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INTEGRATED WATER AND WASTE WATER MANAGEMENT FOR A TOWNSHIP

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ABSTRACT

Global changes impacting on the use of water resources are the reality and recognizing that urbanization will exert a greater impact on human activity compared to climate change, at least up until 2050, requires urgent action. Unavailability of land mainly due to urbanization has led to the considerable increase in number of townships being constructed. With the rate of increase in the number of townships and the development of resources in these townships following opposite directions, planned management and judicial use of existing resources becomes critical. The availability of water resource is one major area of concern considering the drastic increase in the water demand in townships. Integrated Water Resource Management is one of the best ways to ensure water sustainability, for a township it becomes equally important to manage the resources which are limited and excessive amount of waste water being generated from usage. Water demand for the township was projected based on population to estimate the supply required in long term. Thus waste water generated also plays a crucial role as it can be used as resource for recycling and recharging. The water balance of the township is further enhanced with the integrated resource management approach.

INTRODUCTION

Fresh, accessible water is a scarce and unevenly distributed resource, not matching patterns of human development. Over half the world's population faces water scarcity because it plays vital role in the sustenance of all life. Water scarcity acts as a limiting factor in the economic and social development- (Narasimhan, 2008).Global changes impacting on the use of water resources are the reality and recognizing that urbanization will exert a greater impact on human activity compared to climate change, at least up until 2050, requires urgent action. In 2011, in India nearly 31% of the population (377 million people) resided in urban areas and by 2030 it is expected to become almost 50%.Urbanization in India is faced

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with two pronged challenges. On one hand the pressure of the ever-growing existing cities coupled with the colossal challenge of providing them with basic infrastructure and services. But there is also little denying the fact that the civic authorities and government have been trying to make ends meet as far as the quality, adequacy and availability of basic services like water and sewage. The ever-expanding water demand driven by world's growing population and economy, combined with the impacts of climate change, are already making water scarcity a stark reality in many parts of the world. While the water situation in India is not so attractive as of now, reforms have begun to shape and success and this would encourage private investors. With the increased involvement of the private sector, there will be a need for efficient water and waste water management to improve operating efficiency levels. Planning, development and management of water resources for diverse uses may help to generate financial resources, introduce corporate management and improve service efficiency and accountability of users. There is an increased realization of shift from water resources development to water resource management by restructuring and strengthening existing institutions for enhanced service delivery and resource sustainability.

Water deficit is becoming a serious constraint in Indian cities. National Institute of Urban Affairs (NIUA, 2005) concludes that 56 per cent of metropolitan, class-I and class-II cities are dependent on groundwater either fully or partially. Cities are now drawing water from sources hundreds of kilometers away, giving rise to conflicts with the existing users of that water. In buildings, water is used intensively during both construction and operational phases. A large part of water use in buildings can be attributed to the operational phase of buildings, where it is directly related to lifestyle of the occupants. The average water consumption in India has been calculated as 135 liters' per capita per day (as prescribed by the Central Public Health and Environmental Engineering Organization or CPHEEO).

Study on water poverty in urban India by the Mumbai-based Tata Institute of Social Sciences (TISS, 2008) states that at the household level, bathing consumes the highest amount of water. Together, in all the seven cities it surveyed it was found that bathing accounts for about 28 per cent of the total water used. Consumption in toilets (20 percent), washing clothes (19 per cent) and washing utensils (16 per cent) follows. On an average, less than 10 per cent of the total water in a household is used for drinking and cooking.

Urbanization is one of the most critical issues governing the production and use of wastewater. It will need more attention than climate change up until 2050 (OECD, 2012). Large urban areas, but particularly unplanned smaller urban centers present the biggest threat, but also the biggest opportunity for introduction of sustainable approaches to managing resources. There have been many catastrophic impacts of poor wastewater management, but by and large they are unseen or, as is often the case, occur downstream from the places where the pollution originated. In many high-density urban settings, inadequate wastewater and surface water management results in significant intra-urban differences in relation to environmental health impacts. The current approach to curative rather than preventative strategies is not only more resource intensive but also inadequate.

With increase in population, there will be an increase in stress on sanitation and wastewater disposal system. Gupta *et al*., (2004) predicted that recyclable wastewater will meet 15% of total water requirement in 2050.Wastewater is an under-utilized resource. Reuse or recycling can combine an effective environmental and health protection strategy with the recovery of water, nutrients and energy. In water scarce developing countries, grey water reuse in schools, hospitals and government institutions is proving to be an essential alternate water resource to fresh ground, surface or rainwater supplies (Godfrey *et al*., 2006). Studies from the Middle-East and India for example indicate that grey water systems have water saving of between 3.4% - 33.4% per annum (Al-Jayyousie, 2003).

