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Investigation of Rainwater Harvesting System for NIT, Arunachal Pradesh

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Abstract: ***Water is one of the most important resources required for the survival of human beings. Similarly, for the proper and smooth functioning of any educational institute, proper water management measures should be taken. The permanent campus of NIT ARUNACHAL PRADESH is situated in a remote and hilly area, so water sources should be managed efficiently to meet the demand. Arunachal Pradesh is a region of high rainfall and if proper and efficient rain water harvesting is done then large amount of rain water could be collected and brought into proper use. The harvesting of rainwater is basically the collection and storage of rainfall through different techniques and using the collected water to meet the demand of human consumption. In this regard, we attempted to study the impact of rainwater harvesting in meeting the day to day requirements in NIT Jote campus. This project deals with the various scenarios of rainwater harvesting and its usefulness in meeting the water demands of the institute. The analysis shows that 80 litres and 30 litres of water could be supplied to 1150 individuals throughout the year with a storage of 18000 m3 and 4500 m3 respectively for Zone I (hostel and staff quarters). Similarly Zone II (academic blocks, administrative block and central library) requirements also analysed and required size of the tank was proposed. This would result in the reduction of load from the main supply (7 km away) and moving a step towards sustainable development.***
Keywords: Rain water harvesting, rainfall intensity, Annual Demand.

I. INTRODUCTION

Water is one of the most important natural resources available to human being. Among all the earth's renewable resources, water has a unique place. It is essential for the survival of all forms of life, food production, economic development and for general well-being of the society. Water is also one of the most manageable of the natural resources as it is capable of transport, diversion, storage and recycling. All these properties of water explains its great utility for mankind. Over the years, the need for preserving and maintaining water resources has been made at various scientific events. Water is an important source for every living organism, human and plant needs water for survival. Water is a nature's gift given to the people living on the earth. However, the shortage of water supply had become a global issue. The increasing population of the worldwide had lead to increase the water's demand. In addition, develop country try to keep pace with the rapid growth of the country's economy and discharge chemical, solid, rubbish to the river, squatter, land development, slaughter houses, improperly dispose waste from animal husbandries and firms had caused the water pollution problem. The addition of chemical such as chlorine for water treatment process will kill all the bacteria and micro-organisms include the useful micro-organisms contain the water. To solve the problem of shortage of water supply, water collected by a rainwater collection system is the best solution and alternation for the region. Zelenakova et.al described comprehensive rainwater management approaches and an overview of the source control techniques as well as practical examples of rainwater use for non-potable purposes The provision of such a scheme shall ensure a constant and a reliable water supply to that section of the people for which it has been designed. Taipodia et.al did investigation of water supply in NERIST campus. The proposal for rain water harvesting with the suitable estimation of demand and supply was done and the required storage volume was proposed Rainwater harvesting is an important simple low-cost technique that requires minimum specific expertise or knowledge and offers many benefits. Matos et.al did case study to revert the non-sustainable tendency of increasing surface and groundwater extraction to satisfy the rising demand of water, a more sustainable use of this essential resourceRainwater harvesting is a technology used to collect, convey and store rain for later usage. Zhen et.al.[5] did analysis of plans for rainwater reuse in a residential area in Jiangsu, china. To make full use of rainwater resources, and to reduce the environmental stress brought about by rainwater drainage, rainwater sampled in a residential area in Yancheng City . Villarreal and Dixon [8] did Analysis of a rainwater collection system for domestic water supply in Ringdansen, Norrko ping, Sweden.

