When pigs fly:
Citizens at the centre of
integrated urban water management

A report on Rainbow Drive Layout's efforts towards water sustainability

By

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Foreword: Citizens at the centre of integrated urban water management

The challenge of water governance in India today cannot be overemphasized. The Urban regions in India are growing and with it, urban water demand. Across cities and towns in India water governance is becoming a subject of debate. While investments in water infrastructure and institutional models of service delivery are being debated, cities continue to suffer water shortages and have increasing wastewater management issues. People of the city have responded to this situation on their own – various coping strategies have emerged and urban water markets are growing.

Bangalore is a particularly telling case of such a situation. *The single largest coping strategy of people in Bangalore has been recourse to groundwater.* With a political and ecological limit to what Bangalore can source from the River Kaveri, its current primary water source, the search for an alternative paradigm of urban water management is of paramount importance for Bangalore. The story that this report tells, that of a private gated layout in Bangalore called Rainbow Drive, perhaps has many lessons to teach. Above all it is a story that demonstrates that citizens and communities can become the centre of urban water management. Rainbow Drive can be interpreted as a story of how "coping strategies" – when adopted by a water literate citizenry with a sense of responsibility – has the potential to contribute positively to urban water management. The most important contribution this story makes is the larger questions it raises about urban water management for Bangalore.

- Are the "coping strategies" of Bangalore indeed the mainstream of its supply today with the formal institutional supply model a supplementary source? Does the scale of private investment in "coping strategies" far exceed public investment?
- Is there a paradigm where these coping strategies can result in a positive contribution to integrated urban water management?
- Is a water literate citizenry critical to achieve this? What is the role of communication for water literacy? How does one communicate to the citizenry to achieve water literacy?
- How does one leverage the sense of larger good and sense of collective responsibility in the citizenry? How does one harness local leadership?
- How should knowledge of geology and hydrogeology be brought to bear at the level of the citizen who uses groundwater?
- In Bangalore, does groundwater present a more economic source of water – both in financial and energy terms?
- Does groundwater also provide an opportunity to leverage private investment for public good?
- How critical is the role of good administration for water management – an administration that can measure and quantify water fluxes?
- What are the legal and institutional frameworks to achieve the above? Can our current institutions respond to the situation and function in this paradigm?
- How does one embed such a new paradigm into the overall system of governance in Bangalore and our nation?

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Abstract

Rainbow Drive (RBD) is a private, gated residential layout that is representative of an increasingly common land-use pattern in growing cities like Bangalore. Like many other private layouts, RBD is situated outside the reach of the city's water utility, and like other layouts, its residents were left to fend for their own water needs after the inevitable departure of the developer. RBD's Plot Owners' Association (POA) has responded to these tasks with longer-term sustainability in mind, rather than adopting reactive coping strategies. Led by one particularly water-conscious member, the POA has acted on the notion that water demand is the most effective rallying point for galvanizing action toward sustainability measures. Biome's analysis of these efforts has revealed much about the nature of demand in private layouts, as well as the possibilities and constraints of decentralized water governance. In this sense, RBD represents a desirable response of an urban community whose significance ought to be considered in the larger context of urban water management.

Biome Environmental first engaged with RBD after it was called upon by the POA member leading its water agenda to discuss rainwater harvesting with its residents. It quickly became apparent that RBD demonstrated the potential for a model of community action toward sustainable water management. In the absence of any institutional or legal framework to guide it, the POA undertook efforts for comprehensive rainwater harvesting implementation, restructured its water pricing scheme to recover costs and discourage wastage, enforced a ban on private borewells for the sake of the community borewell supply, and methodically approached new borewell exploration. In Biome's years of engaging with communities, this was the first layout we witnessed taking such a comprehensive approach to water management, and Biome thus took up the monitoring exercise in order to develop the full picture of RBD's water management regime and the lessons it might carry for other communities and even city planners. This document is a report of the findings from this investigation.

The RBD story represents impressive advancements and the exceptional challenge of remaking a community to exist in balance with its ecological limits. RBD has succeeded in enhancing the financial viability of its water management regime by doubling monthly revenues and meeting the need to recover its production cost of water and sanitation. This is a vast improvement over its past pricing scheme, though it is limited by the lack of a sinking fund that could accumulate savings for future capital or emergency expenses. It has also succeeded in raising water supply literacy with the residents, though this has not necessarily resulted in reduced demand, and its unsustainable groundwater extraction continues. There is also virtually no understanding among most residents or staff of the Sewage Treatment Plan (STP), and an independent analysis found the STP to be underperforming in terms of the infrastructure and output quality. On the demand side, Biome has identified a correlation between household water consumption and plot size. It is surmised that gardening and lawns are a key driver of the higher household consumption in larger plots, as they tend to have proportionally greater space dedicated to greenery. Verifying this hypothesis would be difficult without direct end-use metering, however, as an attempt to use consumer feedback to understand the break-up of

household demand revealed that consumers tend to underestimate their end-use consumption. Confirmation of this would suggest a potentially crucial role for treated sewage water to bring down the overall demand in borewell supply. Finally, Biome has extrapolated the layout's total water demand when at full occupancy, which will be vital to RBD's future water planning.

The monitoring exercise at RBD has illuminated a few critical points that are valuable in the larger context of urban water management. One such lesson is that the nature of demand in RBD – likely similar to those of other middle to upper income earning communities throughout Bangalore – is very different from the theoretical figure of 135 lpcd used by city planning agencies. The layout's per capita demand of 246 lpcd calls into question the usefulness of a single metric for projecting water requirements throughout the city, and perhaps suggests that improved city planning may be effected by a review of actual demand patterns for different segments of the urban populace.

Another contribution to the larger dialogue of urban water management is RBD's implicit acknowledgment of the aphorism "the great is the enemy of the good". RBD's actions to secure its water supply have not necessarily been preceded by any in-depth scientific or hydrological study. While the POA sought to inform its decisions by science, action has not depended on a total understanding of its groundwater. In contrast to the approach commonly recommended within the hydrogeological community of gathering macro-level data to inform large-scale interventions, RBD's efforts have centered around using readily available data on its demand to spur movement toward a new water management regime. Indeed, once these early efforts gained some traction, the focus has broadened to include supply elements that can enhance and expand these measures.

They did all of this in a context that would not be considered enabling. No laws or tax breaks supporting such efforts. Very few players in the market available to bring comprehensive thinking to water mgmt. and the paradigm of decentralized water mgmt is still in the nascent stages. How to create an enabling environment.

A final lesson of the monitoring exercise concerns the feasibility of RBD's efforts as a model of decentralized water management. RBD accomplished its water management reforms in a context without strong regulatory, legal or financial support from government and relevant agencies, and with few players in the market able to bring comprehensive thinking to bear on a strategy for decentralised water management. In spite of this, RBD has shown that community-managed watsan is possible, but is a great responsibility whose success is contingent upon time and technical capacity. Watsan management presents challenges, technical and social, perhaps unlike those of any other locally managed utility. Resolving these issues demands heavy investments of time, which can be difficult since most POA members have full-time jobs outside of their layout governance duties. And despite its forward thinking leadership, RBD is still dependent on outside consultants and operators to help determine and implement appropriate courses of action. The question remaining is how private actors and urban governance bodies can best serve communities like RBD to fill this vacuum?

The answer to this question lies partly in the wealth of knowledge that is a natural by-product of the work accomplished by the numerous independent players operating in the sustainable water sector. Engaging in this monitoring exercise has shown us at Biome the enormous value to which this knowledge can be put to further the understanding of Bangalore's urban waters along its scientific and socio-economic dimensions.

Pt. 1 – Introduction to RBD and the context for water management reform

Introduction

The Rainbow Drive (RBD) Layout is a progressive layout that has under an enlightened leadership with the will to bring about change, undertaken many "reforms" in the way it supplies and manages water. It is a private gated housing community that experienced water concerns similar to those of other layouts and housing complexes becoming increasingly popular and prevalent in the city of Bangalore. The Rainbow Drive Plot Owners Association (POA) has taken very seriously the business of managing its water as a finite resource. Some of the changes it has undertaken can be an example for other similar housing complexes to emulate. The RBD layout engaged with Biome Environmental Solutions to implement some of its changes. Subsequently with the support of Arghyam Foundation, the RBD POA and Biome has engaged in a monitoring exercise in the layout over approximately a year to understand some of the issues in more detail and evolve learnings for dissemination to a larger audience.

Every attempt has been made to present the activities, key learnings and analytical perspectives in the body of the document while media coverage, substantiating data, calculations etc are presented in the appendix. The document represents the key learnings from the monitoring exercise carried out between Nov 2008 and Nov 2009.

Biome has already "abstracted" the totality of the intervention in such a community into a broad process that any other such community will need to follow with context specific tailoring. This process provides both technical and peoples' angles as well as connects it with larger issues of water management in the city. This "process document" has already been published in www.citizenmatters.in as a four part series. Links to this series as well as other media articles can be found in Appendix 1.

Rainbow Drive history: Context for reform

The 34-acre campus of Rainbow Drive layout was developed ten years ago with 360 plots and six community borewells. Only two of the borewells were used, with the others intended as backups. The current occupancy is 222 homes, 78 of which are filled by tenants and the remaining 144 are filled by the owners.

In the early years of the decade, some residents noted that water wastage throughout the layout was rampant – many people hose-washed their cars each morning, overhead tanks at the layout and household level overflowed with regularity, water was used indiscriminately by construction crews building new homes, and household construction household sumps overflowed during the due to defective float valves that were not promptly replaced.

Starting two to three years ago, residents reported the borewells generating more sand and hard water. Meanwhile, the residents grew aware of neighbouring layouts and apartments running into problems of water scarcity. The southeastern region of Bangalore was coming to be regarded as the "waterless Colony". The borewells of a nearby apartment building with 551 flats had gone completely dry, and the POA was purchasing 100-150 water tankers every day to meet its needs[1].

Aside from the financial implications, some residents recognized that becoming dependent on water tankers would be a much greater inconvenience to its residents than those of some neighbouring apartments and even some layouts. Whereas an apartment building's water supply is stored in a few centralised sumps that can be managed by the property staff, there is no central RBD sump. Rather, each resident has a private sump, and therefore each household would have to coordinate their own tanker delivery for when their supply runs low.

At the same time, flooding was a growing water management challenge. Rainbow Drive, like many other Bangalore developments, was built in the midst of a natural water drainage path that led to frequent flooding. The flooding was even worse for the villagers outside the layout, because Rainbow Drive's peripheral wall effectively dammed the floodwaters. During one heavy rainfall, the homes outside the layout were completely submerged in the floodwaters, prompting the villagers to knock down the peripheral wall. Within a half hour, Rainbow Drive's front gate was flooded up to five feet deep, and residents were unable to exit the layout for work.

As these concerns grew, residents grew unsatisfied with the ongoing layout management by the developer, and formed the Rainbow Drive POA in 2004 to manage their common resources.

Role of the POA

The POA is a registered society with 12 elected members. It was formed in September 2004, and was established with the objectives to ensure the orderly maintenance of the layout, to maintain security and the peace within the layout, to safeguard the interest and rights of individual plot owners, and to maintain civic and other infrastructure facilities of the layout.

The POA is vested with the authority to create rules regarding its objectives that apply to all Rainbow Drive residents. New rules and policies are passed by vote, and though not required for passage, consensus is strongly preferred. The reforms are then typically communicated to the layout residents via circulars distributed by hand to residents'

[1] Charumathi Supraja, "Going from tanker to tanker," *Citizen Matters*, April 1 2008, 2.

homes and also emailed to a Yahoo group established for residents, with a mailing list of approximately 150 people. If there is a likelihood of debate over a new rule, then the POA allows several weeks for resident feedback and revisions if required before activating the rule.

The RBD POA's efforts to manage its water resources began in earnest in 2006, two years after its establishment. The time gap is due in part to the POA's discovery of the difficulty in running a layout and the learning curve involved therein. By 2006, however, a situation more amenable to water management reform had arisen. Concerns about the community's borewell supply and the water scarcity facing neighbouring layouts persisted. As more residents moved in, they increased the pumping load of the borewells, leading to more frequent breakdowns.

A group led by one resident particularly committed to reforming the layout's water management practices ran for the POA as a team in 2006. Upon being elected, they enacted a number of innovative practices intended to increase the efficiency, equity and potentially even the sustainability of their water resources.

Due importance must be paid to the fact that the overall impetus for water management reforms originated with this individual resident. One of the other POA members stated that he joined the POA essentially to support this leader's effort. However, all members agreed that it was necessary for people other than this leader to actively support the reforms with other residents to give the impression of a broad base of support.

It is noted that there is disagreement between POA members about the legal standing of its rules. Determining the legality of its rules will require further investigation at some point in time. The implications of such an exercise are profound. If in fact the rules carry the weight of law, then this could, among other things, potentially grant the POA certain recourse in dealing with uncooperative residents. In the case that the POA has no legal authority to make decisions regarding water and sanitation services, then it is the coupling of social pressure with the democratic legitimacy attributed to POA decisions alone that can uphold these reforms. The legal standing of the reforms also carries strong implications for how replicable they may be in other contexts.

