Design of Rainwater Harvesting for a Residential Building in Composite Climate

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***Abstract*:- Rainwater harvesting is the process of collection of rainwater and recycling it for various potable and non-potable purposes. Today the water shortage crises are rising rapidly and the main reason is due to lack of proper monitoring and controlling of water. This document has been produced to assess the effectiveness of rainwater collection system, the impact of implementing them on saving water and relieving water stress. It proposes the design of smart water management system based on IoT application which helps controlling and monitoring of rain water with the help of Arduino UNO as a microcontroller which helps in processing information received from various sensors such as rain sensor, ultrasonic sensor, flow sensor, leak detectors etc.The sensed information is automatically updated on the user android application through which the user can visualize and monitor the system.**

The literature review introduces all the hardware needed for the monitoring such as Arduinio UNO, rain water sensors, servo motor, male female jumper wires, flow sensors, ultrasonic sensors, leak detectors and software components such as thingspeak.

The paper analyses the feasibility of the two case studies and compares their viability in harvesting rainwater and reducing the dependency on ground water supply. New innovative ideas of water monitoring are explored in both the cases. In the first case study of Azrou city villa building municipal water supply is altered with rainwater supply. This is controlled with the help of control valve and ultrasonic sensors connected to Arduino board.

In the second case study the roof top rain water harvesting is done and the water after quality analysis is recycled for potable use. In both the case the systems are powered with the help of solar panels which makes them more efficient.

Two designs have been proposed on the site located in composite climate at Noida sector 19. In the first case the design of rainwater recharge pits is done which helps in recharging the ground water. Further for controlling the overflow of the water the storage tanks are designed which supplies water for gardening and other non-potable uses.

In the second case the design of storage tanks is done to recycle the water for various potable and non-potable uses after the segregation of water is being done on the basis of the quality parameters such as PH value, turbidity etc. the system is altered with the municipal supply same as in first case study and it gives total recycling of rainwater with no wastage.

So the system becomes effective in storing rainwater and recycling it for various purposes. It helps in reducing the dependency on ground water supply, maintaining the ground water level in a region and prevents over exploitation of ground water demand by rising population.

Keywords—Intenet of things; architecture; planning; eledrly care; physically challenged; challenges;solutions

I. INTRODUCTION

Water conservation is critical because it is one of the most significant factors for all species' survival. According to the Central Ground Water Board's estimates, underground water will be scarce in 15 Indian states by 2025.(Verma, 2021) However, as per the report from Ministry of Environment and Forest, only 10 to 20% rainwater is harvested.(Verma, 2021) In urban areas, it is seen that nowadays concrete structures are constructed everywhere, so it is not possible to recharge the water table by natural process of raining. The rainwater being the source of fresh water gets wasted as it goes to the drains and it is becoming one of the major problem of the present and will results in even more critical consequences in the future. Therefore, a rainwater harvesting system is required in Indian household to conserve water. Population growth all over the world is causing similar problems concerns of how to supply quality water to all. At present , the 21st century core problem faced by the world is water scarcity, the best way to get rid of it to wisely catch the water comes in the form of rain and drain them responsibly, the available ways of collecting rain water are housetops and land surface. One of the most important underlying values in rainwater harvest is that it's an interesting technology and can't produce undesirable consequences. The present vital water crisis facing by India and globally, to sort out a solution there is necessity of continuous monitoring of underground water levels is needed, the present work suggests a way to integrate the rainwater pits and monitoring possibilities over the IoT(Internet of Things) for better understanding of ground water recharge process through Man concerned acts like rain water harvesting.

The IoT is a network technology that monitor the status of cloud for software to analyse in real time and help determine action steps. This technology uses microprocessor, sensor etc. the sensors senses the data and then the sensed data is processed by the microprocessor. The processed data gets uploaded in the cloud for the users to view in mobile phones/web sites.

One of the rapid influence of the IoT is in the field of water monitoring and controlling system. It is because, in the present era, water is considered as the most significant and scare resource. The society deals with too many challenges in managing and conserving the water. Hence there is a need to preserve the water for the future by monitoring the water carefully. Thus the main objective of the research is to describe the various means through which IoT enabled water monitoring and controlling system is achieved. The research produces development of various technologies for capturing and retaining runoff including that from roof tops and roads using this as a valuable sources of water and artificially recharge the recharge pits and finally increasing the ground water level. This can help in reducing the increasing demand on ground water sources.

3. 1.SYNOPSIS

1.1 Aim

- To design rainwater harvesting for the residential building of composite climate and smart monitoring of it using IoT (Internet of things).

1.2 Objective

- To calculate the potential amount of water being collected from rain water harvesting and finding significant reduction in water demand by recycling rain water for residential apartment of composite climate.
- To study and integrate IoT to water management system for continuous and real time monitoring and controlling of rain water.

1.3 Rationale

- The concept of smart rainwater harvesting has only come in the form of ideas, but is very less brought into execution. Water shortages is common is common in densely populated cites and typical system of rainwater harvesting is less likely to be used in today's modern built homes. Hence even though rainwater harvesting can be very effective in these areas, it's not popular enough due to its method of implementation which has not advanced with time.

1.4 Methodology

1. Obtaining the rainfall data.
2. Calculation of total catchment areas.
3. Analysing run-off coefficient for various materials.
4. Determination of volume of water that can be harvested.
5. Design of recharge pits.
6. Estimation of water demands.
7. Calculations of annual savings achieved.
8. Study of smart technologies in monitoring and controlling rain water (IoT based)
9. Implementation in a residential apartment towers of composite climate.
10. Recommendations and conclusions.

1.5 Scope

- Effective water management and harvesting system can be built through the structured interventions of IoT technologies.
- The smart rainwater harvesting (IoT based) has to be used in an effective and conceivable aspect such that it can mitigate the effects of depleting ground water levels and fluctuating climatic conditions. This is relatively a modern research field and it is expected to grow in future. There is lot of work to be done on this emerging area.

1.6 Limitations

- The study does not include any simulation work. All the calculations are being done manually.
- Due to less resources availability on IoT based smart rain water harvesting, the case studies done are of small scale.

2.LITERATURE REVIEW

2.1 Design Factors

2.1.1 Estimate of the quantity that reaches the storm water drain (runoff) depends on the following factors:(NBC, 2016)

a) Type of soil and its absorption capacity.
b) Ground slope and the time in which the area is drained.
c) Intensity of the rainfall for a period.
d) Duration of the rain.

The runoff may be given by the expression:

Q = C.I.A

Where

Q = runoff, m3 /h;
C = coefficient of runoff;
i = intensity of rainfall, m/h; and
A = area of the drainage district, m2.

2.1.2 Coefficient of runoff for various surfaces may be taken as:(NBC, 2016)

Type of Surface	*Coefficient of Runoff*
Concrete roof area	0.9
Paved podium areas and asphalted roads	0.8
Unpaved ground	0.3
Lawns and parks	0.15

Figure 1 Coefficient of runoff for various surfaces(NBC, 2016)

2.1.3 Rainfall intensity

- It is the amount of rain falling in unit time which is expressed in centimetre or millimetre per hour. For design purposes, the mean rainfall intensity is collected for 25 years.(NBC, 2016)

2.1.4 Time of concentration

- It is the time required for the rainwater to flow to reach the longest point of the drainage system.
- Time of concentration is equal to the inlet time plus the time required for the flow to reach the main or branch drain. The inlet time is the time dependent on the distance of the farthest point in the drainage area to the inlet of the manhole and the surface slopes, etc., and will vary between 5 min and 30 min.(NBC, 2016)
- In highly developed sections for example with impervious surfaces it may be as low as 3 min or lower (with good slopes) as in building terraces and paved areas.(NBC, 2016)

2.1.3 Rainwater pipes for roof drainage

a) The roofs of a building shall be so constructed or framed as to permit effectual drainage of the rainwater therefrom by means of a sufficient number of rainwater pipes of adequate size so arranged, jointed and fixed as to ensure that the rainwater is carried away from the building without causing dampness in any part of the walls or foundations of the building or those of an adjacent building.(NBC, 2016)

b) The rainwater pipes shall be fixed to the outside of the external walls of the building or in recesses or chases cut or formed in such external wall or in such other manner as may be approved by the Authority.(NBC, 2016)

c) Rainwater pipes conveying rainwater shall discharge directly or by means of a channel into or over an inlet to a surface drain or shall discharge freely in a compound, drained to surface drain but in no case shall it discharge directly into any closed drain.(NBC, 2016)

d) Whenever it is not possible to discharge a rainwater pipe into or over an inlet to a surface drain or in a compound or in a street drain within 30 m from the boundary of the premises, such rainwater pipe shall discharge into a gully trap which shall be connected with the street drain for storm water and such a gully trap shall have a screen and a silt catcher incorporated in its design(NBC, 2016)

e) If such streets drain is not available within 30 m of the boundary of the premises, a rainwater pipe may discharge directly into the kerb drain and shall be taken through a pipe outlet across the foot path, if any, without obstructing the path.(NBC, 2016)

f) A rainwater pipe shall not discharge into or connect with any soil pipe or its vent pipe or any waste pipe or its vent pipe nor shall it discharge into a sewer unless specifically permitted to do so by the Authority, in which case such discharge into a sewer shall be intercepted by means of a gully trap.(NBC, 2016)

g) Rainwater pipes shall be constructed of cast iron, PVC, asbestos cement, galvanized sheet or other equally suitable material and shall be securely fixed.(NBC, 2016)

h) The spacing will also be determined by the amount of slopes that can be given to the roof. The recommended slopes for the flat roofs with smooth finish would be 1:150 to 1:133, with rough stone/tiles 1:100 and for gravel set in cement or losely packed concrete finish 1:75 to 1:66.(NBC, 2016)

2.1.4 Rainwater harvesting for plotted/group housing developments

- The rainwater harvesting methods adopted for this case are through collection of rooftop rainwater and surface runoff harvesting. A network of rainwater drains in the entire residential area is used for harvesting rooftop rainwater and surface runoff.

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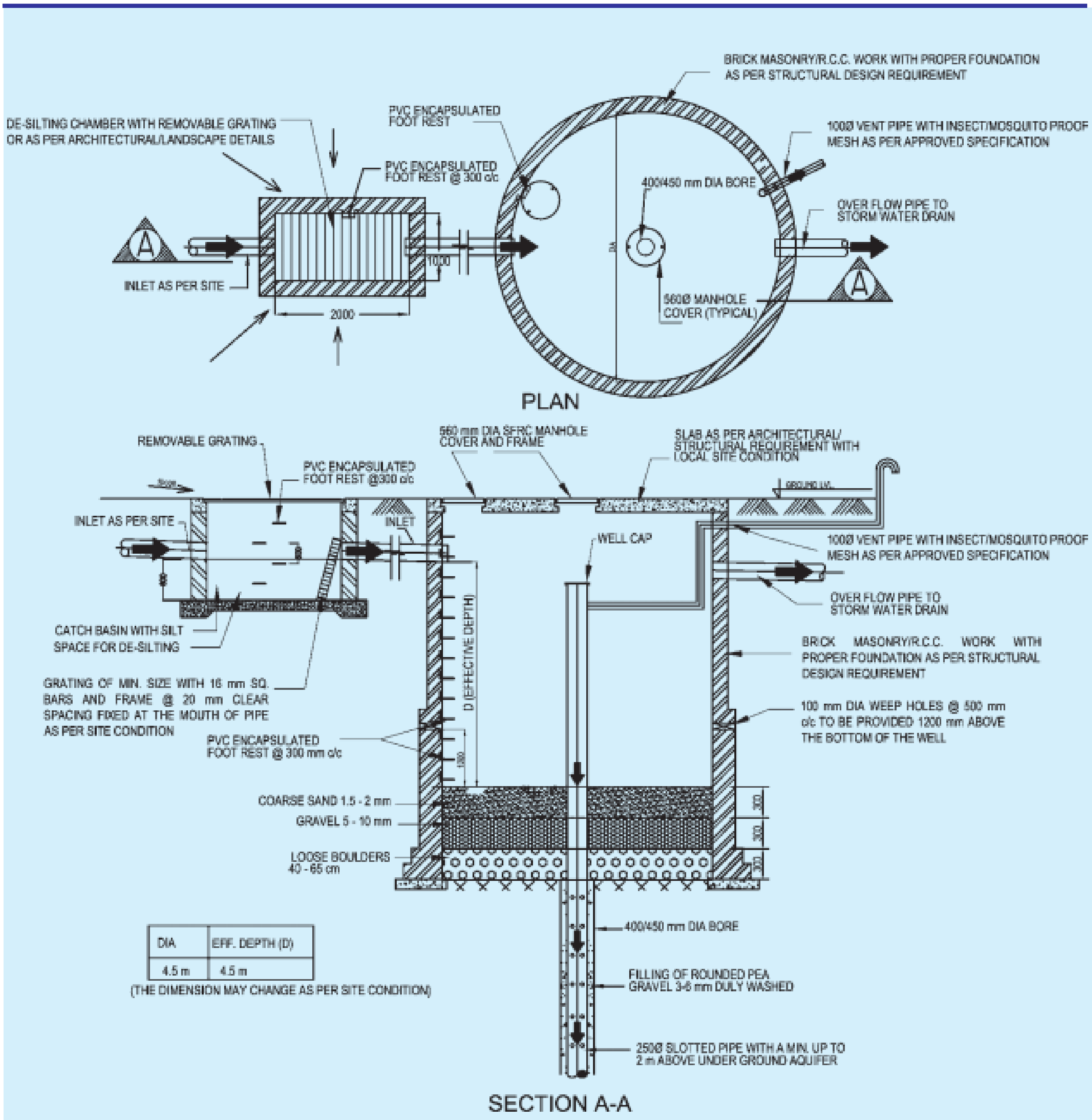

All dimensions in millimetres unless specified.

