Sustainable Groundwater Management
Lessons from Practice

Case Profile Collection Number 21

Groundwater Use in Aurangabad – A Survey and Analysis of Social Significance and Policy Implications for a Medium-sized Indian City

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Aurangabad City, located in the heart of the drought-prone interior of Maharashtra State, is one of the major urban centres of the Deccan sub-region. It is an important example of a progressive fast-growing Indian city experiencing major pressure and high-cost for the provision of imported surface water-supplies, and in which private in-situ groundwater use has mushroomed. As part of the World Bank AAA Study on Indian Groundwater Management, GW-MATE has collaborated with GRASP (Grass Roots Action for Social Participation), a local civil society organization working in community-based natural resource management, to design and conduct a survey of groundwater use in this city (which was largely undertaken in the dry season of 2007). The project was implemented with encouragement and assistance from the Maharashtra State Water-Supply & Sanitation Department (MSWSSD), the GSDA (Maharashtra–Groundwater Surveys & Development Agency) and the Aurangabad Municipal Corporation (AMC).

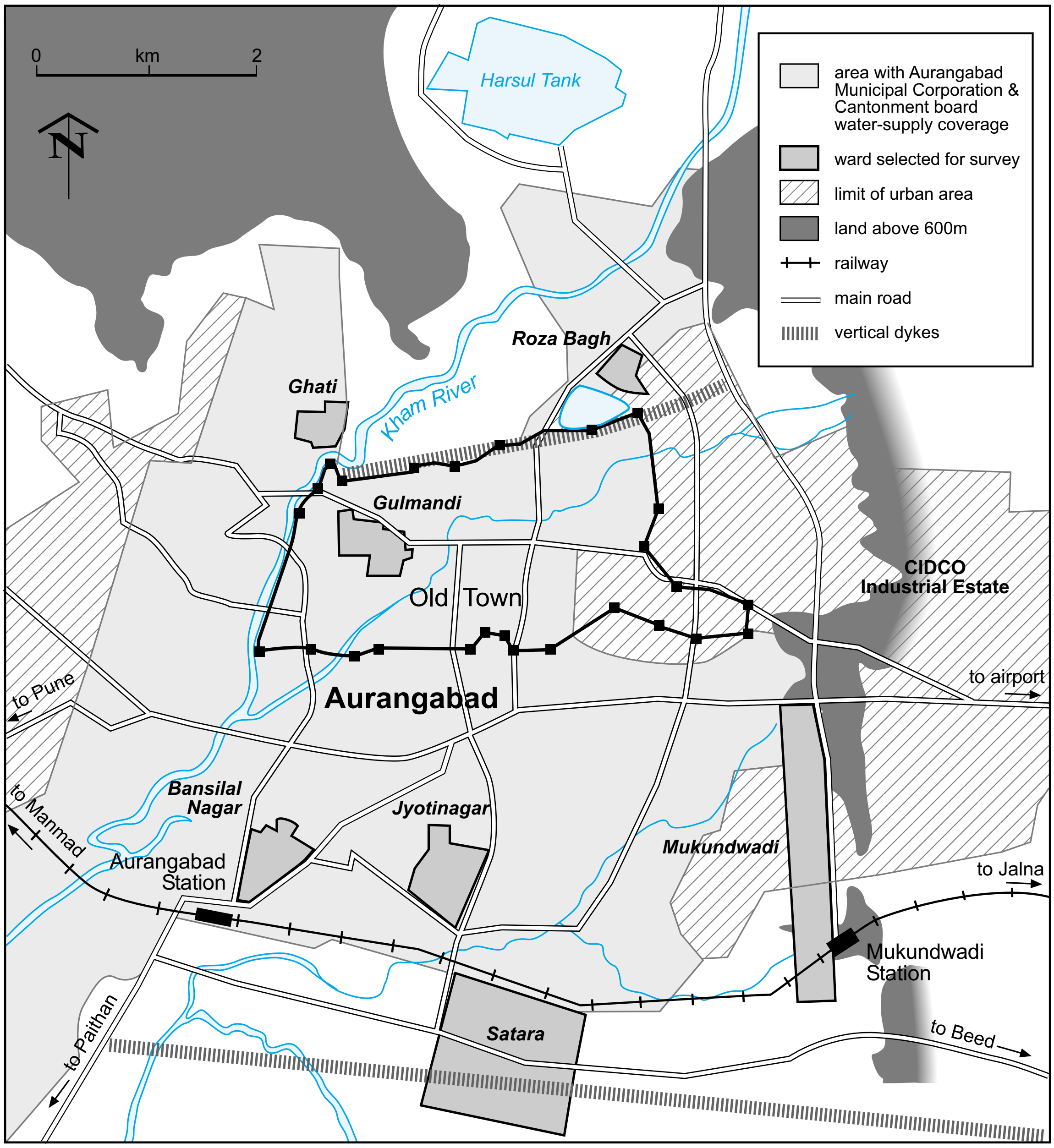
BACKGROUND TO GROUNDWATER USE SURVEY

History of City Water Infrastructure Development

- Aurangabad has a long and dramatic history – being the capital of the Yadavas in the 13th Century, when the renowned Devagiri Fort was constructed, and of the Moghuls in the 15th-16th Century. Three stone-work bund dams and reservoirs, north-east of the fort at a distance of around 1.5 km, were constructed and extended in medieval times, and water was taken from these via a system of conduits to the city gates. To improve water quality a series of aqueducts were subsequently cut into the rock of the surrounding hills capturing surface runoff and conducting it to the habitations of the city – these structures were known as 'nahars' and archaeologists have identified 14 of which 5 are still in operation today (delivering some 6-10 Ml/d and capable of producing a maximum of 20 Ml/d with improved maintenance).

