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Strictly as per the compliance and regulations of :

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I. Introduction

a) Concept of Rain Water Harvesting

The rainwater harvesting consists of a wide range of technologies used to collect, store and provide water with the particular aim of meeting demand for water by humans and/or human activities, which is explained schematically in Figure-1. These technologies can be divided into two main areas depending on source of water collected; namely, the in situ and the ex situ types of rainwater harvesting, respectively.

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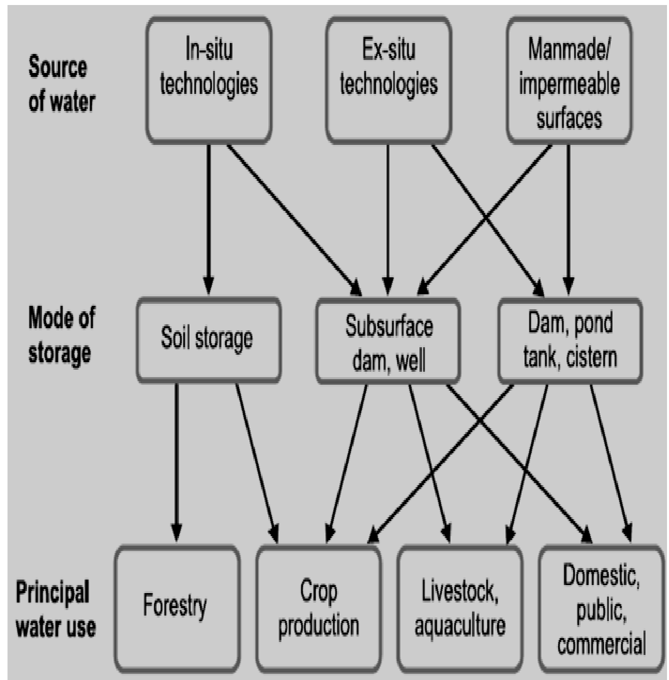

Figure 1 : "Schematic Diagram showing the rainwater harvesting technologies based on source of water and water storage type" [UNEP(2009)]

b) Need For Rainwater Harvesting

Due to over population and higher usage levels of water the surface sources are being over stressed which has led to boring of tube wells at individual as well as at local government's level. The replenishment of ground water (GW) is drastically reduced due to paving of open areas. Indiscriminate exploitation of GW results in lowering of ground water table (GWT) rendering many bore-wells dry. To overcome this situation bore wells are drilled to greater depths. This further lowers the GWT and in some areas this leads to higher concentration of hazardous chemicals such as fluorides, nitrates and arsenic. In coastal areas, over exploitation of GW results in seawater intrusion thereby rendering GW bodies' saline. In rural areas also, government policies on subsidized power supply for agricultural pumps and piped water supply through bore wells are resulting into decline in GWT. The solution to all these problems is to replenish GW bodies with rainwater by manmade means.

c) Indian Scenario: Rain Water Harvesting

The annual precipitation in India is estimated on an average 1100 mm. Although its distribution in space and time is highly variable, most of it is allowed to go waste as run-off water into the sea through the river system. The Government of India (GoI) is also promoting rainwater harvesting through watershed management programme, artificial recharge of GW and roof top rain water harvesting (RRWH) under various schemes. The main function of the urban local bodies is to guide the development according to the master plan prepared by the town & country planning departments and to provide and maintain the services like water supply, sanitation and transportation. The major flaw in these planning processes is that the building bye-laws and development charges do not encourage citizens to adopt RRWH and other measures to conserve the water. Also as water is being supplied at greatly subsidized rates, cost of water is between Rs 8.10 to Rs 6.10 per Kilo-liter at 1998-1999 prices while it is supplied at less than Rs 2.00 per Kilo-liter [GoI (2004)], by the urban local bodies so people are not encouraged to adopt the rain water harvesting which in turn is depleting the precious available water resources resulting in shortage of water in the urban areas. To overcome these problems there is a need to adopt water sensitive development controls as part of the building bye-laws in the master plan of the urban area itself. [Chakrabarti (2000)]

II. Description of Project Area

a) Location

The Dhule town is located at latitude 21°10' and longitude 75°20', lying 57 km. north of Chalisgaon Bombay-Nagpur route of the central railway. The SSVP Sanstha is rendering the valuable services in the field of education for the people living in the Dhule town district, for last 104 years. The main campus of the SSVP Sanstha is located in Vidyanagari area of Dhule town. The campus includes the Science College, Arts College and Commerce College offering secondary and post secondary education along with an engineering college, polytechnic since 1983 and a School, since 2007. The area of these five institutes is clearly demarcated for educational activities; however there is lot of area which is being shared for practical purposes. The administrative and educational working of all these five institutions is independent.

