Urban-rural tensions
& opportunities for co-management

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
GEF ID 3726

Thematic Paper 3:
URBAN RURAL TENSIONS AND OPPORTUNITIES FOR CO-MANAGEMENT

By

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1 Introduction

1.1 Origins of urban-rural tension

Sustained global population growth (Figure 1) has placed an enormous pressure on planet Earth's finite resource of fresh, available water. In many countries, increasing competition for water between agriculture, industry and domestic needs, threatens economic development, food security, livelihoods, poverty reduction and the integrity of ecosystems. Rising demand for groundwater is a particular concern as, in many areas, groundwater production exceeds the level of sustainability (Jones, 2011). By far the biggest rivals in the global water supply contest are:

- the rapidly expanding towns and cities which support over half the world's population and require water for industry, potable supply and sanitation (Chilton, 1997; 1999; Howard, 2004; 2007), and
- the agricultural sector which already consumes some 70% of available resources, much of it to fuel Asia's "green agricultural revolution" (Evenson and Gollin, 2003; Giordano, and Villholth, 2007; Jones, 2010).

By 2030, the global population is projected to reach 8 billion (from 7 billion today) with a concomitant increase in demand for irrigation water, while the proportion of the population living in urban areas is expected to rise to almost two thirds. Much of this growth will occur in low- and middle-income countries where the availability of groundwater can be an important catalyst for economic development. Urban-rural tensions are an inevitable consequence of growth, with the most serious risk of conflict[1] occurring at the rural-urban interface (RUI) and in peri-urban areas (Figure 2) where groundwater is often the only source of water supply (Foster et al., 2000).

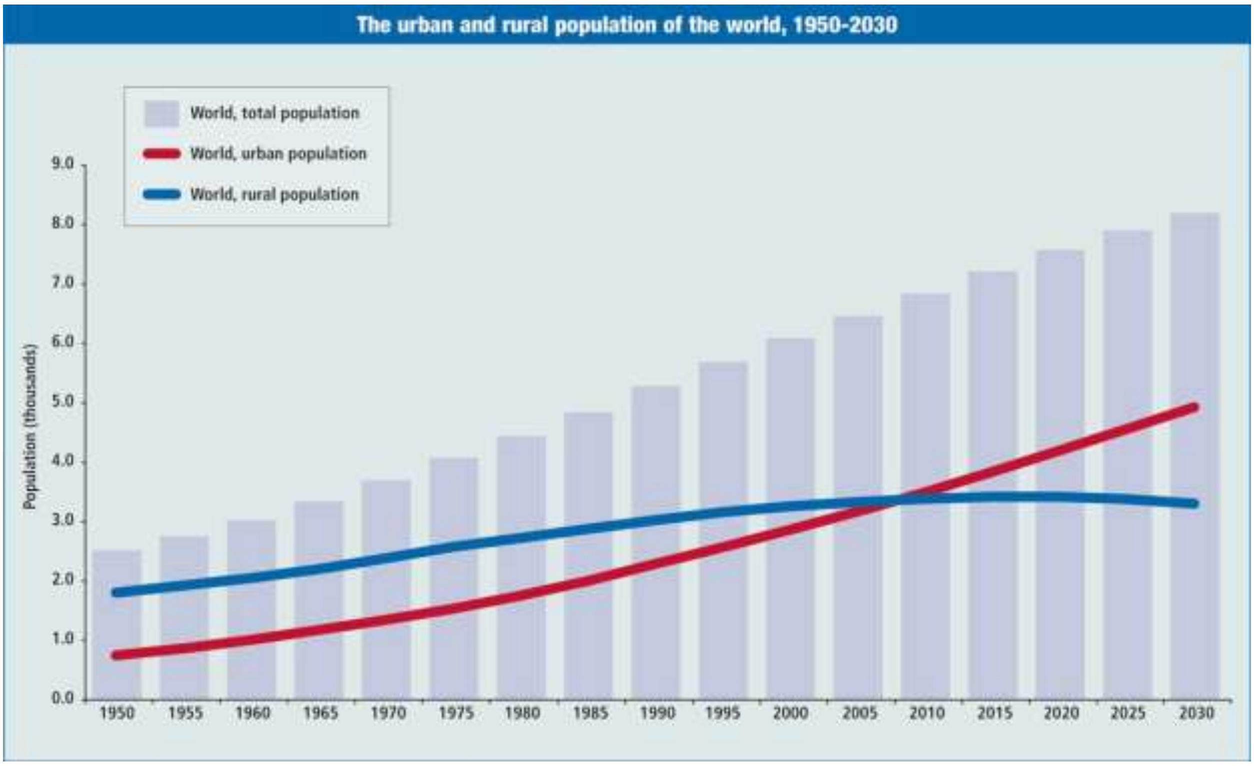

Figure 1. Global and urban population growth (from the UN, 2006)

Much of the growth has occurred during the past 40 years. In 1950 the world had just 75 cities with over 1 million people and by 1975, only Tokyo, New York and Mexico City had reached "megacity" status with populations above 10 million. By 2010, the world had 21 megacities (Table 1) (UN, 2010a), a number that is expected to increase to 29 within 15 years. The greatest rates of megacity growth are being experienced in Lagos (Nigeria), Dhaka (Bangladesh)

[1] *A conflict implies an opposition between at least two categories of actors whose interests are temporarily or fundamentally divergent (Janakarajan et al., 2006). We shift from a tension to a conflict when a verbal, legal or physical confrontation leads to one of the parties implementing a credible threat. Conflicts are normally classified as economic, environmental, social or political.*

and Karachi (Pakistan) with rates well above 2% per annum (UN, 2010b). These are closely followed by the megacities in India (Delhi, Kolkata and Mumbai), and Manila (in the Philippines). In China, less than 20% of the population lived in cities as recently as 1980. By 2011, over 50% of China's population lived in urban areas, a figure that analysts predict will increase to around 70% by 2030.

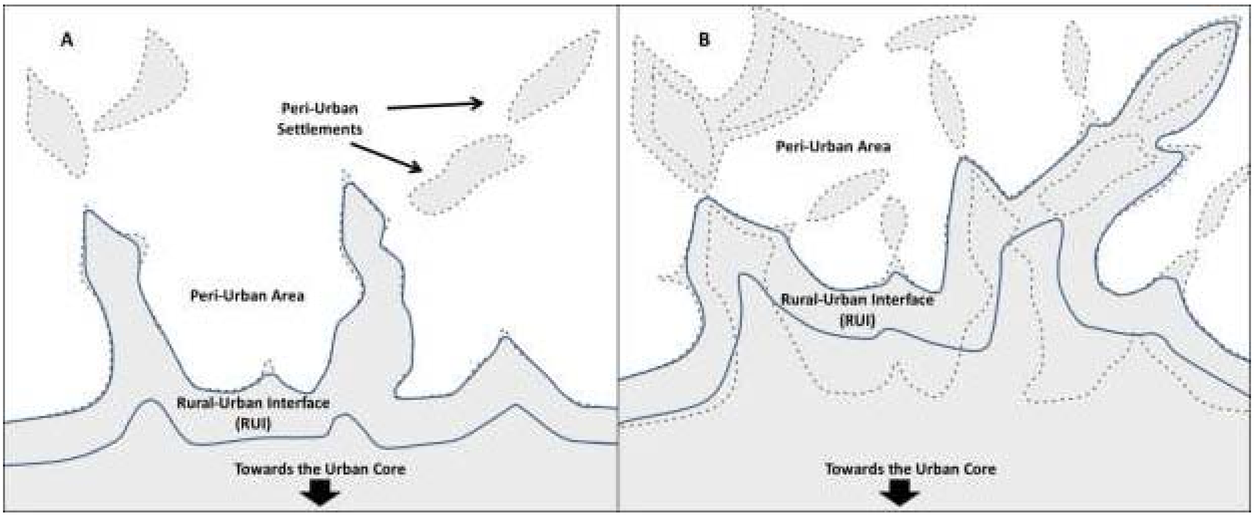

Figure 2. Two stages of urban expansion (A and B). Shaded areas are populated. The rural-urban interface (between the solid lines) and the peri-urban area are shown. Note how peri-urban settlements eventually get absorbed into the urban area and new, peri-urban settlements grow.

Table 1. The world's 21 megacities (data from the UN, 2010a)

City	Country	Population (Millions)
Tokyo	Japan	36.67
Delhi	India	22.16
São Paulo	Brazil	20.26
Mumbai (Bombay)	India	20.04
Ciudad de México (Mexico City)	Mexico	19.46
New York-Newark	United States of America	19.43
Shanghai	China	16.58
Kolkata (Calcutta)	India	15.55
Dhaka	Bangladesh	14.65
Karachi	Pakistan	13.12
Buenos Aires	Argentina	13.07
Los Angeles-Long Beach-Santa Ana	United States of America	12.76
Beijing	China	12.39
Rio de Janeiro	Brazil	11.95
Manila	Philippines	11.63
Osaka-Kobe	Japan	11.34
Al-Qahirah (Cairo)	Egypt	11.00
Lagos	Nigeria	10.58
Moskva (Moscow)	Russian Federation	10.55
Istanbul	Turkey	10.52
Paris	France	10.49

By 2050, the world's urban population is expected to increase by 84% to 6.3 billion. At this time, the world's urban population will be the same as the world's total population in 2004. Virtually all the global population growth will be concentrated in the urban areas of the developing world which are projected to see a rise in population from 2.5 billion in 2009 to 5.2 billion in 2050 (Figure 3). While much of the growth will be driven by a natural excess of births over deaths, part will involve the migration of rural inhabitants who are either attracted to the opportunities urban

areas can provide for alleviating poverty and improving living conditions, or are forced to move in response to political conflict and environmental crises (WWAP, 2009). An even smaller part will involve rural inhabitants living just beyond the rural urban interface (RUI) who simply become absorbed into urban areas as urban limits expand and rural lands are engulfed. Currently, there is no international consensus on how to define where "urban settlements" begin and where they end. This leads to unclear assignments of responsibility and can seriously impede decision-making. As a consequence, many peri-urban areas are simply neglected by city planners and remain unregulated (Ahmed and Alabaster, 2011).

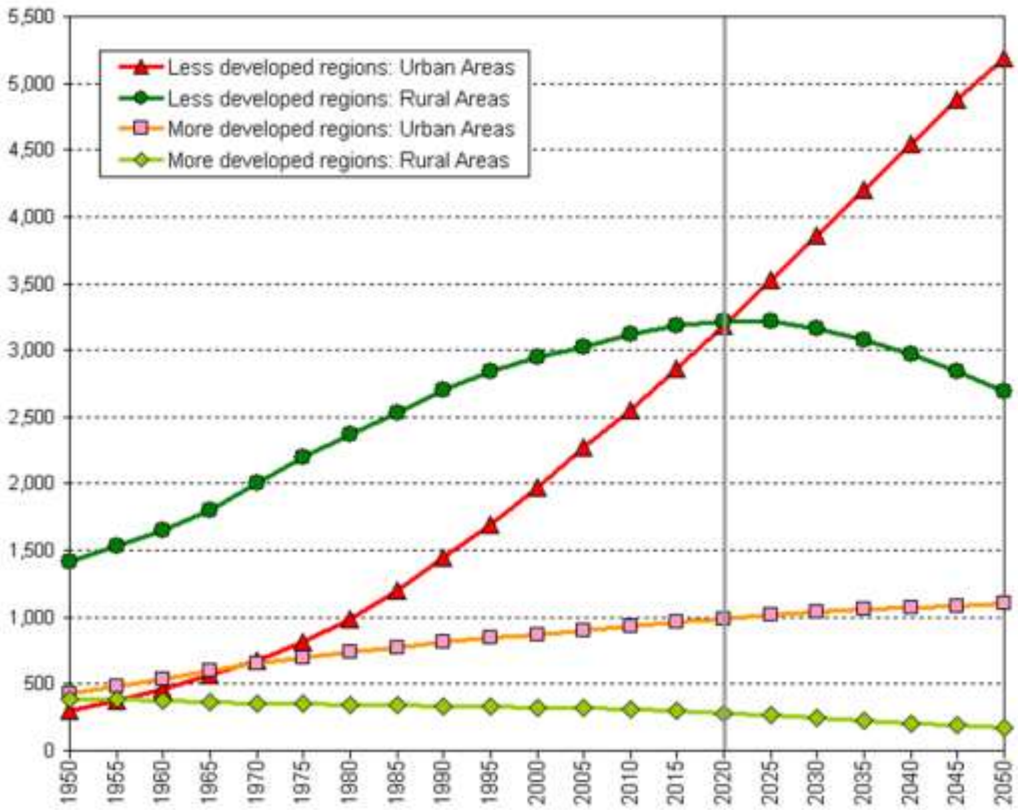

Figure 3. Urban and rural population change for the more developed and less developed regions of the world (in millions) (from the UN, 2006). Beyond 2020, the population of urban areas is projected to exceed the population of rural areas, for the less developed regions.

In the developing world, it is the rural inhabitants who are amongst the most destitute (IFAD, 2001), and it is those living close to the RUI and the peri-urban settlements (Figure 2) who are most seriously threatened by rapid urban growth. For many rural inhabitants, access to a secure source of groundwater provides the only means of escaping abject poverty. Because of its relative ease of extraction, almost ubiquitous extent, negligible treatment requirements, low susceptibility to drought (Calow et al., 2002), and minimal infrastructure costs in comparison to surface water (Llamas et al., 1998), groundwater provides the rural poor with the prospect of generating income as well as meeting domestic needs. At the RUI, the security of essential groundwater supplies is seriously compromised. Rural inhabitants, and particularly the rural poor, face numerous challenges including:

- strong competing demand for groundwater from urban and industrial users including the risk of rapid water level decline due to high-yield municipal wells;
- the threat of groundwater contamination due to urban runoff or leaching of contaminated water from urban pollutant sources such as sewage (Nagaraj, 2005);
- an inability to influence water allocation due to a lack of representation in positions of political and economic power (Torres, 2007; Werna, 1998);

- increased risk to livelihoods from extreme events – droughts and floods, from greater climatic variability and climate change.

1.2 The governance challenge

This thematic paper examines urban-rural tensions and opportunities for co-management. It provides a macro view of how urban-rural tensions develop in various domains and how the development of appropriate structures of governance[2] can reduce conflicts and eliminate, or at least ameliorate, the problem. The role of governance has recently acquired significant meaning and attention within the water sector (World Water Assessment Programme (WWAP), 2003; 2006; 2009). The concept has evolved from a political taboo in North–South development co-operation dialogue to gain wide acceptance as a fundamental issue at global, national and local levels. The framing of water challenges in terms of governance has allowed a broadening of the water agenda to include the scrutiny of democratization processes, corruption, power imbalances between rich and poor countries and between the rich and the poor (Tropp, 2006a). Governance and politics have become recognised as integral components of the water crisis, as well as part of its solution.

Discordance over water is no stranger to the urban environment (e.g. UNESCO, 2006) and the addition of a rural dimension adds an unwelcome level of complexity to the task at hand. Based on studies in India (Janakarajan et al., 2006) conflicts typically arise due to:

- Quantity, with conflicts arising between sectors or users (e.g. agriculture vs. domestic; municipality vs. industries or private users; urban vs. peri-urban or rural);
- Quality, with conflicts arising from the threat of water that is unsafe to drink;
- Access, with conflicts over water rights, price or simply physical accessibility to a water source.

In many respects, the rural-urban interface represents a veritable breeding ground for water conflict as it often forces into co-existence groups with diverse socio-cultural backgrounds and disparate needs and ambitions. Moreover, many of these groups tend to be informal and marginal. They lack community structure, have few legal rights and little or no political representation. As a result they are deprived of institutional support that could respond to their needs.