About Study area

Bangalore (Rural) District consists of eight Taluks, viz Ramanagaram, Channapatna, Magadi, Kanakapur, Devanahalli, Doddaballapur, Hosakote and Nelamangala. Devanahalli taluk is one amongst the eight Taluks in the District.It has a geographical area of 448.12 sq. km, 8 per cent of that of the District total area. The Taluk enjoys salubrious climate and free from extremes. It receives rainfall from southwest monsoon from June to September, the northeast monsoon from October to November. The soil of the Taluk is red sandy soil derived from peninsular genesis, granites and laterites. The soil is red to brownish in color, shallow to fairly deep shallow; loamy to sandy loamy in texture intermixed with fairly large amounts of coarse gravel and pebbles.

The Taluk is mainly dependent on ground water for agriculture, industrial and domestic purposes. The net irrigated area is 8587 hectares; of which 1400 hectares is irrigated by surface water (tanks, canals, etc.) forming 16% to the net irrigated area and remaining 84% is irrigated through ground water (wells, bore-wells). Water supply to Devanahalli town is augmented through bore well sources, for both industrial and domestic purposes. The study area is a proposed township which is located in Devanahalli taluk, between 13°12'38.37" North latitude and 77°39'36.59"East Longitude.

METHODOLOGY

This study is based on Field test data and secondary data collected from various sources. The base data was obtained by various field tests conducted in the study area. The secondary data was obtained from CPHEEO, Central Groundwater Board, Natural Resource Data Management Center, Department of Mines and Geology.

Primary data includes the data collected by field tests for identification and quantification of the water resources in the township. The main aim of this work was to identify measures for water sustainability in the township, which involves various aspects such as: population, water demand, water availability, resource identification, waste water generation, waste water recycling.

Integrated Water Resource Management is one of the best ways to ensure water sustainability, for a township it becomes equally important to manage the resources which are limited and the waste water being generated from usage. The population for the township was forecasted and the water demand for the projected population was estimated as per CPHEEO Water Supply Standards and (NBC, 2005). The Yield of the existing bore wells in the township was identified using Single well Step drawdown Method and the safe yield of the bore wells was determined.

The Groundwater recharge potential estimation was done both by field test and from the secondary data collected. The groundwater recharge potential estimation was done in the field by using Infiltration Test. The vertical seepage of the water into the soil contributes to the aquifer recharge, which serves as the basis for the test. The actual infiltration volume was considered as 50 % of the total infiltration volume in the township due to lack of detention time, runoff loses, evaporation losses and alteration in the intact condition of the soil. The Infiltration volume was also estimated using the secondary data considering normal rainfall in the township catchment area with Infiltration volume as 15% of the total volume of rainfall water received. The recharge potential estimation will provide a brief idea about the stage of ground water development in the township.

The resource yield and the water demand showed a gap hence identification of new water resource was required. Spontaneous polarization or self-potential methods involve measurement of electric potentials developed locally in the Earth by electro-chemical activity, electro filtration activity, or both. For water investigation potentials generated by water moving through a porous medium (streaming potential) is important. Measurements of these potentials have been used to locate leaks in reservoirs and canals (Ogilvy *et al.*, 1969). Spontaneous potentials generally are no larger than a few tens of millivolts but in some places may reach a few hundred millivolts. Relatively simple equipment can be used to measure the potentials.

The new identified points were used to determine the expected yield; the expected yield of the new points was taken as an average of the determined safe yield of the existing bore wells. Roof top rainwater harvesting estimation was done using the secondary data collected.

Soil profile information was generated using Shallow Electric Resistivity Method. Shallow Schlumberger array (four electrode configuration) was used to generate the soil strata information. The strata information up to 50 meters was obtained by measuring the resistivity of the rocks. It consists of four electrodes; two inner electrodes and two outer electrodes inserted into the ground. The inner electrodes were at a distance (mn/2) and outer electrodes distance (ab/2) from the midpoint. A DC source is used to pass current through the external electrodes into the soil and current is measured using the ammeter connected to the external circuit. . The soil strata, mainly the rocks based on the characteristic nature provides resistance to the flow of current passed by the external electrodes. The resistance is measured as voltage in the inner circuit. Resistance for both direct and reverse current at each point is measured as Rd and Rr. The reverse and direct current is sent to increase the accuracy of potential measured as average of the potential for Rd and Rr was taken.

Wastewater generation estimation was done based on population, water consumption by various activities. Dual collection system of grey water and black water separately was proposed and the treatment was scheme was based on typical low load grey water and black water characteristics from residential and commercial sections. The low load grey water collected separately was treated using slow sand filter and was recycled to meet the flushing requirement of the residential section of the township. Black water was collected and treated to be used for meeting commercial flushing requirement and landscaping activities. Water balancing was done for the township and integrated water, waste water management scheme was proposed to provide sustainability to the resources and usage in the township.