NOTE — Depending on site soil condition and keeping the above plumbing details and dimensions in view, the detailed structural/ shop drawing to be prepared, before executing the work.

FIG. 11 ARTIFICIAL GROUND WATER RECHARGE STRUCTURE

Figure 2 Artificial ground water recharge structure (NBC, 2016)

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2.2 Estimation Of Water Demand

Water consumption for one person per day for different activities is 135 litres. Average water consumed for different activities by a person per day is given in the table below:(Meda, 2015)

S.no	Activity	Water consumption
1.	Bathing	55 liters
2.	Toilet flushing	30 liters
3.	Washing of clothes	20 liters
4.	Washing of room	10 liters
5.	Washing of utensils	10 liters
6.	Cooking	5 liters
7.	Drinking	5 liters
	Total	135 liters

Table 1 Water consumption for various activities (Meda, 2015)

2.3 Sizing and Selection of Filter

Filters are used to remove fine particles of dust/bacteria from rainwater. Their selection depends on various factors such as, purpose of use, quality of run off, type of catchment, amount of silt load and type of recharge structure.(Meda, 2015)

Hydrocyclone filter is used in Shilpa Hostel in JNTUA College of engineering Ananthapuramu, South India, which is a low carbon galvanised steel cylinder with a mesh size of 250 microns. It is enclosed in an outer casing of polyethylene and it can withstand a rainfall intensity of 75 mm/hour.(Meda, 2015) Filter working is based on the principles of cohesive and centrifugal force.

It is a static and simple to operate, usually used for phase separations, including solid-liquid, liquid-liquid and liquid-gas separations. They do not have moving parts and they have relatively low capital and operating costs.(Meda, 2015)

SUITABLE UP TO ARAE	225 SQMTRS
Max. intensity of rainfall	75 mm/hr
Working principle	Cohesive forces &centrifugal forces
Operating pressure	Less than 2 feet of head (0.060 kg/cm sq)
Capacity	225 LPM
Filter element	SS-304 screen
Mesh size	250 microns
Inlet	110 mm
Clean water outlet	75 mm
Drain outlet	90 mm
Housing	High density polyethylene
Source of power	Gravity

Table 2 Features of rainy filters FL-200(Meda, 2015)

2.4 Rooftop Rainwater Harvesting Through Recharge Pits

a) In alluvial areas where the rocks with interconnected pores i.e., permeable rocks are bare open to the land surface or are present just below the land surface at a shallow depth, then rooftop rainwater harvesting can be done through recharge pits.
b) The recharge pit technique is adaptable for a roof area of 100m2 and is an efficient method of recharging the shallow aquifers.(Dagwal et al., 2016)
c) Recharge pits may be of any shape and size, generally circular shape is preferred and the diameter of the pit varies between 1.5m to 3 m wide and 2 to 3 m deep which are back filled with boulders (5cm - 20cm), gravels (5mm - 10mm)

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and coarse sand (1.5mm - 2 mm) in graded form. Boulders are at the bottom, gravels in middle and the coarse sand at the top and for smaller roof area, pit may be filled with broken bricks or cobbles.(Dagwal et al., 2016)

d) Adoption of mesh results in prevention of leaves and other debris entering the recharge pit and also a de-silting chamber can be provided at the ground level to inhibit the flow of finer particles to the recharge pit.

2.5 Monitoring Rainwater Harvesting Using IoT (Internet of Things)

2.5.1 Introduction

- At present , the 21st century core problem faced by the world is water scarcity, the best way to get rid of it to wisely catch the water comes in the form of rain and drain them responsibly, the available ways of collecting rain water are housetops, land surface or rock catchments. One of the most important underlying values in rainwater harvest is that it's an interesting technology and can't produce undesirable consequences.(Chandrika Kota et al., 2020)
- With the dawn of the Internet of Things (IoT) from the internet as a web service, an extensive number of devices (objects) and environment are becoming smarter and are capable to interact with one another more than ever before. One of the areas which can be greatly improved by the Internet of Things technology is water management.
- Integrating smart technology in the water industry helps to make all the cities in the world "Smart cities in the near future". The Internet of Things offers new solutions for improving water management to maximize efficient use of this precious resource. Comprehensive water management strategies can reduce water costs by up to 20% which can have a major impact on cities.(Kumar, 2019)
- IoT enables us to execute the water harvesting system by data-based decision making, real-time monitoring of parameters, trend analysis, etc. which helps optimize water use, cost control, effective reuse and manpower reduction.(Kumar, 2019)

2.5.2 Benefits of Smart Monitoring Of Rainwater Using IoT

1. Water monitoring system based on wireless sensor networks is a smart system for controlling the wastage of water by using an ultrasonic sensor to sense the level of water in tank. If the water tank is full or up to the maximum level the sensor will sense it and stop the system automatically. If the water tank is at the minimum level set by user, the sensor will sense it, activate the motor pump at the maximum level.(Kumar, 2019)
2. A smart rainwater harvesting system for analyzing water quality comprises of a smart network-connected device which is attached to a few auxiliary tanks through electronic valves. It consist of 3 tanks: one is for clear water, one is for moderately clear water & one is for least clear water. LDR (light dependent resistors) sensors judges the clarity of the rainwater. Once the tank is full, ultrasound sensor linked to the LDR will beep in order to alert authorities that the tanks are full. Finally, with the help of auto-segregation, water in different tanks are put to use for different purposes.(Kumar, 2019)
3. The use of low-power wide-area (LPWA) Internet of Things (IoT) devices provides significantly greater water management capabilities. LPWA water meters replace mechanical flow meters (typically serving individual properties). These IoT devices are affordable, small and powerful sensors that can be installed across the water value chain to accurately monitor the flow & use of water, the location of leaks & even the quality of the water being pumped.(Kumar, 2019)
4. Efficiency increase: water management companies and associations can use real- time operational control to make smarter business decisions and reduce operating costs. An IoT based reference architecture uses sensors and actuators to monitor and improve water management infrastructures, making them more efficient, reducing energy costs and minimizing human intervention.(Gannoju et al., 2019)
5. Productivity increase: Productivity is a critical parameter that affects the profitability of any organization. IoT allows real-time control, new business models, process optimization, resource conservations, service time reduction, and the capability to do all of this globally, reducing the mismatch of required vs. available skills and improving labor efficiency.(Gannoju et al., 2019)

2.5.3 Requirements for Reference Architecture

The following requirements were put down by IJSMC (International Journal of Applied Science and Computations) in order to establish a fully working water management model:

Requirement #1: The system must be able to cover these water management functions: remote management of physical

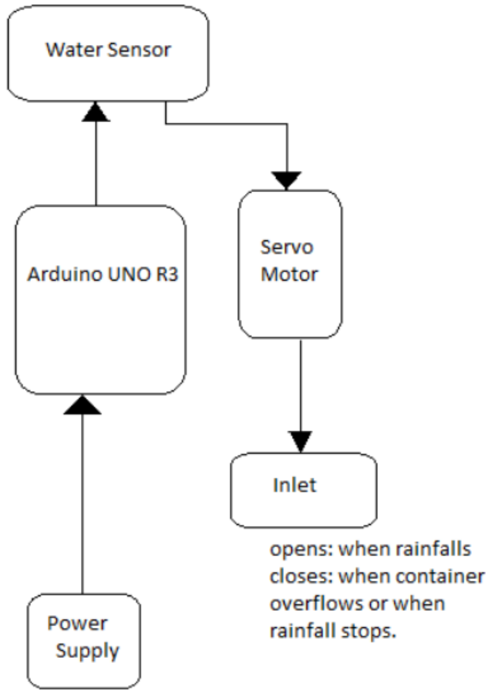

Figure 3 Block diagram for an effective & smart water management system (Gannoju et al., 2019)

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elements & operation of basic units; identification of resources in the water network, definition of conditions & operations over the network.(Kumar, 2019)

Requirement #2: Interoperability must be supported in addition to other applications such as geographic information systems & also databases containing information regarding soils, environment, farming, weather forecasts & other vital areas.(Kumar, 2019)

Requirement #3: It should provide an architecture that is both flexible & extensible for the integration of various systems. To do that, it must define open interfaces among communication and process control layers. Most importantly, it should integrate IoT systems for a direct access to individual water management devices.(Kumar, 2019)

Requirement #4: Lastly, it should support integration with legacy systems, controlling current equipment. Water management infrastructures currently deployed in the countryside comprise of many interconnected & simple devices that are managed solely through the use of legacy systems. They integrate communication functions, data models, & protocols dependent on a specific technology of the manufacturer. Overriding these systems with new ones is not always a feasible solution.(Kumar, 2019)

2.6 Hardware Components

2.6.1 Arduino Uno R3:

The Arduino Uno R3 is a microcontroller board based on a removable, dual-inline-package (DIP) ATmega328 AVR microcontroller. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs). Programs can be loaded onto it from the easy-to-use Arduino computer program. The Arduino has an extensive support community, which makes it a very easy way to get started working with embedded electronics. The R3 is the third, and latest, revision of the Arduino Uno.(Gannoju et al., 2019)

Figure 4 Arduino Uno R3(Gannoju et al., 2019)

2.6.2 Water Sensor:

A water detector is an electronic device that is designed to detect the presence of water and provide an alert. A common design is a small cable or device that lies flat on a floor and relies on the electrical conductivity of water to decrease the resistance across two contacts. The device then performs the task specified by the Arduino Uno R3. The sensor is basically a board on which nickel is coated in the form of lines. It works on the principle of resistance.(Gannoju et al., 2019)

If there is no rain, the resistance between the wires will be very high and there will be no conduction between the wires in the sensor. If there is rain, the water drops will fall on the rain sensor which will also decrease the resistance between the wires and wires on the sensor board will conduct thus triggering the connected DC motor.(Gannoju et al., 2019)

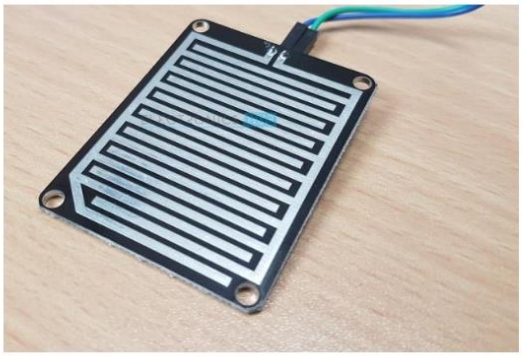

Figure 5 Water Sensor Board(Gannoju et al., 2019)

2.6.3 Servo Motor:

We are using the 12 volts DC motor to operate the vents. The DC motor is connected to the shafts of the vent using gears so that the movement of the vent can be controlled. The power supply for the DC motor is given through the step-down transformer.(Gannoju et al., 2019)

2.6.4 Male-female jumper wires:

The connections to be made require the use of male to female jumper wires.