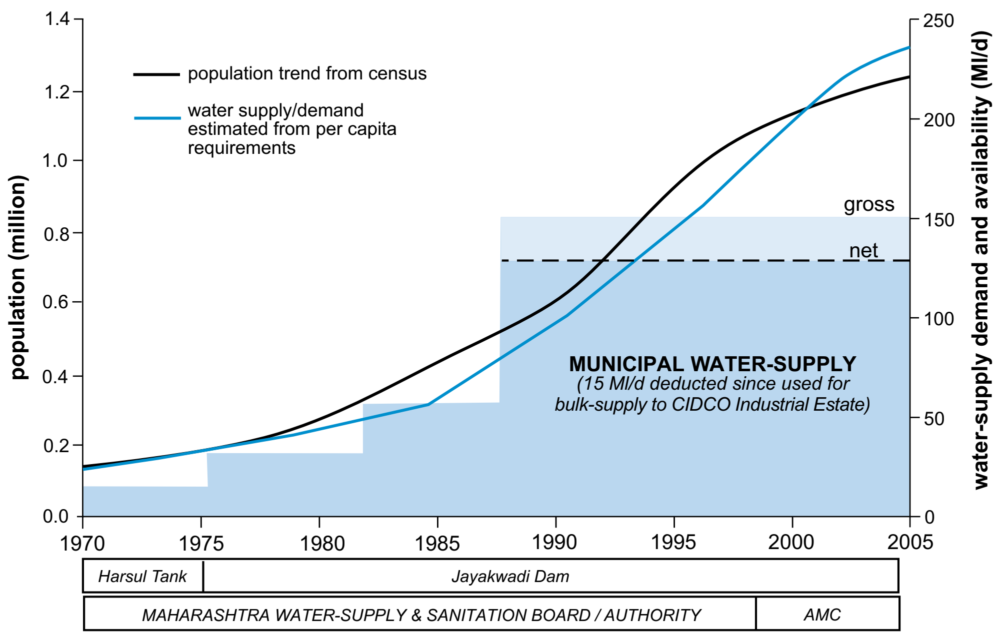
- During the last 20 years, the city has grown markedly as a result of both rapid industrialization and increased administrative status with 'urban corporation limits' having been doubled to an area of 138 km^2 (Figure 1). Public water-supply was earlier the responsibility of the Maharashtra State Water-Supply & Sewerage Board (later Authority) but was taken over by the Aurangabad Municipal Corporation (AMC) in 1998. Prior to 1975 traditional sources provided some 4 Ml/d and an additional 10 Ml/d were derived from the nearby Harsul Dam.

Figure 1: Aurangabad City – map showing general features and location of wards sampled in the water-supply survey



- Following the 1972 drought the authorities opted to invest in a supply from the Jayakwadi Dam & Reservoir (some 45 km distant and at 180 m lower elevation). The first stage implemented in 1975 provided 28 Ml/d, which was increased to 56 Ml/d in 1982 and 100 Ml/d in 1992 (Figure 2), through parallel pipelines and new pumping booster stations, and a preferential allocation of 150 Ml/d from Jayakwadi is now held. While the external pipeline has intermittently experienced significant transmission losses, the AMC water-supply distribution network has currently well over 20% of unaccounted for water, but physical leakage per se is likely to be small because of the very low distribution pressures and most of 'these losses' are due to illegal connections. In addition, the AMC operates about 600 water wells (either reticulating to stand-posts or equipped with hand-pumps) scattered in certain sectors of the city to supplement its supply.