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The possibilities for implementing a rainwater collection system in Ringdansen, a residential area in Norrko ping, Sweden, have been explored by analyzing four scenarios for using rainwater in a dual water supply system to supplement drinking waterIt involves direct collection and storage of the run-off rainwater for direct use in future. The different usage of harvested rainwater can be for domestic purposes like cooking, washing and bathing and agriculture purposes like watering land, feeding cattle etc. It also can be artificially recharged into the ground which is the natural aquifer. Rainwater Harvesting is the way to support Eco-system and Human well-being. One typical roof-top rainwater harvesting system consists of three basic components Catchments or roof surface to collect rainwater ,delivery system to transport the water from the roof to the storage reservoir (gutters and drainpipes) and storage reservoir or tank to store the water until it is used. The storage reservoir has an extraction device that- depending on the location of the tank- may be a tap, rope and bucket, or a pump. The rainwater harvesting system comprises of a number of components for transporting rainwater through pipes or drains, filtration and tanks for storage of harvested water which is shown in fig 1.1. The common components of a rainwater harvesting system are catchment, coarse mesh, gutter, conduits, first-flushing, filter, storage facility, recharge structures etc.

II. NEED FOR RAINWATER HARVESTING IN JOTE CAMPUS

As discussed earlier in the section of introduction – importance of rainwater harvesting at NIT AP Jote campus, we clearly came to know the all the advantages which we can draw out by implementing this small but highly efficient technique in the campus. Thus to increase the potential, benefits of this system and draw maximum advantages from it, we need to have large rooftop areas which will be going to act as catchment areas. More the catchment areas more will be the surface runoff and thus more will be the amount of harvested water.Rainwater harvesting is the one of the important alternative valuable water resources to overcome the growing water shortage due to increasing population, agricultural practices and industries. The proper system of water supply is not only enough for the consumers, but the water supply should meet the demand. Though NIT campus has its own water supply source, but it seems to be inadequate in terms of quantity and scarcity of water in future. So, this study aims to study the prevailing circumstances, particularly in terms of quantity and solution for sustainable water supply.It was found that the adoption of rain water harvesting is the easy and cheapest source of water supply in this location which can be adopted very easily. The water can be stored above the ground or under the ground by capturing the rainwater at the time of rainstorm and consuming it later for various purposes. Arunachal Pradesh is one of the heavy rainfall regions among the north-east region of India and the mean annual rainfall varies from 3000 to 5000 mm.

The new campus of National Institute of Technology, Arunachal Pradesh situated at Jote, PapumPare District will be demanding large volume of water essentially for laboratories of various departments and residents staying in hostels and quarters. It is further identified that PapumPare District has a very good precipitation with the mean of annual rainfall 3200 mm. Moreover transporting necessary water from remote place to the institute may be more expensive and challenging. Hence, rainwater harvesting may be a good option to implement at the campus for partial fulfilment of the water requirement. This study focuses on the design of sustainable rainwater harvesting system at NIT AP Jote campus. In this regard, the future demand and existing water supply system would be analysed critically. Then, a detailed field survey would be conducted to estimate the possible roof water collection, conveyance and collection system for the implementation of the rainwater harvesting.