Figure 6 Servo Motor(Gannoju et al., 2019)

2.6.5 Smart Leak Detectors:

A leak can result in major loss in water, which could have been used in many ways. The smart leak detector can alert, notify and communicate the respective authority for the issue and location.(Kumar, 2019)

Figure 8 Male female jumper wires(Gannoju et al., 2019)

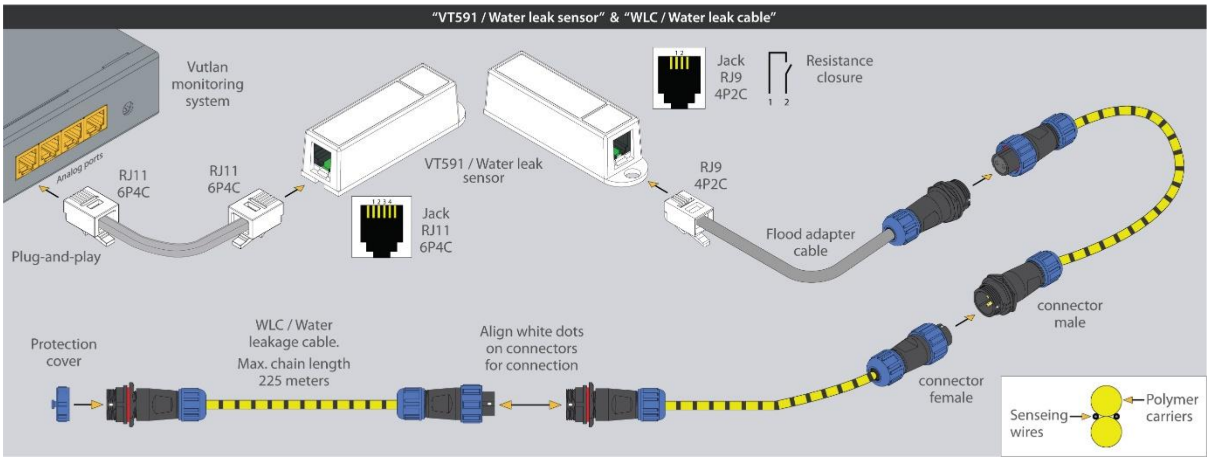

Figure 7 Leakage Detection Using Cable Sensor And Spot Sensor (Vultan, 2019)

2.6.6Ultrasonic Sensors:

There are total 5 levels in the ultrasonic detectors. Level 1 if the water in the water tank is the same or less than 2000 L. Level 2 if the water in the water reservoir is the same or less than 4000 L. Level 3 if the water in the water reservoir is the same or less than 6000 L. Level 4 if the water in the water reservoir is the same or less than 8000 L. Level 5 if the water in the water reservoir is the same or less than 10000 L. The ultrasonic sensor will read information about the water level according to its level and the information through Microcontroller will be sent to the database through the internet. The information will be display on the mobile application.(Suban et al., 2021)

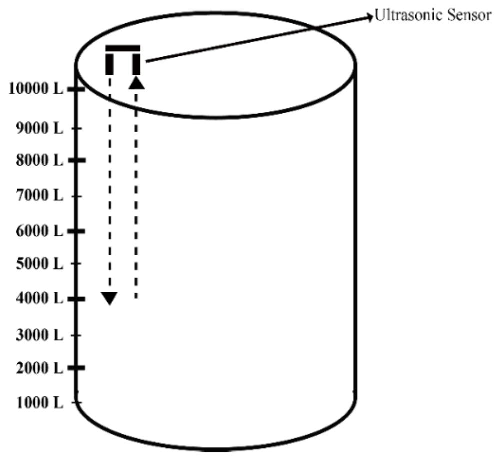

Figure 9 Ultrasonic sensor(Suban et al., 2021)

2.6.7 Flow Sensors:

Water flow sensor consists of a copper body, a water rotor, and a hall-effect sensor. When water flows through the rotor, rotor rolls, its speed changes with different rate of flow. And the hall-effect sensor outputs the corresponding pulse signal. (Seed, 2021)

2.7 Software Components

2.7.1 Thingspeak:

It is an open source IoT software to store and retrieve data from things using http and mqtt protocol in is an open source IoT software to store and retrieve data from things using http and mqtt protocol in internet or a local area network.(Chandrika Kota et al., 2020) It allows to create sensor logging application, location tracking and it also internet or a local area network. Thingspeak allows to create sensor logging application, location tracking and it also updates the current status. We can find this thingspeak in matlab with math works account.(Chandrika Kota et al., 2020)**3.6**

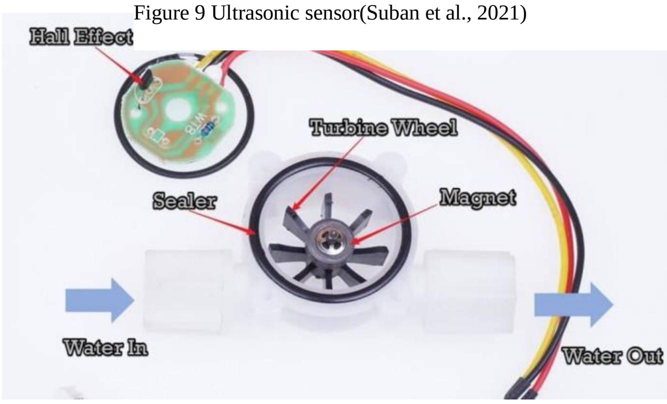

Figure 10 Water flow sensor work principle (Seed, 2021)

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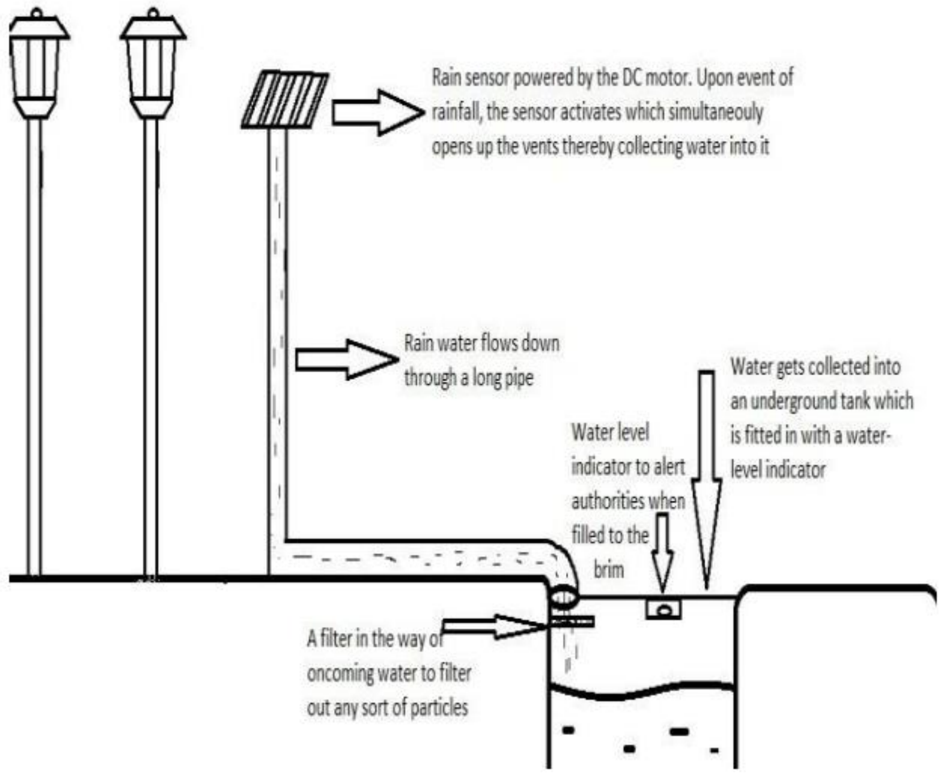

2.8 Proposed system(Gannoju et al., 2019)

Figure 11 Proposed system for IoT based water monitoring(Gannoju et al., 2019)

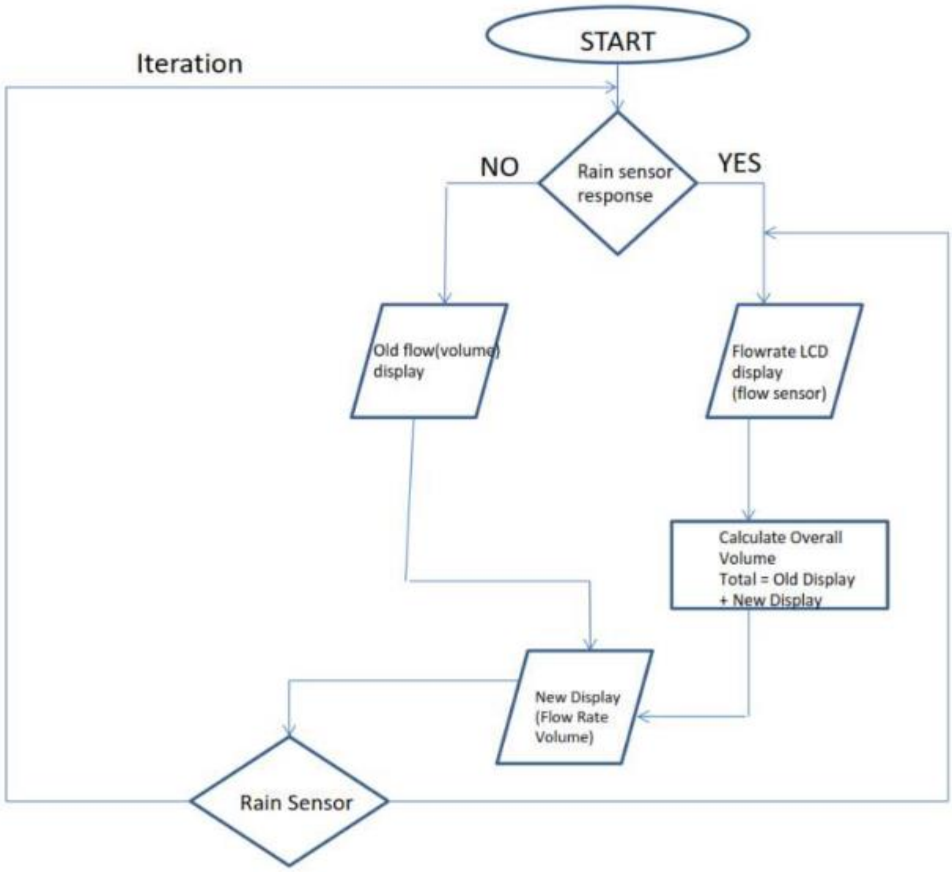

Figure 12 Flow Chart Of Solar Based Rainwater Harvesting Monitoring Using Iot (Chandrika Kota et al., 2020)

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- Firstly, the rain water falls upon the surface of the water sensor which is fixed onto the surface such that it faces the skies.
- Upon sensing the rain droplets, the water sensor activates and begins to send signals to the attached servo motor.
- A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration.
- It consists of a suitable motor coupled to a sensor for position feedback. This sensor is in turned connected to the sliding door on the surface of the ground that slides open to reveal a collecting container for purpose of catching impending rainfall.
- As the rainwater collects into this container, signals are actively sent to the harnesser to denote water levels.
- On the events of overflow of rainwater into the container, the door automatically closes after alerting authorities that the container has been filled to the brim.
- This rainwater collected is finally used for various human activities.

2.9 Impact of IOT on Rainwater Harvesting:

Day by day the shortage of water is increasing because of lack of monitoring, maintaining the costs, controlling and etc., these all are the major reasons why there is increase in shortage of water. To overcome this IOT applications for smart water management system was developed/was brought into picture.(Kumar, 2019)

When talking about impact we mainly focus upon the advantages, so here IOT places an important role since it helps each and every object, person or any other device to connect to the internet and helps to exchange the information.(Kumar, 2019)

2.10 Future Scope of Technology-

- Rain water which is stored can be used in many ways for example if we want to use the stored rainwater for gardening and watering the plants at a particular time then we can set an alarm to disperse the water where we want. And this will be the great advantage for us because we are watering the plants with zero effort.(Gannoju et al., 2019)
- The tanks and all the sensors which need power for working can get the power from solar panels which are exposed to the sunlight to collect the energy from it and converts it into the electric power which can be used by the sensors and all.(Gannoju et al., 2019)
- The Future work will be camera monitoring to monitor the damages occurred in the pit. Human alert method was vigilance when the humans crossing the pit this can be also done by using IR (Infra radiation) sensor.(J.Vinoj & Gavaskar, 2018)

4. CASE STUDIES

4.1 <u>Atlas Villas, Azrou, Morocco</u>

3.1.1 Geographical Description

- Azrou is a city located on the western slope of the Middle Atlas at an altitude of about 1,250 m, about 80 km from the city of Fez.(Design, 2020)

3.1.2 Rainfall data

- Rainfall and precipitation data was extracted from meteoblue, a website working with databases for the past 30 years to get accurate predictions.(Design, 2020)
- The mean annual rainfall based on calculating the total of month's precipitations is 554 mm.(Design, 2020)

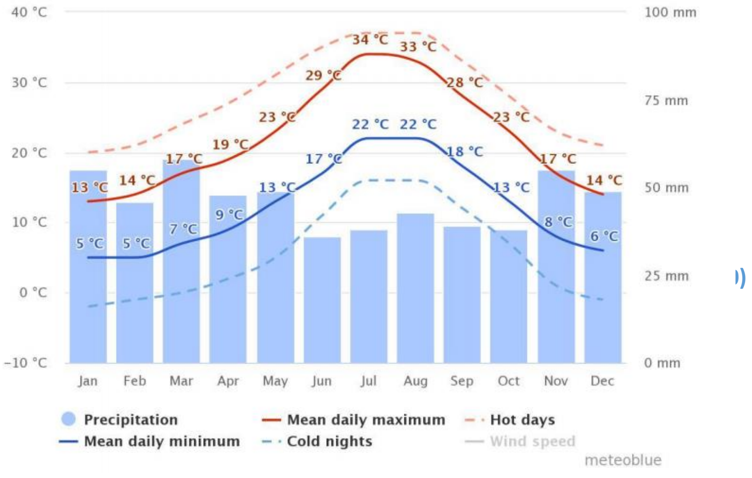

Figure 143 Number of rainy days in various months (Design, 2020)

