying (Ross and Martínez-Santos, 2010) . A fundamental challenge is to design institutions that are not vulnerable to capture by subsets of the community that self-organize to direct the institution against the overall social interest. In a world of episodic structural change, such as social-ecological systems, adaptive learning can lock in to a single institution, model, or parameter estimate. Policy diversification, leading to escape from panacea traps, can come from monitoring indicators of episodic change on slow timescales, minimax regret decisionmaking, active experimentation to accelerate model identification, mechanisms for broadening the set of models or institutions under consideration, and processes for discovery of new institutions and technologies for ecosystem management (Brock and Carpenter, 2007).

13 Applying Practical Policy Principles for Groundwater Governance

Ultimately, effective governance will be dependent upon sufficient capacity to generate the interactions and actions necessary. In the context of water governance, capacity is about the “ability to generate clearly different roles for all in such a way that the actions lead to interaction patterns with maximum outcomes against affordable efforts” (Teisman and Hermans, 2011: 64 in van der Valk and Keenan). Communities across the globe will need to invest in a number of governance capacities that will enable them to integrate the legal, managerial, financial, institutional, and social elements integral to effective water governance (Satijn and ten Brinke, 2011: 51 in van der Valk and Kennan). These investments will help to promote both processes for governance as well as structures to ensure appropriate implementation and evaluation. Below we outline some practical policy principles for groundwater governance that build from the broader observations outlined above. It is important to recognize that few water governance institutions or processes will meet the ideal but rather we present these principles as action steps that have deemed important to effective governance.

13.1 Role of governmental groundwater resource management entities

There is no one-size-fits-all answer to meet groundwater governance challenges, but some overarching principles can be identified to improve water governance.

- A key institutional requirement in many countries for improving groundwater management at field-level will be to transform the role of the government agencies responsible for groundwater from exclusively 'supply-development' to primarily 'resource-custodian' and 'information-provider', and to ensure that such agencies fully engage groundwater users and stakeholders in a participatory management process (Foster, 2006; Garduño et al., 2010).
- Important roles for national governments to ensure strong state/provincial level agencies include:
  - allocating sufficient financial resources and removing bureaucratic obstacles to hiring the required professionals, and recommending adequate salaries and career development (such that they are less vulnerable to corruption)
  - establishing guidelines to address the management of trans-state and internationally-shared aquifer systems
  - providing minimum reference standards for the identification, characterisation, monitoring and evaluation of groundwater basins ‘at risk’, and defined procedures for the specification and implementation of management measures appropriate to the level of risk involved
  - diversifying the curricula for hydrogeologists to include more social sciences (FAO, 2011 Draft Water Tenure Guidelines: 52) and policy
- Realign the responsibility of management of water resources within ministries of environment and other agencies that may be outranked by institutions such as ministries of finance, trade, agriculture, mining, industry, or public services, and attempt to ensure sufficient influence to negotiate effectively with the more powerful entities.
- Separate policymaking from the operational management and provision of water services of different entities and make their links and roles clear (Solanes and Jouravlev, 2009).
- Adopt governance instruments to foster coherence across water-related policy areas and between levels of government, and assess their effectiveness in coordinating water policy at horizontal and vertical levels (OECD, 2011).
- Ensure that agencies and ministries have the necessary capacity and policymaking power (Solanes and Jouravlev, 2006).

- Recognize and tackle the bureaucratic inertia (change of formal rules) and political reluctance or even obstruction and facilitate processes to counter these obstacles (Theesfeld, 2008).
- Link to larger macro-level policy decisions to help strengthen groundwater governance (Garduño et al., 2010). There is large potential to indirect management of groundwater resources by affecting the policy on food (virtual water, increase productivity), energy and trade (Mukherji and Shah, 2005).Undertake a comprehensive review of policy and legislation to examine how existing frameworks support the responsible groundwater governance and make policy and legislative modifications as appropriate.