Role of the layout staff

The layout staff is the administrative arm of the POA, in that it carries out any management-related activities determined by the POA. The staff includes an estate manager, an assistant estate manager, a plumber, and several labourers. The estate manager has a seat on the POA.

The assistant estate manager had been hired in part to fill the role of a water management supervisor. In his 60-hour work week, fully 24 are spent managing the layout's water infrastructure.

In addition to executing the POA's new water initiatives, the staff manage the layout's water infrastructure. That includes the operation of the two Sewage Treatment Plants and the two-three active borewells supplying the water towers, which then distribute water to the sumps of layout owners. Three times a week, the water is supplied twice a day, and the rest of the week it is supplied only once. The tasks required for the borewells and water towers include opening and closing the water tower valves before and after the scheduled water distribution, and switching the borewell operation from automatic to manual on days when water is distributed only once so as to stagger the pumping throughout the day and allow the borewell motor to rest.

Pt. 2 – Integrated Water Management Interventions

The POA enacted each of the water management-related initiatives described below. The reforms emphasize groundwater and demand management. The POA envisions that it will focus on wastewater management in the next phase of reform. The salient actions undertaken by the POA are as follows.

1. Block the digging of private borewells

Even before the involvement of the POA, one of the earliest moves Rainbow Drive residents took toward achieving water sustainability was to ban the digging of private borewells. This originated with the developer's initial encouragement that residents depend on community borewells alone. When some residents sought to sink private borewells, the POA and other concerned residents insisted that private borewells would increase water wastage and reduce the community borewell yields. At one point a group of residents prevented a borewell truck from entering the layout. The POA called upon a hydrogeologist who reported that the community could sustain 10-15 borewells at most, and any more would lead to faster depletion of the water table. This argument eventually prevailed.

2. Data collection to discover consumption and supply patterns

Once the reform-oriented POA was elected, the committee member who championed its water efforts took a year to thoroughly investigate the layout's water management practices and their sustainability. The data from this exercise would inform the process of developing necessary reforms.

The most critical element of his research was the fact that households from the early days of the layout had been required to install consumption meters that measure the quantum of water entering one's sump each day. The meters were then recorded by one of the layout staff every 2 months in order to calculate each household's water bill for that cycle. A common adage in the water management sector is that you can only manage that which you measure, and this data – though sometimes faulty do to malfunctioning meters and lack of incentive to repair meters in a timely fashion – proved to be the cornerstone of the consumption study.

One major finding was that the four unused borewells, intended as backups the two functional borewells, were in fact dry. Another analysis of consumption patterns revealed that roughly one-third of the residents consumed 50% of the layout's water.

Another significant finding was that an enormous amount of water was used for new home construction. Plot owners were not present during construction, and were unaware of the amount of water consumed in the building of their homes. Construction crews had no incentive to save water, and consequently consumed thousands of litres daily. Moreover, this water was potable, which is not necessary for construction.

The most significant finding was that the water pricing was far too low. The flat rate of Rs. 6 per KL did not provide any incentive for water conservation. The POA member also found that water tariff only accounted for the electricity used to pump borewell water. It did not account for the maintenance costs of bore wells, or the costs of cleaning the water tanks, waterproofing leaks, or fixes to faulty piping. Most importantly, it was found that the cost of treating sewage was not accounted in the household water bill at all. Rather, sewage treatment costs, which are much more costly than supply costs, were rolled into the layout maintenance fee that was divided equally among residents. This was inequitable billing, however, since the sewage output per household is proportionate to its water consumption. The POA determined that the true production cost of water was Rs. 16-17 per kilolitre.

In addition to the under-pricing of its water supply and treatment, the payment recovery was poor due to defaulting and lax enforcement of bills. These two factors led to cash crunches in 2007 and 2008 that required the POA to break its Fixed Deposits.

3. Banning bore well use for construction

New construction projects were required to source their water from outside Rainbow Drive. Most typically they would purchase tanker water, whose cost would quickly catch the attention of homebuilders and help ensure more responsible usage.

This decision was essentially necessitated by the fact that construction is recognized as a commercial activity, and all activities tied to it are also commercial, such as electricity consumption. This was discovered when the electricity utility conducted an energy audit of RBD, and found that borewell water was used for home constructions. Since the POA could not identify the specific energy consumed by the borewells for pumping to homes under construction, the utility billed all of RBD's electricity for that month at the commercial rate. This caused the bill to spike by 25%, and the ban on borewell use for construction was passed shortly thereafter.

4. Implementing rainwater harvesting at household and community levels

The POA engaged with Biome to develop rainwater harvesting (RWH) strategies. Biome proposed a community-level approach of implementing groundwater recharge wells in targeted locations to reduce flooding and replenish the aquifer. Biome also proposed that interested households invest in rooftop rainwater harvesting systems for direct storage and use. Eventually, some 5 households implemented rain barrels to collect rooftop runoff, and individual homeowners and the POA collectively invested in 59 groundwater recharge wells of various sizes with a total holding volume of 2,19,000 litres. It is estimated that given Bangalore's rainfall patterns, 9.942 million litres of rainwater is recharged to the ground each year. The map on page 15 presents the spatial distribution of the recharge wells throughout the layout, along with the other water-related infrastructure.

5. New water pricing scheme

The POA determined that unless water was priced appropriately, residents would not value it. They developed a block tariff that accounted for the true production cost of water supply and sanitation. Since average household use was between 24 and 30 KL, the first 30 KL would be priced at cost, which averaged out to Rs. 17/KL.

Rainbow Drive water tariff slabs

Water consumption level	Tariff
First 10,000 litres (0 -10 KL)	Rs.10 per KL
Next 10,000 (10 – 20 KL)	Rs.15 per KL
Next 10,000 (20 – 30 KL)	Rs.25 per KL
Next 10,000 (30 – 40 KL)	Rs.40 per KL
Above this > 40 KL	Rs.60 per KL

The highest pricing slab is set higher than the cost of tanker water to convey that the layout is not interested in supplying large amounts of water for individual households. Rs. 100 savings were built into the pricing slabs for those homes implementing groundwater recharge wells in order to provide an incentive for their uptake. The POA enforces timely payments by penalizing delinquency at Rs. 10/day. Penalties also apply when a household directs its rainwater into the layout's sewerage or if it fails to recalibrate or replace a faulty meter one month after the malfunction is noticed.

The pricing was intended to accumulate savings in order to pay for periodic repairs to the layout's sewage treatment plant, water tanks, etc. However, the POA has since noticed the pricing should be even higher to account for repairs as well as new capital expenditures such as the digging of new borewells, and they will need to revisit the pricing slabs in the future.

The POA changed the billing cycle from two months to one to give residents a chance to make any adjustments to household demand or faulty infrastructure before their water bills became too expensive. After the first month of the new billing scheme, it quickly became apparent that many houses had faulty water meters, as some readings were strikingly high or low.

One immediate benefit of separating water and sanitation pricing out from other layout fees was that it led to a rational restructuring of the other layout expenses. Once sanitation expenses were removed from the general maintenance fee, it became apparent that each of the expenses in the layout – such as landscaping, cleaning the roads, staff salaries and security – were independent of a resident's plot size or behaviour, and therefore they could be averaged equally across all plots.

6. Effectively engaging with the layout residents

The POA recognized the critical importance of communicating the proposed reforms to the entire layout community and gaining their support. One-on-one interactions were considered the most effective, though the POA members also distributed circulars and hosted a resident meeting with Biome to introduce the community to the RWH concept.

More than one POA member asserted that being able to present the economic logic behind the pricing slab scheme was critical. In preparation, the POA member leading the water management reforms developed models that could clearly communicate how the production cost of water and its disposal was found. One POA member stressed that because most RBD residents are in the managerial cadre, they would scrutinize the models to see that enough analysis had been done and that the conclusions were sound. Any holes in the logic would have failed to convince the bulk of the residents.

Two other arguments were emphasized during the process to convince residents of the necessity for reform. The first was to explain how the inconvenience and expense incurred during bore well repair days would only be compounded if they went dry, because the homeowner would have to manage the burden of coordinating their own tanker orders. The second argument focused on residents' sense of fairness by explaining that the old pricing scheme averaged out the cost of sewage treatment evenly amongst all residents, regardless of how much wastewater they produced. Under this scheme, most residents are effectively subsidizing their neighbours' excessive water use.

Two POA members commented that ultimately less than 10% of the residents objected to the new pricing scheme, and that a general body meeting was not even necessary.

7. Additional investments in water infrastructure

In 2008 and 2009, the POA commissioned surveys by a borewell specialist, a water diviner, and a hydrogeologist for the purpose of pinpointing new borewell locations. The rationale for new borewell exploration was that the layout was entirely dependent on only two borewells, and a back-up borewell was deemed a necessity in case either of them were to experience technical or supply problems. Additionally, the POA noticed that the supply from the two borewells was insufficient, as people at the end of the distribution network were not receiving as much as other residents.

Consequently, three borewell locations were identified and attempted. One attempt failed without striking water. The other two wells struck water, though the yields were relatively low compared to the other yielding borewells. Due to the high cost of sinking a motor and laying the water pipeline from the borewell to the overhead tank, only one of the two wells was connected to the system. The other well will serve as a backup should it become necessary.

In addition to the digging of new borewells, the POA invested in a process called hydrofracturing on one of its inactive borewells at Biome's suggestion. Hydrofracturing involves the injection of water at high pressure into the borewell, which blows out any silt blockages that can accumulate in the fissures supplying the borewell's water. The hydrofracturing took place in mid-2009, and a yield test in November 2009 found that the borewell yields approximately 3,000 litres per hour for four hours at a stretch. Upon reviewing the favorable results, the POA plans to invest in a new motor for the borewell and connect it to the water delivery grid by January 2010.

Several additional investments in water infrastructure resulted from Biome's engagement with the POA throughout the monitoring exercise. These include the purchase of source meters for the layout's yielding borewells and investments in renovating the two underperforming Sewage Treatment Plants. There is more information on these investments and the reasoning behind them in the following sections.

The following page contains a map of the water infrastructure throughout Rainbow Drive Layout.

In total, the RBD POA and individual residents have collectively invested approximately Rs. 17,25,000/- toward sustainable efforts.

Private Investments Leveraged		
Collective investment (recharge wells	625000	
Individual investments	750000	
Investment into maj for STP	300000	
Investment into water meters	25000	
Investment into hydrogeology study	25000	
	1725000	Rs towards water literacy and sustainability


RainbowDrive
LEGEND
10ft Recharge Well
20ft Recharge Well
30ft Recharge Well
Water Tower for Phases 1 and 2
Water Tower for Phases 3 and 4
Inactive Borewell
Yielding Borewell (No. 8SWP5329)
Yielding Borewell (No. 8SP6686)
Yielding Borewell (No. 8SP165)
New Yielding Borewell
Revived Borewell
Sewage Treatment Plant for Phases 1 and 2
Sewage Treatment Plant for Phases 3 and 4
Phase 1
Phase 2
Phase 3
Phase 4
13 CROSS
5 MAIN
40 FEET ROAD
30 FEET ROAD
35 FEET ROAD
30' ROAD
1 ST MAIN
Club House
Park
S
E
W
N
designed & printed by
Padmakala creations
Sarjapur Road

Pt. 3 – Demand: understanding consumer behaviour and attitudes at RBD

RBD's water demand

This section attempts to establish a basic understanding of water demand in Rainbow Drive. There is also an attempt to correlate this demand data with a possible ecological framework for water management. Issues of production cost of water and an analysis from an economic perspective will be dealt with separately.

Note on data:
The data used for the analysis presented is:

a) Obtained from consumption meters of the households
b) Obtained for the period February 2008 to February 2009
c) Corresponds to data *after* the implementation of the new pricing scheme, as the data during this period is more reliable.
d) Corresponds to a period of monthly billing cycles.

The Tariff plan during this period of Rainbow Drive is:

Consumption slab	Tariff
Slab 1 (0-10KL)	Rs. 10
Slab 2 (10-20KL)	Rs. 15
Slab 3 (20-30KL)	Rs. 25
Slab 4 (30-40KL)	Rs. 40
Slab 5 (>40 KL)	Rs. 60

Demand: Key Metrics
Based on the analysis (Refer to Appendix 2: Demand – Key Metrics) the following are the key metrics

Metric	Measure	Remarks
Current average monthly layout consumption	6455 Kilo Litres / month	Corresponds to 220 households. There are a total of 360 plots in the layout.
Current average monthly household consumption	29.5 Kilo Litres / household / month	Calculated based on current monthly average total and current no of households
Current daily per capita consumption	246 Litres / capita / day	Calculated based on 4 members per household – which matches Rainbow Drive's average.
Projected average monthly layout consumption at full occupancy	10610 Kilo Litres / month	Projected based on the above per capita values for 360 households.

Demand: Distribution

Distribution of demand was analysed from two perspectives (Refer Appendix 3 for details):

1. With reference to the national urban water consumption norm of 135 liters per capita per day and the layout's average per capita consumption.
2. With reference to plot size of the different plots within the layout to see if any correlation exists.