Figure 2: Historical evolution of water-supply capacity and demand in Aurangabad City since 1970



- Given electrical power shortages for high-lift water-supply pumping, limited storage in the urban distribution system and escalating demand, the overall performance of the AMC water-supply is very poor (quite widely not more than 1-in-48 hours, of inadequate pressure and poor quality) and results in most residential properties, commercial and institutional water-users also having to resort to drilling private bore wells and/or to purchasing tankered water to supplement the corporation supply.

- Concomitantly, the Aurangabad urban area is expanding beyond the current 'corporation limits', especially to the south – and AMC is looking to incorporate the fast-expanding Satara Village within the city proper and also to improve supply capacity throughout the city. Since 2004 they have been considering a scheme to increase the imported water-supply to 325 Ml/d – but the required investment of about I rs 3600 (US $ 80) million for the projected 2030 population of 2.5 million is very large, and the scheme would also have high recurrent pumping costs, raising serious doubts about cost recovery and financial viability.

- Aurangabad City has some main collector sewers and 'institutional builders' constructing authorised new residential property usually provide connections as part of building approval – but the system and associated treatment works (at Chikalthana near the airport) is under-dimensioned and malfunctioning, and in consequence many properties (old and new) discharge their wastewater to the extensive pluvial drainage network (designed to cope with urban monsoon rainfall) which discharge without treatment locally. A very large volume of domestic wastewater from the north and east of the city (perhaps 50% of the total) is thus discharged into natural channels feeding the Kham River – but it not clear to what extent, if any, this is benefiting groundwater recharge and/or prejudicing groundwater quality.

Groundwater Conditions in the City

- Aurangabad urban area has only limited groundwater resources – both in terms of overall resource availability and water well yield potential. It is underlain by Deccan Traps basalt lava flows of mostly horizontal disposition. The occurrence, distribution and movement of groundwater are not uniform in such hard-rock terrain – but broadly speaking a weathered, jointed and fractured basalt containing groundwater (where and while) saturated occurs down to 580m MSL, with massive relatively-impermeable basalt below 560m MSL. These flows are separated by a highly-weathered vesicular basalt with consistent groundwater occurrence, although its water-bearing properties deteriorate eastwards (in the CIDCO area).

- The general direction of groundwater movement is southwest towards and along the valley of the River Kham. But two persistent (vertical) doleritic dykes (Figure 1) act as carriers of groundwater on their northern side but as a barrier to transverse flow. Typical post-monsoon groundwater levels are around 6m BGL but fall to below 10m BGL in many areas during the dry season, and are reported to have been reached 30m BGL by heavy pumping in some areas.

- Current development of groundwater for water-supply uses mainly small-diameter bore wells equipped with small (0.5-1.0 bhp) pumps, although dug-come-bore wells and tube wells are also deployed. In its natural condition the groundwater is reported to be chemically-suitable for domestic water-supply (and not subject to excessive fluoride concentrations) but there is very limited water well quality data available with which to assess the adequacy of well construction and the extent of urban pollution.

- A significant proportion of residential and institutional stakeholders have already installed roof water harvesting systems for groundwater recharge on their premises (and they are now mandatory for new buildings), but such practices have not spread to commercial buildings. Interviews with architects and builders indicated growing awareness of such practices, although it is only large building contractors who have actually installed them in recent schemes, and some contend that customers fear for associated groundwater contamination.

- Although there is a degree of natural variation in aquifer characteristics and groundwater recharge across the city, it became evident early in the current survey that (other than those localities affected by the presence of vertical dykes and the interfluve area at the eastern limit of the city) the most marked spatial variation in groundwater status correlated with the relative service levels of the AMC water-supply and the local urban population density. Thus wards with poor AMC water-supply service levels and high population density tended to be 'groundwater resource depleted' with water wells exhibiting yield failure 1-3 months before the onset of the monsoon and wards with lower population density and somewhat better AMC water-supply appeared to be 'groundwater resource adequate' and this terminology is adopted throughout the report.