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Month	Rainy days
January	7,5
February	8,1
March	10,3
April	10,8
May	12,7
June	11,1
July	12,3
August	13,7
September	11,1
October	8,1
November	7,9
December	6,9

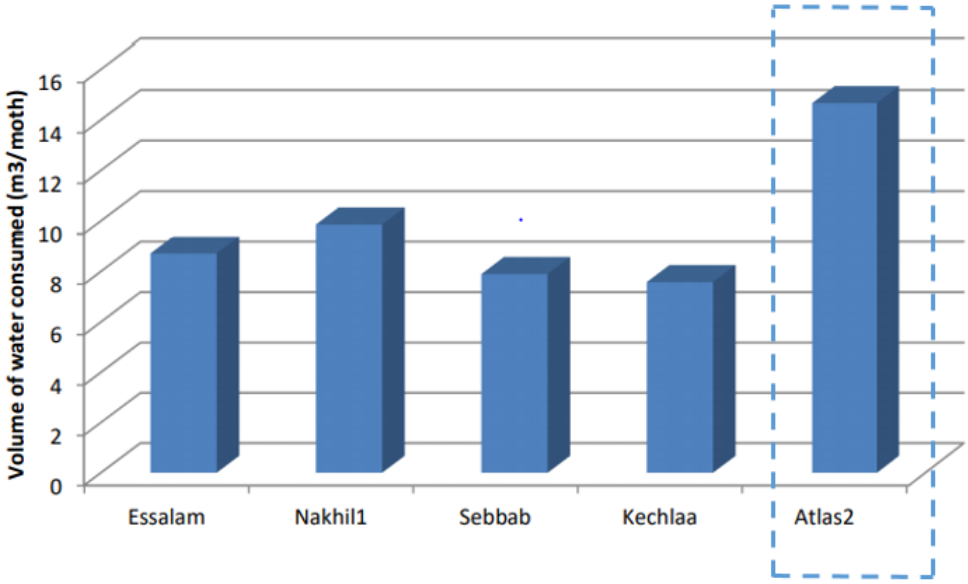

Figure 154 Water consumption demand in of Atlas villa in compariosn to neighbourhood (Design, 2020)

3.1.3Building type and characteristics

Building type Floors	Villas
Floors per buildings	2 (one household)
Height (m)	7m
Roof Area (m2)	149
Roof Type	Flat roof with concrete
Garden Area (m2)	31

Table 3 Buildings type and characteristics (Design, 2020)

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3.1.4 Piping system

Figure 165 Plan of a villa floors showing piping network Based (Design, 2020)

- The pipe coming from the drainage system is diverted outside the house where it meets the first flush filter and then flows into the tank. A 100 mm PVC pipe of 1 to 2 m is used to connect the drainage system to the first flush and tank.
- Based on figure 04, the length needed for the piping network inside the house is: 15.63m.(Design, 2020)
- Using the rule of thumb and a 10% margin of error, the required length for the piping network per floor is: 17.19m(Design, 2020)

Figure 176 Street View Images of Atlas' Villas (Design, 2020)

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3.1.5 Distribution system

- Rainwater is used for toilet flushing, washing machines and taps for non-potable uses. These appliances are already connected to the municipality network.
- A system should be designed to alternate between rainwater and municipality water depending on the water harvested available.
- Pipes coming from the municipality will be disable at the inlet of each appliance and replaced by the piping system coming from the tank. This piping network will be fed by municipality water when rainwater runs low.

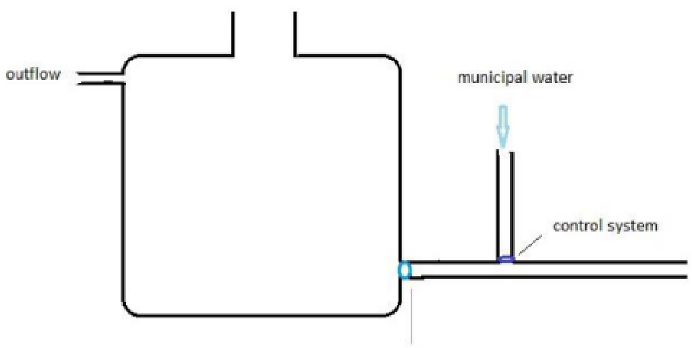

Figure 17 Distribution system (Design 2020)

- Valve 1 is a one way valve also known as a check valve. “It allows fluid to flow in one direction only. These industrial valves are automatically activated by the force produced by the flow of the medium itself through the pipeline and can be classified as an automatic valve”(Design, 2020)
- The control system, that controls the flow of municipality water, can either be automated (a control valve).
- The automated system consists of an ultrasonic distance sensor placed at the top of the tank to calculate the distance to the water level.
- Once the water level drops to the maximum height, a signal is sent to an Arduino board to control and open the valve for municipality water to flow in.
- A pump is used to allow the flow of water to both floors in Atlas Villa.

3.1.6 Economic viability

Initial Investment (Dhs)	8,340
Maintenance per year (Dhs)	176
Savings per year (Dhs)	1,122
Net Cash Flow per year (Dhs)	946
Payback Period (years)	8.81

Table 4 Economic viability of project(Design, 2020)

3.2 Case study II- Residence at H-29, Sector-11, Noida, U.P, India

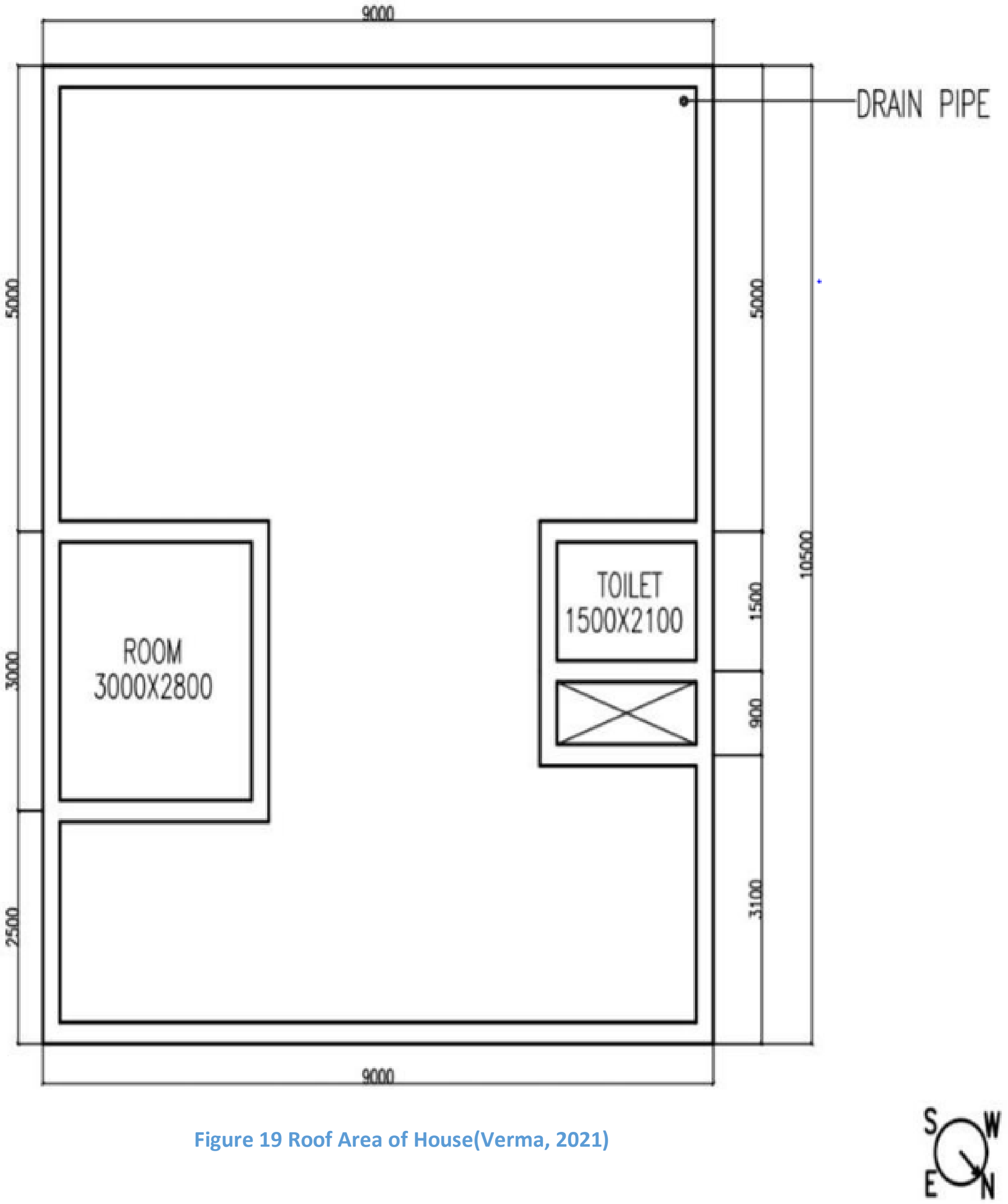

Figure 19 Roof Area of House(Verma, 2021)

3.2.1 Geographical Description

- The project area lies at the longitude 77° 26' 18.58" East and latitude 28° 33' 34.05" North. It is a flat area at an altitude of 639 feet above mean sea level. The topography of the area is plain.
- The soil type is alluvial.

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3.2.2 Rainfall Data

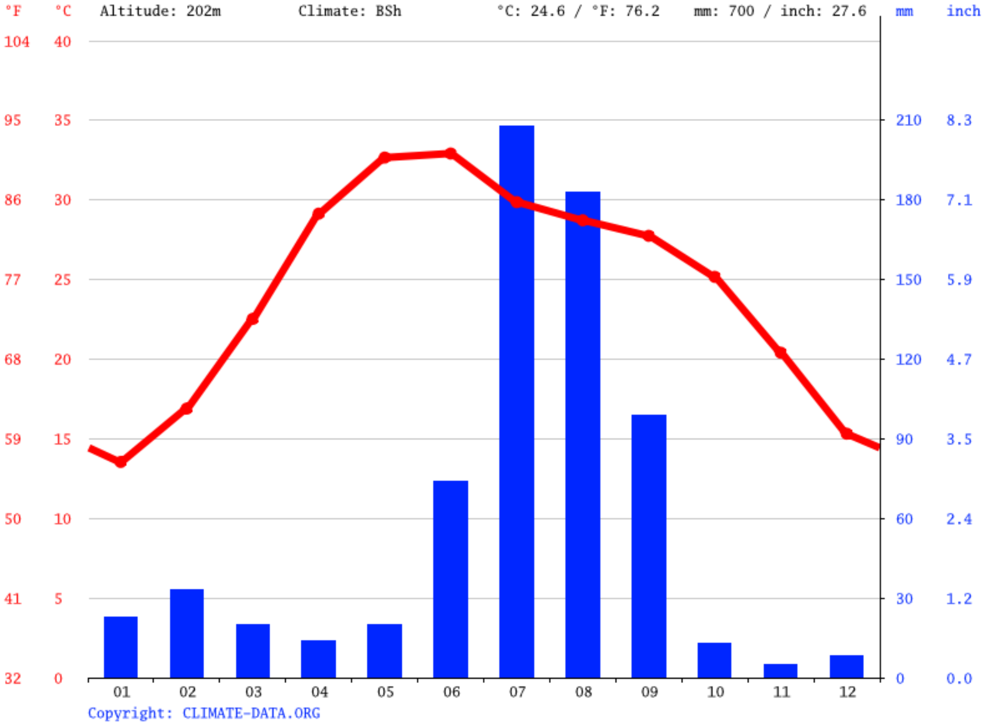

Figure 20 Noida climate graph by month (IMD, 2021)

- The average rainfall is about 700 mm, 27.6 inch per year.

3.2.3 Calculations

- The roof area exposed to the rain is 150 meter square.
- Q=C*I*A, Q= 0.9*0.045*150= 6.075 Cum.
- The drain pipe comes straight down from roof as shown in Figure 6. However, the length of PVC pipe required from pipe end to ground System is approx. 3 m.(Verma, 2021)
- Total implementation cost- Rs. 8306(Verma, 2021)

3.2.4 Proposed System (Verma, 2021)

- The roof is the collection point of the rainwater.
- There are two drainage points at the roof connected with the PVC pipes. The PVC pipes are further connected together using a t-point at its two different ends at the ground side. One of the PVC pipe would be connected at T-point with a little slope.
- The third end of the T-point would be connected to the ground system with a U curve. This curve leads settle down dust particles at one end of the U curve before raising the water into the other side.
- The LDR and turbidity sensors are fixed at the U-point using a suitable mechanical arrangement, so that they are properly exposed to the rainwater.
- The ground system would be mounted in between the PVC pipe and the ground water tank using a suitable mechanism. The water would be segregated in ground water subsystem.
- There would be two outlets from ground subsystem. First outlet would be used for dirty water to direct it towards the ground for purpose of gardening. Second outlet would be used to direct the clean water to ground water tank. A water pump would be used to pump the water towards rooftop water tank.
- The ground system is using the IoT technology for communication and powered using the solar panel to make it self-sustainable.

