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Urban Water Systems in India: A Way Forward

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Abstract

Urban water and wastewater management are relatively under-studied subjects in India. The Indian urban space has been understood in an undifferentiated manner, which ignores the specificities deriving from the stage of urban development, the sources of water, as also the diverse nature of aquifers characterizing urban settlements.

This paper provides a new presentation of the urban water problem and offers a set of solutions that are sustainable, both in ecological and financial terms, and seek to tackle the deep inequities in the urban water space in India. It highlights the significance of groundwater, the dark spot of Indian urban water planning and proposes a typology that could be used to comprehend the diversity of urban aquifer formations. The paper highlights the urban wastewater challenge and emphasises the need to work simultaneously on water and wastewater management.

The paper advances a series of hypotheses, an initial analytical framework and the outlines of a way forward for urban water systems in India, which could provide a rich terrain for further research. The paper concludes with brief illustrative case-studies of two major emerging cities – Indore and Nagpur – where the new approach advocated in the paper could be fruitfully tried out.

Keywords: *aquifers, wastewater treatment, recycling, water distribution, PPP*

JEL classification: *Q*

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Urban Water Systems in India: A Way Forward[1]

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PART A: THE PROBLEM STATEMENT

1. Point of Departure

The global urban population is expected to nearly double to 6.4 billion by 2050, with about 90% of the growth in low-income countries. The predicted increase in the number of urban slum dwellers is to 2 billion in the next 30 years (Global Water Partnership, 2013). In India, the number of people living in urban areas is expected to more than double and grow to around 800 million by 2050. This will pose unprecedented challenges for water management in urban India.

The Indian economy and society already face daunting challenges in the water sector, as we move into the second decade of the 21st century. The demands of a rapidly industrialising economy and urbanizing society come at a time when the potential for augmenting supply is limited, water tables are falling and water quality issues have increasingly come to the fore.

As we drill deeper for water, our groundwater gets contaminated with fluoride and arsenic. Both our rivers and our groundwater are polluted by untreated effluents and sewage, continuing to be dumped into them. Many urban stretches of rivers and lakes are overstrained and overburdened by industrial waste, sewage and agricultural runoff. These wastewaters are overloading rivers and lakes with toxic chemicals and wastes, consequently poisoning water resources and supplies. These toxins are finding their way into plants and animals, causing severe ecological toxicity at various trophic levels. In the developing cities, it is estimated that more than 90 percent of sewage is discharged directly into rivers, lakes, and coastal waters,

[1] This is a paper written for the Indian Council for Research on International Economic Relations (ICRIER) and the Global Green Growth Institute (GGGI). This is a scoping paper that seeks to review available literature to present state-of-the-art knowledge and on that basis make a statement of the problem and propose possible hypotheses and suggest plausible solutions and a framework to understand urban water issues in India.

[2] The writer was Member (Water Resources), Planning Commission, Government of India from 2009 to 2014. My greatest debt of gratitude is, first and foremost, to many discussions and insights from Isher Ahluwalia, who persuaded me to write this paper. The paper also draws heavily upon, and takes forward in many significant ways, the work done to initiate the paradigm shift in water management in India through the 12th Five Year Plan. My special thanks to Sunita Narain, who chaired the 12th Plan Working Group on Urban and Industrial Water. I also thank Himanshu Kulkarni for his exhaustive inputs into the least understood conundrum of urban groundwater in India and in conceptualising the urban continuum schema and the categories of aquifer systems proposed in the paper. Earlier versions of this paper were presented at a national seminar in December 2014 and at a national workshop in February 2015. I thank the participants of both events, especially Siddarthan Balasubramania, AK Gosain, Arunabha Ghosh, Shashikant Hastak, Suneetha Kacker, Rochi Khemka, Ajith Radhakrishnan, Tushaar Shah and Rakesh Singh for their comments and inputs. I thank Sri Siddhartha Ayyagari for able research assistance. My most heartfelt thanks go out to late Sandeep Joshi, whose extraordinary work on urban water and wastewater treatment has been an inspiration and great source of learning for me. His sudden demise, even as he was providing crucial inputs into this paper, has left all water workers of India much the poorer for his absence. I dedicate this paper to his memory.

without treatment of any kind. In India, cities produce nearly 40,000 million litres of sewage every day and barely 20 percent of it is treated. Central Pollution Control Board's 2011 survey states that only 2% towns have both sewerage systems and sewage treatment plants.

Climate change poses fresh challenges with its impacts on the hydrologic cycle. More extreme rates of precipitation and evapo-transpiration will exacerbate impacts of floods and droughts. More intense, extreme and variable rainfall, combined with lack of proper drainage, will mean that every spell of rain becomes an urban nightmare as roads flood and dirty water enters homes and adds to filth and disease.

Conflicts across competing uses and users of water – agriculture and industry, town and country -- are growing by the day. The water shares across agriculture, industry and households in rich, industrialised countries are significantly different from those in India. Rich, industrialised nations use some 86% of water resources for industry and domestic uses, whereas 82% of water resources are used in agriculture in India (Narain, 2012). And water use efficiency in agriculture, which consumes around 80% of our water resources, continues to be among the lowest in the world. At 25-35 percent, this compares poorly with 40-45 percent in Malaysia and Morocco, 50-60 percent in Israel, Japan, China and Taiwan.

Thus, even as this paper addresses the issues surrounding urban water, it is useful to keep in mind, that we face very real challenges in managing water in the economy as a whole and especially in the farm sector. The 12th Plan has proposed a paradigm shift in water management to enable a movement forward in this direction (Shah, 2013). Such reforms are crucial so that more water is released for rapidly growing urban India.

In the next three sections, this paper outlines the problems facing urban India in the water sector. After which, the paper will shift focus to possible solutions and conclude by providing a framework for possible work in the cities of Indore and Nagpur.

2. Deconstructing "Urban" India: Understanding the Continuum

This paper begins by deconstructing the simplistic notion of an "urban India" by presenting a picture of the very different and diverse urban settlements that go into constituting what, rather simplistically, and in an undifferentiated manner, we call urban India. We highlight the unique progression of problems faced by different sized urban agglomerations within this continuum, as also the neglect of small towns and census towns, which appear to have fallen between the cracks of development planning so far. This neglect is also a great opportunity for innovative work *ab initio*, given that these areas do not suffer from the mistakes that have already been made in the larger metros. We present a schema for India's urban continuum, which reveals shifting dependencies on sources of water, in different sized urban settlements, at various stages of growth.

Tables 1 and 2 summarise census data on India's urban population from 1901 to 2011. India's urban population has grown 5-fold over the last 50 years. But what is equally important to note is that urban population has grown in each of the four categories of towns and cities in our table, from the smallest towns with less than 100,000 people to the mega-metros with more than 5 million. Over 112 million people live in these smallest towns, while over 160 million urban Indians now live in large cities with more than a million people. Thus, attending to each category is important in itself and this paper describes how each urban settlement has its own unique set of characteristics and challenges. The small towns have received less attention but they are the locations where the real opportunities lie, as they have not yet committed the kinds of mistakes some of our larger metros already have.

Table 1: Share of Urban Population in Cities and Towns in India, 1901-2011

Year	Population							
	5 million and above		1- 5 million		1 lakh - 1 million		< 1 lakh	
	Cities	% of urban population	Cities	% of urban population	Cities	% of urban population	Towns	% of urban population
1901	0	0.00	0	0.00	25	26.30	1771	73.80
1911	0	0.00	2	9.00	22	18.70	1768	72.30
1921	0	0.00	2	11.40	28	18.60	1887	70.00
1931	0	0.00	2	10.40	34	21.10	2004	68.60
1941	0	0.00	2	12.20	49	26.40	2087	61.30
1951	0	0.00	5	18.90	72	26.20	2720	55.00
1961	1	7.70	6	15.90	100	28.30	2223	48.10
1971	2	13.00	7	13.30	143	30.90	2405	42.90
1981	3	15.60	9	12.10	207	33.50	3027	38.90
1991	4	17.40	19	15.60	276	31.40	3401	35.70
2001	6	21.10	29	16.70	359	30.80	3984	31.40
2011	8	22.59	45	20.03	415	27.62	5698	29.76

Source: HPEC, 2011 and Census of India, various years

Table 2: Population in Cities and Towns of India, 1901-2011

Population (in millions)					
Year	5 million and above	1- 5 million	1 lakh - 1 million	< 1,00,000	Total
1901	0	0	6.8	19.08	25.9
1911	0	2.34	4.85	18.76	26.0
1921	0	3.2	5.22	19.67	28.1
1931	0	3.48	7.06	22.96	33.5
1941	0	5.39	11.66	27.07	44.1
1951	0	11.8	16.36	34.34	62.5
1961	6.08	12.55	22.33	37.95	78.9
1971	14.18	14.51	33.72	46.81	109.2
1981	24.88	19.29	53.42	62.03	159.6
1991	37.86	33.95	68.33	77.68	217.8
2001	60.37	47.78	88.12	89.85	286.1
2011	85.18	75.54	104.17	112.21	377.1

Source: HPEC, 2011 and Census of India, various years

Indeed, we believe it would be most instructive to look at these various urban types as stages in a continuum. By examining the continuum more closely, we would realise the unique situations they face and where solutions would need to focus in each instance. An indicative, diagrammatic of transitions through the four stages of nucleus, growth, expansion and agglomeration is presented in Figure 1. The four stages in the figure broadly correspond to the classification of towns and cities in Tables 1 and 2. Thus, Stage I describes towns with a population of less than 1 lakh, Stage II corresponds to cities with population between 1 lakh and 1 million, Stage 3 covers cities with population from 1 to 5 million and Stage 4 are the mega metros with more than 5 million people. We believe this framework also corresponds with varying degrees of dependence on diverse sources of water in differently sized towns and cities across India's vast eco-geographic landscape.

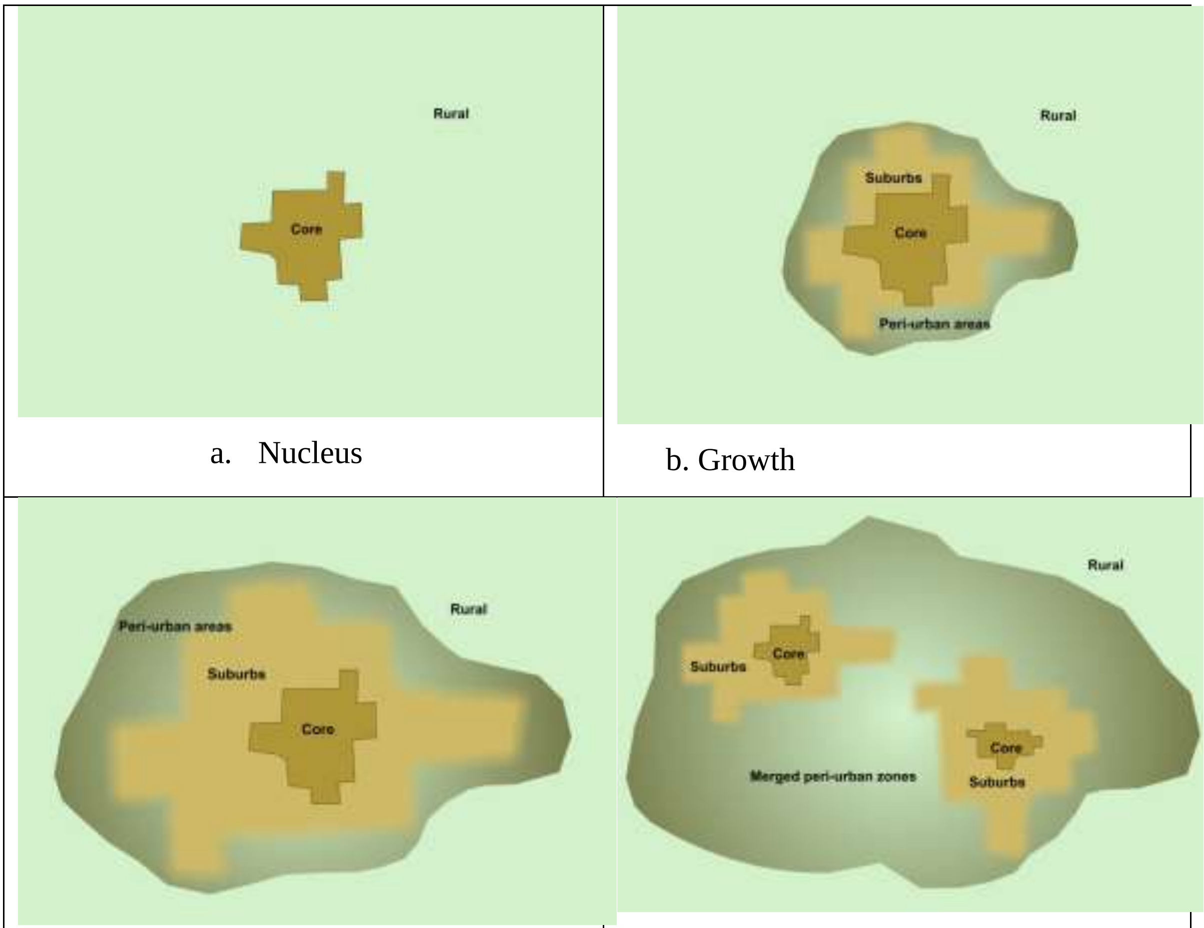
It has been suggested in the literature that dependence on local groundwater reduces as cities grow larger, with urban centres of populations between 10,000 and 100,000 showing highest groundwater dependence and cities with more than a million people showing lowest groundwater dependence (Patel and Krishnan, 2008). However, reliable data and information on the exact nature and magnitude, especially of groundwater use, in differently sized urban centres, is not always forthcoming. Groundwater is an almost invisible resource and therefore often goes unacknowledged in utility planning and management. Secondary data sourced from municipalities and other sources ignore private groundwater use even in larger metropolises in India, not necessarily providing an accurate estimate of the comparative shares of groundwater and surface water in urban water supply.

On the basis of data that is currently available on towns and cities in India, this paper proposes the following continuum hypothesis of stages of evolution of urban settlements in India and their changing dependence of sources of water supply. This is proposed as a possible framework of understanding that needs to be further tested as and when more robust data becomes available on urban India and its sources of water.

Stage One

Small towns in many parts of India face a major water crisis every year, even as they begin to emerge from rural hinterlands, as nuclei for urban growth (Figure 1a). Most such towns are surrounded by the rural landscape of agriculture and almost entirely depend upon groundwater, even where limited surface water supplies are developed, say from tanks and ponds nearby. Groundwater in these towns is commonly sourced through wells in many regions of India and springs in the mountains like the Himalaya. Competition around groundwater resources between rural (agricultural) and urban demand abounds, with water tables often falling across aquifers that are shared between the township and the agricultural neighbourhood. Iniquitous and uncertain water supplies force private well construction within the core area of the township. Groundwater quality concerns are seldom considered, although they are

Figure 1: The Urban Continuum: A Schema in Four Stages



a. Nucleus

b. Growth

c. Expansion

d. Agglomeration

Source: Kulkarni and Mahamuni (2014)

inherent to the supply system, in the absence of a standardized system of water treatment, with continuous intermixing of wastewater and drinking water, resulting from poor sanitation and waste disposal. Institutional mechanisms to address water supply are often poor, with virtually no capacities to address issues of aquifer depletion and contamination, resulting in worrisome public health scenarios. The only intervention considered at some places is the augmentation of recharge through water harvesting. The positive part is that natural recharge areas, in many instances, remain undisturbed as they tend to lie largely in the rural/agricultural hinterland, as open spaces.

These are towns that tend fall off the development map of India but as shown in Tables 1 and 2, these 4000 towns where 100 million Indians live, comprise a substantial part of India's urban population. The heartening part of their predicament is that they have not reached a point of no return and their problems are readily amenable to solutions, with high elements of sustainability and equity and ULB capacities built into them, if only India's policy makers were to pay due attention here.[3]

Stage Two

As small towns become nuclei of growth – area and population wise – suburban areas and peripheral buffers with adjoining rural areas develop (Figure 1b). While the core township may continue to enjoy the privilege of an established 'public water supply system', suburbs and peri-urban areas are almost entirely groundwater dependent. Private bore-wells in the core township area are not necessarily closed down but continue to provide supplements to public water supply, which tends to get more attention than before. Complex water transfers, often in the form of tanker markets develop both ways – from the core to the periphery and also from the rural neighbourhoods to the township areas. The transition from an almost groundwater-based system to a mixed (surface water + groundwater) system begins, with the local development of surface water reservoirs in close proximity to the township. Groundwater quality concerns of some magnitude emerge because much of the suburban and peri-urban neighbourhoods have poor sanitation and waste disposal facilities or have poorly designed soak pits and septic tanks that interfere with aquifers providing drinking water to the growing township. However, much of this contamination goes unnoticed even as public health remains a concern, especially in the monsoon season, when the water table rises. Groundwater, originally used for growing crops, is often transported to the town for filling the gap between growing demands and limited supplies. Some improvement in institutions may happen, but is largely confined to improvements in supply systems, piping and augmentation of water resources, rather than around water management and public health. Sewerage systems begin to develop but are generally restricted to a portion of the areas serviced by piped water supply, usually in and around the core township. Natural recharge areas begin to be encroached upon primarily because of lack of capacity to recognize them as such. Gorakhpur city in Uttar Pradesh could be considered a case here, as much of its water supply is groundwater dependent even as the city faces repeated flooding and waterlogging risks (TERI, 2012).

Another generally unnoticed adverse impact is that on base flows to rivers and streams, caused by increased groundwater extraction. It is not widely recognised but river flow depletion in large parts of India is as much a consequence of groundwater extraction reducing base flows, as it is due to factors like clogged drains and a changing climate. Even where base flows emerge, groundwater resources contaminated from various activities only add to the woes of 'rivers turning into sewers' in our cities. Many of the rivers in large cities bear testimony to this fact.

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[3] Bagli township in Dewas district, part of the groundwater over-exploited Malwa plateau region in Madhya Pradesh, is a typical case in point, well-researched in Samaj Pragati Sahayog (2002), which provides one of the first and perhaps, only comprehensive plan for addressing water supply and solid and liquid waste management in small towns in India.

These small cities, with population less than 1 million, also offer great opportunities for sustainable and equitable systems of water supply and wastewater treatment, with a balanced approach to surface and groundwater.

Stage Three

As towns expand into cities (Figure 1c), the core township remains largely undisturbed and is often labelled 'old city' or 'city centre'. The suburbs and surrounding areas expand rapidly outwards, with increase in population densities. Much of real-estate development happens in these areas. With the formal established 'public water supply' not holding up to the demand, deeper wells are constructed or drilled to supplement public water supply across the city. However, suburbs/peri-urban and sometimes even rural areas get into complex groundwater transfers, largely through tankers. Tanker water supply becomes an established business as water demand for various activities, including booming real-estate, constantly rises. Given the incapacity of the core to treat sewage, the wastewater from such growing towns and cities, eventually drains off directly into rivers, lakes and almost invariably enters groundwater. The suburbs already entirely groundwater dependent and with poor sanitation systems start showing alarming groundwater quality problems which magnify by the impact of added contamination from the core. With natural recharge areas already encroached by concrete, the core looks towards recharge initiatives almost always through rooftop rainwater harvesting. These often lack a scientific base and planning, often leading to problems of water-logging and even basement flooding in some cases. A large sprawling housing colony alone, spread over 360 hectares of land in suburban Pune, was drawing half a million cubic metres of groundwater every year by pumping groundwater from basalt aquifers through 150 odd bore wells in the mid-nineteen nineties (Kulkarni et al, 1997), during stage 2 of Pune's urban trajectory without any focus whatsoever on groundwater recharge.

In the final section of this paper, we propose a focus on two cities in this range. This is because this is the fastest growing segment of India's urban population, with 75 million people living in 45 cities in 2011.

Stage Four

Many large cities in close proximity to one another often 'merge' to create even larger urban agglomerations (Figure 1d). Many examples can be cited today – Mumbai & Thane, Delhi & Gurgaon, Hyderabad & Secunderabad and Pune & Pimpri-Chinchwad. On the other hand, the sheer size of expansion in cities like Kolkata, Bengaluru and Chennai produces the same demands on groundwater resources as that in two merging cities. While the old city or core may have a relatively small footprint (even reduced) of groundwater use, and a larger dependence on piped, surface water, the suburbs almost always witness some level of groundwater usage, although dependencies may have reduced from when the city was in Stage 3. At the same time, the physical merging of peri-urban areas, with increasing population pressures and relatively poor service-provision of public water supply, implies various levels of reliance on groundwater. In Bengaluru, for instance, the southeastern suburbs housing high value real-estate development are serviced entirely by groundwater resources – wells and tankers serviced by wells - even as many of these densely populated areas do not have sewerage and depend upon 'honey suckers or tankers' to take away their sewage to adjoining rural areas (*pers. comm. Biome Trust & ACWADAM*[4]*;* Kvanstrom et al, 2012).

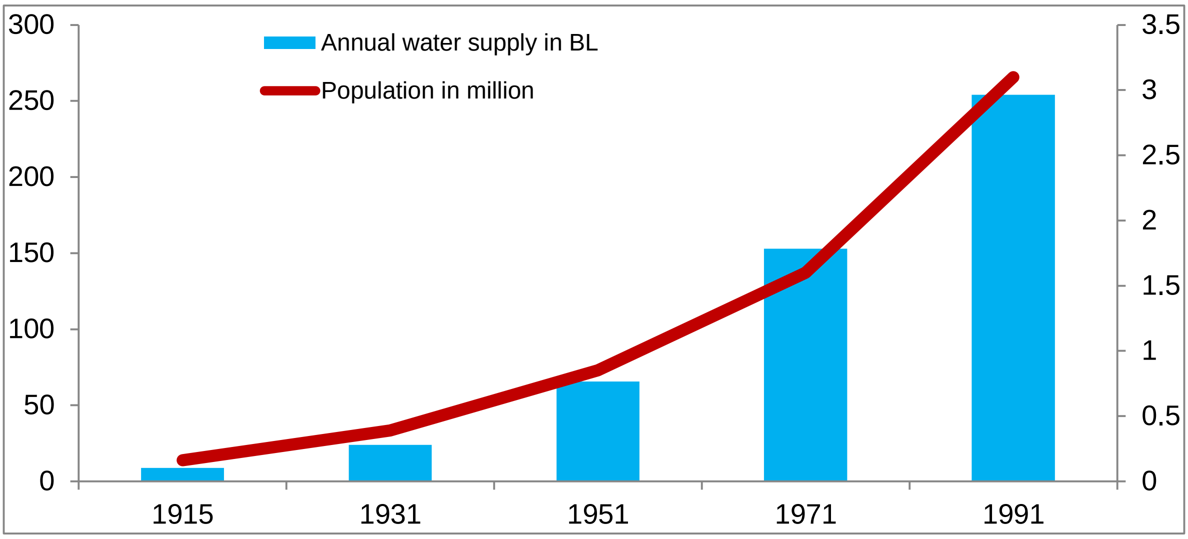
A noteworthy feature in this stage is how the scale-fit between aquifers and urban cover has changed from that in stage 1. In stage 1, while a town often shares a single aquifer with its rural neighbourhood, the sheer size of the urban agglomeration in stage 4 implies that groundwater usage is from multiple aquifers that constitute regional aquifer systems. Impacts of urban activities on such a multiple aquifer system are also quite complex. While aquifer levels drop in parts of such an aquifer system, they rise in others due to recharge from leaking mains and sewers. Groundwater quality changes as a consequence of various point and non-point sources of contamination, especially in the large peri-urban region. Groundwater markets, like in Bengaluru, proliferate and are better organized, as they are often contracted to meet clearly specified demands from housing societies and industry in many of the peri-urban localities.