APPROACH TO URBAN WATER SURVEY

Objectives of Survey

- The primary objective was to take stock of the current role that groundwater plays in urban water-supply (including volumes extracted, use of the resource and benefits enjoyed, and the levels of investment and operational cost involved). There was also interest in making a preliminary appraisal of the quantity and quality status of groundwater resources (including constraints on existing use and the potential for further development). It was envisaged that the survey would represent a type-study for many other medium-sized towns in India, in which private bore well drilling has escalated in response to poor service-levels of municipal water-supply.

- The survey aimed at generating the following outputs as a contribution to facilitating a meaningful policy dialogue on urban groundwater use :
  - a profile of the urban groundwater stakeholder community
  - a review of the socio-economic pros and contras of urban groundwater use
  - an evaluation of the state of groundwater resource development across the city.

  Preliminary policy options could then be elaborated on improving the overall use of groundwater resources in the community interest. and in terms of its implication for municipal water-service planning and finance.

Investigation Methodology

- The investigation methodology developed was designed around systematic rapid assessment techniques in representative sample areas – with quality assurance built into all stages through providing field workers with a careful initial briefing and a refresher workshop after an initial period of field work. The methodology comprised three main elements:
  - **Collection of Secondary Data** – the following were collected from the AMC and other sources: topographic base-map with ward boundaries, water-distribution network map, sewerage network map, ward-wise population statistics, historical water demand and supply data, and water well inventory (with topographic and lithological details where available).
  - **Identification of Stakeholders:** the 'project core team' undertook this at the outset and the categories indicated in Table 1 were identified, with an appropriate approach to data collection being developed in the field survey design.
  - **Field Survey Design, Planning & Implementation:** the field survey deployed two main methods – Focused Group Discussions (FGDs), Structured Individual Interviews (SIIs) (Table 1) – and the

'core project team' scrutinized the available secondary data and then formulated check lists/guidelines for each of these methods, which were pre-tested on a few samples and refined accordingly.

In addition direct survey and visual inspection through site visits were used to verify certain details of the physical infrastructure such as water wells, rainwater harvesting and the water-supply and sanitation situation.

Table 1: Identification of main groundwater stakeholders, users and service providers

STAKEHOLDER GROUP	SURVEY TECHNIQUE
• **Flat Owner Associations** • **Housing Societies** • **Slum Dweller Groups (officially declared)** • Builders & Developers • Industrial Corporations & Associations	**Focused Group Discussions** (normally with office bearers, but sometimes with invited members or direct discussion with residents)
• **Independent Bungalow Owners/ Residents** • **Industrial Premises (ice-making, mineral water, abbatoirs)** • **Commercial Users (hotels, hostals, restaurants, cinemas)** • **Institutional Users (hospitals, colleges, offices)** • **Smaller Business Units** • Water-Tanker Operators • Water Well Drilling Contractors • Municipal Corporation Representatives	**Structured Individual Interviews** (with owners, proprietors or managers, sometimes also including employees or associates)

** main classes of groundwater user groups indicated in bold type*

Selection of Survey Sample

- Aurangabad City comprises of three administrative districts – the Municipal Corporation, the CIDCO & MIDC Industrial Estates and the Cantonment Board Area – and all were considered part of the overall study area of estimated 1.08 million total population. In the AMC district there are 98 'electoral wards' and 'officially-declared' slums currently occur in 13 wards. The field-survey areas were selected on the basis on existing ward-level data (population density, habitation types, water demand, industrial and commercial activity). In May 2007 the sampling methodology was finalized by selecting 6 wards bearing in mind the 'groundwater resource depleted and adequate' distinction – and it was further decided to include Satara village (an adjacent peri-urban area just outside the southern AMC boundary) under consideration for a municipal water-supply scheme.

- Sample composition was kept under continuous review and modified according to data generated. Expert knowledge and population characteristics were used to select representative samples, and to further ensure representativeness preliminary data ware first collected and analyzed from 4 wards before finalizing the selection (Table 2). Within a selected ward, the sampling of stakeholders was done in proportion to the estimated number (or density) of water wells, and not to the population. For domestic residential use a sample of 5-10% was chosen for interview according to user category. In the case of industrial and commercial users, a larger sample (15-20%) was taken since the total number was much less.