Data Integration

The area details of the buildings in the residential and commercial sections were collected. The water resource consumption is based on the population of the township; hence the population forecast was done for both residential and commercial sections. Other primary data was collected by conducting various field tests and the secondary data was also used in estimations.

Population Forecast

In residential area the population forecast was done considering 6 member families in the total area of the buildings. For the commercial section population forecast was done considering 1 person per 200 square feet for the total area of the buildings. Water demand estimations were made based on 135 LPCD water supply requirements as shown in Table 1.

Bore well Yield Determination

There were 8 number of existing bore wells in the township; single well step drawdown method was used to determine the yield of the bore wells. The effective drawdown was determined using the equation (1)

$$Se = \frac{D\text{-}SWL\text{-}5}{2} \quad \ldots\ldots\ldots\ldots (1)$$

Where, Se = Effective drawdown

D = Total water depth

SWL = Static water level

The water level fluctuation due to seasonal variation is considered when calculating the effective yield. The step drawdown pumping at variable discharge is shown in (Fig. 1).

The discharge and (maximum drawdown/discharge) graph is used to determine the slope and intercept as shown in (Fig 2).

The optimum yield for different bore wells was estimated using the equation (2)

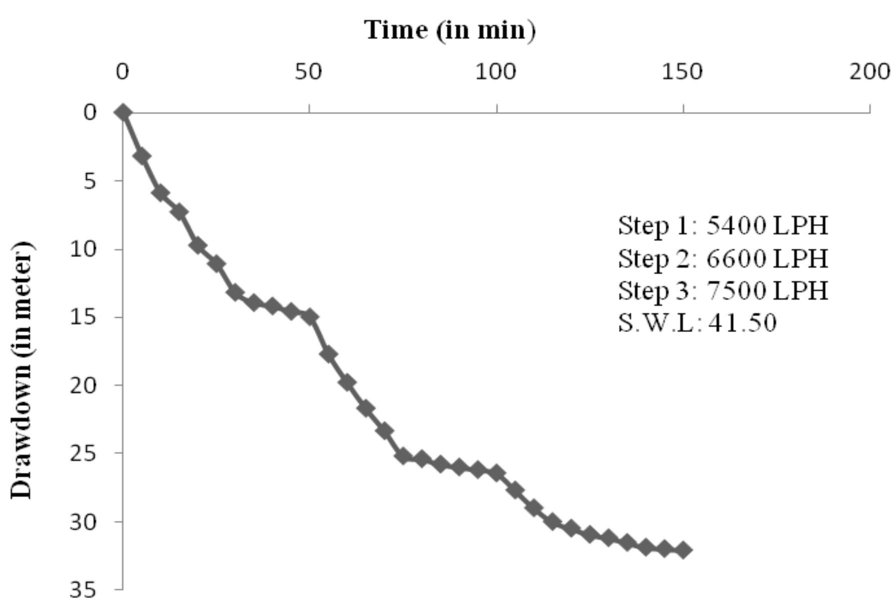

Fig. 1 Drawdown of bore wells at variable discharge ratemeter/min

$$Optimumyield = \frac{\left(-B \pm \left[\sqrt{B^2 + 4 \times C \times Se}\right]\right)}{(2 \times C)} \quad (2)$$

Where, B = Intercept
C = Slope
Se = Effective drawdown

Soil Infiltration Capacity Determination

It was carried out to determine the infiltration capacity of the soil in the township. Both vertical and horizontal seepage takes place but only vertical seepage is considered as it is responsible for the aquifer recharge. The water infiltration into the soil was measured against time and based on the infiltration value the infiltration or ground water recharge volume was estimated. The infiltration rate for the township was taken as an average of test values done at different locations, is shown in (Fig. 3)

Rainfall Infiltration Method: this method is based on the primary and secondary data collected. The infiltration volume in the township catchment area was estimated using equation (3)

Totalvolum =*Area*x*Normalra* inf *all* x35.32x1000x28.32 .....(3)

The Infiltration volume was estimated as 15% of the total volume of water received by the catchment area.

Identification of new potential bore well points

The projected water demand for the township could not be met by using the existing resources in the township, hence identification of new potential bore well points was carried out.

Spontaneous Polarization Test: New potential bore well points identification was done by using Spontaneous polarization test, which measures the earth's natural potential due to inflow and outflow of water in and out of aquifer. The potential measured against distance was plotted to identify 7 new potential points as shown in (Fig. 4)

Roof top rainwater runoff estimation was developed using the primary and secondary data. The rainwater collection from roof top will enhance the water sustainability in the township as shown in Table 2.