Natural recharge areas are seldom protected, in the absence of a clear understanding of aquifers and their boundaries, leading to a clear reduction in groundwater recharge. Sometimes, such reduction is offset by the "unintended" recharge from urban activities, including leakage from water supply lines and sewers. Even as water levels in some parts of the city drop – where heavy groundwater abstraction almost entirely meets the demands of a particular city suburb --, there are periods of 'frenzied' drilling – especially after a drought, further aggravating the water table. Iniquities in supply and varied demands across differing socio-economic strata induce different approaches to groundwater. Even in cities claiming to be surface-water secure like Mumbai, groundwater is used quite prolifically, where even established institutions use a significant amount of groundwater from wells on their campuses, with hardly any reference to groundwater quality. Non-potable needs in many such cities are often met or supplemented through groundwater resources.

In the absence of real-time data on groundwater use in urban India, it is difficult to predict trends in terms of how comparative shares of surface and groundwater shape up through the four-stage transition described above. However, observations across many locations in India, indicate that the volumes of surface water pumped from ponds, tanks and reservoirs, even in surface-water dependent townships, increases with time. In Pune, a city dependent largely on surface water from a battery of reservoirs for many decades, the increase in supply of surface water has matched the rise in population (Figure 2).

[4] Biome Trust, Bengaluru and ACWADAM, Pune are currently involved in a 'participatory urban groundwater management initiative in Southeastern Bengaluru. The initiative is being partnered and supported by WIPRO.

Figure 2: Population and Annual Water Supply (in billion litres) for Pune city, 1915-1991



Source: Deolankar, 1977; Kulkarni et al, 1997

Similar trends in groundwater use are extremely difficult to describe in the absence of reliable data. Even in a city like Pune, where this has been studied extensively (Deolankar, 1977), Lalwani, 1993) and Kulkarni et al, 1997), exact quantification is difficult. However, based on evidence in NIUA (2005), Narain (2012), extensive discussions with public officials, government agencies, researchers and civil society organisations across different towns and cities in India, a first-cut attempt has been made to capture the shifting significance of surface and groundwater in urban water supply over time (Figure 3). The figure summarises key elements at each stage, that a single large city or metro would have gone through over a time-line of the last 6 decades. This is a hypothesis for future research to test further. Our conjecture is that the dependence on surface water grows over time as described in the figure through all four stages of urban growth. However, groundwater follows a more complex and relatively indeterminate trajectory. Especially after the stage when the share of surface water becomes higher than that of groundwater in urban water supply, the trajectory of groundwater, (particularly in the absence of robust data regarding well numbers, pumping volumes and groundwater transfers) becomes indeterminate and could move in three possible directions:

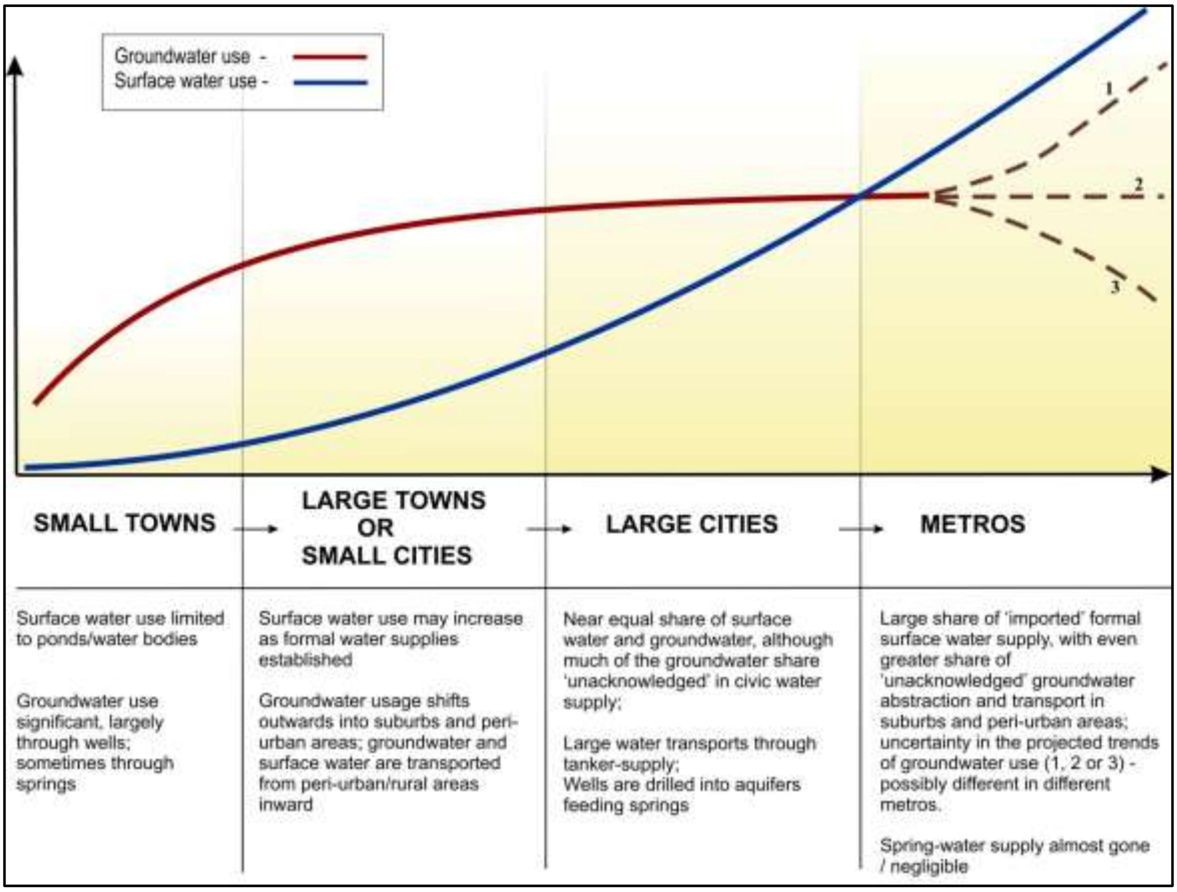
(1) it follows the surface water trends or

(2) it remains stable or

(3) it reduces considerably.

The precise trajectory, the specific path chosen, will depend upon particular aquifer typologies (described in the next section) and socio-economic conditions. But understanding the precise trajectory is significant, both in terms of utility planning and management in urban India

Figure 3: Generalised Trends of Surface and Groundwater Use across variously sized Urban Settlements in India



Source: Kulkarni and Mahamuni (2014)

3. Groundwater: The Blind Spot in Urban Water Planning

As indicated above, our understanding of groundwater in urban India is extremely limited, even though it is absolutely crucial for sustainable and equitable urban water supply planning. International literature lists many factors as determining the great and growing significance of groundwater in urban water supply: increased per-capita use, higher ambient temperatures, reduced reliability of river-intakes, demand – supply imbalances and the modest cost of water-wells are stated as the key factors in the rising dependence on groundwater for people living in the developing cities of the world (Foster *et al*, 2010a).

India is the largest consumer of groundwater in the world. India's annual agricultural use of groundwater resources is in excess of 250 km^3, the largest in the world, leaving China way behind (Shah, 2009). Moreover, 85-90% of rural India depends on groundwater resources for its drinking water supplies (DDWS, 2009; World Bank, 2010). Nearly 70% of irrigated agriculture in India depends on groundwater (Ministry of Agriculture (2013). Recent data from various sources clearly indicates that 'urbanizing' India also has a significant groundwater-footprint. Three recent statistics point to how at least half of urban India clearly depends upon groundwater for its various needs:

1. Averaged for 71 cities and towns, groundwater constitutes 48% of the share in urban water supply (Narain, 2012).
2. In India, 56 per cent of metropolitan, class-I and class-II cities are dependent on groundwater either fully or partially (NIUA, 2005).
3. Unaccounted water in urban areas exceeds 50% according to the CGWB's report on the groundwater scenario in 28 Indian cities (CGWB, 2011).

If harnessed and managed sustainably, groundwater resources can provide a viable option to complement public water supply in large parts of urban India. But groundwater is a 'blind spot' in civic water supply planning in India. Consequently, haphazard groundwater abstraction as a result of rapid urbanization continues as small towns grow bigger and townships aggregate into cities and further into large metropolises. Privately driven, individualistic pumping of groundwater in large parts of urban India has provided benefits for filling out the gaps in public water supply schemes. However, it has also led to problems of co-terminal depletion and contamination of aquifers.

Sustainable management of groundwater is impossible without a much deeper understanding of the types of aquifers within which it is located. There are huge gaps in our knowledge about urban aquifers, their characteristics, the significance of their service value and a comprehensive understanding of the competition and conflicts around groundwater resources. Negative health and economic impacts of falling groundwater quality tend to be concentrated in poor urban areas where residents frequently lack the political pull or financial resources to obtain access to piped water supply and sewage systems (Burke and Moench, 2000). Aquifers are both sources and sinks, highlighting the need to bring groundwater into discussions around improved sanitation and sewerage systems in India's growing urban agglomerations.

City water agencies only provide estimates of the groundwater that they 'officially source' and 'officially supply' with no records of the amount of groundwater that is privately extracted in a city (Planning Commission, 2012). We list below the reasons for groundwater being a blind spot in urban planning:

1. Most urban utilities are unable to 'acknowledge' groundwater use in towns and cities in the absence of actual data and information outside groundwater usage in formal municipal supplies.

2. Given the 'fuzziness' of boundaries between various administrative sub-sectors of urban civic bodies – core cities (old town areas), sub-urban region, peri-urban sections and the immediately neighbouring rural portions – it is difficult to track the rapidly changing picture of 'water demand and supply' in urban agglomerations.

3. It is difficult to ascertain the actual share of groundwater in an individual urban household, say on the basis of a household survey. When one attempts to do this, it often becomes clear that the actual supply to the household is greater than water supplied through the formal system.

4. As small towns transition to large cities, there are phases of 'uncertainty' in civic supply. These uncertainties are inevitably filled up by groundwater pumping, either in-situ through private well construction or through tanker-water supply sourced from wells in the rural hinterland.

5. Finally, much of urban growth is around building and construction of homes, i.e. real estate development. Many cities have norms that do not allow 'water for construction' to be sourced from municipal supplies. Water for construction, even for large housing complexes in cities like Pune is almost entirely groundwater, whether such construction is located in the core city area, suburbs or the peri-urban regions around towns and cities.[5]

Aquifers in large regions of India act as both sources and sinks for various loads, ranging from sullage to sewage and from industrial waste to agricultural residues like pesticide and fertilizer. Groundwater resources in growing urban centres are therefore likely to become contaminated as much by residual contaminants from erstwhile agricultural activities and poor rural sanitation as by contamination from more current haphazard waste-water disposal. Urbanisation and the associated industrialization provide numerous sources of diffuse and multipoint pollution posing long-term risks to deeper groundwater that are not fully appreciated (Morris et al, 1994). Only 32.7% urban Indians are connected to a piped sewer system and 12.6% – roughly 50 million urban Indians – still defecate in the open (Census of India, 2011). Large parts of the modern cities remain unconnected to the sewage system as they live in unauthorised or illegal areas or slums, where state services do not reach (Shah, 2013). Surveys of groundwater quality in many cities, therefore, reveal a large magnitude of water-borne pathogenic contamination – commonly referred to as bacteriological contamination – clear signs of groundwater contamination by sewage. In the city of Lucknow, during the period of its initial urban growth, nitrate concentrations ranged between 25 and 50 mgN/l, indicating that about 20% of the nitrogen was being leached to the water table (Morris et al, 1994).

There is increasing recognition and acknowledgement of the need to understand and recognize groundwater recharge as an important aspect of urban planning in India. But there is little understanding of aquifer character and dynamics behind the rhetoric of groundwater recharge.[6] This is clearly acknowledged in the 12th Five Year Plan, which makes a strong case for recognizing the existing role of groundwater in city water supply, and the need to provide for recharge, especially by stressing the role of local water bodies in this respect (Planning Commission, 2012).

In the international literature on urban groundwater, it is claimed that with urbanisation there is a rise in groundwater recharge rates. Apparently, the reduction in natural rainfall recharge through land-surface 'impermeabilisation' is more than compensated by physical water-mains

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5 In Pune city, for instance, municipal water connection is provided only after the completion certificate to a house or housing complex is sanctioned by the Municipal Corporation, with nearly all water requirements during construction being met by well-water at the site or tanker-supply usually sourced from wells in other locations.

6 Unlike a significant debate and discussion around groundwater recharge in rural India through watershed development (Farrington et al, 1999; Batchelor et al, 2000; Shah et al, 1998; Gale et al, 2006; Shah, 2009), there is little in terms of specific understanding of the concept of 'Managed Aquifer Recharge' in Urban India.

leakage, by infiltrating pluvial drainage and by the ‘return’ of wastewater via in-situ sanitation and main-sewer leakages (Foster et al, 2010). This is especially in cases where part of the water-service infrastructure is relatively old and/or poorly constructed and the municipal water-supply is largely ‘imported from external sources’. We believe there is an urgent need to understand the tradeoff between encroachment of natural recharge areas through infrastructure cover – mainly concretization and other such activities that decrease the areas of ‘permeable surfaces’ – and the addition to aquifers from leaking piped water supply and sewerage lines. Aquifer recharge in urban centres is often incidental or accidental, a consequence of uncontrolled practices of wastewater reuse and/or disposal. Because of this groundwater recharge is seldom optimized from the point of view of maximizing water resource recovery and minimizing aquifer quality deterioration (Foster et al, 1994).

It is claimed that urbanisation significantly affects the natural water cycle in terms of the quantity and quality of water (Vazquez-Suni et al, 2005). What is more important however is the question of how ‘natural recharge areas’ to aquifer systems progressively get ‘encroached upon’ by infrastructure in the absence of a process of recognising the importance of recharge zones as part of urban planning. The size of natural areas shrink as does their importance, given that groundwater itself has low priority in the minds of both users as well as planners. Conservation and protection of natural as well as artificial recharge zones in and around growing towns and cities is of utmost importance in an urban groundwater management plan. Protecting recharge areas is relevant both in ensuring optimized groundwater storage as well as in preserving basic groundwater quality, even as the clamour for rooftop rainwater harvesting gathers momentum in large sections of urban India.

Groundwater Resources in Urban India

A groundwater typology can be defined by hydrogeological settings, aquifer scales and the socio-economic factors of a region (Kulkarni and Shankar, 2009). Hence, the typology of groundwater decides *how* and *how much* does the water stored in an aquifer change as a consequence of groundwater recharge and extraction. The primary basis for a groundwater typology is the geology of a region, given that various geological formations host ‘aquifers’, with the characteristics of these aquifers – mainly the transmissivity, storativity and groundwater quality – determining the groundwater flow and stocks in the region. India’s geological diversity lends itself to varied hydrogeological conditions not just across the country, but even within a single village or watershed. These conditions are reflected in well yields and in the short and long term responses of *aquifers* to natural and anthropogenic fluxes.

Understanding aquifers in the context of India’s groundwater crisis has become quite important. This rationale has led to the aquifer mapping and management programme under India’s 12th Five Year Plan (Planning Commission, 2012). India’s aquifer typology is based on seven broad hydrogeological settings that the country can be divided into (COMMAN, 2005; Kulkarni et al, 2009; Vijay Shankar et al, 2011). Our purpose is to articulate how this typology lends itself to the peculiarities of groundwater resources in urban India.

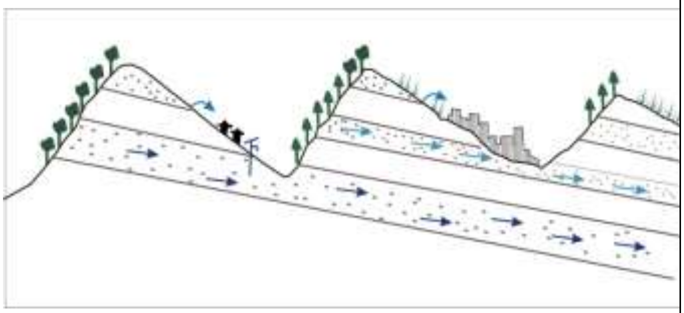
Kulkarni and Mahamuni (2014) divide variously sized towns and cities into six categories

(Figure 4)[7]. This was attempted using a GIS framework of overlays upon the 4-fold urban classification described above. This classification is probably a first of its kind and is evolving as the GIS analysis is sharpened. However, it provides a useful indicative 'typology' of groundwater resources in urban India.

1. Himalayan Mountain Systems

Even though only 2.5% of the larger cities and 8% of smaller towns are located in the Himalayan mountain regions, the uniqueness of its hydrogeology and ecosystems warrants a separate category under the urban groundwater typology. To begin with, the hydrogeology is represented by numerous local aquifers, at many locations and altitudes in this expansive region. These aquifers feed springs that form the primary means of water supply to both rural and urban habitations and also contribute significantly to base flows in streams and rivers of the Indo-Gangetic river basins. Even by gross, conservative estimates, there are over a million perennial springs in the Indian Himalayan Region alone (*pers. comm. ACWADAM*[8]). Given the structural complexity of rock formations in the Himalaya, these aquifers, although local, are often fed by recharge from distant locations.

Figure 4(a): Mountain aquifer systems



	Mountain Systems **Population**	**Towns/Cities**
A	> 5 million	0
B	1-5 million	0
C	1 lakh – 1 million	8
	Total cities (A+B+C)	8
	Total cities (% of total)	2.5
D	< 1 lakh	457
	Towns (% of total)	8
	e.g. Chamba, Dharamsala, Shimla, Manali, Palampur, Kaza, Nainital, Almora, Mussoorie, Darjeeling, Gangtok, Aizawl, Shillong	

The single largest problem surrounding groundwater and urbanization in the region is that the sinking of wells – for public and private water supply – interferes with spring discharges, often taking up groundwater that would otherwise have flowed as (natural) discharge from a spring. Secondly, in many instances, aquifer continuity across villages and towns presents the potential of contamination from on-site sanitation and waste-disposal sites. Thirdly, in the absence of a

7 Sketches are not to scale

8 ACWADAM is part of an emerging 'Springs Initiative' supported by Arghyam Trust, Bengaluru. ACWADAM has already partnered with leading Civil Society Organisations like PSI, Chirag and Himmothhan in different parts of the Himalayan region. Some of these partners have also been part of the 'springshed initiative', a unique approach to spring water management in the Himalaya, led through the dynamic efforts of the Rural Management and Development Department (RMDD) of the Government of Sikkim through their *Dhara Vikas Programme* (www.dharavikas.org)

protocol of including hydrogeology in urban planning, the concept of 'protecting' recharge areas is largely missing, although recent initiatives have provided promising approaches to spring water management and 'springshed development' activity (Tambe et al, 2011; Mahamuni and Upasani, 2011). Moreover, tourism has pushed rapid infrastructure development in many of these townships. The town of Leh, in Ladakh district of Jammu and Kashmir, for instance, which largely depended on spring-water to meet its household needs is increasingly turning into a town of bore wells as tourism pressure and urbanisation builds up rapidly. With such pressures, not only are bore wells and springs competing for groundwater from 'common' aquifers, water that was allocated to agriculture in the peri-urban pockets of Leh is also affected, with infrastructure interfering with 'natural recharge zones' (ACWADAM, *pers. comm.*). The situation is similar in many Himalayan towns, Shimla, Manali, Palampur, Almora, and Gangtok, to name a few.

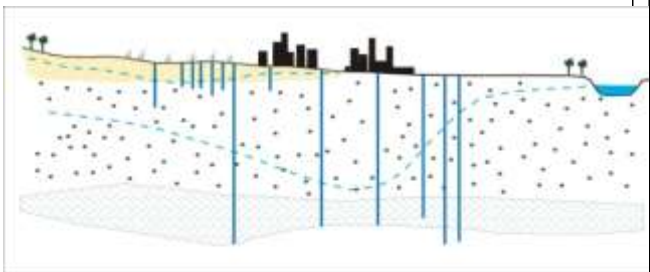
Apart from the above factors, land-use changes and the variable and changing climate, are sources of immediate concern around the sensitivity of aquifers to changes in storage and quality. While agriculture has remained largely rain-fed, there are trends of shifting to irrigation at scale, building another layer of competition around fragile and low-storage aquifers, particularly in the peri-urban areas of small and large townships.

2. Extensive Alluvial Systems (largely the Indo-Gangetic Alluvial Plains)

The two main regions of large-scale groundwater extraction coincide with the two largest hydrogeological settings within the typology – the extensive alluvial systems and the crystalline (basement) system, described later. In a reference to the ever increasing trends of groundwater pumping in these two regions of India, Postel (1999) had suggested that two thirds of the annual overdraft of global groundwater to the extent of 200 km^3 (supporting 10% of the global food production) was occurring in western and peninsular India, corresponding to these two regions.

The vast region of groundwater exploitation in the northwest regions of the country is from alluvial aquifers, largely in the form of unconsolidated sediments deposited to form the vast plains of Indus and Ganga River Basins, lying in Punjab, Haryana, part of Rajasthan and Western Uttar Pradesh. Further east, this region grades into the flood-prone areas of Eastern Uttar Pradesh, Bihar, parts of West Bengal and Assam (Brahmaputra river basin).

