PUTTING THE CITIZEN AT THE HEART OF WATER MANAGEMENT:

A STUDY OF WATER IN BANGALORE

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By

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Excerpt from Hardin's "Tragedy of the Commons":

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy. As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?"...Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another.... But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit -- in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all. (Hardin 1968)

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ABSTRACT

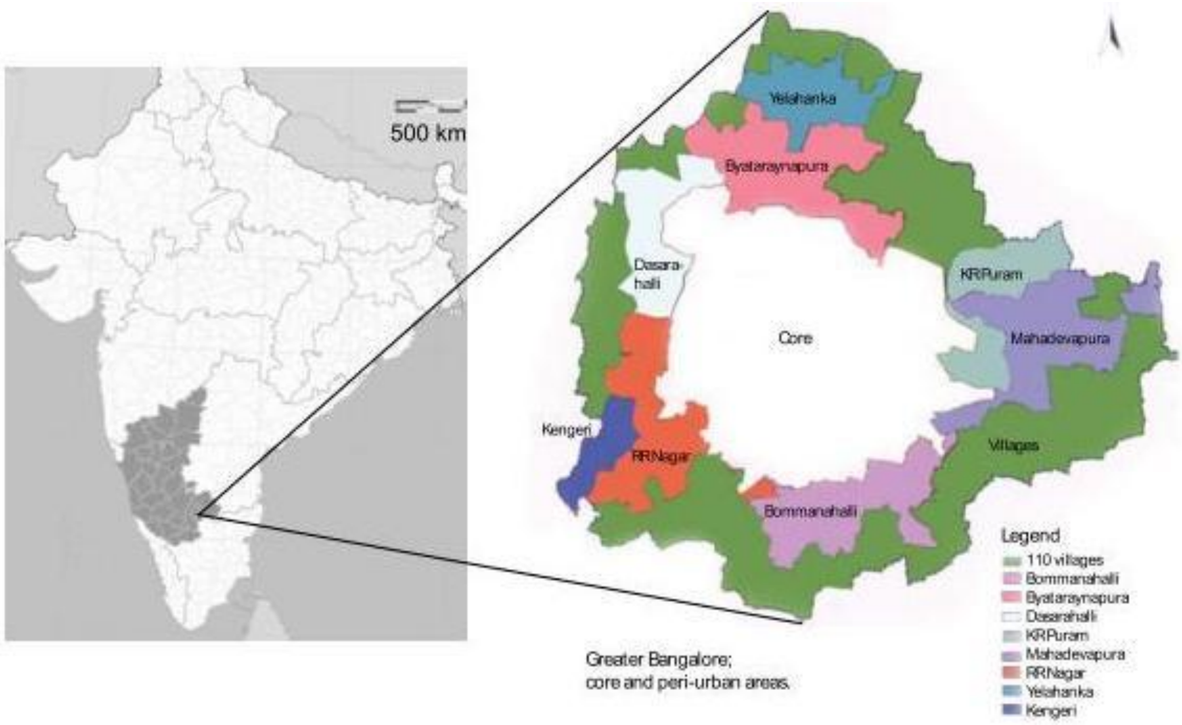
The focus of this thesis is the innovative process by which citizens in Bangalore, India have become engaged with the problem of water management through rainwater harvesting. Bangalore currently faces a water shortage of 500 million liters per day and, unless it dramatically changes its approach, acute water shortage by 2025. An effective water management scheme in Bangalore requires institutional restructuring to enable integrated management of water resources, strong legislation to protect groundwater, major infrastructural improvements to limit leakage, a shift in planning culture that more explicitly recognizes the link between the natural world and human settlements and stronger integration of science in planning. It is clear that any one of these actions is not easily implementable in the near term due to institutional, financial, and political challenges. In the absence of any near-term solutions for the water crisis, civil society has played a critical role in pushing the local water authority to make rainwater harvesting mandatory through the Bangalore Water Supply and Sewerage (Amendment) Act, 2009.

This thesis aims to add to two larger theoretical discussions: governing the commons and finding innovative solutions and processes for resource management. Governing the commons, especially in the dynamic context of rapidly growing cities that face systemic scarcity, requires a strong state to effectively restrict wasteful practices and mining of resources and a strong civil society to curb demand. As such, the scarcity-induced innovation framework (Srinivas and Sutz, 2008) has been applied to identify rainwater harvesting as an innovative approach to engage citizens in the heart of water management and curb demand. Rainwater harvesting is not presented here as a panacea, nor is it meant to distract from the need for the state to play a much stronger regulatory and implementation role.

INTRODUCTION

This thesis focuses on the city of Bangalore as an archetype of cities that face rapid urbanization, increasing environmental pressures, resource and/or institutional scarcities. Bangalore (Bengaluru) is the capital of the Indian state of Karnataka, in southern India (Figure 1) and has a population of over eight and a half million.

Figure 1: Map of India showing the location of Bangalore in the state of Karnataka



Source: Gronwall 2010(not to scale)

The focus of this thesis is on the city's approach to water management. Bangalore currently faces a water shortage of 500 million liters per day (MLD), exorbitant electricity costs from pumping water from their main surface water source – the Cauvery River, a rapidly decreasing water table and an ever increasing urban population.

What makes Bangalore exceptionally interesting as a project site is its strong civil society, which has become increasingly more active due to a lack of local representation in municipal governance and planning (Benjamin 2000). Urban planning and most of the city's services, including water, are managed by parastatal, rather than local, agencies and have a vested interest in supporting economic growth rather than equitable and sustainable development. Many of the livability initiatives, including environmental policies, have thus been initiated by civil society rather than by government. In the case of water management, civil society was instrumental in building citizen support for rainwater harvesting and in influencing the water authority, the Bangalore Water Supply and Sewerage Board (BWSSB), to make rainwater harvesting mandatory for existing buildings over 2400 square feet and new buildings over 1200 square feet through the Bangalore Water Supply and Sewerage (Amendment) Act, 2009.

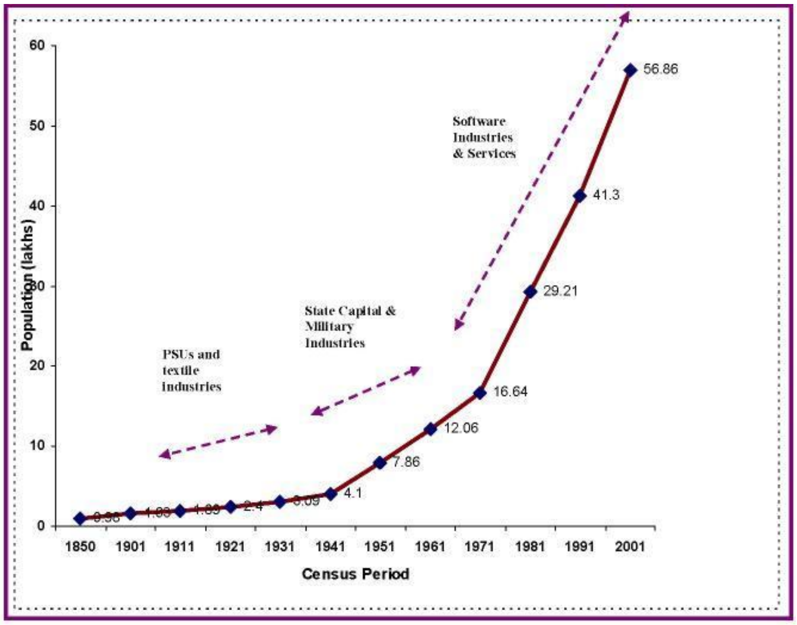
This thesis uses the scarcity-induced innovation (SII) framework (Srinivas and Sutz, 2008) to better understand how scarcity has led to an innovative citizen-based demand-side approach to water management in Bangalore. The SII framework helps identify solutions that are viable despite cognitive, physical, institutional and socioeconomic barriers. A matrix of water management initiatives was developed using secondary data analysis and interviews to highlight rainwater harvesting as the only workable near-term approach.

The original approach to this thesis was that rainwater harvesting was an innovative technology that should receive greater government support – through incentives and penalties – to drive more rapid and widespread adoption. A more comprehensive review of the city's institutional framework, state of water supply and geology signaled an urgent need for a deep reprogramming in the city's approach to water management – a need for getting citizens involved in the heart of water management. This thesis will show that in the case of natural resource management, where supply side solutions are rapidly wearing thin, innovative processes are needed to engage citizens in the problem and that a slower, more organic scaling-up process is necessary to allow for deep cultural shifts that effectively reduce demand.

BACKGROUND

Like many other rapidly growing global cities, Bangalore's services and urban infrastructure haven't been able to keep up with its economic, demographic and physical growth. The city's economic development (post India's 1947 independence) can be described by four distinct phases (Heitzman 1999), all of which reflect a prevailing emphasis on national- and state-driven economic growth. The first phase, during the 1950s and 60s, was marked by the national government's investment in Bangalore as a hub for public sector research and production facilities. During the second phase, in the late 60s and early 70s, state government bureaucracy increased to match the rise in state-run businesses. Soon after, during the real estate boom in the late 1980s and mid-1990s, Bangalore garnered more attention throughout the country and became one of Asia's fastest growing cities (Benjamin 2000; Dittrich 2007). In the 1990s, during the third phase of Bangalore's growth, India liberalized its economy to meet the International Monetary Fund's lending conditions. These reforms opened the country up to international trade and business, leading to a series of deregulation policies and tax reforms and a complementary emphasis on providing necessary infrastructure to encourage foreign investment. The fourth phase captures the emergence of Bangalore as a preferred hub for high-technology research and production and its rise in status as a global competitor. The Information Technology industry in Bangalore grew despite nation-wide industrial stagnation (Benjamin 2000) in the 1990s, reinforcing national and state emphasis on investing in infrastructure primarily for these industries.

Figure 2: Link between Industry Change and Population Growth

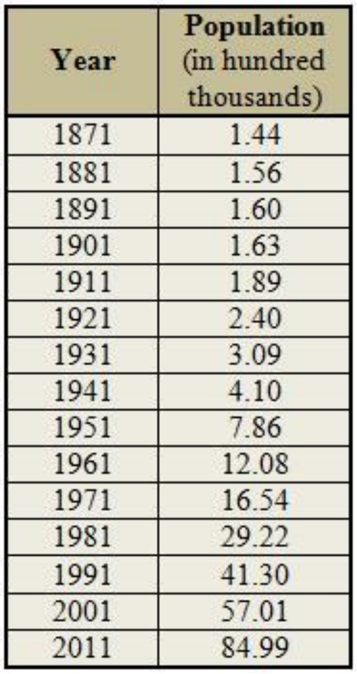


Source: Thippeswamy report 2008 (unpublished)

As seen in Figure 2, the changes in Bangalore’s dominant industries during this time were linked to rapid increases in population. The most important features to note in Bangalore’s economic development pattern are (1) the centralized system of governance, with national and state objectives taking precedence over municipal objectives; (2) the resulting imbalance in prioritization of promoting industrial and economic growth over addressing local livability issues; and (3) the effect of urbanization on land use and demand for natural resources.

A glance at the population growth from 1871 to 2011(Table 1) reflects a rapid increase in population, with the population most recently being placed at 8.5 million. The rapid economic growth of the city has also led to an increase in high-end lifestyles. The combination of these factors has led to increase water demand. Historically, this demand has been met through supply-side approaches or, in other words, by increasing the supply of water by capturing more surface, ground and rainwater. It is clear now, as the city faces a 500 MLD shortage and an increasing population, that the city needs an innovative approach to water management[1].

Table 1: Bangalore's Population Since 1871



Year	Population (in hundred thousands)
1871	1.44
1881	1.56
1891	1.60
1901	1.63
1911	1.89
1921	2.40
1931	3.09
1941	4.10
1951	7.86
1961	12.08
1971	16.54
1981	29.22
1991	41.30
2001	57.01
2011	84.99

Source: Census Data

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[1] 500 MLD is the official, but conservative, estimate of the city’s water shortage. Local water professional estimated an additional shortage of 250 MLD.

LITERATURE REVIEW OF INNOVATION

The purpose of this thesis is to understand why some approaches to natural resource management, such as rainwater harvesting in Bangalore, seem to be more successful than others in gaining the support of civil society and government. The assumption is that these solutions emerge because they are in some way more innovative than others. It is therefore important to discuss what is meant here by innovative and what we can learn about the process of innovation that can be applied to broader contexts.

The following literature review broadly describes the evolution of innovation literature, starting with standard models that describe innovation in relation to economic growth and ending by highlighting more recent literature that focuses specifically on innovation in developing countries. The review describes drivers of innovation – research and development, market demand, user-producer interactions, local knowledge and scarcity. Of these, I focus on scarcity-induced innovations (Srinivas and Sutz 2008) as a framework for my analysis of rainwater harvesting in Bangalore.

R&D, Demand and Innovation

The most simplistic model of innovation, the linear[2] model, focuses on the development of explicit knowledge through research and development (R&D) activities (Johannessen 2009). The underlying assumption, that R&D-driven innovations lead to economic growth, engenders policies that encourage investment in R&D. Although R&D is undoubtedly a catalyst for innovation, the linear model presents innovation as a constricted one-off process and fails to capture the dynamism or evolution implicit in innovation. A second model, demand-driven innovation (Schmookler 1962), emphasizes the role of market demand in the emergence of innovations. Fluctuations in market demand capture preferences, which can then be used to innovate products that more closely match consumer demands. This assumption is characterized by laissez-faire policy recommendations (i.e. 'let the market drive innovation'). In the late 1980s, both of these models came under attack for over-simplifying the process of innovation. The first because it is myopic and fails to account for drivers of innovations outside of R&D; the second because the level of information derived from changing demands is too basic to account for evolving innovations.

Interaction and Innovation

Lundvall's description of innovation emerged to fill this gap. He recognized that innovations occur "as the result of collisions between technical opportunity and user needs" and that there exists an interdependent relationship between innovation and production (Lundvall 1985). In this model, user-

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[2] Linear: R&D →innovation → economic growth

producer interactions – which take the form of information exchange, product exchange and cooperation – spur innovation. The Lundvall model describes a more dynamic model of innovation – one that is constantly evolving and that, although developed for existing users, can be easily diffused to other markets.