Determination of Soil profile

Soil profiling helps to analyze and understand the soil structure and distribution within different depth ranges. It would help to identify locations and adopt appropriate methods to enhance the water sustainability.

Shallow Electric Resistivity Method: Shallow Schlumberger array (four electrode configuration) was used to generate the soil strata information. The strata

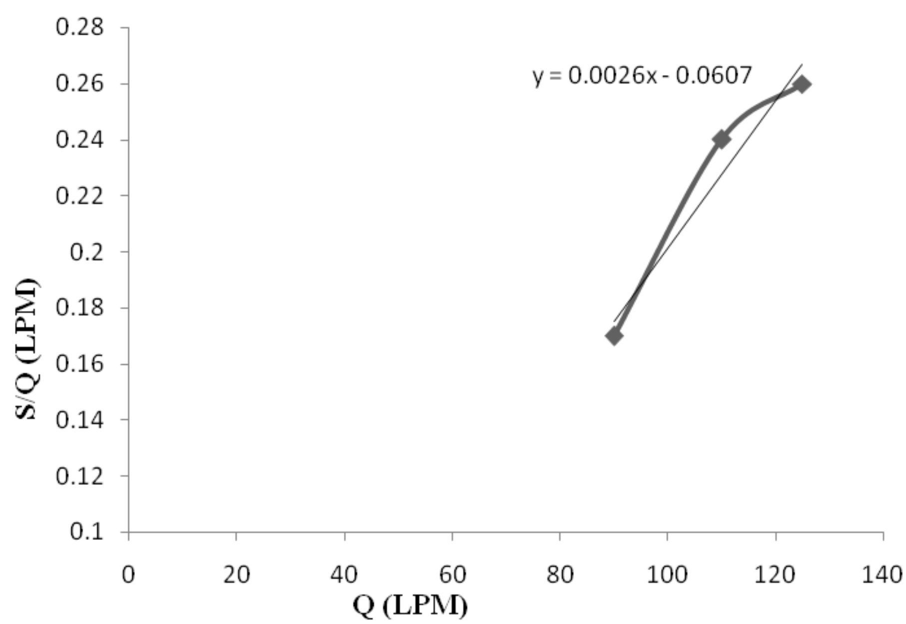

Fig. 2 Ratio of Maximum drawdown by Discharge

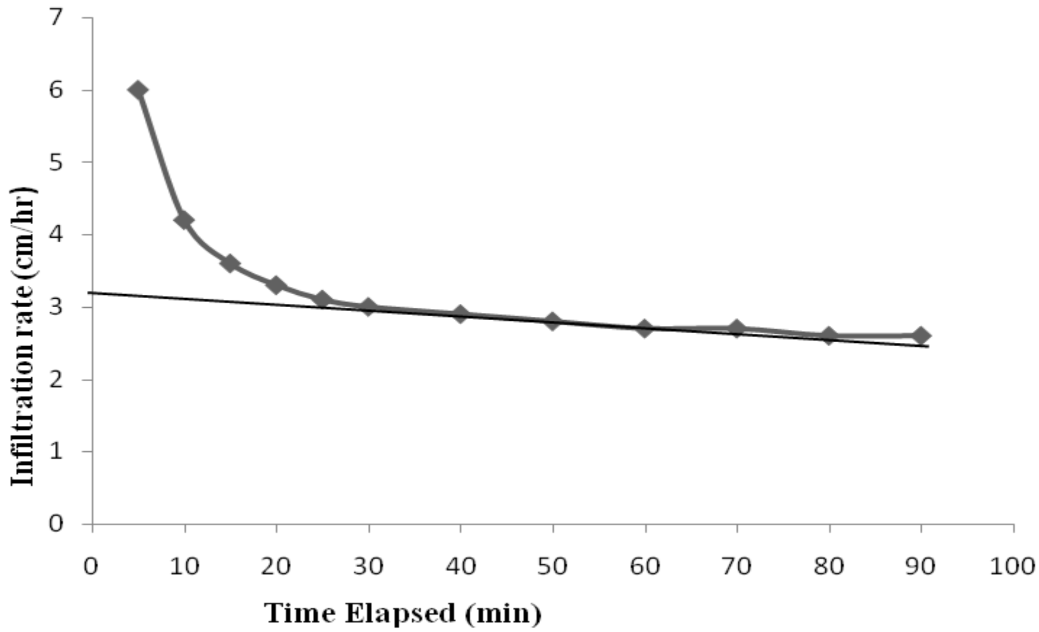

Fig. 3 Infiltration rate for the water in townshipcm/hr.