1.3 Thematic paper approach

The thematic paper comprises three major chapters. Chapter 2 (below) provides baseline information for the paper and describes the existing state of groundwater governance as it relates to the urban environment and urban-rural relationships. The chapter examines the types of tension and conflict that arise over water in urban areas, thereby highlighting the underlying governance issues that must be addressed. In Chapter 3, the tensions and conflicts are analysed in further detail using specific examples from around the world. Here, the objective is to develop an understanding of the extent, nature and root causes of urban-rural tension, and the opportunities to resolve, or at least moderate, the problem through co-operation and good governance. The governance issue is explored in greater detail in Chapter 4 where appropriate models of governance are examined and opportunities for urban-rural co-management of groundwater are discussed. Conclusions are briefly drawn in Chapter 5. The paper draws heavily on material previously published by individual authors and agencies. The sources of this material are provided in the closing bibliography.

[2] *Water Governance refers to the range of political, social, economic, and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society. It comprises the mechanisms, processes, and institutions through which all involved stakeholders, including citizens and interest groups, articulate their priorities, exercise their legal rights, meet their obligations and mediate their differences.*

2 The Baseline

Water issues related to urban growth have been well documented with poor water governance frequently cited as the root cause of the tensions and conflicts that arise. Unfortunately, the vast majority of urban water studies and “in depth” analyses, have considered water management in the broader sense with little effort made to articulate the important distinctions between groundwater and surface water as water supply sources and how such differences must influence water governance. In this chapter (Chapter 2), the relationship between urban water conflict and governance in cities is reviewed, highlighting the particular plight of those living within the rural-urban interface and peri-urban areas.

2.1 Urban water management - a global review

Concern for urban population growth and the need to address increasing demand for water in novel, yet sustainable ways, has been high on the global water sector agenda for more than twenty years. First explicitly embraced in the Dublin Statement on Water and Development (1992), the formidable challenge of supplying rapidly growing cities with adequate supplies of water for drinking and sanitation, has since remained a topic of continuous discourse. It has featured strongly at recent World Water Fora (The Hague, 2000, Kyoto, 2003, Mexico, 2006 and Istanbul, 2009) and has formed a major component of UN World Water Development Reports (WWAP, 2003; 2006; 2009). Between 2002 and 2007, urban water issues were examined in some detail during the 6th Phase of UNESCO’s International Hydrological Programme (IHP-VI Focal Area 3.5 “Urban areas and rural settlements”), and between 2000 and 2010, the protection and management of groundwater in urban areas represented a major focus of the World Bank’s Groundwater Management Advisory Team (GW-MATE) and resulted in numerous briefing notes, case profiles and strategic overviews (see Foster et al., 2010a,; 2010b; 2010c), together with important contributions to the peer reviewed journal literature (e.g. Kemper, 2004; Foster et al., 2011).

The series of urban water projects implemented under UNESCO’s IHP-VI culminated in an International Symposium on “New Directions in Urban water Management” which was held in Paris during September 2007. This meeting concluded with the adoption of “The Paris-2007 Statement on New Directions in Urban Water Management” which contained a summary of its main deliberations and built strongly on the findings of previous World Water Fora and key international conferences e.g. the Beijing Declaration and Platform for Action (UN Fourth World Conference on Women, 1995), the Paris Statement of 1997 (Symposium on Water, City and Urban Planning, 1997), the United Nations Millennium Declaration (2000), the Marseille Statement (UNESCO Symposium on Frontiers in Urban Water Management: Deadlock or Hope?, 2001), the Johannesburg Plan of Implementation (World Summit on Sustainable Development, 2002), the UN CSD-13 policy recommendations on practical measures and options to expedite implementation of commitments in water, sanitation and human settlements (13th session of the United Nations Commission on Sustainable Development, 2005). The Paris-2007 Statement re-emphasised the stress placed on water resources by unprecedented rates of population growth and urbanization, and drew attention to a “widespread crisis of urban water governance, particularly in developing countries”, noting:

- Fragmented institutions (geographically and across different aspects of the water cycle),
- Weak regulatory and institutional frameworks, excessive centralization, an unclear division of responsibilities between the central and local governments, inefficient and outdated management practices, and misguided decision-making due to short-term political or commercial interests that lead to inadequate capacity to address urban water challenges.
- Limited user participation, leading to inequality among the urban population served by water services and an increasing number of urban water conflicts.

The Paris-2007 Statement stressed the need to adopt new approaches to water management in urban areas, approaches that might include:

- Practising the protection and sustainable management of groundwater, as an indispensable source of water supply for a large part of the world’s population.
- Moving away from water-supply management alone to water-demand management.

- Understanding and accounting for the complex socio-economic issues associated with urban water management (e.g. concepts such as social inclusion, affordability, user participation, preferences and acceptability).
- Drawing the distinction between water as a service and water as a resource, especially with respect to understanding conflicts and their resolution (the lack of such a distinction is the root cause of many urban water conflicts and is a key consideration for water rights and allocation issues).
- Adopting an integrated and participatory approach to urban water management by engaging with a wide circle of stakeholders from users (customers) to professionals (planners, builders) through learning alliances where appropriate.

The Paris-2007 Statement concluded that sustainable urban water management should be based on several key concepts, including: 1) enhancing resilience of urban water systems to global change pressures, 2) making interventions over the entire urban water cycle, 3) invoking demand management including a reconsideration of the way water is used (and reused), 4) making more prudent use of existing infrastructure, 5) making more frequent use of local and natural systems, 6) improving governance and financial management structures and 7) promoting more active stakeholder participation. In particular, it was recommended that higher priority be given to the protection and holistic management of groundwater and that technological innovations such as advanced water and wastewater treatment processes, grey water reuse and eco-sanitation be adopted in co-operation with stakeholders who could help overcome technological, institutional, and economic barriers to sustainable water management measures.

The IHP-VI urban water studies also led to a compendium of essays (UNESCO, 2006) that focused on water conflicts in a broad range of urban settings. This work (parts of which are analysed in Chapter 3) found that most urban conflicts involve (Barraqué, 2006):

- Quality/extension of drinking water services and their continuity
- Quality/extension of waste-water collection and treatment
- Urban hydrology problems (storm water control)
- Impact of large cities upon their environment, in particular water resources use and misuse
- Financing of investments issues
- Tariff setting and cost recovery
- Degrees of freedom left to urban dwellers vis-à-vis the services provided.

However, the document also revealed stark differences between developed and developing countries on a range of issues, mostly related to commodification i.e. the commercial character of the service which is widely accepted in the developed world, but is highly contentious in countries where a significant proportion of the population cannot afford to pay for services. Many low and middle income countries were also found to suffer from water scarcity, such that the most common sources of conflicts were:

- Lack of access to clean water sources for the poor,
- Quantities of water available for public services (reallocation issue of water rights), and
- Quality issues that result from either overexploitation or industrial pollution (the decreasing quality of raw water implies growing treatment costs).

The most recent UN World Water Development Reports (WWAP, 2006 and 2009) have continued to blame urban water problems on inadequate water governance, noting that in many cases, corruption[3] has seriously undermined efforts to improve governance systems. Within public service institutions for water, corruption remains one of the least addressed challenges. Frequently ignored and tacitly accepted, corruption was once seen as a 'necessary evil' that could on occasion 'grease the wheels' of development efforts (Tropp, 2006b). Today corruption is seen as a

[3] *The United Nations Development Programme (UNDP) defines corruption as 'the misuse of public power, office or authority for private benefit – through bribery, extortion, influence peddling, nepotism, fraud, speed money or embezzlement. Although corruption is often associated with government and public servants, it also prevails in the private sector'. Corruption concerns not only the exchange of money and services, but also takes the form of cronyism, nepotism and various kinds of return for favours (Transparency International, 2004; UNDP, 2004).*

scourge that must be defeated (Stalgren, 2006). It can be manifest in many different ways and its scale may vary substantially across types of water practices and governance structure according to the perceptions and moral values of actors involved. However, the negative consequences of corruption are unequivocal (UNDP; 2004; Tropp, 2006b):

- It reduces economic growth and strongly discourages water sector investments.
- It undermines the performance and effectiveness of both the public and private sectors, leading to inefficient and unequal allocation and distribution of water resources and related services.
- It decreases and diverts government revenues that could be used to strengthen budgets and improve water and other services, especially for poor people.
- It breeds impunity and dilutes public integrity. It renders rules and regulations ineffective, often leading to uncontrolled water pollution, overpumping and depletion of groundwater, lack of planning, degradation of ecosystems, and unrestrained urban expansion leading to heightened water tensions. Discretionary powers and uncertainties in policy and law enforcement create unpredictability and inequalities and can also lead to complete circumvention of the rule of law and justice system.

Corruption is symptomatic of poor governance. It is also a primary reason why reforms of governance systems have been slow to materialise and gain acceptance.

2.2 Incorporating the special and unique attributes of groundwater

Another important impediment to the reform of urban water governance has been a systemic failure to acknowledge the special and unique attributes of groundwater, attributes that demand special attention when it comes to water management. Groundwater and surface water derive from the same atmospheric source (precipitation), and are indistinguishable when they emerge from a pipe in the home, factory or farmer's field. However, that is where the similarities end. Although they share the same water cycle, groundwater and surface water behave on very different spatial and time scales (Table 2) and require approaches to resource management that are quite distinctive (Theesfeld, 2010) and rarely fully understood. In terms of this paper, the challenge is to ensure that the special and unique attributes of groundwater are adequately appreciated and appropriately acknowledged in models of urban water governance.

Table 2. Essential differences between surface water and groundwater (modified after Puri and Naser, 2003).

Rivers	Aquifers
Long, linear features.	Bulk 3-dimensional systems.
Use of resource either limited to close to the river channels or requires transport via pipeline.	Aquifers naturally convey resource to within one well's length of users.
Replenishment always from upstream sources.	Replenishment may take place from any or all directions.
Rapid and time limited gain from replenishment. Limited storage – prone to drought.	Slow response to replenishment. Very large natural storage allowing net gain to be drawn upon over long time period. Resilient to drought.
Little opportunity to manipulate storage within river body.	Unlimited opportunity to manipulate storage in aquifer body.
Abstraction has an immediate downstream impact.	Abstraction impact in any or all directions and slowly manifest over years and decades.
Little impact on upstream riparian.	May have an equal impact on both upstream and downstream riparian.
Pollution impacts transported downstream rapidly (order of metres per second).	Very slow movement of pollution (order of metres per year).
Pollutant transport invariably downstream, upstream source may be unaffected.	Pollutant transport controlled by local hydraulics. An operating well may induce upstream movement of pollution towards itself.

Groundwater represents, by far, the world's largest and most ubiquitous source of fresh, accessible water. It therefore comes as no surprise that many of the world's most populated cities can attribute their early origins to the good quality groundwater obtained from shallow private wells. Where available, groundwater is generally favoured over surface water since it is well protected from surface contaminants, is less susceptible to drought and climatic variability and can be introduced incrementally, one well at a time, to meet growing private, municipal and industrial demand with minimal upfront capital expenditure. Research has shown that most urban areas evolve

through a series of distinct stages as they gradually age (Morris et al., 1997). Associated with these stages are developments in infrastructure, most notably related to water supply systems and sanitation. The early stages begin with the village or small settlement that gradually grows into a market town (Barrett and Howard, 2002). Subsequent stages include rapid industrialisation and urbanisation, which is followed by suburbanisation as the population becomes decentralised. During early stages of development, water is normally supplied by shallow, unplanned private wells in a generally central location; on-site sanitation is the primary method of disposal for human waste. As growth accelerates, the settlement commonly experiences severe degradation of shallow groundwater quality associated with a slow decline of water levels, conditions observed in many emerging cities today. Deeper wells, initially for municipal use and later for industry often provide a temporary solution, but eventually there is a shift towards new supply wells developed in increasingly remote peri-urban areas (Morris et al., 1997) (Figure 4). At this stage, the city has become a major net importer of water.

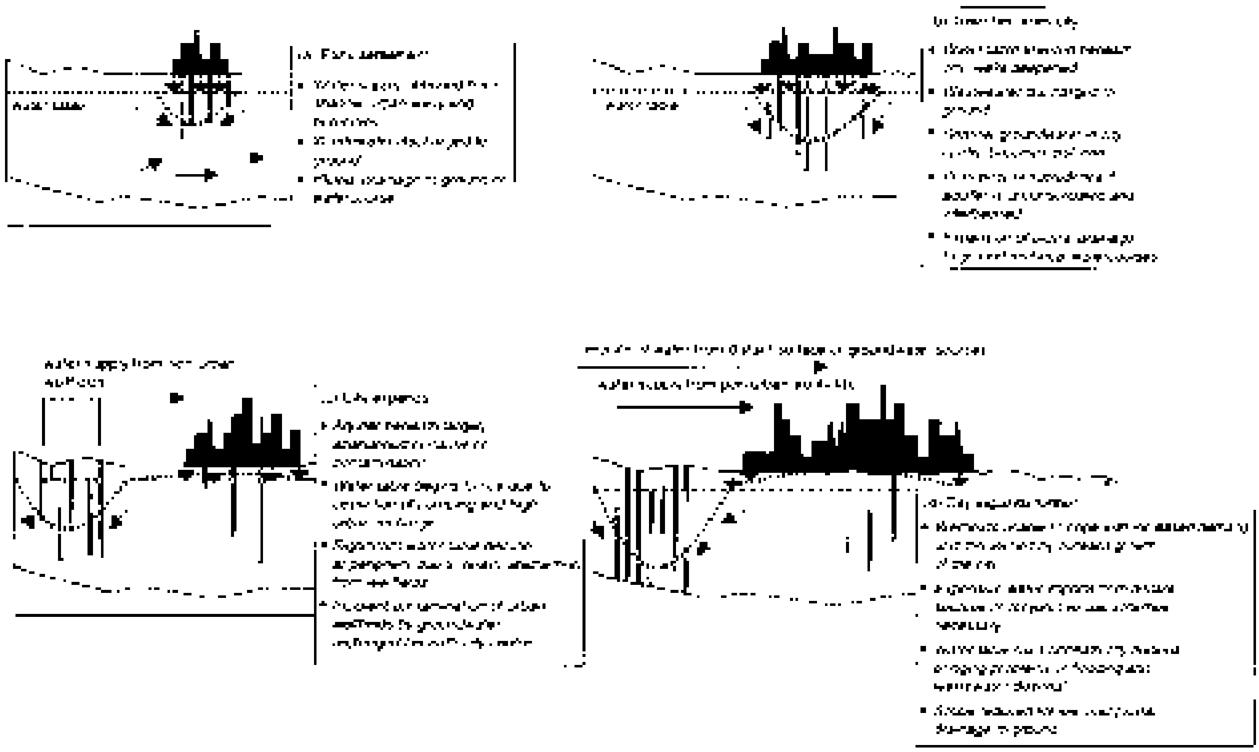

Figure 4. The role of groundwater during the evolution of a city (from Barrett, 2003, after Morris et al., 1997 and Foster et al., 1998).