Figure 4(b): Alluvial Aquifer Systems



	Alluvial	
	Population	**Towns/Cities**
A	> 5 million	5
B	1 - 5 million	19
C	1 lakh – 1 million	118
	Total cities (A+B+C)	142
	Total cities (% of total)	46
D	< 1 lakh	1847
	Total towns (% of total)	32
	e.g. Amritsar, Chandigarh, Ludhiana, Patiala, Meerut, Delhi, Bareilly, Lucknow, Allahabad, Varanasi, Patna, Kolkata, Cuttack, Guwahati, Jorhat, Dibrugarh, Bhubaneshwar	

Some 46% of large cities and 32% of small towns in India are situated within the alluvial aquifer setting. While the western part of the region has witnessed groundwater depletion, parts of the eastern plains face a constant threat from flooding and are water-logged. Chandigarh, Delhi, Lucknow, Allahabad, Varanasi, Patna are some examples of large cities located within this setting.

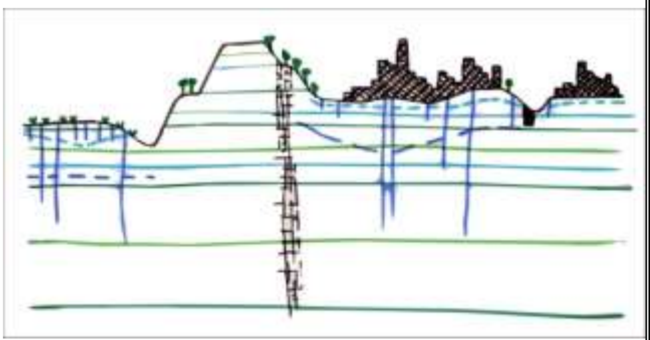
In multiple, overlying aquifers, with *virtually infinite lateral boundaries*, competition appears through a race to drilling *deeper* and pumping *more* (Kulkarni and Vijay Shankar, 2014). Even as well-numbers grow, some users with larger pump capacities can capture extra water, although the relative share of water available to each may progressively decline as water levels across the aquifer drop over the long term. But once the aquifers are depleted, it requires a major effort to revive them, since groundwater recharge has to take place at a regional scale, with large volumes of water.

Despite the presence of large rivers – mostly the tributaries and main channels of Indus and Ganga – there is great dependency of domestic water and water for agriculture on groundwater resources in this setting, with many industrial zones depending upon groundwater as well. Moreover, groundwater quality across this setting is a major concern with Arsenic dominating many areas. Other contaminants cannot be ruled out from areas where agriculture has prospered with heavy inputs of irrigation, fertiliser application and pesticide / insecticide usage. Complex groundwater markets are emerging in both the drier western parts of the basin as well as in the eastern (flood-prone) region in the form of what is labelled 'collusive opportunism' by Shah (2009) in his description of India's groundwater anarchy. As cities grow in the region, the most alarming question will be that of groundwater quality a factor that changes with space, time and depth. Hence, expanding urban space, competition with rural water supplies with the constant potential of hitting a groundwater contaminant zone, are the emerging challenges for the region.

3. *Volcanic (Basalt)*

The basalt rocks of western and central India represent voluminous outpouring of lava that solidified and gave rise to an extensive (more than half a million km^2) and thick pile (hundreds of metres) of “lava flows”. Basalt aquifers also constitute a layered system and exhibit a high degree of variation that leads to a range of aquifer properties (Deolankar, 1980, Kulkarni *et al.*, 2000). Basalt aquifers are heterogeneous in nature with limited storage and are pumped heavily for irrigation in some pockets. Their limited areal extent and thickness implies that groundwater in such aquifers occurs only on a local scale, unlike in alluvial aquifers. Basalt aquifers are usually coterminous with small watersheds that may, for instance, include a few villages, sometimes even a single village. A bigger settlement like a city or even a town often taps multiple basalt aquifers, with a layered system of weathered and fractured rock giving rise to aquifers at different depths or disconnected, shallow aquifers defined by zones of rock-weathering. Layered hard-rock aquifers, therefore, offer the competitors a similar setup as layered alluvial aquifers, but of limited extent, and therefore with smaller groundwater storages.

Figure 4(c): Basalt Aquifer



	Volcanic (Basalt) Population	Towns/Cities
A	> 5 million	2
B	1-5 million	6
C	1 lakh to 1 million	24
	Total cities (A+B+C)	32
	Total cities %	10.5
D	< 1 lakh	391
	Total Towns %	7
	Mumbai, Nagpur, Pune, Nasik, Aurangabad, Akola, Nanded, Solapur, Buldana, Indore, Dewas, Ujjain, Bidar, Bijapur	

Many hard-rock systems depend upon storage in their weathered zone and transmission through their fractures. While basalt aquifers come under serious competition within the rural arena where individual irrigation wells compete for a limited stock of groundwater, the urban domestic demand does not necessarily need large amounts of water from individual wells. Hence, even if well yields are limited, basalt aquifers offer sufficient incentives for household groundwater sourcing, given that drilling rates for a bore well are quite affordable for urban citizens in Central-West India. Moreover, groundwater in basalt is of reasonably good quality as compared to the alluvial and crystalline aquifer systems, an added incentive to tap into your backyard through a borehole that is able to supplement surface water supply where such supplies exist. Most towns and cities in Western and Central Maharashtra, South Gujarat, parts of Saurashtra, large parts of Western and Central Madhya Pradesh and portions of North Karnataka and Northwestern Andhra Pradesh would fall under this category.

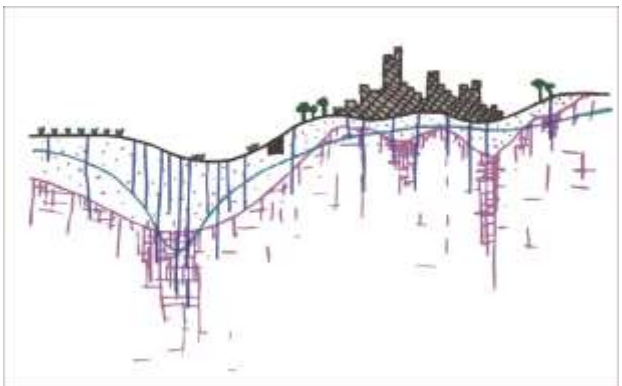
In a layered system of low-storage aquifers, groundwater use shows more of vertical interference between wells that often extends to large sections in a city. Competition around drilling deeper is quite intense, both during severe water cuts in a town or city, say during a drought in the region or when agriculture-driven groundwater overexploitation sets in within the region where urban and rural demands are imposed on an aquifer system shared by towns/cities and neighbouring villages.[9] Towns and cities underlain by basalt in the western part of this region have a prevalence of conjunctive surface water and groundwater use. Large urban agglomerations like Mumbai, Pune, Pimpri-Chinchwad and Kolhapur are located in the 'dam-dominant' region of India. Unacknowledged use of groundwater, especially in suburbs and peri-urban areas of even these large cities, is significant and measurement of groundwater usage outside that in formal public supply would be higher than the 10% mentioned for basalt in NIUA (2005).

While, the largely inert nature of basalt implies relatively better groundwater quality compared to most of the other aquifer systems, the quick flow through fractures to such aquifers implies that contaminants that seep through the surface, especially where water levels are shallow, enter the aquifer rather quickly leading to episodes of pathogenic (mainly bacteriological) contamination.

4. Crystallines (Igneous and Metamorphic rock) Aquifers

The other region where groundwater exploitation has emerged as a large-scale challenge is in peninsular India within the crystalline aquifers in the Godavari, Krishna and Kaveri river basins of peninsular India. This setting is the second largest hydrogeological setting in India, after the alluvial system described before. Some 31% of small towns and 36% of larger cities are located in this hydrogeological setting.

Figure 4(d): Crystalline aquifer systems



	Crystallines Population	Towns/Cities
A	> 5 million	4
B	1-5 million	21
C	1 lakh to 1 million	89
	Total cities (A+B+C)	114
	Total cities %	35.5
D	< 1 lakh	1773
	Total towns %	31
	e.g. Bhilwara, Bengaluru, Bolangir, Kalahandi, Hyderabad, Ranchi, Coimbatore, Nalgonda, Tumkur, Mysore, Vellore, Salem, Dindigul, Kottayam, Thrissur	

[9] The well-documented case of Dewas city in Madhya Pradesh illustrates the emergence of a water crisis by the competitive drilling and pumping of groundwater in and around the growing city, even as far back as the early 1990s (Samaj Pragati Sahayog, 1994).

Aquifer conditions that govern storage and flow of groundwater in crystalline formations change even over very short distances, similar to those in basalt. However, the degree of heterogeneity of aquifer conditions is not as stark in crystalline rocks as that in basalt, although the highly variable well yields and consequently, the groundwater pumping patterns are of similar nature in both. Where regional weathering and fracture patterns have developed in crystalline rock formations, the groundwater conditions are almost akin to those in a shallow alluvial aquifer (COMMAN, 2004). Such variability leads to fundamentally diverse recharge and discharge conditions in these aquifers, a fact that is seldom understood during groundwater development and management. Crystalline aquifer systems tend to be depleted rapidly when intensive development occurs. Owing to low storage generally, water levels fall rapidly and shallow wells go out of service as water contained in the upper weathered and fractured zone is pumped out. Furthermore, as water is confined to the near-surface weathered zone, groundwater availability in hard rock regions also tends to be much more sensitive to recent precipitation as also vulnerable to surface-related contamination.

One of the most significant factors that affects these aquifers as part of the urbanisation process is that much of the local aquifer storage in a shallow, unconfined (or phreatic) crystalline aquifer may be 'lost' when deep foundations for infrastructure such as housing are excavated and concreted.

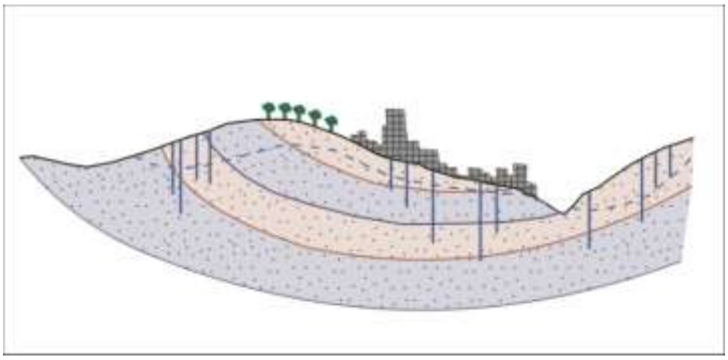
Urban centres in Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Odisha, Jharkhand and Chhattisgarh, along with large parts of the Bundelkhand Region of Madhya Pradesh and Uttar Pradesh are underlain by crystalline rock aquifers. Bengaluru, a case in point, is among the fastest growing cities in India. The main source of supply for Bengaluru's water utility is the river Kaveri, 100 km away and lying 500 m below Bengaluru. The city has an ecological and legal limit to its access to its current surface water source. The city however has a history of local captive sources of water (from lakes and shallow aquifers through open wells), which are rapidly dying. Arkavathi, the local river, is now dry on account of base flow depletion from groundwater overexploitation, especially through deep bore wells. Bengaluru's administrative sub-units have all been declared groundwater overexploited. The poor of the city, whose access is anyway largely constrained, are particularly dependent on groundwater. Groundwater now caters to domestic needs and drives real estate, commercial and industrial activity in many parts of Bengaluru. Some parts of Bengaluru city, especially the south-eastern quadrant, which houses industries, high value housing complexes and gated communities, depend entirely on groundwater sourced from private in-situ wells and bore wells or from contracted tanker supply which sources groundwater from deep bore wells (Biome Environmental Trust, *pers. comm.*).

5. Consolidated Sedimentary Formations

Only about 3% of small towns and 4% of the larger cities are underlain by these formations, which host local to quite regional scale aquifers and aquifer systems. Some of these rocks may hold groundwater recharged over longer time frames of decades, and maybe hundreds of years. Many of these formations also host some mineral deposits that are obtained through quarries and mines. Hence, towns and cities that have interface with mining activities are likely to have interference of mining over potential groundwater stocks. Townships in the coal belt of East-

Central India, like Dhanbad and Hazaribagh in Jharkhand and Chandrapur in Maharashtra or Adilabad in Telangana are a few examples. Many of these areas not only show private access to groundwater from high yielding aquifers (generally high storage and quick transmission) but also have a significant proportion of public water supply dependent on groundwater from these aquifers.

Figure 4(e): Consolidated sedimentary formations



	Sedimentary Systems Population	**Towns/Cities**
A	> 5 million	0
B	1-5 million	1
C	1 lakh to 1 million	12
	Total cities (A+B+C)	13
	Total cities (% of total)	4.0
D	< 1 lakh	172
	Towns (% of total)	3.0

Eg Dhanbad, Hazaribagh, Adilabad, Chandrapur, Raipur, Rewa, Cuddapah, Kota, Bundi

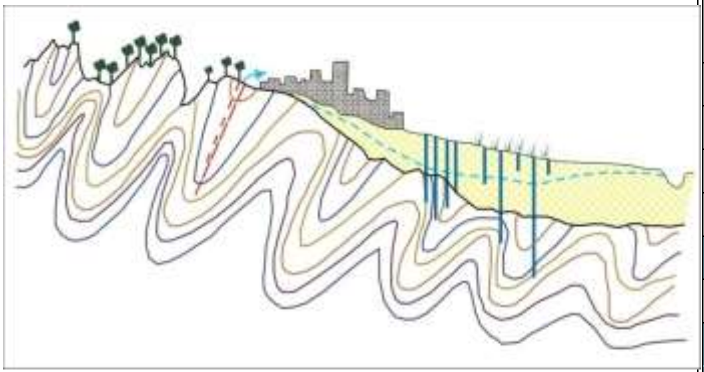
Many of the mines in the adjoining areas of such townships dewater underground aquifers as part of the ‘dewatering’ of mines, without the townships being aware of such impacts. Similarly, groundwater quality in such areas is always questionable and random testing of wells for Iron, Fluoride and Arsenic has yielded fairly high levels of contamination from some of these chemical constituents.

6. Transition zones

The best examples of transition zones are towns and cities located at the interface of mountain / hill ranges and the plain areas, although other transitions are also possible (between two or even three of the preceding ‘types’). Hence, we have illustrated here, as an example, the transition between the foothill portions of the Himalayan system and the adjoining alluvial region. Commonly called the ‘terai’, this region shows a sudden break in the mountain slope along with the significant change in porosities and permeabilities of the two aquifer settings. Many springs emerge at this interface. There are reports of Arsenic pockets in these transition zones, which have a mix of spring water in the uplands and shallow tube-wells fitted with hand-pumps on the other.

Townships like Bagdogra in West Bengal, Haldwani in Uttarakhand and Kalka in Himachal Pradesh are some examples. Other examples are the small and large towns that are situated at the interface of Aravalli ranges and the adjoining alluvial plains, including the growing city of Gurgaon.

Figure 4(f): Zones of aquifer setting transition



	Mixed Population	Towns/Cities
A	> 5 million	0
B	1-5 million	0
C	1 lakh to 1 million	0
	Total cities (A+B+C)	0
	Total cities (% of total)	0
D	Towns	1142
	Towns (% of total)	20
	eg Gurgaon, Bagdogra, Haldwani, Kalka, Bhopal, Bhuj	

It should be apparent from the above description why it is so important to understand the specific nature of the aquifer(s) present within each location, in order to be able to undertake sustainable and equitable management of groundwater. The National Aquifer Management Programme initiated in the 12th Plan, with its initial focus on aquifer mapping, holds out the hope that over the next decade we will have a better idea of the nature of the aquifers that hold our groundwater and we will be able to forge strategies for better groundwater management in urban India.

4. India's Urban Areas in a 6x4 Matrix

It should be apparent from the above description why it is so important to understand the specific nature of the aquifer(s) present within each location, in order to be able to undertake sustainable and equitable management of groundwater. We now propose the classification of all of India's urban settlements into a 6x4 matrix, which captures both the stage of urban expansion (4 stages) and the aquifer type they belong to (6 types). The strategy to address the problem of urban water would need to be different in each of the 24 cells of this matrix. The first step in devising these strategies would be to appropriately locate each of India's towns and cities into these cells. An initial illustrative classification of 150 towns and cities is provided in Matrix 1. It is important to note that towns and cities will move towards the right in each row of the matrix, as they grow in size. Hence, solutions need to be formulated in a deeply dynamic manner. Which is why it makes most sense to focus on those towns where precipitate errors have not been made and there is still scope for fresh, innovative work *ab initio* of the kind described later in this paper

Matrix 1: Classification of 150 Towns and Cities by Stage of Development and Aquifer Type

Aquifer Type	**Stage of Urban Development**	**Nucleus**	**Growth**	**Expansion**	**Agglomeration**
Mountain systems – mainly Himalaya		Banihal (J&K), Kaza (HP), Bhimtal (UK), Namchi (Sikkim), Jowai (Meghalaya)	Leh (J&K), Palampur, Hamirpur (HP), Nainital, Almora, Mussoorie (UK)	Anantnag (J&K), Nainital (UK), Darjeeling (WB), Itanagar (Arunachal Pradesh), Aizawl (Mizoram)	Jammu, Srinagar (J&K), Shimla (HP), Shillong (Meghalaya), Gangtok (Sikkim)
Extensive alluvial systems largely within the Indo-Gangetic and Brahmaputra flood plains		Fazilka, Abohar, Sangrur (Punjab), Kaithal (Haryana), Raebareli, Fatehpur (UP), Sitamarhi, Bettiah (Bihar), Nadadwip (WB)	Barmer (Rajasthan), Ferozepur, Bhatinda (Punjab), Jaunpur, Meerut (UP), Hissar, Kurukshetra (Haryana), Saharsa, Madhubani (Bihar), Burdwan (WB), Dibrugarh (Assam)	Jodhpur (Rajasthan), Kanpur, Gorakhpur, Moradabad, Bareilly (UP), Ludhiana, Amritsar (Punjab), Darbhanga (Bihar)	Chandigarh, New Delhi, Allahabad, Varanasi, Lucknow (UP), Ahmedabad (Gujarat), Patna (Bihar), Kolkata (WB), Guwahati (Assam), Bhubaneshwar (Odisha)
Deccan Volcanic forming the plateau uplands of West-Central India		Palghar, Paud, Saswad, Bhor, Chiplun (Maharashtra), Bagli, Karnavad (MP)	Lonavala, Ratnagiri, Beed (Maharashtra), Pithampur, Dewas (MP)	Satara, Wardha, Amravati, Kolhapur, Latur, Nanded, Baramati (Maharashtra), Ujjain (MP)	Mumbai, Thane, Pune-Pimpri-Chinchwad, Aurangabad, Nagpur, Nashik, Solapur (Maharashtra), Indore (MP)
Geologically ancient Crystalline Rock Formations of peninsular, eastern and northwestern India		Chalakudy (Kerala), Sivakasi (TN), Kunigal (Karnataka), Kosigi, Daulatabad (Telangana), Khunti, Lohardaga (Jharkhand)	Palakkad (Kerala), Madanapalle (AP), Chitradurga, Gadag, Davangere (Karnataka), Karimnagar, Nalgonda (Telangana), Purulia (West Bengal), Jhansi (Jharkhand)	Thrissur (Kerala), Coimbatore, Thiruvannamalai, Madurai (TN), Jamshedpur (Jharkhand)	Bengaluru, Mysore (Karnataka), Hyderabad (Telangana), Thirupati, Visakapatnam (AP), Ranchi (Jharkhand), Ernakulum, Thiruvananthapuram (Kerala)
Sedimentary Rock Formations from various parts of India		Karaikudy, Ariyalur (TN), Tadipatri (AP), Badami (Karnataka)	Tiruchirapalli (TN), Kadapa (AP), Shahbad (Karnataka), Satna (MP)	Kurnool (AP), Chandrapur (Maharashtra), Bilaspur (CG), Bhuj (Gujarat), Jabalpur (MP)	Raipur (CG)
Transition zones at the interface of two or more of the above formations		Jaisalmer, Neemrana (Rajasthan)	Sangamner (Maharashtra), Hazaribagh, Dhanbad (Jharkhand), Shahdol (MP)	Gwalior (MP), Siliguri (West Bengal)	Vadodara (Gujarat), Dehradun (UK), Agartala (Tripura), Nagpur (Maharashtra)

Note: AP: Andhra Pradesh; CG: Chhattisgarh; HP: Himachal Pradesh; J&K: Jammu and Kashmir; MP: Madhya Pradesh; TN: Tamil Nadu; UK: Uttarakhand; WB: West Bengal

5. Demand and Supply of Water in Urban India

We must begin by recognizing with the Planning Commission's Working Group on Urban and Industrial Water for the 12th Plan that the system of estimating demand and supply of water in cities is rudimentary and leads to poor accounting and poorer planning. Indian cities compute demand by simply multiplying the population by a guesstimate of water demand per capita. The guidelines provided by the Central Public Health and Environmental Engineering Organisation (CPHEEO) are used at times by city planners, but these often fail to provide clarity about how much water is needed. For instance, the guidelines differentiate between cities with (135 lpcd) and without sewerage (70 lpcd) systems. But these do not indicate how much area must be under a sewerage system before a city qualifies for higher water norms. Then the guidelines provide that cities could provide additional water if hospitals, schools, airports and institutions require 'considerable quantities", which is again left vague.

Table 3: Norms fixed by the CPHEEO Manual

Sno	Classification of towns/cities	Recommended maximum water supply levels (lpcd)
1	Towns provided with piped water supply but without sewerage system existing/planned	70+ 15% for leakage
2	Cities provided with piped water supply where sewerage system exists/planned	135+ 15% for leakage
3	Metropolitan and Mega cities provided with piped water supply where sewerage systems existing	150+ 15% for leakage

Source: Ministry of Urban Development, Central Public Health and Environmental Engineering Organisation Manual on Water Supply and Treatment, Third Edition -Revised and Updated (May 1999), New Delhi.