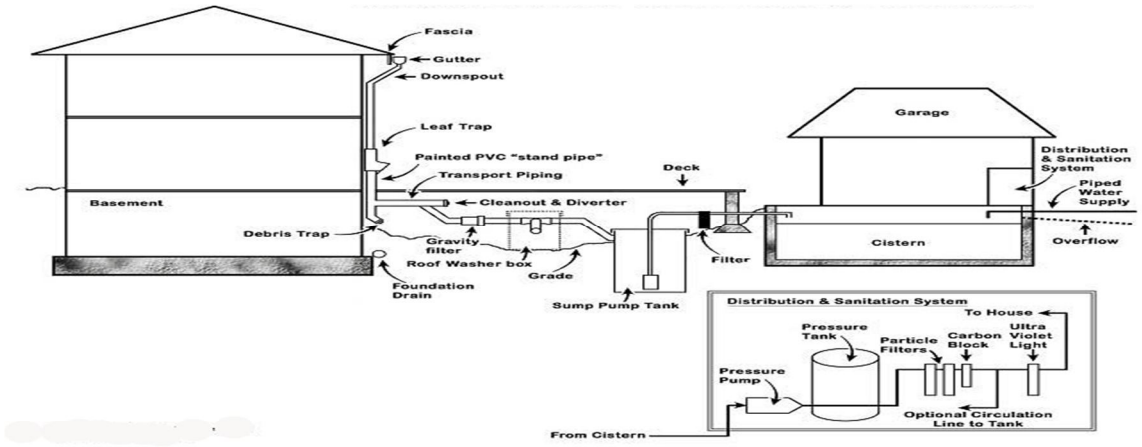


Fig 1.1 Schematic diagram for typical Rainwater Harvesting System

III. STUDY AREA

NIT, AP (JOTE CAMPUS) is located at 93.61E longitude and 27.14 N latitude in Papumpare district of Arunachal Pradesh at an elevation of about 250 meters above mean sea level.This study included and considers all the major buildings having large rooftop areas. Hence, study areas includes all the halls of residence, staff quarters, all the departmental building (Computer science, Electronic, Mechanical, Chemical, Civil, Electrical, Bio-tech), conference hall, main institution building including (central library, computer centre, and various laboratory).Fig 4.1, showing majority of the buildings considered for rainwater harvesting system at NIT AP Jote campus. The entire campus is divided into two zones. Zone I contains "Hostels and staff quarter", and Zone II contains "Academic block, Central library, Conference hall and all departmental building.