b) Necessity of Project

The water resources and the drainage system in the premises of these five institutes are shared. The gross area of the premises is 77,700 sqm, out of which 37 numbers of buildings in the premises constitutes 24938 sqm roof top areas. In present situation the rainwater from this huge roof top area is drained out of campus to nearby stream as overland flow and the guided flow through existing drainage network at some places. The overland flow leads to the erosion of soil from unpaved area in premises and chocking of the existing drainage system due to silting. This huge roof top area, if used for RWH, has immense potential for GW recharging. This will result in rise in GWT which in turn will increase the yield of the open dug wells and also the duration of their services. The benefits of the rise in GWT will be not being limited to the SSVPS premises; the nearby area will also be benefited from it. It will be an added advantage as discharge of institute's social responsibility. The GW recharge will also dilute the poor quality water percolated in the GW throughout the year from the two number of unlined streams (Nalas), carrying the waste water discharge from residential area located on north and west side of the residential area. The success chronicle of the proposed RWH project will motivate the other institutes, premises and big housing projects to adopt such installation to make the better environment.

III. Methodology for Planning & Design

a) Assumptions

The following are the assumptions; which are made in this proposed RRWH project-

- The rainfall intensity is taken as 50 mm per hour with the help of map, instead of actual applicable for Dhule region.
- The life of the RRWH system is considered as 40 years & the annual rate of interest is taken as 4% for calculating the annual equivalent cost (AEC) of the system.
- It is assumed that 40% of quantity of water which is recharged in ground is utilizable during lean period.

b) Buildings and Rooftop Area

An integrated planning for RRWH system for all five institutes is proposed. The entire area is divided in six zones, each having individual ground water recharge structure (GWRS). These six zones are shown in Figure - 2. All the buildings in premises are coded showing the institute's to which they belong and the number of building.

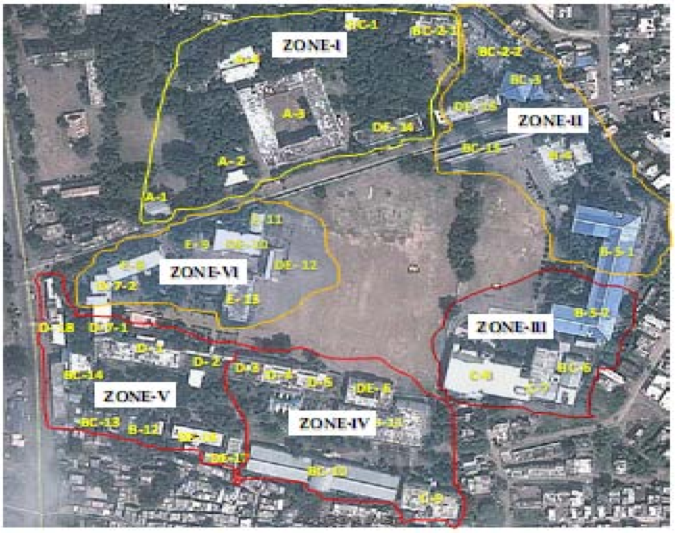

Figure 2 : "Boundaries & Buildings in Six Zones for RRWH"

The codes of buildings are A, B, C, D & E for North Point school, Engineering College, Polytechnic, Science College and Arts and Commerce College respectively, along with the number of particular building. The two codes for a building mean that the building is shared by two respective institutes. The area of each building in different zones and their height are given in Table-1. These zones are planned by considering the elevation of GWRS with respect to the elevation of buildings in such a way that the harvested rain water from rooftop will reach to it under gravity through underground conveyance system. All the major buildings are divided into two or more parts depending upon their rooftop area and zones.