These facts combined with the blind spot and under-reporting of groundwater means that we have really no firm estimates on urban water demand and supply. Even so, valiant efforts have been made by researchers to hazard water demand projections (WDPs). Mckinsey Global Institute (2010) estimates that the demand for urban water will increase by 2.4 times, from 83 billion liters per day in 2007 to 189 billion liters per day in 2030. The gap between basic demand and supply is likely to increase by 3.5 times. The World Bank has projected that the annual water demand will be 1050 BCM by 2025 of which 20 per cent will be from industrial use and 5 per cent from domestic use. A most recent review of various global WDPs by the International Water Management Institute (Amarasinghe and Smakhtin, 2014) concludes:

"Considering that the projection period of some WDPs have now passed, this paper examines how closely such past projected withdrawals match current water withdrawals to identify lessons that can be learned and strengthen future studies on WDPs. Six WDPs conducted before 1990 and seven conducted after 1990 are analyzed in detail. The review shows that the pre-1990 WDPs overpredicted current water use by 20 to 130%. Unrealistic assumptions on the norms of water use in different sectors were the main reasons for large discrepancies. The post-1990 WDPs had sophisticated modeling frameworks. Yet, the post-1990 WDPs of the 'business as usual' (BAU) scenarios show substantial underestimation globally, and large deviations for sectors and countries, from the current water-use patterns. The average per capita domestic water withdrawals at present already exceed projections made by the BAU scenario for 2025. BAU projections for the agriculture sector are mostly under- or over-estimated (-11% to 3%). For India, the underestimation ranges from 20 to 90 billion cubic meters or 3 to 14% of the total water withdrawals"

Clearly, improvements in water use efficiency in agriculture predicted by the WDPs have not yet come to pass. Availability of water to meet rapidly growing urban demands will critically depend on these improvements taking place, in the absence of which the demand-supply gap in urban water will be even wider than projected. This dire situation, thus, makes the solutions proposed in this paper acquire an even greater urgency. While there would be deep location-specificity in the strategies across cells in the matrix presented in Matrix 1, it is also possible to identify some common elements of urban water strategies that would cut across all urban locations in India. To an enunciation of these common elements that mark a break from the previous approaches adopted in this sector, we now turn.

PART B: MOVING TOWARDS SOLUTIONS

In proposing these possible solutions, the attempt we have made is to not only learn from the mistakes of the past but to also build on the innovations that appear most promising in providing cost-effective, sustainable solutions. The aim is also to suggest mid-course corrections that could help chart a better future for India's urban areas. What we describe in Part B of this paper are some of the common elements that would need to characterise solutions across all towns in our 6x4 matrix

1. Urban Groundwater Management in India: Framework for Action

Water usage in towns and cities is more than what is 'supplied' through the formal, public water supply system. This "extra" water, which does not get accounted for, is almost always groundwater. Such unaccounted use of groundwater also creates problems during the design of sewerage and sewage treatment. Hence, detailed estimation of groundwater usage is necessary even in the so-called 'surface water dependent' towns and cities. At the same time, groundwater resources offer recourse to many when public supply becomes uncertain. Portions of suburban and peri-urban areas of many growing cities often entirely depend upon groundwater. Such dependence is also a strong indicator of on-site (rather than sewerage) sewage disposal in the form of soakways, soakpits and septic tanks.

Understanding groundwater resources, including their recharge, patterns and magnitude of uses and groundwater quality is crucial for urban aquifers. Mainstreaming groundwater resources into urban water supply systems can also provide relief against the clamour for surface water imports from long distances that always have the risk of competition and conflicts with rural areas. Harnessing groundwater resources, as part of urban water supply systems in India requires proper assessment, continued monitoring and systematic management of groundwater resources. Developing deep understanding about groundwater resources is as much a function of the diversity of aquifers as it is of the nature and extent of groundwater use. The aquifer mapping and management programme, one of the highlights of India's 12th Five Year Plan could be used as an instrument to begin this process. The following key steps could form the building blocks of an urban aquifer management programme in India:

1. Identifying status of existing groundwater resources in cities through participatory mechanisms, focusing mainly on 'sources'. An exercise involving citizens, educational institutions like colleges and urban utilities could be undertaken. Industry may be invited to invest CSR funds into a public-private-partnership effort on aquifer mapping and groundwater management for urban India.
2. Assessment of the groundwater resources through a participatory 'aquifer mapping' approach coupled with systematic studies by institutions with appropriate capacities can be specifically undertaken for all towns and cities in India. This exercise should include the identification of natural recharge areas, groundwater discharging zones such as springs and seeps and quantification of aquifer characteristics, namely transmissivities, storativities and groundwater quality. Such Urban Groundwater Profiling could be initiated across a sample that represents variously sized towns and cities in each type within India's wide-ranging aquifer typology.
3. Profiling stakeholders, including users, tanker operators, drilling agencies and developing mechanisms for registering water sources could be undertaken as part of the database on urban groundwater.
4. It is only after the first three steps that mainstreaming - at least part of the private groundwater sourcing into the public water supply system – can be considered. As an order of progression, ascertaining quantitative and quality-related groundwater security must form part of the urban water security plans. This must also include appropriate approaches, through a public programme, to groundwater recharge, which is allied to the protection, conservation and upkeep of water bodies.
5. In-situ waste-disposal of any kind should be avoided keeping in mind the connection of such sites with key aquifers in the regions of urban agglomeration. In other words, hydrogeology must be considered during waste-disposal, sewage and sullage management and design of sewerage and sewage-treatment.
6. Developing a framework of regulatory norms around urban groundwater use and protection of urban aquifers by preserving natural recharge areas becomes important provided the above steps are carefully initiated. Similarly, it is also important to acknowledge and understand changes in river flows and quality and the precise relationship between aquifers, aquifer systems and the river flowing through a town or city. Estimating the quantities and quality of base flows becomes significant in this regard.
7. Finally, developing an institutional structure required for mapping the aquifers, and initiating groundwater management as an integral part of urban governance.

2. Focus on Recycling and Reuse of Wastewater

As argued in the 12th Plan document, perhaps the most important lesson from urban water work in India is the need to tackle water and waste water together, with primacy being given to treatment of sewage. Thus, even as cities worry about water, they need to focus on the waste this water will generate. Sewage invariably goes into streams, ponds, lakes and rivers of the city, polluting the waterworks so that health is compromised. Or it goes into ground, contaminating the same water, which will be used by people for drinking. It is no surprise then that surveys of groundwater are finding higher and higher levels of microbiological contamination – a sign of sewage contamination. This compounds the deadly and costly spiral. As surface water or groundwater gets contaminated, the city has no option but to hunt for newer sources of its supply. Its search becomes more extensive and as the distance increases, the cost of pumping and supply increases.

We have no national accounts for the excreta we generate or the excreta we treat or do not treat. The fact is that we have no way of really estimating the load of sewage in our cities, because of the different ways in which people source water and the different ways in which people dispose sewage. Currently, we measure sewage in the most rudimentary of ways: we assume that 80 per cent of the water officially supplied by municipalities is returned as sewage.

The imperative is to provide sanitation to all, but equally to ensure that this facility is hygienic and that it does not add to pollution. The 2001 Census found 74 per cent of urban India had access to sanitation; 46 per cent urban Indians had water closets. But it did not specify whether these flush toilets were connected to septic tanks or underground networks or open drains. The 2011 Census has corrected this anomaly as its data sheet differentiates between toilets and disposal systems. It is important to note that Census 2011 shows that only 32.7 per cent urban Indians are connected to a piped sewer system and 12.6 per cent – roughly 50 million people – still defecate in the open. The challenge is enormous and needs urgent intervention, which provides both sanitation facility and disposal.

Table 4: Sanitation Facilities in Urban India

No	Facility	
1	**Flush/pour toilet latrine of which connected to**	**72.6**
A	Piped sewer system	32.7
B	Septic system	38.2
C	Other system	1.7
2	**Pit latrine of which**	**8.3**
A	With slab/ventilated improved pit	6.4
B	Without slab/open pit	0.7
C	Night soil disposed into open drain	1.2
3	**Service latrine of which**	**0.5**
A	Night soil removed by human	0.3
B	Night soil serviced by animals	0.2
4	**No latrine within premises of which**	**18.6**
A	Public latrine	6.0
B	Open	12.6
	Total	**100.0**

Source: Census of India 2011, Houses, Household Amenities and Assets: Latrine Facility, Office of the Registrar General and Census Commissioner, India

No Indian city is in a position to boast of a complete sewerage system, which can keep up with the sanitation and pollution challenge. In fact, most Indian cities have a massive backlog of incomplete sewage systems or systems in serious need for refurbishment and repair. The most advanced city is Bengaluru with 3610 km of sewage lines and 14 sewage treatment plants. The rough estimation is that the city generates some 800-1000 mld of sewage and the installed capacity to treat is roughly equivalent – some 721 mld. It also has high tariff; 100 per cent metered supply, high recovery of its dues; 100 per cent water supply and substantial investment in sewage infrastructure. However, there is a significant underutilization of treatment capacity because Bengaluru’s sewage treatment plants only receive some 300 mld of sewage. In other words, less than half the sewage is trapped and half is treated. It is no wonder then that its waterways – rivers and lakes remain polluted and nitrate levels in groundwater are increasing, which is dangerous for health.

Large parts of the modern cities remain unconnected to the sewage system as they live in unauthorized or illegal areas or slums, where the state services do not reach. Moreover, there are also zones within the growth pockets of a large city where even authorized housing remain unconnected to both water supply and sewage systems, at least over a certain period of time. In both these situations, it is critical, we invest in sewage systems, but it is equally and even more critical that we invest in building affordable and scalable sewage networks. This will require relooking at the current technology for sewage and its treatment.

If sewage systems are not comprehensive – spread across the city to collect, convey and intercept waste of all – then pollution will not be under control. Currently, according to estimates of the Central Pollution Control Board, the country has installed capacity to treat roughly 30 per cent of the excreta it generates.

Table 5: Waste Treatment Capacity in Indian Cities

	Class 1 (0.1-1 million)	Class II city (50,000-999,000)	Total
Wastewater generated (mld)	35,558	2,697	38,255
Waste treatment capacity (mld)	11,554	234	11,788
Missing capacity (mld)	24,004	2,463	26,467
Untreated Waste (%)	**68%**	**92 %**	**70%**

Source: CPCB 2009, *Status of Water Supply, Wastewater Generation and Treatment in Class-1 cities and Class-II towns of India*, Central Pollution Control Board, Delhi

Just two cities, Delhi and Mumbai, which generate around 17 per cent of the country's sewage, have nearly 40 per cent of the country's installed capacity. What is worse, some of these plants do not function because of high recurring costs – electricity and chemicals and others because they do not have the sewage to treat. In most cities, only a small (unestimated) proportion of sewage is transported for treatment. And if the treated sewage – transported in official drains – is allowed to be mixed with the untreated sewage – transported in unofficial and open drains – then the net result is pollution.

The added problem is that the location of the hardware – the sewage treatment plant – is not designed to dispose off the treated effluent so that it actually cleans the water body. Most cities don't seem to think of this factor when they build their infrastructure for sewage. They build a sewage treatment plant where there is land. The treated sewage is then disposed off, as conveniently as possible, invariably into a drain. But as this drain collects the untreated waste of large numbers of people, the end result is pollution.

It is also clear that India has a huge backlog of sewage facilities to build. In most cities settlements have grown without underground sewerage infrastructure. 'Fitting' in the sewage lines into already built, crowded and congested and haphazard construction is a difficult task. This challenge is compounded by the fact that even where sewerage lines exist, they are already buried, broken or chocked. Worse, nobody really knows the state of disrepair. But even as the old needs repair, there is much more that needs to be built as city's sprawl out of control. The fact is that Indian cities have the opportunity to reinvent sewage paradigms, simply because they have not yet built the infrastructure. They can leapfrog into new ways of dealing with excreta, which is affordable and sustainable.

The principle has to be to cut the cost of building the sewage system, cut the length of the sewage network and then to treat the waste as a resource – turn sewage into water for irrigation or use in industry.

According to the Centre for Science and Environment, a survey of 71 cities across India highlights that 26 per cent (19 cities) of cities had no system at all for sewage collection. Another 40 per cent (29 cities) have a partial provision in which 80 per cent of this sewage is not collected. Rest of the 23 cities claim to have sewage network but do not have any account of sewage generated (CSE, 2012).

The treatment cost of sewage is also extremely high. One MLD of sewage in centralised treatment costs around Rs. 1 crore. In order to minimize the costs involved, decentralised waste water management systems have been proposed. The various advantages of decentralised waste water treatment are:

- Decentralised systems can easily cater to the un-served areas and minimize the pressure of transporting to a single location.
- It drastically reduces the cost of treatment and O&M costs compared to the conventional system.
- Site-specific treatment technologies can be designed based on the land use.
- Minimise land requirement for treatment.

What is more, large volumes of sewage generated in the cities can also be an opportunity for sustainable water management. With basic level treatment of sewage, the water can be reutilised in industries and power plants. The water sludge after treatment can also be used as manure in agriculture; this measure may result in revenue generation to ULB. Investment in sewage treatment can avoid many negative externalities, like controlling water pollution, ground water contamination, tapping water from distant sources and public health problems[10]. It is in the interest of the city to find ways to find buyers and users for its sewage. In this way it can work out the effluent profile of its treated effluent and segregate its waste to meet the needs of the end-user.

The sewage treatment system must plan for safe disposal, before it can even be planned for treatment. The following could be options:

a. Discharge directly in rivers or lakes to add to water quality

b. Discharge in lakes or other water-bodies designed for secondary treatment for recharge of groundwater

c. Piped to green spaces for watering

d. Channels for irrigation in agriculture

e. Reuse in industry

In each case, treatment plan will be different. But in all cases, the treated effluent will improve the hydrological cycle. It will return water and not waste to the environment. Kolkata, for instance, had an intricately designed system for waste management -- using agriculture and fisheries to reuse its discharge. In this system, the waste is treated at no cost to the city. In fact it provides livelihood benefits to people. This wetland of the city is its kidney and also its

[10] According to WSP (2010), inadequate sanitation in India costs 2.8 trillion rupees annually (Rs.2180 per person).

sponge – it cleans waste and helps to mitigate floods. Similarly in Hyderabad large proportion of the treated and untreated waste is an important resource for the farmers who live in the vicinity. Studies done by the International Water Management Institute (IWMI) estimate that some 40,000 hectares (ha) of land is irrigated using the domestic-industrial waste concoction from the Musi. The problem is that this reuse is not planned, so that policy ensures that water used for agriculture meets parameters, which will make it useful for agriculture but not harmful for humans. This would require cities to segregate industrial waste from domestic waste. It would then require treatment of waste to remove pathogens and to meet parameters for discharge on land.

Chennai has the distinction of having the country's first recycling project – the city's sewage was sold to the Chennai Petroleum Company Limited (CPCL), which in turn used reverse osmosis technology to filter sewage and turn it into water for its use. In this water-scarce region, the refinery found the option viable. This cost is cheaper as compared to the commercial and industrial water rates of MetroWater. More importantly, it is reliable. Even when there is no water to source, there is always sewage to buy.

In February 2010, the town of Nanded in Maharashtra issued orders to revise its development control regulation to include grey water recycling systems. The byelaws are applicable to all housing, commercial and industrial premises more than 2000 sqmetres or if the water quota is more than 60,000 litres/day. In these regulations, the waste from the toilets needs to be separated from grey water – bath and kitchen waste and taken into a separate discharge system. This grey water is then to be recycled and reused for non-potable purposes. The house or institution owner, who has done grey water recycling, will be entitled to a rebate in the water, sewage tax. This is after the municipal officer is satisfied that the building or residential structure "has successfully reduced their potable water consumption by a specific percent". Nanded is not the first city to do this. In 2009, Rajkot amended its byelaws making recycling mandatory for buildings more than 270 sqm. Again, the purpose was to separate out the grey from the dark water and to encourage use of this 'reusable' water for non-potable purposes. Under JNNURM 46 cities have included byelaws on reuse of recycled water.

3. Industrial Water

A rapidly emerging element of urban water, which requires much greater focus on recycling and reuse, is industrial water. Indian industry is currently excessively dependent on fresh water and tends to dump its untreated waste into our rivers and groundwater. Overall, the water footprint of Indian industry is too high, which is bringing industry into conflict with other parts of the economy and society. There is huge scope for reducing the industrial water footprint and this can be done through technologies and investments, which have a very short payback period.

In an increasingly industrialising economy like India, it is extremely important that industry adopts the best international practices to improve water use efficiency. This can be broadly done in two ways:

- reducing the consumption of fresh water through alternative water-efficient technologies or processes in various manufacturing activities; and

- reusing and recycling the waste water from such water intense activities and making the reclaimed water available for use in the secondary activities within or outside the industry.

Such an approach is extremely important to reduce the water footprint of Indian industry, both in terms of fresh water used, as also polluted wastewater released untreated into the environment. The urgency of this issue is because water conflicts are increasingly arising across the length and breadth of India between competing users and uses. And industry, as a relatively new user of water, needs to recognise that economising on the use of water is now an essential ingredient in ensuring sustainability of its operations and may be in its own enlightened self-interest.

A study by the Prayas Energy Group (2011) suggests that coal-based thermal power plants need massive amounts of water, both for cooling and ash disposal. In case of coastal power plants, the water requirement is normally met from the sea, but for inland TPPs, water is a far more critical issue. Out of the 192,804 MW with environmental clearance, about 138,000 MW or 72% are inland. Of these, close to 50% are concentrated in four river basins, namely, Ganga (33,255 MW), Godavari (16,235 MW), Mahanadi (14,595 MW) and Brahmani (6534 MW). While some of the these basins like Mahanadi are considered water surplus, if the needs of agriculture, local communities like small farmers, riverine settlements, fisher-people, and the environment are considered, most river basins in India including the Mahanadi would be stretched to meet these multiple demands. In such a situation, water withdrawals by thermal plants, especially a large number of plants in a basin / sub-basin, have the potential to lead to intense conflicts.[11] In April 2010, Mahagenco, the state power generating company of Maharashtra, had to shut down several units of the 2340 MW super thermal power station in Chandrapur district, due to a lack of water. Deficient rainfall had led to a severe water shortage, and the water in the Irai dam (the source of water for the plant) had to be reserved for drinking water purposes, resulting in a loss of generation of 1900 MW. Now close to 8,000 MW of coal-based TPPs are in the pipeline in this very district, including an expansion by the 1000 MW capacity of the Mahagenco plant, which will also source water from the same Irai dam.

Using a thumb rule from the Central Electricity Authority (CEA) that consumptive use by coal-based TPPs is about 3.92 million cubic metres per 100 MW per year, and that there are 117,500 MW of inland coal-based power plants with environmental clearance granted, Prayas Energy Group arrives at a total consumptive water use of about 4608 million cubic meters. This is the requirement only for the plants with environmental clearance, so the water needed will be significantly higher once projects in the pipeline are also considered. Moreover, a river basin may have enough water at the basin level, but may be overstressed in the area where the plant

[11] For example, in 2007, more than 30,000 farmers gathered at the Hirakud reservoir (on the Mahanadi river), forming a human chain in protest against the allocation of water to industries when they were not getting water for irrigation. Now a large number of TPPs are being proposed in this very basin.

is located. Equally, the availability of water varies through the year, and it may be particularly difficult to provide water to plants in summer. The Chandrapur example illustrates this well.

TERI has estimated that in 1999–2001 out of a total of about 83,000 million litres per day (MLD) of water discharged by all the industries in India, about 66,700 MLD (~80 per cent) is cooling water discharge from thermal power plants. CSE puts the figure closer to 90%. During the same period, it was estimated that for every MW of power produced, Indian thermal power plants consumed about 8 times more water than those in developed nations. This is mainly attributed to the once-through cooling system (open loop system). Cooling towers and ash handling are the major water consuming areas and account for about 70 per cent of the water use within the plant. Comprehensive water audits conducted by TERI at some of India's largest thermal power plants revealed immense scope of water savings in the cooling towers, and ash handling systems. Once-through systems are becoming uncommon in the world. However, in India, many plants still operate the once-through cooling system. A rough estimate suggests that by converting all the thermal power plants in India to closed-cycle cooling systems, about 65,000 MLD of fresh water can be saved. Apart from cooling towers, generally a large quantity (about 40 per cent of the freshwater intake) is also consumed in the ash handling process. Ash residue is converted to slurry using freshwater and transported to nearby dykes for disposal. The water is often not recycled/partially recycled, leading to wastewater discharge. Recapturing and recycling this water has a significant potential for water savings.

The payback period for the proposed wastewater treatment and recycling system is less than 3 years. From a national perspective, where a large number of power plants other than NTPC still function on the once-through cooling system, there is considerable scope to improve water-use efficiency and conserve water resources

The first step in this direction will be to make comprehensive water audits a recurring feature of industrial activity so that we know what is being used by the industrial sector at present and so that changes can be monitored and the most cost-effective basket of water efficiency technologies and processes designed and implemented to reduce water demand and increase industrial value added per unit of water consumed. The water audit will consider both quantity and quality aspects as the need to reduce polluting discharges to the aquatic environment or to sewage systems is often the key driver to water saving. The starting point will be large units in water-intensive industries such as thermal power, paper and pulp, textiles, food, leather (tanning), metal (surface treatment), chemical/ pharmaceutical, oil/gas and mining.

We must make it mandatory for companies to include every year in their annual report, details of their water footprint for the year. This would include

- the volume of fresh water (source-wise) used by them in their various production activities (activity-wise)
- the volume of water used by them that was reused or recycled (again activity-wise)
- a commitment with a time-line that the company would reduce its water footprint by a

definite amount (to be specified) within a definite period of time (to be specified).

Simultaneously, we must develop benchmarks for specific water use in different industries and would ensure their application in the grant of clearances for industrial projects.

The second step would be to examine the measures to levy charges for water use and incentives for water conservation. Currently, the Water (Prevention and Control of Pollution) Cess Act 1977 is the only instrument to impose cess on discharge of effluent water from industrial units. This charge is based on the quantum of discharge from the industry and is used to augment the resources of the Central and State Pollution Boards. The charges imposed through the water cess are not enough of a disincentive for industries to reduce their water footprint. It is important to examine this Act and other provisions and options to increase the charges imposed on water use and effluents substantially. This is particularly important where industries use groundwater and do not pay municipalities, water utilities or even irrigation departments for water use. The importance of water pricing as an instrument for change is critical.

The third step would be to publicly validate the water audit of industries so that this builds experience and confidence on the best practices. This water reduction commitment of each industry will be tracked for compliance and enforcement through environmental regulatory institutions.

The water audit would also help identify training requirements and the best way of achieving behavioural change within the business. The maximum water saving will be delivered when both behavioural change and hard measures are successfully adopted by the end user.

In order to more credibly move industry along this path, central and state governments need to set an example by undertaking their own audits of water use in their premises and setting targets for ensuring less water use and changes in technology and behaviour that will reduce waste.

It is also be very important to develop a forum that would

- provide information on industry-specific good practices in wise water use;
- undertake to develop expertise in water audits and water use advisory services;
- provide details of "exemplar" case studies that are relevant to the different industrial sectors operating in India;
- provide a "gateway" for accessing information about water saving and water efficiency technologies in rain-water harvesting, recycling and reuse, water conserving devices and support to helping behaviour change.