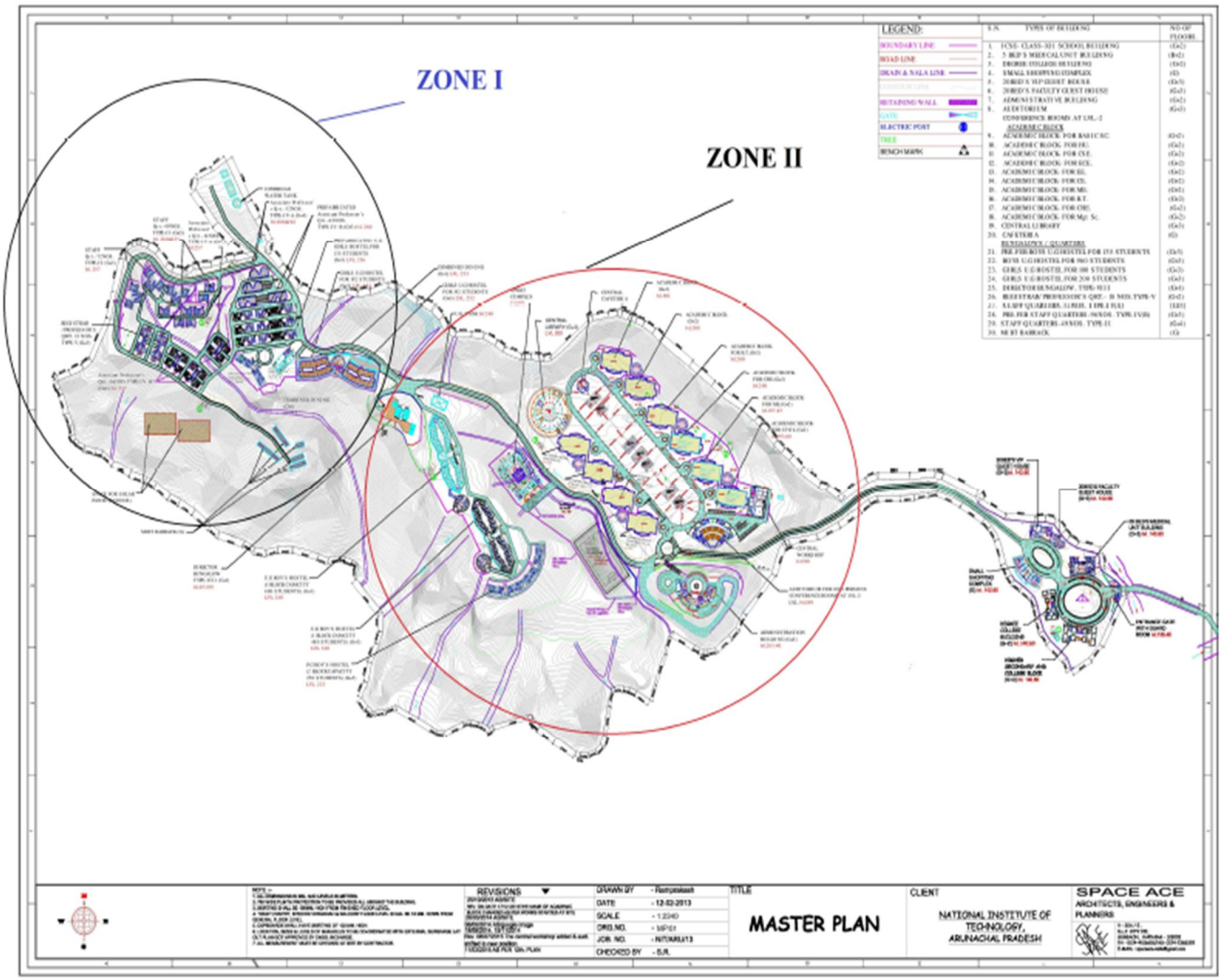


Figure 4.1 NIT AP jote map

Jote has a tropical climate and receives high rainfall during Southwest monsoon (June-September) and retreating Northeast monsoon (December-January). Average annual rainfall ranges between 300cm to 500cm. The rainfall data for papumpare district for the 11 years (2006-2016) are being taken from the Arunachal Pradesh meteorological department, Itanagar which is assumed to be same for the station of NIT AP (Jote campus) have been tabulated and average monthly rainfall data has been calculated in Table 4.1.The proposal aims at the effective implementation of rainwater harvesting at the NIT, AP (Jote campus),for which certain parameters have to be quantified. The roof areas were found out in order to calculate the exact quantity of harvestable water available. The monthly harvestable water and demand were also calculated.

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TABLE 4.1: Rainfall Data (mm) 2006-2016 for Itanagar (APMD)

MONTH/YEAR	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
JANUARY	38.4	7.2	73.4	35.8	NA	9.4	32.8	2.5	6.5	NA	34.2
FEBRUARY	200.6	93.4	21.2	9.4	NA	23	6.6	9.3	65.7	30.0	9.60
MARCH	38.8	98.8	156.8	41.2	310	113.6	36	116.8	29.5	60.2	101.1
APRIL	168.8	417.2	199.2	197.8	439.9	186	336	79	13	100.9	409
MAY	417.8	500.8	605.4	485.2	393	337.6	289	557.9	563.6	115.7	482
JUNE	930.4	900	987.4	494.4	713.8	413.4	819	471.7	779.6	1158.9	398
JULY	365	691.4	750.2	483.6	416.8	936	779.2	551.5	546	319.2	660.6
AUGUST	171	367.6	824.9	516.2	366.9	518.2	494	405.6	741.6	483.5	193
SEPTEMBER	244	533.6	363.2	123	674.8	274.8	537.8	333.4	570	221.4	486.7
OCTORBER	105.4	112.8	157.4	240.4	45.8	37.2	215.6	167.4	51.2	87.5	225.3
NOVEMBER	30.8	12.8	NA	26.4	83.8	17.4	3	24	20	NA	NA
DECEMBER	10.8	3.4	6.4	12.6	19.1	12.9	5	2.8	20	16.2	NA

The rooftop surface area is nothing but the catchment area which receives rainfall. Catchment area of the different hostels and Institutional departments are obtained by "detailed project report"(DPR) which is provided by Engineering Cell NITAP. The estimated number of employees and visitors for the new campus building was given by the building management team.