Table 1 : "Rooftop Area Statistics – Zone Wise"

Sr	ZONE	Code	Effective Area (Sqm)	Ht (m)	Type	Sr	ZONE	Code	Effective Area (Sqm)	Ht (m)	Type
1	ZONE-I	A-1	184.87	7.2	SR	1	ZONE-IV	C-9	684.00	9.4	FR
2		A-2	178.50	2.7	SR	2		BC-10	1800.00	3.4	SR
3		A-3	2549.00	9.7	FR	3		B-11	1500.00	9.4	FR
4		A4	636.00	3.4	FR	4		DE-6	600.00	6.4	FR
5		BC-1	106.32	6.4	FR	5		D-5	330.00	6.4	FR
6		BC-2-1	468.58	9.8	FR	6		D-3	300.00	6.4	FR
7		DE-14	581.10	3.4	FR	7		D-4	300.00	6.4	FR
		SUM	**4704.37**					SUM	**5514.00**		
1	ZONE-II	BC-2-2	365.64	9.8	FR	1	ZONE-V	DE-17	258.00	6.4	FR
2		BC-3	587.57	9.4	SR	2		DE-16	330.00	6.4	FR
3		B-4	736.15	9.4	SR	3		BC-12	105.00	6.4	FR
4		B-5-1	2009.40	9.4	SR	4		BC-13	420.00	6.4	FR
5		BC-15	316.80	2.7	SR	5		BC-14	565.00	6.4	FR
6		DE-15	561.56	6.7	FR	6		DE-18	400.00	3.0	FR
		SUM	**4577.12**			7		DE-7-1	432.00	6.4	FR
1	ZONE-III	B-5-2	1811.95	9.4	FR	8		D1	504.00	6.4	FR
2		BC-6	699.61	6.4	FR	9		D2	432.00	6.4	FR
3		C-7-1	581.10	9.4	FR			SUM	**3014.00**		
4		C-7-2	741.32	9.4	FR	1	ZONE-VI	D-7-2	324.00	6.4	FR
5		C-8	620.34	9.4	SR	2		E-8	444.00	6.4	FR
		SUM	**4454.32**			3		E-9	444.00	3.2	FR
1	ZONE-IV	C-9	684.00	9.4	FR	4		DE-10	540.00	6.4	SR
2		BC-10	1800.00	3.4	SR	5		E-11	109.20	6.4	FR
3		B-11	1500.00	9.4	FR	6		DE-12	158.40	6.4	SR
4		DE-6	600.00	6.4	FR	7		E-13	544.50	6.4	FR
5		D-5	330.00	6.4	FR			SUM	**2564.10**		
6		D-3	300.00	6.4	FR		GRAND SUM		**24938.00**		
7		D-4	300.00	6.4	FR						
		SUM	**5514.00**								

c) Design Steps

The methodology for the planning and designing of RRWH system in each zone is explained in following steps;

- The route of RCC pipe below ground is finalized with the location of intake chambers to collect the harvested water from the different buildings of zone and to discharge it in GWRS.
- The area of each building in the zone is calculated and the planning for horizontal drain pipe on wall (HPW) or gutter at the edge of sloping roof (HGW) and vertical drain pipe on wall (VPW) is done in such a way that the VPW will discharge into one or two intake chambers depending upon the size of rooftop and location of chamber.
- In case of sloping roof the area of rooftop is increased by 20% for pitch more than 25° and 10% for less than 25°. The increased area is taken for calculation purpose.
- The HPW, HGW and VPW are designed as per norms as discussed. The rate of flow of each VPW discharging into different intake chamber is calculated.
- The RCC pipes below ground are designed for the corresponding discharge and available ground slope. The size of intake chamber is selected on the basis of available ground slope. In case of flatter slope the intake chamber of higher size may be selected.
- The open dug well is the most suitable GWRS option in the area. An open dug well of 6.0 m diameter with horizontal bores of 115 mm diameter, 6 Nos. of length 30 m each are proposed.

d) Cost Estimation

The cost estimation of different components of RRWH project for each zone is done on the basis of District Schedule of Rates (DSR) of Maharashtra Jeevan Pradhikaran (MJP) for year 2010-11. The cost of semicircular gutters is considered as 67% cost of pipe of same size. The cost of minor fittings in PVC gutters and pipes are taken as 5% of the cost of same. The correct alignment and proper fitting of pipes and gutters in building is essential to avoid malfunctioning of the system and hence a special provision of 10% cost of pipes and gutter is kept for this purpose. The cost estimation of special structures, i.e. intake chamber and chamber with vent pipe is done separately and the same cost is taken. The life of the RRWH system is considered as 40 years and the annual rate of interest is taken as 4%, which is normally the interest of soft loan by various financial institutions for the purpose of calculation of annual cost of the project.

e) Sample Calculations for Zone : I

The list of buildings and their rooftop type and area is given in Table – 1. The total effective rooftop area in the zone is 4704.37 sqm. The average annual monsoon rainfall with 60% probability is 494.94 mm and is considered for calculating the RRWH volume. The planning for route of underground drainage system is shown in Figure -3, which also shows the ground RLs and the chainage of various intake chambers.