Innovation driven by user-producer interaction and exchange is costly. The associated costs increase as geographic distance between production and consumption increases and as cultures – and their nuances in communication – between users and producers differ. Just as markets are ill-equipped to provide sophisticated information, communication across wide geographic distances is overly simplified and standardized to conform to situational and cultural differences. Frequent user-producer interactions and geographic proximity and cultural similarity in production and consumption lead to more refined innovation. This opened up the literature to the importance of local innovation.

However, Lundvall's model excludes consideration of socioeconomic factors that may affect innovation and highlights a gap in innovation literature. In other words, there is very little literature describing what separates innovation in developing countries from that in developed countries. So, while there are many overlaps in the literature – discussions of 'local capabilities, forms of learning, and linkages' (Lorentzen 2010), for example, there are few schemas for ways to identify and encourage innovation in developing countries.

Innovation in Developing Countries

Scarcity

> *'...in "underdevelopment" or the conditions of so-called developing countries pursuing their own form of industrialization, there is another logic related to innovation: rather than starting with available inputs, innovation often starts facing the lack, weakness, or inadequacy of inputs of several different kinds.'* (Srinivas and Sutz 2008)

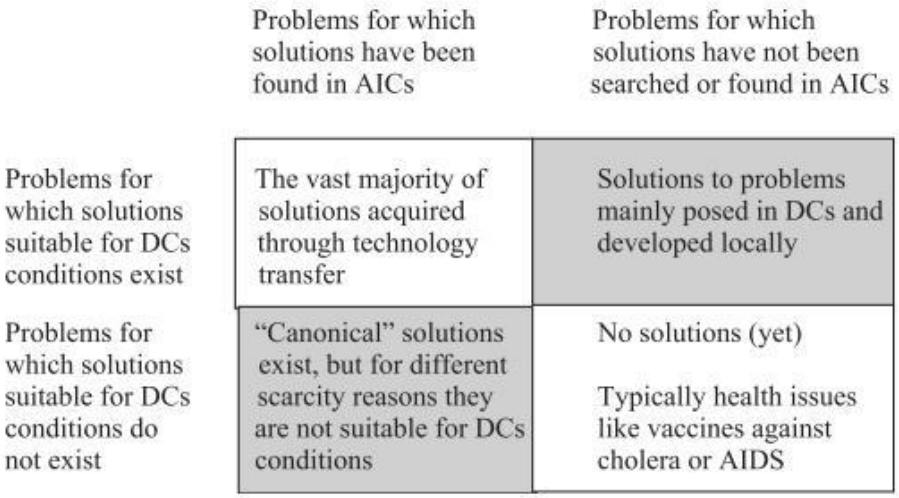
Srinivas and Sutz (2008) point to scarcity-induced innovation (SII) as a framework for contextualizing the relationship between innovation and development. By generalizing the conditions that lead to innovation, and by categorizing them all as the same 'kind' of innovation, previous literature missed the importance of adaptation to limited resources. Although Srinivas and Sutz recognize that extreme scarcity will inhibit innovation, they argue that some level of scarcity may also encourage innovation. Their definition of scarcity includes inadequate infrastructure and lack of access to input materials, institutional support, skilled labor, and knowledge. However, they differentiate between these 'incidental' scarcities, present in all countries, and 'ambience', or 'systemic', scarcities characteristic of developing countries.

> *"Thus, scarcities in the innovation environment are present everywhere. But while in industrialized countries scarcities are "incidental", that is, the specific instance of scarcity can be remedied relatively systematically, in industrializing countries there are few isolated scarcities. This is what suggests the term 'ambience'."* (Srinivas and Sutz 2008)

They're more interested in 'systemic' scarcity and the learning that follows from adapting to this type of scarcity. Thus, the SII framework makes two valuable contributions to the literature on innovation just in its discussion of scarcity. First, it highlights the fact that 'scarcity' is a relative term and, to some extent, a social construct. It can be a barrier or catalyst to innovation, depending on how it is approached. Thus, the second contribution is that the SII framework recognizes the value in this approach, or the learning process by which a given solution is applied in conditions of scarcity.

The SII framework also provides a two-by-two matrix (Figure 3) of problems based on the types of scarcities they face. AIC refers to advanced industrialized countries while DC refers to developing, or industrializing, countries. The top left quadrant represents conditions in which solutions exist and, assuming technology transfer occurs, can be adapted to local conditions. It more or less holds all the standard approaches to problems. The top right quadrant represents solutions that are developed locally and need to be scaled up to be adopted more widely. The bottom right quadrant represents problems that either have no known solution or haven't been adequately researched. The bottom left quadrant holds problems for which solutions do exist but cannot be applied to the developing country context due to scarcity (can be institutional, physical, cognitive, or a mixture of the three). Srinivas and Sutz point to the gray quadrants as having the greatest potential in the context of industrializing countries.

Figure 3: Scarcity-Induced Innovation (SII) Framework



	Problems for which solutions have been found in AICs	Problems for which solutions have not been searched or found in AICs
Problems for which solutions suitable for DCs conditions exist	The vast majority of solutions acquired through technology transfer	Solutions to problems mainly posed in DCs and developed locally
Problems for which solutions suitable for DCs conditions do not exist	"Canonical" solutions exist, but for different scarcity reasons they are not suitable for DCs conditions	No solutions (yet) Typically health issues like vaccines against cholera or AIDS

Source: Srinivas and Sutz 2008

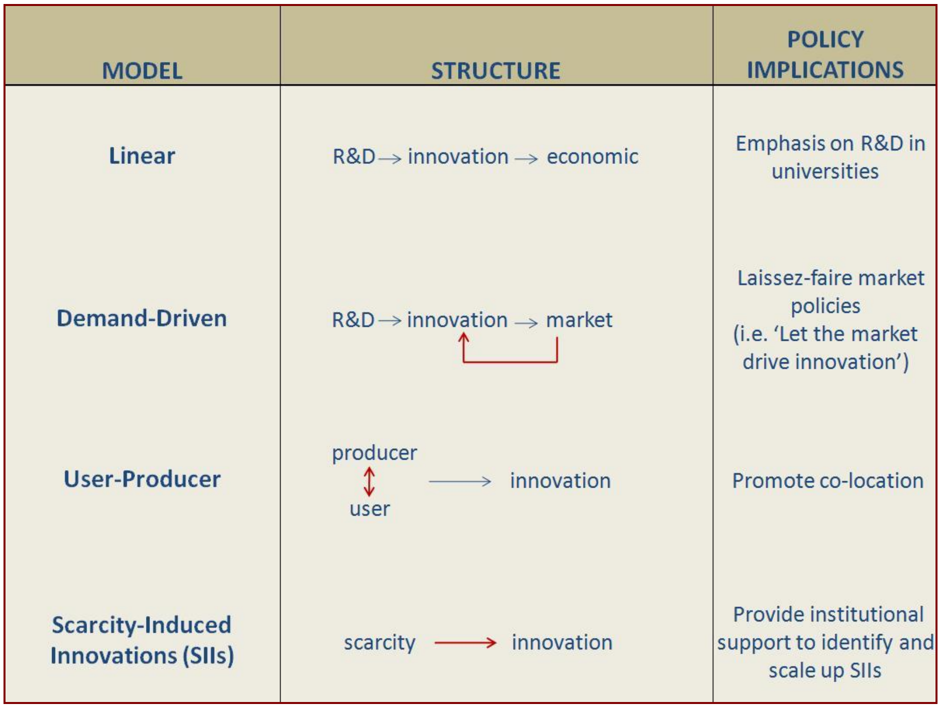
The framework is not meant to be taken as a static division but rather to highlight the fluidity of moving from one quadrant to another through institutional changes (Srinivas and Sutz 2008). Thus, with some ingenuity, local innovations can be scaled up and, if they are given the proper institutional support, can shift from the top right quadrant to the top left. Although the SII framework draws attention to identifying innovations within conditions of scarcity, it doesn't go into any detail on the process of scaling-up.

Back-End Users

One proposed method to promoting broader adoption of an innovation, especially relevant to the context of developing countries, is by marketing the innovation to back-end users (Murray and Ray 2010). Murray and Ray posit that some innovations may be more quickly adopted if they are advertised to back-end users, for which a market exists for the by-products of the innovation, rather than to the front-end users that actually use the technology. More specifically, they point to the efficacy of marketing sanitation systems to back-end users that would have a market demand 'for the products of sanitation (e.g., treated wastewater, fertilizer, alternative fuel)' rather than waiting for front-end users (households and communities) to come to a consensus on their demand. Nearly all innovation literature assumes that rapid and widespread adoption of the innovation will maximize efficacy. Their contribution is interesting because it suggests that rather than depending on community consensus-building for adoption of the innovation, it is more efficient to define new (indirect) markets that more quickly absorb the innovation for financial gain. Although it may seem tangential to the literature review's focus on drivers of innovation, it is mentioned here to raise awareness about the need to match innovative solutions with equally innovative scaling-up processes.

The following table (Table 2) briefly reviews the four models of innovation described thus far.

Table 2: Overview of Relevant Innovation Theories



MODEL	STRUCTURE	POLICY IMPLICATIONS
Linear	R&D → innovation → economic	Emphasis on R&D in universities
Demand-Driven	R&D → innovation → market	Laissez-faire market policies (i.e. 'Let the market drive innovation')
User-Producer	producer ↕ user → innovation	Promote co-location
Scarcity-Induced Innovations (SIIs)	scarcity → innovation	Provide institutional support to identify and scale up SIIs

Bangalore's economic success has largely been due to the national and state government's emphasis on the first few approaches to innovation – in other words, through investment in research and development, through increased public-private interactions and through co-location of industries. Although these models are important for driving economic growth, they miss the potential of local innovations. Local innovations, especially related to livability issues, could potentially be 'scaled up' throughout the region or nation since they face the same (cognitive, physical/institutional, socioeconomic) barriers.

The SII framework diverges from other models of innovation largely because it expands the focus from *sources* of innovation to the actual *process* by which that innovation is scaled up. If we look at the bottom left quadrant of the two-by-two matrix, the typical supply-side approach to water shortage – expanding infrastructure to draw more from surface or groundwater– is not viable in Bangalore due to scarcity. Rainwater harvesting, a local innovation, emerges in the top right corner of the matrix with the potential of being successful if scaled up properly. Application of the SII framework is limited to conceptualizing the "scaling-up" process and does not explain what types of structural or institutional changes need to occur to enable innovations to be more successfully dispersed. Therefore, although this thesis builds around the SII framework and the theory of innovation, much of the analysis is based around ideas of weak state vs. strong state and the role of the state vs. civil society as they apply to water governance. For this, it may also be helpful to give a brief overview of the literature on water governance.

Water Governance

> *"Each man is locked into a system that compels him to increase his herd without limit -- in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."* (Hardin 1968)

By far the most well-known contribution to literature on resource management has been Garrett Hardin's *Tragedy of the Commons*. Hardin describes that as a rational actor, man will use resources indiscriminately to maximize his utility regardless of the net long-term effect on that resource. The allegory he uses is of men allowing their sheep to graze without constraint; when the pasture is filled with just one or two herders, this practice may be sustainable but as soon as the population increases, the resource is exhausted. His conclusion is that, although imperfect and not inherently equitable, central government and property laws are crucial to governing the commons.

Eleanor Ostrom has been a more recent, and equally prominent, contributor to the debate recognizing that "[i]n the absence of effective governance institutions at the appropriate scale, natural resources and the environment are in peril from increasing human population, consumption, and deployment of advanced technologies for resource use, all of which have reached unprecedented levels" (Dietz, Ostrom and Stern 2003). She criticizes Hardin's emphasis on state-established governing institutions and points, instead, to successful examples of self-governance (Ostrom 1990). She argues that while self-governance is not always effective, neither is state-governance and, therefore, neither should be overlooked.

Water management falls under the tragedy of the commons – without some institutionalized framework for water governance, water is wasted, polluted and mined. Karen Bakker has written extensively on water governance and the privatization of water as an emerging water management strategy. She posits that emphasis on community-led approaches to managing the commons runs the risk of overly romanticizing the community's ability to self-organize cohesively and to govern the resource in an effective and equitable way:

> *"Much activism in favour of collective, community-based forms of water supply management tends to romanticize communities as coherent, relatively equitable social structures, despite the fact that inequitable power relations and resource allocation exist within communities."* (Bakker 2007)

Therefore, the state plays an important role in ensuring equitable redistribution of resources and since both communities and states play unique and equally important role in governing the commons, “the most progressive strategies are those that adopt a twofold tactic: reforming rather than abolishing state governance, while fostering and sharing alternative local models of resource management” (Bakker 2007).

RESEARCH DESIGN AND METHODOLOGY

Data collection was primarily conducted through semi-structured interviews and secondary data analysis. Secondary data analysis focused on reviewing local news sites (*Times of India, Deccan Herald, Daily News and Analysis, Citizen Matters),* blog postings of local water organizations and experts, water-related legislation and various water-related reports. The primary objectives were to capture publicized suggested water management strategies and to identify the current culture around water use and management in Bangalore. This information was then used to construct a matrix of initiatives that are needed for the city to effectively deal with its long term water needs. The matrix also identifies factors that made some initiatives more feasible than others and highlights why rainwater harvesting alone has managed to be successfully accepted by citizens and government.

Semi-structured, open-ended interviews helped fill in the gaps in reporting and gauge the perceived efficacy of local approaches to water management. During the first five months of research, interviews were conducted via Skype and lasted 30 – 60 minutes. In cases where schedules did not align, I sent my interview questions to my subjects and they responded through email. I targeted urban planning and design practitioners, academics that were familiar with water management in India, and local water experts.