Benchmark of consumption	No of households	Percentage of households
Up to 135 LPCD	32	14%
Up to 246 LPCD (layout average)	130	59%
Greater than 246 LPCD	89	40%

- The above indicates that most of the households have a demand much greater than the norm of 135 LPCD
- A significant 40% of the layout consume more than the layout average.

An attempt was made to try and correlate the latter of the above observations with the plot size :

<table>
<tr><th>Consumption slab (Higher than average layout consumption)</th><th>Plot sizes <= 1000 sq ft</th><th>Plot sizes between 1000 to 2000 sq ft</th><th>Plot sizes between 2000 to 3000 sq ft</th><th>Plot sizes between 3000 sq ft to 4000 sq ft</th><th>Plot sizes greater than 4000 sq ft</th></tr>
<tr><td>Slab 4 (30-40KL)</td><td rowspan="2">55 % of these plots falls into these higher consumption slabs</td><td rowspan="2">33% of these plots falls into these higher consumption slabs</td><td rowspan="2">32% of these plots falls into these higher consumption slabs</td><td rowspan="2">46% of these plots falls into these higher consumption slabs</td><td rowspan="2">60% of these plots falls into these higher consumption slabs</td></tr>
<tr><td>Slab 5 (>40 KL)</td></tr>
</table>

From the above it can be seen that the distribution of higher consuming households increases as the plot size increases, with the exception of the smallest plot sizes. Based on this, the following has been surmised:

a) Regarding the exceptionally higher percentage of high-consuming small plot homes, the smallest plots actually represent a larger plot that has multiple homes within it, but which share a single water meter and therefore show a higher consumption slab – these plots are therefore not representative of a demand trend correlating to plot size.

b) Larger plots consume more water, it is assumed, due to proportionally larger gardens/driveways. During the next phase, the contribution of gardening use to demand in these households will be assessed.

To test our assumptions of how water was being used at the household level, we selected five households for a more in-depth analysis of household end uses. Two participants were drawn from Slab 5, one from Slab 4, and two from Slab 2. The expectation was that the samples from Slab 2 would provide the benchmark of "normal" water consumption against which we could compare higher-end users. We also wanted to whether the nature of water use was different between high- and low- water users or if it was more a difference of degree.

The data for this household demand analysis was collected in the form of in-person interviews, on-site measurements, and an end-user questionnaire. A copy of the questionnaire listing all the data points captured from the participating households can be found in Appendix 4.

Unfortunately, the methodology was faulty in the sense that it was highly dependent on user feedback. The discrepancy between one the actual household consumption and the estimate gathered from one participant was 400 litres per day. The lesson this exercise seems to suggest is that end-users tended to poorly understand their own water consumption patterns. To develop an accurate picture of household consumption would likely require end-use metering or an extended data-collection training session for household participants.

<u>Analytical Perspectives and an Ecological Framework for water management</u>
The project layout demand in the "Key Metrics" table above shows that there will be a *64% increase* in demand for the layout once it reaches full occupancy. Given that this entire layout is dependent on groundwater resources, the key questions are:

a) Is this demand too high and unsustainable? What measures should be taken to bring net freshwater demand down?
b) Can current groundwater resources sustain the layout as it moves towards full occupancy?
c) How much more should be invested in recharge for longer term sustainability of these resources?

Some perspectives on the above questions are presented in the following two scenarios of RBD's water consumption at full occupancy:

<u>Scenario 1 assumptions:</u>

1. Per capita demand remains as they are presently at 246
2. Significant more investment in Rooftop rainwater harvesting, Recharge and wastewater reuse.
3. These investments are represented by % efficiency of capture of rainfall run-off from rooftops and other areas. Further all the gardening requirement reuses wastewater in this scenario

<u>Scenario 2 assumptions:</u>

1. Per capita demand is reduced to 135 LPCD

2. Significant increase investment in rooftop rainwater harvesting, groundwater recharge and wastewater reuse.
3. These investments are represented by % efficiency of capture of rainfall run-off from rooftops and other areas. Further all the gardening requirement reuses wastewater in this scenario.

Analysis of Scenarios 1 and 2:
A cursory analysis of Scenarios 1 and 2 reveals that reducing per capita consumption will have far greater impact on RBD's groundwater supply than investments in community-level sustainable water practices.

Scenario 1 shows that even if RBD accommodates its entire gardening demand with treated wastewater and harvests fully 80% of rainwater falling on rooftops and other surfaces, there will still be an annual overdraft of 32 million litres of groundwater.

Scenario 2 shows that a reduction in per capita demand to 150 lpcd, use of treated wastewater for all gardening needs, and more modest investments in rainwater harvesting will produce 2 million-litre net addition to groundwater supply.

The quantum of disposed wastewater in each scenario is of particular note, and may merit consideration for groundwater recharge if it should prove to be of sufficient quality.

Scenario 1 : Current Demand levels and Full Occupancy

Occupancy

		%	Total no HH
Occupancy for model		100%	360
Current occupancy		61%	220
Persons per household			4
Occupancy at 100%		100%	360

Demand

Total demand	10627	KL / month	or	130	ML / year
Per capita Demand	246	LPCD			
Gardening demand	25	LPCD	(assumption)		
Total Annual gardening demand	1080	KL / month	or	14	ML / year

Discharge

Discharge rate	80%	of non-gardening consumption	
Discharge	93	ML / year	

Land Use

Total Area of layout		34	acres	
Rooftops	60%	82416	sqm	
Other areas	40%	54944	sqm	

Rainfall Runoff

Rooftops	72	ML / year
Other areas	32	ML / year

Water Sources and Demand Match at an Annual Level

Efficiency of Rooftop Rainfall capture			80%
Efficiency of capture for Recharge			80%
Extent of gardening demand from WW			100%

Rooftop rainwater	58	ML / year
Gardening from wastewater	14	ML / year
Net groundwater dependence	58	ML / year
Recharge into ground	26	ML / year
Net annual groundwater overdraft	**32**	**ML / year**
Disposed wastewater	**79**	**ML / year**

Scenario 2 : Reduced Demand levels (150 LPCD) and Full Occupancy

Occupancy

		%	Total no HH
Occupancy for model		100%	360
Current occupancy		61%	220
Persons per household			4
Occupancy at 100%		100%	360

Demand

Total demand	6480	KL / month	or	79	ML / year
Per capita Demand	150	LPCD			
Gardening demand	20	LPCD	(assumption)		
Total Annual gardening demand	864	KL / month	or	11	ML / year

Discharge

Discharge rate	80%	of non-gardening consumption	
Discharge	55	ML / year	

Land Use

Total Area of layout		34	acres	
Rooftops		60%	82416	sqm
Other areas		40%	54944	sqm

Rainfall Runoff

Rooftops	72	ML / year
Other areas	32	ML / year

Water Sources and Demand Match at an Annual Level

Efficiency of Rooftop Rainfall capture			60%
Efficiency of capture for Recharge			80%
Extent of gardening demand from WW			100%

Rooftop rainwater	44	ML / year
Gardening from wastewater	11	ML / year
Net groundwater dependence	24	ML / year
Recharge into ground	26	ML / year
Net annual groundwater overdraft	**-2**	**ML / year**
Disposed wastewater	**44**	**ML / year**

Consumer response to new pricing policies

Reactions to the water pricing changes was divided, though in general the opinion was supportive. Some residents reported being "furious" upon reading the announcement of the price hike, though only a few posed strong opposition arguments on RBD's resident email listserv. Several who were unhappy with the changes to the pricing had accepted the logic behind the hike, though not necessarily the scale of the increase.

Residents interviewed did not report any reduction in consumption as a result of the higher prices.

Observations of household water uses

RO systems
As survey of the 85 households found that 54% use reverse osmosis (RO) systems for their drinking and cooking water, with an average estimated discharge output of 20 litres per household/day. Assuming the discharge estimate to be accurate, then RBD generates 8,56,000 of high TDS discharge annually from RO systems along. Approximately half of that amount is going toward gardening and car washing, with the other 4lakh litres going to the STPs. Full results from the RO survey can be found in Appendix 5.

The survey found that the residents made these decisions believing that their water is hard, a suspicion that was reinforced by the salespeople who sold them their systems. However, we tests taken on the layout's two active borewells reveals that the hardness levels fall below the desirable limit of 300 ppm.

Car washing
A theme that every resident interviewed raised was car washing. This was commonly noted as the single greatest behavior change toward water conservation taken at the household level. Most residents have drivers, who invariably used the hose to clean the owner's car in the mornings. A campaign was launched by the POA and other residents to encourage all residents to wash their cars less frequently and to instruct their driver to use buckets instead of hoses. Though a formal POA rule on the same was defeated, the campaign has clearly had a psychological impact on residents. The actual quantum of water saved by reducing the number of car washes and switching to bucket washing is presently unknown, though the assistant estate manager reported a noticeable reduction in the amount of water used to wash cars in the mornings as a result of a POA campaign to convince residents to use buckets instead of hoses for car washing and to reduce the number of days to wash their cars.

Household RWH

Samples of rainwater were taken from two 500-litre barrels at different households – one household was tested in May, August, and September 2009, and the other household was tested in May and September 2009. The samples were submitted to a lab for potability testing. Both results from the May test were shown to be potable after treatment for bacteria (boiling, Aquaguard). One household's rain barrel was empty in August, but the other home's sample was shown to be potable, and an H2S strip test to check for the presence of E. coli or Faecal coliform was clear.

In September, the rains had recently filled both barrels, and though the overall water quality was good in both samples, both were deemed not potable. One sample was ruled not potable because of the hazy color of the water, though the bacteriological and chemical analyses were clear. Our suspicion is that the color is related to the fact that runoff enter the rain barrel directly without any filtration or first rain separation, so when a sample is taken recently after a rainfall, the silt and organic matter in the water will have yet to have entirely settled to the base of the tank. The second rain barrel was deemed not potable due to high iron content, though the other parameters, including bacteriological contamination were clear. The high measurement was inexplicable, however, since the catchment had no presence of rusting or other sources that could contribute iron.

Though the samples were not uniformly clean, both homeowners were impressed with the overall water quality of their rain barrel water, and expressed interest in exploring the possibility of collecting more water from their terrace and directing it into their sumps after filtration.

One other aspect of household RWH use was observed during a survey of the open wells throughout the layout carried out in September 2009. The surveyor found that five residents had converted small recharge wells on their properties into rainwater sumps to use for irrigating their gardens. Further investigation of this phenomenon is warranted to determine why the wells were converted and how the residents have been using and maintaining the sumps since the conversion.

Ban on private borewells &
Ban on community borewells for construction

Each of these measures were uniformly supported by those interviewed. Every respondent was in favor of the restrictions on private borewell exploration, and most were strongly supportive of the notion to strictly maintain the practice of only relying upon community borewells. The belief expressed was that private borewell exploration would lead to indiscriminate consumption and thus dry up the water sources at a much faster rate than if all water was sourced collectively.

Pt. 4 – Supply: understanding RBD's groundwater supply and service delivery

Groundwater dependence and management

RBD is completely driven by groundwater, which highlights the critical importance of sound groundwater management. An overall groundwater management regime at RBD can be informed by an understanding of the borewells and their behavioural characteristics, an understanding of the hydrogeology of the area and the overall economics of groundwater-based water supply. This section captures data and presents some analytical perspectives around these issues. It also presents some key learnings from the process of arriving at this data and analysis. While the findings present a clear direction for progress, it must be noted that the data and analysis would require additional efforts to bring to completion.

Current infrastructure

The map on page 15 above points out the yielding and dry borewells present in RBD. These borewells pump water to two centralized overhead tanks handling distribution to different parts of the layout. The water from the overhead tanks is then released to the households as per a water release schedule. A pipe network takes this water to the household sumps, where each household is consumption metered. The households are then billed as per the Tariff regime described above on a monthly cycle.

Installation of source metering

To establish a clearer understanding of the borewells, their relative contribution to the yields and costs of supplying water to the layout, Biome worked with the POA to install source metering of the borewells. This was done completely at the cost of the POA.

Two source water meters were installed to the two highest yielding borewells. However technical problems were faced with these water meters – they kept getting blocked / jammed by sand particles that the borewell pumped out. Subsequently filters were installed on the source meters and its performance is now being monitored. However due to these technical problems faced, the estate management staff has not been able to collect and maintain data regularly from the source meters. Some persistence and talking to the POA is necessary to embed the practice of maintaining the source water meter and maintaining its data.

All borewells in Rainbow Drive already had separate electrical metering.

The following you tube movie gives the installation process the first time around:
Electrical and Water Metering of borewells

The following are some photographs of the same (source meter and filter).



Borewells and Pumping from the Borewell

Currently RBD's water is dependent on three critical borewells. The pumping schedule of the borewells and the water release schedule to the households is provided in the Appendix 6. Different borewells are also named in the Appendix 7.

Of the three yielding borewells (8SWP 5329, 8SWP 6686 and 8SP 165) two borewells (8SWP 5329, 8SP 165) contribute most significantly to the total volume of water pumped. They also represent the major electricity consumption for pumping. However, as source metering was not completed and faced technical problems during the period of the study, data on individual borewell contributions to the total quantum of water pumped is not available. However, individual electricity consumed is available.