POINTS	CHAINAGE	Ground RL
	m	m
IC-1	0	263.285
IC-2	60	262.605
IC-3	74	261.890
IC-4	130	261.390
IC-5	137	261.295
IC-7	208	260.950
IC-8	234	260.455
GWRS-I	273	260.375
IC-6	0	262.055
IC-7	35	260.950
IC-9	0	260.975
GWRS-I	25	260.375

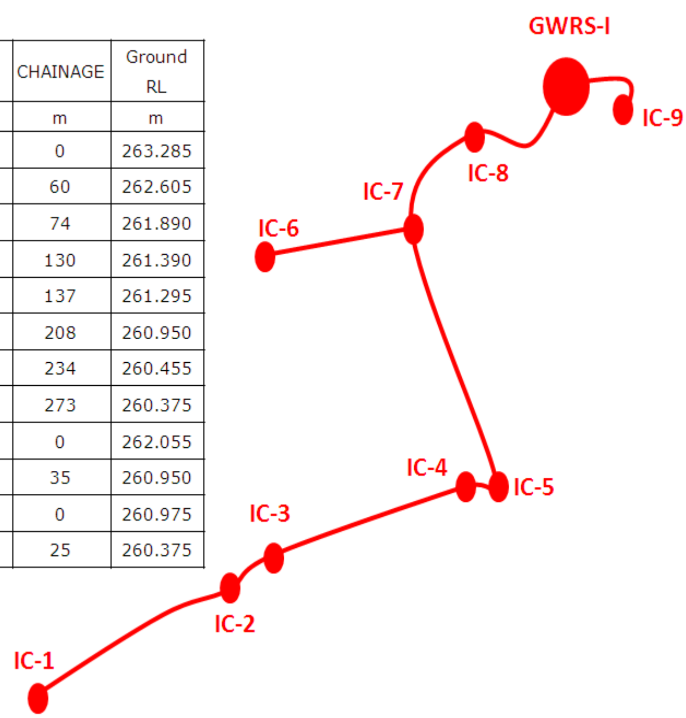

Figure 3 : Conveyance System below Ground for Zone-I

The PVC gutter for sloping roof i.e. HGW, PVC drain pipes on wall i.e. HPW and VPW are designed for all seven buildings in zone-I. The detailed are shown in Table-A.1 attached in appendix.

After planning and designing the RRWH system for all buildings, the rainwater discharge at each intake chamber is summed up and the size of underground pipe line system is calculated. The detailed calculations for the sizes of the underground reinforced cement concrete (RCC) pipes are shown in Table – A.2. The chamber with vent pipe are proposed at an average distance of 30 m or at the places of change in direction. The height of the intake pipe in intake chamber is taken as per the availability of ground slope to avoid the deep excavation.

The abstract of estimate for RRWH system for zone-I is shown in Table – A.3. The GWRS is open dug well of 6.0 m diameter, 15 m deep and 30 m x 6 Nos of horizontal bores of 115 mm size. The AEC is estimated with and without the cost of GWRS.

IV. Conclusions

a) Cost Analysis

The total capital cost and its breakdown such as cost of pipes in buildings, conveyance system below GL and the cost of GWRS for all the six zones are shown in Figure - 4.