These interviews were supplemented by a week-long site visit in March 2012, during which I conducted face-to-face interviews with individuals from the Mines and Geology Department, Geological Society of India, faculty from the Indian Institute of Science (IISc), BWSSB officials, local rainwater harvesting consultants, and other practitioners that deal with local water management. These interviews typically lasted much longer than those done through Skype, ranging from two to five hours. Apart from these interviews, I also joined meetings with civil society representatives ranging from individuals that call for citizen-led planning to Janaagraha, a local watch-dog NGO. In total, including email exchanges, Skype conversations and in-person interviews, I conducted roughly twenty formal interviews. I also had numerous informal conversations to gain a better understanding of the level of awareness about the shortage of water and to gauge public impression of the city’s response to the problem. The site visit enabled me to access print articles, books, reports and presentations that were not accessible online. I collected clippings from *The Times of India* every day to understand how the local press was framing the problem and the proposed solutions. I observed that a great deal of attention was on the unequal access to water, overdependence on (and lack of) groundwater and tension between unregulated private water tankers and citizens.

Finally, I visited the BWSSB-sponsored Sir. M. Visvesvaraya Rainwater Harvesting Theme Park in Jayanagar, Bangalore to observe the types of visitors (i.e. their motivations for visiting their park), their level of engagement with the information presented, the quality of information presentation (in terms of scientific depth and interactiveness) and the type of material that is provided. I received a tour of the park from one of the two civil engineers on staff full-time and spoke to them about the types of visitors and their level of engagement with the materials and information presented at the park.

FINDINGS AND APPLICATION OF THE SII FRAMEWORK

The various parts of an integrated approach to water management in Bangalore exhibit three of the defining characteristics – cognitive, institutional or physical, socio-economic (Srinivas and Sutz 2008) – of SIIs, making it an ideal paradigm by which to explore the SII framework. The findings have been organized accordingly to help frame the discussion around the existing challenges that make some water-management related initiatives, such as rainwater harvesting, more "successful" than others. Success is a relative term; measured here by level of government, citizen and civil society support rather than by the amount of water captured.

A Pressing Need to Break from Supply-Side Approaches

As detailed in this next section, the city's historic approach to increasing demand has been to expand infrastructure and to draw more from its three primary sources of water – surface, ground and rain. The first two sources have been nearly exhausted, rendering the supply-side approach increasingly impractical. This signals the presence of *cognitive* conditions that give rise to SIIs, described as when 'the innovator... is unable to use [the canonical set of solutions]... and faces the need to address the problem differently' (Srinivas and Sutz 2008).

Surface Water

Bangalore's early water needs were primarily met through a system of *kalyanis*, or tanks, and were augmented by ponds and wells. By 1896, the city recognized a need for filtered water and began to use water from the Hesaraghatta Lake, roughly 20 kilometers from the city along the Arkavathy River. This became India's first dedicated, and protected, system for drinking water. Although the supply was increased in 1915 through the addition of three more pipelines, by 1933 the city had to construct a new reservoir near the Thippagondanahalli Halli (also along Arkavathy) to supply an additional 148 million liters per day (MLD). The city's water supply continued to be dependent on the Arkavathy River until the 1980s.

The Bangalore Water Supply and Sewerage Board (BWSSB) was established through the "Bangalore Water Supply and Sewerage Act, 1964" as part of a World Bank lending requirement, making it the oldest board in India to oversee water supply and sanitation. The BWSSB is a board of three to seven members appointed by the state government. It is a parastatal agency and, therefore, not beholden to the local municipality.

As can be seen in Table 2, the BWSSB initiated the Cauvery Water Supply System (CWSS) in 1973 to match the city's increasing water demand. The Cauvery River, Bangalore's main perennial water source, stands 100 km southwest of the city at an elevation gradient of close to 500 meters. The cost of pumping water up this gradient accounts for about sixty five percent (Grönwall 2010) of the BWSSB's budget. Since the start of the project, the BWSSB has expanded the CWSS infrastructure every decade. Cauvery stage four, phase two, is expected to be completed by June or July of 2012 and will account for an additional 500 MLD, yielding a total supply of 1,400 MLD from the Cauvery River[3]. TG Halli, the only other source of surface water supply, contributes very little, resulting in a total gross water supply yield of roughly 1,425 MLD.

Table 2: BWSSB Water Supply Projects

Source	River	Year of Commission	Optimal Drawal (MLD)	Current Drawal (MLD)
Hesaraghatta Scheme	Arkavathy	1896	36	-
TG Halli CRS Scheme	Arkavathy	1933	148	40[4]
CWSS I	Cauvery	1973	135	135
CWSS II	Cauvery	1982	135	135
CWSS III	Cauvery	1993	270	270
CWSS IV Stage IV phase 1	Cauvery	2002	270	270
CWSS Stage IV Phase II (under implementation)	Cauvery	2012	500	0

Source: Recreated from Thippeswamy 2011

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[3] *The Times of India*: "Greater Bangalore's water hopes float on Cauvery phase II". Dec. 19, 2011.

[4] Whereas the other numbers on the chart are the same throughout charts, this number varies depending on the source. M.S. Mohan Kumar et al (2011) have the same table but quote 60 MLD for the current supply from T.G. Halli. A similar table from a presentation by Mr. Thippeswamy quoted 0 MLD.

There are, however, great inefficiencies in the system that result in a ‘loss’ of 50% of the total surface water supply. Unaccounted for water (UfW), or the total supply minus approximated public water supplied and meter readings for commercial, industrial and residential uses, makes up about 43%, or 408 MLD, of the total supply. Of this, about 25% is due to physical losses from leakages while 18% is due to financial losses resulting from inaccurate meter readings and unauthorized, or illegal, consumption. Added to this are Non-Revenue Losses (NRL) of about 67 MLD due to maintaining the infrastructure (i.e. loss of revenue from having to shut down parts of the infrastructure for maintenance) and for firefighting. As can be seen in Table 3, this means that, in total, about 50% of the total surface water supply is Non-Revenue Water (NRW). This is compared to the standard international level of about 16%.

Table 3: Breakdown of Non Revenue (NRW) and Revenue Water from Total Supply

Total Water Input	**Authorized Consumption**	**Billed Authorized Consumption**	Billed Metered Consumption	**Revenue Water**
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	**Non Revenue Water (NRW)**
			Unbilled Unmetered Consumption	
	Water Losses	**Apparent (Financial) Losses**	Unauthorized Consumption	
			Customer Meter Inaccuracies and Data Handling Errors	
		Real (Physical) Losses	Leakage on Transmission and Distribution Mains	
			Leakage and Overflows from the Utilities Storage Tanks	
			Leakage on Service Connections	

Source: Adapted from BWSSB Presentation

Therefore, of the 1,017 MLD left [1425 MLD (total surface water supplied by BWSSB) – 450 MLD (UfW + NRL)], about 50 MLD is used for non-domestic uses, including industries, commercial and educational institutions, leaving roughly 925 MLD for domestic use. This amount has proved to be insufficient to meet the current demand of the city, with a modest estimate of a 500 MLD water shortage. Although this shortage will be met once Cauvery stage 4 phase 2 has been completed, the city cannot withdraw any more water from the Cauvery due to legal limitations[5]. Therefore, population growth and changing lifestyles will only lead to increased demand that can no longer be met through increased withdrawal from the Cauvery.

Not all parts of the city receive an even distribution of water. This is partially because of inadequate water pressure due to the city's uneven terrain, leaks and illegal connections that reduce the pressure of the overall system and a lack of government response. A recent series in *The Times of India* focusing on Bangalore's water scarcity, highlighted the lack of institutional willingness to address the problem: "BWSSB officials themselves admit that 'political interference' over the years has ensured they are unable to distribute water supply evenly in the area"[6]. The problem is further compounded due to the inadequate coverage of BWSSB infrastructure. This is partially due to the physical, demographic and economic growth, but also due to the city's administrative boundary growth in 2007. Bangalore city was administratively limited to the Bangalore Mahanagara Palike (BMP) area (see yellow core region in Figure 4) until very recently. BWSSB was only responsible for supplying water and sanitation throughout this 240 sq. km. area. In July 2007, the administrative boundaries were expanded to include eight municipalities (each denoted in a different color) and their Urban Local Bodies (ULBs) along with 110 villages to create the Bhruhath Bangalore Mahanagara Palike (BBMP), an area of roughly 800 sq. km. This means that, virtually overnight, the BWSSB became responsible for an area increase of 333% but without being given the adequate funding to extend the water and sewerage infrastructure.

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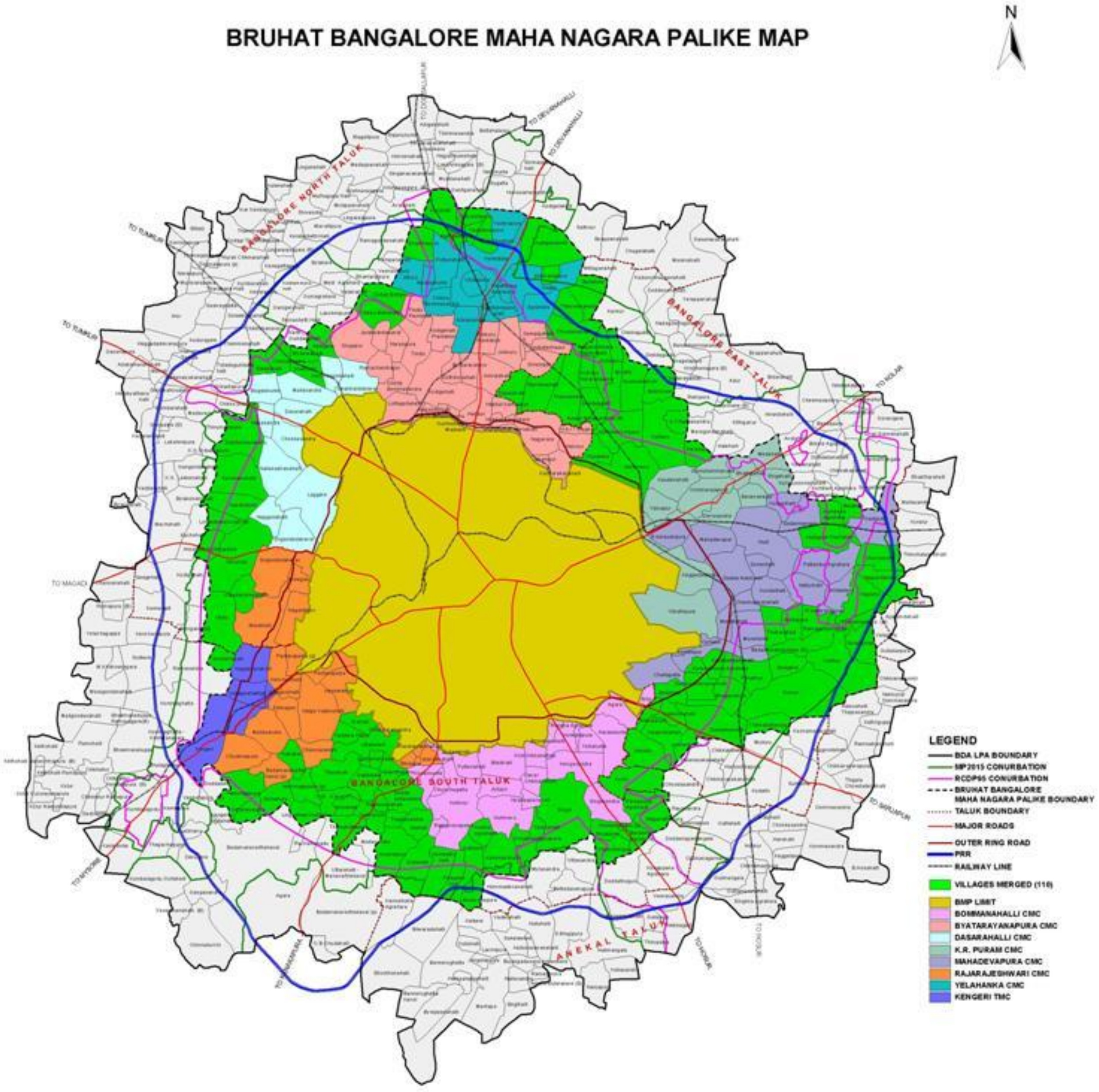
[5] The Cauvery Tribunal's water allocation for Bangalore will be reached with the completion of the CWSS project.

[6] "Bangalore South also has Water Worries." *The Times of India*, Bangalore. Mar. 13, 2012.

Figure 4: BBMP Administrative Area with BMP, Additional Municipalities and Villages Highlighted



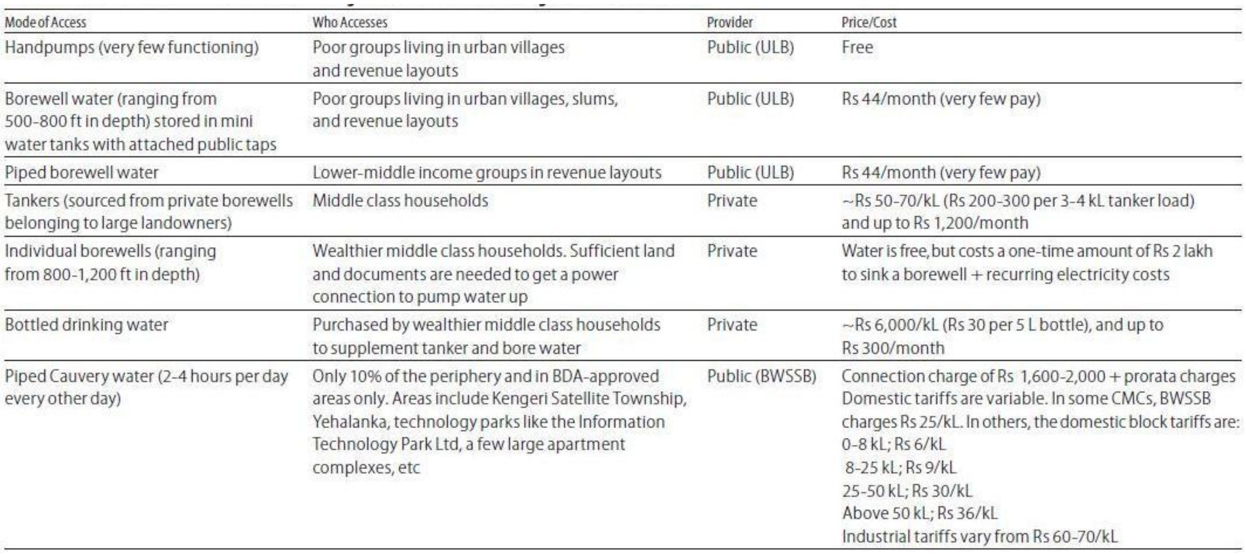
Therefore, most of the periphery of the BBMP area does not have access to BWSSB water or sewerage infrastructure and is therefore heavily reliant on groundwater.