Most mature cities eventually go into industrial decline and enter a post-industrial stage. The combination of declining industrial demand for groundwater with additional aquifer recharge due to the leakage of imported water from reticulation systems causes water levels to rise throughout central parts of the city. Pumping may be required to resolve the problem, but since the groundwater quality is poor, the well discharge must be directed to waste. Meanwhile, escalating demand for potable supplies means that water levels in peri-urban and rural areas remain seriously depressed. As observed by Barrett and Howard (2002), many of the problems reflect a lack of hydrogeological understanding and poor long-term planning. Most cities import, store, and generate enormous amounts of potentially, water-contaminating chemicals (Figure 5) and the density of water quality monitoring wells is rarely sufficient to provide early detection of contaminants that migrate orders of magnitude more slowly in aquifers than they do in surface water courses. Volatile organic compounds from leaking underground storage tanks represent the greatest cause of groundwater quality degradation in the more prosperous cities, while faecal pathogens, nitrogen compounds (usually nitrate) and dissolved organic carbon (DOC) are the primary water quality concerns in cities of the developing world due to the close proximity between wastewater handling, disposal or reuse facilities and the underlying phreatic aquifer (Foster, 1990; Morris et al., 1997) (Figure 6). Across the globe, widespread contamination of shallow urban groundwater (Howard and Gelo, 2002; Howard and Israfilov, 2002; Lerner, 2003) and the subsequent under-utilization of the urban groundwater resource provides clear evidence of a failure in resource management (Barrett and Howard, 2002). As recognised by Morris et al. (2002), a particular

problem in emerging nations is the ability to develop and enact management policies within the limited financial and institutional resources typically available to those responsible for planning and managing the urban water infrastructure.

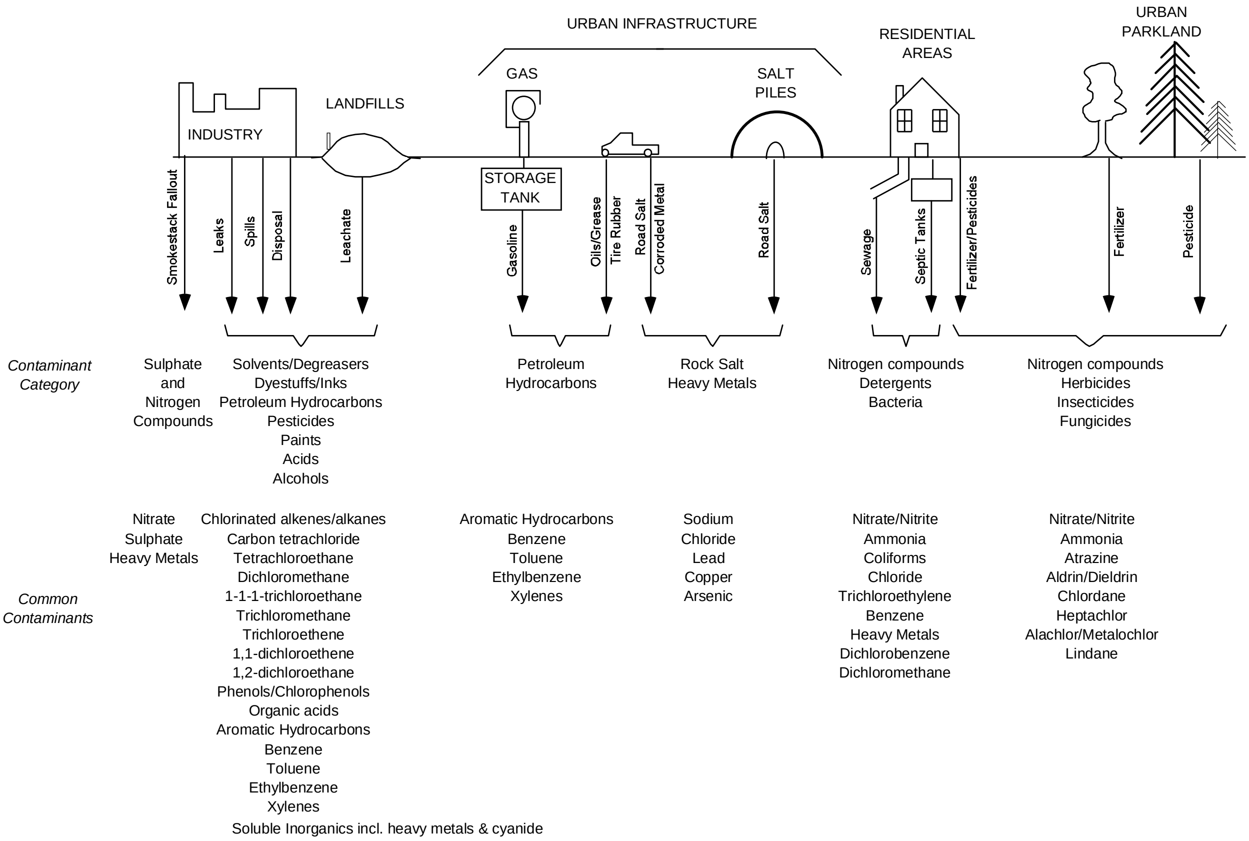

Figure 5. Sources of groundwater contamination in urban areas (from Howard, 1997).

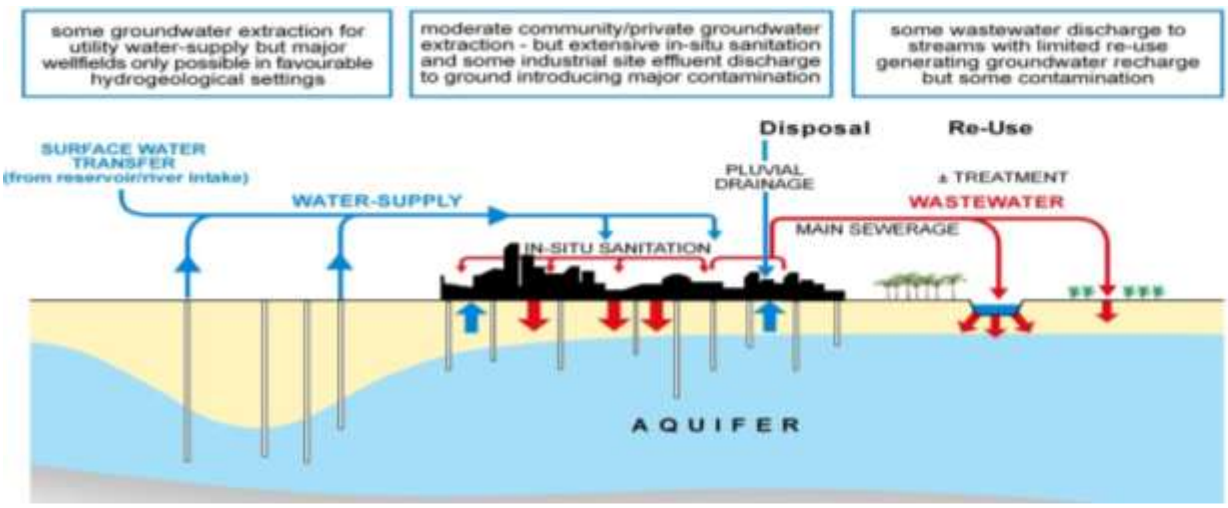

Figure 6. Unconfined groundwater and the man-made urban water cycle in developing cities.

Despite the enormity of the urban groundwater problem, there remain good reasons for cautious optimism. Issues related to urban groundwater are clearly complex and the science of urban groundwater is extremely young when compared to its surface water counterpart. Nevertheless, much has been learned about the impacts of urban development on groundwater during the past 40 years, and that knowledge is gradually being incorporated into the urban planning and groundwater management process. For example, excellent progress has been made on:

- Understanding sources of urban recharge and quantifying components of the urban water balance;
- The development of novel techniques for augmenting aquifer recharge;
- Pollutant source characterization, mechanisms of contaminant release and the behavior of contaminant plumes;
- Disposal methods for all types of domestic and industrial waste;
- Approaches to monitoring;
- Aquifer vulnerability mapping and methods of groundwater protection, and
- Identifying opportunities for integrated / conjunctive use of ground and surface water sources.

In addition, there have been major advances in the development of computer model codes, many of which link seamlessly with urban database systems for the purposes of:

- Performing urban water budget assessments;
- Providing three-dimensional, transient simulations of the aquifer systems;
- Identifying "ZOCs – zones of contribution" - areas around production wells that require special attention in terms of aquifer protection;
- Conducting aquifer susceptibility and vulnerability assessments;
- Predicting groundwater travel times and eventual fate for contaminants in the system;
- Determining "optimal" pumping and water extraction rates and, most importantly;
- Testing and evaluating alternative water management scenarios, and thus supporting pro-active decision-making.

Some of these urban groundwater models (e.g. Howard and Pokrajac, 2011) acknowledge the importance of the entire urban water cycle and can simulate the interactions that take place between groundwater, surface water and the complex network of water services including sewers and pressurised water supply systems.

In conclusion, the science is well advanced and the technology is strong. What is lacking is the structured framework of good governance that can fully exploit these major scientific and technical achievements. More importantly, governance structures are required that appropriately recognise the essential differences between groundwater and surface water, differences that can have very serious implications for water management policy.

2.3 Urban water issues at the rural-urban interface and peri-urban fringe

In recent years, an increased focus of attention on urban water issues related to urban population growth has drawn greater attention to areas at the urban-rural interface and within the peri-urban fringe, areas where much of the growth takes place. As a compounding issue, changing patterns of rural-urban integration in these areas (IFAD, 2011) provide an additional level of complexity to the water management problem.

Urban areas represent the engines of the world's economy, generating enormous benefits by concentrating human creativity and providing infra-structure and a workforce for intensive industrial and commercial activity. Urban growth brings new markets and increased human capital and opportunities for greater wealth and prosperity. Over the long term, cities will be the principal source of future economic development, but along with such promise comes immense challenges, notably in the form of concentrated poverty in largely peri-urban settlements characterized by squalid, sub-standard with no security of tenure (i.e. "slums") (Black, 1994). Some peri-urban slums house as many as 70 % of the city population.

Slums result from a noxious combination of weak governance, underinvestment in basic infrastructure, poor planning to accommodate growth, infrastructure standards that are unaffordable by the poor, and insufficient public transportation that limits access to employment. Left unaddressed, urban slums threaten both national and international security, human health, and environmental sustainability. Most slum dwellers have low social status, low self-esteem and little or no representation and influence at levels of political power.

Peri-urban slums areas are frequently neglected by city planners. Most are unregulated and poorly serviced, and water quality degradation due to uncontrolled disposal of industrial, domestic and human waste is widespread. The majority of large cities enjoy the benefits of at least some water and sanitation infrastructure in their central areas, and in many cases, this is being improved and expanded by private companies or public utility commissions (PUCs), both of which can expect significant cost recoveries in the form of tariffs or taxes. Peri-urban slums seriously lack comparable infrastructure and services and are frequently forced to use water sources that are unsafe, unreliable and sometimes difficult to access on a regular or continuous basis. Sanitation, where available, tends to be limited to latrines that are often shared with so many others that access and latrine cleanliness is difficult. Unsafe drinking water and inadequate sanitation have dire implications for human health, particularly the health of children and the elderly.

As a further complication, urban encroachment onto fertile agricultural areas inevitably leads to the decline and/or displacement of peri-urban farmers who find that the scarcity of farmland is matched only by the scarcity of affordable freshwater for irrigation. In response, the peri-urban farmer often turns to urban wastewater (both treated and untreated) as the only reliable means of irrigating crops and maintaining a livelihood. Wastewater flows are typically more reliable than freshwater sources and are rich in the nutrients required for the cultivation of high-value crops. Unfortunately, the widespread use of wastewater has obvious implications for the edibility of crops sold at the market; moreover, the use of wastewater for irrigation seriously threatens the potable quality of shallow groundwater supplies. Authorities are also concerned that the seemingly beneficial, environmentally “green”, re-use of wastewater presents obstacles to installing wastewater treatment plants.

Assessing the risks associated with wastewater use is often difficult, as any enforcement of water quality standards is often complicated by ambiguous lines of authority; for example, should standards be enforced by health, agricultural or water supply and sanitation agencies? Consequently, its use is largely unregulated. A nationwide survey in Pakistan (WWAP, 2006) showed that approximately 25% of all vegetables are irrigated with untreated urban wastewater and that such vegetables, usually cultivated close to the urban markets, were considerably cheaper than the vegetables imported from more remote regions of Pakistan (Ensink et al., 2004). Similarly, 60% of the vegetables consumed in Dakar, Senegal are grown within the city limits using a blend of groundwater and untreated wastewater (Faruqui et al., 2004).

2.4 The role of policy reforms

It would be remiss to evaluate global efforts to supply water to rapidly growing cities without considering the major reforms of water service that have taken place across the world during the past 20 years or more, primarily the result of various political and economic pressures. Prior to the 1990s, water industries in most countries operated as national monopolies. Since then, many countries have moved to introduce “decentralised” systems of water service, often with varying degrees of success. For example, several Asian countries, including Indonesia, Pakistan and the Philippines, embarked upon radical decentralization programmes (WWAP, 2009) and, in many Latin American countries (e.g. Argentina, Chile, Colombia, Panama and Peru) national monopolies were sub-divided into hundreds of municipal providers as part of a wider process of devolution across all areas of government. Rapid decentralization also took place in Eastern Europe and Central Asia following the political turnaround that devolved responsibilities to lower tiers of government. However, the “purse strings” have stayed mainly at the central level, a problem that is not uncommon for countries that choose to decentralize and devolve. In Africa, where only Tanzania and Ethiopia have chosen to decentralise rapidly, Ethiopia is running into problems because the transfer of important decision-making responsibilities to district and village levels has not been followed by the transfer of funds for capacity development.

In general, decentralization has not been a considered response to the specific water sector problems, but is more the consequence of wider national reforms. As a result, local governments often found themselves responsible for providing water service while lacking the capacity to deliver. Private sector involvement has had limited success. In larger urban centres this has been primarily for political reasons, while in smaller cities and rural areas, economic

viability is an additional problem. Thus, the real transition for most water consumers has not been from public to private, but rather from unregulated centralized public provision to regulated decentralized public provision. Today, most urban and peri-urban areas in the world are served by publicly owned and managed utilities, a model that is likely to continue (WWAP, 2009). In many developing countries, the performance of public utilities is often constrained by low motivation, poor management, inadequate cost recovery and political interference. The lack of public sector reform can be a serious obstacle to sustaining and increasing coverage and service. A particular challenge is to encourage public sector utilities to extend services to informal urban settlements (mostly slum areas) where cost recoveries tend to be low. Remarkably, good success can be achieved in such situations by partnering with local community groups or supporting private sector initiatives. For example, new contractual approaches have been developed in Paraguay, for example, to target the increased involvement of *aguateros* (mostly small-scale water companies), that have developed piped water supplies in peri-urban areas without public funding. These *aguateros* can now legally take part in public bidding processes, and their performance can be monitored, thus improving accountability.

2.5 IWM, IWRM, IUWM and the role of groundwater

Integrated Water Resources Management (IWRM) together with its similarly motivated sister water management principles (IWM - Integrated Water Management and IUWM – Integrated Urban Water Management) was first promoted by the United Nations in the 1950s. IWRM principles featured strongly at the United Nations Water Conference, held in Mar del Plata, Argentina, in March 1977 but the concept did not enjoy any serious traction until the 1990s when the principles of IWRM began to be endorsed by numerous international institutions.

IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000). Operationally, IWRM (and similar approaches) involves the application of knowledge from a range of disciplines, together with the insights from stakeholders, to develop and deliver efficient, equitable and sustainable solutions to the world's water problems. It can be described as a comprehensive tool for managing, developing and delivering water to consumers in a way that is socially, economically and environmentally responsible.

The IWRM model has enjoyed considerable acclaim. It has been adopted as a pre-requisite for compliance within the European Union's Water Framework Directive of 2000, and has provided guidance for subsequent EU water development programs such as the EU Water Initiative. Moreover, IWRM's open, multi-stakeholder approach to water management is undoubtedly the primary reason that the role of governance in water issues has achieved global attention. That said, IWRM is not a panacea for the world's water problems and has, from a purely practical standpoint, done little more than raise awareness for the complexity of urban water problems and point those responsible for solving such issues in more productive directions. While IWRM's primary attribute is its demand that global water issues be approached holistically, the number of factors that need to be considered and "integrated" is so large that practical implementation is impossible unless the list is strongly redacted. Herein, serious problems arise. According to Biswas (2008), the application of IWRM to real world water projects has left much to be desired. At a scale of 1 to 100 (1 being no integrated water resources management and 100 being full integration) Biswas suggests that there isn't a project in the world that would earn a score of 30 or more from an objective analyst.