Box 1: Water Use Efficiency in UK Industry

In the UK, water companies have a statutory duty to promote the efficient use of water and as a result, water companies (in England and Wales) carry out a range of water efficiency activities with the purpose of promoting water efficiency to their customers. This water efficiency activity has been a duty under the Water Industry Act (WIA91 section 93a) since 1996. To date targets for water savings have been set by water companies themselves. However, as of 1 April 2010 water companies will be working within a regime of mandatory water efficiency targets set by Ofwat (Office of Water, Regulator) for all water companies to achieve. These targets can be achieved by either targeting domestic or industrial customers, but the targets must be met year on year. The water efficiency targets comprise three key elements:

- An annual target to save an estimated one litre of water per property per day through water efficiency activity, during the period 2010-11 to 2014-15.
- A requirement to provide a minimum level of information to consumers on how to use water more wisely.
- A requirement that each company actively helps to improve the evidence base for water efficiency.

In addition to target setting, the water industry set up and funded an organisation called Waterwise to make the case for large-scale water conservation. Waterwise is a UK NGO focused on decreasing water consumption in the UK and is central authority on water efficiency information and guidance in the UK (http://www.waterwise.org.uk/)

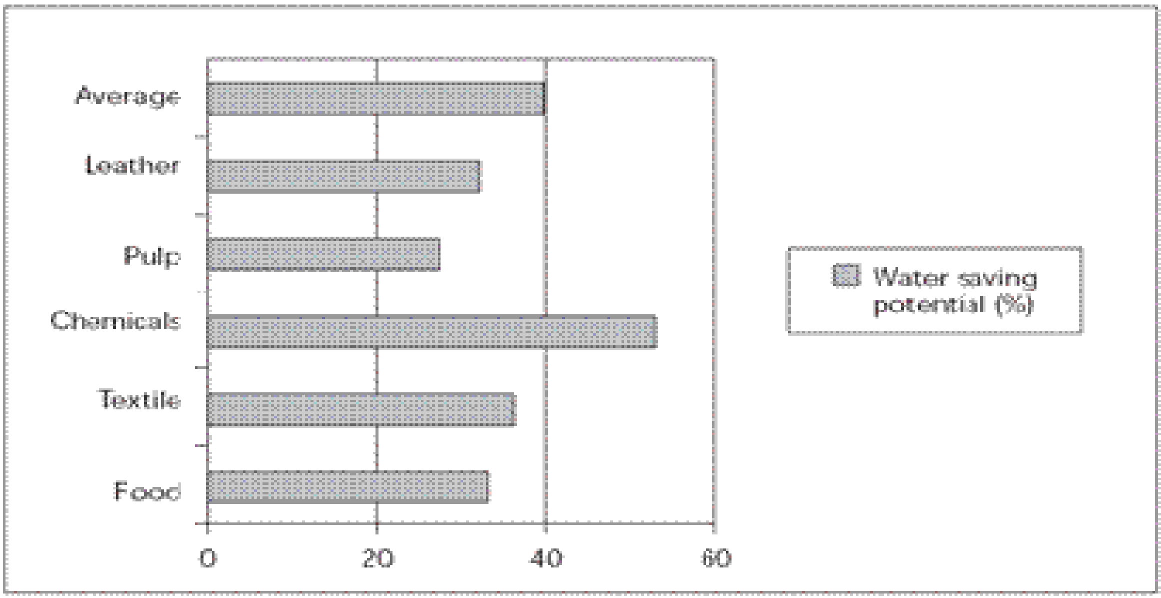
Another NGO operating in the UK is Envirowise, which offers free and independent support to businesses to help them become more resource efficient and for them to save money. Since 1994, Envirowise has helped UK industry save more than £1 billion by reducing waste early on in their organisation processes. A part of this waste minimisation strategy includes water (http://envirowise.wrap.org.uk/uk/Topics-and-Issues/Water.html)

The National Symbiosis Program is a UK based organization, which promotes the efficient use of resources in industry and has previously worked in water. The UK Government publishes a Water Technology List covering water-using devices, which contribute to water efficiency. Envirowise publish a range of information on industrial water use, water using devices and water conservation. The Watermark project published water use and water efficiency benchmarks in 2003 for 17 categories of building. Industry Trade Associations such as the Food and Drink industries group provide information and guidance on best practice in water use.

Source: Planning Commission (2012)

Once such systems are in place, there is enough experience from across the world to show that significant economies can be effected in water use. Reported water savings range from 15% to 90% of current water use, depending on the industrial sub-sector considered, the individual process investigated or the combination of water saving measures analysed with the most commonly found figures being within the 30-70% range. A study carried out by ICAEN for the Catalonia region in Spain between 1992 and1997 shows potential water savings for different industrial sectors of 25-50% (see Figure 5). The same study stressed that around 35% of cost-saving measures were implemented in areas of management and control, 32% in the process and 18% in the reuse of effluents.

Figure 5: Water Saving Potential in Industry



Source: Planning Commission (2012)

Possible water savings (average values) for different types of actions are presented in Table 6.

Table 6: Potential Water Saving from Various Measures in Industry

Efficiency measure	Percentage of water saved
Closed loop recycling	90%
Closed loop recycling with treatment	60%
Automatic shut-off	15%
Counter current rinsing	40%
Spray/jet upgrades	20%
Reuse of wash water	50%
Scrapers	30%
Cleaning in place (CiP)	60%
Pressure Reduction	Variable
Cooling tower heat load reduction	Variable

Source: Envirowise (2005): *Cost-effective Water Saving Devices and Practices for Industrial Uses*, United Kingdom

The regulatory system for water usage in industries also needs to be strengthened. Currently, the environmental regulations require industries seeking clearances to provide information about water sources, which in turn is provided by the state government irrigation departments or groundwater boards. This permission for water does not take into account availability, especially in water-stressed regions.

4. Protect and Prioritise Local Water Bodies

The first priority for cities when planning water supply should be the protection, restoration and recharge of their traditional water bodies. This would reduce costs of supply from a distance and also preserve the ecology of the city. For there is a growing concern that climate change and its promise of growing intensity of extreme rain events will bring even more flooding to cities and even more despair. The Centre for Science and Environment reports that out of about 1012 water bodies in Delhi, about 70 are under partial and about 98 are under total encroachment. Encroachments severely reduce the water holding capacity of the natural reservoirs. This results in outflow of water during monsoon, leading to widespread floods.

Rain, as it is said is decentralized, and so should be water supply. Water bodies capture rain or floodwater from rivers. But these have been neglected, desecrated and decimated. This is not to say that these sources will suffice to meet the city's water needs. But these are certainly the start of the water supply pipeline. The rest of the solution lies in taking back the water, treating it and then recharging the same water body and aquifer – water to water.

There is no specific legislation in India to protect water bodies – urban or rural. In December 2010, the Union Ministry of Environment and Forests issued the Wetlands (Conservation and Management) Rules, 2010. Under the rules, wetlands have been classified into different categories based on location and size. In addition, the Central Wetland Regulatory Authority has been set up for regulation. But these rules, important as they are, still leave out most urban water bodies from the ambit of protection. These lakes and water systems, which at one time even gave names of the localities and people, are in desperate need of recognition and protection.

Today, cities have grown over the water body and its functional parts – its drains and its catchment. Guwahati is the one city, racked by incessant flooding, which has decided to legislate the protection of its key water structures. It has identified the land holding the water and recorded the area of the catchment in its Waterbodies Preservation and Conservation Bill 2008. But it is finding protection difficult. The catchment over years has been legally handed over to buildings. It has also been taken over by the city's poor for their settlements. This scenario is not unique to Guwahati. What makes matters worse is that in many instances, water-bodies have been truncated to suit truncated and disjointed bureaucracies and policies. In most cases either the water-body itself has been divided – the water-head is owned by one agency and the water-body by another. Or there will be many agencies that 'own' different water-bodies of the city and so planning, policing and protecting is difficult. Jammu and Kashmir is one state, which has mandated its Lakes and Waterways Development Authority the right to manage not just the lake but also the catchment. Clearly, this is the model for other cities as well.

The agenda for change requires each city to consider, as first source of supply its local water-body. Unless these structures are built into the water supply infrastructure, there will be only lip service for protection and at best, efforts to ‘beautify’ the lakefront for recreational purpose, not for its essential life-giving service. Therefore, cities must only get funds for water projects, when they have accounted for the water supply from local water-bodies. This condition is vital. It will force protection and will build the infrastructure, which will supply locally and then take back sewage – the water’s waste connection -- also locally. It will cut the length of the pipeline twice over – once to supply and the other to take back the waste.

On September 6, 2014, the Madurai Bench of Madras High Court gave a landmark ruling directing the Government not to grant layout approval or building plan permission on lands located on water bodies. It was responding to a Public Interest Litigation (PIL) on the subject. This historic judgment is not only a wake-up call for Tamil Nadu, but for other States as well where a significant number of small water bodies are dying. Earlier, in 2013, the Supreme Court directed authorities in Kanpur Dehat District to check encroachments on the water bodies in their jurisdiction. The Rajasthan High Court in 2012 also came down heavily on the State government over the illegal allotments and encroachments in the catchment area of water bodies.

5. Need to Shift Focus to Management and Distribution

As the 12th Plan document emphasises, as important as the quantum of water to be supplied, is the problem of its management and equitable supply to all. In most cities, water supply is sourced from long distances. In this system of bringing water from far and in distributing it within the city, the length of the pipeline increases, as does the cost of infrastructure and its maintenance. In the current water supply system, there are enormous inefficiencies—losses in the distribution system because of leakages and bad management, not to mention the quality of water supplied within and across towns and cities. But equally, there are huge challenges, for water is divided very unequally within cities. As per the NSS 65th round, only 47 per cent urban households have individual water connections.

Currently, cities estimate that as much as 40-50 per cent of the water is ‘lost’ in the distribution system. Even this is a guesstimate, as most cities do not have real accounts for the water that is actually supplied to consumers. Nagpur is an exception in this regard. The city has prepared a water-loss balance sheet. According to this calculation, of the 765 mld the city sources from the Pench forest and tiger reserve – some 40 kms away – it finally collects money for a mere 200 mld – or 32 per cent of what is sourced. The city loses as much as 140 mld, a quarter, in bringing water from the reserve. The revenue loss because of this leakage wipes out its entire budget.

Table 7: Nagpur’s Water Highway: Losing as it Travels

Nagpur	Losses	Balance
Journey begins: water is sourced		765 mld
Losses in canal	140 mld	625 mld

Measurement losses in raw water purchase	125 mld	500 mld
Treatment	20 mld	480 mld
Distribution/commercial losses in theft/meter error	235 mld	245 mld
Collection losses	45 mld	200 mld

Source: Planning Commission (2011)

The length of the pipeline adds to distribution losses and financial costs. This cost is not computed or understood when cities map out the current and future water scenario. In most cases (as evident from the city development plans submitted to JNNURM for funding), cities emphasize the need to augment supply, without estimating what it will cost, in physical and financial terms. Data suggests that most cities spend anywhere between 30-50 per cent of their water supply accounts for electricity to pump water. As the distance increases, the cost of building and then maintaining the water pipeline and its distribution network as increases. And if the network is not maintained then water losses also increase. All this means that there is less to supply and more to pay. The end result is that the cost of water increases and the government finds it impossible to subsidize the supply of water to all. The situation is worse in the case of the poor who often have to spend a great deal of time money to obtain water since they do not have house connections.

Thus, we must shift the exclusive focus on augmentation of water supply to managing the supply for all and managing to supply clean water. First, we will have to spend less in bringing water to our houses. In other words, cut the length of the pipeline to reduce the electricity and pumping costs and its resultant 'leakage'. This means that we will have to revive local water bodies and recharge groundwater, so that we can source water from as close as possible. Secondly, we must use less, not more water in our homes, so that we have less to treat and less to dispose off. Thirdly, we must again cut the costs and transportation of sewage – use decentralized networks and use a variety of technologies to treat sewage as locally as possible. Finally, we must begin to learn that we will have to reuse every drop of our sewage – turn it into drinking water with expensive technology or re-use and recycle it in our gardens, in our industries or use it (after treatment) to rejuvenate natural water bodies. This would require change of standards so that groundwater pollution boards incentivize the reuse of wastewater for recharge. This water-waste agenda needs to be incorporated deliberately into city plans. This will require reworking the reform conditions, essential for investment in this sector.

6. Financial Implications and the need to consider Alternative Technologies

Costs of Treatment[12]

[12] This section draws heavily on Planning Commission (2011)

The High Powered Expert Committee (HPEC, 2011) Report on Indian Urban Infrastructure and Services uses service norms prepared by the Ministry of Urban Development, Government of India to estimate both additional demand for water over the next 20 years but also the unmet demand for the current population, as well as the cost of asset replacement. Per capita investment cost (PCIC) is estimated by city size class and by sector using data from a sample of projects under the two components of the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), i.e. the Urban Infrastructure and Governance (UIG) Scheme and the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT), as also projects funded by the World Bank.

Table 8: Estimated Investments Required during 2012 - 2031 (2009-10 Prices)

Cost Indicator	Unit	Water Supply	Sewerage
Estimated Capital Cost	Rs. Crores	3,20,908	2,42,688
Per Capita Capital Cost	Rupees	5099	4704
Per Capita O&M Cost	Rupees	501	286

Source: HPEC, 2011

It is clear that urban India will require huge investments in building and keeping pace with the water and sewage infrastructure needs of all. In the past five years JNNURM has been an important game-changer in this sector, providing much needed public funding to build and refurbish assets. Under JNNURM the bulk of the projects are for water and sewerage – some 70 per cent of the sanctioned

The cost of water treatment depends on the quality of the water to be cleaned. Conventional water treatment technologies, in use in most cities, require relatively clean and living water, water that conforms to most parameters of surface water quality. The capital cost of such technology would be Rs 20-22 lakh/mld currently; operation costs would be minimal – Rs 0.01-0.10/kl. But as water quality deteriorates, the cost of treatment is going up. Most cities are installing plants with modern technologies, using flocculation or membranes. The most expensive plant in the country is in Agra, where polluted water in the Yamuna has made the city’s task impossible. The city will end up paying a phenomenal Rs 1 crore/mld and as much as Rs 4-5/kl to clean its water for supply.

Table 9: Cost of Water Treatment: Modern Plants in India

Plant	Technology	Capacity (mld)	Capital cost (Rs/crore)	Capital cost (Crore/mld)	O&M costs (Rs/kl)	Power costs (Rs/kl)	Total O&M costs (Rs/kl)
Sonia Vihar, Delhi	Presettler-Pulsator+ Aquazur (Degremont)	635	189	0.30	0.38	1.04	1.43
Chembarambakkam	Pulsator Aquazur (Degremont)	530	135	0.25	0.39	0.82	1.21
TK Halli-1	Pulsator+ Aquazur (Degremont)	300	45	0.15	0.22	0.10	0.32
Nagpur	Pulsator+ Aquazur (Degremont)	120	15	0.13	0.39	1.04	1.43
TK Halli-II	Aquadaf+ Aquzur (Degremont)	550	190	0.34	0.32	0.10	0.42
Minjur, Chennai	Desalination plant	100	473	4.73	48.66	10-12	59-61
Nemmeli	Desalination plant	100	1034	10***	--	--	21

Source: Planning Commission (2011)

The cost of a treatment plant for waste depends on two key factors – the quality of raw influent and the quality of the receiving medium. Currently, most cities do not have treatment plants, installed or running to treat human excreta or chemical industrial waste. Furthermore, most sewage treatment plants use basic technologies for cleaning waste. These were built at a time when the characteristic of waste was basic – biological and not chemical – and more importantly, the receiving environment had capacities to assimilate the treated waste. CPCB's last detailed evaluation on sewage technologies in mid-2006 revealed that most cities use waste stabilisation ponds or activated sludge process (ASP), a conventional sewage treatment system, which uses biological processes to settle solids and then a variety of aeration systems to oxidise and clean the waste. According to this report, 60 per cent of the sewage treatment plants were based on some variation of this technology. This was reconfirmed in 2009, by the National River Conservation Directorate in its compendium of sewage technologies found that, under the Ganga Action Plan, 60 per cent of the treatment capacity was based on conventional ASP.

Table 10: The Sewage Ladder -- Costs of Treatment

Technology	**City**	**Capacity (mld)**	**Land (ha/ mld)**	**Capital cost (Crore/mld)**	**O&M costs (Rs/kl)**	**Energy consumption (kWh/mld)**	**Power costs (Rs/kl)**	**Total O&M costs (Rs/kl)**
Waste stabilisation ponds	Mathura (mid-1990s)	12.5	1.12	0.35	0.60	--	--	0.60
Activated sludge	Okhla–Delhi (mid-1990s)	72	0.15	0.26	4.40	211		4.40
UASB	Agra (2003)	78	0.26	0.24	0.70	11		0.70
Advanced Aerobic Biofilteration process (Effluent BOD_5< 10mg/l, TSS < 15 mg/l)	Sen Nursing Home and Delhi Gate-Delhi (2003)	2 x10	0.04	0.50 (as in 1995)	1.73	220-284	1.28	3.01
High Load ASP + AerobicBiofilteration process & Cogeneration (effluent BOD_5< 15mg/l, TSS < 20 mg/l)	Rithala-Delhi (2003)	182	0.05-0.08	0.40 (as in 1995)	0.87	215	0.38 (from Grid)	1.25
ASP with Nitrification and Denitrification (Effluent BOD_5< 20mg/l, TSS < 30 mg/l)	Raja Canal-Bangalore (as in 2002)	40	0.13-0.23	0.80	0.57	197	0.74	1.31
Sequential Batch Reactor/C-Tech	Haridwar 2011)	27		0.8				
Tertiary treatment (after partial Secondary Treatment, BOD =80 mg/l, TSS=100 mg/l)	TTP at V Valley-Bangalore (as in 2002)	60	0.02	0.50	1.14	144	0.54	1.68
Extended Aeration + Tertiary Clarification + Sand Filteration + UV	Lalbagh-Bangalore (2005)	1.5	0.25	2.00	5.11	950	3.63	8.74
Membrane Bioreactor (MBR) (Effluent BOD_5< 5 mg/l, Turbidity< 2 mg/l)	Cubbon Park-Bangalore(2005)	1.5	0.19	3.00	5.48	1,100	4.13	9.61

Source: Planning Commission (2011)

The big issue for sewage technology is the price of capital, the availability of land and the cost of operation and maintenance. Land is in short supply in urban areas. It is particularly so because sewage treatment is discounted in public planning. In the mid-1990s, when the first-generation sewage treatment plants were built, they cost Rs 20 lakh to Rs 30 lakh per mld. Today, the same plants cost close to Rs 1 crore per mld to build, with operation costs increasing because of rise in energy bills. The recently ordered SBR technology plant for the city of Kolhapur will cost the city some Rs 1 crore per mld and more. The sewage treatment projects sanctioned under the National Ganga River Basin Authority will cost anywhere between Rs 2.4 to 8 crore per mld – partly because they involve the construction of sewage networks and interception systems as well.

If the cost of capital investment in building the sewage treatment plant is taken at Rs 1 crore per mld and if the quantum of sewage is taken at the current 'gap' (untreated) sewage then India needs to invest Rs 30,000 crore to build capacity to treat its 30,000 mld of sewage. But this is if the cost of treatment does not increase even further. We know that the choice of technology and its cost will depend on the capacity of the giving and receiving environment. As rivers become dry and polluted, sewage and waste treatment will mean more advanced and more expensive technologies. We must also recognise that large parts of cities remain unconnected to the sewage system as they live in unauthorised or illegal areas or slums, where the state services do not reach.

Given these facts, it is critical that urban infrastructure is planned carefully and funded with scrutiny to assess how cities will afford costs and how they will build for sustainability. It becomes imperative to consider the question of technology options in this sector. Cities can also find ways for (at least partial) cost recovery, by putting restrictions on freshwater use and actively promoting the sale and use of sewage treated water from which they can earn revenue even if it is priced at a discount. Companies with large water requirements that build their own pipelines to the city's sewage treatment plant can recover their pipeline costs in a few years just by buying treated water at a lower price than the industrial tariff. We must begin more and more to think in terms of the concept of the "polycentric city". With decentralised systems of wastewater treatment and water supply.

New Alternative Technologies[13]

Technologies provide a certain set of infrastructure and equipment for controlling, regulating and monitoring of processes for desired outcomes. All the physico-chemical, bio-mechanical or bio-chemical processes require a certain housing, contact time and separation of reactants or products from the matrix for continual conversion. In case of wastewater treatment technologies, the aim is to separate the solids (either floating or settle-able or dissolved organic or inorganic pollutants) from the water so that quality of water is restored for further intended disposal pattern.

[13] This section draws heavily on the pioneering work of Sandeep Joshi and his organisation SERI

Initially the aerobic or anaerobic technologies were developed to treat the organic matter, which consumed dissolved oxygen - a vital element for aquatic life. The strength of organic matter in water is measured in the pollution analysis by COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand). This organic matter is attacked by heterotrophic microorganisms, which need organic carbon and energy source. Their population is the function of input concentration of utilizable carbon and energy source.

Heterotrophic microorganisms are categorized into two main groups - aerobic and anaerobic. There are some other groups such as facultative and micro-aerophilic depending upon their adaptability to the surrounding environment. The presence or absence of oxygen has a major role in bio-conversion, bio-degradation and bio-transformation by heterotrophic organisms. Aerobic processes are simple and direct since the organic carbon is directly converted into carbon dioxide. But in anaerobic processes, there are numerous steps and conversions giving rise to various by products such as organic acids and gases like hydrogen sulphide, methane etc.

A combination of aerobic and anaerobic processes is more effective in wastewater treatment. A series of treatment units comprising anaerobic, micro-aerophilic and aerobic process is powerful for organic pollution treatment along with nitrate and phosphorus removal. All these processes, occurring in different treatment units separately, create a cumulative effect in the **soil-scape process** for point source pollution or **green bridge** system for non-point source pollution.

Detritus feeding organisms consume the pollutant because it is a nutrient for them. And the wastes generated from this process are useful for green plants, which, in turn, absorb carbon dioxide from the atmosphere. Thus, the pollutants get transferred to biogeochemical cycles of carbon and other elements. Carbon gets stored in vegetation and subsequently in the soil. Plants store carbon in the forms of live biomass. Once they die, the biomass becomes a part of the food chain again and eventually enters the soil as soil carbon. This is a natural process, which doesn't need electricity at all. Hence, these eco-technologies – using ecological engineering principles to treat pollution – have incalculable advantages over energy intensive technologies. Through carbon deposition, vegetation can function as a carbon sink.

Conventional technologies, normally employed to treat the pollution from point sources, are not that effective against non-point sources of the pollution. It has been estimated that Pune city will need about 3000 MW electricity per day to run its sewage treatment plants based on conventional energy intensive technologies. Energy is also required for the disposal of huge sludge from the conventional engineering wastewater treatment technologies.[14] To generate that much electricity daily 3000 tons of carbon dioxide will be released into the environment.[15] Applying the same logic nation-wide, it will be 120,000 tons each day. On the other hand, untreated wastes left in the water bodies will lead to increase of GHGs mostly due to generation

[14] Natural systems do not generate sludge at all. Therefore, there is no requirement of energy for sludge disposal.