Groundwater

> *"Of the 198 wards of the Bruhat Bangalore Mahanagara Palike, only 125 wards are being provided with piped water by the BWSSB. It is estimated that there are over three lakh[7] borewells in Bangalore city alone, resulting in over-exploitation of ground water."*[8]

The above quote highlights a spatial dimension to dependence on groundwater but there's an added socioeconomic component. Given the infrequency of piped water and inaccessibility in some areas of the city – especially in the North and East – many residents rely on water tankers and bottled water to meet their domestic needs. However, much of the population is priced out of these sources and relies more heavily on groundwater. In a 2009 study published in *Economic and Political Weekly*, Ranganathan et. al. conducted household surveys and interviews to quantify the cost of different sources of water. Table 3describes the different sources of household water and their associated costs – highlighting bottled water and piped Cauvery water as options available only to the middle and upper class and groundwater as the only affordable option for lower income groups.

Table 3: Different Modes of Access in Greater Bangalore in Order of Ascending Socioeconomic Status



Mode of Access	Who Accesses	Provider	Price/Cost
Handpumps (very few functioning)	Poor groups living in urban villages and revenue layouts	Public (ULB)	Free
Borewell water (ranging from 500-800 ft in depth) stored in mini water tanks with attached public taps	Poor groups living in urban villages, slums, and revenue layouts	Public (ULB)	Rs 44/month (very few pay)
Piped borewell water	Lower-middle income groups in revenue layouts	Public (ULB)	Rs 44/month (very few pay)
Tankers (sourced from private borewells belonging to large landowners)	Middle class households	Private	~Rs 50-70/kL (Rs 200-300 per 3-4 kL tanker load) and up to Rs 1,200/month
Individual borewells (ranging from 800-1,200 ft in depth)	Wealthier middle class households. Sufficient land and documents are needed to get a power connection to pump water up	Private	Water is free, but costs a one-time amount of Rs 2 lakh to sink a borewell + recurring electricity costs
Bottled drinking water	Purchased by wealthier middle class households to supplement tanker and bore water	Private	~Rs 6,000/kL (Rs 30 per 5 L bottle), and up to Rs 300/month
Piped Cauvery water (2-4 hours per day every other day)	Only 10% of the periphery and in BDA-approved areas only. Areas include Kengeri Satellite Township, Yehalanka, technology parks like the Information Technology Park Ltd, a few large apartment complexes, etc	Public (BWSSB)	Connection charge of Rs 1,600-2,000 + prorata charges Domestic tariffs are variable. In some CMCs, BWSSB charges Rs 25/kL. In others, the domestic block tariffs are: 0-8 kL; Rs 6/kL 8-25 kL; Rs 9/kL 25-50 kL; Rs 30/kL Above 50 kL; Rs 36/kL Industrial tariffs vary from Rs 60-70/kL

Source: Ranganathan et. al. 2009

The inadequacy of the BWSSB infrastructure, combined with the high cost of bottled and tanker water, means that the city augments nearly half of its domestic water needs with groundwater[9]. Although

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[7] One lakh is 100,000.

[8] "Water Sellers Have to Pay". Deccan Herald. Oct. 31, 2011.

groundwater has always been used, the introduction of high speed drills in the 1970s made extracting water much easier. Initially borewells were drilled 30-40 meters and were mostly fitted with hand pumps, thereby limiting the amount of extraction. The introduction of diesel and, more so in the case of Bangalore, electric pumps enabled more rapid extraction.

There are now more than one hundred thousand borewells within the BBMP area that account for an additional 200 MLD supply of water (Thippeswamy 2011). Other estimates, based on inquiries made with the BWSSB, BBMP and private drilling companies suggest that there are nearly 312,000, or 3 lakh, borewells (Chandra 2011). The3 lakh figure is derived from the roughly 105,500 privately owned borewells registered with the BWSSB (as of 2010), the 7,000 BWSSB-owned borewells and an estimated 200,000[10] borewells that are privately owned but unregistered (Chandra 2012). The lack of regulation over borewell proliferation and groundwater extraction has led to a rapidly decreasing water table[11].

The problem is further intensified by the physical structure of the city and its unique geology, both of which make groundwater recharge extremely difficult. The soil cap in the Bangalore area is roughly 1-1.5 meters and primarily red sandy and gravelly loam. These fine soils are generally associated with low infiltration capacities and high run-off rates, making vegetation extremely important to slowing down the rate of runoff and allowing for rainwater penetration. In the case of Bangalore, of the 800 sq. km of the BBMP area, roughly 560 sq. km has been built up. Only 240 sq. km has been left as green area in the form of parks, gardens and golf courses. While this pattern of land use is true of most cities, the geology of Bangalore makes groundwater recharge significantly more difficult.

Bangalore sits on hard rock or, more specifically, granite (igneous rock) and gneiss (metamorphic rock). Granite is the dominant type of rock in the western part of Bangalore whereas gneiss formations are dominant throughout the rest of the city. Igneous and metamorphic rock are crystalline in structure, with little space between the interlocking crystalline minerals, making it very difficult for water to pass through. Any penetration has to occur through cracks, referred to as joints, faults or fractures. The Indian Peninsula is of the Archaean age, dating back over 3Ga, or 3 billion years. Therefore, the rocks have undergone a certain level of secondary decomposition after having been exposed to different weather

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[9] "Saved by the Bill? Let's See". *The Hindu*. Mar. 22, 2011.

[10] This figure is derived from the assumption that every private residence has at least one borewell. Therefore, the number is based on the number of houses in the BBMP area that could physically have a borewell, minus those that are registered with the BWSSB. (Chandra 2010)

[11] The water table level differs throughout the city. In the center of the city, where most have a water and sewerage connection, the water table is high due to low use of groundwater and leakage from the water and sewerage pipes. In the periphery of the city, beyond the reach of BWSSB infrastructure, there is much higher dependence on groundwater and therefore much lower water table levels.

conditions – winds, humidity, dry conditions, rain, etc. (Gronwall 2010). The weathered mantle extends, on average, 15 meters below the surface and is normally intensely jointed, allowing for a high rate of infiltration. Below this level sits the unweathered mantle with fractures and joints extending to 280-290 meters, thereby enabling partial penetration by water. This part of the bedrock is considered to be a semi-confined aquifer condition. Finally, below this layer is a hard massive rock body that remains impermeable to water, and allows the build up of the water table. In most parts of the city, borewells cannot expect to gain access to water at depths greater than 280 meters.

These factors combined – the physical buildup of the city and its geology – make recharge very difficult. Figure 5[12] more clearly illustrates the importance of controlling groundwater extraction and borewell depth. Groundwater in zones I and II is replenished in much less time than that of zone III.

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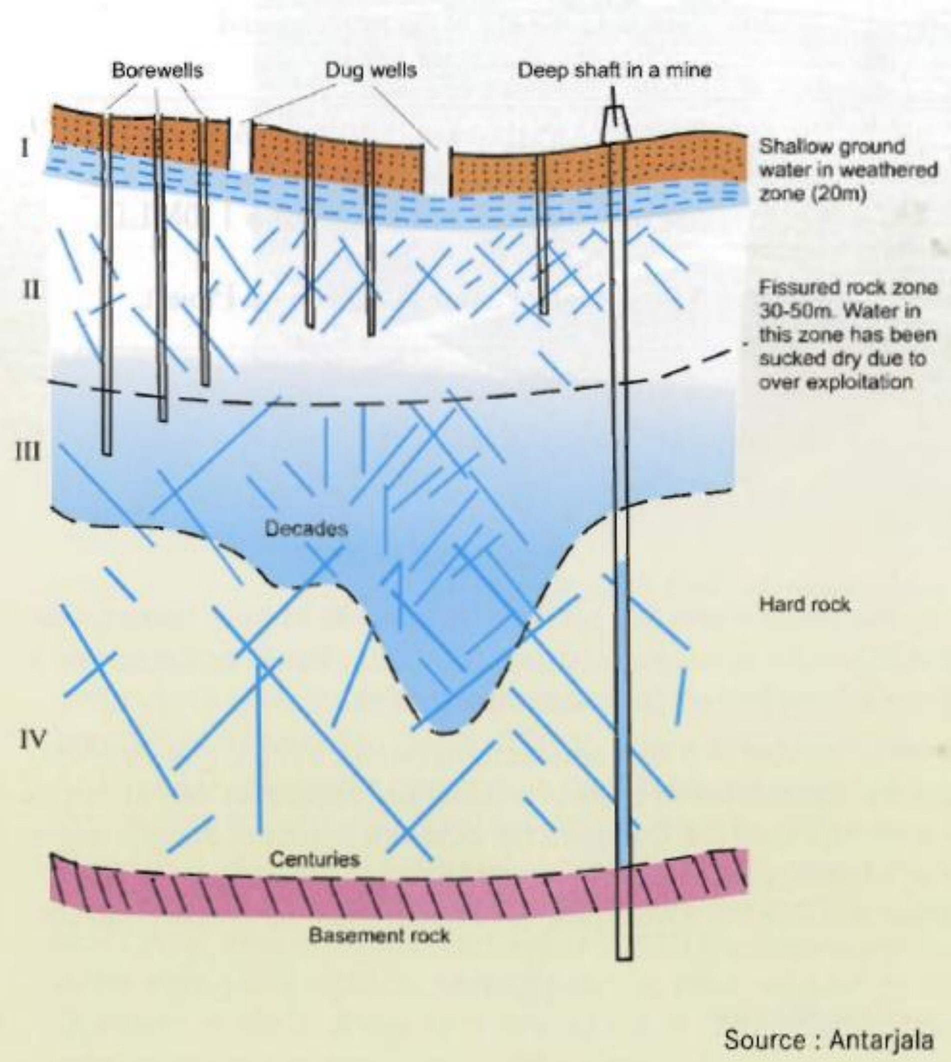
[12] Taken from an "Earth Day 2011: Sustainable Water Resources – Rural and Urban Challenges" pamphlet from the Geological Society of India and the Ministry of Earth Sciences.

Figure 5: Diagram of Borewells and Rock Profile



Source : Antarjala

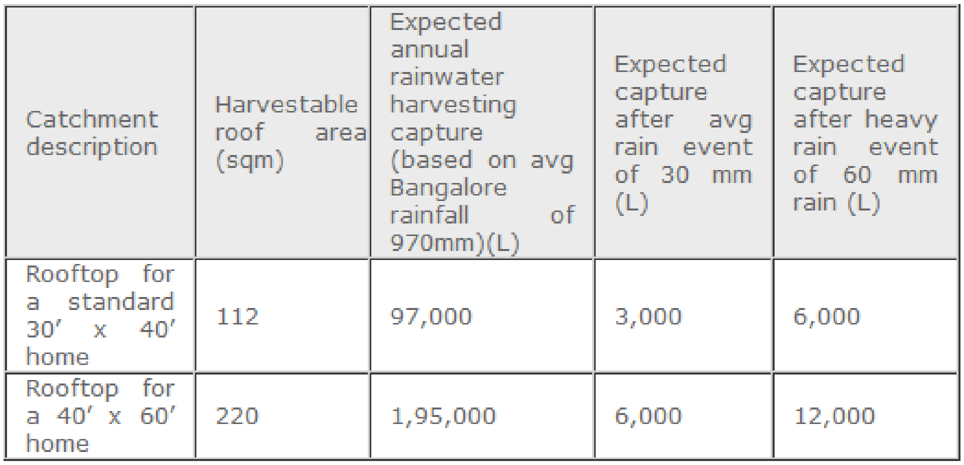
The drilling of borewells is currently unregulated and done in an unscientific, haphazard way – borewells are drilled until they happen to strike water. In addition, since many of the borewells are not registered, and therefore not metered, there's no way to regulate groundwater extraction. Extraction rates, estimated to be 3,200 hectare meter (ham) per year, have greatly exceeded recharge rates, estimated to be 12,450 ham/yr (Chandra 2012). Although the exact measurements are difficult to calculate, it is clear by the rapidly lowering water table that groundwater is literally being mined.

Rainwater

The third primary source of water is rainwater. Bangalore receives an average annual rainfall of about 970 mm primarily during two rainy seasons; the monsoon season from June-September and the post-monsoon season from November-December. The expanded span of rainfall makes rainwater harvesting a viable and substantial source of water at the household level.

In a four-part series posted on *Citizen Matters*, a Bangalore-focused online news site, the Rainwater Club used Table 4 to demonstrate the physical benefits of rainwater harvesting for a 30 × 40 sq. ft. home and a 40 × 60 sq. ft. home[13].

Table 4: Benefits of Rainwater Harvesting



Catchment description	Harvestable roof area (sqm)	Expected annual rainwater harvesting capture (based on avg Bangalore rainfall of 970mm)(L)	Expected capture after avg rain event of 30 mm (L)	Expected capture after heavy rain event of 60 mm rain (L)
Rooftop for a standard 30′ x 40′ home	112	97,000	3,000	6,000
Rooftop for a 40′ x 60′ home	220	1,95,000	6,000	12,000

Source: Rainwater Club

The conclusion they point to from these figures is that, in a 30 × 40 sq. ft. home, a family of four could potentially have all their water needs met for four to five months or, in a 40 × 60 sq. ft. home, for five to six months. This is, of course, dependent on the size of the storage tank, the frequency of rain and the family's use of water. Regardless, it is still a considerable source of non-potable water at the household level.