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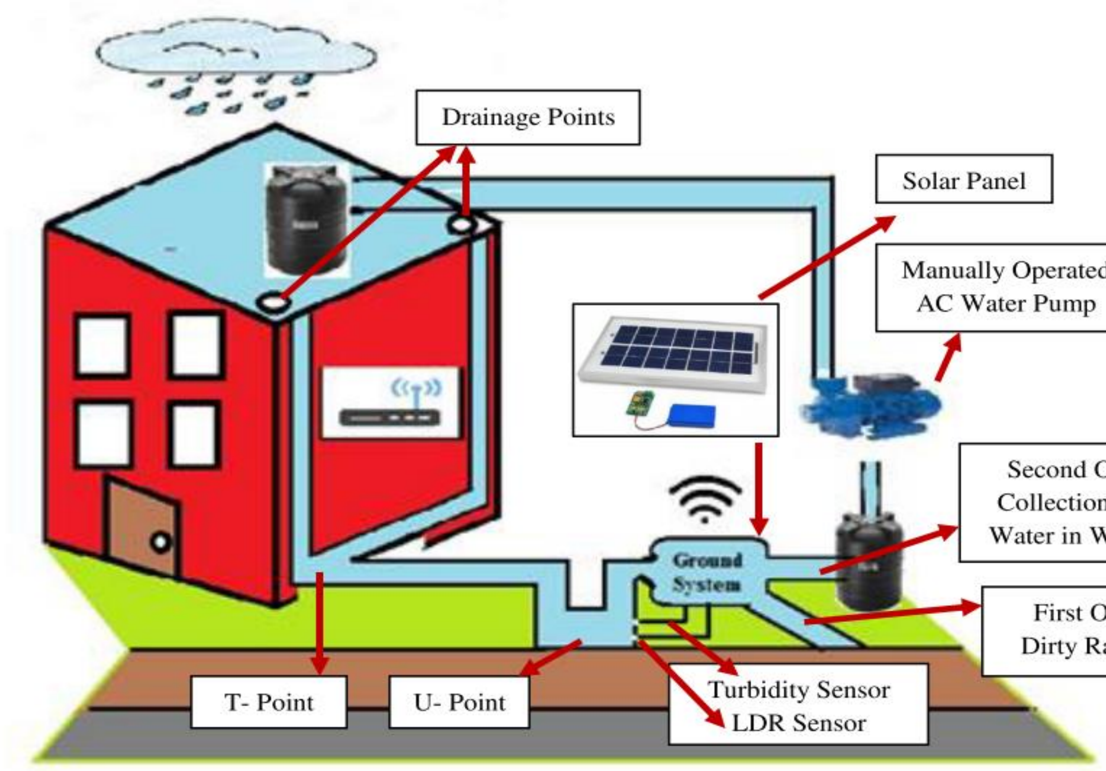

Figure 21 Layout of the self-sustainable low cost rainwater harvesting system(Verma, 2021)

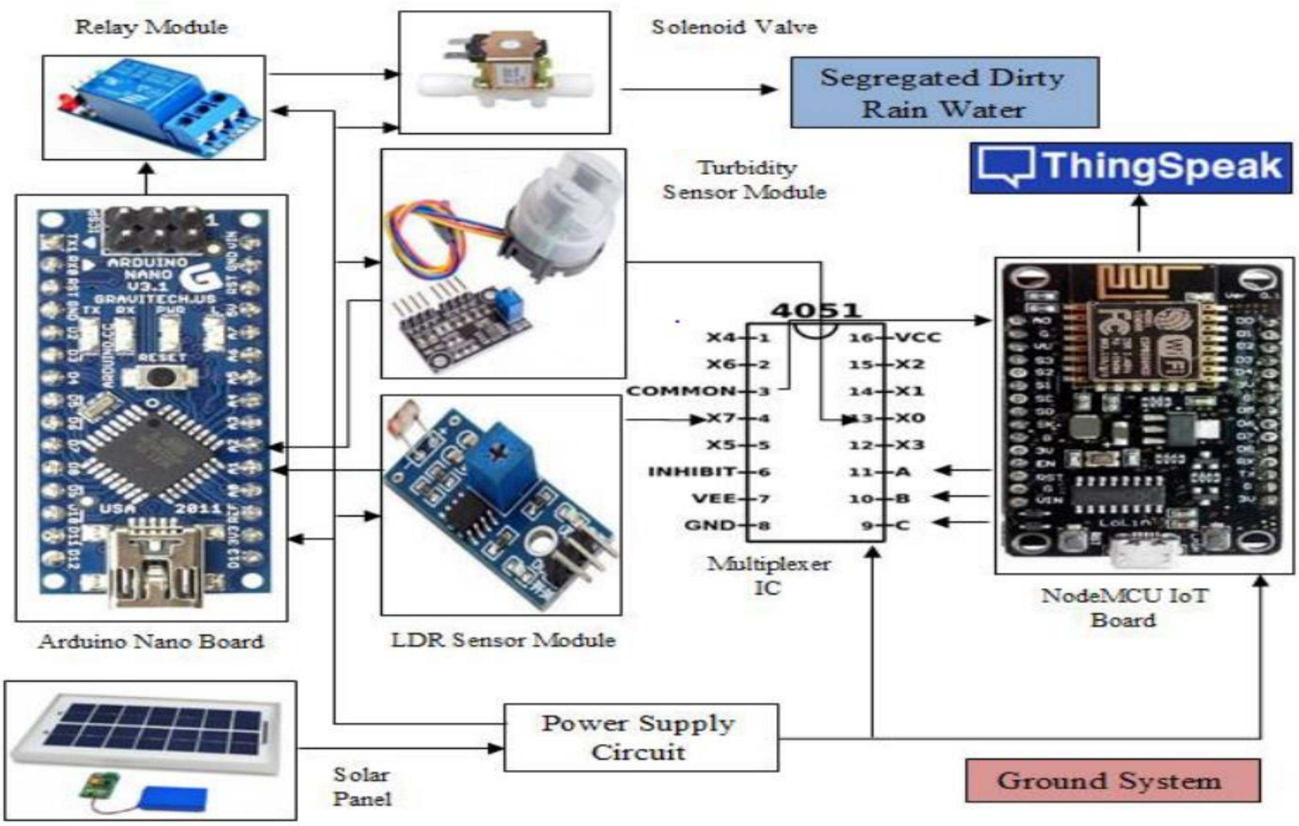

Figure 22 Block diagram of the ground system for rainwater harvesting (Verma, 2021)

3.3 Case Studies Comparative

	Case study 01	Case Study 02
Total catchment	180 square meter	150 square meter
Total Runoff	7.77 Cum	6.075 Cum
Annual rainfall	554 mm	700 mm
Household capacity	7 people	4 people
Initial investment	Dhs 8340	Rs. 8306
Ultrasonic sensors	Yes	No
Rain sensors	Yes	No
Software used	-	Thing Speak
Solar panel operated	Yes	Yes
Quality analysis	No	Yes
Micro controller	Arduino	Arduino, Node MCU
Water demand	60-80%	More than 50%

Table 5 Case Studies Comparison (Author, 2021)

3.4 Case study analysis

- In both the case studies the proposed system was powered up using solar panel which makes them self-sustainable.
- They are economical viable as in both the cases it saved the considerable amount of money spent on energy of transportation of water from municipal supply and pumping of water from underground aquifers.
- The system was successful in lowering water consumption demand in the households, by the usage of non-potable harvested water, and limiting the demand on natural water reservoirs.
- The demand reduction on water consumption in both the cases was found to be more than 50%.
- The IoT based quality analysis done using turbidity and PH sensors in case 2 was helpful in segregating and storing water on the basis of it contamination level, and recycling it for various potable and non-potable purposes.
- Further if the system is implemented on the larger scale townships would help in preventing the flooding of rainwater and proving larger catchment areas.

4. DESIGN AND IMPLEMENTATION

DESIGN OF RAIN WATER HARVESTING FOR RESIDENTIAL HOUSING AT NOIDA

4.1 Project details

- Site area- 49778.17 sq.mt., 12.3 acres
- Ground Coverage- 14%
- Total built up- 27821 sqm
- F.A.R- 0.55
- Location- Sector 19, Noida
- Latitude- 27°52'06.3'N
- Longitude - 78'04'26.4'E
- Height- S+4
- Total residential flats- 696
- Number of towers- 6
- Total residential population- 3201
- Floating population- 417
- Climate- Composite
- Ground water level- 26.7 m
- Soil type- Clay Loamy
- Vegetation- Trees and plantation along road avenues and reversed forest.
- Rainy days- 57
- Average rainfall- 700 mm

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4.2 Climatic and Geographical Data

4.2.1 Average Monthly Snow and Rainfall in Noida (Uttar Pradesh)

- A lot of rain (rainy season) falls in the months: July, august and September.
- Noida has dry periods in January, February, March, April, may, October, November and December.
- On average, July is the wettest month.
- On average, November is the driest month.

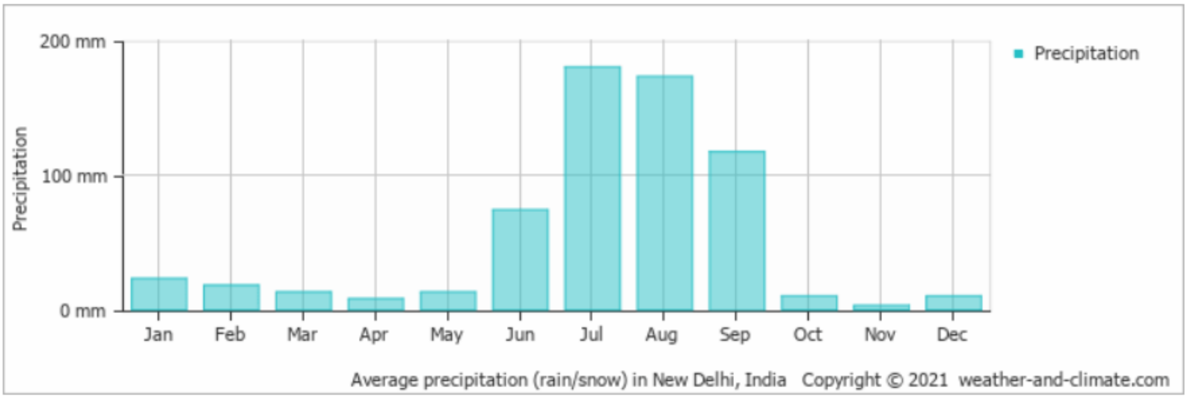

Figure 23 Noida rainfall graph(Climate data.org, 2021)

- The average amount of annual precipitation is: **700 mm (27.6 in)**

4.2.2 Ground Water Level

- The **water table** in **Noida** has depleted by around 17 metres since 2016.
- A government report has revealed that the **level** of **groundwater** has slid from 9.9 metres in 2016 to **26.7 metres** this year.

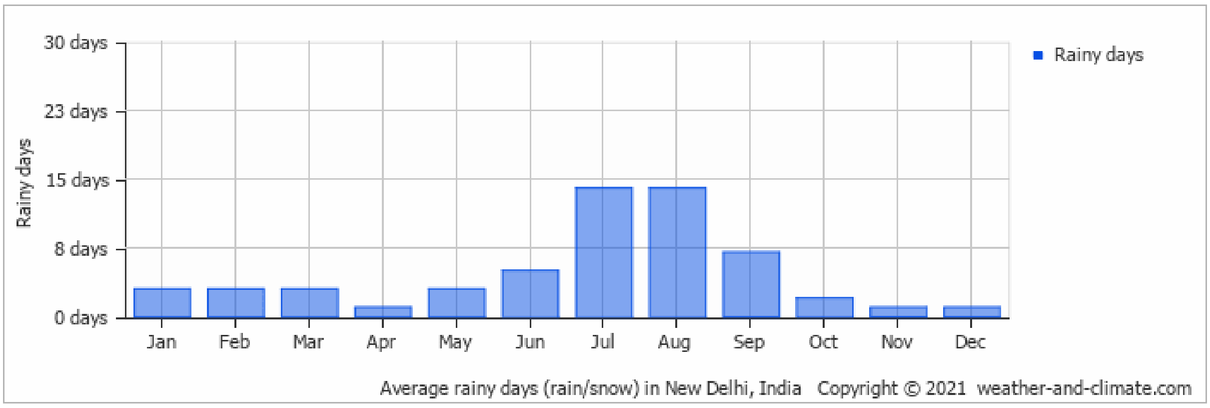

Figure 24 Noida rainfall graph (Climate data.org, 2021)

4.2.3 Average Monthly Rainy Days In Noida (Uttar Pradesh)

- Noida has dry periods in April, October, November and December.
- On average, July is the rainiest.
- On average, November has the least rainy days.
- The average annual amount of rainy days is: 57.0 days(Indian meteorological department, 2021)

4.2.4 Soil Type and Characteristics

- Noida falls under the catchment area of the Yamuna River, and is located on the old river bed.
- The soil is clay loamy.
- The water holding capacity of the soil is 1.75-2.50 inches of water per foot of soil.(Wikipedia, 2021)
- By weight, its mineral composition is about 40–20% concentration of sand–silt–clay, respectively.(Wikipedia, 2021)

4.3 Calculations

- Catchment area of one cluster- 1159.21 Sqm
- Catchment area of 6 clusters- 6955 Sqm

- Catchment area of roads and pavement- 14000 Sqm
- Catchment area of green areas- 28823 Sqm
- Total catchment area- 1181 Sqm

	Catchment areas (A)	Run-off coefficient (C)	Intensity of rainfall (I)	Q= C*I*A
Roofs	6955 Sqm	0.9	700 m	438 Cum
Roads and pavement	14000 Sqm	0.45	700 m	441 Cum
Green areas	28823 Sqm	0.15	700 m	302 Cum
		Total		1181 Cum

Table 6 Determination of catchment areas (Author,2021)

4.3.1 Total Volume

- Volume Required = 1181 X 0.250
- Volume = 295.25 Approx.