TABLE 4.2: Rooftop Area Of Zone I

Types Of Building	Area (m^2)	Population
UG BOYS HOSTEL(I&II)	2630*2=5260	960
UG GIRLS HOSTEL(I&II)	952.75*2=1905.5	384
STAFF QUARTER TYPE II	70*14=980	49(quarters) *4=196
PRE- FABRICATED UG GIRLS HOSTEL	580	135
STAFF QUARTER TYPE IV A	135*8=1080	46 (quarters) *4 =184
PRE-FABRICATED STAFF QUARTER TYPE IV B	128*18=2304	99 (quarters) *4=396
TOTAL	12109.5	2255

TABLE 4.3: Rooftop Area Of Zone II

Types Of Building	Area (m^2)
ADMINISTRATION BUILDING	1068
ACADEMIC BLOCK FOR CSE, CIVIL, BIO-TECH, CHEMICAL, MECHANICAL, ECE,EE, HU ,MANAGEMENT, BASIC. SC,	(2381 * 10) =23810
CENTRAL LIBRARY	3047
AUDITORIUM	1180
TOTAL	29105

The determination of average monthly rainfall are calculated by following Formula:

$$Average\ monthly\ rainfall = \frac{Total\ monthly\ rainfall}{Total\ number\ of\ years}$$

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TABLE 4.4: Average Monthly Rainfall Data

Month	Total Monthly Rainfall(mm)	Average Monthly Rainfall(mm)
JANUARY	240.2	26.69
FEBRUARY	468.8	46.88
MARCH	1102.8	100.2545
APRIL	2546.8	231.5273
MAY	4748	431.6364
JUNE	8066.6	733.3273
JULY	6499.52	590.8655
AUGUST	5082.5	462.0455
SEPTEMBER	4362.7	396.6091
OCTOBER	1446	131.4545
NOVEMBER	218.2	27.275
DECEMBER	109.2	10.92
TOTAL		3189.48

TABLE 4.5: Mean Number of Rainy Days

Month	Mean No. Of Days
JANUARY	2.57
FEBRUARY	6.42
MARCH	10.28
APRIL	19
MAY	17.71
JUNE	21.28
JULY	23.71
AUGUST	18.14
SEPTEMBER	15.42
OCTOBER	8.85
NOVEMBER	3.71
DECEMBER	2

The mean number of rainy days in a month is an important consideration in the estimation of the monthly harvestable water. In this regard data obtained from the Arunachal Pradesh meteorological department has been given in table 4.5.
The rainfall intensity for NIT JOTE campus is given in table 4.6 calculated below formula:

$$Rainfall\ intensity\ per\ day\ = \frac{average\ monthly\ rainfall}{No.\ of\ rainy\ days}$$

The Rainfall available after losses assuming water loss for all type of sources to be 0.1 inch and this loss is considered after each event of rainfall. Hence, 2.54 mm/day of rainfall loss after every rain event. Hence, Rainfall available after losses = (rainfall intensity per day) – 2.54 mm per day that is tabulated in Table 4.7. This total available monthly rainfall takes into account the rainfall, which is available after losses .
Total available monthly rainfall = (rainfall available after losses) x (mean no. of rainy days)

Table 4.6: Rainfall intensity per day (mm/day)

JANUARY	10.38
FEBRUARY	7.30
MARCH	9.75
APRIL	12.19
MAY	24.37
JUNE	34.46
JULY	24.92
AUGUST	25.47
SEPTEMBER	25.72
OCTOBER	14.85
NOVEMBER	7.35
DECEMBER	5.46

Table 4.7: Rainfall Available After Losses (mm/day)

JANUARY	7.84
FEBRUARY	4.76
MARCH	7.21
APRIL	9.65
MAY	21.83
JUNE	31.92
JULY	22.38
AUGUST	22.93
SEPTEMBER	23.18
OCTOBER	12.31
NOVEMBER	4.81
DECEMBER	2.92

Table 4.8 Total available monthly rainfall (mm)

JANUARY	20.16
FEBRUARY	30.57
MARCH	74.14
APRIL	183.27
MAY	386.65
JUNE	679.28
JULY	530.64
AUGUST	415.97
SEPTEMBER	357.44
OCTOBER	108.98
NOVEMBER	17.85
DECEMBER	5.84
TOTAL	2810.10