Figure 6 describes the basic components of rainwater harvesting system – the catchment surface (rooftop), storage tank, gutters and pipes that carry water to the tank, and the screens and first-flush system that filter the rainwater before it goes into the tank. The water can then either be used for non-potable uses or for groundwater recharge.

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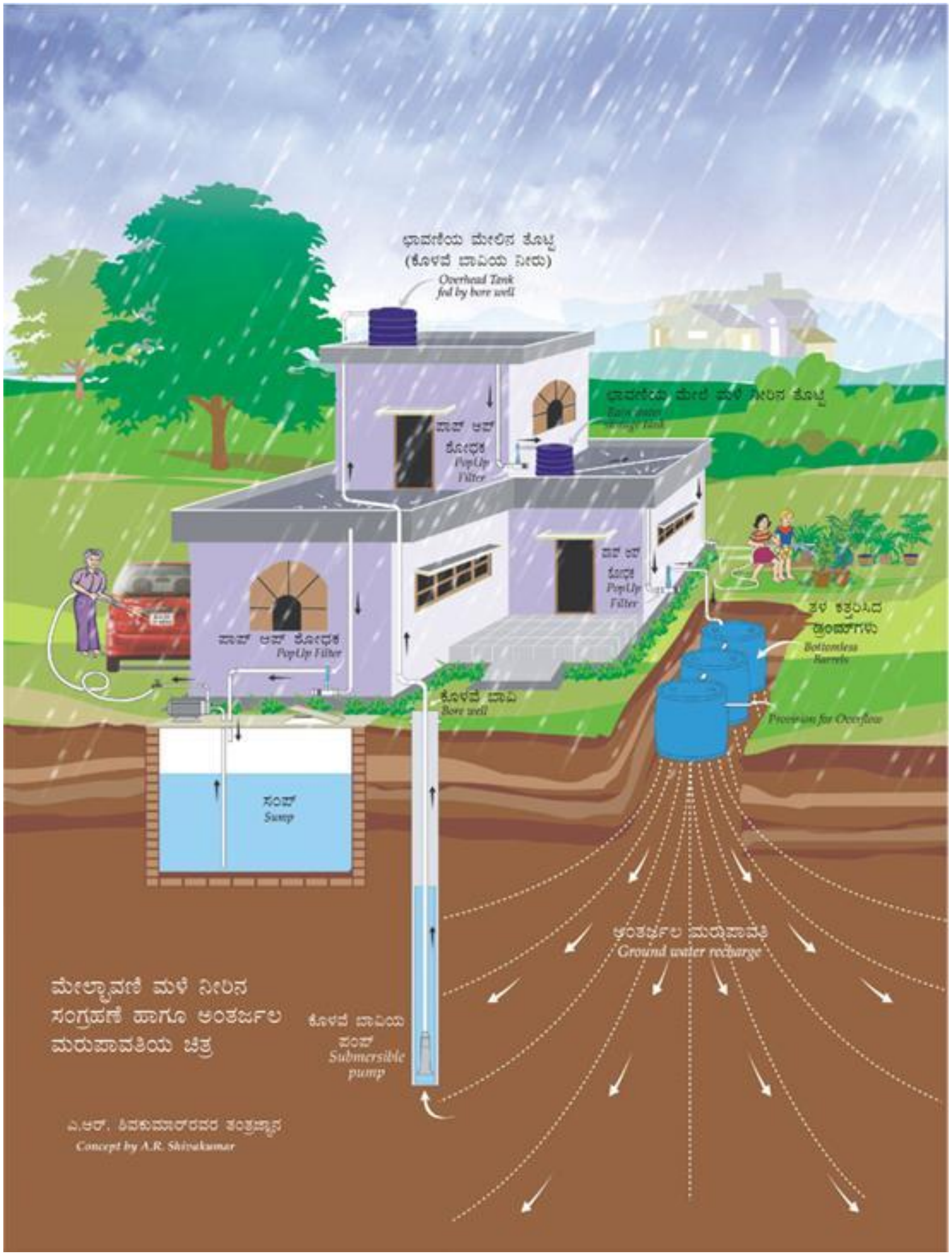
[13] Rainwater Club. "RWH in a layout: What, how, why and how much." *Citizen Matters*, Nov. 10, 2008.

Figure 6: Diagram of Rainwater Harvesting System



Source: BWSSB[14]

Rainwater harvesting is not unique to Bangalore; it has been used throughout India to augment surface and groundwater supplies and was relatively recently endorsed by the Government of India through the

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[14] Featured on the inside cover of the RWH brochure provided for free at the Sir. M. Visvesvaraya Rainwater Harvesting Theme Park.

Jawaharlal Nehru National Urban Renewal Mission (JNNURM) mechanism[15]. The JNNURM provides a list of optional reforms as part of the Submission on Basic Services to the Urban Poor. Among these, optional reform (ix) is "revision of by-laws to make rain water harvesting mandatory in all buildings to come up in future and for adoption of water conservation measures" (GoI 2009). Each state and municipality is given the flexibility to devise its own system of implementation and incentives/penalties package.

The Urban Space Consultants, a private consultancy firm in India, prepared a primer specifically for the optional reform on establishing and implementing rainwater harvesting legislation. The report briefly highlights three examples – two states that successfully adopted and implemented RWH (Tamil Nadu and Indore) and one that failed in implementation (Hyderabad). The results of this case study are described in Table 5 below.

Table 5: Overview of RWH Case Studies

	Tamil Nadu	**Indore**	**Hyderabad**
Reform	RWH mandatory for **all public and private buildings** (municipal laws); Nodal Agencies established for RWH; penalties made clear	RWH mandatory for **all new buildings over 250 sq. m.**	RWH mandatory for **all new buildings over 300 sq. m**; Mandatory to provide RWH in all group housing and commercial complexes
Implementation	Two phases: 1) Mandatory for all buildings, 2) Extended to ponds, highways and streets	Building Dept. of IMC issues Sanction and Completion certificates once RWH is installed; Separate RWH dept.	WS&S Board constructed 14,000 RWH structures in critical areas
Technical	Technical manual on website; TN and Chennai WS&S Boards provide technical assistance	----	----
Awareness	Workshops, street plays, door to door campaigns; 2500 youth educated in RWH	RWH Dept. coordinates with NGOs	Special cell at WS&S board with information on RWH

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[15] JNNURM was created in 2006 as a national funding mechanism to support urban infrastructure improvement, provide basic provisions to the urban poor and to encourage decentralization of governance and planning as envisioned by the 74th Constitutional Amendment Act.

Incentive/Penalty	No water or sewerage connection unless RWH system is installed; If deadlines aren’t met, officials construct a structure and recover cost like Property Tax	Rebate of 6% on Property Tax as incentive	-----
Success/Failure	48 lakh buildings installed RWH	No figures were given but the report clearly identified RWH in Indore as a success.	Lack of interest by government officials; government sponsored contractors were too expensive; only 10% of applications actually executed RWH

Source: Compiled from "Rainwater Harvesting Reform Primer Under JNNURM" (2009)

The factor that differentiates the success of Tamil Nadu and Indore from the failure in Hyderabad seems to be the regulatory role of the government – the strict use of penalties and incentives. In the case of Tamil Nadu, households that did not install the rainwater harvesting system in time were penalized by having their water and sewerage connections cut. Indore, on the other hand, used a 6% rebate on property tax as an incentive for installing the systems. A future study could be built around these cases from a water governance perspective but, given the limited time for this thesis, will not be explored here.

Rainwater Harvesting in Bangalore

The path of Bangalore’s adoption of rainwater harvesting was different than that of many other cities. The story begins in 1996 with a group of architects, planners and engineers that formed the Rainwater Club and started, very early on, by looking at alternate systems that could decrease demand on piped water and groundwater. The founder of this organization, S. Vishwanath, was later very instrumental in pushing the state to adopt rainwater harvesting into legislation in 2006. It’s important to note here that JNNURM funding did not provide the impetus for the adoption of rainwater harvesting in Bangalore’s case since this was before the optional reforms were added. Although it had been made a part of state legislation, the municipality did not successfully promote or implement adoption of rainwater harvesting systems and rainwater harvesting remained a fanciful solution for a very small minority.

Two years later, the BWSSB took on the responsibility of promoting and regulating the use of rainwater harvesting systems through the “Bangalore Water Supply and Sewerage (Amendment) Act, 2009”. Now with a clear owner, rainwater harvesting could become a serious water reform. Under the

Act, every owner or occupier of a building greater than 2400 square feet, or any owner of new development greater than 1200 square feet, has to provide a rainwater harvesting structure for the building. Roughly 52,000 buildings fall under this description. The original deadline for the act was May 29, 2010 but this was pushed back - first to May 2011 and, most recently, to the end of March 2012. A recent article in *Deccan Herald* described the reaction to an extension of the deadline;

> *"Residents, who were in a hurry to install RWH systems earlier, withdrew the bookings after the deadline was extended. They are more concerned about the deadline than about their responsibility towards water conservation," said Vijay Raju from Rainy Filters, a dealer of RWH systems.*[16]

The sudden cancellation of rainwater harvesting system installations reflects a lack of understanding of the severity of the water shortage in Bangalore or, at the very least, a cynicism about the benefits of rainwater harvesting.

In May 2010, the BWSSB enacted technical guidelines specifying that 'while designing the roof based rain water harvesting the capacity of a storage structure or for artificial recharge structures to ground water, a provision at the rate of 20 ltrs. or more capacity per sq. mtr. of the roof area shall be adopted' and that 'the rate of 10 letters. or more capacity per sq. mars. of the land surface shall be adopted' for land based rainwater harvesting[17]. Local planners and rainwater harvesting advocates point to the fact that technical guidelines about rainwater harvesting are now built into legislation as being very unique to Bangalore. In effect, it re-engineers the way architects, planners, engineers and government think about the built environment. It also created a new market for technical consultants. The Rainwater Club, arguably the most influential civil society organization at the outset of this process, went on to found Biome Environmental Solutions in 2008. Biome is a Bangalore-based firm that promotes environmentally sustainability through architecture, design, environmental planning and training workshops. The approach to the physical environment realigns to strike more of a balance between urban growth and the natural world. For example, Biome's website describes that, "Utilizing setbacks, front gardening and open terraces for sustainable landscaping can give nature a chance to recreate the loss caused by the construction. This process calls for sensitivity to local water availability, weather patterns, and replanting local species and food-producing vegetation"[18]. While these may seem like very minute changes, if implemented on a much larger scale, they could increase the amount of green space, allow for higher rainfall infiltration rates (thereby improving groundwater recharge), reduce the amount of run-off

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[16] "RWH only for deadline, not for water's cause." *Deccan Herald*, Mar. 26, 2012.

[17] "Bangalore Water Supply and Sewerage (Rain Water Harvesting) Regulations, 2010." Excerpt from the BWSSB Rain Water Harvesting Theme Park booklet.

[18] "Impact on the Land" section of Biome website (www.biome-solutions.com).

and potentially decrease the intensity or frequency of floods. Biome also considers the energy required for construction materials, the effect of design on the amount of energy that is captured within the house (e.g. heating, cooling, natural light), closed-loop water systems and end-use water conservation devices. This re-engineering of design occurs outside of the market as well, with citizens integrating similar adaptations to their own homes (Appendix A).

A year later, in May 2011, a new revision to the act added that either a rainwater harvesting structure *or* a ground water recharge structure (open well or bore well) must be constructed[19]. The act also created a regulatory bite; any owners that did not comply with the act by the given deadline would be disconnected from BWSSB's piped water and sewerage infrastructure. Since the act was first enacted by the BWSSB, over 38,000 households have installed RWH systems, leaving roughly 16,000 buildings threatened to have their water connections cut off by the BWSSB if they did not install RWH systems (Karthik 2012) by the end of March 2012. At the time of writing this thesis, no action had yet been taken against these households and, instead, when the BWSSB Engineer-in-Chief was pressed on how many houses would have their connections cut, he responded "None. We are giving one more opportunity to the people. The Water Inspectors will visit houses with Watermen and find out the reason for not installing the Rain Water Harvesting system.[20]" It is yet remained to see whether or not the BWSSB will carry out its threat or simply extend the deadline once more.

Limitations of Rainwater Harvesting

With almost daily mentions in the local news and heavy advertisement by the government, it's easy to mistake rainwater harvesting for a panacea to the city's water shortage. The original approach to this thesis was that rainwater harvesting is a scarcity-induced innovation that needs greater government support to ensure broad adoption and maximized benefits. However, field research uncovered the limitations of the physical benefits of rainwater harvesting. A careful review of its characteristics – limited scope due to cost and lack of incentives/penalties, institutional inability to tightly regulate and the danger of haphazard rainwater recharge – reveal that its benefits are limited if we measure its success entirely by the amount of water it provides.

First, the scale of adoption is limited by the cost of the system and installation. The average cost of the system is somewhere between Rs 15,000 – 20,000[21]. Therefore, the direct benefits of the

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[19] Bangalore Water Supply and Sewerage (Amendment) Act, 2011

[20] "BBMP extends RWH installation deadline." IBNLive. Apr. 10, 2012.

[21] Rs 15,000 – 20,000 roughly converts to $300 - $400 USD. Price range taken from "RWH only for deadline, not for water's cause." *Deccan Herald*, March 26, 2012.

intervention are limited to middle- and upper-class families. Many complained that they had no real motivation to adopt the system in the absence of incentives and penalties.

Second, the BWSSB's limited ability to regulate the adoption of the rainwater harvesting systems and the use of the water once it is collected raise questions about the efficacy of this approach. As the following quote demonstrates, the burden of proof now rests on homeowners, who must take photographs of the rainwater harvesting system and submit them to the BWSSB.