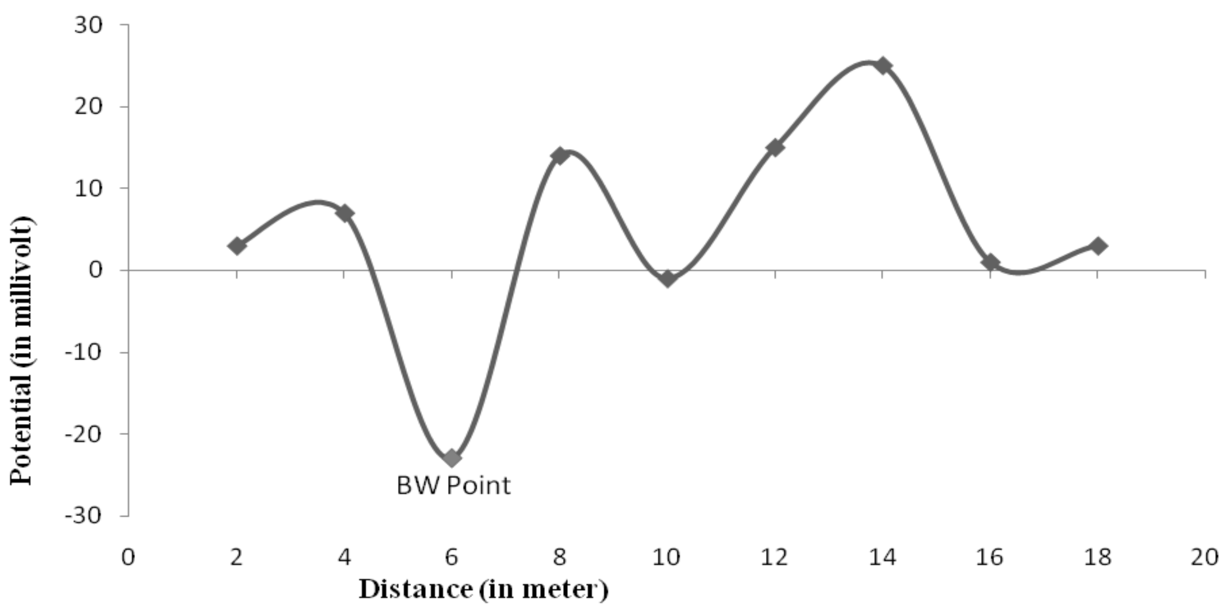

Fig. 4 Earth's Natural Potential millivolts/meter

information upto 50 meters was obtained by measuring the resistivity of the rocks.

Waste water generation estimation

Total waste water generated was estimated from the population and the typical percentage of water usage for various daily activities as shown in table 3.

Low load waste water and black water generation estimation was done to assess the possibility of dual collection system and recycling of waste water to meet the flushing and landscaping demands of the township (Table 4).