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IV. RESULT AND DISCUSSION

The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area and the amount that can be effectively harvested is called the water harvesting potential. The calculation is divided into two parts zone I and zone II. Zone I :Upper part (hostel, staff quarters) and Zone II: Lower part (academic blocks, central library and administrative block). The formula for calculation for harvesting potential or volume of water received or runoff produced or harvesting capacity is given as:-

Volume of water received (m^2) = area of catchment (m^2) x amount of rainfall (m)

We have calculated the volume of required water in two zone :

Total roof area of zone I = 12109.5m^2 (Hostel area)

Total roof area of zone II = 29105 m^2 (Academic area)

The rainfall volume can be calculated as shown below:

Rainfall volume Zone I = (Total roof area Zone I) X (Average rainfall)

Rainfall volume Zone II = (Total roof area Zone II) X (Average rainfall)

The detailed rainfall volume calculation is shown in table 5.1

TABLE 5.1: Rainfall for Zone I and Zone II

Month	Average Rainfall(mm)	Rainfall Volume Zone I (m^3)	Rainfall Volume Zone II (m^3)
JANUARY	20.16	244.14	586.79
FEBRUARY	30.57	370.23	889.83
MARCH	74.14	897.84	2157.94
APRIL	183.27	2219.28	5333.99
MAY	386.65	4682.17	11253.53
JUNE	679.28	8225.69	19770.33
JULY	530.64	6425.81	15444.34
AUGUST	415.97	5037.19	12106.80
SEPTEMBER	357.44	4328.45	10403.36
OCTOBER	108.98	1319.64	3171.73
NOVEMBER	17.85	216.17	519.57
DECEMBER	5.84	70.72	169.97
TOTAL	2810.10	34037.33	81297.53

A. Annual Demand For Zone I (Hostel Area)

Calculation for UG and PG hostel: (SCENERIO I)

Scenario I: This scenario basically includes the calculation which deals with meeting the water demand of 1150 students with a fixed supply of 80 litres per individual throughout the year.Total population is 1150,Assuming supply of 80 lit/capita/day and total volume of water required per day =1150*80 =92000 lit/day so Volume of water to be supplied for 1 month =92000*30 =2760000 lit/month=2760 m^3/month.

Assuming monthly demand to be approximately 2800 m^3/month

Scenario II: This scenario basically includes the calculation which deals with meeting the water demand of 1150 students with a fixed supply of 30 litres per individual throughout the year.

Total population =1150.Assuming supply of 30 l/capita/day.

Total volume of water required per day =1150*30 =34500 l/day.

Volume of water to be supplied for 1 month =34500*30 =1035000 l/month =1035 m^3/month.

So monthly demand is 1035 m^3/month.

In scenario **I** the harvested rain water would be providing 80 lpcd of water to 1150 individual, to meet the demand of 2800 m^3 of water per month, water is needed to be stored in the months of excess rainfall. From table 5.2 total amount of water deficiency is 14261.98m^3~ 15000m^3 which is needed to be stored in the months of May to September, for fulfilling the continuous demand in the month of October to April. In addition to this a volume of 2800m^3 ~3000m^3 is needed to be combined with the fixed storage. Thus a storage of 18000m^3 of water would be provided to serve the 1150 students.