PRINCIPAL RESULTS OF SURVEY

Pattern of Groundwater Use

- In the wards selected for sampling the dependence upon private groundwater sources ranged from 100% (in the case of some residential and commercial users) to a minimum figure of 12% (in the case of some smaller business units). It was very evident that dependence on groundwater was inversely proportional to the regularity and adequacy of the municipal piped supply – and was total in Satara Village where no other supply is yet available. The data for the various user categories indicated that 33-100% of residential users in groundwater-adequate areas and 70-100% in groundwater-deficient areas are dependent on private water wells for 3-6 months/year (especially in the dry season), and usage patterns are similar for institutional and commercial users.

Table 2: Summary of characteristics of Aurangabad City wards selected for field survey

WARD NAME	WARD CHARACTERISTICS	MUNICIPAL SUPPLY	GROUNDWATER RESOURCES
Bansilal Nagar	primarily an older residential area with high water consumption, mainly with independent bungalows and one slum -- close to railway station thus significant commercial activity has developed (many restaurants, hotels)	moderate	adequate
Ghati	Moderately populated upper middle class area with civil hospital and medical college	reasonable	adequate
Gulmandi	in old walled town - an important commercial area with many shops on ground floor of buildings and upper floors in residential use	poor	depleted
Jyotinagar	relatively recent area populated by upper middle class families on southern edge of city with many multi-storied (3-4 floor) apartments	poor	depleted
Mukundwadi	gradually grew as urban settlement housing lower middle class families, with one slum and some multi-storied (3-4 floors) apartments	poor	depleted
Roza Bagh	sparsely-populated area in north of city with mix of residential buildings and few academic institutions	reasonable	adequate
Satara	rapidly growing peri-urban village just south of municipal boundary with high water demand, but no groundwater above depth of 50 m	none at present	depleted

- The use of water wells by residential users starts to increase from February-March in some areas and from April in others, and reaches a maximum in May-June (with the increase in use being in the range 20-50%) – although the pattern with institutional and commercial users is much more specific to their business or operational cycles. Longer pumping hours by residential users in the hot dry season (May-June in particular) is partly due to yield reductions associated with falling water-table and partly to reduction in the availability of AMC water-supply (to 1-2 hours/day in Ghati, Gulmandi and Bansilal Nagar wards and to 1 hour every 2nd day in others).

- Purchasing water from tanker operators has long been common practice in Aurangabad during the hot dry season – but the drilling of private bore wells has reduced the volumetric dependence greatly (Table 3). But up to 50% and 67% of residential users in groundwater resource adequate and depleted areas respectively have to resort to purchasing tankered water for some weeks per year, since their minimum requirement could not be met from the AMC piped-supply or from their own groundwater sources (because of water well yield failure in the hot dry season) – and institutional and commercial users also tended to follow suit. Discussions with stakeholders suggested that this pattern of tanker-water purchase has been more or less the same in recent years, except in areas which have witnessed marked population growth and increased water well drilling where groundwater shortages were reported to be growing.

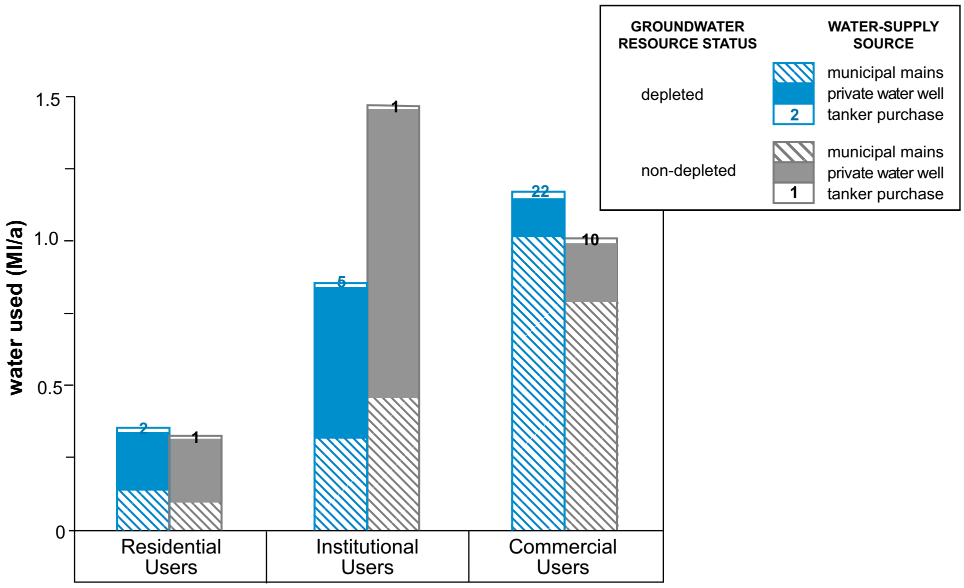
Table 3: Proportion of water users in main categories that are dependent upon different water-supply sources in selected Aurangabad wards *