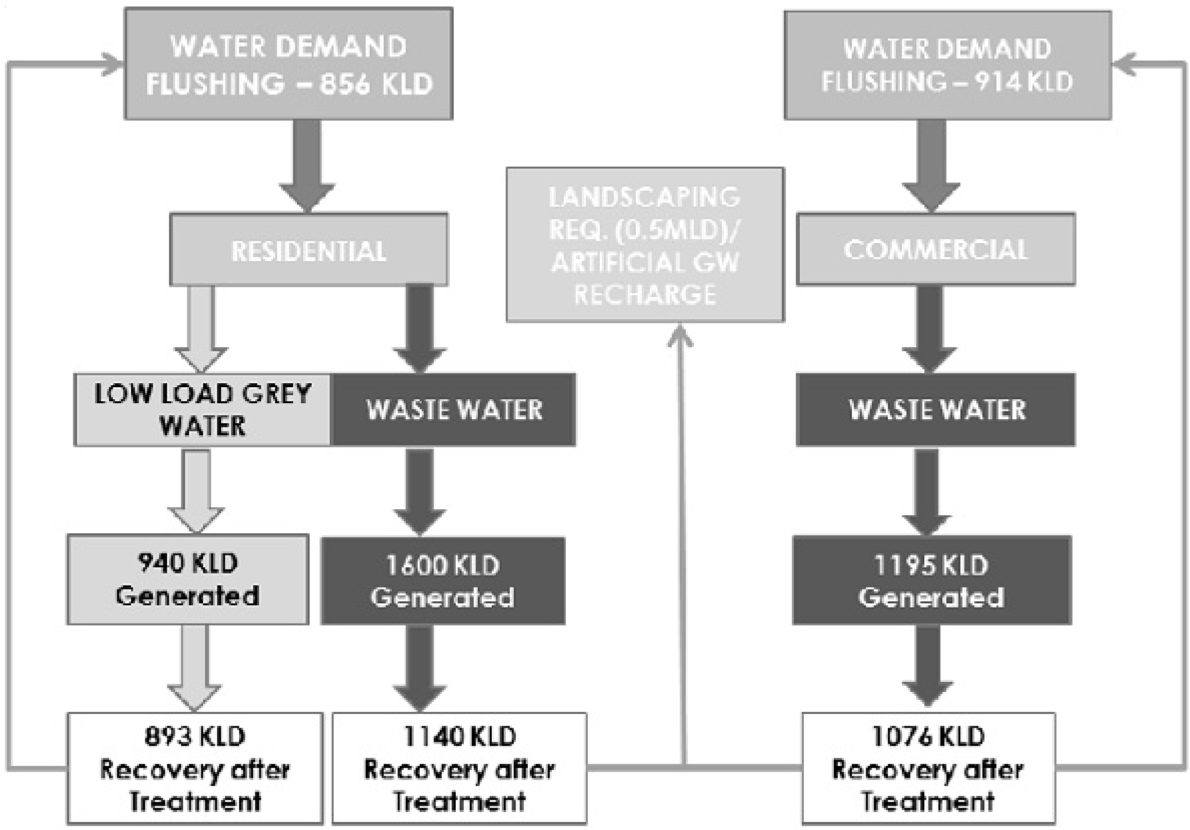

Fig. 5 Waste water Management Flowchart

RESULTS AND DISCUSSION

The determination of optimum yield from each bore well is used to determine the depth at which pump should be fixed such that it will remain submerged even after continuous pumping for 10 hours. The safe yield for continuous pumping of 10 hours was estimated for each bore well ie., 70 % for yield test done in rainy period as shown in Table 5.

Table 4 gives the yield of water source available at the township and helps to identify the gap between the forecasted water demand and the availability of water. The yield of the existing bore well was estimated as 0.5 MLD as compared to the water demand being 2.4 MLD for the township.

The Infiltration volume for the township is an essential parameter that determines the ground water recharge potential of the township. The Infiltration rate was determined to be 0.101cm/s ie. 1.46m/day, this was used to estimate the actual infiltration volume (Table 6). Actual infiltration volume was taken as 50% of total infiltration volume calculated due to losses by evaporation, runoff and detention time.

For comparison infiltration volume was estimated by the Rainfall Infiltration Method using the secondary data. It shows the fluctuation in the infiltration volume that can occur in the real case scenario as shown in Table 7.

7 new potential bore well points were identified using the SP Test (table 8). Hence the expected yield of new bore well points was estimated using the average yield values of the existing bore wells.

Overall Drinking water balance was developed for the township including existing, newly identified water resources and roof runoff as shown in Table 9.

Waste water management plan including dual collection system and recycling for various activities was developed for the township as shown in (Fig. 5)

Figure 4 represents the proportion of waste water generated as low load, high load and black water and Collection of a low load and black water separately for treatment. The treatment is based on their typical characteristics for recycling.