4.3.2 Number of Recharge Pits and Desilting Tank

- Providing desilting tank of size = 2.5 x 1.75 x 2 m.(Effective depth)
- Capacity of desilting tank of given size (Cum.), **A = 8.75**
- Providing recharge pit of size = 3 x 2 x 2 m. (Effective depth)
- Capacity of recharge pit of given size (Cum.), **B = 12**
- Hence total combined capacity of one set of desilting tank and recharge pit, (Cum) = **A+B = 20.75**
- Therefore no. of desilting tank and recharge pit required = 295.25/20.75 =14.22, Say **nos. 14**
- Thus, there will be a set of **14 desilting tanks (2.5 x 1.75 x 2 m) and recharge pits(3 x 2 x 2 m) of capacity 8.75 Cum. and 12 Cum.** respectively.

4.3.3 Water Demand

- For one residential dwelling (1BHK)- 4X135= 540 litres
- For one floor- 540x37= 19989 litres
- For one tower- 19989X 4= 79920 litres
- For 6 towers- 479520 litres
- Total rain water harvested – 295250 litres.
- Total reduction which can be achieved- 61.5 %

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4.4 Site plan

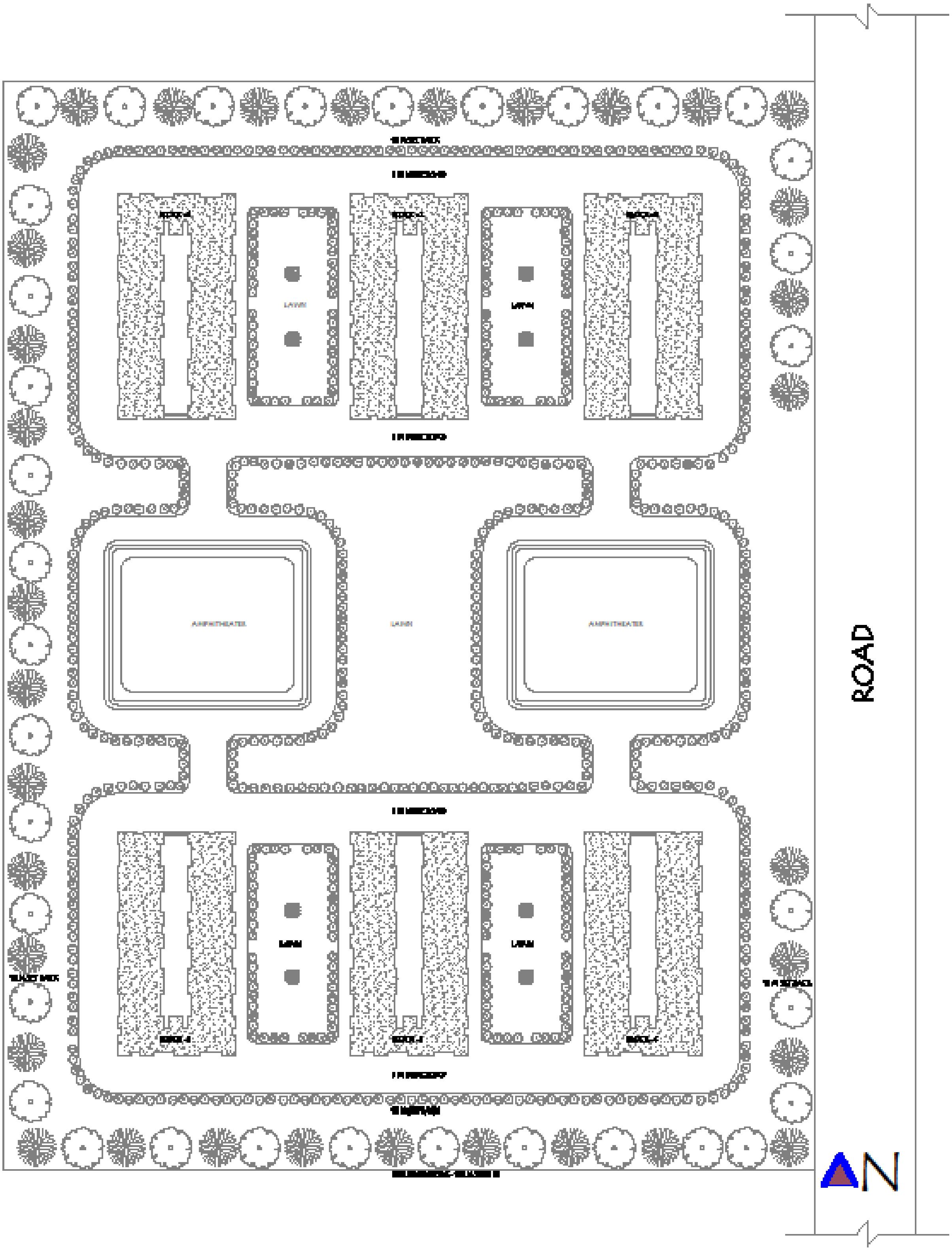

Figure 25 Site Plan, Hypothetical site at noida sector-19 (Author, 2021

4.5 Proposed Case-I

- In first proposed case 11 number of recharge pits are designed to recharge the ground water level. In case of overflow

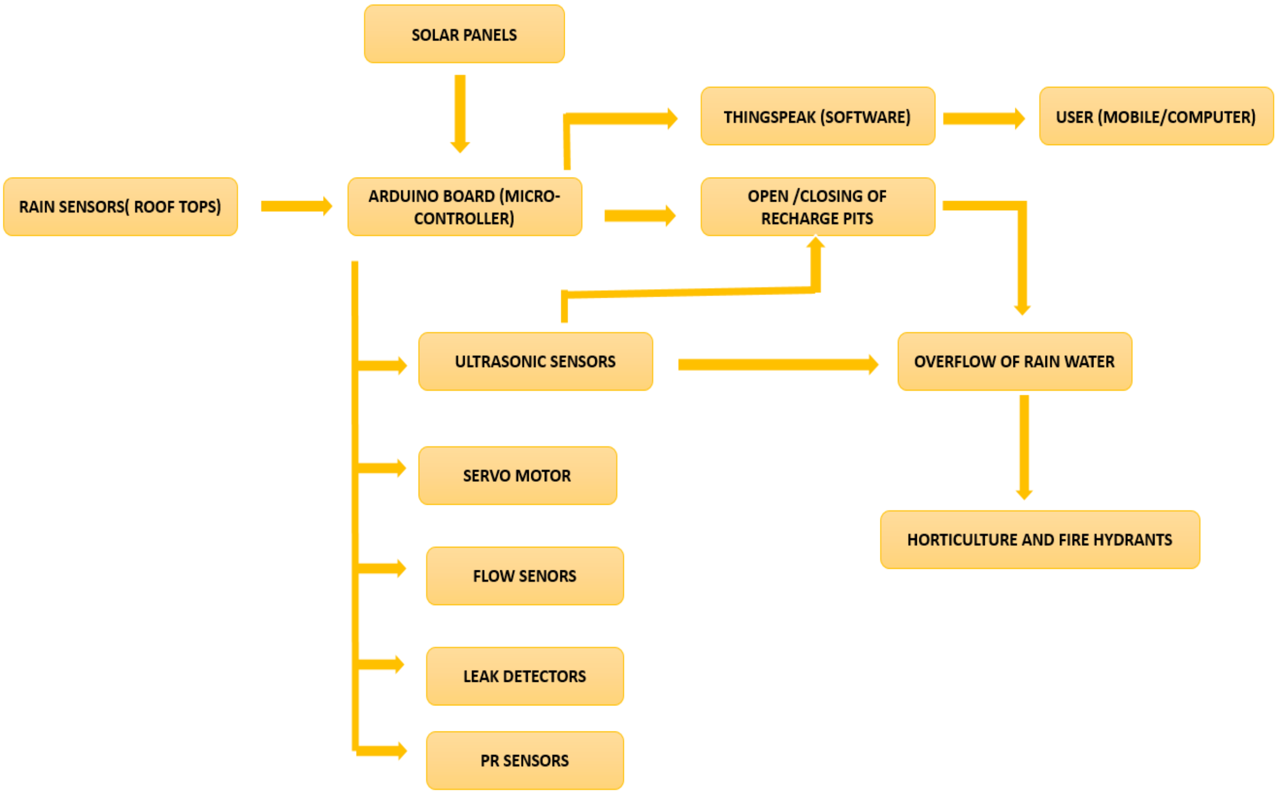

Figure 26 Proposed Design for Case I (Author, 2021)

the water is further diverted to the storage tanks, which can be recycled for horticulture and fire hydrants.
- The system will be monitored with the help of IoT, ultrasonic sensors will help in knowing the level of water in pits And tank, which will help in controlling the overflow.
- Automatic on/off of recharge pits as soon as the rain water sensors senses rain and infra radiation sensors to prevent accidents of people falling into pits.
- The system will be controlled with the help of Arduino UNO, which will be operated with the help of solar panels, making it more sustainable and efficient.
- The system helps in maintaining the ground water level in an area with proper recycling of rain water with no wastage.

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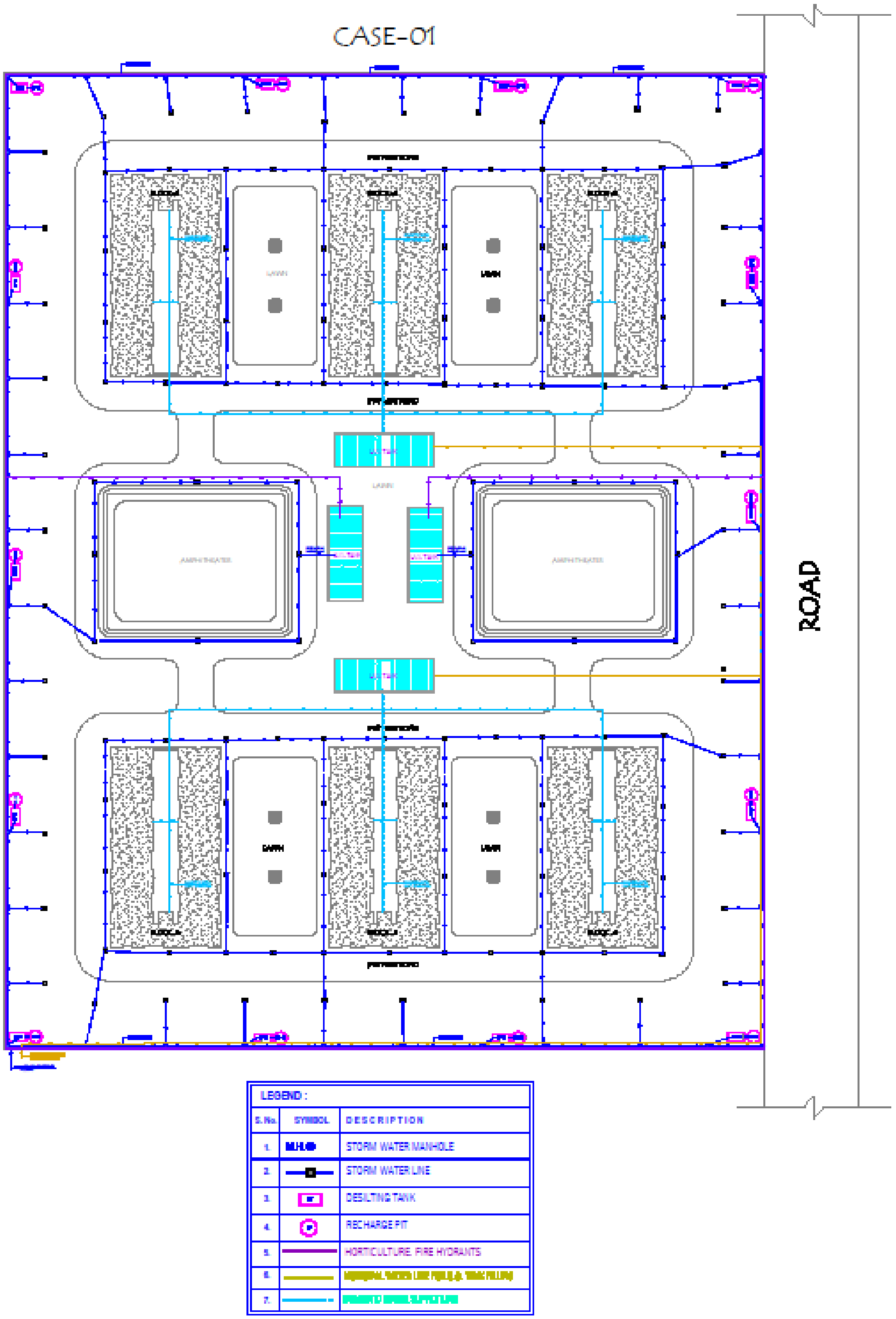