13.2 Role of information and science

- There is strong need and potential for the development of national research programmes to gather representative groundwater data directly in countries and regions where dependence upon groundwater is high (Mukherji and Shah, 2005). Governments should commit themselves to provide sufficient resources for groundwater monitoring and assessment
- There is an increasing availability of Remote Sensing-images which can help estimate the surface components of groundwater systems such as recharge and discharge support those groundwater resource managers that lack in-situ monitored data. Remote-sensing images, which can be used rather inexpensively or at no costs, can also be used in negotiations on groundwater resources allocation as they provide impartial proofs of land use.
- Socio-economic information, which plays a more subtle role related to poverty alleviation, health standards and social vulnerability, should also be collected (Knueppe, 2011; Mukherji and Shah, 2005; Moench et al, 2003). Assessing the effectiveness of water information systems and databases in bridging the information gap is a difficult task but OECD evidence shows that hydrological and physical water information is far more advanced and accessible than economic and financial data to guide decision-making (OECD, 2011).
- Collaborative efforts for the acquisition and sharing of hydrologic data and information can serve to overcome institutional asymmetries (Megdal and Scott, 2011). Scientific and technical data may also serve to facilitate negotiations on water allocation and coordination of management roles and help resolve conflicts and disputes (Moench et al., 2003).
- Global organizations like UNESCO-IHP, IAH, FAO and bridging organizations like IGRAC need to continue spreading this message and facilitate countries to make it work. The international community, acting through bilateral and multilateral aid mechanisms, should provide greater support for date collection and management (FAO, 2011 Draft Water Tenure: 51).
- In countries that lack basic hydrological data, a greater investment in data collection and data management will be necessary (FAO, 2011 Draft Water Tenure: 51).

  Create early warning systems based on indicators to assist with disaster-preparedness. Because adaptive approaches do not require full understanding of resource dynamics and build off coping strategies that populations are already engaged in, such approaches may be able to produce 'results' more rapidly than they can be integrated into management initiatives. In addition, they often do not require the introduction of new institutions (such as water rights) and may be able to minimize politically difficult decisions (such as extraction controls) in the short term. This is important because the institutional capacity and data essential for active integrated management of the resource base is absent in many countries and could take decades to develop (Moench et al., 2003).

13.3 Role of public participation

- Since groundwater management is more about influencing the behavior of individual groundwater users and potential polluters, than top-down allocation of a clearly-defined natural resource, the process of enabling and nurturing stakeholder participation is an especially critical groundwater governance instrument (Garduño et al., 2010)

- Leadership in groundwater governance is essential for planning and implementation processes and to facilitate communication between all of the relevant stakeholders, sectors and governmental agencies, and to support information exchange between stakeholders and national governments (Knueppe, 2011).
- It is necessary to train the staff of NGOs and citizen groups on both technical groundwater issues and on policy and policymaking techniques.
- Develop and enable community-management of groundwater resources (which includes training and organization of the community, training of the civil servants in guiding public participation processes and formal establishment of the different roles and responsibilities and accountabilities of the various groups in policies and regulations) (Mukherji and Shah, 2005).
- Expand opportunities for public participation: The UN Economic Commission for Europe's "Aarhus Convention" (1998), a multilateral environmental agreement through which the opportunities for European citizens to access environmental information are increased and transparent, may serve as a model for others. It is a way of enhancing the environmental governance network, introducing a reactive and trustworthy relationship between civil society and governments and adding the novelty of a mechanism created to empower the value of public participation in the policymaking process and guarantee access to justice.
- Modern information technology such as internet and social media can also serve to greatly improve the connectedness of various groundwater groups of stakeholders across the world (Villholth, 2006). Such virtual media enables such groups to form communities of practice and exchange and discuss on norms, values, preferences, experiences, success and failures, lessons learnt knowledge, information and data. The conference of parties are part of so-called social learning processes, which are assumed to lead to confirm and change social practice and the associated interpretation of the environment (Pahl-Wostl, 2007).

13.4 Role of scale and fit

- Continuously analyze the impact of the existing and proposed macro-policies on water development and use and keep an open and frank dialogue with those responsible for creating and implementing the policies (Solanes and Jouravlev, 2006).
- The national government can promote bottom-up approaches by playing an active role in the mobilisation of people in local processes, providing funds and technical services for local initiatives, investing in infrastructure, building capacity and expertise among practitioners, and coordinating initiatives that span more than one local government.
- Strive to build coherence across scales (Hoff, 2009). To better achieve vertical integration of governance systems across levels, water management should be coherently addressed by local action (such as land and water use), national policies (such as agricultural or export subsidies), and international agreements (such as protocols to the climate convention or trade regimes).
- Utilize global policy networks to help achieve smarter horizontal governance approaches.
- Multi-level governance capacities increase when actions across levels and across domains of content and responsibility are sufficiently aligned (Gupta, 2011).
- Craft bridging organizations that manoeuvre between scales and international groundwater initiatives to help play an intermediary role and promote the co-production of knowledge (Cash et al., 2006; Vilholth, 2006).
- Create governance instruments to address the mismatch between hydrological and administrative functional units (OECD, 2011).