TABLE 5.2: ANNUAL DEMAND ZONE I(SCENERIO I)

Month	Demand (m^3) (A)	Rainfall (m^3) (B)	Extra Water needed to meet the demand(m^3) (A-B)	Excess water after meeting the demand(m^3) (B-A)
January	2800	244.14	2555.85	-
February	2800	370.22	2429.77	-
March	2800	897.83	1902.16	-
April	2800	2219.3	580.73	-
May	2800	4682.2	-	1882.17
June	2800	8225.7	-	5425.69
July	2800	6425.8	-	3625.81
August	2800	5037.2	-	2237.18
September	2800	4328.4	-	1528.45
October	2800	1319.6	1480.36	-
November	2800	216.17	2583.83	-
December	2800	70.72	2729.28	-
Total			14261.9866	14699.31

TABLE 5.3: ANNUAL DEMAND ZONEI(SCENERIO II)

Month	Demand (m3) (A)	Rainfall (m3) (B)	Extra Water needed (m3) (|A-B|)	Available Water (m3) (|B-A|)
January	1035	244.14	790.86	-
February	1035	370.22	664.77	-
March	1035	897.83	137.161	-
April	1035	2219.27	-	1184.21
May	1035	4682.17	-	3647.17
June	1035	8225.69	-	7190.69
July	1035	6425.80	-	5390.81
August	1035	5037.19	-	4002.19
September	1035	4328.44	-	3293.45
October	1035	1319.64	-	284.64
November	1035	216.17	818.83	-
December	1035	70.72	964.28	-
Total			3375.90	24993.18

In scenario II, the harvested rain water would be providing 30 litre of water to 1150 individual, to meet the demand of 1035 m^3 of water per month, water is needed to be stored in the months of excess rainfall. From table 5.3 total amount of water deficiency is 3375.90m^3, which is needed to be stored in the months of April to October, for fulfilling the continuous demand in the month of November to March .In addition to this a volume of 1035 m^3 is needed to be combined with the fixed storage, so total storage required is 4410.9 Thus a storage of 4410.9~4500 m^3 of water would be sufficient to serve the 1150 students.

B. Annual demand for zone ii (academic area)

C. Toilet flushing demand & laboratories demand

The amount of water required for the flushing of toilet is depend upon total number of building which is 11 and total number of bathroom in each building is 6 so total number of bathroom is 66 and the number of toilets in each bathroom is 5 ,So total no of toilets is 330 and number of flushing per day is 10 .Assuming 10 litre of water is required for one flushing. Total volume of water required is 33000 litres/day.Amount of water consumed per month will be 990m3/month

No. of laboratories in college buildings are 5. Assuming 100 litre of water is required for laboratories per dayAmount of water required per month is 15 m^3/month.Total water consumed for toilets and laboratories purpose is 1005 m^3/month

Table 5.4: ANNUAL DEMAND ZONE II

Month	Demand (m3) (A)	Rainfall (m3) (B)	Extra Water needed (m3) (|A-B|)	AvailableWater (m3) (|B-A|)
January	1005	586.79	418.21	-
February	1005	889.83	115.17	-
March	1005	2157.94	-	1152.94
April	1005	5333.99	-	4328.99
May	1005	11253.53	-	10248.53
June	1005	19770.33	-	18765.33
July	1005	15444.34	-	14439.34
August	1005	12106.8	-	11101.8
September	1005	10403.36	-	9398.36
October	1005	3171.73	-	2166.73
November	1005	519.57	485.43	-
December	1005	169.97	835.03	-
Total			1853.84	71602.02

The monthly demand for zone II is 1005m^3. Water is needed to be stored in the months of March to October which is required to fulfil the demand which is 1853.84 m^3 in the deficient months (November to February),thus leading to total storage of 2858.84m^3~ 3000m^3 .
Hence a volume of approximately 3000m^3 should be stored by approximate tank to fulfil the demand of zone II.