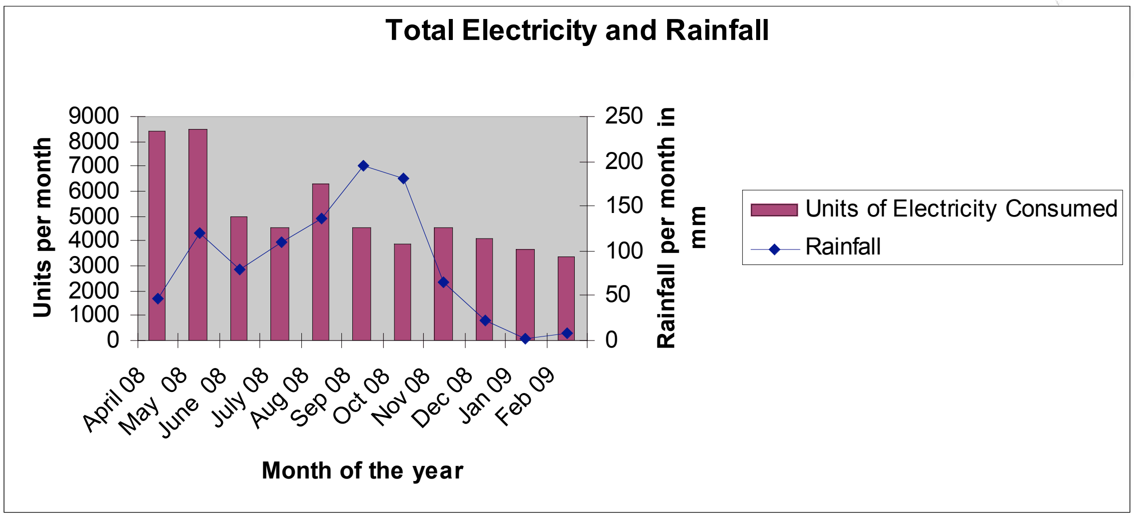
Based on the above data, an overall analysis of pumping energy consumed has been done. The below graphs represent three metrics. Before getting into the metrics themselves, a short note on the data used is warranted.

a) All electricity consumption data has been compiled based on real data during the period from electricity bills of the various borewells.
b) Since reliable data from the source metering is absent, all water consumption data has been based on consumption meter readings during the same period. This data is however reliable due to the frequent maintenance of consumption meters.
c) The consumption metering data runs on a monthly cycle starting in the middle of each month. However, the electricity consumption data runs on a monthly cycle starting beginning of each month. For this reason, the monthly consumption data for each month has been halved and each half apportioned to the appropriate month of the electricity billing cycle.

The tabulation of all the data is available in the Appendix 7. Three critical metrics, their relevance and questions they raise now follows:

I) Total energy consumed for pumping and its monthly variation

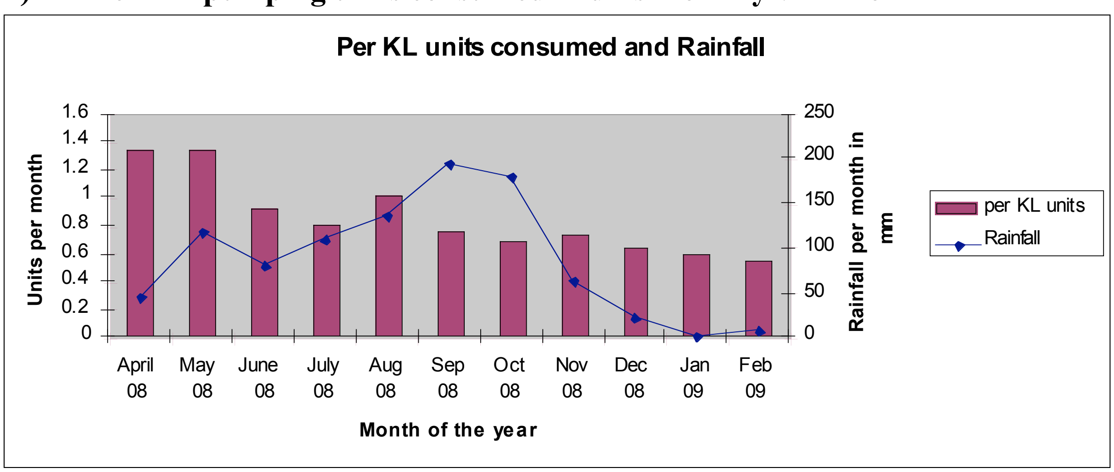
The table below provides the variation of pumping units consumed over the year. Overlying the bar graph is the rainfall pattern (average in Bangalore).



From the above table it is clear that –

a) There is an inverse correlation between rainfall and pumping units consumed. The total electricity consumed reduces on high rainy months and those that immediately follow it. The electricity consumed is highest in April-May when pre-monsoon is setting in but these represent the months with the longest gap in rainfall. (Variation from 3350 units to 8400 units)
b) It must be remembered that the demand across the months are not uniform and therefore while the above is useful in understanding pumping units consumed across the year, it does not yet reflect changes in demand across the year.

II) Per KL pumping units consumed and its monthly variation



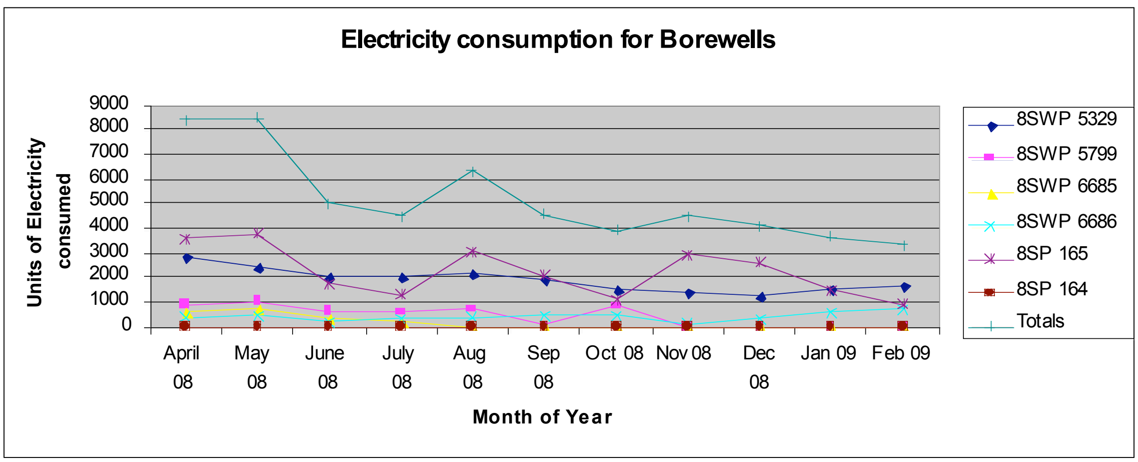
From the above table it is clear that:

c) The inverse correlation trend between rainfall and pumping units consumed in the total pumping units consumed is also displayed in the Per/KL units consumed !!!. This metric factors in the variation of demand across the months. The variation is between 0.55 units / KL to 1.35 units / KL. i.e. the per KL units consumed is more than doubling during April / May.

d) However, the above is a result of aggregating volume discharges from different borewells and aggregating the units of electricity consumed. Therefore this correlation can be due to one of two reasons –
   - Possibility 1: Rainfall is resulting in changing water tables which is resulting in change in per/KL pumping costs. However this is strange given that a given borewell installation has a fixed discharge pump working against a constant head across the year. This needs further understanding of pump behaviour vis-à-vis water tables. Does water table changes actually affect pump discharge?
   - Possibility 2: Since this is based on aggregate data and not on individual borewells, during the non-rainy seasons the relative contributions of different borewells is different. i.e. there is perhaps a greater reliance on a specific borewell which is affecting the pattern of per KL costs.

The above needs further investigation and greater knowledge on the depth of each of the borewells and the depth at which their pumps are hanging. The above remain hypothesis and need to be verified. These borewells are old, the POA and the estate office have clearly stated that they do not have reliable information on their depth etc. Getting this information will need its own investigations.

III) Electricity consumed by individual borewell and its monthly variation



From the above table it is clear that:

a) The variation of pumping electricity consumed across the year for different borewells are different.
b) A comparison between 8SP165 and 8SWP5329, the two highest contributing borewells, shows that the variation in electricity consumed in the former is far greater than the variation in electricity consumed in the latter. The former is influencing the total electricity consumption curve significantly.
c) The above is of special relevance in the light of understanding Metric II above.

An overall perspective from the above three metrics vis-à-vis water supply and its economics is:

a) Data of depths of borewells, depths at which pumps are installed and their relationship with water table is critical to understand. Source metering of water is critical for this. In general on the ground, such critical data is lost as in Rainbow Drive. This data can help make more economic choices on water, understand borewell behaviour and thereby maintenance *and* help in correlating investments in recharge to borewell performance.
b) An understanding of local hydrogeology would contribute greatly to the above analysis.
c) We also hope that this will lead to certain generic understandings that can help make economic and ecological decisions of ground water and ground water management independent of studies such as this conducted at every site.

Production cost of water

The production cost of water at Rainbow Drive was arrived at considering the complete cycle of water i.e. right from pumping the water out from the borewells to treating wastewater and disposing the wastewater. Calculating the production cost of water requires the incorporation of all capital and running costs to the layout's borewell, STP and other water infrastructure. Biome has compiled every expense from 2006 to the present, and processing these along with the consumption data to determine the cost of each KL's supply and disposal.

The full details of the calculation of production cost are available in the toolkit "Calculating the production cost of water", which will assist other communities in assessing the ongoing performance of their own borewells.

The production cost calculated has been based on:

a) Actually incurred costs for under various headers during the study period. The headers include Pumping costs,
b) Based on actual demand during the same period.
c) Projected costs for maintenance of Rainwater harvesting wells.
d) An allocation for a sinking fund towards capital recovery and water security costs.

Broadly the production cost is broken into two components:

1. Operations and Maintenance costs: This factors in costs incurred to actually achieve the supply and distribution of water and treatment and disposal of waste water. It includes pumping costs, cost of maintaining the infrastructure, costs incurred in paying out STP (Sewage treatment Plant) operators, maintaining STP infrastructure. It also includes projected costs for maintaining the POA's (collective) investment in Rainwater harvesting – essentially that of maintaining wells. This also apportions salaries paid out to Estate management personnel towards their efforts for water operations.

2. Sinking Fund: This is designed to factor in three critical aspects of water management that will not be reflected in operating costs. They are –
   - Infrastructure Capital cost recovery. In general this is achieved by amortizing the capital costs of the infrastructure over its life time. Inflation rate of interests can be assumed.
   - Foreseen costs of new water resources development given the ground water dependence (eg: drilling a new borewell). This is a strong function of local hydrogeology, condition of existing borewells and expected demand growth rates. However in principle it boils down to the cost of digging new *equally well yielding* borewells amortized over a time period which current borewells are expected to last before they stop yielding.
   - A planned creation of a fund for sustainability investments such as rainwater harvesting or waste water reuse.

The Production cost of water can then be used to arrive at a Tariff regime that factors all the above and keeps creating a sinking fund that can readily be used by the POA as a "water utility" for upkeep, investments and security measures for water.

When the above model was applied in the context of Rainbow Drive based on real costs incurred, the results were as below :

Per KL Production Cost of Water : Based on Total Average Current Monthly Consumption

Current Average Monthly consumption	6455	KL / month	Volume of imported water annually	**0** KL / year
Total no of months of production cost	12		POA supply volume	**6455** KL / month

Componentised Per KL Costs

Pumping Costs	3.700503	Rs / KL		
Supply infrastructure maintenance	0.979783	Rs / KL		
Waste Water treatment	6.901924	Rs / KL		
RWH Maintenance	0.258198	Rs / KL		
Avg cost of imported water	0	Rs / KL		
Overheads	1.515105	Rs / KL	**13.35551 Rs / KL**	**Operations and Maintenance costs**
Capital recovery costs	0	Rs / KL		
Fund for New Water resources	2	Rs / KL		
Fund for Water security investment	1	Rs / KL	**3 Rs / KL**	**Capital Recovery and Water secutiry costs (Sinking fund)**
Total / **Total PER KL Cost**	**16.78856**	**Rs / KL**		

The overall production cost is around 16.7 Rs / KL out of which 13.3 Rs / KL is purely operations and maintenance costs.

In the above calculations for the sinking Fund :

a) Capital recovery costs are zero as the capital costs of infrastructure are not amortized and reflected in the production cost. This is because at RBD people preferred to not have this reflected – they have paid already for the capital costs when they bought the plots. Any major infrastructure investment in existing infrastructure would need an explicit fund raising exercise.

b) Fund for New water resources – represents a sinking fund necessary for drilling of new borewells incase of drying up of existing borewells. It has been arrived at assuming the two high yielding borewells at Rainbow Drive have a life of 2 years and it costs around 1.5 Lakhs of Rupees to drill one new yielding borewell.

c) Fund of Water security investment – represents a sinking fund necessary for continued investments in recharge wells for the next two years at the rate of 5 wells per year.