> *"After installing RWH system in your home or apartment complex, ask for a copy of the certificate from the trained plumber/contractor and attach the same with two photographs of RWH in your house. Attach the same with a letter and submit them to the nearest BWSSB office."*[22]

Even with this system in place, the BWSSB lacks the capacity to ensure proper use or maintenance of the system. In addition, the BWSSB has pushed back the deadline for installation several times. This inability to regulate has had negative effects on the public's perception of the BWSSB's ability to govern. The 'government-supported' endeavor is viewed by many residents as ineffective and weak, thereby perpetuating cynicism about rainwater harvesting and leading to further disenfranchisement with the local government.

Third, although rainwater harvesting is encouraged by the government as a way to recharge groundwater, without proper education, citizens may overestimate the value of recharge or potentially contaminate groundwater. First, Bangalore's geology makes recharge a slow affair. Figure 7 shows two types of recharge - shallow and direct aquifer recharge. The first involves digging a twenty foot hole in the ground and letting rainwater percolate into the weathered zone. Due to the geology, groundwater recharge by this method takes several weeks. Without an understanding of the geology, the average citizen will assume that their recharge will instantly increase groundwater levels. This may result in a reduction of guilt that might have otherwise kept them from wasteful water practices. The second method, direct deep aquifer recharge, allows for more rapid recharge through dry borewells.

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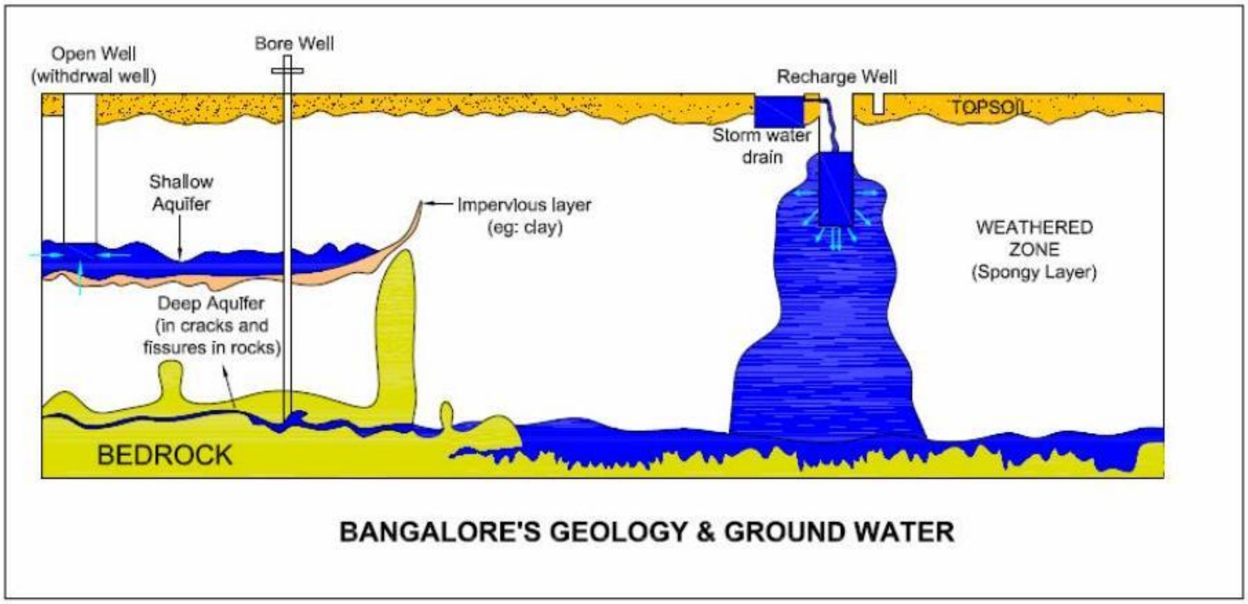
[22] RWH deadline IS AROUND." CityPlus.

Figure 7: Recharge Wells



Source: Presentation by Biome Environmental Solutions (Pvt Ltd and Trust)[23]

However, if the injected water is in any way contaminated, the entire groundwater supply will become contaminated and is virtually impossible to clean.

All three points – limited scope, institutional difficulty in regulating and questionable benefits of groundwater recharge – describe the limitations of rainwater harvesting and the danger of misrepresenting it as a panacea.

Current Scenario

The current scenario is an intractable circular water paradigm, as shown in Figure 8. The water and sewerage infrastructure (administered by BWSSB) serves the center of the city but does not extend to the periphery. Historically, the 110 villages on the periphery managed their groundwater as a common-pool resource. This pattern is a familiar one; tight-knit communities that can "maintain frequent face-to-face communication and dense social networks" are often able to manage the commons more effectively than governments (Dietz, Ostrom and Stern 2003). However, an 'increase' in population (i.e. their addition to the BBMP area) resulted in the need to turn the responsibility of water governance over to the state. Governance over groundwater is further complicated due to competition between residents and roughly 1,000 private water suppliers in the city:

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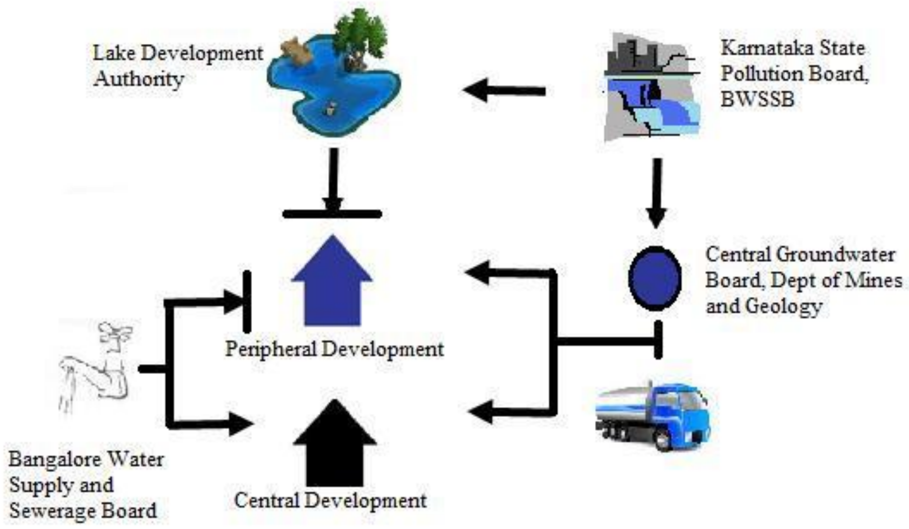
[23] Biome Environmental Solutions (Pvt Ltd and Trust) are two legal entities created in 2008 by members of the Rainwater Club.

> *"I had always wondered how the old well in my house had no water during the past two summers. I have now learnt that water suppliers have huge borewells close to my house and grab the underground water, affecting our wells. Because we don't get enough Cauvery water, it becomes inevitable to depend on wells and borewells, but the situation has worsened in the past two months largely because of private water tankers."*[24]

Legally, the Central Groundwater Board (CGWB) has to give permission to private water sellers in order for them to drill borewells but, to date, "not a single private water seller has approached them"[25].

Figure 8: Schematic Representation of Current Water Scenario in Bangalore



The villages also, at one time, depended on the system of 184 lakes[26]. However, these lakes are no longer a viable source of clean water due to encroachment and pollution[27].

Bangalore has reached its legal limits on the amount of water it can withdraw from the Cauvery river, cannot afford the cost or potential environmental impacts of drawing water from other (further) surface water sources and is facing a rapidly depleting water table. In other words, any effective approach to water management will have to diverge from the traditional supply-side approach and focus instead on improving the efficacy of current water practices and on demand-side management.

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[24] "Pvt players pump out more, create scarcity". *The Times of India*. Mar. 13, 2012.

[25] "Water tanker owners operate without license." *The Times of India.* Mar. 15, 2012.

[26] Number quoted by several water authorities in the proceedings for the conference "Water Famine by 2020 in Bangalore".

[27] The pollution is a result of the incomplete sewerage system and, as seen in 2011, occasional industrial pollutant dumping (city corporator was revealed to be dumping industrial pollutants into the Nagavara tank).

A Pressing Need to Work Outside the Institutional Landscape

Conversations with local planners and NGOs revealed four main relevant findings related to planning in Bangalore. First, Karnataka's statutory planning power has not decreased since it was legislatively established in 1961 through the Karnataka Town and Country Planning (KTCP) Act despite the decentralization of planning and governance that was envisaged in the 74th Constitutional Amendment Act. Introduced in 1992, this national Act outlines eighteen functions – the first of which is urban planning – to be transferred from national and state levels of government to the municipality. In actuality, land use and zoning power is vested in the Bangalore Development Authority (BDA), a parastatal agency, and not the Bruhat Bangalore Mahanagara Palike[28] (BBMP) – the locally elected urban body. Thus parastatal and municipal agencies overlap in function and jurisdiction, embroiling planning and governance in an unworkable quagmire. This resulted in national and state policies that promoted economic growth without addressing local concerns about the insufficiency of local infrastructure. Decentralization must occur to allow municipal and regional agencies to guide future urbanization in a way that is sustainable, especially in terms of water resources.

Second, while initial research emphasized a rift among the three levels of governance – the municipality of Bangalore, Karnataka state, and the national government – due to competing agendas, interviews revealed bottlenecks in planning due to lack of communication and cooperation. The following excerpt from a recent article[29] in *Daily News and Analysis* captures the finger pointing and blame shifting among the various water agencies:

> *'"Over-exploitation of the natural sources of water and lack of scientific data has led to lakes drying up. The groundwater recharge systems will slowly collapse unless recharged soon. In the outskirts, where apartments and high-rises are mushrooming, groundwater levels have gone down drastically.* ***This has happened mainly due to the little or no communication between the stakeholders and civic bodies****"... The BWSSB disagrees. The board says that it is not the BWSSB's duty to communicate with other agencies, and that it should be done by the department of urban development.'*

The institutional culture needs to be built up around communication and cooperation to ensure an integrated and comprehensive approach to water management.

Third, fragmentation of water management responsibilities makes a comprehensive and integrated water management scheme difficult. Storm water management is overseen by the

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[28] Also known as the Greater Bangalore City Corporation.

[29] "After 16 yrs, alarm rings for Karnataka's geology department", *Daily News and Analysis*, Mar. 22, 2012.

BBMP (municipal level agency), piped water and sewage by the BWSSB (parastatal agency); groundwater is loosely overseen by the Department of Mines and Geology (state department) and the Central Groundwater Board, lakes by the Lake Development Authority (autonomous organization created by the state) and wastewater by the Karnataka State Pollution Board. As one local practitioner said, "We have [at least] 5 different institutions and don't have the institutional culture of talking across the table". Add to this the host of other state government agencies with overlapping responsibilities– such as, in the case of redeveloping Bangalore's system of lakes, the Minor Irrigation Department, Karnataka Pollution Control Board, Forest Department, Bangalore Development Authority (BDA) and the Department of Revenue (Sundaresan 2011) – and the result is a tangle of superfluous iterations that prevent a comprehensive approach to water management. The most recent addition to water agencies has been the Karnataka Groundwater Authority (KGA), a state-level agency created to oversee management of the state's groundwater supply[30]. Although the act proposes increased regulation and tariffs to reduce borewell proliferation and extraction of groundwater, it will only add to the current confusion unless the KGA has clear responsibility and is given adequate enforcement power.

Fourth, government-led environmental initiatives are ineffective – potentially due to a lack of capacity and political unwillingness. The thrust of effective environmental initiatives has been spearheaded by non-profit organizations and communities. Organizations such as *Hasiru Usiru*, *Arghyam*, and the *Environmental Support Group* have all been actively raising awareness and promoting action against environmentally harmful development. There is currently a large movement by communities all over Bangalore to clean up the system of lakes (Sundaresan 2011) after years of poor management by the government. Sunderasan uses the example of the Rajapalaya Lake clean-up efforts to illustrate the potential for getting citizens more actively involved in planning:

> *I want to suggest that we should move beyond frameworks that separate government actors from the non-government ones or locals from non-locals to help us understand the processes that have led and may lead to the making or unmaking of the urban commons in Bangalore. I also want to suggest that the very possibility of producing commons in this case has been through claiming the public sphere of urban governance – the identification that planning is "commoning". Claiming the commons involves claiming planning.* (Sunderasan 2011)

All of these points demonstrate, at the very least, a perceived notion of institutional scarcity faced by residents of Bangalore and explains the phenomenon of a strong civil society. Civil society's reaction to

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[30] The KGA was created under the Karnataka Groundwater (Regulation and Control of Development and Management) Act of 2011.

the lack of government-led environmental action has been to work outside of the institutional architecture to induce government support.

In summary, any viable approaches to Bangalore's water shortage have to account for (i) the need to break away from a supply-side approach, (ii) the need for equitable policies that take socioeconomic factors – such as the heavy reliance of lower income groups on groundwater – into account, (iii) the difficulty of trying to operate within the current institutional framework and (iv) the need for a solution that engages civil society, citizens and the government.

Developing a Matrix

The following list of initiatives was compiled based on research, interviews and a transcript of a recent Bangalore-based conference, “Water Famine by 2020 in Bangalore”, attended by local water experts, representatives from all of the water-related agencies and civil society. None of these interventions is individually considered to be a panacea – it is clear that the city will need an integrated water management strategy that employs a combination, if not all, of the following.

Restructure Government Framework: This requires restructuring agencies and clarifying responsibilities to create a single agency with a clear mandate to oversee integrated water management. So far there seems to be very little action to this effect. Instead new agencies, such as the Karnataka Groundwater Authority, are still being created.

Enforcement of Urban Planning: Stronger coordination needs to occur between the planning authority, Bangalore Development Authority (BDA), and the Bangalore Water Supply and Sewerage Board (BWSSB). This includes stronger land use regulation to prevent construction in flood-prone low-lying areas and greater protection against lake encroachment. In addition, city and regional plans need to take the effect of future population growth on natural resources into account.