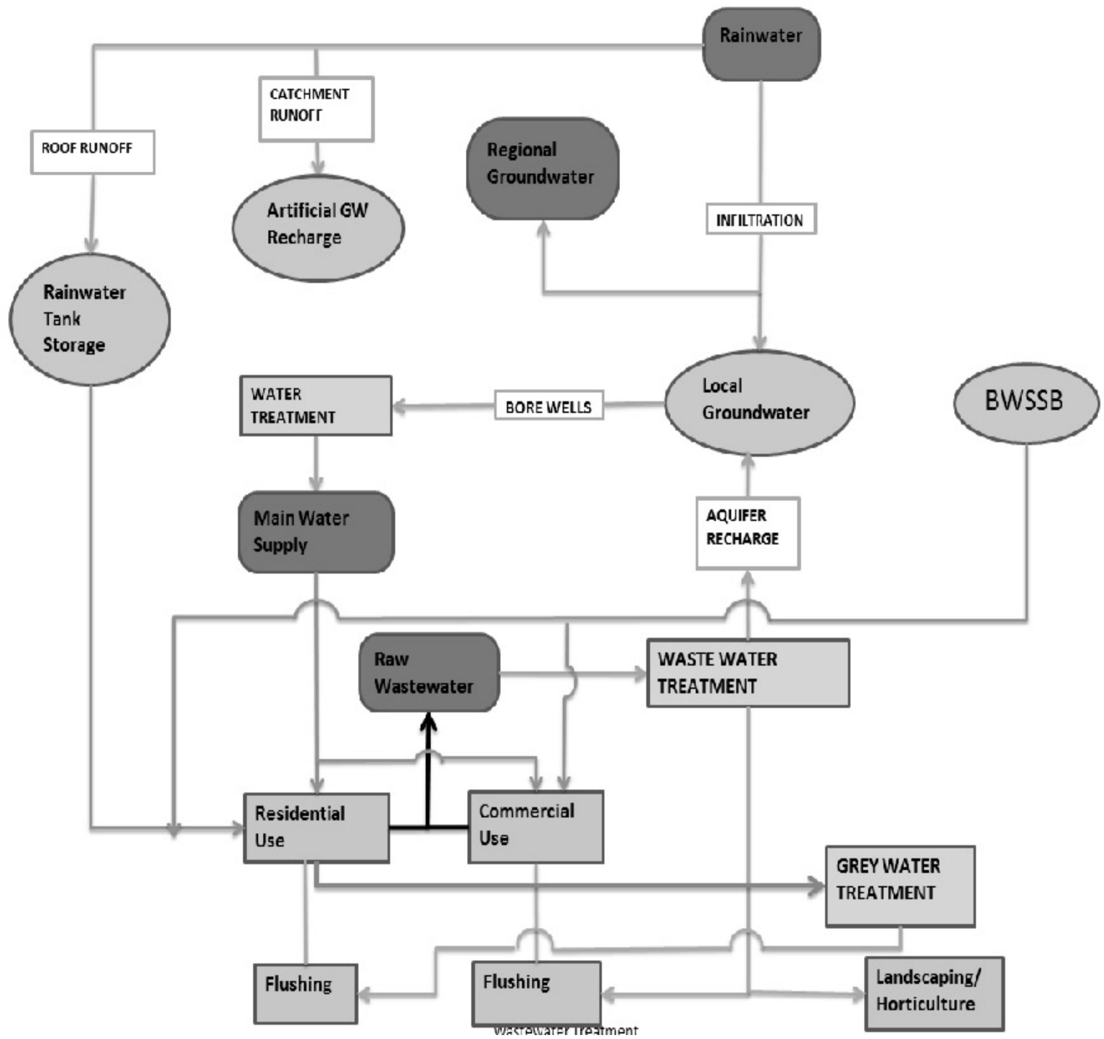

Fig. 6 Integrated Water and Waste water Management Flowchart

Integrated water and wastewater flow scheme was developed which is shown in (Fig. 6).

The limited availability of resources and the high water demand in the townships has been the major concern. Hence to ensure water sustainability in the township, integrated water and waste water management provides an effective strategy. According to integrated management principle wastewater should also be seen as a source and recycling an essential measure to boost sustainability.

CONCLUSION

The problem of water scarcity, waste water and unavailability of land for individual residents does enhance the growth of newly developing townships in many parts of India. All these townships aim at providing all the facilities required for all age group people within permissible distance. As the complexity of townships is increasing the management of water resources, waste water is looked upon with prime importance.

This work provides is aimed at proper water management, waste water and solid waste management in townships. The population projection of the township was used to determine the water demand. The water sustainability studies were carried to identify the availability of existing water sources in the township. The water balance was obtained for the township using

Table 1. Population Forecast and Water demand Estimation for the Township

Particulars	Residential Population	Total Water Demand (KLD)	Drinking demand (KLD)	Domestic usage (KLD)	Flushing demand (KLD)
Phase 1	1884	254	25	153	76
Phase 2	708	96	10	57	29
Apartment 1	1880	254	25	152	76
Apartment 2	580	78	8	47	23
Apartment 3	1570	212	21	127	64
Apartment 4	960	130	13	78	39
Villament 1	448	60	6	36	18
Villament 2	588	79	8	48	24
Phase 3	1600	216	22	130	65
Phase 4	3200	432	43	259	130
Phase 5	5500	743	74	446	223
Cub house	-	25	3	15	8
Row House	120	16	2	10	5
Total Residential	19038	2595	260	1557	779
Floating Population	1904	260	26	156	78
Total population	20942	2855	285	1713	856

Particulars	Commercial Population	Total Water demand (KLD)	Drinking usage (KLD) 5%	Domestic usage (KLD) 30%	Flushing usage (KLD) 65%
School	1306	59	3	18	93
Hospital	317	143	7	43	331
Complexes	17489	787	39	236	512
Service Apartment	249	34	2	10	22
Commercial	2482	112	6	34	73
Hotel	803	145	7	43	94
Total	22647	1279	64	384	831
Floating	2265	128	6	38	83
Total population	24912	1406	70	422	914

Overall Water Demand for Township

Particulars	Residential demand in KLD	Commercial demand	Overall demand
Drinking water demand	285	70	356
Other domestic water demand	1713	422	2135
Flushing water demand	856	914	1771
Fresh water demand (Drinking+ domestic)	1988	492	2491