In effect, the success of IWRM as a practical tool depends heavily on the factors selected for "integration" i.e. which are listed and which are omitted. Since the term "water" includes both ground and surface water sources by implication, it is generally assumed that groundwater and the role of aquifers are automatically included within IWRM's process of integration. In practice, nothing could be further from the truth. Debates on global water policy that rage at international water fora remain largely transfixed on surface water issues. For the most part, very little recognition or weight tends to be given to the vital function that groundwater plays in the global water cycle and the immense benefits that could be derived from the improved management of groundwater. A failure to recognise the unique and special attributes of groundwater represents one of the lost opportunities of IWRM.

2.6 Policy issues arising from current trends of urban groundwater use in developing cities

There is considerable evidence to suggest that dependence on groundwater for water-supply is increasing in developing cities (Foster et al., 2011). This is occurring in response to:

- population growth,
- increasing per capita use,
- higher ambient temperatures and
- reduced security of river-intake sources due to quality degradation and climate change.

The growth is facilitated by the generally modest cost of waterwells and the fact that aquifers lie within a well's length of users (Foster et al., 1998). It is estimated that over 1.5 billion urban dwellers worldwide currently rely on groundwater (Foster et al., 2010b).

Where urban centres are underlain and/or surrounded by high-yielding aquifers, this has allowed water utilities to expand mains water-supply incrementally at modest capital cost—usually resulting in better mains water- service levels, lower water-supply prices and less private in-situ use. However, there are rarely sufficient groundwater resources within urban areas themselves to satisfy municipal water-supply demands and resource sustainability (both quantity and quality) often becomes an issue.

The growth in urban groundwater use is not restricted to cities with ready access to high-yielding aquifers (from which major utility water-supplies are drawn), but also widely occurs where the utility water-supply is imported from considerable distance (usually from a surface water source). In such cases, private in-situ waterwell construction has often flourished due to inadequate (present or historic) municipal water-service levels and/or high water prices. For example (Foster et al., 2010b):

- In Brazil many cities experienced major private water-well drilling 15–20 years ago, in response to water-supply crises during extended drought, but such water wells continue because they provide a lower-cost water supply.
- In Sub-Saharan Africa, despite much higher unit costs of drilling, water wells (for direct water collection or reticulation to standpipes) are widely the fastest growing source of urban water supply in the struggle to meet escalating demand.
- In Peninsular India, water well use for urban residential self-supply is ubiquitous in the face of very poor utility water services (often 1-in-24 hours or less) and greatly reduces dependence on expensive tankered water supplies.

In terms of water management policy, an immediate issue concerns the relative benefits and risks of in-situ residential use (Table 3) and how this can be regulated given that many wells are technically illegal. In the developing world, in-situ private self-supply from groundwater widely represents a significant proportion of water actually received by users (Foster et al., 2011), and its presence, while impossible to quantify reliably, has major implications for municipal water utilities. The initial motivation for the private capital investment in self-supply is usually triggered during periods of partial failure or highly inadequate municipal water-supply service—essentially as a coping strategy. However, continued use is essentially a cost-reduction strategy, since the actual (or perceived) cost of in-situ groundwater is lower than that of the applicable municipal water-supply tariff. In some cases, the initial investment itself is justified by cost reduction, where water well capital costs are modest when compared to cumulative municipal water-supply tariffs.

The other major policy issues relate to municipal groundwater use (Table 4). They include (Foster et al., 2011):

1) Integrating groundwater into infrastructure decision-making

   A more integrated approach to municipal water-services and urban development is required to avoid persistent and costly problems – and this must include consideration of groundwater sustainability,

especially where local aquifers are providing an important component of municipal water-supply. In developing cities, a frequent concern is that too much public water-supply abstraction is concentrated within urban municipal limits, leading to deep unstable cones of piezometric depression and causing secondary problems (induced pollution of contaminated surface water, saline-water intrusion and land subsidence). Given the dynamic nature of groundwater in urban areas, it is appropriate to take an adaptive approach to resource management that is guided by predictive groundwater flow models and fine-tuned on the basis of data continuously collected from a network of monitoring wells (water levels and water quality). In the long-term, sustainable municipal water supply solutions will likely involve:

- The conjunctive use of groundwater and surface water resources (Paling,1984);
- Aquifer recharge enhancement using stormwater infiltration techniques (Ward and Dillon, 2011) designed to minimise groundwater pollution risk;
- Greater efforts to reduce distribution losses

An adaptive management approach (NRC, 2004; Gleeson et al., 2012) is essential, as the predicted impacts of pumping are never completely reliable, and management plans will always require at least minor refinement. A particular concern in urban areas is that relatively small operational changes in the wellfield may lead to water-table rebound and the risk of damage to urban infrastructure and sanitation systems.

2) Proactive land-use management to reduce groundwater pollution threats

To control or reduce the pollution threat to municipal water wells, it is essential to take a proactive approach on urban land use involving:

- Prioritising recently urbanised areas for coverage by mains sewerage or limiting density of new urbanisations with in-situ sanitation to contain nitrate contamination to tolerable levels;
- Establishing municipal water-well protection/exclusion zones around any municipal sources that are favourably located to take advantage of parkland or low- density housing areas;
- Using groundwater pollution hazard assessments to identify municipal water wells with an especially high risk of contamination from toxic synthetic organic substances;
- Avoiding the creation of 'upstream' polluting discharges and making the best 'downstream' use of wastewater without compromising groundwater quality in existing municipal water wells and wellfields (Foster and Chilton 2004).

3) Development of protected 'external' municipal wellfields

Cities dependent upon groundwater for municipal water supply widely encounter problems of increasing and/or elevated concentrations of residual persistent urban contaminants (notably nitrate). The most cost-effective way of dealing with this type of problem is by dilution through mixing (i.e. blending) , which requires a secure and stable source of high-quality supply such as that produced from a suitably located and carefully protected 'external wellfield'.

In the developing world, the promotion of external well- fields often encounters impediments related to fragmented administrative powers for land-use and pollution control between the major actors. The problem is especially difficult where the needs of a growing urban area conflict strongly with agricultural interests. There are no established procedures or incentives for the resource interests of an urban municipality to be assumed and maintained by a neighbouring rural municipality, such that adequate protection can be offered for the capture area of the external wellfield.

Table 3. Advantages and disadvantages, from a public administration perspective, of urban private, in-situ residential water supply from groundwater (Foster et al., 2011).

Pros	Contras
Greatly improves access and reduces costs for some groups of users (but not directly for the poorest because without help they cannot generally afford the cost of water-well construction).	Interactions with in-situ sanitation can cause a public-health hazard and could make any waterborne epidemic more difficult to control.
Especially appropriate for 'non quality-sensitive' uses—could be stimulated in this regard to reduce pressure on stretched municipal water supplies.	May encounter sustainability problems in cities or towns where principal aquifer is significantly confined and/or mains water- supply leakage is relatively low.
Reduces pressure on municipal water-utility supply and can be used to meet demands whose location or temporal peaks present difficulty.	Can distort the technical and economic basis for municipal water- utility operations, with major implications for utility finance, tariffs and investments.
Incidentally can recover a significant proportion of mains water-supply leakage.	

Table 4. Summary of major policy issues related to urban municipal groundwater use (from Foster et al., 2011).

Issue	Implications
Municipal water-supply benefits and risks.	Groundwater use for municipal water supply has many benefits (including capacity to phase investments with growth in demand and high quality, requiring minimal treatment), but it comes with a need for integrated planning of urban land use, effluent discharges and solid-waste disposal to avoid insidious and near-irreversible pollution.
Protected municipal wellfields.	Since some degradation of groundwater quality in urban municipal water wells due to persistent pollutants is likely, it is necessary, in parallel, to develop 'external wellfields' and declare their capture areas as 'protected zones' to guarantee that a proportion of the total resource is of high quality and available for dilution or substitution, and keep them protected as urban area expands
Conjunctive use with surface water.	The rates of replenishment of aquifers may not be sufficient to meet the demands of larger cities sustainably and in this situation it is preferable to use available groundwater resources and large storage reserves conjunctively with surface-water sources, thereby conserving groundwater for use during drought and other emergencies.
Future drainage problems.	Avoiding radical reductions in municipal water-well use (due to an increased offer of subsidised mains water supply or to quality deterioration/pollution rumours) with water-table rebound (to higher than the pre-urbanisation condition), which could result in potentially serious sanitary problems and infrastructure damage in lower-lying areas.

Clearly, solutions are available to deal with important planning issues as they relate to groundwater. The overriding challenge is to provide a framework for water governance in urban areas that can facilitate action on these solutions. For example (Foster et al., 2010a):

- In urban environs land-use classification and control are generally the domain of municipal or local government, and the absence of mechanisms whereby water resource agencies can influence the process is a frequent governance weakness.
- In many developing countries, legislation to cope with undesirable land-use practices is often weakly enforced or even non-existent and progress with implementing controls in the interest of groundwater are highly dependent upon stakeholder awareness and participation.

In Chapter 3 (the Thematic Diagnostic - below) we conduct a more detailed analysis of governance issues by reviewing water-related problems in cities where groundwater plays a major role. The findings of this analysis are carried through to Chapter 4 where appropriate models of urban water governance are identified and discussed.

3 Thematic Diagnostic

The purpose of this chapter is to provide a closer examination of how water governance (or the lack of it) influences the management of groundwater in and around cities. Recognising that a complete and thorough review of the all the world's cities lies well beyond the scope of this paper, preference is given to cities that can provide insight to the types of urban groundwater issue that commonly lead to tensions and conflict. In total nine cities are considered. They include Mexico City (3.1), Taiz (Yemen) (3.2), Delhi (3.3), Chennai (formerly Madras) (3.4), Fortaleza (Brazil) (3.5) and Cochabamba, Bolivia (3.8) where groundwater problems remain largely unresolved, and Narayanganj (Bangladesh), Bishkek (Kyrghyzstan) (3.6) and Bangkok (3.7), where important progress is being made. The various successes and failures provide a valuable insight to the opportunities for urban groundwater management and how good governance can be achieved. A particular feature of these case studies is that they illustrate the human dimension of the management problem and the role individual consumers can and must play in the pursuit of sustainable solutions.

3.1 Mexico City

The Mexico City Metropolitan Area (MCMA) (pop. 21.2 million) enjoys one of the highest coverage levels of water supply and sewerage in the country (Castro, 2006). The average Mexico City resident uses 300 litres of water each day which far exceeds the internationally accepted standard of 100 liters to cover essential household needs. Despite calls for demand management, water remains highly subsidized with only 5% of the water supply cost recovered (Castelan, 2001). In reality, the 300 litre "average" likely includes the 30-40% of this water that is "lost" via leaky reticulation systems. It also conceals the fact that individual use varies from as much as 600 litres per day in richer parts of the city, to just 20 litres per day in poor areas. Since the 1980s, the MCMA and surrounding areas have seen recurrent social conflicts sparked by water service issues. Problems in the region include groundwater overexploitation, land subsidence, the risk of major flooding, poor water quality, inefficient water use, very limited wastewater treatment, and health concerns about the reuse of untreated wastewater in agriculture.

Reliable data are difficult to obtain. However, the MCMA appears to derive around 70% of its water from the severely over-exploited local aquifer system (over 45 m^3/s pumped for municipal use compared to a natural recharge of about 20-25 m^3/s). The remaining water needs are imported. Around 15 m^3/s are obtained from the Cutzamala river basin to the west, a transfer that is energy-intensive as it requires a vertical lift of over a 1000m. A very important issue that had not been resolved concerns the compensation of communities that were resettled due to the construction of the Cutzamala project (Tortajada, 2006). Just as contentious is the 6 m^3/s of groundwater that is imported from the Lerma basin, a distance of about 60km to the west of the city. The project began in 1942 with delivery $4m^3/s$ and this was increased to $14m^3/s$ between 1965 and 1975. The supply was scaled back to 6 m^3/s due to environmental impacts and social conflicts. Overexploitation of the aquifers in the Lerma area reduced the fertility of the soils, and many lands supporting irrigated crops were reverted to rain-fed agriculture with little consideration of compensation to farmers. More recently, a newly planned diversion of water from the Temascaltepec basin (5 m^3/s) has stalled (Molle and Berkoff, 2006) due to fierce resistance from farmers who fear that tunnel construction will dry up springs (El Naranjo, La Huerta, El Sombrero y El Chilar) and affect agricultural production (predominantly maize, sugar cane, banana, tomato, melon and peas).

The challenges for Mexico City remain enormous as serious interruptions in water supply would be viewed as a national crisis that could readily destabilise the federal government. Overcoming these challenges is made particularly difficult by the highly fragmented institutional arrangements for water management with various, and sometimes overlapping, responsibilities distributed across all levels of government. These include:

1) the Federal government and its National Water Commission (Comisión Nacional del Agua (CNA) which is responsible for regulating the use of water resources, financial investment, and the import of bulk water from neighbouring basins;

2) the State of Mexico, which supplies bulk water, treats wastewater and assists municipalities with water and sanitation services in the part of Greater Mexico City that lies within the State of Mexico;
3) 59 municipal governments and one municipality in Hidalgo State individually responsible supplying water distribution and sanitation services to their local constituents;
4) the water department of the MCMA's Federal District which is in charge of water distribution and sanitation for its local jurisdiction; and
5) two irrigation districts in Hidalgo state who take responsibility for irrigation using the city's wastewater.

In 2007, the Federal Government, the State of Mexico and the Federal District attempted to overcome these institutional barriers to effective water management by launching a US$2.8 billion Water Sustainability Program. The aims of this program were to minimise the risk of major floods, treat all collected wastewater and reduce groundwater overdraft. At the same time, the government of the Federal District launched a 15-year "Green Plan" with water conservation as its central theme. The plan included measures to increase aquifer recharge through land use controls and recharge wells, the construction of tertiary wastewater treatment plants that would allow treated wastewater to be used for aquifer replenishment, eradication of illegal connections and the installation of water meters that would ensure all users paid for the water they used. While these measures were expected to reduce groundwater abstraction in Greater Mexico by 10% and the overdraft by 25%, additional measures would be required to balance abstraction with aquifer recharge.

Any hope that the water situation will improve for the city of Mexico seems to be stifled by Jordan et al. (2010) who suggest that the complex administrative structure with competing jurisdictional interests, remains a major obstacle towards any significant progress.

3.2 Rural-urban transfers of groundwater in Taiz, Region, Republic of Yemen

Yemen (pop. 24.3 million) is the poorest country in the Middle East with a 35% employment rate and dwindling natural resources. The modern Republic of Yemen formed in 1990 when traditionalist Islamic North Yemen and Marxist South Yemen merged after years of cross-border conflict. However, serious tensions remain with southerners complaining that northern part of the state is economically privileged. Widespread corruption is a major obstacle to development in the country, limiting local reinvestments and driving away regional and international capital.

With renewable water resources of only 125 cubic meters per capita/year Yemen is one of the most water-scarce countries in the world. Today, there are probably as many as 70,000 wells in Yemen, the majority of which were drilled without license and are under private control. Since 90% of water withdrawals are used for agriculture, issues related to land and groundwater governance are a common source of conflict. Inadequate legislation and ineffective institutions heighten the problem. According to the Yemeni Constitution, surface and groundwater resources are communal property, which is consistent with customary Islamic principles of water management.