Plug Leaks: The physical and financial losses of the BWSSB need to be reduced from 50% to the international standard of 16%. The BWSSB has made commitments to reduce leakage substantially in the next few years but it will require physical improvements to the system as well as policy changes to minimize unbilled authorized consumption and apparent financial losses (Table 3).

Groundwater Regulation: Shallow aquifers can be recharged more easily and could therefore be used to augment domestic water use. Deep aquifers should be reserved for droughts. The Karnataka Groundwater (Regulation and Control of Development and Management) Bill 2011 was passed on March 17, 2011. Under the bill, “commercial users – water tankers, industries and commercial establishments” will have to register borewells, install meters and pay user fees[31]. The bill also created the Karnataka Groundwater Authority (KGA), a state-led agency with a mandate to manage groundwater throughout the state. Ideally, a single agency would have a clear mandate to oversee an integrated water management scheme. However, in the absence of this change, the KGA will need to be given the resources and legislative power to effectively regulate commercial users and manage groundwater use.

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[31] “Ground Rule – Get Borewell Registered.” *Deccan Chronicle*. Jan. 5 2012.

Integration of Science: Although the Department of Mines and Geology measures groundwater throughout the city, a more comprehensive system of measurement needs to be established to maintain groundwater quality and to encourage "smart" groundwater use. Part of the challenge is that the fragmentation of water responsibilities has led to an institutional culture of avoiding an integrated approach. For example, the BWSSB doesn't have a single hydrologist on staff even though it maintains 7,000 borewells.

Investment in Sewerage Infrastructure: 53%[32] of the sewage that is generated in Bangalore is left untreated and much of it is carried into water bodies by the rain. The BWSSB has rehabilitated 30 km of sewerage lines through the Environmental Action Plan-A. Plan-B will involve rehabilitation and replacement of an additional 80 km of the existing sewerage system. Plan-C (to be completed by 2014) will involve rehabilitation and replacement of 109 km of sewers. Although this will substantially decrease the amount of sewage that seeps into the groundwater, a comprehensive approach will require greater investments to extend sewerage infrastructure to all parts of the city. The main challenge here is financial[33].

Toilet to Tap: There have been several calls to recycle water to the tertiary level to use as *new* (potable) water and employ a dual pipe system to use wastewater more efficiently (e.g. Singapore). The challenges here are financial and cultural. The *Toilet to Tap* campaign has been successfully implemented in some cities (Orange County, California) but requires an effective marketing campaign to help general public get over the "yuck factor"[34].

Restoration of Lake System: The system of lakes is important for rainwater capture, groundwater recharge and flood mitigation. The Lake Development Authority was established in 2002 to oversee restoration of remaining lakes but has been largely ineffective. The BBMP and BMP are also responsible for the restoration process but the impetus for lake clean-up campaign mainly comes from residents living around the lakes. Their lake-cleanup efforts have so far taken the form of lake beautification rather than actual water clean up. Real clean up will require heavy financial investment, strong enforcement and a cultural shift in the public understanding of the hydrological value of lakes.

Rainwater Harvesting: BWSSB has made rainwater harvesting compulsory for existing buildings over 2400 square feet and new buildings over 1200 square feet. The deadline for installation has been pushed

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[32] Figure from conference ("Water Famine by 2020 in Bangalore") proceedings. Quoted by Dr. Kanwer Pal, Secretary to the Government, Ecology and Environment.

[33] Plan-A received funding from GoI and GoK. Plan-B is funded through JNNURM, GoI, and JICA. Expected to be completed by end 2012.

[34] "Toilet-To-Tap: Getting Past the Yuck Factor." *Planetizen*. May 28, 2008.

back several times. Most recently, although the BWSSB threatened to disconnect water and sewerage connections to houses that did not comply with the March 2012 deadline, no action has been taken.

Understanding the Matrix

The following matrix (Table 6) is a summary of the interventions and the types of challenges they face. Although, the definitions and selection of barriers that each initiative faces may seem arbitrary at first glance, as nearly all of these measures face some level of political, financial, cultural and institutional barriers, they were selected based on secondary data and interviews. Here, "political" barriers are those that are explicitly linked to political popularity (i.e. "Will this measure threaten political longevity?"). "Financial" barriers describe municipal government finance (i.e. "Can the municipality afford to pay for it?"). "Cultural" barriers are loosely defined here - in the case of "Integration of Planning and Natural Resource Management", for example, the cultural category refers to a gap in planning culture whereas, in the case of "Toilet to Tap" the cultural category refers to a general distaste for the program (i.e. the "yuck" factor that also kept San Diego from adopting the program). "Institutional" barriers refer to the government's (in)ability to effectively enforce and regulate due to fragmentation in the various levels of government (national, state and municipal) and the multitude of agencies[35].

Table 6: Matrix of Bangalore's Approach to Water Scarcity

Necessary Approach	Political	Financial	Cultural	Institutional
Restructure Government Framework	×			×
Enforcement of Urban Planning	×		×	×
Plug Leaks		×		
Groundwater Regulation	×	×		×
Integration of Science			×	×
Investment in Sewerage Infrastructure		×		
Toilet to Tap		×	×	
Restoration of Lake System		×	×	×
Rainwater Harvesting				×

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[35] The political and institutional categories could be seen to overlap in many cases. Political barriers refer to an almost conscious failure to regulate due to the political cost, whereas institutional barriers refer to an inability to regulate due to government hierarchy/structure and interaction between different agencies.

If we refer back to the schematic two-by-two for scarcity-induced innovations (Srinivas and Sutz 2008), we find that many of the proposed solutions – especially those related to improving or expanding infrastructure – fall loosely in the bottom left quadrant where "*canonical* solutions exist, but for different scarcity reasons they are not suitable for DCs conditions" (Srinivas and Sutz, 2008). The potential for the solutions to work exists but they are difficult to implement due to political, financial, cultural and institutional barriers.

Rainwater harvesting emerges as the only solution that gains the dedicated effort of civil society and the government because it overcomes each of the four barriers. First, rainwater harvesting is much less *political* than other water management measures, such as restructuring water tariffs to reduce subsidies or prohibiting groundwater extraction. Second, the cost of rainwater harvesting is shifted onto households, making it relatively inexpensive for government to support, thereby overcoming *financial* barriers. Third, it was initiated by local civil society, making it a *culturally* appropriate innovation that provides clear benefits at the household level. Fourth, it overcomes some of the *institutional* challenges that the other initiatives face because it has a clear owner. Although the BWSSB has had trouble regulating rainwater harvesting, the fact that the agency assumed responsibility for the initiative made it viable.

ANALYSIS - Benefits and Limitations of Rainwater Harvesting

The matrix clearly shows why rainwater harvesting emerges as the low hanging fruit of an integrated water management approach. However, compared to the other initiatives on the matrix, the benefits of rainwater harvesting are very limited. What, then, accounts for the enthusiasm for rainwater harvesting in civil society and government? The benefits and limitations of rainwater harvesting require an analysis through two questions: (1) What value does rainwater harvesting serve as a scarcity-induced innovation and how can this value be scaled up?; and (2) What does the use of rainwater harvesting, as a public participation tool, say about the role of government and civil society in water management moving forward?

Rainwater Harvesting as a Scarcity-Induced Innovation

"Can we put the citizen at the heart of water management?"

Most innovation theories regard innovation to be a 'quick-fix' – technological advances that drive *rapid* economic development, procedural innovations that *rapidly* improve efficiency (and growth), etc. These also assume that the greatest benefit comes through *rapid* adoption. However, the research findings describe the danger of rapidly scaling-up rainwater harvesting through government-sponsored incentives and penalties and the limited benefits of rainwater harvesting if we are to judge the initiative as a supply-side approach (i.e. based on its ability to increase water supply). We must therefore re-evaluate our initial categorization of rainwater harvesting. The scarcity-induced framework (Srinivas and Sutz 2008) enables us to identify (i) rainwater harvesting as a scarcity-induced innovation, (ii) the value of rainwater harvesting, and (iii) the best way to scale it up.

As a civil-society led initiative that arises from systemic scarcity, rainwater harvesting falls into the upper right hand quadrant of the SII framework as an innovative *process*. Due to conditions of scarcity, civil society learned to navigate outside of, and yet still engage, government to lead a water management initiative. This is also seen in the case of lake redevelopment in Bangalore (Sunderasan 2011):

> *These residents learnt how the governmental technologies of administrative bureaucracy worked, its constituent parts, what influenced its speed, how and who it was run by and for whom, how to move it and so on. They learned the language and processes of public administration and the legal system along with the vernacular and legislative process of urban politics. They learned how local engineers, politicians, MLAs, commisioners, planners, secretaries and ministers were involved in the planning and governance of their neighbourhood and the city. They learned who was important at which level of*

> *governance. Whenever they encountered the complex and thick network of democratic governance, they helped each other navigate this network.* (Sundaresan 2011)

This learning process by which communities step up to compensate for the government's failure illustrates Ostrom's emphasis on self-governance as an important alternative to state-instituted governance.

The second innovative characteristic of rainwater harvesting in Bangalore is inherently tied to its value. When confronted with the limited benefits of rainwater harvesting (e.g. limited scope due to cost) local advocates tout the value of rainwater harvesting as a targeted *water literacy-promoting tool* used to curb demand. One might argue, for instance, that rainwater harvesting can be made more affordable to low-income households through subsidies or technological adaptations, such as using bamboo[36] for the gutters. The local advocate's response is that rainwater harvesting is much more effective as a demand-side approach if it focuses on middle- and higher-income households since these households can afford to have wasteful water practices (e.g. washing cars, watering yard, etc.). This innovative use of rainwater harvesting, as a tool to curb demand, deserves some reflection. The canonical approach to water shortage has been to increase supply by expanding infrastructure. This is no longer viable in Bangalore as surface water and groundwater sources have reached, and exceeded, their limit for withdrawal. Of all the initiatives listed in the matrix, rainwater harvesting alone breaks from the traditional supply-side approaches and assumes a (water) demand-side approach.

Although rainwater harvesting increases non-potable water supply at the household scale, its real value is in promoting water literacy. The issue, therefore, is to find a way to increase the scope of people that adopt rainwater harvesting systems without inhibiting the learning process. The SII framework calls attention to the process by which an innovation is scaled up but does not go into any detail about the actual process. In the case of scaling up rainwater harvesting in Bangalore, government support (through incentives/penalties, for example) can be counterproductive to the goal of using rainwater harvesting as a literacy promoting tool for three reasons. First, the BWSSB has been forced to push back the deadline for installation of rainwater harvesting systems several times due to a lack of capacity in regulating the adoption and out of a fear of political backlash. This has resulted in increasing disenfranchisement with the government and general cynicism about rainwater harvesting. Second, although the BWSSB has enthusiastically promoted rainwater harvesting through a variety of mediums, including a theme park, heavy promotion has led to a misconception that rainwater harvesting is a panacea. The SII framework pointed out the malleability of the term 'scarcity'. Although government officials talk about the severity of the situation quite openly, focusing so much attention on rainwater harvesting as a solution has

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[36] The gutters are usually made using PVC pipes, vinyl, aluminum or steel.

effectively degraded the perceived intensity of scarcity. In other words, the corresponding interpretation can easily become “This problem will be solved once everyone installs rainwater harvesting systems”. This returns to one of the previously mentioned limitations of rainwater harvesting, that without proper education, citizens may incorrectly conclude that they’ve ‘done their part’ once they install rainwater harvesting systems. Third, the application of incentives and penalties (e.g. Tamil Nadu and Indore) may result in more rapid adoption of the technology but is counterproductive to the slower process of water literacy promotion that must occur for rainwater harvesting to have real value.

The Role of Government

“Should we put citizens at the heart of water management?”

The danger of romanticizing rainwater harvesting as an innovative solution to resource management is that it diverts attention from the need for government reform and stronger government accountability. Civil society took on the added responsibility of water management in reaction to the government’s lack of action. If we return to the matrix and highlight more effective initiatives – such as enforcing urban planning to prevent development in low-lying flood-prone areas or regulating groundwater use – we see that these are not implemented due to the government’s inability, or unwillingness, to regulate. However, given that the role of government in scaling-up rainwater harvesting may be counterproductive to the value of rainwater harvesting as a water literacy tool, it would be naive to assume that the BWSSB views this to be the most effective strategy. Why, then, does the government mandate rainwater harvesting over other initiatives?

From the government’s perspective, rainwater harvesting has two clear benefits. First, mandating rainwater harvesting is an ‘easy win’ for BWSSB; it seems to be doing *something* about the water shortage, doesn’t suffer any political costs and assumes minimal financial costs. Second, if households reduce their piped water demand by using more rainwater, the BWSSB actually stands to recover some of its losses. The cost of pumping water from the Cauvery River is roughly Rs 18 per kiloliter or, with the cost of the leakages included, roughly Rs 46 per kiloliter. National benchmarks for water tariffs require the BWSSB to heavily subsidize water, starting the lowest block tariff for domestic use at Rs 6 per kiloliter. These costs are partially offset by a higher block tariff for commercial water use but the Board is still incurring a financial loss. Raising the block tariffs would be controversial and politically very difficult. Therefore, reducing households' consumption of piped water would save the BWSSB money by virtue of not having to subsidize large amounts of water for domestic use[37].

The benefits of rainwater harvesting do not, however, explain why the government has not supported any of the other initiatives listed in the matrix, such as groundwater regulation. One could argue that the fragmentation of water governance has led to several gaps in oversight or that no government agency has the capacity to regulate drilling and groundwater extraction. Neither of these answers – unclear responsibility and lack of capacity – is very convincing given that the BWSSB has taken on added responsibility (mandating rainwater harvesting) and conducts random checks to ensure implementation of the system. A third reason, political unwillingness, is much more likely. The BWSSB has no real incentive to regulate groundwater use since groundwater often serves as a short term solution to inadequate coverage and infrequent piped water. Both the BWSSB and the BBMP still drill borewells to meet immediate water needs. This must be seen as a short term alleviation of a much larger problem rather than an effective approach, but the political cost of trying to strictly enforce groundwater regulation is still much too high. In the case of rainwater harvesting, for example, the BWSSB recently threatened to cut off the water and sewerage connections of any houses that had not installed the systems by end of March 2012. There was a great outcry from citizens, who argued that such an action would be unfair since the city's piped water supply is inadequate in terms of quality, coverage and frequency. In other words, why should households incur the cost of installing rainwater harvesting systems when the state itself is not capable of providing a basic service?