V. CONCLUSION

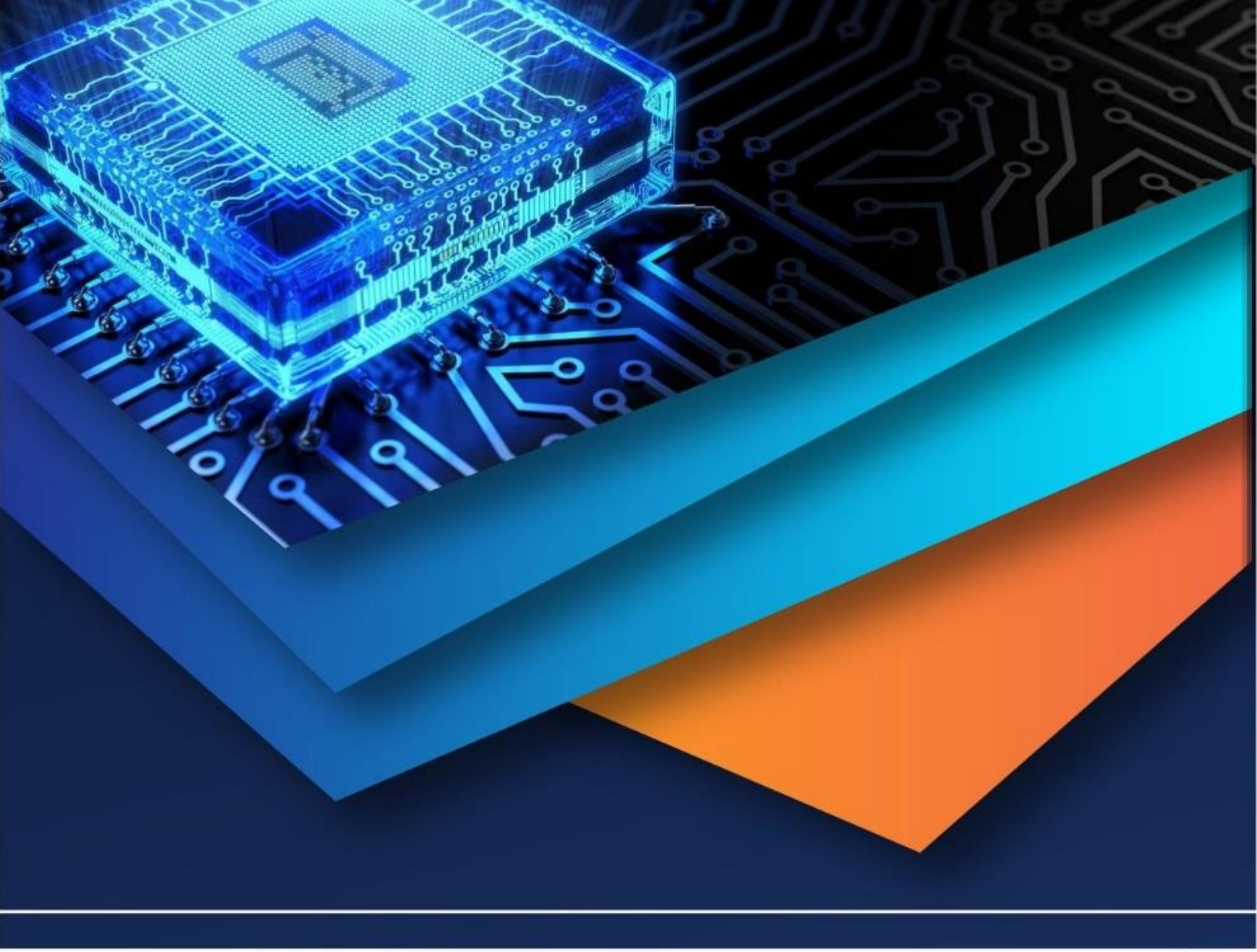
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Analysis of rainfall, demand and the amount of water to be harvested has been done. The analysis has been done by dividing the area into two zones, zone I(hostel, staff quarters) and zone II(academic block, administrative block and central library).Zone I analysis has been performed for two scenarios in which demand is taken as 80 lit/capita/day and 30 lit/capita/day. After the analysis it is found that for 80 and 30 litres demand a storage of 18000 m^3 and 4500 m^3 respectively are required for fulfilling the demand of 1150 individuals throughout the year.
The analysis done for Zone II shows that a storage of 3000 m^3 is required to meet the demands of academic blocks (laboratories and bathrooms), central library and the administrative block.

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