It must be observed from the above production cost that:

a) Wastewater treatment operations and maintenance is the single highest contributor.
b) Pumping costs are very significant.
c) It is possible to reflect desired future investments for security/sustainability as a part of the production cost of water, and, that this component is less than some of the operations and maintenance components.

Performance of water pricing scheme

RBD's water management cost recovery can be determined by running the total production cost of water against the layout's watsan income from monthly water bills. This review also needs to take into account the reduction in revenue on account of defaulted payments.

The period reviewed was April 2008 through March 2009. Over the course of that period, the total production cost of water is Rs. 10,34,518/-. This figure accounts for the costs of pumping, supply infrastructure maintenance, wastewater treatment, HR costs, and community-level RWH maintenance.

The total billing during that same period was Rs. 12,79,515, which would cover the production cost as well as build up some savings for the sinking fund. However, the analysis below of four billing cycles during the April 08 – March 09 period reveals that an average of 17.7% of bills are defaulted each month. It must be noted that the assistant estate manager in charge of bill collection argues that all defaulters tend to pay within a 3-month period, so further analysis of every month's billing is warranted.

Bill period	Total billing	Total recvd	Total outstanding	% default
Feb-March 2009	111716	93236	18480	0.16541946
Mar-April 2009	127792	96339	31453	0.24612652
June-July 2008	137893	118503	19390	0.14061627
Sept-Oct 2008	94363	80314	14049	0.14888251
TOTAL	**471764**	**388392**	**83372**	**0.17672396**

Even if an average default rate of 17.7% is assumed, the total revenue from April 2008 to March 2009 was still Rs. 10,53,041/-, which is enough to cover the layout's production cost of water, though not sufficient to accumulate a sinking fund.

Pricing scheme performance under demand management conditions
One of the key lessons of the RBD monitoring exercise is the central role that demand management must assume to achieve a more sustainable groundwater balance. Should demand management practices take hold, then one needs to model the performance of the pricing regime under different demand scenarios to determine its financial viability.

A feature of the present pricing scheme is that lower end users are essentially cross-subsidized by the higher end consumers, as reflected by the fact that the two lowest slabs are lower than the production cost of water. A hypothesis that needs to be tested is that a reduction in higher-end consumption will make the cross-subsidy financially unviable, thereby requiring a price hike in the lower slabs to recover the production cost of water.

Two scenarios need to be tested. The first would consider a likely scenario of successful demand management, wherein the high-consumption users in Slabs 4 and 5 reduce their average demand to the layout average of 246 litres per capita per day (lpcd) while demand amongst lower-consumption users remains the same. The second scenario would consider a very successful demand management campaign that reduces the average consumption to 135 lpcd.

One would expect in both of these scenarios that the drop in consumption amongst higher-end consumers would require calls for a revision of tariff regimes to recover the production cost of water even at the lowest slabs. However, in communities such as RBD which are relatively economically homogeneous, the rationale for subsidizing lower consumption on the grounds of providing "lifeline" water does not apply.

Staffing

A key learning of interviews with the staff members is that they possess good capacity to conduct operations once they are well-defined. They had a very clear understanding of the different water management changes that have been brought about by the POA's activity. The staff dooes not have a technical capacity in the sense that they are not aware of the technical issues related to the STPs or borewells, and they don't have an understanding of how meter readings are to be interpreted.

This lack of technical understanding prevents the staff from being able to negotiate terms with partner agencies providing technical services for STP or borewell management/maintenance. Additionally, this knowledge gap precludes any proactive measures by the staff to ideate on further improvements to the overall water management regime. The knowledge gap also partly explains the lack of consistency in keeping current with data collection for the rain gauge installed to track RBD's total rainfall or to respond when technical difficulties befell a source meter installed on one of the layout's borewells.

One thing that this monitoring exercise made clear is that human capital is at the core of answering the question of how sustainable RBD's water management regime is, and to what extent the successes of RBD can be replicated elsewhere. Efforts to build the staff's capacities will benefit the layout's water management, and these must be driven by a dedicated POA.

Hydrogeology in the layout

Biome has gathered data for the purpose of developing a basic understanding of RBD's hydrogeology. Hydrogeological analysis ought to be crucial practice for strengthening the water management framework at any layout entirely dependent upon groundwater, and even more so when a groundwater recharge strategy is pursued. However, there are few if any resources available to guide communities in conducting such an exercise, as most hydrogeological surveys are focused on macro-level trends. Therefore, Biome devised a set of activities in order to generate at the very least a rough sketch of the character of RBD's hydrogeology.

The aims of these exercises are two-fold: first, we would like to understand the appropriateness of RBD's groundwater recharge strategy given its underlying conditions; second, we hope to identify the existence and nature of a shallow aquifer that could potentially be tapped as an additional source of water for the layout's needs in the future. Use of shallow aquifer water could partially offset the water and pumping demand from the borewells.

After discussing potential exercises with expert hydrogeologists, Biome has conducted two surveys of all the layout's open wells, three slug tests on selected wells, and water quality tests on the yielding borewells and a selected open well across different seasons.

We have collated the complete results from the slug tests in Appendix 8, open well surveys in Appendix 9, and water quality tests in Appendix 10, and will consult with qualified experts to determine what insights or conclusions can be drawn from the same. Below are some initial observations of the data.

Slug tests
According to interviews with more than a dozen residents of RBD, flood mitigation is considered among the most tangible benefits of RBD's groundwater recharge efforts. Though 2008 had presented higher than average monsoon rainfall. One resident commented about a neighbour whose basement had frequently flooded during heavy rains, but which no longer does since several recharge wells on his street were sunk.

Due to the wells' success as a flood control measure, a second set of 10 recharge wells was built in November 2008. These ten new wells were sponsored at the collective level by the RWA. Several privately funded wells were also dug over the course of the monitoring exercise, and the layout's well total today is 59.

Our modelling below has projected that given Bangalore's rainfall patterns and the recharge well capacity at RBD, the annual quantum of rainwater recharged into the ground is 9.942 million litres.

Total RBD recharge estimate annually for an average rainfall pattern								
Total no of recharge well holding volume				219	KL			
Total number of recharge wells				55				
No of recharge wells in drain				25	wells			
No of recharge wells in compound				30	wells			
Rainfall distribution assumption			Per shower		Entire Rainy season			
days	mm rain	total	Wells in the drain	Wells in compound	Wells indrain	Wells in compound		
1	80	80	4000	4000	120000	144000		
2	60	120	4000	4000	240000	288000		
3	30	90	4000	3000	360000	270000		
4	25	100	4000	2500	480000	300000		
8	20	160	4000	2000	960000	480000		
42	10	420	4000	1000	5040000	1260000		
					7200000	2742000	9942000	Litres
							or	
							9.942	Million litres

To test the validity of this modelling as well as the hypothesis that RBD's recharge wells do effectively mitigate local flooding, we decided to conduct slug tests on four wells spread geographically across the layout. A slug test is a basic exercise to gauge the recharge capacity of a given open well by discharging a column of water or "slug" into the well and observing the rate at which it percolates into the ground. The intent was to conduct slug tests during the dry season, pre-monsoon season and rainy season to develop an understanding of how the recharge rate functions under different seasonal conditions. Two of the open wells were tested in each of the three target seasons, and two were tested during the pre-monsoon and rainy seasons.

A cursory analysis suggests that RBD taken in its entirety is an effective recharge zone, though the recharge rates vary considerably from location to location, with some wells recharging rapidly and others significantly slower. However, to draw any final conclusions from the data, a trained hydrogeologist's perspective will be required.

Since standing water was witnessed in several of the test wells even during the dry season, further investigation of RBD's open wells is warranted to explore for the presence of a shallow aquifer. A recommended course of action would be to conduct a pumping test, whereby a well with a pre-existing column of water would be emptied by a submersible pump and then observed for the time required for the water level to return, if at all, to the original level. Knowledge of the recuperation rate of the wells would give more solid evidence of the presence and nature of a shallow aquifer, and it would also guide any future pumping regime to put shallow aquifer water to use.

<u>Open well surveys</u>

We conducted open well surveys during the pre-monsoon and rainy seasons to note the presence or absence of water in 34 of the layout's 59 open wells. The primary objective of this exercise was to search for evidence of a shallow aquifer. After the two surveys, we have tabulated the data and grouped them into three main catchment areas as per the general south-north orientation of RBD's topography. An initial reading of the data suggests that there is a presence of a shallow aquifer, though as with the slug tests, the analysis and inference regarding the extent to which it could be deployed requires hydrogeological expertise.

Groundwater quality analysis

We twice sampled an open well that has been observed to yield water throughout the year. If the water is to be put to any use, it must be safe for the purpose to which it will be applied. The first sample was taken in February 2009, in the midst of the dry season, and the second sample was taken in the early weeks of the rainy season in August 2009. In both cases, the water's appearance was clear, and the February report suggested that subject to a bacteriological examination, the water was of potable quality. Moreover, each of the parameters tested in August were, as expected, lower relative to the February sample as a result of the recent rainfall.

These samples suggest that the shallow aquifer water in RBD is of high quality and should certainly be considered for application in the households upon a more comprehensive understanding of the recharge rates.

We also sampled water from the borewells supplying the water for all of RBD in January and August 2009 two observe for any seasonal variation in groundwater quality. One sample tested the water supplied by two borewells that is delivered to all homes in Phases 1 and 2 located in the northern half of the layout, while the other sample was taken from the borewell supplying all of Phases 3 and 4. In both instances, the water from Phases 1 and 2 was harder than the water from Phases 3 and 4.

Regarding the two samples from Phases 1 and 2, the measure of Total Dissolved Solids (TDS) rose from 480 mg/L in January to 571 mg/L, which is higher than the desirable limit of 500 mg/L set by the BIS 105000 drinking water specification, but still well within the permissible limit of 2000 mg/L. Additionally, the readings for Chloride and Nitrate increased slightly from January to August. The other parameters tested either stabilised or fell slightly between January and August.

Regarding the two samples from Phases 3 and 4, one finding of note was that while the measure of Total Dissolved Solids (TDS) increased, nearly every other parameter tested in August was equal to or lower than the January sample, including total hardness.

Since the samples were sent to different labs in January and August, testing error may account for some of the variation noticed between months. The extent of testing error and any additional significance to be assigned to these samples would call for the inputs of a water quality expert.

Following the August sample, Biome's attempt has been to embed this practice within the POA, as water quality testing of one's groundwater supply is recommended once every six months.

Pt. 5 – RBD's wastewater management analysis

Wastewater management analysis

The Rainbow Drive layout has two STPs – one for Phases 1 and 2, and another for Phases 3 and 4. Interviews with residents, Managing Committee members and staff indicate that there is very little understanding of how the STP's operate or what happens to the wastewater after treatment. This dearth of awareness was striking, if not surprising, because understanding RBD's wastewater management system is crucial for several reasons:

1. Nearly 50% of the production costs of water is contributed to by the operations of the STP at Rainbow Drive.
2. As the analysis of RBD's demand has shown above, wastewater treatment is a very critical component of its overall water management, and the question of how to deal with treated wastewater remains an open question for the layout.

An STP consultant with 30 years of experience in the field was brought to RBD for the purpose of analyzing RBD's STP management regime, and samples of raw and treated sewage from each of the STP's were submitted for testing. The expert's opinion had deemed the STP's to be gravely inadequate both in terms of infrastructure, staff capacity and discharge of treated wastewater.

Insufficient facilities
Each STP exhibits deficient designs that made for greater difficulty of operation. No dimensions or drawings of the plant were available, and therefore there is no way of knowing the basis of each STP design and to calculate how much wastewater each STP is capable of treating per hour & per day. Knowing the maximum capacity of each STP is is especially important to know when there are 140 plots yet to be developed. The consultant's recommendation was to demolish the existing STPs and revamp the entire infrastructure.

Personnel
The STP maintenance and operations are outsourced to a third party agency which is paid for on a monthly basis. This agency's exact functions are unknown to most staff and Managing Committee members. The estate management team was unaware of capacities or any other technical specifications of the STP. The operators from the third party agency were carrying out the operations in a rote manner without an idea of what the results of their actions should be. There appeared to be no Operation Manual for either of the plants.

Disposal of treated wastewater
Treated wastewater disposal is problematic for the layout. Some of the treated wastewater is used for gardening purposes in the layout's clubhouse area, though much of it is discharged into stormwater drains and neighboring sites. The storm water drain of

the main road outside RBD's entrance is at a higher level than the layout, and this water occasionally backs up in part due to neighboring layouts' similar methods of wastewater disposal.

The quality of the treated wastewater is also problematic. Samples of the treated sewage taken by Biome and submitted to Ion Exchange laboratory for a full examination have shown it to fail KSPCB standards for wastewater. The consultant referred to it as a "sewage in, sewage out system", whose quality is not fit for sustained use on lawns and gardens due to the likely presence of pathogenic bacteria that will eventually effect the groundwater quality.