Taiz (pop. 600,000) is a city in the Yemeni Highlands, lying at an elevation of about 1,400 metres above sea level. After the capital Sana'a and the southern port of Aden, it is the third largest city in Yemen, and like most Yemeni cities it has a highly unreliable water supply. Increasing numbers of people have to rely on more costly water supplied by rural private wells and imported by water tanker. The quality of this water is questionable because these tankers are used for many other purposes.

During the late 1990's efforts have been made by the National Water Resources Authority (NWRA) to improve the water supply for Taiz by implementing a system of water transfers from rural to urban communities. Key features of this system included both demand management measures (such as input taxation and public education campaigns) and social measures (through a regime of tradable water rights). The water transfer system was developed over a period of several years in close consultation (and often in heated debate) with the local rural communities, particularly farmers, who traditionally have little faith in government institutions. The process was considered as a

valuable opportunity for confidence-building and special efforts were made to avoid any breakdown in the dialogue. As an end result, the communities agreed that rural-urban transfers should proceed according to the following key principles (UNDESA, 2002, WWAP, 2003):

- There should be clearly defined rights, taking into account ethical considerations such as priority for drinking water needs.
- Except for water needed for drinking and basic needs, water should be allocated through market-like processes. Water rights should be tradable and, to the extent possible, there should be direct compensation for individuals willing to transfer their water rights to others, which is commensurate with the rights transferred.
- Water transfers should be verifiable. Those who agree to transfer their water rights must reduce their water use accordingly.
- The local communities should participate in designing the rules and mechanisms to govern rural-urban transfers, including a mechanism for monitoring compliance and punishing violators.
- NWRA should have an oversight role in rural-urban transfers to ensure resource sustainability and equity.

3.3 Access to potable water supplies in the National Capital Territory of Delhi, India

Most cities in India face a severe scarcity of water, a problem that is seriously compounded by population growth. Much of the growth takes place in peri-urban areas where land is rapidly consumed by unplanned urban housing, industrial premises and disposal sites for urban waste (both solid and liquid). Very little effort is made to provide basic water services to these areas and this frequently results in unplanned and unregulated exploitation of groundwater, mostly by private operators (Janakaranjan, 2005). In many respects the problems are more severe in the cities sited on the low-storage hard-rock aquifers of peninsula India than they are in cities and large towns on the Indo-Gangetic floodplains. For example, Lucknow City (pop. 2.9 million) is situated on the Central Ganga alluvial plain, and has access to thick, productive alluvial sand aquifers such that water scarcity is more related to the city’s ageing, leaking, and regionally inefficient water distribution system than it is by resource availability constraints (Foster and Choudhary, 2009).

In the National Capital Territory of Delhi (NCT), (pop. 16.7 million) the water supply is erratic, unequally distributed and well below international standards. In Delhi, the public undertaking (the Delhi Jal Board, DJB) is simply unable to meet the city’s water and wastewater needs (Janakaranjan et al., 2006). The mismanagement of water particularly affects the urban poor in city slums where supplies average 27 litres per person per day (Llorente, 2002). In response, the city has seen a rapid rise in the use of low-cost water wells for residential self-supply as an essential “coping strategy” that greatly reduces dependence on expensive tanker supplies (Foster et al., 2011). As a consequence, aquifers are becoming depleted due to increasing demand.

In Delhi, as throughout India, the natural response to rationed water supply, an inefficient delivery of municipal services and lax regulations has been for users to develop compensatory strategies. These strategies are described as “decentralised governance structures” and can be formal or informal. With “formal strategies”, private operators sell water via water tankers. The absence of regulation means that the source of this water cannot be guaranteed with some opportunistic companies reselling public water or untreated groundwater from illegal wells. More reputable private operators support better regulations but have received little support from the government. They struggle to provide services which are both reliable and affordable. “Informal structures” are developed by the poor and rich alike. The poor are more likely to take a “free-ride” on the public network via illegal connections, while higher income households will often install devices to store water in roof-top tanks and install tube wells for in-situ supply. Neither the formal nor informal strategies can be considered socially, economically and environmentally sustainable.

All these decentralized solutions have a fairly high cost, despite water being apparently free. One of the solutions mentioned concerns the institutionalization of community participation mechanisms that are good for at least three

reasons: it would enable these costs to become endogenous and facilitate the organization of a system of transparent redistribution; the residents would actually be able to ensure the up-keep of the decentralized installations; it would facilitate more effective management of the resource through the detection of leaks and better management of the demand. The rights of access would be ensured. This requires considerable institutional improvements in the different localities studied, and in particular the setting up of mechanisms for consultation, negotiation and above all of regulation.

Janakaranjan et al. (2006) recommend that the first goal should be the simplification of the institutional framework by redefining responsibilities in order to better coordinate the various decision levels, avoid the overlapping of tasks and limit the intervention capacity of discretionary powers. The second stresses the concept of a democratic decision-making process in which all the interest groups in the system would be represented (from the infra-local level to that of the whole area), which would act like a broad-based regulatory framework. Lastly, the third proposition considers it essential to redefine the constituents of the public service and its articulation in operational terms. It especially implies a reversal of the perspective, in the sense that the service should not be conceived in a technocratic top-down manner by imposing arbitrary norms, but in terms of the fundamental needs that should be met, taking into account the different systemic effects.

3.4 Growing conflicts with peri-urban users in Chennai (formerly Madras), India

The city of Chennai is one of the more seriously afflicted cities in India (Janakaranjan, 2005), with the Chennai Metropolitan Water Supply and Sewerage Board (Metro Water Board or MWB), supplying less than 50% of the population's need. As in most Indian cities, groundwater plays a crucial role in filling the demand gap (Zérah, 2000). Unfortunately, the city's groundwater resources are seriously depleted. In some areas water levels are so low that intrusion of seawater has occurred. Immediately north of the city, the seawater extends 16 km in land from the coast. To date, there has been no solution to the water supply crisis in Chennai. Possible megaprojects (involving major inter-basin transfers) have been rejected due to cost.

For the past two decades, the MWB has relied heavily on the transport of water from public wells and agricultural wells located in peri-urban villages. The present supply to Chennai is about 103 million litres per day which is pumped from city boreholes, the Poondi, Tamarapakka, Flood Plains, Kannigaiper and Panjetty wellfields located to the northwest just beyond the Chennai Metropolitan area, and the Minjur and Southern Coastal Aquifer well fields that lie within Metropolitan area to the north and south of the city of Chennai, respectively. Importing groundwater from peri-urban areas can create various types of tension (Janakaranjan et al., 2006).

1. Impact on poverty and livelihoods. Groundwater extraction from common lands in per-urban villages is not new. In 1969, the MWB dug 10 wells in the common lands of a nearby village to solve a water crisis in Chennai and transported water through pipelines. The MWB also demanded that farmers in many of the villages sell the water pumped from their irrigation wells, and many agreed. A study carried out by Gambiez and Lacour (2003) showed that farmers fell into three groups:
   A) those who refuse to sell water to the MWB.
   B) those who own wells and sell their water to the MWB;
   C) those who do not own wells and need to buy water from the first group to irrigate their fields;

   An analysis of these groups showed that group A) suffered a slight loss of income due to a reduction in cultivated area, presumably a direct influence of peri-urban population growth and the transformation of rural land to urban. By comparison, groups B) and C) were markedly affected. Between 2000 and 2001, farmers contracting with the MWB (Group B)) reduced their cultivated area by 43 per cent, while increasing their revenue for the period 1999-2002 by 80% , the water sales business proving considerably more lucrative than farming. Dependent farmers (Group C)) were the losers, seeing a considerable reduction in both irrigated land and farming income. This simple illustrates how a simple arrangement, initiated by a public undertaking, can create problems with severe social and economic implications.

2. Tensions over the lax regulatory framework. By the mid-1980s, when Chennai's available sources of water supply began to decline, the Chennai Metropolitan Area Ground Water (Regulation) Act was passed that enabled the MWB to grant or deny permits to construct wells in designated areas and to grant or deny licenses for extraction, use or transport of groundwater. The purpose of the act was to ensure that groundwater be used exclusively for domestic needs and prevent the common practice of transporting groundwater by trailer, lorry, or similar goods vehicles. Two decades later, the MWB has been the main violator of the legislation, causing much of the groundwater overdraft in peri-urban villages that the Act was designed to prevent. The MWB continues to draw groundwater from the designated areas, expanding its "catchment area" to peri-urban areas as much as 50 km beyond city limits. It also operates lorry-tankers without license. Many private lorry-tankers also transport groundwater from remote peri-urban areas, mostly to industry, many operators complaining that their permit applications have been ignored. In terms of permits to sink new wells, the legislation is also widely disregarded. Many industries draw water in contravention of the Act; they are also a major cause of water quality degradation. However, as is common throughout India, enforcement remains a major issue, and there is no evidence to indicate that the MWB has prosecuted any industry for violating regulations.

Finding solutions to the Chennai water supply problems will be difficult. However, there has been some success in creating a meaningful dialogue on the issue through a multi-stakeholders platform (MSP) designed to create multi-stakeholder dialogue (MSD). For Chennai, a 65-member multi-stakeholder committee was initially established compromising water users from both urban and per-urban areas. It included farmers (both water sellers and non-water sellers), landless agricultural labourers, women self-help groups, NGOs, researchers, lawyers, urban water consumers and a few government officials. More members were added at subsequent committee meetings. The MSD process has addressed several key issues including declining groundwater levels, declining agricultural activities, emerging livelihood problems, seawater intrusion, deteriorating water quality, water and soil pollution, sand mining and people's growing unrest. The challenge will be to secure the co-operation of the MWB and similar government agencies in getting potential solutions implemented.

3.5 Groundwater Use in Metropolitan Fortaleza – Brazil

In 1950 37% of Brazilians lived in urban areas (19 million urban dwellers). By 2000 the urban population had risen to 137 million representing 81% of the total. With a population close to 2.3 million (the metropolitan region is currently over 3.4 million), Fortaleza is the 5th largest city in Brazil and one of Latin America's fastest growing cities. CAGECE (Companhia de Agua e Esgoto do Ceará) is responsible for the city's mains water supply and provides service to 60-70% of the population using surface water. This service is unreliable during periods of peak demand and almost fails completely during periods of drought. According to Foster and Garduno (2006), this has prompted a remarkable 40-60% of the population to seek supplementary water supplies in the form of in-situ water wells. This practice is common for multi-residential properties but is also popular for single occupancy dwellings. Groundwater is also a popular choice for the manufacturing, recreation and tourism sectors. A 2002-03 water well inventory documented almost 10,000 wells, a six-fold increase over 1980. On the downside, reconnaissance sampling showed water quality problems in over 70% of the wells. The primary problems included NO_3 and NH_4 related to waste water discharge from unsewered sanitation and elevated salinity due to seawater intrusion. Also a significant number of the larger users (over $2m^3$/hour) were found to be operating without permits. The authors recommended that water supply provision and sanitation/drainage infrastructure of Fortaleza be analysed to assess the current influence of groundwater self-supply, together with associated potential future opportunities and risks. They also identified the need to stimulate high-level discussion and policy-decision on groundwater issues as they relate to urban infrastructure planning in Fortaleza, and on a proactive management campaign with institutional roles clearly defined for the various actors.

3.6 Approaches to aquifer protection plan development in Narayanganj, Bangladesh and Bishkek, Kyrghyzstan

The pollution of shallow groundwater by human, domestic and industrial waste represents one of the most serious constraints on groundwater utilisation in rapidly urbanising areas. Yet, very few cities outside the high-income world

have developed and implemented strategies for protecting groundwater as integral parts of their groundwater management plans. Morris et al. (2000; 2002; 2005) present two examples of cities where, despite a limited resource and knowledge base, locally appropriate and hydrogeologically sound groundwater protection plans have been successfully developed following close consultation with local stakeholders. The cities include Narayanganj, Bangladesh and Bishkek, Kyrghyzstan.

Narayanganj (pop. 2.9 million) is located on the flat Ganges-Brahmaputra-Megna alluvial plain of central Bangladesh. Long known for its jute industry, the city has become an important textile manufacturing centre in addition to its expanding soap-making, metal re-rolling and metal and wood furniture manufacturing industries. It is 90% on groundwater for supply but has no wastewater disposal system, relying on dispersed on-site sanitation in urban, peri-urban and rural areas. The city is fast becoming an industrial satellite suburb of Dhaka, a megacity centred 20 km to the north-west which is undergoing rapid, unchecked growth.

Bishkek (pop. 850,000) is Kyrghyzstan's industrial centre and is 100 % aquifer dependent for potable, domestic, commercial and industrial water supplies which are provided by both intra-urban and peri-urban wellfields. The city lies on the outermost northern flanks of the foothills of the Alatau range of the Tien Shan Mountains at an elevation of 725 - 900 m above sea level. The wastewater disposal system includes mains sewers for industrial, commercial, apartment and public buildings, and dispersed on-site sanitation for many low-rise residential areas. The relative importance and geographical extent of the latter is not well documented, but may be significant. A wastewater treatment plant for domestic and industrial effluent is located to the north of Bishkek.

Commencing in 1998, aquifer protection plans were developed for the cities using a very similar approach. The work began with aquifer vulnerability and subsurface contaminant load surveys to provide pollution risk assessments (Calow et al., 1999; Morris et al., 2002). Data for these assessments were sought from as many information sources as possible (Table 5) including and thereby involving, where possible, national agencies. The second and arguably most important stage was to engage groundwater stakeholders in the development of the groundwater protection plan. This plan involved a concise set of policy guidelines and a groundwater resource planning map. The overall purpose of this novel collaborative approach was to engender a greater ownership of the groundwater protection policies and thereby make them enforceable.

Table 5. Pollution risk assessment information sources (modified after Morris et al., (2002)).

Organisation/Agency	Narayanganj	Bishkek
Municipal Water Supply Utility	√√	√
State Geological/Hydrogeological Survey		√√
State Water Resources Agency	√	√
National Environment Agency		
National Map Survey Department		
National Government Census/Statistic Agencies	√	√
Other State Ministries/Departments/Agencies	√	
National/Municipal Public Health Department	√	√
University or Other Water Research Institute	√	√√
Municipal Planning/Public Works Departments		
Chamber of Commerce/Trade Organisation		
Consultants' Reports		
Commercial Directories/Institutions	√	√√
External Support Agencies e.g. UNDP	√	

Key: √√ Important source of data; √ provided some data; Blank - unable to provide relevant data/not available

Key to the identification of stakeholders in Bishkek and Narayanganj was a clear understanding of each city's groundwater development setting and urban water infrastructure. These were quite different in each city. For example, in Narayanganj:

- Industrial users are important and influential stakeholders, meriting extra effort in consultation;
- There is overlap between rural and urban water supply agencies, especially in the peri-urban area;
- Users of the shallow aquifer, which still serves as a resource as well as a receptor proved difficult to represent;
- No primary stakeholder groups could be identified.

By comparison, in Bishkek:

- State sector agencies remain the predominant stakeholder group members;
- Only secondary stakeholders could be identified;
- A post-independence depression in industrial activity offered opportunities for context-sensitive planning intervention to support a sound basic infrastructure;
- Although the upper aquifer is not widely used for potable supply, hydrogeological conditions indicate the potential for rapid vertical movement of pollutants to deeper supply aquifers.

In both cities it proved impossible to identify representative primary stakeholders (those with a direct resource interest, including groundwater users) who could participate in a consultation process. Although participation by primary stakeholders was considered desirable, it was recognised that such user groups, sufficiently organised (and thus representative) will be found only in some urban contexts. In Narayanganj the absence of this stakeholder class was more than compensated for by the diversity of secondary stakeholders (intermediaries in the delivering of policies, projects and services to primary stakeholders). These were drawn not only from public sector agencies/ministries but also local government and trade/industry associations. In Bishkek public sector organisations dominated the stakeholder spectrum but nevertheless (presumably as a result of underfunding and poor coordination post-independence) proffered a diversity of views and were actively engaged in the discussion of options.