USER CATEGORY	AMC PIPED SUPPLY	PRIVATE WATER WELLS	TANKERED WATER	OTHER SOURCES**
Residential	50% (45%)	38% (35%)	8% (10%)	4% (10%)
Institutional	48% (47%)	29% (46%)	23% (7%)	0% (0%)
Commercial	51% (52%)	17% (17%)	19% (31%)	13% (0%)

* *first percentage in each case is for 'groundwater resource depleted areas' and those in parenthesis for 'groundwater resource adequate areas'*
** *this miscellaneous category includes AMC standposts and handpump water wells, small tanks, and family contacts with more secure neighbouring sources*

- The data collected from the survey facilitated estimation of the overall quantities of water used by different stakeholder categories (Figure 3). The average consumption by a residential household is estimated to be in the range 0.32-0.35 Ml/a (depending on ward characteristics) – much less than the established norm for tropical urban areas (equivalent to 200 lpd/person). The use of groundwater was found to be very significant in 'gross volume terms' for domestic purposes (averaging 70% in 'groundwater resource depleted areas' and 30% in 'groundwater resource adequate areas'), whereas for institutional and commercial users it varied widely according to the nature of the operation or business. The purchase of tanker water was today found to be less than 2% by volume of total use in most user categories.

Figure 3: Estimated average annual water use by different user categories distinguishing groundwater resource adequate and depleted areas



Financial Analysis of Water-Supply Provision

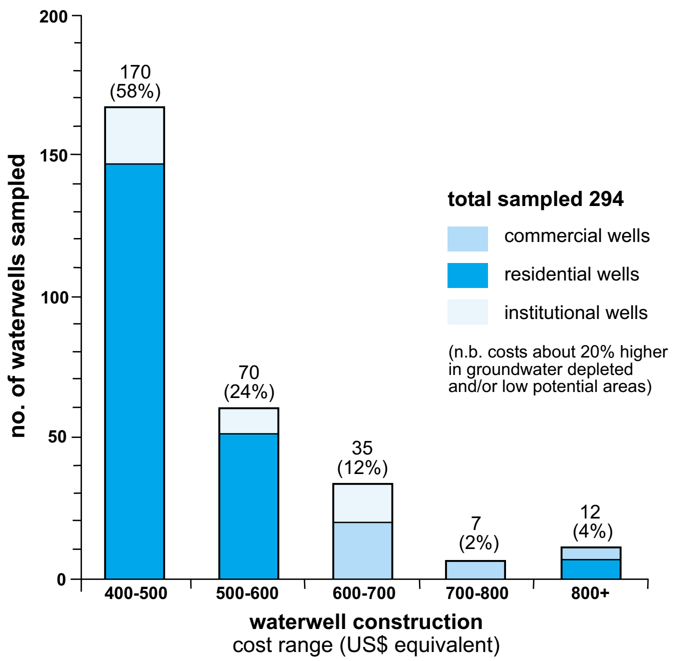
- The unit capital investment on water well construction ranges from IRs 15-45,000 (US$ 330-1,000) with an estimated average of IRs 17,250 (US$ 380) (Figure 4) – interviews with drilling contractors confirmed these observations. The costs of bore well drilling have been stable in recent years at rates of IRs 425-450/m (US$ 9.4-10.0/m) at the end of the wet season increasing to IRs 500-525/m (US$ 11.1-11.7/m) in the hot dry season. All of the above adds up to substantial private investment across Aurangabad City and a projection from the sample data indicates figures of IRs 80-100 (US$ 1.8-2.2) million in wards with 'groundwater resource depletion' and about 60-65% of this value in 'groundwater resource adequate' wards.

- The main operating expenditure of groundwater users was on electrical energy for pumping – and users reported costs of IRs 500-3,000 (US$ 11.1-66.7) per month on electricity bills, rising during the hot dry season. A review of recurrent expenditure of users for water-supply reveals groundwater costing IRs 7-11/m^3 (US$ 0.15-0.24/m^3) as compared to tankered water sales at around IRs 60/m^3 (US$ 1.33/m^3). The highly-subsidized municipal piped-supply (based on fixed annual charges for almost all domestic users) is equivalent to IRs 1.35/m^3 (US$ 0.03/m^3) – although in reality the AMC incurs operation and maintenance costs of about IRs 7.20/m^3 (US$ 0.16/m^3) making the real cost compatible with that of private groundwater use. A proposal of 2003 for increasing AMC connection charges from IRs 1,200 to IRs 1,800 (US$ 26.7-40.0) for residential users and from IRs 5,300 to IRs 6,500 (US$ 117.8-144.4) for commercial users has not yet been implemented.