Each month, the third party STP agency submits treated wastewater samples to an independent laboratory for testing. No sample has failed the lab's standards to date, though there are some concerns about this. For one, they do not test for nitrate, which is a critical parameter of wastewater testing. Additionally, they use KSPCB's old limits as their benchmark for treated sewage quality, which are decidedly less rigorous than present-day standards. Indeed, if they used present day KSPCB standards, both of the STP agency's samples reviewed would have failed the test for Total Suspended Solids. More importantly, the STP agency's test results stand in marked contrast to those taken by Biome. Each of the STP agency's test show samples to be within the limits for BOD, whereas Biome's samples fail the BOD test.

The STP consultant commented that his prior employer had used to send samples of its wastewater to independent laboratories, and found it was possible to get some labs to manipulate results to its liking. Of course, it cannot be assumed that this is the case at RBD, but what can be assumed is that there appears to be a potential conflict of interest involved with STP operators submitting tests to labs from which they desires positive results.

Progress during the Monitoring period

From the beginning of Biome's engagement with Rainbow Drive and during the monitoring period, Biome has been consistently talking with the POA about the importance of good waste water management. Mr Jayawanth Bhardwaj, the key driver of reforms in the layout, has also been internally driving a similar agenda. As stated above, as a part of the monitoring exercise an independent consultant provided an opinion which was unequivocally critical of the existing set up. Subsequent to this, equipped with the ecological framework for water management and the scenario playing based on that (Refer to Chapter on demand), a meeting with the entire Plot owners Association was conducted.

In this meeting an idea was proposed: If waste water is treated to rechargeable qualitites and recharged, the layout would have nearly a zero ground water overdraft. This got the POA thinking and added elbow to Mr Jayawanth's internal efforts. This led to a dialogue on the possibilities of implementing a new Sewage Treatment plant based on Soil Bio Technology. A dialogue was conducted with Professor Shankar, of Vision Earth Care Pvt Ltd – the pioneer in soil bio technology (SBT). This was chosen on the recommendation of Biome as the claim was that it would treat waste water to potable quality standards. Prof Shankar was flown down to Bangalore (by the POA) and the POA, Biome and VEC were all involved in a meeting to discuss the possibilities of deploying SBT. The dialogue for SBT is still ongoing – however immediate deployment has been postponed due to cost reasons (it was estimated that an SBT plant for the layout would cost around Rs 50 Lakh). However this entire dialogue has brought to focus the importance of waste water management and the POA's thought processes around it has gained momentum. The POA is currently implementing major maintenance works on the STP for an immediate lower capital cost solution to ensure the treatment quality meets atleast the current pollution control norms. The dialogue for a longer term improvement in waste water management continues to play itself out in the POA meetings.

Appendix 1:

Links to media articles about Rainbow Drive Layout

(Note: some links may be de-activated. If you wish for a soft copy for any of the articles, please contact Nate Stell at nate@biome-solutions.com for the same.)

a) Published in Citizen Matters – an online news platform that also facilitates citizen journalism (http://bangalore.citizenmatters.in/)

Water supply from the bottom up
RWH in a layout: getting started
RWH in a layout: engaging the people
RWH in a layout: What, how, why and how much
RWH in a layout: Residents are water managers

b) Published in the Times of India, 20 October 2008, Bangalore Edition.

Drops of Hope

c) Published in the Livemint (The Wall Street Journal), 14 November 2008,

Water Water

d) Published in The Hindu (Supplement : Property Plus), 29 November 2008, Bangalore Edition.

Managing water in a Layout

e) Published in Time Out Bengaluru, 22 January 2009,

Water idea, Sirji

f) Published in Bangalore Mirror, 16 February 2009,

Water at the end of the Rainbow

g) Published in Mid-Day.com, 12 September, 2008,

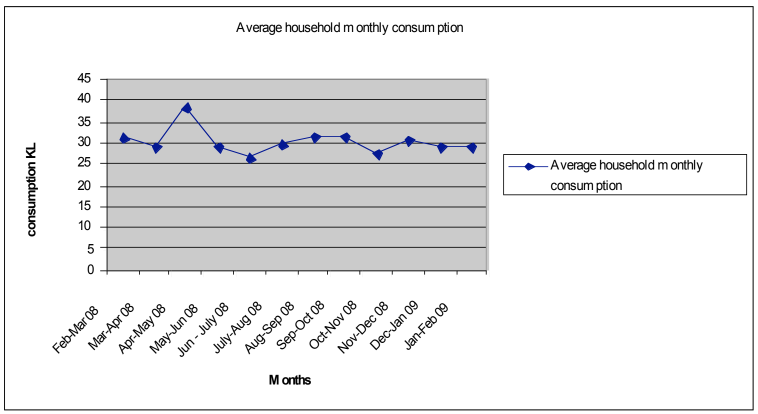
Saved by the well

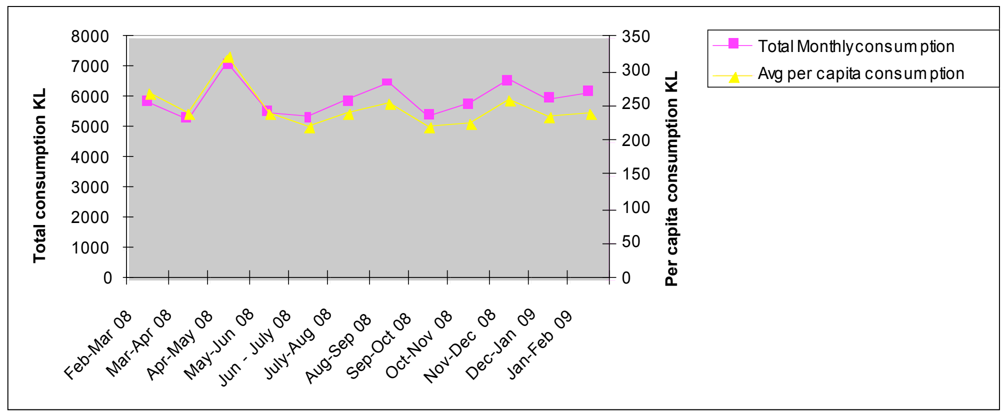
h) Published in DNA, 7 June 2009,

Who owns Bangalore's rainwater?

Appendix 2:
Demand Metrics

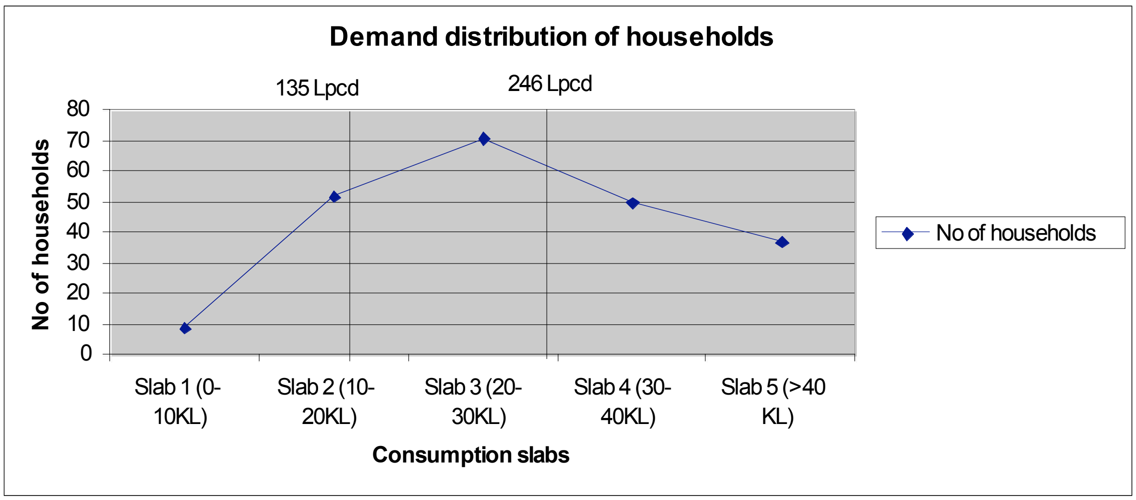
	2008										2009	
	Feb-Mar 08	Mar-Apr 08	Apr-May 08	May-Jun 08	Jun - July 08	July-Aug 08	Aug-Sep 08	Sep-Oct 08	Oct-Nov 08	Nov-Dec 08	Dec-Jan 09	Jan-Feb 0
Total Monthly consumption	5865	5266	7117	5512	5333	5901	6485	5405	5790	6546	5976	61
Avg per capita consumption	271	238	321	238	222	241	256	219	225	258	237	2
Average household monthly consumption	31.4	29.5	38.5	29.5	26.6	29.9	31.7	31.7	27.9	30.9	29.3	2
Total no of households corresponding to this consumption	187	179	185	187	201	198	205	205	208	212	204	2



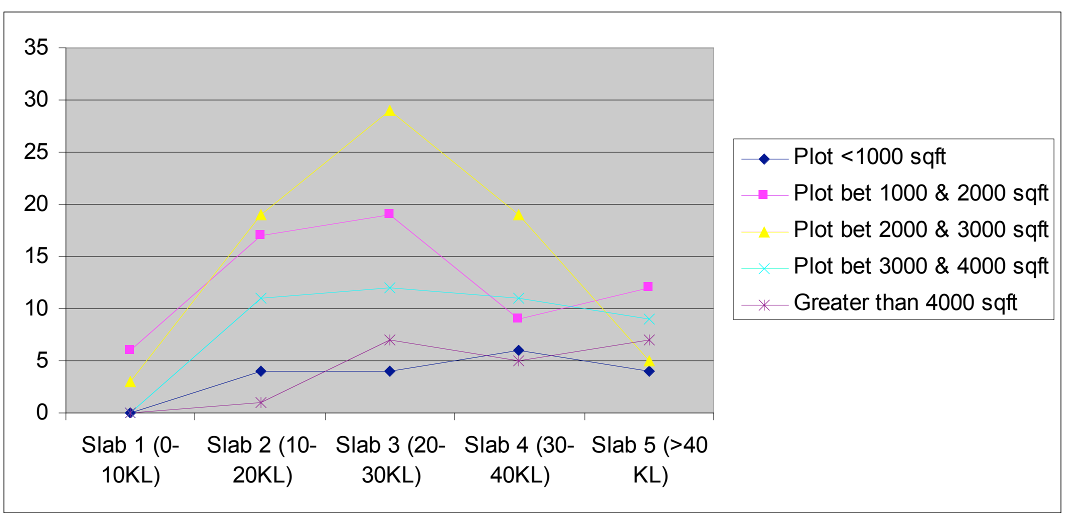


Appendix 3:
Demand Distribution

Consumption slab	No of households	Consumption 1	Consumption 2	%
Slab 1 (0-10KL)	9	0	10	4
Slab 2 (10-20KL)	52	10	20	24
Slab 3 (20-30KL)	71	20	30	32
Slab 4 (30-40KL)	50	30	40	23
Slab 5 (>40 KL)	37	40	100	17
Total	**219**			**100**



No of households upto around 135 litre per capita (1st two slabs)	32	Households
No of households upto 246 lpcd (Average of layout)	130	Households
No of households greater than 246 lpcd (Average of layout)	89	Households



Appendix 4:
Household demand analysis questionnaire

Users

- How many people live/work in the home?
  - Breakup – kids, adults, staff
    - Do staff live in the home?
    - What age group are the kids?
- Within the family, who spends the most time in the house?
- How often do staff come (maid, gardener, driver)?
  - What times?
  - What do they do while here?

Usage points

- **Bathroom**
  - Toilet
    - How many toilets in the home?
    - What kind of toilets?
      - Pour or flush?
      - Dual flush toilet?
      - Note the model and if capable of part/full flush.
    - How many people use each particular toilet?
    - Do people practice part flush/full flush?
    - (Put a tally sheet in the toilet to be kept for 3 days)
      - (Stick a note card on the flush itself to remind users to make the tally.)
  - Shower
    - How often to residents take showers?
    - Do residents use bucket baths or shower baths?
      - (What's the volume of the bucket?)
      - (If a shower bath, measure the time it takes to fill a vessel of known volume to determine the flow rate.)
    - (Provide a tally sheet.)
      - How many buckets used for each bucket shower.
      - Length of time for shower bath.
    - *Alternative to tallying shower use (this might be easier and just as reliable)*
      - For bucket showers, how many buckets used for each bath?
      - For shower bath, how long for each bath?
  - Wash basin
    - (Open the tap and fill a mug of known volume, noting the time it takes to fill the mug to determine the flow rate.)
- **Kitchen**
  - Kitchen tap & wash basins
    - (Open the tap and fill a vessel of known volume, noting the time it takes to fill to determine the flow rate.)