13.5 Role of Economics

- Use economic incentives to steer changes of individual users' behavior but also change in institutional behavior (Hoff, 2009).
- Develop best practices guidelines to incorporating the scarcity value of water in water pricing.
- Develop best practices guidelines for recognizing third-party impacts, and then utilize this information in developing water-management policies.
- Develop market approaches to optimize water allocation and the provision of water services and the management of the resource but never without governmental guidance that regulate potential market distortions (Solanes and Jouravlev, 2009).

14 Way forward—Set of Practices for "Responsible Groundwater Use"?

We opened this paper by pointing to the large, remaining gaps in our understanding of how water is an integral part of society and its relationship to the planet's environment. The concept of sustainability offered an opening for formalizing this connection and recognizing that water is a fundamental human value as well as a critical resource. Going further, we have recognized that, at their root, all modes of tapping, distributing, and managing water supplies are the result of organized human effort, usually achieved through institutions.

We have termed this enterprise governance. It applies equally to surface water and groundwater, and in this exercise we have addressed the role of governance of subsurface water, which according to many practitioners and observers remains largely uncharted, incompletely assessed, and notably uncertain and complex. As a result, because our understanding of groundwater systems is incomplete, the design of suitable approaches to and paradigms for governance is a work in progress.

In the course of reviewing the literature and assessing prevailing notions on how groundwater is being governed across the globe, we have sensed a very palpable rise in the recognition of the centrality of governance. It's difficult not to notice how far we have come since the days when water management was left solely to engineers and technocrats.

Our purpose here has been to discover principles, knowledge gaps, challenges, and perhaps most importantly, lessons learned. By analyzing these lessons—both positive and negative—through the medium of case studies and other practical and theoretical findings, we have attempted to uncover a set of practices that with luck may guide the way to "responsible groundwater use." These practices, if they are to succeed, will need to be flexible, responsive, incremental, cost-effective, culturally sensitive, equitable, and politically astute. Put another way, they will have to factor in the dynamics—that is, the prevailing physical and societal driving forces—and the desires and vagaries of human and institutional behavior in the particular social-process system in which the management of water is embedded. In other words, insofar as feasible, governance should strive to be context-based and adaptive to the greatest degree possible.

Accordingly, to achieve long-term sustainability of groundwater management (and water management, in general), each country will have to govern its water resources within its own financial, technological, and institutional capability, and strategically use available international resources. This calls for considerable ingenuity at the appropriate governance levels to figure out the most appropriate ways of proceeding in specific contexts.

Finally, following Ostrom, et al. (2007), we recognize that prescriptions for sustainability and good governance should be accompanied by a healthy measure of modesty by observers whose intended panaceas too often prove naïve in real-world settings.

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16 Acronyms used

CABI – Commonwealth Agricultural Bureaux International

CBO – community based organization

CGG – Commission on Global Governance

DWA – Department of Water Affairs (South Africa)

EA – Environmental Agency (UK)

EIA – environmental impact assessment

EPA – Environmental Protection Agency (US)

FAO – Food and Agriculture Organization (UN)

GEF – Global Environment Facility

GMA – Groundwater Management Act of 1980 (Arizona, US)

GoG – Government of Gujarat (India)

GWG – Groundwater Governance Project (GEF)

GWMate - Groundwater Management Advisory Team

GWP – Global Water Partnership

HWRP – Hydrology and Water Resources Program (World Meteorological Organization)

IAH – International Association of Hydrogeologists

IHD – International Hydrological Decade

HLPE – High Level Panel of Experts

IHP – International Hydrological Program (UN)

IIED – International Institute for Environment and Development

IWRM – integrated water resources management

ISARM – Internationally Shared Aquifer Resources Management Initiative

MA – Millennium Ecosystem Assessment

NGO – nongovernmental organization

NWA – National Water Act of 1998 (South Africa)

NWSAS – North Western Saharan Aquifer System

OECD – Organisation for Economic Co-operation and Development

OSS – Observatoire du Sahara et du Sahel

UN – United Nations

UNDP – United Nations Development Program

UNECE – United Nations Economic Commission for Europe

UNEP – United Nations Environment Program

UNESCO – United Nations Educational, Scientific and Cultural Organization

WGF – Water Governance Facility (UNDP)

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