Figure 28 Proposed design case for rainwater harvesting (Author, 2021)

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4.6 Proposed Case-II

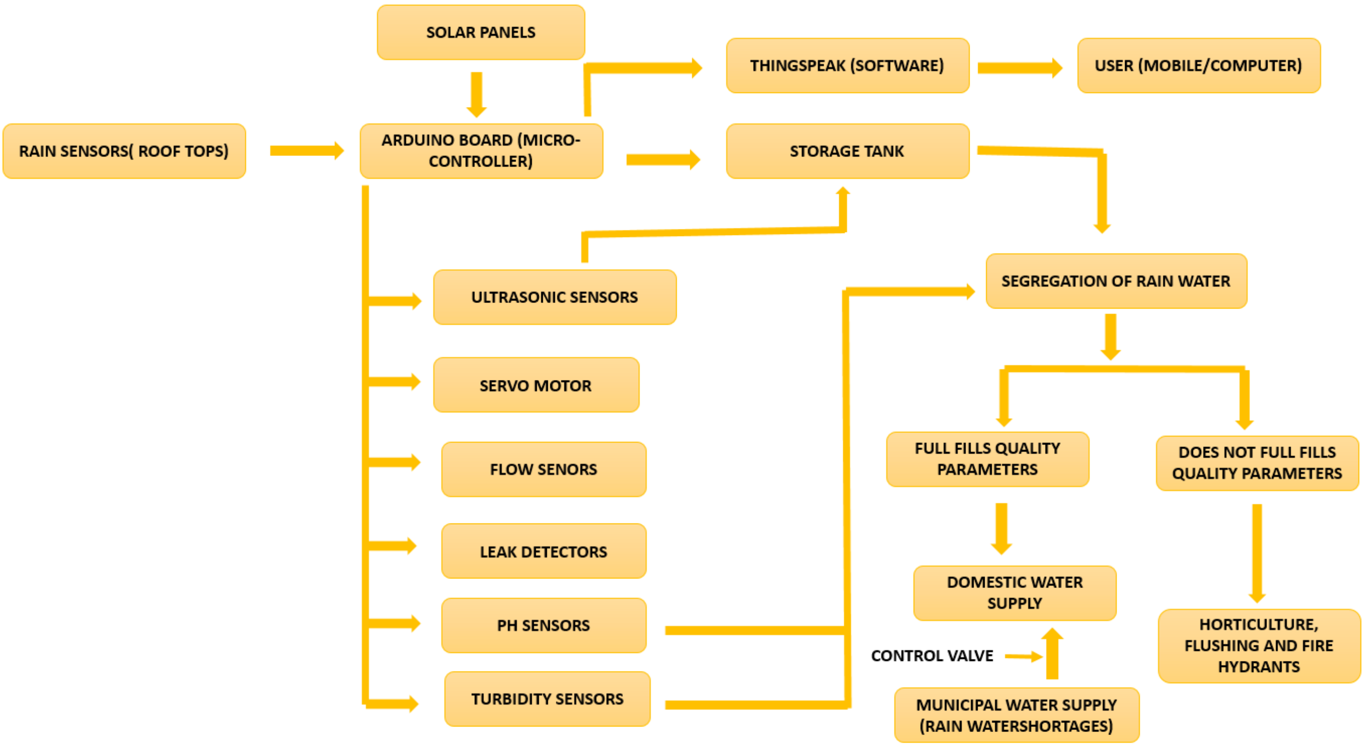

Figure 29 Proposed Design for Case II (Author, 2021)

- In second proposed case storage tanks are being designed. In this system we use of various water quality analysis sensors such as PH, Turbidity.
- The segregation of water is done in a way that if the PH value falls between 6.5-8.5 and turbidity value is less then 5 NTU so the water will be diverted to the domestic supply tank. This tank is integrated with municipal supply line so that in case the stored rain water level falls so, it is automatically detected with the help of ultrasonic sensors and then the supply is taken from municipal supply.
- The control valve integrating the municipal supply and rain water supply will be automatically operated by the user through Arduino microcontroller.
- If the rain water PH and Turbidity does not fall under drinking water standard then it can be diverted to the other tank, from where it can be recycled to horticulture, flushing and fire hydrants.
- The system can help in reducing the dependency in municipal water supply and there will be proper recycling of rain water.

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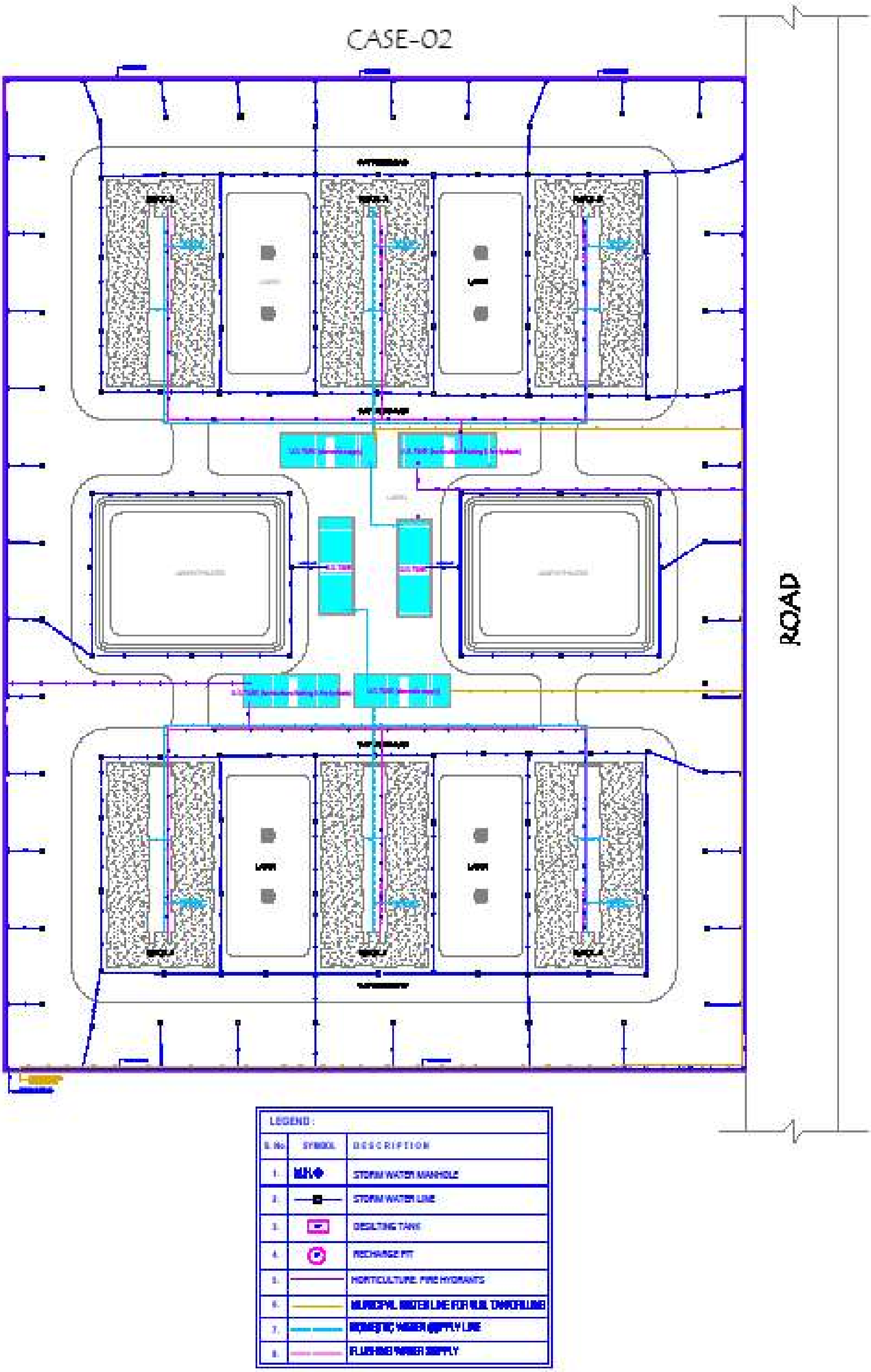

Figure 30 Proposed design case for rainwater harvesting (Author, 2021)

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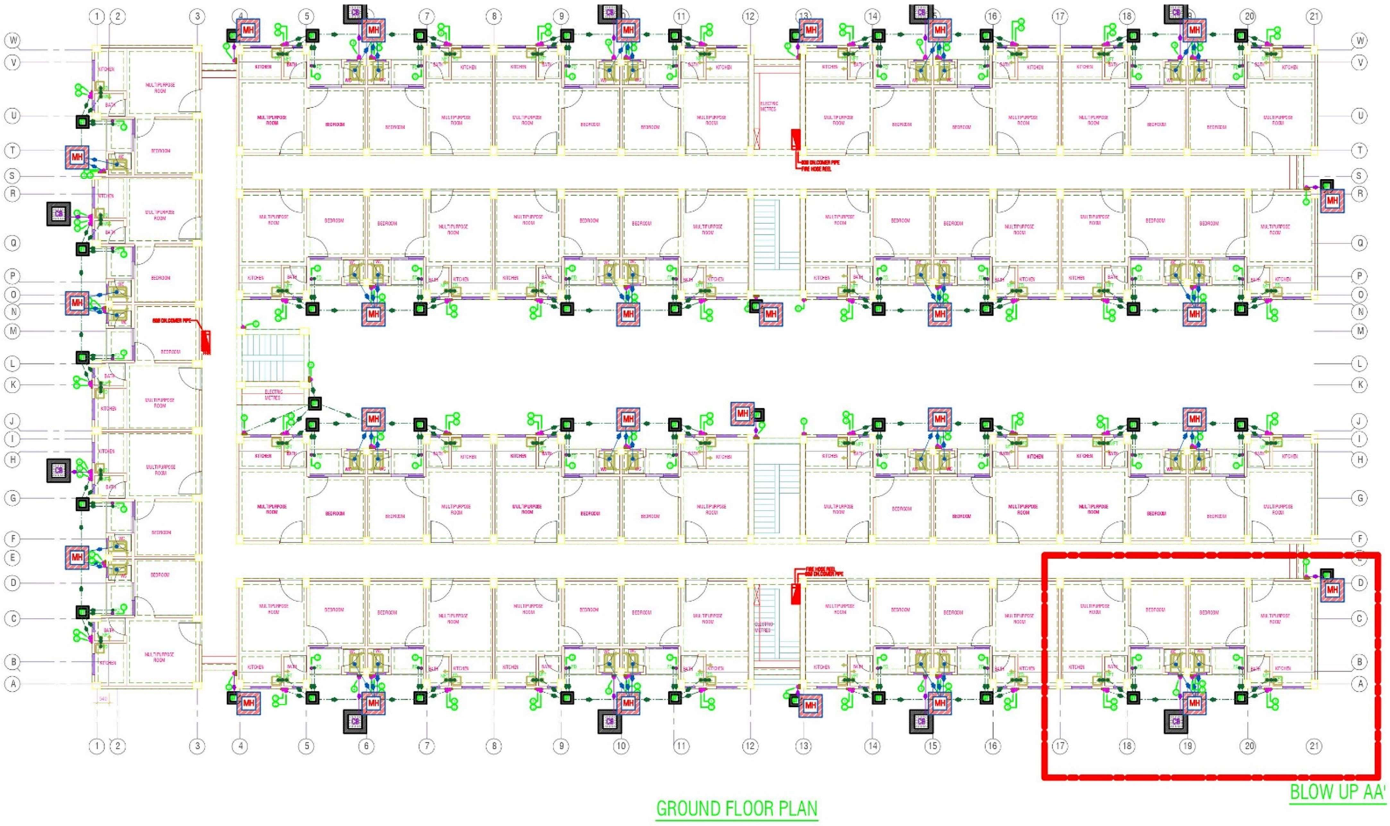