  - Is there a mechanical dishwasher?
    - How many loads a day?
    - How much water does each load use? (Look at the manuals or get the model and make of the machine and look up on the web.)
  - Hand dishwash / kitchen sink
    - Does the bulk of dishwashing happen in the utility area or in the kitchen sink?
    - How many times a day are dishes done?
    - What type of a tap in the kitchen sink?
      - (Open the tap and fill a mug of known volume, noting the time it takes to fill the mug to determine the flow rate.)
    - When washing dishes, does the maid use a bucket or use a running tap only?
      - Usually a mix of the bucket use and the tap.
      - Get an idea of the bucket size.
    - We'll approximate cooking and drinking based on the # of ppl there.
- **Utility area**
  - Is a washing machine used for clothes?
    - How many loads a day?
    - How much water does each load use? (Look at the manuals or get the model and make of the machine and look up on the web.)
  - Bucket washing for clothes?
    - Are all or some clothes/garments bucket washed?
    - How many loads a day/week are bucket washed?
    - How many buckets are used per load?
    - (Take the measurements of the bucket to determine the volume.)
  - How often is home swabbed/mopped?
    - How many buckets used for this activity?
  - Are there any other regular indoor cleaning activities not mentioned here?
    - How many buckets used for this activity in a week?
- **Garden**
  - (Observe the garden, click snaps.)
  - Is there a gardener? What time does s/he come? How often? Does s/he have a mobile so that we may contact them directly sometime?
  - What days and times is the garden watered?
  - How long does it take to water the garden?
  - Is a bucket or hose used?
    - If bucket, how many buckets are used.
      - (Get the measurements of the bucket)
    - (If a hose is used, determine the time it takes for hose to fill a vessel of known volume.)
- **Car park**
  - Is the driveway washed?
    - How many times a week?

- Bucket wash or hose?
  - If bucket, how many buckets are used?
    - (Volume of bucket used?)
  - (If hose, determine the time it takes for hose to fill a vessel of known volume.)

- Car wash
  - How many cars?
  - How often are they washed in a week?
  - Bucket wash or hose?
    - If bucket, how many buckets are used?
      - (Volume of bucket used?)
    - (If hose, determine the time it takes for hose to fill a vessel of known volume.)

Appendix 5:
RO Survey Analysis

RO Survey Analysis

Total houses	84
Without RO	38
With RO	46

Brands

Aquaguard	21
Eureka	3
Forbes	1
Kent	10
Ena Kofer?	1
Nature fre?	1
Zero B	6
Brand not mentioned	3
Total	**46**

Uses

Drinking	5
Cooking	1
Both	40
Total	**46**

Amount of wastewater (litres)

Litres	No. of houses	Percentage
0-5	6	12.77
6-10	13	27.66
11-15	4	8.51
16-20	5	10.64

21-25	3	6.38
26-30	3	6.38
31-40	2	4.26
Over 40	2	4.26
No response	9	19.15
Total	**47**	100

How the wastewater is used	
Car wash	1
Floor	1
Gardening	15
Vessels	1
Waste	22
Total	**40**

	Litres
Average wastewater per household	**21.27**
Average wastewater in households that do not reuse	18.61
Average wastewater in households that reuse the water	23.79

Number of people per house

No of people	Houses
2	3
3	9
4	19
5	11
6	2

	12	1
Total		**45**
Average number of people per house		**4.18**

Other household treatment (collated largely from houses without RO systems)

Aquaguard	22
Electricity free filter	1
UV filter	2
Water softener	5
Water softener with magnetic treatment	1

Other observations

Houses using only mineral water	9

Appendix 6:
Data for Borewells and Pumping

Pumping and Release Schedule of Water at RBD

Pumping Schedule		
	Phase 1 and 2 (2 borewells)	**Phase 3 and 4 (1 borewell)**
Pump Name	**Pumping Time / duration**	**Pumping Time / duration**
Mon 1st pump	9:00 AM – 4:00 PM	10:00 AM – 10:00 PM
Mon 2nd pump	5:30 PM – 10:30 PM	
Tues 1st pump	9:00 AM – 4:00 PM	10:00 AM – 1:00 PM
Tues 2nd pump	5:30 PM – 10:30 PM	
Wed 1st pump	9:00 AM – 4:00 PM	10:00 AM – 10:00 PM
Wed 2nd pump	5:30 PM – 10:30 PM	
Thurs 1st pump	9:00 AM – 4:00 PM	10:00 AM – 1:00 PM
Thurs 2nd pump	5:30 PM – 10:30 PM	
Fri 1st pump	9:00 AM – 4:00 PM	10:00 AM – 10:00 PM
Fri 2nd pump	5:30 PM – 10:30 PM	
Sat 1st pump	9:00 AM – 4:00 PM	10:00 AM – 1:00 PM
Sat 2nd pump	5:30 PM – 10:30 PM	
Sun 1st pump	9:00 AM – 4:00 PM	10:00 AM – 1:00 PM
Sun 2nd pump	5:30 PM – 10:30 PM	
Water Release Schedule		
Water Release schedule	**Phase 1 and 2**	**Phase 3 and 4**
Mon 1st release	8:30 AM – 10:00 AM	8:30 AM – 10:00 AM
Mon 2nd release	5:00 PM – 7:00 PM	5:00 PM – 7:00 PM
Tues 1st release	8:30 AM – 10:00 AM	8:30 AM – 9:30 AM
Tues 2nd release	5:00 PM – 7:00 PM	
Wed 1st release	8:30 AM – 10:00 AM	8:30 AM – 9:30 AM
Wed 2nd release	5:00 PM – 7:00 PM	5:00 PM – 7:00 PM
Thurs 1st release	8:30 AM – 10:00 AM	8:30 AM – 9:30 AM
Thurs 2nd release	5:00 PM – 7:00 PM	
Fri 1st release	8:30 AM – 10:00 AM	8:30 AM – 9:30 AM
Fri 2nd release	5:00 PM – 7:00 PM	5:00 PM – 7:00 PM
Sat 1st release	8:30 AM – 10:00 AM	8:30 AM – 9:30 AM
Sat 2nd release	5:00 PM – 7:00 PM	
Sun 1st release	8:30 AM – 10:00 AM	8:30 AM – 9:30 AM
Sun 2nd release	5:00 PM – 7:00 PM	

In the above the reference to 1st and 2nd pump are as follows

Phase 1 and 2:
8SP165 – Opposite - Plot 137
8SP6686 – Opposite – Plot 170

Phase 3 and 4:
8SWP5329 – between plots 244 and 245

Appendix 7:
Tabulation of borewell pumping electricity consumed at RBD

Borewell details			Units of Electricity Consumed											
Borewell No	Borewell depth	Borewell HP	April 08	May 08	June 08	July 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Totals
8SWP5329		7.5	2842	2444	2036	2025	2121	1951	1476	1421	1226	1560	1725	20827
8SWP5799		5	889	1054	679	584	712	65	877	0	0	0	0	4860
8SWP6685		5	684	712	322	233	0	0	0	0	0	0	0	1951
8SWP6686		5	363	460	227	330	399	427	460	146	302	598	687	4399
8SP165		5	3613	3814	1729	1331	3062	2097	1096	2956	2595	1473	926	24692
8SP164		5	0	0	0	0	0	0	0	0	0	0	0	0
Totals		32.5	8391	8484	4993	4503	6294	4540	3909	4523	4123	3631	3338	56729
Rainfall			46	119	80	110	137	195	180	64.5	22	2.7	7.2	
		demand	6191.5	6314.5	5422.5	5617	6193	5945	5597.5	6168	6261	6070.5	6015	
		per KL units	1.355245094	1.343574313	0.920792992	0.8016735	1.0163087	0.7636669	0.6983475	0.7333009	0.658521	0.598139	0.554946	

Demand Across the year											
Feb-Mar 08	Mar-Apr 08	Apr-May 08	May-Jun 08	Jun - July 08	July-Aug 08	Aug-Sep 08	Sep-Oct 08	Oct-Nov 08	Nov-Dec 08	Dec-Jan 09	Jan-Feb 09
5865	5266	7117	5512	5333	5901	6485	5405	5790	6546	5976	616

Appendix 8:
Results from slug tests on select RBD recharge wells

Plot 13 well slug tests (17' deep well)

Jan-09				May-09				Sep-09			
Day of reading (Saturday or Sunday)	Time of Reading	Depth of water from ground level	Water present before slug?	Day of reading (Sunday or Monday)	Time of Reading	Depth of water from ground level (feet)	Water present before slug?	Day of reading (Saturday or Sunday)	Time of Reading	Depth of water from ground level	Water present before slug?
28/Jan	10:58	0'	No	24/May	12:28	0'	Yes, at 17' 6"	11/Sep	12:55	2' 4"	No
28/Jan	11:02	10"		24/May	13:28	4' 6"		11/Sep	13:10	3' 9"	
28/Jan	11:05	1' 5.5"		24/May	14:28	8' 3"		11/Sep	13:25	5'	
28/Jan	11:10	2' 1"		24/May	15:28	10' 2"		11/Sep	14:25	7'	
28/Jan	11:15	2' 8.5"		24/May	16:28	11' 6"		11/Sep	15:25	9'	
28/Jan	11:25	3' 3.5"		24/May	17:28	13'		11/Sep	16:25	11' 6"	
28/Jan	11:30	3' 7"		25/May	10:00	17'		11/Sep	17:25	13' 8"	
28/Jan	11:45	4' 9"									
28/Jan	12:00	5' 11"									
28/Jan	12:30	7' 7'									
28/Jan	13:00	8' 5"									
28/Jan	13:30	9' 5"									
28/Jan	14:00	10' 1"									
28/Jan	15:00	11' 3"									
28/Jan	16:00	12' 2"									
28/Jan	17:00	12' 9"									
29/Jan	18:00	13' 4"									
29/Jan	9:15	16' 6"									
29/Jan	12:45	16' 10"									
29/Jan	14:25	16' 11"									
29/Jan	17:15	17' 1"									
30/Jan	8:30	Empty									

Plot 250 well slug tests (27' deep well)

Jan-09				May-09				Sep-09			
Date of Reading	**Time of Reading**	**Depth of water from top of well**	**Water present before slug?**	**Day of reading (Sunday or Monday**	**Time of Reading**	**Depth of water from ground level (feet)**	**Water present before slug?**	**Day of reading (Sunday or Monday**	**Time of Reading**	**Depth of water from ground level (feet)**	**Water present before slug?**
29/Jan	11:18	6' 4"	Yes, at 24' 11"	24/May	11:30	0'	Yes, at 18'	12/Sep	15:35	1'	Yes, at 24'
29/Jan	11:36	6' 9"		24/May	12:30	6"		12/Sep	16:35	1' 9"	
29/Jan	12:06	7'		24/May	13:30	1'		12/Sep	17:35	2' 5"	
29/Jan	12:37	7' 3"		24/May	14:30	1'					
29/Jan	12:56	7' 4"		24/May	15:30	1'					
29/Jan	13:15	7' 5"		24/May	16:30	1' 6"					
29/Jan	13:45	7' 6.5"		25/May	10:00	6' 3"					
29/Jan	14:15	7' 8"									
29/Jan	15:15	7' 11"									
29/Jan	17:30	8' 4"									
30/Jan	8:30	11' 1"									
30/Jan	13:50	11' 6"									
31/Jan	15:00	14'									

Plot 428 well slug tests (16' deep well)

May-09				Sep-09			
Day of reading (Saturday or Sunday)	Time of Reading	Depth of water from ground level	Water present before slug?	Day of reading (Sunday or Monday)	Time of Reading	Depth of water from ground level (feet)	Water present before slug?
24/May	13:10	0'	Yes, at 16' 6"	11/Sep	13:25	1' 7"	No
24/May	13:20	2' 6"		11/Sep	13:40	2' 2"	
24/May	13:30	3' 6"		11/Sep	13:55	2' 7"	
24/May	13:40	4' 6"		11/Sep	14:25	3'	
24/May	13:50	6' 4"		11/Sep	15:25	3' 8"	
25/May	10:00	7' 6"		11/Sep	16:25	4' 10"	
				11/Sep	17:25	5' 6"	

Plot 36 well slug tests (17' deep well)

May-09				Sep-09			
Day of reading (Saturday or Sunday)	Time of Reading	Depth of water from ground level	Water present before slug?	Day of reading (Saturday or Sunday)	Time of Reading	Depth of water from ground level	Water present before slug?
24/May	11:50	4"	Yes, at 13' 6"	11/Sep	12:40	1'3"	No
24/May	12:05	8"		11/Sep	12:55	1' 10"	
24/May	12:20	1'		11/Sep	13:20	2' 10"	
24/May	13:00	1' 6"		11/Sep	13:50	4' 5"	
24/May	14:00	3' 6"		11/Sep	14:50	6' 6"	
24/May	15:00	6' 6"		11/Sep	15:50	8'	
24/May	16:00	9' 4"		11/Sep	16:50	9' 10"	
24/May	17:00	12'					
24/May	18:00	15' 6"					
25/May	10:00	15' 6"					

Appendix 9:

Open well test log - compiled findings

Location (plot #)	Catchment	May 24 & 25, 2009 Well depth	May 24 & 25, 2009 Water level: distance from ground level (ft)	Sept 12 & 13, 2009 Well depth	Sept 12 & 13, 2009 Water level: distance from ground level (ft)
284 (Stormdrair	1	17' 10"	12'	17'	15'
302/303	1	14' 8"	13' 8"	11' 8"	10' 11"
310	1	6' 8"	3' 6"	6'	3"
311 (Stormdrair	1	18'	17' 6"	16' 8"	Empty
315	1	17' 6"	15' 4"	17'	14' 11"
320	1	7' 6"		5'	Empty
326	1	20'	3'	19' 4"	19'
329 (Stormdrair	1	18'	17' 6"	16' 5"	16'
335	1	8'		8'	6'
359	1	19' 5"		19'	18'
371 (Stormdrair	1	18'	17'	17'	16' 8"
398 corner (Sto	1	19' 2"		18'	Empty
89	2	20'	17'	17'	13' 10"
93 (Stormdrain)	2	19'	18' 6"	17'	16'
247 (Stormdrair	2	19'		18'	17' 10"
248	2	17' 5"	12'	16'	12' 6"
250 (Stormdrair	2	28'	9'	27' 5"	23' 8"
424	2	20'	16'	18' 8"	Empty
426 (Stormdrair	2	19'	15'	16' 9"	Empty
7 (Stormdrain)	3	19'	18'	19'	18'
9	3	23' 6"	22' 6"	22'	21'
13	3	19'	18'	17' 3"	16' 10"
35 (Stormdrain)	3	19'	17'	17'	12' 10"
36 (Stormdrain)	3	19'	17' 6"	17' 3"	Empty
42	3	10'		10'	9"
54	3	20'	17'	18'	16' 3"
58 (Stormdrain)	3	19'		16'	14' 8"
64/65	3	20'	15'	17' 9"	Empty
68/1	3	20'	18'	17' 4"	Empty
78 (Stormdrain)	3	19' 6"	16' 6"	16' 10"	Empty
80	3	19' 5"	17' 5"	18'	9' 6"
81	3	19' 6"	16' 6"	18'	17'
99/1 (Stormdrai	3	19' 3"	18' 7"	17' 5"	12' 6"
107	3	19' 6"		18' 6"	17'


RainbowDrive
LEGEND
10ft Recharge Well
20ft Recharge Well
30ft Recharge Well
Water Tower for Phases 1 and 2
Water Tower for Phases 3 and 4
Inactive Borewell
Yielding Borewell (No. 8SWP5329)
Yielding Borewell (No. 8SP6686)
Yielding Borewell (No. 8SP165)
New Yielding Borewell
Revived Borewell
Sewage Treatment Plant for Phases 1 and 2
Sewage Treatment Plant for Phases 3 and 4
Catchment 1
Catchment 2
Catchment 3
Club House
S
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designed & printed by
Padmakala creations
Sarjapur Road

Appendix 10:
Water quality tests for select RBD open well and yielding borewells

Test 1 for open well at Plot 250 (Feb 2009)

GOVERNMENT OF KARNATAKA

DEPARTMENT OF MINES & GEOLOGY, STATE GROUND WATER CELL, BANGALORE

CHEMICAL ANALYSIS REPORT OF WATER SAMPLE

NAME OF THE OWNER: Rainbow Drive

LOCATION: Sarjapura Road

TALUK: Bangalore DISTRICT: Bangalore

SOURCE: Bore well/Well/Spring/Stream

LABORATORY NUMBER: 102 DATE OF RECEIPT: 2/2/09

	Constituents	mg/L	Indian Standard Drinking water Specification IS 10500 : 1991	
			Desirable limit	Permissible limit
A	TYPE : CATIONS			
1.	Calcium (Ca)	61	75	200
2.	Magnesium (Mg)	04	30	100
3.	Sodium (Na)	36	---	---
4.	Potassium (K)	8.01	---	---
5.	Total Iron (Fe)	0.12	0.3	1.0
B	TYPE : ANIONS			
1.	Carbonate (CO_3)	Nil	---	---
2.	Bicarbonate (HCO_3)	105	---	---
3.	Chloride(Cl)	81	250	1000
4.	Fluoride (F)	0.21	1.0	1.5
5.	Nitrate (NO_3)	10.2	45	No Relaxation
6.	Sulphate (SO_4)	49	200	400
C.	Total Dissolved Solids (TDS)	330	500	2000
D.	Specific Conductance μmhos/cm	510	---	---
E.	Total Hardness	168	300	600
F.	pH	7.82	6.5-8.5	No Relaxation

COLLECTED BY : The party

ANALYSED BY : Staff

DATE OF ANALYSIS : 2/2/09

LABORATORY NOTE : Source potable subject to Bacteriological Analysis

N.V. Shashirekha

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Test 2 for open well at Plot 250 (Aug 2009)

Sampling method: --- NOT APPLICABLE
Sample received on: 13.08.09
Sample Description: COLOURLESS AND CLEAR
Test starts date: 17.08.09
Sample Quantity: 1 LIT
Test completed on: 19.08.09

S.NO	TEST PARAMETER	UNITS	RESULT	PROTOCOL
1	TOTAL DISSOLVED SOLIDS	mg/l	232	
2	NITRATE	mg/l	3.3	
3	TOTAL HARDNESS	mg/l	125.7	
4	FLUORIDE	mg/l	< 1.0	
5	CALCIUM	mg/l	36.6	

END OF REPORT

Test 1 for Phase 1 & 2 borewell (Jan 2009)

GOVERNMENT OF KARNATAKA

DEPARTMENT OF MINES & GEOLOGY, STATE GROUND WATER CELL, BANGALORE

CHEMICAL ANALYSIS REPORT OF WATER SAMPLE

NAME OF THE OWNER: Rainbow Drive

LOCATION: Sarjapura Road

TALUK: Bangalore DISTRICT: Bangalore

SOURCE: Bore well/Well/Spring/Stream Sa. No. RBD-BW1

LABORATORY NUMBER: 959 DATE OF RECEIPT: 16/1/09

	Constituents	mg/L	Indian Standard Drinking water Specification IS 10500 : 1991	
			Desirable limit	Permissible limit
A	TYPE : CATIONS			
1.	Calcium (Ca)	82	75	200
2.	Magnesium (Mg)	16	30	100
3.	Sodium (Na)	67	---	---
4.	Potassium (K)	1.7	---	---
5.	Total Iron (Fe)	0.24	0.3	1.0
B	TYPE : ANIONS			
1.	Carbonate (CO_3)	Nil	---	---
2.	Bicarbonate (HCO_3)	239	---	---
3.	Chloride(Cl)	98	250	1000
4.	Fluoride (F)	0.27	1.0	1.5
5.	Nitrate (NO_3)	26	45	No Relaxation
6.	Sulphate (SO_4)	58.5	200	400
C.	Total Dissolved Solids (TDS)	480	500	2000
D.	Specific Conductance μmhos/cm	830	---	---
E.	Total Hardness	268	300	600
F.	pH	7.72	6.5-8.5	No Relaxation

COLLECTED BY : The party

ANALYSED BY : Staff

DATE OF ANALYSIS : 16/1/09

LABORATORY NOTE : Source potable subject to Bacteriological analysis.

N. Shashirekha

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Test 2 for Phase 1 & 2 borewell (Aug 2009)

S.NO	TEST PARAMETER	UNITS	RESULT	DESIRABLE LIMIT (As per IS 10500 Drinking water Specification)	PROTOCOL
1	pH AT 25°	-	7.03	6.5-8.5	IS 3025 (p 11), 1983, R 2002
2	TURBIDITY	NTU	<1	5	IS 3025 (p 10), 1984, R 2002
3	COLOUR	Hz. Unit	<5	5	APHA 21ST EDITION
4	TOTAL HARDNESS (As $CaCO_3$)	mg/l	262.9	300	IS 3025 (p 21), 1983, R 2002
5	CALCIUM (As Ca)	mg/l	77.7	75	IS 3025 (p 40), 1991, R 2003
6	MAGNESIUM (As Mg)	mg/l	16.7	30	IS 3025 (p 46), 1994, R 2003
7	TOTAL ALKALINITY (As $CaCO_3$)	Mg/l	212.9	200	IS 3025 (p 23), 1986, R 2003
8.	CHLORIDE (As Cl)	mg/l	117.7	250	IS 3025 (p 32), 1988, R 2003
9	SULPHATE (As SO_4)	mg/l	34.1	200	IS 3025 (p 24), 1986, R 2003
10	RESIDUAL CHLORINE (As Cl)	mg/l	< 1	0.2	IS 3025 (p 26), 1986, R 2003
11	NITRATE (As NO_3)	mg/l	28.5	45	IS 3025 (p 34), 1988, R 2003
12	IRON (As Fe)	mg/l	0.09	0.3	IS 3025 (P 53), 2003
13	COPPER (As Cu)	mg/l	< 0.05	0.05	IS 3025 (p 42), 1992, R 2003
14	MANGANESE (As Mn)	mg/l	< 0.1	0.1	IS 3025 (p 59), 2006
15	TOTAL DISSOLVED SOLIDS	mg/l	571	500	IS 3025 (p 15), 1984, R 2003
16	FLUORIDE (As F)	mg/l	< 1.0	1.0	APHA 21ST EDITION
17	CHROMIUM (As Cr^{6+})	mg/l	< 0.05	0.05	IS 3025 (p 52), 2003

Test 1 for Phase 3 & 4 borewell (Jan 2009)

GOVERNMENT OF KARNATAKA

DEPARTMENT OF MINES & GEOLOGY, STATE GROUND WATER CELL, BANGALORE

CHEMICAL ANALYSIS REPORT OF WATER SAMPLE

NAME OF THE OWNER: Rainbow Drive

LOCATION: Sarjapura Road

TALUK: Bangalore DISTRICT: Bangalore

SOURCE: Borewell/Well/Spring/Stream Sa. No. RBD-BW2

LABORATORY NUMBER: 960 DATE OF RECEIPT: 16/1/09

	Constituents	mg/L	Indian Standard Drinking water Specification IS 10500 : 1991	
			Desirable limit	Permissible limit
A	TYPE : CATIONS			
1.	Calcium (Ca)	58	75	200
2.	Magnesium (Mg)	17	30	100
3.	Sodium (Na)	61	---	---
4.	Potassium (K)	1.2	---	---
5.	Total Iron (Fe)	0.12	0.3	1.0
B	TYPE : ANIONS			
1.	Carbonate (CO_3)	Nil	---	---
2.	Bicarbonate (HCO_3)	238	---	---
3.	Chloride(Cl)	64	250	1000
4.	Fluoride (F)	0.29	1.0	1.5
5.	Nitrate (NO_3)	15	45	No Relaxation
6.	Sulphate (SO_4)	48.6	200	400
C.	Total Dissolved Solids (TDS)	410	500	2000
D.	Specific Conductance µmhos/cm	690	---	---
E.	Total Hardness	212	300	600
F.	pH	7.34	6.5-8.5	No Relaxation

COLLECTED BY : The party

ANALYSED BY : Staff

DATE OF ANALYSIS : 16/1/09

LABORATORY NOTE : Source potable subject to Bacteriological Analysis.

Nevshashikek

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Test 2 for Phase 3 & 4 borewell (Aug 2009)

S.NO	TEST PARAMETER	UNITS	RESULT	DESIRABLE LIMIT (As per IS 10500 Drinking water Specification)	PROTOCOL
1	pH AT 25°	-	7.3	6.5-8.5	IS 3025 (p 11), 1983, R 2002
2	TURBIDITY	NTU	< 1	5	IS 3025 (p 10), 1984, R 2002
3	COLOUR	Hz. Unit	< 5	5	APHA 21ST EDITION
4	TOTAL HARDNESS (As $CaCO_3$)	mg/l	205.7	300	IS 3025 (p 21), 1983, R 2002
5	CALCIUM (As Ca)	mg/l	57.9	75	IS 3025 (p 40), 1991, R 2003
6	MAGNESIUM (As Mg)	mg/l	14.8	30	IS 3025 (p 46), 1994, R 2003
7	TOTAL ALKALINITY (As $CaCO_3$)	Mg/l	232.3	200	IS 3025 (p 23), 1986, R 2003
8.	CHLORIDE (As Cl **)**	mg/l	65.4	250	IS 3025 (p 32), 1988, R 2003
9	SULPHATE (As SO_4)	mg/l	28.1	200	IS 3025 (p 24), 1986, R 2003
10	RESIDUAL CHLORINE (As Cl)	mg/l	< 1	0.2	IS 3025 (p 26), 1986, R 2003
11	NITRATE (As NO_3)	mg/l	14.0	45	IS 3025 (p 34), 1988, R 2003
12	IRON (As Fe)	mg/l	0.07	0.3	IS 3025 (P 53), 2003
13	COPPER (As Cu)	mg/l	< 0.05	0.05	IS 3025 (p 42), 1992, R 2003
14	MANGANESE (As Mn)	mg/l	< 0.1	0.1	IS 3025 (p 59), 2006
15	TOTAL DISSOLVED SOLIDS	mg/l	485	500	IS 3025 (p 15), 1984, R 2003
16	FLUORIDE (As F)	mg/l	< 1.0	1.0	APHA 21ST EDITION
17	CHROMIUM (As Cr^{6+})	mg/l	< 0.05	0.05	IS 3025 (p 52), 2003