[15] Based on the data generated by the US Department of Energy, in association with the Environment Protection Agency

of methane gas in enormous quantities. So alternatives have to be seriously considered which seek to meet human needs with minimal ecological disruption, even as they bind and subtly manoeuver natural forces to leverage their beneficial effects.

Of course, it is also important to recognise limits of eco-technologies. Effectiveness of technologies is dependent on the specific range of concentration of various pollutants and flow of the wastewater. For example, excess of solids clog the filters or biological treatment reactors cannot tolerate fluctuations in hydraulic loading or organic loading because in these systems selective group of microbes have substrate specificity and load factor. These mechanically controlled biological systems need high energy inputs to maintain the suitable growth conditions and nourishment for these microbes.

Vertical eco-filtration techniques were developed in the 1990s to treat wastewaters from domestic and industrial wastewaters. These innovations helped industry to reduce operational costs substantially by reducing electricity consumption, chemical and man-power requirements. Over time, the vertical eco-filtration technique was converted into horizontal eco-filtration technique or the green bridge system. This has now been successfully tested out at several locations across the country -- College of Military Engineering (CME), Pune in 2003 (treating wastewaters without electricity or chemicals); Udaipur's Ahar River in 2010 (increased dissolved oxygen from 0 to 8 mg/l in just 60 days; poor fishermen and farmers benefitted due to alleviation of pollution in the river and downstream Udaisagar lake); restoration of Buddha Stream of Sutlej River receiving wastewater from Ludhiana's urban and industrial areas; restoration of 5-stream Rasoolabad Ghat Complex in Allahabad, Ganga (flow ranging from 0.5 MLD to 10 MLD) in 2011.

The case for considering these alternatives is outlined in a summary fashion in Tables 11 and 12. The tables provide an order of magnitude of the superiority and cost-saving involved in using eco-technologies and also provide a comparative picture of standard technologies and their alternatives in a variety of dimensions of economic, social and ecological significance. The least that we can say is that these tables present a strong case for serious consideration of eco-technologies, especially given the humongous investment requirements of water and wastewater treatment in urban India.

Table 11: Comparison of Eco-technologies and Conventional Technologies for Sewage Treatment

No	Particulars	Conventional	Soil Scape Filter	Savings
1	**Capital Cost**			
1.1	**Land / Area**			
1.1.1	Area required for 100 KLD, Sq. m (treatment + supplimentary)	300	100	**66%**
1.1.2	Cost of area required for 100 KLD@ Pune's Rate Rs. 7500 per Sq.m.	Rs. 22,50,000	7,50,000	**66%**
1.2	**Civil Work**			
1.2.1	Construction, Machinery, Electrical & Pipework Cost for 100 KLD	Rs. 30,00,000	Rs. 18,00,000	**40%**
1.2.2	Time required for installation (in days)	180	60	**66%**
2	**Running Cost**			
2.1	**Energy Costs for treatment**			
2.1.1	Energy required for treating 100 kLD in KW-H/year	73000	Nil	**100%**
2.1.2	Electricity Cost for 100 KLD @Rs. 6/- per kw-h	Rs. 4,38,000	Nil	**100%**
2.2	**Maintenance Costs**			
2.2.1	Equipment Maintenance for 100 KLD per year	Rs. 3,60,000	Nil	**100%**
2.2.2	Chemicals / consumables for 100 KLD per year	Rs. 3,00,000	Rs. 1,00,000	**50%**
3	**Environmental Costs**			
3.1	**CO_2 Emissions**			
3.1.1	Emissions due to use of concrete for construction ($CO_{2\ eq}$)	250	Nil	**100%**
3.1.2	Emissions due to electricity used for treating 100 KLD (CO2 eq)/year	75	Nil	**100%**
4	**Returns**			
4.1	**Recovery (per annum)**			
4.1.1	Clean water 80% of input @ Rs 30/100lit.	Rs. 8,76,000	Rs. 8,760,000	
4.1.2	Solids as manure @ Rs 10/Kg	Rs. 1,31,400	Rs. 1,31,400	
4.1.3	Time required for tangible results after installation (in days)	90	7	**92%**
5	**Social Benefits**			
5.1	Lower selling price of surrounding land due to odour problem	Negative impact	No Odour	
5.2	Fish Production	Negative impact	Positive impact	
6	**Ecological Benefits**			
6.1	Increase in Biodiversity	Nil	Return to multispecies	

Source: Joshi (2014a)

Table 12: Technologies available, cost, socioeconomic and maintenance and repair considerations for sewage treatment options

	Particulars	BAF	TF	ASP	MBR	SBR	Root zone Technique	Soil Scape Filter	Phytorid technology
1.	Wastewater Source	Point Source	Point Sources	Point Sources	Point Sources	Point Sources	Point Sources	Point Sources	Point source
2.	Application	For domestic and industrial wastewaters containing non toxic organic matter only	For domestic and industrial wastewaters containing non toxic organic matter only.	For domestic and industrial wastewaters containing non toxic organic matter only	For domestic and industrial wastewaters containing non toxic organic matter only	For domestic and industrial wastewaters containing non toxic organic matter only	For domestic and industrial wastewaters containing non toxic organic matter only	For domestic and industrial wastewaters, even for wastewater containing toxic organic and inorganic	For domestic wastewaters only
3.	Ancillary units	Eqaulisation tank, neutralization tank, primary settling, aerated filter and secondary settling tanks	primary settling, Trickling filter and secondary settling tanks	4 units Requirement of equalization tank, neutralization, primary settling and secondary settling tanks	Neutralization tank, Primary clarifier , Areation Tanks & Membrane Reactor, Sludge Dying Bed	One tank, it is Fill & draw system in which all process carried out sequentially in same tank .	Properly designed treatment tank, Graded filling material, Acclimatized, aerobic, anaerobic & facultative Bacteria, Acclimatized & selected indigenous plants.	One unit only The requirement is of neutralisation if the pH of wastewater is not in the range of 6.5 - 8.5	Properly designed screening tank, pri. Settling chamber, phytorid bed & selected indigenous plants.
4.	Hydraulic loading $m^3/m^2.d$	1 - 20	1 -10	1 - 3	12 - 14	--	0.06 – 0.25	1 - 2	0.2
5.	HRT (h)	1.3	-	4 - 8	2 - 5	9-30	5-10	Nil	5-8
6.	Organic loading (COD/BOD) $Kg/m^3.d$	1.5 – 4	1.6	0.32 – 16	0.4 – 1.5	0.08 - 0.24	0.25	5-10	3
7.	COD/BOD reduction range	75 – 93%	65 - 90%	85 - 95%	85 -95%	85 – 95 %	91%	90-98%	80-95%

	Particulars	BAF	TF	ASP	MBR	SBR	Root zone Technique	Soil Scape Filter	Phytorid technology
8.	Sludge production (Kg/Kg BOD)	0.15 – 0.25	0.3 – 0.5 or 0.63 – 1.06	0.6	0.0 – 0.3	0 – 0.3	Nil	Nil	Nil
9.	Fecal coliform reduction(%)	0 %	0 %	0 %	0 %	0 %	0 %	99%	85-95%
10.	Electricity requirement	200	150	300	200	3 - 10	50	Nil	Nil
11.	Failures	Even small concentrations disturb the process.	Even small concentrations disturb the process.	Even small concentrations disturb the process.	Even small concentratios disturb the process.	Even small concentrations disturb the process.	Even small concentratios disturb the process.	Nil because it is natural process	No provision sludge digestion; Produces bad odour due to anaerobic digestion of sludge, and mosquitoes due to stagnant water in treatment tank.
12.	Key parameters of process	PH, TSS, BOD,COD & Toxic Substance	PH, TSS, BOD, COD & Toxic Substance	PH, TSS, BOD, COD & Toxic Substance	PH, TSS, BOD, COD & Toxic Substance	PH, TSS, BOD, COD & Toxic Substance	PH, TSS, BOD, COD & Toxic Substance	PH	PH, TSS, BOD, COD & Toxic Substance
13.	Maintenance	Skilled	Skilled	Skilled	Skilled	Skilled	Skilled	Simple	Simple but revamping of filter bed is very difficult
14.	Installation cost per MLD in Rs. lakhs	160	140	120	600	225	180	90	150
15.	Operational Cost for 1 m3/d	6/-	6/-	8/-	25/-	16/-	2/-	2/-	2/-

Source: Joshi (2014b)

Abbreviations: BAF: Biological Aerated Filter; ASP: Activated Sludge Process; MBR: Membrane Bioreactor; TF: Trickling Filter; SBR: Sequential Batch reactor; STAC: Saprobic Trophic Adsorption & Cycling

7. Public Private Partnerships: A Review

In implementing urban water solutions in India, there has been an increasing recourse to delegated management or what has been called the Public-Private Partnership (PPP) route.[16] Under delegated management, an owner of water supply and/or wastewater infrastructure contracts out various aspects of water utility management to another entity, which may be either privately or publicly owned. To some degree, all utilities delegate: they may outsource various tasks to consultants or manufacturers of physical plants, for example. In the water sector, "delegated private utility" is understood to refer to outsourcing of core activities such as construction, operations and maintenance, and customer services.

There are two main motivating factors here: one, the massive investments required in this sector in a rapidly urbanising economy like India, which cannot be met by government alone and two, the lack of technical proficiency in urban local bodies in our country, which means there is a need for an agency to execute these projects with professionalism and efficiency.

Features of delegated management contracts include

- The participation of the private company does not extend to ownership of assets
- Contracts are time-limited (between 1 and 30 years, typically)

There are a wide variety of risk and responsibility-sharing options such as:

- Selective outsourcing (service contracts)
- Management contracts
- Lease/concession contracts

Current models of city water PPPs are diverse, from concessions for treatment plants to service contracts for billing, collection and metering. Most projects focus on distribution improvement – that is, managerial and technical skills of the private company are employed to improve functioning of the water distribution system. Only in a few places has the country experimented with citywide distribution—Jamshedpur, where the industrial house of Tatas have set up the water supply system, and in Tirupur, where a joint sector company is in charge of this hosiery capital's water. Naya Raipur in Chhattisgarh has decided to give its water distribution contract to Jindal Company on private partnership mode. Kolhapur in Maharashtra has the distinction to be the first to go in for PPP for sewage treatment.

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[16] This section draws heavily on Planning Commission, 2011 and the paper *Water Utility Management: Urban Water Supply Reform and Use of Private Public Partnerships* prepared by the Centre for Energy, Environment and Water for the Planning Commission (NWFRS, 2011)

Table 13: Private Water Efforts in India

	City/ value	Operator	Scope	Private investment	Status (as of June 2011)
1	Tirupur (1993) Rs 1000 crore	IL&FS	To build, operate and charge for water supply	Yes: Rs 1000 crore	Operational
2.	Salt lake, Koltaka (2010) Rs 60 crore	Jusco-Voltas	30 year contract for management of water supply and sewerage -- distribution contract	Yes: Rs 60 crore	Under implementation
3.	Chennai (2006) Rs 473 crore	IVRCL	100 mld desalination plant – bulk supply on fixed rates	Yes: Rs 473 crore	Operational
4.	Nagpur (2007)	Veolia	7 year contract for 24x7 for distribution system – distribution, rehabilitation, augmentation and bulk supply	No: Management contract	Under implementation
5.	Hyderabad	Arad	5 year contract Non-revenue water reduction and performance improvement	No: Management contract	Operational
6.	Hubli-Dharwad,-Belgaum-Gulbarga (2005)	Veolia	4 year contract to increase connections, supply 24x7 water – distribution contract – in pilot areas	No: Management contract	Operational
7.	Latur, Maharashtra (2008)	Subhash Projects	10 year contract for distribution	No: Management contract	Work suspended as disputes arose on terms of contract and delays
8.	Mysore Rs160 crore	JUSCO	24x7– over million people and 150,000 connections	No: Management contract	Under implementation but may require renegotiation as final contract underestimated work and money
9	Haldia Rs 100 crore	JUSCO	25 year contract for design, development, operation and maintenance of water supply in Haldia on lease (of existing assets) and BOT of new assets	Lease cum BOT	Under implementation
10	Dewas (2006) Rs 60 crore	MSK projects	Bulk water supply to industries	Yes: BOT	Ongoing but is facing problems as industries are reluctant to take water at agreed rates; domestic supply is irregular and theft from pipeline is common.

11	Khandwa (2009) Rs 115.32 crore)	Vishwa Infrastructure, Hyderabad	Conveyance of Narmada water over 52 km and ensure 24x7 water supply	BOT (90% public financing of Rs 96 crore); concessionaire to invest rest and pay for O&M; base price Rs 12 kl	Under implementation but long-term viability of project is questionable
12	Shivpuri (2010) Rs 60 crore	Doshion-Veolia, Ahmedabad	Bringing water from Modhikheda dam and supply 24x7 to city	BOT (90% public financing of Rs 54 crore); concessionaire to invest rest and pay for O&M; base price of water set at 15.40 kl	Under implementation
13	Naya Raipur (2009) Rs 156 crore	Jindal Water Infrastructure	Wells on Mahanadi, pipeline to city, treatment distribution and billing for 52 mld	BOT	Under implementation
14	Kolhapur (2010) Rs 75	Vishwa	76 mld sewage treatment plant	BOT (70% – Rs 52 crore public financing and to pay for fixed and variable cost of treated sewage)	Under implementation

Source: Planning Commission (2011)

Conceptually, the way responsibilities and risks are shared between public and private can be shown as follows:

Table 14: Responsibility and Risk Matrix for Delegated Management Contracts

Responsibility	Service Contract	Management Contract	Lease Contract	Concession	BOT/BOOT
Duration	2 – 3 years	3 – 7 years	8 – 15 years	15 – 30 years	15 – 30 years
Ownership	Public	Public	Public	Public	Private and Public
Capital	Public	Public	Public	Private	Private
O&M	Private	Private	Private	Private	Private
Commercial Risk	Public	Public	Shared	Private	Private
Overall Risk					

Source: NWFRS, 2011

In general, the higher the element of public good, lesser is the likelihood of private investment (PwC, 2011). The major reasons are (Satyanarayana and Swamy, 2011):

- ✓ Lack of adequate project development.
- ✓ Projects not being bankable.
- ✓ Most of the earlier projects being operator-led rather than government/ULB-led, which in absence of adequate project development, has led to protracted negotiations and stifled successful project implementation.
- ✓ Procurement issues—projects based on negotiated contracts and not through a competitive bidding process.
- ✓ Security of payments to private operator.
- ✓ Low tariff regime.
- ✓ Lack of credible information.
- ✓ Lack of government support and political will.

The experience with regard to PPPs in the water sector has not been encouraging as a number of private sector participation initiatives have either failed or were renegotiated (Harris, 2003; Tiwari and Nair, 2011). Majority of the current PPP projects have emerged where capital cost has been borne by the public sector while the operation and management are carried out by private sector (Tiwari and Nair, 2011). Prominent areas of private players are engineering, procurement and construction services (EPC), project SPV /holding companies and equipment manufacturing (Gadkari and Maheshwari 2011). A total of 54 PPP projects are in operation (IRR, 2011). These include PPP projects for:

1. Development and Maintenance of infrastructure
2. Industrial water supply
3. Desalination and sewage treatment

During the early 1990s majority of the PPP projects were completely financed by private operators with focus on bulk water augmentation. The initial focus of utilities on increasing source capacity ie bulk supply augmentation through private sector investments proved to be a non-starter as the utilities were operationally inefficient with high volume of water losses and were not even recovering the operating costs. Lack of preparation and treating the PPP contracts similar to conventional piecemeal contracts based on 'Length-Breadth-Depth' (LBD) measurement framework resulted in abandonment of projects (NWFRS, 2011). Most of these projects failed because weak financial strength of project proponents and opposition to privatisation (WSP 2014). However, from early 2000 most projects were taken up where majority of capital investment is through public funds with focus on improving service delivery components. The key requirements for success of delegation are summarised in the following table.

Table 15: Key Requirements for Success of Delegated Management Contracts

Criteria	Management contracts	Lease contracts	Concession contracts	BOT/BOOT contracts
High levels of political commitment	Essential	Essential	Essential	Essential
Consistency in PPP Strategy	Essential	Essential	Essential	Essential
Establishment of an independent regulator	Important	Essential	Essential	Important
Preparedness to undertake tariff reform	Desirable	Important	Essential	Important
Community consultation	Essential	Essential	Essential	Important
A "pro-poor" policy	Essential	Essential	Essential	Important
Transparent processes for contract award	Essential	Essential	Essential	Essential
Simple, measurable and reasonable targets	Essential	Essential	Essential	Essential

Source: NWFRS, 2011

In India, currently, most projects are publicly funded and the capital belongs to the water utility. The private entity brings in managerial expertise. However, in the Chennai-desalination project, for instance, the proponent has invested in the capital project costs of the plant, but on the guarantee of long-term off take of the output. Similarly in the Haldia project JUSCO, has been contracted by the Haldia Development Authority to take on lease existing assets and invest in building new assets and create systems for management. In this case, JUSCO is the water operator of the project, with the responsibility for selling water and earning revenue. It promises a guaranteed income to the development authority—over the 25 years concession period—of Rs 1,220 crore. This model has been applied in Salt Lake as well, where there are substantial residential areas for the utility to reach and recover costs. It is early to say if these projects will fructify and will be successful if providing models for private investment in water, with returns that are bankable. But clearly, these few models must be carefully watched and experience for the future gathered. Where the operators invest in capital, then the agreement is to allow them to earn revenue from higher tariffs. In Haldia, where the project is primarily geared to industrial users, the Haldia Development Authority has kept the charge of setting tariffs, with the contract agreeing that these will increase by 3 per cent at the minimum each year. But in Salt Lake city, JUSCO has been allowed to levy 'water and sewerage charges' of Rs 25/kl (Rs 15 for water and Rs 10 for sewerage) from connected industries. It pays for bulk water at Rs 5 kl, which it needs at a specified quality. The tariff escalation of 10 per cent is accepted every five years. The 'risk' of collecting the charges remains with JUSCO.

In the water supply projects of Madhya Pradesh – Khandwa and Shivpuri – the base tariff is set before the project takes off. What is surprising here is that even with 90 per cent public financing, the project is only viable when the tariff is between Rs 12-15 kl – way above what water utilities across the country can charge or recover. In other words, in these two cases, public subsidy for capital does not lower costs of providing water. In almost all other cases, the tariff is set by the public utility and its private contractor has the responsibility for improvement of recovery of the charges, for which it is paid a pre-determined fee. For instance, in the case of Karnataka 24x7 projects, the operator is paid over Rs 5/kl, based on performance indicators.

In almost all cases (except Salt Lake city) there is no reference to costs of sewage, which will need to be inbuilt into the project design and management costs. It is clear that the quantum of water, if it increases, will increase the quantum of sewage as well. No project, it would seem, is designed to take care of the capital and operational costs of this fall-out. This is the biggest risk in the projects of today. In most other cases, the private operator, has limited financial exposure and limited risk. The payment is given to manage the operations of the project, based on pre-determined performance indicators – quantum of leakage loss to be reduced or resolution of complaints in serviced area.

The private sector claims that even in situations where public funds are driving the project, risks remain considerable, as it has to deliver. Guaranteeing performance is difficult as the project design often is misleading and inaccurate. In these cases, the contract requires modifications – on the design and cost – but this put the project in a bind, as renegotiation on tendered agreements is difficult in most cases. The project then becomes unviable or even poor in implementation. For instance, in Mysore, where JUSCO bid for a performance-based contract to refurbish the city's water supply system to provide 24x7 water, it found that the total pipeline that needed replacement was 1,900 km, not 800 km, and the cost rocketed accordingly. There may be a need for renegotiation with related complexities related to transparency and accountability. If the cost is not revised, the work will be half done and results will be poor. The aim of the investment will be negated. Without baseline data on the water-sewage situation in a city, contracting becomes difficult and estimating costs of what needs to be done almost impossible. As a result, some serious players are not bidding for projects. The newer water contracts are going to newer companies and it is yet an open question how serious these will be in a difficult and untested business.

Box 2: Khandwa's PPP project

Khandwa is a mid-size town in the heart of Madhya Pradesh – with 0.2 million inhabitants in 2010. The city administration estimates that on the basis of 135 lpcd, it needs 29.53 mld, but can provide only 17.20 mld. Therefore, it has proposed that it should forget all its many decaying lakes in its midst and concentrate on getting water from the Indira Sagar project, being built on Narmada, some 52 km away. With this scheme in hand, which would involve bringing water from this distance and building-refurbishing pipelines for its distribution and for recovery of its bills the city government when on a hunt. It said its local agencies were weak and unable to function because of political interference. The project could only take off, if there was a private party, which would take on the task of water supply. PPP made the project attractive and viable and the idea was sold.

In 2009, the tender document was put out and a Hyderabad based infrastructure company, Vishwa won the contract. The total cost of the project was put at Rs 115.32 crore and the deal was struck. The company has the responsibility to build the water transportation network and to supply 24x7 water to all of the city inhabitants.

But what is interesting is that in this PPP, the private side, does not bring in capital funding. The government of India provides 80 per cent and the state government another 10 per cent – adding up to Rs 96 crore in public financing. The private company contributes a mere 10 per cent.

The deal is sold on the basis of the operational costs and the inability of the city administration to recover its water bills. As a result, even with public financing of 90 per cent, the water tariff has been set at Rs 12 kl. The calculations are that the company will sell Rs 14.81 crore worth of water each year – some 34 mld – of which 29 mld is for supply and another 5 mld for losing. It will spend Rs 7.62 crore in operation and maintenance and so in this calculation it is a sweet deal.

However, these calculations leave the sums unsolved. The fact is that the city government in 2007-08 recovered a mere Rs 94 lakh in water bills, after spending Rs 3.18 crore on distribution – roughly 30 per cent recovery. Now magically, the private company will be able to charge and recover tariffs of Rs 12 kl – which is roughly double of what even Bangalore pays for its water. This is when the city, according to government's own assessment is poor – roughly 40 per cent lives in slums. Then there is no metering or any distribution system to speak off. Now the private company is expected to turn around this situation but nobody says how. Instead the project document is replete with the standard infrastructure conditions – for instance, it says that there will be ‘no competing facility” created during the time of its 25 year concession period. This condition could be disastrous, if the company, as can be safely assumed, will not be able to supply 24x7 water to all of Khandwa’s poor inhabitants for Rs 12 kl. This would mean that governments, once tied into the contract cannot even invest in improvement of local water bodies – lakes and ponds or recharge groundwater.