- Anticipating the need to raise much increased revenue for a new municipal water-supply scheme, the AMC has been trying to introduce volumetric charging (for a significant proportion of its current 90,935 domestic and 883 commercial connections) – but has encountered much popular resistance as well an inadequate metering network. Clearly the widespread established access to groundwater via private water wells will also act as a serious constraint to the degree that AMC could realistically raise and recover their water charges.

- Users from all categories unequivocally expressed their preference for municipal water-supply for two main reasons – (subsidized) low price and (perceived) good quality (they considered groundwater as 'too hard' for washing purposes). More than 80% of correspondents (except for small business units) expressed 'willingness to pay' for an assured and adequate water-supply from the municipality – indicating an 'affordable connection charge' between IRs 500-2,500 (US$ 11.1-55.5) and an 'acceptable recurrent cost' of IRs 100-300 (US$ 2.2-6.7) per month. Residents from 'groundwater resource depleted' areas were willing to pay more than those in 'groundwater resource adequate' areas.

Figure 4: Current costs for private water well construction in Aurangabad City

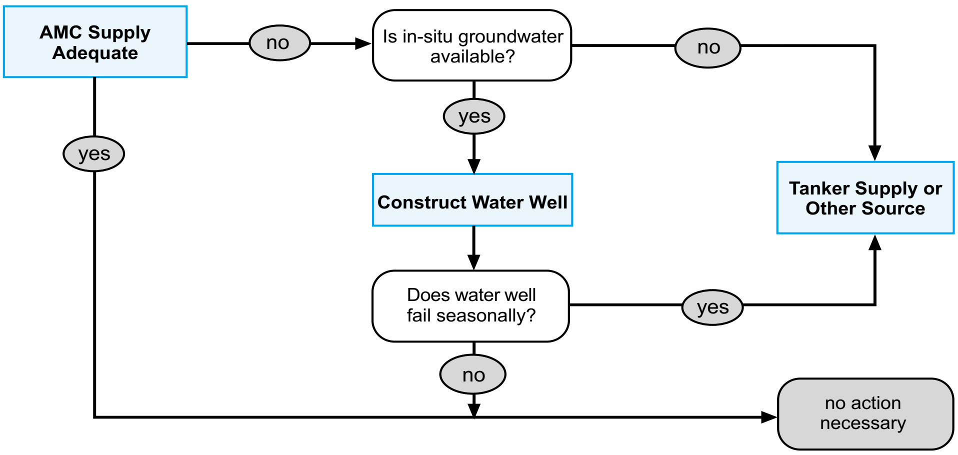


SUMMATION WITH POLICY IMPLICATIONS

- Groundwater resources currently provide a very significant proportion of the total water requirement of Aurangabad City and large private investments have been mobilized for water well construction. This is believed to be the situation in many cities of 'hard-rock peninsular India' despite the strictly limited groundwater potential of the associated aquifers and serious depletion that often accompanies such intensive use.

- The choice of groups of residential users to drill private (or community) water wells (Figure 5) is essentially independent of the level of groundwater availability (both in a well yield and sustainable use sense) – and is primarily a 'coping strategy' driven by the inability of the municipal water-supply utility to meet their requirements and the fact that shallow water wells (even if only of very modest yield) are now of relatively low-cost and provide a much more economical source of supply than that purchased from water tankers.