Table 2. Roof top Run off Estimation for Residential Buildings

Particulars	
Residential Roof top area (in sq.m)	57592.27
Runoff Coefficient	0.8
Normal Rainfall (in mm)	767
Number of Rainy days	60
Runoff (in m^3/day)	599
Roof top runoff yield (in MLD)	0.6

Table 3. Waste water generation Estimation

Particulars	Populationin Residential	Expected Sewage generation (85%) in KLD
Phase 1	1884	216
Phase 2	708	81
Apartment 1	1880	216
Apartment 2	580	67
Apartment 3	1570	180
Apartment 4	960	110
Villament 1	448	51
Villament 2	588	67
Phase 3	1600	184
Phase 4	3200	367
Phase 5	5500	631
Cub house	-	21
Row House	120	14
Total Residential	19038	2206
Floating Population	1904	221
Total (including floating)	20942	2462
Particulars	**Population in Commercial**	**Expected Sewage generation (85%) in KLD**
School	1306	50
Hospital	317	121
Complex	17489	669
Service Apartment	249	29
Commercial	2482	95
Hotel	803	123
Total Commercial	22647	1087
Floating	2265	109
Total (including floating)	24912	1195

Table 4. Residential Low load Grey water generation

Particulars	Bathing 55% (in KLD)	Hand wash 6% (in KLD)	Grey water Generation 90% (in KLD)	Recovery 95% (in KLD)
Phase 1	84	9	84	80
Phase 2	31	3	31	30
Apartment 1	84	9	83	79
Apartment 2	26	3	26	25
Apartment 3	70	8	70	66
Apartment 4	43	5	43	41
Villament 1	20	2	20	19
Villament 2	26	3	26	25
Phase 3	72	8	71	68
Phase 4	142	16	142	135
Phase 5	245	27	245	233
Cub house	8	1	8	8
Row House	6	1	5	5
Total Residential	856	93	855	812
Floating Population	86	9	86	81
Total (including floating)	942	103	940	893

different methods to identify the fluctuations that might occur in the water balance. Basically followed field yield test showed a deficit in water supply; hence various methods like Spontaneous polarization and Electrical resistivity were used to identify new water sources. The qualitative analysis was carried out and treatment scheme was proposed.

The waste generation estimations were done and two different management schemes were proposed for the management of waste water generated. First method was dual collection system with low load grey water and black water from residents being collected separately and treated. Since Grey water typically has low concentration of contaminants slow sand filter based treatment scheme was proposed. Second method consists of collection of black water in residential and commercial waste water separately and treatment. The flushing water demand of 30% and 60% for residential and commercial respectively was proposed to be met by the treated grey water and waste water. Integrated water and waste water management

Table 5. Estimation of Safe yield of existing bore wells

Bore well	Optimum Yield (LPD)	Safe Yield (LPD)
1	78600	54600
2	150600	105000
3	150600	105000
4	67800	47400
5	157200	109800
6	29400	20400
7	30600	21000
8	51000	36000
Total	499200 (0.5 MLD)	

Table 6. Estimation of Actual Infiltration volume from Field Infiltration Test

Township Area (sq. km)	Infiltration rate (m/day)	Infiltration Volume (MCM)	Actual Infiltration Volume (MCM) (50%)
0.607	1.46	0.36	0.18

Table 7. Estimation of Infiltration volume from Rainfall Infiltration Method

Township Area (sq.km)	Normal Rainfall (mm) 1901-70	Volume (TMC)	Runoff (TMC) 20%	Evaporation (TMC) 15%	Infiltration (TMC) 15%
0.607	767	0.016	0.003	0.002	0.004
In MCM	-	0.45	0.09	0.07	0.07

Source: Rainfall data :NRDMC, Bangalore Rural 2011.

Table 8. Estimation of Expected Yield for new bore well points

Particulars	
Number of identified bore wells	7
Expected Yield of each bore wells (in LPH)	8000
Expected Total Yield (in LPH)	56000
Total Pumping hours	10
Total Yield (in LPD)	560000 (ie. 0.6MLD)

Table 9. Estimation of Overall Water Balance for the Township

Description	
Overall Fresh water demand for township (in MLD)	2.5
Water Source	Groundwater (bore wells)
Number of Existing bore wells	8
Estimated Yield of Existing bore wells (in MLD)	0.5
Number of identified bore wells locations	7
Expected Yield of the bore wells (in MLD)	0.6
Residential Rain water Harvesting yield (in MLD)	0.6
Water Balance (in MLD)	-0.8

provides an effective and efficient management strategy to promote sustainability in the township.

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