Then the project has nothing to say or do with the sewage this water will result in. Given that the water-utility or local municipality will be further starved of money as the customers will be busy paying for expensive water, pollution is a guarantee.

But Khandwa is a clear success as its neighbouring city of Shivpuri has already signed on to a similar deal, but with an even higher base price of water – Rs 15.40 kl.

Source: Planning Commission (2011)

In India municipal water reforms have become synonymous with 24x7. The reasoning of these projects is impeccable: supply constant water so that pressure in the pipes will reduce leakage from sewage pipes and, in turn, reduce contamination of household water supply. Furthermore, create tight management contracts based on performance terms so that leakage -- non-revenue water -- is reduced. This will add to the financial viability of the municipality/water utility. The most cited example is from Karnataka, where in 2004 the cities of Hubli-Dharwad, Belgaum and Gulbarga were chosen for continuous water supply demonstration projects. Later, Mysore was added to the list. In Tamil Nadu, Madurai’s 24x7 has been announced. In Maharashtra, besides Mumbai, work has stared in Nagpur and Pimpri-Chinchwad, a city on the outskirts of Pune. Many other cities are waiting to adopt 24x7 schemes.

Karnataka’s water reform began with a project period of 2004-2008, but this was extended to 2011. The Rs 237 crore project, funded jointly by the World Bank and the state government, has led to the establishment of the Karnataka state urban water supply council. The project awarded performance-based management contracts to private companies—French water major Veolia water won the contract—to repair the water system for 24x7 supply and to manage operations, including billing and collection, in the pilot zones in February 2011, with some Rs 200 crore spent, the project had laid 108 km of transmission mains, 238 km of distribution mains and 26,045 metered house connections. Continuous water supply was operationalized in all demonstration zones across the three cities. Leakages are down without any major increase in water tariffs. The project also included a specific tariff plan for the urban poor, defined as those living in houses of less than 600 sq feet built up area.

Table 16: Karnataka's 24x7 Achievements: What has been Done

	Demonstration zones	Reached (no of house connections)	Real losses (litres/connection/day/metre pressure
1	Belgaum (south)	4566	5.21
2	Belguam (north)	4314	10.52
3	Hubli	7834	5.45
4	Dharwad	5945	4.84
5	Gulbarga	3386	2.36
	Total	26045	

Source: Planning Commission (2011)

To reduce losses the pipeline network had to be completely re-laid and modernised. The new pipes are of high-density polyethylene (HDPE), replacing PVC pipes. A system has also been devised to check data from meters over a 24-hour period; if the meter is running during non-use hours of the night, leaks can be isolated and fixed. In the project area, tariffs have been revised upwards, but functioning and high-quality meters ensure the measure is accurate and based on consumption. There are four slabs, with tariffs ranging from Rs 6 per kl to Rs 20 per kl, the latter for consumption above 40kl. This has helped cross-subsidise revenue collection. The Dharwad demonstration zone has 5,500 connections with a population of 37,000. Veolia's records show 43 per cent of the customers consume less that 15kl per day, contributing to 15 per cent of the total water charges and 16 per cent of the water used. On the other end of the spectrum, 40 per cent of the households use more than25 kl per day, use 60 per cent of the water and account for 58 per cent of the collections. Monthly collections in this pilot zone have increased from Rs 2.5 lakh to Rs 8 lakh, which pushes towards financial sustainability.

It is important to analyse the experience of 24x7 to understand how it will succeed in the country. Firstly, it is clear that the challenge of scaling-up and replication will be significant. In Hubli-Dharwad the pilot project has taken time for implementation and has also been implemented at significant capital cost. In other words, reaching 10 per cent of the twin cities' existing connections has taken 7 years. It has also been costly. How will this reach the rest of the city, and by when? More importantly, will it impact the supply and sustainability of water sources—will there be quantifiable reductions in the amount of water to be sourced for supply? As yet, there is no evidence to suggest this will happen. Secondly, more experience is needed to assess its effectiveness: For instance, the claim on the reduction of leakage also needs to be carefully scrutinized, as the experience is limited. The proponents of this scheme often end up comparing the total leakage (as estimated) for a city, against the reduction of leakage seen in limited households with careful intervention. While extrapolating, due care needs to be taken of other variables. Thirdly, financial sustainability must be reviewed: The project (across all cities), with high tariffs and efficiency of recovery, is not able to balance its books. This is also because the cost of water is high, over Rs 12 per kl. Interestingly, the cost to the operator and auditor is more than the cost of bulk water—Rs 5.45 per kl. Clearly, in this scenario, the big question is the cost of delivery of water in our cities and what this will do to the sustainability of local bodies and the strain on the already poor investment of sewage systems. The more water the city uses, the more its sewage. It is clear that the cost of management will have to be paid and the question remains that if these costs are paid then even public water utilities would be able to deliver on supply and quality.

Fourthly is the question of sewage. In other words, more water will be supplied, which will not be paid for completely. And in addition, more sewage because of the increased water supply will be generated, which will not be paid for at all. In this way the public utility will be burdened with these costs, without sources of revenue. It is clear that these projects must be reviewed to ensure that the cost of building sewerage infrastructure and running it are provided in the initial design.

Water and sewage costs must be paid for, but the questions are how will this cost be recovered and how much can be charged? It is important to note, that contrary to perception, many municipalities and water utilities have in the recent past raised tariffs for domestic and industrial use. But the question is how will they recover their bills. Meters do not exist and where they do, they often do not work. The cost of recovery adds to the costs of operations. This is where inventive solutions are needed. But it is also a fact that the higher the costs of operations the less the municipality and water agency can and will balance their books. In fact, municipalities have found that they can recover part of their costs through high tariffs on industrial users. In a survey of water utilities, jointly by the Union ministry of urban development and the Asian Development Bank, commercial and industrial consumption of water averaged to 15 per cent in the 20 cities surveyed. In Bengaluru, while the commercial and industrial usage is 5 per cent of its total water supplied, the billing amounts to almost 40 per cent. This city, which charges Rs 6 per kl for the lowest domestic slab and Rs 36 per kl for the highest, charges as much as Rs 60 per kl for industrial and commercial use. The situation is the same in Chennai and other key cities. Hyderabad has also revised its tariff, arguing that most metropolitan cities like Chennai, Mumbai and Bengaluru charge higher rates for non-domestic use. Its tariff is now Rs 35 per kl, against Mumbai's Rs 40 per kl and Delhi's Rs 50 per kl. But interestingly, Hyderabad is the only city, which charges increased rates -- Rs 60 per kl -- where water is used as a raw material–in bottled water, soft drinks or alcoholic beverages.

It is also logical that cities, struggling to find ways to meter all houses that use water, will recover costs from high-users of their product. These are institutional buyers, easier to locate and easier to bill. It is for this reason that most cities have different rates for water usage in commercial and industrial areas. The danger however is that as the price increases, industries and institutions simply move to the source that provides them cheaper water – groundwater. This then leads to greater unsustainability of this resource.

If meters are needed to measure and account for water—then the technology for these is also the most neglected within the country. It is well known most customer meters will register airflow. Given that most cities have intermittent water supply, this could lead to inaccurate reading. But no study exists on the extent of such error. In 2003, Chennai MetroWater commissioned a study, funded by the World Bank, to study how it should implement a citywide metering scheme. The experiment threw up interesting and difficult issues regarding the workability of meters. There are no real facilities to test and to certify meters, something all water utilities need before they can go ahead and procure or ask customers to install. The country has only three laboratories – Fluid Control Research Laboratory (FCRI), in Palghat, Kerala, Electronic and Quality Development Centre of the Gujarat government in Gandhinagar and BIS Central Laboratory in Sahibabad near Delhi. These laboratories test against basic parameters laid down by the Bureau of Indian Standards (BIS). These parameters and tests need an urgent revamp as does the capacity for testing and certification.

Box 3: Chennai: Learning about working meters

In 2003 Chennai hired Generale des Eaux, a French water multinational, to recommend how it should implement a city-wide metering scheme. The study, funded by the World Bank, started and ended with the simple proposition that if the city installed meters and raised bills it would reduce distribution losses, the unaccounted-for water. The study, which took a detailed look at some 1,600 connections—a tiny proportion of the mega city population—found that the technology of meters needed careful review.

To check reliability, the study installed different makes of Indian and foreign-made meters, costing less than Rs 500 to over Rs 3,500. Each meter was sent to the Fluid Control Research Laboratory in Kerala for initial performance. The pilot study then tested the meters after 6 months and again after 12 months.

Since 'reading of air' in meters was a key concern, the study adopted a revised methodology to assess this factor. The study used the highly accurate class D in-line type customer meters as reference meters. The flow recorded during the time when there was no water in the system was considered as registration of air. But the agency found that this method was very laborious and slow; the results, too, not consistent. It then sourced specific meters from Europe and the UK, which would not read air.

All this done, it took some 45,000-meter readings from October 2003 to December 2004. The single biggest problem it found, in roughly 40 per cent of the cases, was that the meter reading mechanism would get blocked due to silt. High dissolved solids in the water would block the filter meters. In another 30 per cent of the cases, access was blocked. Meters were installed in pits where rubbish or other material was thrown; sometimes, the property where the meter was installed was found locked. This was the biggest problem—it required meter readers to go back again and again to check and record. Another problem noted was condensation. Moist air would condense the face of the meter dial. All in all, the study found that meters could be working to record more or less of what was being supplied. This meant that as customers found the meter readings difficult to accept, they did not pay

Source: Planning Commission (2011)

Jamshedpur has been able to install meters across its area or has used the technology of measurement to reduce its losses. Jamshedpur is uniquely placed because of the nature of the township–it is an industrial town of the Tata's steel industry. Its work to control distribution losses is exemplary. Most cities – Chennai, Hyderabad and even Bengaluru – have pilot projects on metering and measurement. But these cities are finding it difficult to scale up this work. Cities are experimenting with various kinds of electromagnetic meters. Bangalore has installed some 38,000 meters, Nagpur 15,000 and Chennai roughly the same.

There is a huge challenge to scale up these experiments. Equally, it is clear no city knows the full cost of this transition: the cost of the household meter is only a small component, for the pipelines that bring water to the house have to be refurbished drastically for the system to work. Hyderabad, for instance, started its pilot non-revenue water reduction project in early 2000. By 2006, the city replaced some 140 km of cement mains and 650 km of modern pipes. It also installed 73 bulk flow meters and changed the domestic meters in some 1,76,000 households. Still, there was no result—the water utility could not assess or quantify reduction in water losses. It then decided to take up a micro-study in two sites, where it installed conventional and flow meters in some 40 households each. The study showed some reduction in measurement of unaccounted water, from 33 per cent to 29 per cent in conventional meters and from 25 per cent to 18 per cent in flow meters. The city then took up the challenge to tackle a medium-level pilot project, in the rich locality of Banjara. It was confident that this time it would learn to deal with this challenge. The area was relatively easy to map, for the source of water was from a single point and meters existed in households. The effort was laborious. Each day, city water officials were tasked to record daily readings from the bulk meters to check on water supply and to reconcile this with individual meters. But with all this done, the study was still not accurate and the city could not reconcile its water accounts. Now Hyderabad is devising a new experiment to arrest its water loss. It is putting in place a SCADA (system for supervisory control and data acquisition) for mapping its water system. It hopes this will help it get a handle on the losses.

The question also is if metering of households is indeed the best (and only) way ahead in managing an efficient billing and accounting system. Chennai, for instance, has no metering but it has an efficient revenue collection system. The city lowers its costs using the existing property tax system to collect its water bills. The water and sewerage tax is a component of the annual rental value of the property, collected in two equal installments.

Surat shows the possible way ahead, as it combines various options to manage its water. First, it has taken control of its high-value and bulk consumers, to check for water consumption. Out of the 770 mld the city supplied in 2011, roughly 55 mld (7 per cent) is directed to industrial users, whom it charges Rs 22 per kl. Each user has been metered using electromagnetic instruments and water consumption is carefully monitored. As a result, losses are down to negligible; the city even imposes a leakage charge on industry, of 5 per cent, to cover its missing water. As a result, the city earned in 2009-10 some Rs 36 crore from industrial users, a little less than half its annual revenue. The city water agency is now exploring the possibility of contracting out its sewage for tertiary treatment, which it can use to supply additional water to industries. It has received proposals from private companies, willing to treat and sell sewage-water for Rs 18 per kl.

In addition, it has identified its bulk users: hotels, malls, hospitals and the like. In each such case, defined as a user with over ½ inch pipe, the city water agency installs meters and charges hefty rates (Rs 18 per kl). All new areas are also metered. In the rest of the city, water bills are raised as a component of the property tax. This city has a collection efficiency of 93 per cent for this tax. But the charge is miniscule and so the option is for the city to increase its flat water rate, based on the size of property or location. It has mapped the city for leakage–the old city area was found to be the worst in this regard, and so the city is taking remedial steps to improve piping. The bottom line is that Surat, with just 1 per cent of its area metered, has a cost recovery of 92 per cent and its efficiency in collection of water charges is 94 per cent. The downside is that it still has 20 per cent (estimated) non-revenue water. This nuanced and step-up approach is a good example for other cities to follow.

Box 4: Jamshedpur: the town that counts

This industrial town, which has grown around the Tata Iron and Steel Company (TISCO) has set up its own water provider—JUSCO. Also a Tata company, this is India's first private sector service provider in the water business. Its core area of work is in managing the water and waste business of Jamshedpur, but now it is branching out to offer its services to many other needy cities and industries.

In Jamshedpur, a town spread over some 64 sq km, with roughly 0.7 million inhabitants, JUSCO is responsible for water and waste services. It supplies some 190 mld over a network of 550 km of water mains. The key achievement is that in this town non-revenue water—or water that gets lost, say through leakage or in other ways—has been brought down from 36 per cent in 2005 to below 10 per cent by 2010. The success lies in the company's ability to manage its water supply efficiently. It has replaced pipes and has service-guarantee conditions. It monitors leakage and distribution losses through a city-wide computer mapping system. JUSCO says that with all this done, failures (complaints) about the water system are down from 44 each month to nil. Its 57,000 connections are not completely metered—only30 percent are—but with losses down, operating costs have lowered and recovery has improved. It has only 4 employees per 1000 connections, lower than most cities even in Asia.

The big question now is if this Jamshedpur experience can be replicated in other cities of the country. JUSCO, which has now bagged performance-based management contracts in Mysore, Haldia and Salt Lake cities for supply of water and reduction of losses, will have to work its magic once again.

Source: Planning Commission (2011)

PPPs in India: The Way Forward

While it is clear that lack of financial resources in government and human resources at the ULB level have led to the PPP option being considered seriously in urban water in India, it is also abundantly clear that for PPPs to be a viable option, many reforms need to be urgently undertaken at various levels:

I. *<u>Governance and Institutional:</u>*

a. Seetharam (2007) highlights that the experience with private sector world-wide has shown that, where governance is weak, privatisation of the essential water and sanitation services results in raising costs and reducing access and quality for the less well-off. Hence there is a need to strengthen the ULB capacities for effective service delivery. Capacity building of ULB personnel should be an integral part of PPP design so that a smooth exit path is available for the private player and ULB after the contractual agreement period is over.

b. Most of the ULBs do not have appropriate and updated data of their infrastructure systems. This results in poor planning and implementation. Currently, the available data lacks reliability and is not regularly updated. Hence there is a need for continuous monitoring and evaluation from the state level nodal agency.

c. State level nodal agencies should play a key role in strengthening ULB capacities.

II. Community Awareness and Political Intervention:

In most of the PPP projects there was opposition from the citizens with regard to increase in tariffs and high cost of installing meters. Public consensus with political intervention will be a critical component for successful PPP implementation.

III. Rethinking Current PPP practices

The most recent review of PPP projects world-wide (Vidal 2015) claims "that 180 cities and communities in 35 countries, including Buenos Aires, Johannesburg, Paris, Accra, Berlin, La Paz, Maputo and Kuala Lumpur, have all "re-municipalised" their water systems in the past decade. More than 100 of the "returnees" were in the US and France, 14 in Africa and 12 in Latin America." As most of the PPP models have not achieved significant success for both ULB and the private operators, there is a need to review of current PPP models on urban water supply:

a. There is a serious dearth of local capacity even in private operators regarding the way PPP projects must be positioned and articulated, fully taking into account legitimate popular sensitivities regarding water.

b. There is also felt need for good transaction advice and in many cases the transaction advisors resort to 'copy cut and paste' methods of emulating from other contracts even though each local situation and condition is different from others.

c. Mechanisms to address the contract rebasing to reflect the true costs which are unpredictable in case of networks which are buried and are difficult to assess in terms of rehabilitation requirements.

d. Pricing of water will work only when it happens in a decentralised, transparent and participatory manner, with an assurance of quality supply

In conclusion, we must also note the caution of the United Nations report on Global Assessment Report on Disaster Risk Reduction (2013) states that India is at a greater risk for opting Public Private Partnership (PPP) mode of investment for raising its public infrastructure where the governments has less control over its executing private partners and the latter has little interest in long term safety of the projects. As there is not enough regulatory mechanism to control and monitor these projects, they are highly vulnerable to risks if any natural disasters occur.

8. Capacity Building of ULBs

It is clear that Indian cities need capacity to take managerial and technological decisions regarding essential public services and to implement and deliver these services to all. This internal capacity is even more important in the situation where many elements of the urban services are to be contracted to private companies.

Although one of the key goals of JNNURM was to incentivise building of ULB capacity, it is not clear this architecture has actually led to major changes on the ground. Devolution of powers to ULBs as per 74th Constitutional Amendment Act faces the most critical bottleneck of lack of professional human resource capacities among ULBs. So functions got devolved with the 74th Amendment and funds through the JNNURM but able functionaries remain a rare species. Policy making, service provision and regulation still rely heavily on the state government bureaucracy.

Currently, water supply and sewerage services in cities are run by complex institutional setup with overlapping jurisdictions and fragmented roles and responsibilities. The responsibilities for these services are shared by ULB for operation and maintenance and para-statals for investing in capital infrastructure. In few metro cities, services are provided by an independent authority. Institutional fragmentation with regard to policymaking, financing, regulation, and service delivery has also contributed to the poor state of urban water service delivery (IIR, 2011).

Water charges levied by ULBs are very low and fee collection is poor so that even recovery of operation and maintenance (O&M) proves difficult. Water boards in India are able to recover only 30 to 35 per cent of the O&M cost (HPEC, 2011). Planning Commission (2011) has pointed out that capacity building has been accorded low priority and it is largely confined to event based administrative training. There is no systematic planning, resource allocation or skill enhancement programmes. An overall organisational development strategy both at state and ULB level is missing.

There is no one best model that is currently in place to manage water and sanitation services in the country. Therefore, what is needed is to build internal capacity to measure, to review, to implement and to monitor these services, with the objective of providing water to all and taking back and treating and reusing sewage of all. The challenge is to find models of service delivery and technologies that are affordable and sustainable. Therefore, we need a deliberate and innovative strategy to build this capacity:

a. To greatly build internal capacity at the Union Ministry of Urban Development and CPHEEO to be able to provide guidance and effective monitoring of funded projects.

b. To build capacity of municipal officials and engineers to implement innovative and emerging technologies and approaches in water and sanitation.

c. To strengthen state and city level water supply and sanitation institutions.

One of the major underlying reasons for the poor performance of water utilities is lack of dedicated cadre. There is evidence that well established municipal cadre in a few states (Karnataka, Maharashtra and Tamil Nadu) had a positive impact on governance, reforms initiatives, attracting external funding and technological innovation. Other states without requisite municipal cadre lagged far behind in each of these respects (GoI, 2014). Global experiences of successive water bodies/utilities in institutional reforms focus on the key principles, namely: decentralisation of responsibilities to local governments; building autonomous utilities with tariff rationalisation; dynamic leadership and human resource development; and community participation. As the water governance and institutions dynamics change from state to state, there is a need for state level water (and sanitation) programme driven approach with equal emphasis on infrastructure development and capacity. Maharashtra is the first state in India which to come up with a comprehensive programme on sustainable water (and sanitation) management. In 2010, Government of Maharashtra launched Maharashtra's Sujal Nirmal Abhiyan (MSNA), a state-led integrated water and sanitation programme, aimed at reforming the performance of ULBs. The programme is implemented by Department of Drinking Water supply and Sanitation with support of Maharashtra Jeevan Pradhikaran (MJP). It covers all ULBs (around 250 cities), except Mumbai, for delivering water and sanitation in a sustainable manner. The programme incentivises reform by making grant release entirely performance based. It offers an example for other States to emulate.

PART C: FOCUS ON INDORE AND NAGPUR

1. Methodological Framework for a Solution to Water Supply Problems in these Cities

The five key objectives of any urban water system can be taken as:

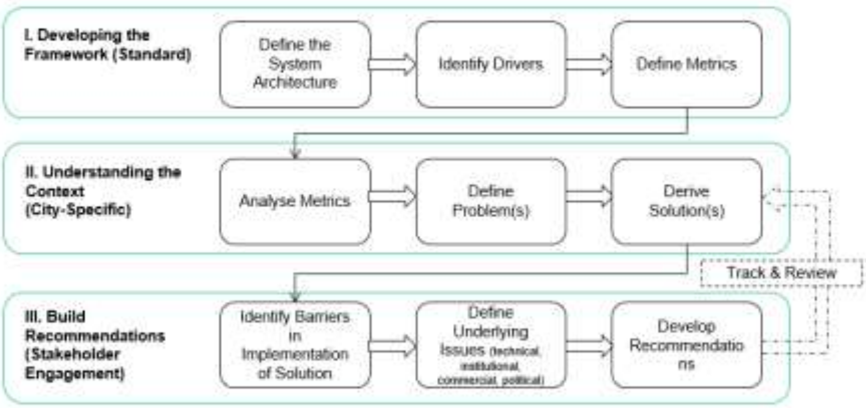
- Adequacy - to be able to meet the demand of users
- Affordability – to be able to arrive at a balance between system costs and willingness and ability to pay of users
- Accessibility - access to all users
- Reliability - reliability in supply and distribution of water
- Quality - preserve quality of water at its supply sources and also ensure delivery of water as per standards

Any water supply system would be judged within this framework of objectives, translated into measurable indicators of each objective. An intensive wastewater treatment, recycling and reuse drive for urban and industrial water would potentially also provide massive co-benefits in health, environment, energy saving and social equity. These impacts and interactions have also to be adequately factored into the design and evaluation of water systems and not treated as independent issues and problems, which results in sub-optimal performance of water systems. A robust quantification of co-benefits in urban centres could be of great value to analyse the sector more comprehensively from the perspective of financial sustainability and investment.