Rainwater harvesting, as a civil society-led water literacy promotion tool, is a double-edged sword. On one hand, it engages the average citizen in the problem of water management and has the potential to significantly curb demand, making it an invaluable application to general resource management. On the other, it is an 'easy win' for the BWSSB and has acted as a smoke-screen, diverting attention from much deeper changes that need to be made for a truly effective integrated water management scheme.

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[37] Local rainwater harvesting advocates have marketed rainwater harvesting to BWSSB in this way to gain government support. This no different from marketing sanitation systems to back-end users who stood to make a profit rather than to front-end users (Murray and Ray 2010).

CONCLUSIONS AND RECOMMENDATIONS

> *Commons, in other words, can be exclusive and regressive, as well as inclusive and progressive. Indeed, the role of the state in encouraging redistributive models of resource management, progressive social relations and redistribution is more ambivalent than those making calls for a "return to the commons" would perhaps admit. Thus, the most progressive strategies are those that adopt a twofold tactic: reforming rather than abolishing state governance, while fostering and sharing alternative local models of resource management.* (Bakker 2007)

Hardin and Ostrom both recognized the importance of governing shared resources but approached the problem from different directions. Whereas Hardin put his faith in property rights and in the state to protect those rights, Ostrom had more faith in a community's ability to self-govern. Bakker, on the other hand, recognized the potential shortfalls of relying on only one of these and advocated, instead, for a combination of both to ensure more equitable and efficient governance. Governing the commons becomes increasingly more complex in the context of developing countries since they face systemic scarcity that makes orthodox solutions irrelevant. Common problems, such as water management, require innovative technologies and processes that can overcome cognitive, physical, socioeconomic and institutional barriers. The scarcity-induced innovation (SII) framework emerges as the most applicable model of innovation because it begins with the assumption that scarcity leads to innovative processes (Srinivas and Sutz, 2008). The two-by-two SII matrix draws attention to local innovations, in the top right quadrant, and the learning process by which those innovations are scaled-up.

An effective water management scheme in Bangalore requires major investment in extending water and sewerage infrastructure, improvements in existing infrastructure, institutional restructuring that identifies one agency with a clear mandate to oversee (integrated) water management, stronger regulation of groundwater, a planning culture shift towards recognizing the link between the natural world and human settlements and a stronger integration of science in resource management. Rainwater harvesting is the only initiative to overcome the political, financial, cultural or institutional barriers and to gain the support of civil society and government.

In this case, rainwater harvesting was the only initiative from the matrix (Table 6) to gain traction because (i) it is a *locally* developed innovation; (ii) it circumvents existing institutional, financial, political and cultural barriers; (iii) it has substantial and immediate benefits for the end-user (i.e. households); and (iv) for the back-end user (i.e. BWSSB). Like the citizen-led lake redevelopment effort in Bangalore, it represents an innovative process that puts the citizen at the heart of water management. Finally, if it is used as a water literacy tool with the end-goal of curbing demand, it signals a new demand-side approach to resource management.

There are several ways to support the diffusion of rainwater harvesting in a way that reinforces its use as a water literacy promotion tool:

Government: Incentives and penalties related to the installation of the rainwater harvesting system may result in more rapid adoption of rainwater harvesting but don't guarantee effective water use by the household. Incentives related to water use, rather than installation, may be more effective. As one local rainwater harvesting advocate pointed out, the decrease in demand on piped water can be measured by the comparing water bills before/after installation of rainwater harvesting systems. Subsidies could be then be given to households based on the amount of piped water they save. In this way, they are rewarded for their water practices, rather than just for installing the system.

Awareness campaigns: The dissemination of rainwater harvesting technology needs to be matched by a careful awareness campaign. The BWSSB enthusiastically promotes rainwater harvesting through conferences, events and the Sir. M. Visvesvaraya Rain Water Harvesting Theme Park[38]. In all of these forums, rainwater harvesting should be presented as a very small piece of a much larger problem rather than as a panacea.

Media: There are nearly daily mentions of rainwater harvesting in the media. Media outlets should be encouraged to relay a more scientific understanding of the situation to the general public and to highlight more examples of innovative water use by individuals and communities. Stories about individuals like AR Shivakumar or communities like Rankanagar (see Appendix), whose innovative water systems mirror a deeper understanding of the need to preserve natural resources, will serve to stimulate conversation around the potential to innovate within one's own household or community.

Civil Society: Local water advocates in non-profit organizations, environmental groups and academia play a crucial role in supporting the broader adoption of rainwater harvesting and, more importantly, encouraging a cultural shift in the way citizens view themselves as part of the problem and in their water use practices. Rainwater harvesting also provides an entry point for citizens into a larger discussion on governance. Civil society can play an important role in organizing cohesive messages calling for greater government action.

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[38] The park is free to the public and has received over 8,000 visitors since it opened last year. It features a seventy-seat mini-theater with videos for educational and training purposes, an open amphitheater used for water-related skits, solar energy displays and twenty-six models for adapting rainwater harvesting to material input, budgetary or technical constraints.

Local Planners, Architects and Engineers: Rainwater harvesting, especially the built-in technical guidelines, presents an opportunity to re-engineer the built environment. These professionals can influence design through their work but can also try to have a much broader impact by pushing for additional guidelines that are inclusive (i.e. affordable) and promote environmental sustainability.

It's crucial for each of these groups to actively promote adoption of rainwater harvesting in a way that demonstrates the severity of the water shortage and the near-term impacts of a business-as-usual path.

The case of rainwater harvesting in Bangalore also provides an important lesson to be applied more generally to resource management and governing the commons. As populations continue to rise, cities will increasingly be faced with the tragedy of the commons. Supply-side approaches, those that increase supply, are only temporary solutions. In the case of limited resources, such as water, a much deeper re-education process needs to occur for us to protect the commons. The rainwater harvesting paradigm may have useful application in other cities that face acute water shortages and poor state-led water governance. Mandating rainwater harvesting in Jakarta, Indonesia, for example, may engage citizens at the level of the household and catalyze more debate around the city's growing water demand and the need for stronger state action.

This thesis is not meant to, by any means, aggrandize the value of rainwater harvesting to the extent that it shifts focus away from the government's role in resource management. A weak state, one that cannot effectively regulate use, prevent overextraction or provide resources in an equitable way, only increases the intensity of the tragedy of the commons. Rainwater harvesting has provided an entry point to the larger problem of water governance; civil society should use it to call for increased accountability and action by the government. This thesis has primarily focused on the failures of the BWSSB, not in an effort to paint a one-sided image of the agency, but to capture broader institutional problems. Therefore, the following suggestions should be seen as a call for broader government reform to enable a more integrated water management strategy.

Establish a clear leader: Fragmented levels of government and agencies are not uncommon in the developing country context. A re-organization of the government infrastructure may not be viable, or desirable, in the near-term in Bangalore. It may be more effective to, instead, establish an agency with a clear mandate to oversee an integrated water management strategy.

Stronger Enforcement of Water Regulations and Urban Planning: The current situation is riddled with agencies that are unable, or unwilling, to exercise their full power. The following is an excerpt on necessary characteristics of adaptive and effective governance.

> *Whether enforcement mechanisms are formal or informal, those who impose them must be seen as effective and legitimate by resource users or resistance and evasion will overwhelm the commons governance strategy.* (Dietz et. al. 2003)

Strong regulation is critical to protecting groundwater, preventing further encroachment of lakes, and avoiding future casualties resulting from development in flood-prone low-lying areas. Without it, as we have seen in the case of BWSSB pushing back the rainwater harvesting deadline, citizens become disenfranchised with both the innovation and the government.

Integration of Science and Planning: There's no clear or easy solution for the problem of water management in Bangalore. A blanket prohibition of groundwater extraction, for example, may not even by upheld by government agencies like the BWSSB or the BBMP, which drill borewells to meet the immediate water needs of citizens. Stronger integration of science can be used to highlight shallow aquifers that are more easily recharged, recharge zones and groundwater levels throughout the city, and the quality of groundwater. This information can help promote "smarter" use of groundwater and more effective recharge.

Talking Across the Table: Interviews with local practitioners highlighted a general unwillingness to share valuable information, especially by government agencies. In most cases this means planning without all the necessary data or re-inventing the wheel each time information is needed by an agency. Civil society – especially academia, non-profit organizations and think-tanks – have made a tremendous contribution in trying to engage everyone in urban issues and in providing basic information that is needed for planning and policymaking. Planners, policymakers and government officials should also help develop a culture of 'talking across the table'.

These recommendations could be applied to almost any city. I don't mean to naively assume that the above changes are easy to implement, will be seen in the near future or won't come with their own set of problems. However, the alternative to these, a weak state that shrugs off responsibility for governing the commons, will lead to indiscriminate mining of our remaining resources.

As we become increasingly faced with limited and rapidly depleting resources, we will need to find innovative solutions and processes to govern what little commons are left. Given a future of increasing scarcities, local solutions that emerge in the top right of the scarcity-induced innovation (SII) framework (Srinivas and Sutz 2008) may prove to be our most promising options. It is equally naive to believe that governments alone can efficiently manage resources (Hardin) as it is to believe that communities alone can equitably self-manage resources (Ostrom). This problem requires a simultaneous bottom-up and top-down dual approach (Bakker). We can no longer afford to think like Hardin's herdsman, who maximizes his utility by allowing his cattle to graze throughout the commons uninhibited. Innovative local solutions, that engage citizens at the heart of resource management, need to be combined with strong state regulation to protect what remains of our commons.

APPENDIX A: “Homing in on green truths”

The following is the excerpt from an article published in *Deccan Herald* on Oct. 3, 2011 highlighting the innovative approach to water management by scientist AR Shivakumar.

“For scientist A R Shivakumar and his family, ecofriendliness is a way of life. And it is showing the way to others too. Sourabha, their family home, is truly extraordinary. From the past 14 years, it is 100 per cent self-sufficient in terms of water resources including drinking water, and has no municipal connection. It draws water from a depth of 30 ft in an area where the groundwater norm is 250-300 ft. It uses just 80 units of power monthly for a four-member family; boasts of natural airconditioning; zero-bacteria drinking water without waterfilters; a biodiverse environment; and is cockroach-free, etc.Shivakumar has perfected a range of award-winning eco-friendly measures and inventions for this. He is Executive Secretary, KSCST, Indian Institute of Science (IISc), Bangalore; and provides technical support to the world’s biggest rainwater-harvesting project.

Groundwater recharge

Total water self-sufficiency is achieved through rainwater harvesting and groundwater recharge using a pop-up filter and barrel system, both his inventions. With Bangalore receiving about 1,000 mm rainfall annually, his 2,400-sq-ft plot receives 2.4 lakh litres. And not a drop is allowed to run outside. Sourabha has an overall 45,000-litre storage capacity—the rest is discharged into the earth via Shivakumar’s (named after him) barrel system of groundwater recharge.

He has also rejected conventional steel pipes to save energy loss from friction and used instead single-piece HDPE pipes. Before the water flows underground, it passes through the pop-up filter which removes large impurities. The filter can pop up and release extra water in case of excess flow or filter getting choked when the family is away.

We are offered water by Shivakumar’s wife Suma, herself engaged in greening the colony by planting saplings and herbal plants, from a jug containing a silver foil. They explain this innovation: “We get pure drinking water from rain water without using electricity, chemicals or water filters. Collect raw water in a clean, closed container for a day’s requirement (eight to 10 litres per family per day) and immerse in it a pure-silver foil (10 by 30 cm) or wire for eight hours.

The water is 100 per cent bacteria-free, has no side-effects, and the foil doesn’t impart any taste or odour to the water.”

APPENDIX B: “Harvesting rain woes for summer redemption”

The following is the excerpt from an article published in *The Times of India* on March 26, 2012 highlighting the innovative approach to water management by the Raganakar community.

“Things had gone horribly wrong for Rankanagar two years ago. Its groundwater table had dried up and water wasn't available in borewells even after digging 800-1 ,000 feet deep. Trapped between the seasonal vagaries of swirling rainwater and depleting groundwater resources, residents, led by Rankanagar and Neighbourhood Residents' Welfare Association, saw the answer in BWSSB's mandatory rainwater harvesting campaign.

They dug 13 rainwater harvesting wells linking the roadside drains, killing two problems with one stroke. Waterlogging during rainy season has virtually been eliminated, while the dying borewells have sprung back to life this summer.

"The rainwater harvesting wells were designed by us with help from IISc scientists in 2010. Pulakeshi Nagar MLA Prasanna Kumar helped us and the financial aspect was taken care of. Now, we have 13 such wells in roadside storm water drains. Not a drop of water fallen in this locality goes waste," asserts MM Naazim, secretary of the association.

The wells have been designed in such way that they trap rainwater flowing on the drains. The muck, if any, is filtered in the well because it has four different layers of filtration processes installed. Apart from metallic grills, the wells have perforated slabs of sand layer, jelly stones and grill mesh and slopes down towards the pit. The 80-foot-deep wells are laid with concrete rings.

"We have surveyed the locality inch by inch. We understood the flow of rainwater as per the drainage network and fixed 13 appropriate places for the wells. It's the most environmental friendly practice and prevents soil erosion. Besides, it is low cost and easy to manage," said G Dev Prasad, vice president of the association.

"In 2005, when we were first supplied with Cauvery water, I used to get water once in three days and I'd consume 40,000 litres every month. But now supply is on alternative days, but I draw only 6,000 litres. The only way to manage the crisis is to harvest rain. Besides the community approach, individual bungalows too harvest rainwater," said Vaziruddin M, president of the association.”

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