Figure 5: Water-supply investment decision path for private residential user

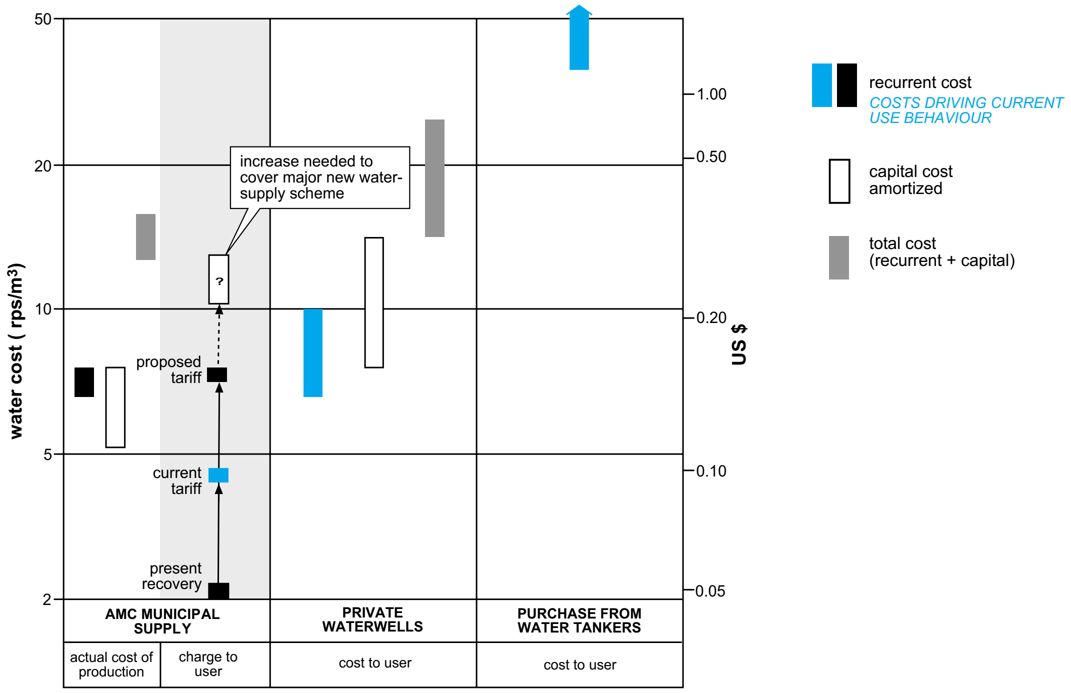


- A detailed engineering economics evaluation of water-supply costs has not been undertaken but indicative relative costs (Figure 6) demonstrate this point and suggest that private water well use is likely to be competitive with the full economic cost of a major municipal water-supply scheme based on imported treated surface-water from a distant source.

- The question of water-quality hazards associated with inadequate sanitary completion of urban water wells to prevent drainage ingress and/or more generalized urban groundwater pollution will have sooner-or-later to be taken into consideration. But a substantial and systematic sampling/analytical survey will be required to assess the level of such hazards (since very few reliable data are currently available) and it was not found feasible to undertake such work within the current investigation. Having said this there is also equally serious concern that the microbiological and chemical quality of the municipal water-supply itself may be seriously compromised as a result of consistently low pressure and intermittent flow, and that water-tanker supplies are not subjected to sanitary inspection and control.

- It is concluded that the planning of future water-supply of the many Indian cities similar, in water-supply terms, to Aurangabad should not ignore the role of private self-supply from groundwater – and the following policy recommendations stem from this reality:
  - access to groundwater (and its relative cost (Figure 6) and reliability) will unquestionably affect residential users 'willingness to pay' for improved municipal supply and thus the viability of major investments in new schemes to import and treat water from distant sources
  - moreover, when planning the provision of mains sewerage improvements the prevalent use of groundwater from private water wells should be taken carefully into consideration volumetrically and ways of independently charging for sewer use introduced
  - in evaluating the benefits and risks of in-situ groundwater use, microbiological and chemical quality should be a factor that is taken into consideration and appropriate advice provided – but until much more data on both the quality of groundwater obtained from adequately-constructed water wells and from municipal water-supply connections needs to be generated

Figure 6: Indicative relative costs of main sources of Aurangabad City water-supply



- the use of urban groundwater is in certain ways logical, especially for meeting the demand for sanitary and laundry purposes, where a more expensive treated water-supply is not justified – if this option is promoted in areas with adequate groundwater resource availability, new municipal water-supply capacity could be focused upon groundwater resource-depleted areas
- municipal authorities should provide more fiscal incentives and technical guidance to promote private action on urban roof and paved area water harvesting and recharge enhancement, and for the reduction of groundwater pollution risk from wastewater disposal and the storage and handling of hazardous substances.

- However, there remains an institutional vacuum in India when it comes to urban groundwater resource use, which needs to be filled if realistic and robust policy formulation is to occur and be consistently pursued. In the case of Aurangabad City some form of standing committee or working group on groundwater use comprising members from AMC, MSWSSD and GSDA, would appear to be required.

Publication Arrangements

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