We outline below a systems approach which would comprehensively map all drivers and their impact outside the narrowly defined water system. This approach gives a comprehensive view of the interrelationships of these drivers at a glance, which can also be analysed individually for their impact on the environment or other service sectors, with respect to context.[17]

The first step involves developing system architecture with drivers and appropriate metrics to measure performance.[18] The second step requires extensive analysis of data in context of a city. Analysing metrics highlight problem areas and possible solutions. The third step involves stakeholder consultation to understand barriers in implementation, underlying issues in order to finally develop recommendations.

Such an approach would give a better quantification of co-benefits and a more meaningful cost-benefit evaluation of alternative technology and management options being considered by city planners.



Demonstration Projects

In order to showcase the power of the framework we are proposing, it is useful to identify locations where the beta-testing would occur. It is our considered view that one of the most effective ways in which we can mobilise the people's participation that is necessary in making any urban water project successful, is to focus on the revival of rivers flowing through the city.

17 We thank GGGI for their input into this section of this paper

18 Examples of this exist across the globe. A framework developed by the Centre for Re-Inventing America's Urban Water Infrastructure places the water system in the context of its priority objectives such as demand management, resource recovery, public health protection etc. Similarly, the National Water Account 2010 conducted by the Government of Australia for Perth has developed a systems framework indicating all channels of supply and demand which can be analysed for the management of water resources. (GGGI, 2014)

The government has rightly focused attention of the Ganga river and this has mobilized tremendous popular energy in this direction.

We propose the selection of Indore and Nagpur and the river Khan and Nag within these cities, to take the present project forward. The choice of Indore and Nagpur is based on our judgment that

1. Both Nagpur and Indore have already gained experience in innovative attempts at tackling the urban water problem
2. There is a strong network of local contacts in these cities who are already active on the ground there
3. These are the right size of urban conglomeration for us to take up so that we can showcase doable impact at scale
4. There has been active expression of high-level political support and interest there. Mr. Nitin Gadkari, Hon'ble Union Minister is MP from Nagpur and Mrs. Sumitra Mahajan, Hon'ble Speaker of the Lok Sabha is MP from Indore. Both have shown keen interest in resolving the water problems of their cities and are very keen to transform rivers Nag and Khan into clean free-flowing rivers.

Nagpur Baseline

Nagpur is the 13th largest urban conglomeration in India. It is also Maharashtra’s second capital. The table below provides some indicative figures about Nagpur’s water supply. Nagpur’s total water availability is about 625 MLD of which, 470 MLD is treated and made available for supply. The city also gets 10 MLD from groundwater, a marginal amount when compared to the total supply. Since 1942, Nagpur has been sourcing its water from Kanhan river, located 20 km from the city. The city has an older source – the Gorewada Lake - about 10 km to the north-west of the city. The lake has been in use since 1911. Another potential source the Pench Dam, is 45 kms away. Various phases of the Pench Project were commissioned for augmenting Nagpur’s water supply during the last decade.

Nagpur: A Brief Profile

Municipal area (sq km)	218
Approximate area of urban sprawl (sq km)	700-800
Population 2005 (million)	2.4
Population 2011 (million)	2.7
Total water demand as per city agency (MLD)	411
Water sources	Surface water – Kanhan river, Gorewada tank and Pench Project
Surface water supply (%)	100
Groundwater supply (%)	Marginal
Total water supplied (MLD)	470
Actual supply (MLD)	329
Population served by supply system (%)	85
Sewage Generated as per water supply	404
Actual sewage treated	70

In 2008, the city ramped up its supplies to 530 MLD with commissioning of renovated Pench I and II treatment plants. The foundation stone for the 240 MLD Kanhan Water Treatment Plant was also laid, and the Nagpur Municipal Corporation (NMC) started supplying water to 76 new layouts. It is recognised that the projects planned till 2031 will just be enough to meet the projected demands till that point in time. It is good to see that steps are being put in place for groundwater recharge through rainwater harvesting and rejuvenation of lakes in and around city.

The major concern is the question of various 'losses', as water travels from various sources to the distribution points and households. Estimates indicate that there is more than 50% loss of water from the point of sourcing to that of access. This clearly needs to be fixed, given that this may also be one aspect of 'induced recharge to groundwater', creating a paradox of groundwater exploitation being inadvertently offset by inefficient supply of sourced water.

Water supply service area is the statutory limit of Nagpur Municipal Corporation. The total service area within the City is 217 Sq km of which about 7 sq km area is under catchment of lakes, most of them in the peripheral zones of the city. The city is divided into 10 administration zones. There are 422 identified slum areas within the city. NMC is providing basic civic infrastructure like water supply, drainage, sanitation and roads to these slums. It is reported that a majority of slums within the core city area are connected to formal civic services. Slums located in the fringe areas are supplied by tanker-water or by bore wells. Some 30% of city population resides in slums.

Nagpur is one of the few cities in India which has attempted to ramp up its sewage treatment capacities in line with growth in population and augmentation cycles of water supply.

Sewage Treatment Plants in Nagpur

Water source	Water treatment plant	Year of commissioning	Distance from the city (in km)	Treatment capacity (in MLD)
Gorewada tank	Old Gorewada	1936	8	16
River Kanhan	Kanhan waterworks	1942	18	108
Pench dam	WTP Phase I	1981	14	113
Pench dam	WTP Phase II	1994	14	133
Pench dam	WTP Phase III	2003	14	100

Nag *nadi* is a relatively lower-order drainage system that runs through Nagpur city. In other words, Nagpur lies in the head regions of the river with the river-catchment located in the region to the northwest and west of the city. Nagpur city is located quite close to the catchment divide between Wainganga and Wardha river basins Nag nadi and Pili nadi, flowing through Nagpur, are tributaries of Kanhan river, which confluences Wainganga river further southeast of Nagpur city. Gorewada, Ambajhari and Phutatal are the three major tanks / surface water bodies in Nagpur city, in addition to numerous small tanks that have seen significant deterioration over a period of time.

Highly concentrated sewage of Nagpur is carried by the Nag river. Nag River is black coloured with foul odour and floating fecal particles. It mostly receives sewage from the adjacent residential population and effluents from industrial areas. Due to lack of oxygen and biodiversity of phytoplankton and zooplankton, anaerobic degradation makes the water unsuitable for any type of use.

Nagpur city is underlain by a 'mixed' geology. Even though a large part of Nagpur is influenced by the geology of 'basalt' rocks that occupy much of the catchment areas of the 'Nag nadi' in the Western Parts of Nagpur and the uplands outside the city further west, it is important to acknowledge that the 'crystalline rocks', mainly in the form of granites and gneisses occupy the eastern parts of the city and extend further to the East and Southeast of the city. Moreover, sedimentary rocks – mainly sandstones – are exposed in the form of a thin strip running between the basalts to the west and gneisses to the east. Hence, Nagpur is a part of the 'transition' typology under the classification of urban aquifer systems provided in this paper.

CGWB's projections state that 406 ham of water will be available for domestic and industrial purposes in Nagpur taluka, with about 3500 ham for future irrigation. Groundwater is stated to be of reasonably good quality, with pockets of high dissolved solids in addition to pockets with high amounts of nitrates, fluoride, copper and manganese. The latest figures from GSDA (Maharashtra) and CGWB (Central Government) indicate that Nagpur taluka shows 31.19% as the 'stage of groundwater development' indicating that it is in the 'safe' category with regard to the degree of groundwater exploitation. However, numerous, unaccounted for wells and bore wells continue to be used in the city, especially in the emerging suburbs and peri-urban zones of the city. The older areas of the city have a larger number of dug wells, while the emerging areas have a large number of bore wells, although the precise numbers cannot be estimated.

The municipality acknowledges the fact that there are more than 600 bore wells fitted with hand pumps where no water supply network exists. In the newer parts of the city, borewells have been drilled in almost every residential plot. These are often used to supplement the water demand. In the peripheral areas, where new residential colonies have come up recently, many of the households have water supply exclusively from borewells.

One of the hydrographs for Nagpur city (CGWB data) indicates a slight rise in water level. The hydrograph shows a regular seasonal fluctuation with a marginally rising trend of 0.004 m/year. Given the significant but unacknowledged pumping of groundwater, way above the NMC estimate in the formal water supply, this hydrograph may imply a significant amount of 'induced' recharge from leaking water mains and sewage lines also indicating to a much larger 'drinking water quality concern' that again is unrecognised in the water supply and health domains of Nagpur's municipal governance.

One of the biggest unknowns in urban river system management is the relationship between surface flows and groundwater. The processes taking place in the catchment areas of Nag nadi and the amount of groundwater extraction between the catchment zones and within the city all contribute to the flow in a river. All of these processes have a significant bearing on the base flows into a river. The most significant 'grey area' for Nagpur city is the absence of reliable estimates on base flow contribution to Nag river, a fact that is important to acknowledge because of the increasing importance being given to reviving Nag River. Given that groundwater exploitation is not considered such a major issue in and around Nagpur (based on secondary data), it is important to study how much current magnitudes of groundwater pumping are influencing base-flow behaviour of Nag river, including the quality implications stemming from leaking sewers and other contamination factors.

Indore Baseline

Indore is the 15th largest city in India. It is one of the rapidly growing urban agglomerations around one of India's oldest and busiest transport corridors – the Mumbai – Agra – Delhi highway. It is the largest city and commercial capital of the state of Madhya Pradesh. With a municipal area close to 150 sq. km., and a population of over 2 million people, Indore is also part of a larger region of intensive agriculture through a cotton-soyabean-wheat cropping system. Indore Municipal Corporation (IMC) manages the water requirements of Indore city. The water demand of the city is met from multiple sources such as Narmada river, local reservoirs, ground water and private water suppliers through tankers, which is also predominantly groundwater.

Today, the most important source of water for the city of Indore is the Narmada Water Supply Project, which involves pumping water from a distance of 70 km from the Narmada river. Despite the long distance and costly supply of the water to the Indore, the per capita water availability remains below the prescribed standards of CPHEEO (Central Public Health &

Environmental Engineering Organization). The total water supply to Indore is 273MLD including the third phase of the Narmada project. Water supply remains uncertain even today, particularly in summers, where gaps in civic water supply continue to be filled by intensive use of groundwater.

Indore: A Brief Profile

City	Indore
Municipal area (sq km)	134
Total area (sq km)	504.87
Population 2005 (million)	1.8
Population 2011 (million)	2.1
Total water demand as per city agency (MLD)	243
Water sources	Surface water and groundwater
Surface water supply (%)	94
Groundwater supply (%)	6
Total water supplied (MLD)	204
Actual supply (MLD)	133
Population served by supply system (%)	54
Sewage Generated as per water supply(MLD)	239
Actual sewage treated(MLD)	78

Out of the 273 MLD of water supply to the city, groundwater is estimated to provide around 23 MLD, with the larger proportions being supplied through various phases of the Narmada project and from the old system of Yashwant Sagar and Bilaoli tanks. A water security study (ACCCRN Phase II, 2010) reports illegal water connections in the range of 20,000 to 40,000 accounting for 30-50% loss. Failure of Narmada supply is witnessed occasionally. The local sources (reservoirs) have silted up and have lost nearly 25% of their capacity. Based on the projections form the past growth rate, it is expected that the population will increase to about 4 million by 2030. Industrial demand is expected to double from 30 MLD to 60 MLD by 2030. After deducting the current supply, a gap of 360 MLD is expected by 2024. Total net requirement is expected to reach 564 MLD by 2024. Narmada piped supply is expected to provide 360 MLD by 2011 and an additional 360 MLD by 2024.

The Khan river in Indore is formed by the confluence of the Khan river, Saraswati river, Bhamori nala and a stream originating in the neighbourhood of Shirpur talab. The broad flow direction is from the south to the north, with the head reaches at the divide between the Narmada and Chambal river basins. The Khan river is part of Chambal river basin. It flows through the heart of Indore city and traveling around 50 km distance before confluence with the Kshipra River at Ujjain.

Sewage from more than 400 spots in Indore city flows into Khan river, which has converted the river into a big nullah. Indore Municipal Corporation treats only 90 MLD of sewage at Kabitkhedi, the rest is disposed without treatment into Khan River. Total industrial effluent generated is 2.2 MLD. Downstream of Indore, from Kabitkhedi to Sanwer, the Khan river water is being used for growing vegetables and irrigating crops by farmers. This poses a very high risk of food chain contamination. Khan River is fully covered with water hyacinth.

Indore taps heavily into its groundwater resources. Bore wells as a public water supply source officially constitute about 8% of the total water supply. There are an estimated 30,000 private tube wells in the city but precise information regarding these is not always available. A bigger concern though is that Indore is part of a region which has a fairly long history of groundwater exploitation. The Malwa region where Indore is located has had a long-standing history of heavy groundwater use from the weathered-fractured basalt aquifers that have limited storage. Water levels in the multi-aquifer basalt system have been declining as annual abstraction rates have exceeded annual rates of natural recharge. The increasing urban demand along with a competing demand for agriculture has imposed a peculiar situation that warrants special focus.

Indore city is quite close to the head reaches of Khan river, less than 25 to 30 km as the crow flies. Indore city is underlain entirely by basalt geology. Indore city, therefore, is part of a 'trappean' landscape involving regional plateaux with outcropping ridges of basalt. The layered sequence of basalts in the sub-surface implies that there are multiple aquifers of highly inhomogeneous nature, wherein conditions in wells (and therefore their yields) change significantly even over short distances. Given the history of groundwater use in agriculture, with deep bore wells progressively replacing the shallow, large-diameter dug wells, some sources have tended to tap a multi-aquifer system leading to extensive exploitation of groundwater in the region.

CGWB's projections for Indore tehsil indicate that it has the highest magnitude of groundwater draft for industry and domestic water supply within the district. District level assessment of groundwater resources by CGWB indicates that projected net availability of groundwater for irrigation is 'minus' 60.05 MCM, a clear indication of the state of aquifers in the district. Given the pressures of urbanisation and industrialisation in the region, the competition for groundwater from the limited storage, highly heterogeneous aquifer systems between irrigation, industry and urban water supply can only increase. As an indication of the magnitude of depletion of groundwater in Indore city, data from CGWB shows that groundwater levels in Indore dropped by 14 m over 2000 and 2006 at the rate of 2.5 m / year. Groundwater quality in and around Indore city is stated to be reasonably good except for high electrical conductivity pointing to high TDS counts in certain pockets. Having said that, it is also important to remember that microbial contamination of groundwater as well as contaminants from other sources cannot be ruled out in the absence of comprehensive data on the same.

2. Synoptic Overview of Elements of a Proposed Comprehensive Action Plan for Indore and Nagpur

The action plan for the two cities will be encased in a methodological framework, which will include the following elements based on the insights generated by this paper:

1. <u>Strengthening the Data Baseline</u>

Secondary information about demography, climate, weather, groundwater and the history of water supply to the city will be collected in order to formulate a robust baseline. Putting the baseline in the form of GIS maps can also be attempted. Piloting certain innovative ‘community action’ can begin during the baseline development process itself, in order to test ground for some crucial points of community action. An online data sharing platform that allows citizens to share crucial data along with its spatial representation can be developed just after or even in parallel to the baseline compilation phase. Working with communities, schools and colleges can catalyse a minimum data-set to be represented on an online ‘participatory tool’. A strategy for wider citizenry to use the tool and contribute data can be put in place. Various forms of activities to reach out to citizens and engage them with the “waters of the city” can be established. The communication and dissemination ‘tool’ should be interfaced with a public domain ‘urban water database’ that includes a strong groundwater component.

On weather and climate data, two levels of data will be gathered; firstly to understand long-term trends in rainfall and evaporation and secondly to understand the intricacy of weather, especially to develop simple weather-based groundwater scenarios. These two aspects will require collection and collation of data from existing met stations – Indian Meteorological Department and other agencies which maintain long-term data. IMD can be requested to provide the long-term trends of key meteorological factors that have influenced water resources in the region and how these trends are likely to influence climate and water resources in future. Data from existing weather stations in various institutes located in the city can be requisitioned to complement IMD long-term trends. Such data, along with the IMD long-term data will help in the analyses of changing patterns of groundwater storage and recharge in the city’s aquifers.

Existing information on the “supply” of water to different parts of the city, including formal civic supplies, informal supplements (mostly groundwater) and usage patterns (deduced from locational – core city, suburbs, periurban zones and periphery – and situational – type or neighbourhood / domestic or corporate or industry etc. This data will need to be collected through household survey in addition to the existing data with municipalities. Ward-wise citizen groups can also be used to collect such information.

Information on wastewater, treatment and sanitation mechanisms in different parts of the city will come from the appropriate agencies, including municipal departments.

2. *Building a Strong Framework of Participatory Planning*

All the work under this plan needs to happen within a framework of people’s participation. Foregrounding this principle is important given the sensitivities involved in the water issue. The leadership of all elements of the action plan needs to be within people’s institutions, as appropriate. Elected representatives, civil society organisations, the municipal corporations, the private sector, water utilities, groundwater and pollution control authorities all need to work in close co-ordination with the state government.

3. *Mapping, Preservation and Revival of Local Water Bodies*

As stated in this paper earlier, and based on the priorities set by the 12th Five Year Plan, these will be first draw on water sources in the cities. This will contribute to cutting costs by reducing distances water needs to travel by providing more local sources, improve local ecology and also provide an invaluable source of groundwater recharge for the rapidly depleting aquifers

4. *Ecological Restoration of Nag and Khan Rivers*

The goal is the ecological restoration of the highly polluted stinking Nag and Khan rivers to convert them into healthy and beautiful natural river-fronts using natural technologies, which require minimal electricity and chemicals. It will revive the native biodiversity making it a natural river course by eliminating the stress of sewage.

Ecological restoration of these rivers needs to use an appropriate mix of various proven methods like green bridge system with benthic system, green pitching, riverine wetlands and eco-filtration banks, thorough an analysis of the pollution load and catchment treatment, based on strong public support and participation. The green bridge is a porous dam using locally available materials like stone, sand, soil and certain products with locally growing marshy plants, either along the river or across the banks. Green bridge filters help in reducing the suspended solids by filtration process, reduction in COD/BOD by aerobic degradation, formation of ecological food chain and cycling of material and bacterial consortium inputs. The process of ecological restoration of the riverine-riparian ecosystem of these rivers can be done in a period of 12 months. Pre-project Stream Ecological Health Assessment for Treatment (SEHAT) requires at least 6 months (including monsoon period), with 3 months for diagnostic analysis and eco-design.

5. *A New Plan for Groundwater Management*

a. To map and characterize the aquifer systems in these two cities including the aquifers the city shares with the rural neighbourhood, particularly in the head regions of Nag and Khan rivers. This will include aquifer characterisation using various measurements at representative locations – groundwater levels, water quality, aquifer characteristics like transmissivities and storage coefficients and groundwater abstraction, to obtain a three-dimensional perspective about aquifer geometry, groundwater quality & contamination, extraction foci. Aquifer mapping vis-à-vis the overall hydrology (river system, tanks and ponds and other surface water infrastructure) urban growth, land-use change and the urban/sub-urban/peri-urban/rural continuum, using participatory processes and tools like GPS; maps resulting from the mapping exercise can be developed on a GIS platform. This is particularly relevant with regard to the interface between the aquifers in Nagpur and Indore and the Nag and Khan rivers respectively. Aquifer characterisation and mapping will also layer a social dimension – i.e. from the perspectives of changing land-use and water use patterns and patterns of social controls of groundwater extraction and recharge.
b. To demonstrate and pilot a participatory approach towards urban integrated groundwater management, particularly in collecting and maintaining data and in developing knowledge-systems on groundwater, involving citizen groups and communities.

c. To ensure that this mapping should lead to the development of an aquifer "zonation" plan, based on aquifer geometry and patterns of use (in these zones)
d. To employ interdisciplinary participative methods of systematic mapping and characterisation of groundwater resources in and around the urban agglomeration of the two cities.
e. To establish implications for governance and to attempt mainstreaming of groundwater management within relevant local and regional institutions, including development of regulation protocols (and possibly formal legislation) around groundwater.
f. To develop A clear understanding about the hydrogeological dynamics and social controls on the urban groundwater resource. An organisation with appropriate capacities should lead this effort and will be responsible for synthesising hydrogeological data on aquifers and associated information collected. Maps, charts and even simple models / simulations will be used to develop the understanding the dynamics that control urban groundwater behaviour. All this information must progressively flow into a public-domain database.
g. To build a decision-support tool that is in tune with different zones for the city, particularly for those areas that are prone to over-extraction of groundwater and/or to contamination from activities will be developed. This decision-support tool will be derived with specific reference to the more "sensitive" zones of the city, where actions on groundwater extraction / waste and sewage disposal / other such activities have a significant bearing on the accumulation, movement and recharge of groundwater in the city's aquifers.
h. To develop a strategic action plan for managing groundwater including recharge (centralised and decentralised), community-action and strengthening the regulatory framework around water, with special focus on groundwater and aquifers and also keeping in mind scenarios resulting from the impacts of Climate Change and the strategic actions in developing adaptation plans in context to the city. The plan will be a result of the understanding of resources (mapped using a GIS platform), human behaviour and chalking out a feasible action plan involving hydrogeologists, governing bodies and the citizenry.
i. To build a comprehensive action plan on groundwater including:

1. An urban groundwater recharge plan that integrates various approaches to be undertaken in the city, including protection of 'key natural recharge areas' or 'zones' inside the city limits.

2. A catchment conservation – watershed-type interventions + ecosystem restoration – in the catchment regions of Nag and Khan rivers; some of the recharge measures for the city's aquifers may also be undertaken in this zone.

3. A groundwater discharge zone protection plan. It is also likely that polluted groundwater is discharging to the river channel or some of the partly treated on untreated sewage and waste-water interfere with such natural discharge zones. A plan to protect and conserve such zones can be a novel 'first of its kind' initiative undertaken in Nagpur and Indore.

d. Developing and implementing a menu of institutional reforms on groundwater management, including the possibility of mainstreaming a greater use of decentralised groundwater resources within the public water supply system so that the Municipal Corporation can, in parallel, develop a robust framework of legislative instruments around groundwater resources.

6. *Working with Industry to Lower Water Footprint*

In line with the proposals in this paper, an enormous scope exists for reducing the dependence of industry on fresh water sources by increasing the reliance on recycled and reused water. In this manner, the dumping of untreated effluents by industrial units into the groundwater and river systems can also be reduced, thereby improving quality of water.

7. *Training and building capacities* at various levels is crucial and a strategy to train utility staff, elected representatives, volunteers from civil society and citizens from various wards must be developed.

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