3.7 Successful control of groundwater production in Bangkok, Thailand

Buapeng and Foster (2008) report on a progressive, adaptive, and eventually successful, control of groundwater abstraction in Greater Bangkok, in the face of serious environmental degradation. It demonstrates how consistent and persistent application of regulatory measures (licensing and charging) targeted in objectively-defined priority areas can reverse trends in groundwater resource decline and environmental degradation with minimal discontent amongst users.

Greater Bangkok (pop. 12 million) is underlain by 500m thick accumulation alluvial and marine sediments that support a very productive multi-level aquifer system. The uppermost clay which confines and helps protect the aquifer system throughout much of the urban area thins out north of the city where most of the recharge occurs. Widespread exploitation of groundwater for urban water-supply commenced in the 1950s and this led to land subsidence of over 60 cm in the centre of the city by the mid-1980's. The subsidence caused substantial damage to the urban infrastructure and exposed the city to a high risk of flooding during tidal surges. In addition, the lowering of the potentiometric level to below mean sea-level significantly raised the threat of groundwater quality degradation due to the intrusion of seawater.

In response to the growing problems, the public water authority progressively closed its pumping wells beginning in 1985. However, although production was eliminated by the late 1990s, increased domestic, commercial and industrial tariffs for mains water-supply (imported from distant sources) triggered a massive increase in the drilling of private water wells for:

- Domestic and low-demand commercial users requiring wells about 150m deep to supply around 1 Ml/d;
- Industrial users requiring expensive 500m deep wells to produce up to 10 Ml/d.

Faced with deteriorating environmental problems, the government increased its efforts to control pumping by:

- defining 'critical areas' where water well drilling would be banned;
- adopting the power to seal water wells in areas with mains water-supply coverage;
- licensing and charging for groundwater according to metered (or estimated) abstraction rates.

Initially, pricing was set at nominal levels that provided little incentive to reduce pumping but did, at least, establish the administrative framework and provide a useful database. Subsequently, charges were increased and structured to ensure that the greatest financial burden was borne by industrial and commercial users in "critical areas". Public awareness campaigns were introduced and the well sealing program was aggressively pursued. Slowly, the situation was brought under control.

By 2008, there were just over 4000 licensed water wells in Greater Bangkok providing about 15% of the total water-supply. Licenses are required for all wells more than 15m depth (i.e. exploit the main freshwater aquifers. Around 58% of the current licensed production is for industrial use. Many of the largest industrial water-users have been driven out of Greater Bangkok by the high water charges. The other primary user group includes private urbanizations/large apartment blocks that do not have access to mains water supply. Conflicts arose in some districts when an extension of the mains water-supply resulted in substantially higher costs for water. The dispute was resolved by allowing water well users to continue use of their wells conjunctively for the duration of their present licence, and to retain their wells as a back-up supply for 15 years, provided they were adequately metered and open to inspection.

One groundwater management aspect which remains outstanding concerns groundwater pollution control in the recharge area to the north of Bangkok. While the local regulatory agency has the responsibility and capability to identify areas of higher vulnerability that lie within the capture zones of municipal wells, it has no jurisdiction over activities that are potentially polluting e.g. the storage and handling of industrial chemicals, effluent discharge to the ground and agricultural practices. This urban-rural "co-management" issue clearly needs to be resolved.

3.8 A cautionary tale of water privatisation in Cochabamba, Bolivia

Cochabamba, Bolivia is a thirsty, sprawling city of an urban population of over 600,000, and a metropolitan population exceeding 1 million. The fourth largest city in Bolivia, its population quadrupled towards the close of the 20th century due to an influx of migrant workers from the countryside. The city is ringed by dozens of slum neighbourhoods (*barrios marginales*) lacking connection to municipal water supplies. This means that state subsidies to the water utility went mainly to support industry and middle class neighbourhoods. The poor neighbourhoods managed to secure water supplies from communal wells that were drilled with the help of foreign aid and were maintained by local water co-operatives.

In 1997, conditions on the World Bank US $600 million loan for debt relief included the privatization of the water supply for Cochabamba, and two years later a private consortium *Aguas del Tunari* (majority owned by the US-based Bechtel Corporation) was granted a 40-year concession contract to rehabilitate and operate both the municipal water supply network and all the smaller ones. The contract provided for exclusive rights to all the water in the district including the aquifers used by the water cooperatives. Meters were installed on community wells and within a very short time water supply prices were raised by amounts that, while "modest" for high volume users, effectively denied access to safe drinking water for the poor. Workers living on the local minimum wage of US $60 per month were faced with water bills that consumed 25% of their income. In 2000, a broad coalition of workers, farmers and environmental groups formed the "*La Coordinadora*" that organized a general strike and massive protests in opposition of the rate hikes. A "water war" (Finnegan, 2002) erupted with battles on the streets and mass arrests.

Martial law was soon declared but this failed to stem the protests. *Aguas del Tunari* decided to abandon the city, and the government revoked the concession contract. *Aguas del Tunari*, essentially a team of engineers brought in from overseas, had given little thought to how its plans would be received in the city, and its operation, however best intentioned, had been destined to fail.

Following the exit of *Aguas del Tunari*, responsibility for Cochabamba's water supply was returned to the old public utility SEMAPA which was thoroughly overhauled. The government also introduced a law that granted legal recognition to traditional communal practices and ensured protection of small independent water systems. Nine years later, SEMAPA continues to suffer from all of the problems that seem to plague public utilities throughout the developing world: unmanageable debt, water losses through leakage and infamously poor service. The new SEMAPA, having driven away investment, finds itself desperately in need of new capital. It seems the Cochabambinos may have won the battle against privatisation in the streets (Kohl, 2004) but have lost the war in their efforts to secure a fair and affordable water supply.

3.9 Some of the lessons learned

A striking characteristic of many of the case studies presented here is the resilience and resourcefulness of water users in the face of water adversity. While many of the actions can be considered unlawful in the sense that wells are often drilled without permits and appropriate fees are rarely paid, especially for illegal connections to mains supplies, the pooling of significant financial resources to construct a well and setup pipe networks demonstrate a certain willingness to pay a fair price for water, at least amongst those who can afford it. The tragedy is that "solutions" involving the use of groundwater (or in the case of Bangkok, by banning the use of groundwater), as novel and creative as they may be, are entirely in response to a problem e.g. lack of access to water or serious environmental degradation. The real challenge is to create <u>proactive</u> solutions that are part of a pre-conceived, water resource management plan - a plan that considers both quality and quantity aspects and is developed in close collaboration with all stakeholders using good data, sound science, and reliable demographic projections. Moreover, this plan needs to be fully embedded in the urban planning process. This challenge and opportunities to meet this challenged is explored in Chapter 4. Much of discussion on governance in Chapter 4 is based on the strategic overviews, briefing notes and case profiles published by the World Bank's Groundwater Management Advisory Team GW-MATE (Foster et al., 2010c).

4 Groundwater Governance and Opportunities for Rural-Urban Co-Management

4.1 Mechanisms for reducing tension

The core challenge for good governance of urban water supply includes an urgent need to identify and prioritise the courses of action required if continued growth of the world's cities is to be sustained. Urban-rural tensions are an inevitable consequence of growth and a frequent root cause of such tensions is "water scarcity" i.e. the lack of access to an adequate supply of suitable quality water. In such cases, problems are heightened in peri-urban areas where urban, industrial and agricultural users directly compete for the same resource. In other cases, water scarcity relates more to the inefficient water distribution system (reticulation networks – tanker supplies) than it is by the total size and quality of the water resource. It is this type of water scarcity that has driven the explosive increase of private in-situ water wells in many cities throughout the world.

If the world's rapidly growing cities are to be provided with adequate supplies of potable water on a sustainable basis, then urgent solutions are required. These solutions are undeniably complex given that many cities face competing political, societal and economic interests and limited financial resources for technological innovation and essential infrastructure. However, the choices are relatively simple and can usually be categorised into three basic options (Sharp, 1997):

- Increase the available water supply;
- Temper water demand (demand management);
- Manage the water resource more efficiently.

Increasing the available water supply

The availability of the water supply can be increased by various methods including but not limited to:

- New groundwater resources;
- Resource mining;
- Aquifer recharge management using artificial recharge;
- Water blending;
- Substituting poorer quality water for some uses

Locating new groundwater resources may not represent a serious option for cities facing severe overdraft problems. However, for many cities, it is a potential solution that is too often ignored in favour of alternative, surface water sources. Imported surface water may provide reliable, short-term benefits but can be unreliable in the longer-term. Intensive use of groundwater (groundwater mining) is always an important option as it can facilitate economic growth, while allowing postponement of investment in dams, long distance transfers and desalination plants etc. However, it needs to be positively planned, and realistically evaluated, and close control over groundwater production must be exercised. There must also be a clear and feasible plan for alternative water supplies when the groundwater resources are exhausted. There isn't a prosperous nation in the world that has not benefited at some time from intensive use of groundwater, although mostly due to an ignorance of the hydrogeology and associated long-term risks than through a carefully evaluated and planned production strategy.

A more permanent solution is to augment the resource through artificial recharge or "managed aquifer recharge" (MAR) (Ward and Dillon, 2011). Urban areas are net "creators" of water since the very limited vegetation and extensive impermeable surfaces return relatively little of the incoming precipitation to the atmosphere as evapotranspiration. Modern technologies allow the resulting stormwater runoff to be directed into the subsurface for storage and ultimately use. Artificial recharge is not limited to stormwater; treated wastewater can be "polished" to potable standards using MAR techniques.

An important consideration is that the vast majority of water used globally does not need to meet potable water quality standards. Too much potable water quality is used for industrial, agricultural and many urban purposes when

poor quality water would readily suffice. In effect, if alternative water sources of lower quality water could be directed to meet at least some of these needs, significantly more potable water would be available to meet human demand for safe water. An alternative means of making good use of inferior quality water is to blend it with good quality water in such proportions that the water meets water quality guidelines that are appropriate for its intended use. Ideally, this would require that a suitably located and carefully protected 'external wellfield' be established as a stable source of high-quality supply.

Demand management

Demand for groundwater can be tempered through a wide variety of measures. Typically, they include:

- Limiting the number and depth of wells through controls on the issue of well construction permits;
- Limiting accessibility to municipal supplies to certain periods of the day;
- Price structuring e.g. water metering and tariffs;
- Water conservation (e.g. use of technologies that use less water to perform the same task).

In many developing countries, per capita usage of water is already very low and there are few opportunities for significant savings to be made at the domestic level by adopting water conservation practices unless major incentives for reducing water use are established. Some reduction can be achieved by limiting household accessibility to water to just a few hours each morning and evening, as is practiced in India (Limaye, 1997). Unfortunately, this does little to control usage during those times water is made available.

At the communal and municipal level, demands on the aquifer can be reduced by limiting pumping. However, according to Morris et al. (1997), this is better achieved by strict controls on the construction of water wells (through licensing) as opposed to simply restricting pumping rates via permit for wells that are already constructed. Many argue that it is pointless to regulate water usage if laws are not adequately enforced and violators are not prosecuted. Limaye (1997) argues that the greater the number of rules and regulations, simply the greater the level of illegal activity.

Perhaps the most effective means of controlling demand is the disincentive that results from increased water tariffs. As described by Morris et al. (1997), this can be achieved at the wellhead by imposing realistic charges for raw water based on one or more of the following:

- Recovering full costs incurred by the regulatory body for administering resource development and evaluating, monitoring and managing the groundwater resource;
- Including the potential cost of providing alternative raw water supplies to users in the event the source goes out of commission;
- Acknowledging the full cost of environmental impacts that will likely accrue due to the water undertaking.

Pricing water based on the quality and quantity of water pumped at the wellhead provides an incentive for more effective demand management including the reduction of leakage from pressurised water-mains. In many large cities leakage rates exceed 30% and can cause additional problems to city infrastructure such as flooded basements, tunnels and underground electrical utilities. Water pricing can do little to encourage water conservation at the consumer level, however, unless the charges can be passed on to these users equitably according to the actual amounts used. This requires individual metering which can be expensive to install and maintain but is a proven means of reducing wastage. Unfortunately, domestic metering is such an administrative burden that many fees go unrecovered. The exercise may also prove counter-productive if user fees exceed what the user can realistically afford to pay. In all cases, education is a crucial starting point as an informed public can be an accepting public. Education in good, responsible water management practices and the need for such practices must be focused at all levels of government, industry and the population at large.

Efficient management of the resource

Ultimately there are limits to which supply can be increased and demand reduced. The long-term sustainability of groundwater supplies for growing cities requires that groundwater be managed far more efficiently. This means that water quality impacts must be minimised and that available water reserves must be managed to maximise their utility. Recognising that surface water is an important component of the urban water cycle and a critical water source for most cities, significant additional management benefits can be obtained by optimising their combined development through conjunctive use (Paling, 1984). Conjunctive use recognises the interdependency between the ground and surface water resources of a basin and ensures that maximum benefit is obtained by integrating ground and surface water resources into a single resource management plan. To date, unfortunately, most conjunctive use encountered in the developing world amounts to a "piecemeal coping strategy" (Foster et al., 2010b) in response to an urgent resource problem.

According to Barber (1997), management of our groundwater systems should be underpinned by science. The role of the scientist is to address perceived problems and develop solutions that can be used by resource managers. Management practice can then evolve by incorporating scientific developments into an overall strategy to achieve best-available practice. Fortunately, the science is well advanced and there a wealth of excellent ground and surface water modelling tools that can be used for:

- Quantifying the water budget;
- Performing vulnerability assessments and identifying "ZOC's – zones of contribution" -areas around wells most in need of protection;
- Predicting groundwater travel times for contaminants in the system;
- Determining "optimal" pumping and water extraction rates, and
- Testing and evaluating alternative water management scenarios.

Despite a critical lack of reliable data for urban areas, these models can greatly assist in the development of management programs and provide support for decision-making. "Assist" is the key word since the formulation of appropriate management action plans is as much social as it is technical. It is a long-term process that demands sustained national and international political commitment, social consensus and substantial improvements in the types of data so essential for resolving complex aquifer flow dynamics and the patterns of socio-economic demand that are placed upon the resource. Waiting for data, however, is not an excuse to delay action (Burke and Moench, 2000).

There is a strong school of thought that strategies for groundwater management are most effective when they

- are developed in close co-operation with stakeholders, and
- fully acknowledge economic, social and political conditions.

This philosophy equally applies to aquifer [water quality] protection plans that should form an integral component of groundwater management. Traditionally, water projects in developing countries have been instituted using the "top down" management approach that rarely considers the interests and specific needs of the individual users, but satisfies, at least in principle, the goals and aspirations of government officials, consultants and support agencies. In the poorest countries, the interests of stakeholders, including users within the local communities, are totally ignored. According to the principle of participatory management, first introduced at the 1992 Dublin International Conference on Water and the Environment, the development of water policy should adopt a participatory approach that involves users, planners, and policy makers at all levels. Most importantly, the participatory approach would require that decisions be taken at the lowest appropriate level which, in practice, means the direct involvement of local and regional agencies representing community interests. All stakeholders must be satisfied that their needs are being met as ultimately, workable solutions will not be forthcoming without the full commitment and co-operation of all levels of government, industry and the population at large. In effect, current problems with urban

groundwater management will not be resolved until governments seek to work with groundwater users and resist trying to regulate and control them.