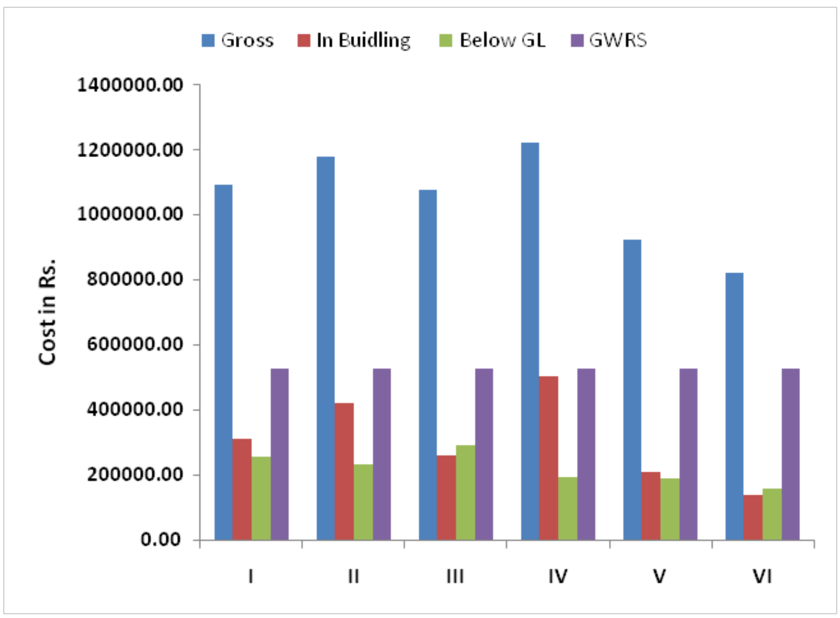

Figure 4 : Cost Breakdown of RRWH System in All Six Zones"

The unit cost of water with and without GWRS for 100% & 40 % utilizable quantity is shown in Figure -5.

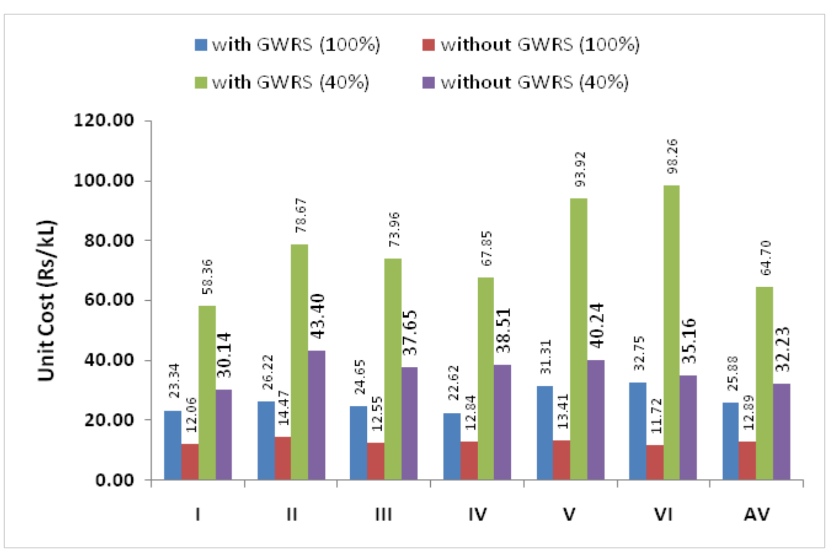

Figure 5 : Unit Cost in All Six Zones

The AEC versus the RRWH potential of all six zones is shown in Figure 6.

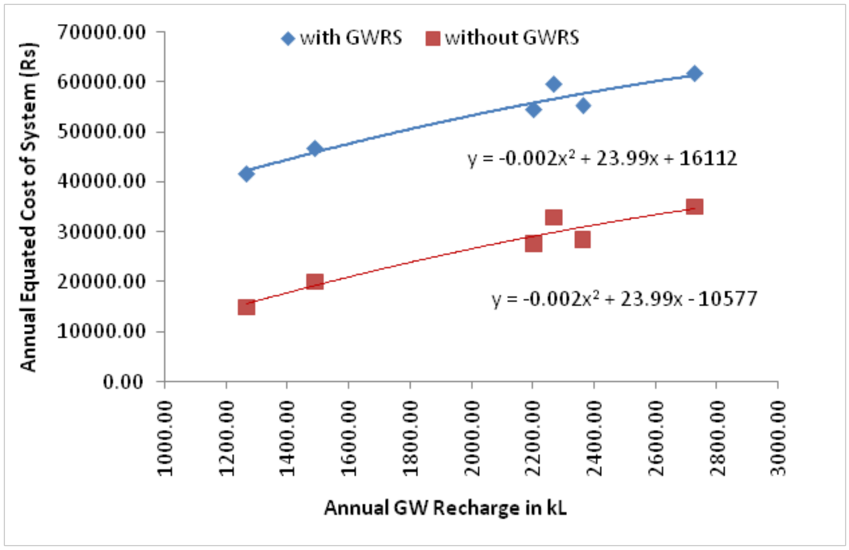

Figure 6 : Annual equated cost versus Annual GW Recharge

The split of costs in % of gross cost of different elements of RRWH system i.e. pipes in buildings, pipes below ground and ground water recharge structures for whole premises is shown in Figure-7.

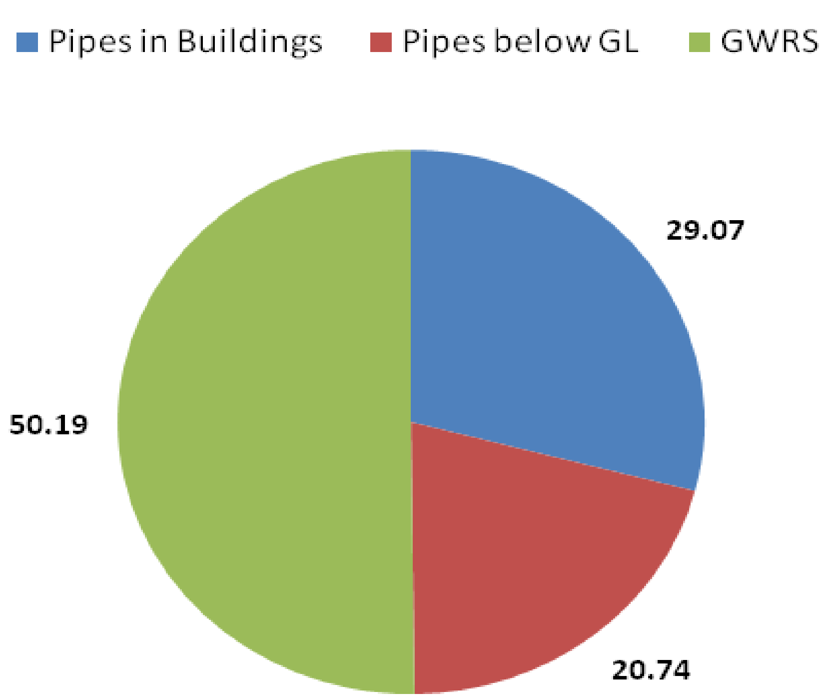

Figure 7 : % of Cost of Different Elements w.r.t. Gross Cost

b) Comments

The 40% utilization of recharged water is taken as a real life situation. The unit cost of recharged GW as calculated for the two scenarios, i.e. by considering the 100% water utilizable and second only 40% water is utilizable. In both the cases the cost is higher as compared to the market price of water. However, the environmental benefits of the ground water recharging with good quality water justifies such projects.

It is evident from Figure -7, that 50% is the cost of GWRS. These structures are not meant only for recharging purpose. These may be used the ground water resource structure, to tap the recharged water. Hence, the full cost of these structures on the part of the RRWH system cannot be justified.

c) Future Scope

There is enough quantity of rain water, which can harvested from the play grounds, paved and semipaved circulation area and the garden area of the institute premises. These areas are around 3 – 4 times the rooftop area in the institute's premises. In the case study of SSVPS premises, which is presented here, the rooftop area is around 1/3rd of the gross area. If the RW from remaining area is harvested for GW recharge, through the proposed GWRS, the unit cost will have steep fall and the project may become financially more viable. Thus, the micro-level study of RWH from the remaining area of premises along with the water requirement of the premises may add new dimension to such project.

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Table A.1 : Design of RRWH System for All Buildings in Zone-I

1	Building Code & Roof Type						A-1 : SR	
	Plan Area A (m^2)			184.87	Effective Area A_{eff} (m^2)			221.84
	Annual RRWH Potential (kL)			109.80	Total Discharge from Rooftop (LPS)			3.08
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	13.00	110.92	1.54	5546.10	160.00	HG
	3	4	13.00	110.92	1.54	5546.10	160.00	HG
	4	5	13.00	110.92	1.54	5546.10	110.00	HPW
	4	IC-1	7.20	221.84	3.08	5546.10	110.00	VPW
2	Building Code & Roof Type						A-2 : SR	
	Plan Area A (m^2)			178.50	Effective Area A_{eff} (m^2)			214.20
	Annual RRWH Potential (kL)			106.02	Total Discharge from Rooftop (LPS)			2.98
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	17.00	107.10	1.49	5355.00	160.00	HG
	3	4	17.00	107.10	1.49	5355.00	160.00	HG
	4	5	11.00	107.10	1.49	5355.00	110.00	HPW
	4	IC-2	2.70	214.20	2.98	5355.00	110.00	VPW