4.2 Groundwater governance.

Groundwater is a classical 'common pool resource', a term used to describe a natural resource whose size or characteristics makes it virtually impossible to exclude potential beneficiaries from deriving benefits from its use. Such resources are vulnerable to the so-called 'tragedy of the commons' (Harding, 1968) in which actual and potential stakeholders act solely in their own individual short-term self-interest rather than taking into account long-term communal requirements. While Hardin recommended that the tragedy of the commons could be prevented by either more government regulation or privatizing the commons property, Ostrom (1990; 2005) suggests that simply passing control of local areas to national and international regulators can generate even greater problems. Ostrom argues that the tragedy of the commons may not be as prevalent or as difficult to solve as Hardin implies, since locals often demonstrate an ability to find solutions to the commons problem themselves; when the commons is taken over by national regulators, those solutions can no longer be used. Ostrom's work provided a series of design principles for stable local common pool resource management (Ostrom, 1990; 2005; 2009a; 2009b). In terms of groundwater governance, the "Ostrom Principles", provide a practical guide to co-operative groundwater management and are especially appropriate for urban groundwater management given the multitude of potentially competing interests. Based on the Ostrom principles the management approach would involve (Foster et al., 2010a):

- Clearly-defined boundaries for resource evaluation and allocation, and congruence with prevailing local conditions and constraints;
- Formal recognition by government of the water management rights of the community;
- Collective arrangements for decision making;
- Layers of nested stakeholder groups to cope with larger resource systems;
- Effective monitoring with stakeholder involvement;
- Graduated sanctions on users who do not comply with communal rules;
- Low-cost, efficient conflict-resolution mechanisms.

The character of groundwater also means that links with the governance of the environment, and other land and water resources, are decidedly relevant. For example, groundwater resources are highly dependent upon land-use in the main 'aquifer recharge areas' and any changes in land-use can significantly affect both the rates and quality of recharge. Thus, groundwater governance cannot be addressed without due consideration for the processes that determine or control land-use. In urban areas, land-use is generally controlled by the municipal or local government, and the absence of mechanisms whereby water resource agencies can influence land use planning is a common governance weakness. By the same token, the groundwater supply for many urban areas is obtained from peri-urban well fields such that rural land-use practices and the intensification of agricultural production (largely determined by national agriculture and food policy) exert a very strong influence on groundwater recharge rates and quality.

It is also important to appreciate the effect 'cross-sector drivers' may have on groundwater resource use and pollution potential since it is likely that provisions will be required to influence associated macro-level policy decisions.

Figure 7 shows the key elements required for the development and implementation of an "Action Plan" for sustainable groundwater management (Foster et al., 2010a). While there can be no "one-size-fits all" when it comes to models of groundwater governance, Figure 7 provides a blueprint for developing governance structures for a range of situations including urban areas. Significantly, the starting point must always involve a thorough

understanding of the resource setting. It will include the definition of the manageable groundwater bodies[4] , and will be followed by assessments of the hydrogeologic condition and socioeconomic situation. These factors, in essence, define the problem and shape the solution.

The cumulative operational experience of GW-MATE in assessing the effectiveness of existing provisions and capacity for the exercise of adequate groundwater governance (in areas where groundwater resources are experiencing significant stress from intensive development and/or pollution pressure) has been distilled into a priority list of benchmarking criteria. These are shown in Table 6 (Foster et al., 2010a).

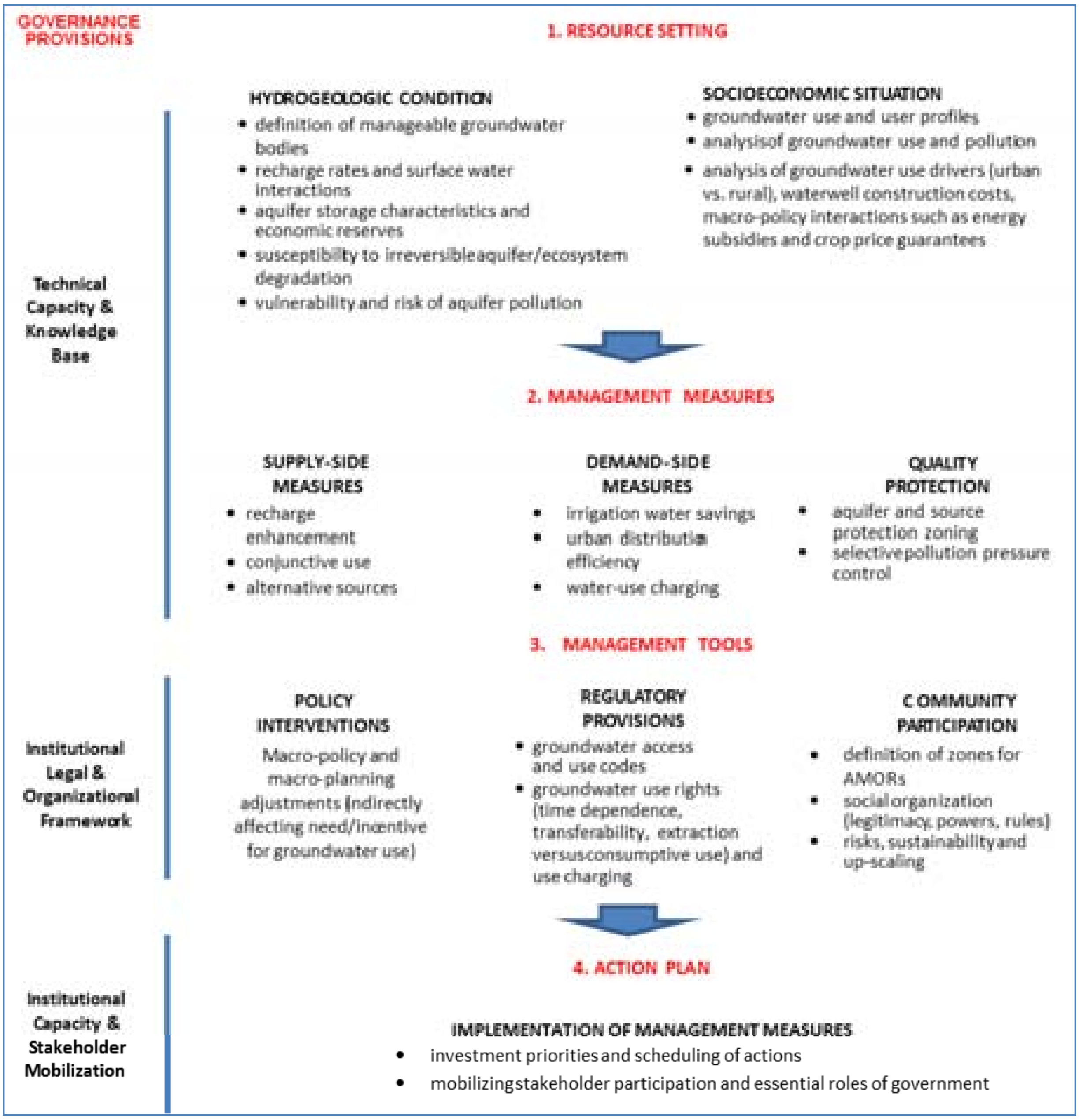

Figure 7. A framework for the development and implementation of a groundwater management action plan with corresponding governance provisions (modified after Foster et al., 2010a).

[4] 'groundwater bodies' are defined as resource management units with clearly-defined and scientifically-sound boundaries (usually parts of aquifer systems), which can be related, as necessary, to the overall basin in which they occur.

Table 6. Check list of 21 key benchmarking criteria for the evaluation of groundwater governance provision and capacity (modified after Foster et al., 2010a).

TYPE OF PROVISION/ CAPACITY		CHECK LIST	
	No.	**CRITERION**	**CONTEXT**
Technical	1	Existence of Basic Hydrogeological Maps	For identification of groundwater resources with classification of typology
	2	Groundwater System Conceptual Model Development	
	3	Groundwater Body/Aquifer Delineation	
	4	Groundwater Potentiometric Head Monitoring Network	To establish resource status
	5	Groundwater Pollution Hazard Assessment	For identifying quality degradation risks
	6	Availability of Aquifer Numerical 'Management Models'	At least preliminary for strategic critical aquifers
	7	Groundwater Quality Monitoring Network	To detect groundwater pollution
Legal & Institutional	8	Waterwell Drilling Permits & Groundwater Use Rights	For large users, with need of small users noted
	9	Instrument to Reduce Groundwater Abstraction	Waterwell closure or constraint in critical areas e.g. overexploited or polluted areas
	10	Instrument to Prevent Waterwell Operation	
	11	Sanction for illegal Waterwell Operation	Penalizing excessive pumping above permit
	12	Groundwater Abstraction and Use Charging	"Resource tariff" on larger users
	13	Land-Use Control on Potentially-Polluting Activities	Prohibition or restriction since a potential groundwater hazard
	14	Levies on Generation/Discharge of Potential Pollutants	Providing incentive for pollution prevention
	15	Government Agency as 'Groundwater Resource Guardian'	Empowered to act on cross-sectoral basis
	16	Community Aquifer Management Organisations	Mobilizing and formalizing community participation
Cross-Sector Policy Coordination	17	Coordination with Agricultural Development	ensuring 'real water saving' and pollution control
	18	Groundwater-Based Urban/Industrial Planning	To conserve and protect groundwater resources
	19	Compensation for Groundwater Protection	Related to constraints on land-use activities
Operational	20	Public Participation in Groundwater Management	Effective in control of exploitation and pollution with measures and instruments agreed
	21	Existence of Groundwater Management Action Plan (see Figure 7.)	

Primary considerations include:

1) Institutional and Legal Provisions
   Foster et al. (2010a) suggest that in assessing the current status of governance provisions, careful distinction should be made between:
   - The Institutional Framework: the national and/or state constitution and related government structure;
   - Local organizational arrangements i.e. organization for water resources management and water services provision at a lower-level ;
   - Primary Legislation: the legislative material (such as the Water Law) as approved by the legislature, which states policies, principles, approaches and mechanisms, and
   - Legal Regulations: legislative material issued by the executive to explain implementation details, as empowered by the primary legislation.

   They warn, however, that attempts to modify legal provisions and organizational arrangements for groundwater governance can be politically difficult and time consuming and they suggest a duel approach

to the problem that seeks to make progress within the existing framework, while working in parallel on necessary legal reforms.

2) Provision for Stakeholder Participation

   Since an important goal of groundwater management is to influence the behavior of individual groundwater users and potential polluters, participation by representative stakeholders is a critical groundwater governance instrument. This is because:

   - Top-down management decisions taken unilaterally by regulatory agencies without social consensus are often impossible to implement; stakeholders need to feel a sense of ownership in key decisions;
   - Important groundwater management activities such as monitoring, policing and tariff collection can be carried out more efficiently and economically through cooperation.
   - Stakeholder participation facilitates the integration and coordination of decisions relating to groundwater resources, land use and waste management.

   With respect to urban groundwater governance, it is essential that all users are adequately represented including peri-urban and rural users. Foster at al. (2010a) suggest that Water Users Associations (WUAs) responsible for the management of irrigation systems are not enough alone to ensure stakeholder participation for rural groundwater resources, and there is need of a system for higher-level user and stakeholder participation which they refer to as an “aquifer management organization” (AMOR) (see Figure 7). This would be formed at the initiative of the water resource regulatory agency, in which all WUAs and other main groups of stakeholder are represented. Based on their GW-MATE operational experience, Foster at al. (2010a) believe that while decentralised groundwater management with some form of stakeholder participation is the most appropriate management approach, national governments need to ensure state/provincial/municipal level agencies receive adequate funds to hire and retain the well trained professionals required to perform the necessary work.

4.3 Urban groundwater governance issues – within city limits

Few groundwater-dependent cities are able to obtain adequate supplies from within city limits, but those that do need to maximise the quantity of the available resource while safeguarding water quality. Unfortunately, there is all too often a vacuum of responsibility and, therefore a lack of accountability, for urban groundwater. For example, groundwater use sustainability can be greatly influenced by a wide array of local developmental decisions, which are rarely examined in an integrated way, including:

- production and distribution of water-supplies (by municipal water-service utilities and public-health departments);
- urbanisation and land-use planning (by municipal government offices);
- installation of sewered sanitation, disposition of liquid effluents and solid wastes (by environmental authorities, public-health departments and municipal water-service utilities).

It means that at best, responsibility for the sustainability of groundwater supply is divided between a number of organisations, none of which is normally willing, indeed capable of taking the lead necessary for coordinated management action. Typically these organisations include municipal water-service utilities, provincial/state government water-supply and public-health engineering departments, central and/or provincial/state/basin groundwater resource agencies and environment protection/pollution control agencies. Municipal water-service utilities are usually best equipped to handle the engineering of waterwell construction and operation, but rarely show interest in understanding and managing the resource base. It means that the criteria for waterwell siting and construction are normally based on efficiencies of cost and are not considered in terms of optimal use of the groundwater resource. It is said that “Urban groundwater tends to affect everybody, but is often the responsibility of ‘nobody’.” This clearly needs to change.

Foster et al. (2010b) recommend the following policy actions to ensure physical sustainability of the urban groundwater resource base:

- definition of areas with critical levels of resource exploitation as a basis for restricting further development;
- providing clear criteria by area for issuing of waterwell permits (in terms of safe separation and maximum pumping rates);
- controlling municipal and private groundwater abstraction on the basis of defined areas – including the relocation of municipal waterwells, increased resource-use fees, and (even) closure of private waterwells where local conditions so merit;
- maximising use of aquifer recharge enhancement techniques taking provisions to avoid groundwater pollution;
- monitoring and periodic evaluation of groundwater resource status, including the use of numerical aquifer simulation models.

In addition, they suggest a much more integrated approach to urban water-supply, mains sewerage provision and land-use is required to avoid persistent and costly problems. This would include the following types of measure:

- prioritising some recently urbanised areas for coverage by mains sewerage so as to protect their good quality groundwater from gradual degradation;
- establishing municipal source protection and/or exclusion zones, especially around any municipal waterwells that are favourably located to take advantage of parkland or low-density housing areas;
- assessment of the sanitary protection standards of municipal waterwells and the risks of wellhead contamination, and how they can be reduced;
- undertaking groundwater pollution vulnerability mapping and hazard assessment, and being prepared to abandon some municipal waterwells where the contamination risk by toxic synthetic substances is very high;
- avoiding creation of polluting discharges in 'upstream areas' that could percolate and compromise the groundwater quality of municipal waterwells.

A common problem in the developing world is that the vast majority of private urban water wells are either illegal or unregulated, a situation that is counterproductive for both the private user and the public administration. Where appropriate, a more constructive approach would be to legalise such wells. This would allow:

- urban groundwater users to receive sound information and advice relevant to their use (pollution risks/alerts, use precautions, etc.) and be protected against the impacts of excessive total abstraction and/or inadequate well spacing.
- sanitary completion standards for water wells to be improved and their potential interaction with in-situ sanitation units (latrine, cesspools, septic tanks, etc.) reduced.
- the public administration to obtain better data on private use and establish better relationships with private users and well drillers and pump suppliers,
- opportunity to collect information on water quality.

In terms of aquifer management, water-supply security can be significantly enhanced by:

1) Adopting an adaptive water resource management approach (Gleeson et al., 2012) that allows decision-makers to adjust and fine tune the management plan (the Adaptive Management Plan - AMP) approach as more is learned about the aquifer and its behaviour. The AMP, however, should never be considered as a convenient substitute for a full scientific understanding of the aquifer system but instead as an opportunity to refine a fundamentally robust management plan as more data on groundwater levels and quality trends become available.

2) A carefully conceived program, well supported by long-term data that optimises ground and surface water resources through conjunctive use.

The best aquifer management plans are underpinned by a transient numerical aquifer model - a "decision-support tool", calibrated with historic groundwater abstraction and drawdown data. This model would be used to and explore management options with the AMP, including prospects for conjunctive use. It would also be used to examine the opportunities and risks associated with intensive groundwater use.