3	Building Code & Roof Type						A-3 : FR	
	Plan Area A (m^2)		2549.00	Effective Area A_{eff} (m^2)				2549.00
	Annual RRWH Potential (kL)		1261.60	Total Discharge from Rooftop (LPS)				35.40
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	31.50	312.90	4.35	15645.00	160.00	HPW
	2	3	31.50	625.80	8.69	31290.00	225.00	HPW
	3	IC-3	9.70	938.70	13.04	23467.50	200.00	VPW
	4	5	20.00	215.76	3.00	10788.00	140.00	HPW
	5	6	22.10	431.52	5.99	21576.00	180.00	HPW
	7	8	26.40	316.63	4.40	15831.25	160.00	HPW
	8	6	26.40	633.25	8.80	31662.50	225.00	HPW
	6	IC-4	9.70	1064.77	14.79	26619.25	200.00	VP
	9	10	20.00	215.76	3.00	10788.00	140.00	HPW
	10	11	22.10	431.52	5.99	21576.00	180.00	HPW
	11	IC-7	9.70	431.52	5.99	10788.00	140.00	VPW
4	Building Code & Roof Type						A-4 : FR	
	Plan Area A (m^2)		636.00	Effective Area A_{eff} (m^2)				636.00
	Annual RRWH Potential (kL)		314.78	Total Discharge from Rooftop (LPS)				8.83
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	26.50	134.68	1.87	6734.00	110.00	HPW
	2	4	24.00	269.36	3.74	13468.00	140.00	HPW
	3	4	26.50	134.68	1.87	6734.00	110.00	HPW
	4	IC-6	3.40	636.00	7.48	15900.00	140.00	VPW
5	Building Code & Roof Type						DE-14 : FR	
	Plan Area A (m^2)		581.10	Effective Area A_{eff} (m^2)				581.10
	Annual RRWH Potential (kL)		287.61	Total Discharge from Rooftop (LPS)				8.07
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	14.90	193.70	2.69	9685.00	125.00	HPW
	2	3	14.90	387.40	5.38	19370.00	180.00	HPW
	3	4	14.90	581.10	8.07	29055.00	225.00	HPW
	4	IC-5	3.40	581.10	8.07	14527.50	160.00	VPW
6	Building Code & Roof Type						BC-1 : FR	
	Plan Area A (m^2)		106.32	Effective Area A_{eff} (m^2)				106.32
	Annual RRWH Potential (kL)		52.62	Total Discharge from Rooftop (LPS)				1.48
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	5.30	53.16	0.74	2658.00	75.00	HPW
	2	3	5.30	106.32	1.48	5316.00	90.00	HPW
	3	IC-8	6.40	106.32	1.48	2658.00	75.00	VPW
7	Building Code & Roof Type						BC-2-1 : FR	
	Plan Area A (m^2)		468.58	Effective Area A_{eff} (m^2)				468.58
	Annual RRWH Potential (kL)		231.92	Total Discharge from Rooftop (LPS)				6.51
	Design of Rainwater Collection System on Wall/Roof							
	From	To	L (m)	CA (m^2)	Q (LPS)	Size (mm^2)	Dia (mm)	TYPE
	1	2	19.50	117.22	1.63	5861.00	110.00	HPW
	2	6	19.50	234.44	3.26	11722.00	140.00	HPW
	3	4	14.00	78.14	1.09	3907.00	90.00	HPW
	4	5	14.00	156.28	2.17	7814.00	110.00	HPW
	5	6	14.00	234.42	3.26	11721.00	140.00	HPW
	6	IC-9	9.80	468.58	6.51	11714.38	140.00	VPW

- SR - Sloping Roof, HG-Horizontal Gutter, VP - Vertical Pipe, HPW - Horizontal Pipe on Wall
- Pitch of Roof (Degree) = 26-35, Area Correction Factor = 1.2, Rainfall Intensity - 50 mm/hour
- External Gutter Size per unit of Drainage Area - 50 mm^2/m^2,
- Horizontal Down Pipe Size per unit of Drainage Area (< 15^O Slope)- 50 mm^2/m^2
- Vertical Down Pipe Size per unit of Drainage Area - 25 mm^2/m^2

Table A.2 : Design of Underground Pipe Line for Zone-I

Points	Chainage	GRL	Q-ADD at Intake Chamber	LENGTH	Q-PIPE	DROP	SL-Available (X)	Pipe Dia
	m	m	LPS	m	LPS		1 : X	mm
MAIN LINE-1								
IC-1	0.00	263.285	3.08					
				60.00	3.08	0.680	88.24	100.00
IC-2	60.00	262.605	2.98					
				14.00	6.06	0.715	19.58	100.00
IC-3	74.00	261.890	13.04					
				56.00	19.09	0.500	112.00	150.00
IC-4	130.00	261.390	14.79					
				7.00	33.88	0.095	73.68	200.00
IC-5	137.00	261.295	8.07					
				71.00	41.95	0.345	205.80	250.00
IC-7	208.00	260.950	13.47					
				26.00	55.42	0.495	52.53	250.00
IC-8	234.00	260.455	1.48					
				39.00	56.90	0.080	487.50	300.00
GWRS-I	273.00	260.375						
BRANCH LINE								
IC-6	0.00	262.055	7.48					
				35.00	7.48	1.105	31.67	100.00
IC-7	35.00	260.950	5.99					
					13.47			
MAIN LINE - 2								
IC-9	0.00	260.975	6.59					
				25.00	6.59	0.600	41.67	100.00
GWRS-I	25.00	260.375						

Table A.3 : Abstract of Estimate RWHS for Zone-I

Sr	Description of Items	Unit	Qty	Rate (Rs/Unit)	Cost (Rs)
1	PVC Pipe + Jointing				
	75 mm	RMT	11.70	110.00	1287.00
	90 mm	RMT	19.30	154.00	2972.20
	110 mm	RMT	120.70	224.00	27036.80
	125 mm	RMT	14.90	304.00	4529.60
	140 mm	RMT	120.00	382.00	45840.00
	160 mm	RMT	92.80	496.00	46028.80
	180 mm	RMT	59.10	625.00	36937.50
	200 mm	RMT	19.40	733.00	14220.20
	225 mm	RMT	41.30	945.00	39028.50
	160 mm	RMT	60.00	345.60	20736.00
2	RCC Pipe below GL				
	100 mm	RMT	134.00	284.00	38056.00
	150 mm	RMT	56.00	468.00	26208.00
	200 mm	RMT	7.00	636.00	4452.00
	250 mm	RMT	97.00	887.00	86039.00
	300 mm	RMT	39.00	1231.00	48009.00
3	Pipe Minor Fittings - Material	10% of Cost of Pipes			21788.06
4	Pipe Fixing in Wall - Labour	20% of Cost of Pipes			43576.12
5	Gutters Minor Fittings - Material	10% of Cost of Gutters			2073.60
6	Gutter Fixing in Roof - Labour	20% of Cost of Gutters			4147.20
7	Lowering & Laying - RCC Pipes				
	100 mm	RMT	134.00	31.00	4154.00
	150 mm	RMT	56.00	45.00	2520.00
	200 mm	RMT	7.00	59.00	413.00

	250 mm	RMT	97.00	79.00	7663.00
	300 mm	RMT	39.00	96.00	3744.00
8	Excavation & Refilling				
	Soft Murum (0.60 x 0.30 m)	Cum	59.94	114.00	6833.16
	Hard Murum (0.60 x 0.20 m)	Cum	39.96	127.00	5074.92
9	Intake Chamber				
	Intake Pipe 1.0 m	No	3	1207.00	3621.00
	Intake Pipe 1.5 m	No	3	1559.00	4677.00
	Intake Pipe 2.0 m	No	3	1911.00	5733.00
10	Chamber with Vent Pipe	No	11	620.00	6820.00
11	GWRS (Open Dug Well with Bore)	No	1	497450.00	528250.00
Gross Cost- Rs.					1061668.66
Cost in Building-Rs.					310201.58
Cost in Conveyance Below Ground-Rs.					223217.08
Cost of GWRS-Rs.					528250.00
Annual Quantity of RRWH-kL					2364.35
Life of Project -Years		40		Rate of Interest -	0.04
Equivalent Annual Cost Factor					0.0505
Equivalent Annual Capital Cost with GWRS -Rs.					53639.21
Equivalent Annual Capital Cost without GWRS-Rs.					26950.17
Capital Cost/kL (considering 100% utilizable) - Rs/kL-					22.69
Capital Cost/kL (without GWRS) (considering 100% utilizable) - Rs/kL-					11.40
Capital Cost/kL (considering 40% utilizable) - Rs/kL-					56.72
Capital Cost/kL (without GWRS) (considering 40% utilizable) - Rs/kL-					28.50