In summary, groundwater is a fundamental component of the urban water cycle and the overall challenge is to fully integrate groundwater into urban land use planning, water supply and waste management, whatever its status (Table 7). Groundwater is far more significant in the water supply of developing cities and towns than is appreciated. However, organisations responsible for urban water-supply and environmental management often have a poor understanding of groundwater and its unique attributes. This lack of understanding often leads to groundwater pollution most notably related to inadequate in-situ sanitation. Because contamination of large aquifers occurs slowly, and out of public sight, it may be decades before the problem is fully manifest. By such time, full remediation of the problem is likely to be prohibitively expensive. Whichever model of governance is selected for urban groundwater management, there can be no substitute for knowledge and understanding of the aquifer system and a sound groundwater database.

Table 7. Summary of major policy issues associated with urban groundwater (after Foster et al., 2010b).

MAJOR POLICY ISSUES ASSOCIATED WITH URBAN GROUNDWATER	
ISSUE	**IMPLICATIONS**
Municipal Water-Supply Benefits	Groundwater use for municipal water-supply has many benefits (including capacity to phase investments with demand growth and high quality requiring minimal treatment) but it usually comes with a need for integrated planning of urban land-use, effluent discharges and solid-waste disposal to avoid insidious and near irreversible degradation by pollution.
Private In-Situ Use Benefits & Hazards	Private in-situ use for urban residential, commercial and industrial water-supply can have significant benefits not only to the user but to the community (reducing demand on utility supplies, providing water in areas or volumes difficult for the mains network, not using high-quality mains water for garden irrigation and commercial / industrial cooling) and these benefits need to be valued in terms of the marginal cost of providing a volumetrically-equivalent alternative water-supply – but poorly-constructed and shallow urban waterwells can present a significant health hazard due to fecal contamination (in serious waterborne disease outbreaks) or chemical contamination (especially in areas without mains sewerage).
Water-Sector Financial Considerations	Widespread self-supply can have major financial implications for water-service utilities, in terms of loss of revenue from potential water sales, difficulties of increasing average tariffs and recovering sewer-use charges from those operating private waterwells.
Conjunctive Use with Surface Water	The rates of replenishment of aquifers may not be sufficient to meet the demands of larger cities sustainably and in this situation it is preferable to use available groundwater resources and large storage reserves conjunctively with surface water sources – conserving groundwater for use during drought and other emergencies.
Future Drainage Problems	Should abstraction radically diminish (due to an increased offer of subsidised mains water-supply or to quality deterioration or pollution rumours) then groundwater levels will rise progressively to higher than the pre-urbanisation condition, potentially with serious sanitary problems and infrastructure damage in lower-lying areas.
Protected Municipal Wellfields	Since some degradation of groundwater quality in urban municipal waterwells due to persistent pollutants is likely, it is necessary in parallel to develop 'external wellfields' and declare their capture areas as 'protected zones' to guarantee that a proportion of the total resource is of high quality and available for dilution or substitution.

4.4 Urban groundwater governance issues beyond the city limits – opportunities for rural-urban co-management

Most groundwater-dependent cities are ultimately reliant on external aquifers over which they may little, if any, jurisdiction or influence. Recognising the huge demand for groundwater in rural areas to meet agricultural needs, an unhealthy competition for the resource is emerging in many towns and cities, with those living at the rural-urban interface (RUI) and in peri-urban areas at the heart of the conflict. Not surprisingly, there are two diametrically opposed perspectives to this urban-rural issue.

Rural communities believe that the economic and power dynamics of this competition leaves them at a disadvantage because they cannot generate comparable financial returns or are less represented in positions of power (lobby groups, politics etc.) and unable to influence water allocation. Studies have shown, for example, that water exported from rural areas to urban centres leads to food insecurity and unemployment (IFAD, 2001). Farmers well recognise that contamination of groundwater represents the greatest threat to their livelihoods and that groundwater used in rural areas on the periphery of cities is seriously threatened by polluted urban runoff or leaching of contaminated water from urban pollutant sources (Nagaraj, 2005). They find that regulation of groundwater is very difficult due to the number of actors involved. NGOs, foreign government assistance programs and private companies often act independently and work with different government ministries when implementing their agendas. The lack of co-ordination prevents responsible resource management and promotes depletion of aquifers. Individual rural users who typically use their shallow wells for domestic supply and small-scale livelihoods are the first to be affected by lowered water tables.

From an urban water supply perspective, cities believe that activities in peri-urban and rural areas pose a serious threat to the sustainability of their supply. For example, over-pumping often invites groundwater salinization, and agriculture can lead to contamination by fertilizers, pesticides, herbicides and, in some cases, wastewater. They recognise, as a “best management practice”, the need to protect peri-urban wellfields through regulation e.g. with their capture areas declared as ecological or drinking-water protection zones. They find, however, that any attempt to establish procedures and incentives for resource protection often encounters administrative impediments related to fragmented powers of land-use and pollution control. Too often, there is an enormous disconnect between water and land use regulations.

The solution to this apparent impasse is co-management of the groundwater resource at the catchment scale with strong representation of all stakeholders. In some respects the approach would be similar to that involved in managing transboundary aquifers, except that the “boundary” refers to the rural urban interface and the players involved will be somewhat different. As indicated previously, there is no “one-size-fits-all” when it comes to groundwater governance. However, a recent study of rural-urban co-management opportunities that was recently conducted in the city of Zhengzhou, China (Sun et al., 2009a) demonstrates some of the key institutional and policy considerations. As described briefly below, it shows how a balance can be achieved between urban and rural use as a means to sustainable development based on integrated groundwater-surface water and urban-rural management principles.

Zhengzhou (pop. 7.2 million) is located in the lower reaches of the Yellow River in water-scarce northern China. It has a total area of 7,446 km^2, about 15% of which is occupied by the city of Zhengzhou, the capital of Henan province. 39% of Zhengzhou’s population live within city limits and 61% reside in the surrounding rural area. Groundwater represents about 70% of Zhengzhou’s water supply. Just over 50% of the groundwater is used for agriculture (down from 58% in 1995) while industrial and domestic uses are 31% and 17% respectively. Despite many attempts to conserve water by controlling development, groundwater remains over-exploited and many environmental problems related to over-development exist. Between 1990 and 2000, the number of tube wells increased from 37,164 to 42,763 resulting in a lowering of the water table and a shift from shallow to deep tube wells. Most of the new deep tube wells were funded by the government or village collectives (Sun et al. 2009b). Shallow groundwater quality is also a problem. In the city, pollution sources include wastewater from industry and

domestic sewage, while in rural areas the problem is agricultural fertilizer, pesticides, and wastewater from livestock. According to the Water Resources Bureau of Zhengzhou, 1.5 million farmers (38% of all farmers) do not have access to safe drinking water from ground or surface sources.

In theory, at least, many of the problems could be resolved by requiring that all water-resources management including groundwater should be under the Ministry of Water Resources and its provincial and local arms. The reality, however, is that like most of the world (Nanni and Foster 2005) management is scattered amongst a multitude of agencies, many with overlapping responsibilities. Insufficient communication and, in some cases, competing interests have resulted in groundwater regulations and policies being ineffectively implemented, or even conflicting. For example one agency in Zhengzhou was working to close urban tube wells while others continued to open new wells. Unfortunately, the development of an “ideal” model of truly integrated groundwater management is unrealistic in practical terms, both for the short and long terms. However, a reasonable goal is the building of institutional frameworks under which ministries and agencies with differing mandates and goals can share information on the state of groundwater resources and the impacts of use, thereby generating at least partial coordination of policies for groundwater management. Sun et al. (2009a) suggest that within Zhengzhou, the Water Resources Bureau of Zhengzhou could take the lead and serve as a focal point for communication and coordination of the ground-water functions and policies of the other various actors involved in the areas of groundwater management.

It is the co-ordination of functions and polices that provides the key of opportunity for co-management of rural and urban groundwater use within those agencies, as well as the opportunities for urban-rural conjunctive use. For example, wastewater treatment and the re-use of domestic and industrial wastewaters for irrigation in rural areas can improve environmental conditions while reducing the demand on groundwater. Provided it is not seriously degraded, surface water, is generally more appropriate for irrigation purposes, with good quality groundwater best reserved to meet more demanding domestic and industrial needs (Villholth, 2006). However, in practice, the reverse tends to occur because farmers find it convenient to draw groundwater from a well close to their fields, while water intakes for central municipal water-supply distribution systems may well be taken from larger rivers. Co-management of the resource would provide at net benefit ensuring more surface water and treated wastewater is used for agriculture while groundwater urban users have priority over groundwater.

Sun et al. (2009a) suggest that co-management of urban and rural groundwater may also reduce the overall costs of groundwater management, indicating that most management efforts tend to focus on urban areas with their relatively higher economic output. They suggest that a proportionately higher gain may be obtained from investing in water saving technologies and cropping reforms in rural areas that could lead to real water savings that in turn could benefit urban water supply. Incentives would be required to encourage adoption of water savings technologies and this is often best achieved through pricing and cost controls. Another option for increasing water-use efficiency while protecting farm income is to give farmers an opportunity to benefit from increases in water prices by allowing them to sell “their” water. However, this would need to be carefully regulated to avoid excessive exploitation.

It is concluded that co-management of urban and rural groundwater is a worthy goal with many potential benefits for all users. However, this would need significant reform of the institutional arrangements that exist for most developing cities, together with a closer re-alignment of management objectives. Important first steps should include increased public awareness, concerted dialogue amongst stakeholders and data-sharing amongst agencies that have an interest in water management. The starting point for co-management is co-operation.

5 Conclusions

Global population growth has placed a huge burden on supplies of fresh, available water. In many countries, increasing competition for water between agriculture, industry and domestic needs, threatens economic development, food security, livelihoods, poverty reduction and the integrity of ecosystems. Within 20 years, the global population is projected to rise from 7 billion to 8 billion with all this growth taking place in urban areas.

The scale of urbanisation poses monumental opportunities and challenges (SIWI, 2011). Most of the world's urban growth occurs in developing countries, where well-serviced centres are surrounded by expanding stretches of under-serviced suburbs and peri-urban slums. Since there is no international agreement on how to define "urban" limits, many suburban and peri-urban areas are seriously neglected when it comes to urban planning and the provision of adequate water services. Successful, developed-world strategies for urban development simply cannot be replicated in less developed countries where a serious disconnect between water management and urban planners is well documented. In many cases there is no urban planning at all. Without the planning of urban space and infrastructure, opportunities to provide adequate water and sanitation services are seriously compromised.

History has shown that where urban water delivery services are positively planned, centralised systems of water service approach often fails. In response, many countries adopted a "decentralised" approach but these have shown mixed success with affluent residents often enjoying significantly better access to water services than the poor or those from rural areas. In many cases, decentralization has failed because financial resources have tended to remain at the central level and the transfer of important decision-making responsibilities to district and village levels has not been followed by the transfer of funds for essential capacity development.

A compounding problem in the global effort to supply rapidly growing cities with water and sanitation services has been the failure to consider the fundamental nature of the resource and show respect for the fundamental differences that exist between surface water and groundwater as sources of supply. Concern for urban population growth and the need to address increasing demand for water has been high on the global water sector agenda for more than twenty years. The "global urban water crisis" has been well documented and the lack of good water governance has been cited as an underlying problem in urgent need of attention. However, virtually all the debates on global water policy that have raged at international water meetings during the past two decades have remained transfixed on surface water issues. The role and importance of groundwater has been practically ignored. Integrated Water Resources Management (IWRM) and its multi-faceted, integrative approach to water systems management has been widely publicised as the solution to the world's water issues, but in truth it has not served us well in the urban areas of the world. This is because IWRM gives very little recognition to the vital function that groundwater plays in the global water cycle and the immense benefits that could be derived from the improved management of groundwater. A failure to recognise the unique and special attributes of groundwater represents one of the lost opportunities of IWRM.

To some extent, the neglect of groundwater reflects an "out of sight, out of mind" mentality which has promoted ignorance for water movement in the subsurface. However, neglect has also arisen because groundwater and surface water systems are spatially distinct and, in terms of water flow velocities, operate on totally different time scales. Reasons aside, the unfortunate consequence is that tools for urban water management rarely, if ever, incorporate an adequate understanding of aquifers either during the analysis stage or, just as importantly, during the subsequent management decision-making. For example, groundwater resources are highly dependent upon land-use in the main 'aquifer recharge areas' such that any change in land-use can significantly affect both the rates and quality of recharge. This means that groundwater governance cannot be adequately addressed without considering the processes that determine land-use. In urban areas land-use classification and control are generally the domain of municipal or local government, and the absence of mechanisms whereby water resource agencies can influence the process is a frequent governance weakness. Similarly, groundwater supply for many urban areas is obtained from peri-urban well fields such that rural land-use practices and the intensification of agricultural

production (largely controlled by national agriculture and food policy) exert a very strong influence on groundwater recharge rates and quality.

Fortunately, some excellent work has been conducted on groundwater governance during the past ten years, notably by the World Bank's Groundwater Management Advisory Team (GW-MATE) and others. This work has raised the profile of groundwater in the political arena and drawn attention to the widespread use of groundwater in many of the world's most impoverished cities, and has provided excellent blueprints for building appropriate governance structures and the various roles that must be played. These blueprints are founded on a realisation that current problems with urban groundwater management will be resolved only if governments work with groundwater users rather than attempting to regulate and control them. In all cases, an effective groundwater management action plan is required that needs to be developed with in close consultation with stakeholders. This must include the representation of both peri-urban and rural users. Top-down management decisions taken unilaterally by regulatory agencies without social consensus are often impossible to implement. Stakeholders need to feel a sense of ownership in the plan and the decisions that are made.

Good urban groundwater governance and the development of appropriate groundwater management action plans must begin with a fundamental understanding of the resource setting. The resource setting will include both the hydrogeological conditions (aquifers, recharge rates, economic reserves and vulnerability to pollution) and the socio-economic situation (demand, users, and groundwater-use drivers such as well construction costs and energy subsidies). In turn, a sound knowledge of the resource setting will lead to the identification of various management measures related to a) the supply side (e.g. recharge augmentation and conjunctive use), b) the demand side (e.g. water use tariffs) and c) sustainable water quality (e.g. well head protection). It is essential that the technical capacity to deliver the necessary knowledge base is in place. National governments need to ensure state/provincial/municipal level agencies receive adequate funds to hire and retain the well trained professionals required to perform the necessary work. Whichever model of governance is adopted for urban groundwater management, there can be no substitute for a sound knowledge and understanding of the aquifer system.

Ultimately, good governance and the successful implementation of urban groundwater management plans require the establishment of appropriate institutional frameworks. These would normally include departments and agencies at the national and/or state level working interactively with regional and city governments. The latter would normally be obliged to help execute national/state policies while assuming various degrees of responsibility for the provision of water services and the development/implementation of water management plans. Many institutional models can be found and clearly, there is no "one-size-fits all". Based on their GW-MATE operational experience, Foster et al. (2010a) support a decentralised approach to groundwater management that includes effective stakeholder participation. They go on to warn, however, that attempts to modify legal provisions and organisational arrangements for groundwater governance can be politically difficult and time consuming, and instead propose an approach to the problem that seeks to make progress within the existing framework, while working in parallel on appropriate legal reforms.

Since many of the world's groundwater-dependent cities rely to a large extent on peri-urban wellfields, there is a particularly urgent need to work with peri-urban and rural communities to ensure that resources are adequately protected and that the needs of both sets of users are adequately met. While this can be achieved to some extent by broad stakeholder participation, the ultimate challenge will be develop aquifer management plans that provide for rural-urban co-management. While co-management of urban and rural groundwater is a worthy goal with many potential benefits for all users, this would need very significant reform of current institutional arrangements. Important first steps should include increased public awareness, concerted dialogue amongst stakeholders and data-sharing amongst agencies that have an interest in water management. The starting point for co-management is co-operation.

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