Figure 31 Plumbing layout of a residential tower (Author, 2021)

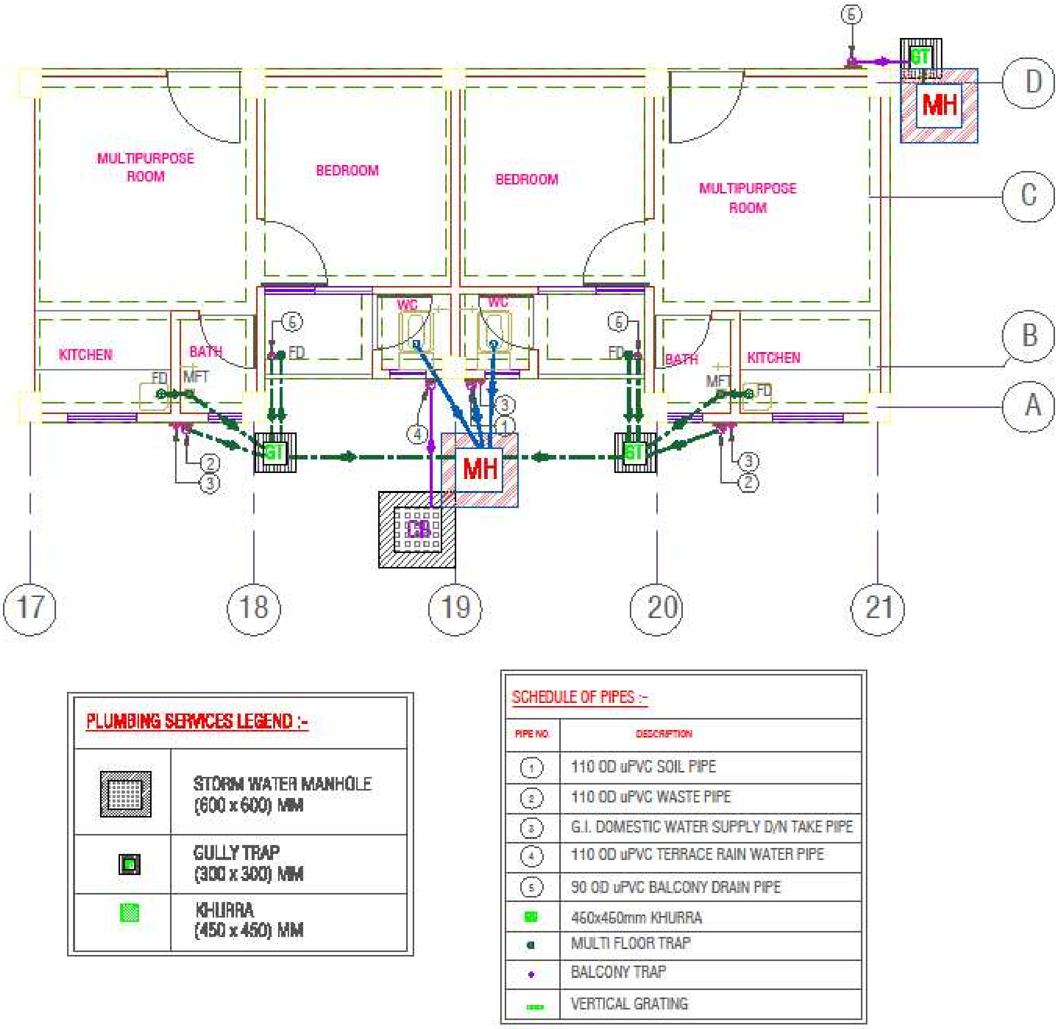

Figure 32 Deatil of Plumbing at AA' (Author, 2021)

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5. OUTCOMES

5.1 Recommendations

- The first system is feasible for recharging of water and regulating the over flooding of the rainwater, storing it and recycling it for various purposes so the system can be adopted in the region where the ground water has depleted to the level of concern.
- The second system is suitable where the quality of the rainwater is good for drinking since there the stored rainwater is integrated with municipal supply line. The system can help in bringing down the dependency on ground water supply.
- The future work can be camera monitoring it is nothing but just watching the level of pit and to monitor the damages occurred in the pit. Human alert method was vigilance when the human crossing thee pit this can also done by using IR sensor.

5.2 Conclusions

- The IoT based rainwater harvesting provides better results for collection and recycling of rainwater. It helps in solving most of the problems of traditional RWHS.
- There is fast replenishing of ground water due to illegal boring is not being recharged by rainwater which results in the depletion of groundwater to alarming levels so the proposed design helps to retain the quality of precious rainwater and also to collect rainwater in areas of small size houses.
- The proposed system reduces the labour cost and it immediately track the changes occurring in real time monitoring such as lack of visibility into distribution, collection, distribution and consumption patterns, leak detection, overflow/insufficiency in the pits and tank etc. results in time consuming, costly and reactive services.
- To minimise these losses, and to address mounting concerns about drought, flooding, and water quality, water industry is now adopting advanced sensor and communication solutions designed specifically for "smart" Internet of Things (IoT) water management.
- The tanks and all the sensors which need power for working can get the power from solar panels which are exposed to the sunlight to collect the energy from it and converts it into the electric power which can be used by the sensors and all.
- The collected rainwater can be recycled for various purposes such as horticulture, car wash, road wash, flushing and if it full fills the quality parameters so it can be used for potable purpose also hence it can reduce the dependency on municipal supply and ground water can also be conserved.
- One of the disadvantage of the people need to have active internet connection for getting the data in Mobile application or desktop through cloud and if the sensor goes down there is no indication to that, manually the owner has to detect it.
- The proposed IoT based water controlling and monitoring can be applied to other water networks such as in irrigation to improve system efficiency and sustainability by better management of the water resources.

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6. ANNEXURE

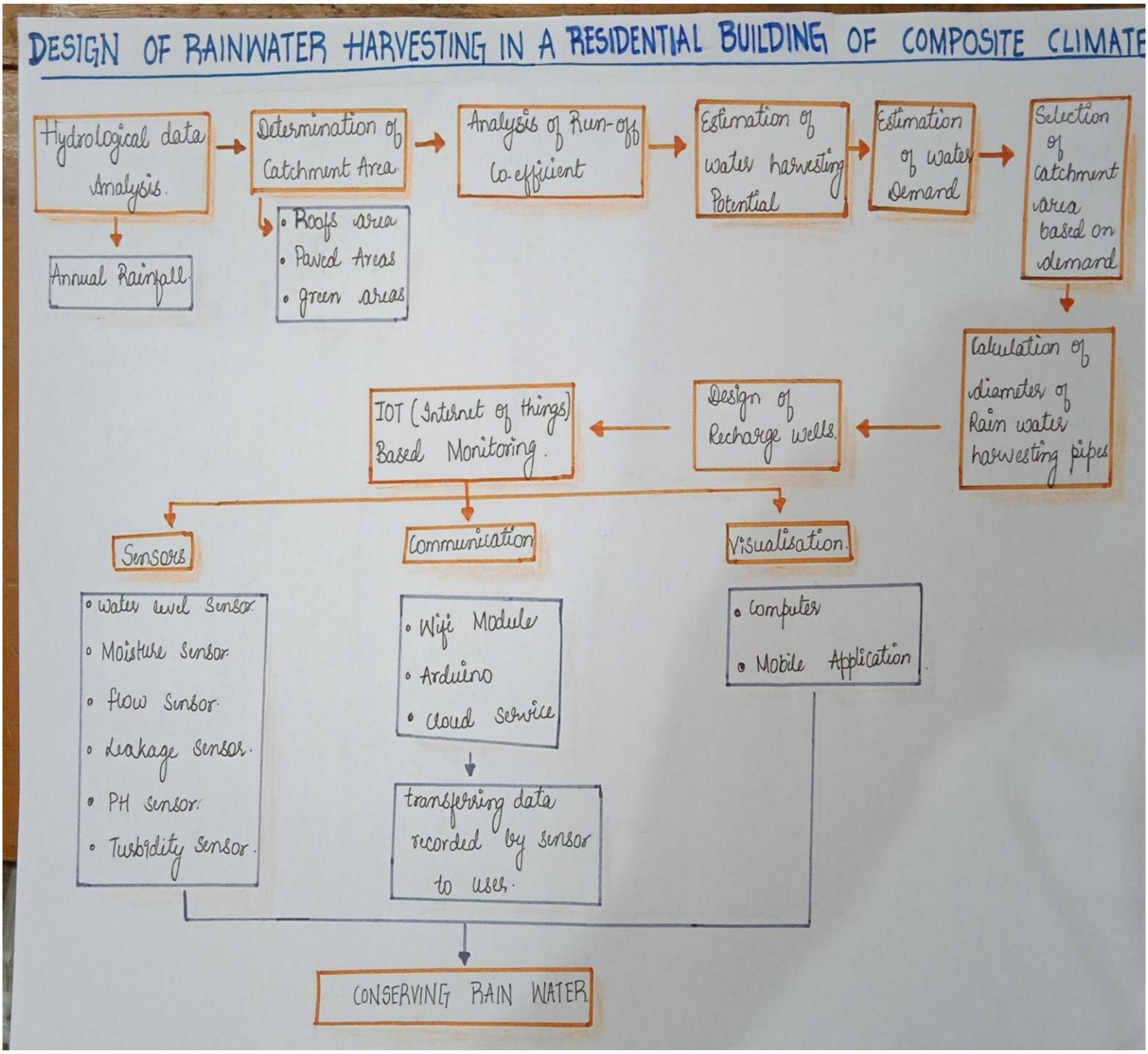

Figure 19 Doodle of workflow diagram (Author, 2021)

7. 7. REFERENCES

7.1 Annotated Bibliography

1. Ranjan, V., Reddy, M. V., Irshad, M., & Joshi, N. (2020). The Internet of Things (IOT) Based Smart Rain Water Harvesting System. *2020 6th International Conference on Signal Processing and Communication, ICSC 2020*, 302–305. https://doi.org/10.1109/ICSC48311.2020.9182767
The research focuses on analysis of quality parameters of a rainwater with the help of IoT (Internet of things). The existing methods of rainwater harvesting i.e. surface runoff harvesting and rooftop rain water harvesting are described in brief. Further the authors have introduces their smart approach of rainwater harvesting with the help of the proposed model based on IoT based monitoring and segregating the water on the basis of its PH value. Through this they have tried to establish a direct connection between the user and the rainwater harvesting structures with the help of various components such as Arduino microcontroller, PH sensors, ultrasonic sensors, rainwater sensors, servo motor and various other connections with generates necessary information and transfers the information to user through internet to the desktop or smart phone. The information is immediately uploaded on the webpage as the PH sensor determine the value. On the basis of it the user can segregate the water to the various tank accordingly and further it could be recycled for various activities or treated as per contamination.

2. J.Vinoj, & Gavaskar, D. S. (2018). Smart City Rain Water Harvesting (IoT) Techniques. *International Journal of Scientific Development and Research (IJSDR)*, *3*(8), 1–6. https://www.ijsdr.org/papers/IJSDR1809001.pdf
In this the authors have proposed a smart centralized rain water harvesting project was using to save the rain water process and using more sensors (rain water sensor, ultra sonic sensor),and Arduino. Arduino is the micro controller. Arduino is connected to rain water sensor, when the rain starts rain water detector sensor will automatically open the pit, and water level sensor is attached inside the pit. The water level sensor is to find the water level and when the pit is filled, automatically gsm module send the information to the water board and finally pit will be closed. In this system, the processes will automatically takes place without the help of users and the water level details will be stored in the computer system permanently. Whenever the water board needs, that can utilize the accurate date of the rain water movements will be tracked easily. The main benefit of this project is, it is more efficient than the home based rain water saving system.

3. Gannoju, R., Hasan, N., & Sayeed, N. (2019). *Global journal of engineering s cience and researches*. *231*(C), 231–239. http://www.gjesr.com/Issues PDF/ICITAIC-2019/27.pdf
The authors have an idea to modernize rainwater harvesting but the work towards its implementation is underway & execution is a fairly easy task. The general setup although customizable, consists of an elevated surface upon which a water sensor powered by Arduino is fixed. A servo motor too is connected to the water sensor & is powered by the Arduino. Upon the occurrence of rainwater, the water sensor activates & signals are sent to the Arduino. The code on Arduino is processed resulting in the activation of servo motor such that an inlet for collecting rainwater opens up. Simultaneously, an email is sent to the user's mobile to notify him/her whenever the inlet opens upon detection of rainfall and consequently closes once it's over. Thus, our proposed system works towards the betterment of water management in cities, making it a new venture towards collecting water the smart way.
4. Mu, J. S., & Jeon, Y. Bin. (2014). *Smart Water Management System using Arduino*. *April*, 132–135. https://www.grdjournals.com/uploads/conference/GRDCF/007/024/GRDCF007024.pdf
The author has proposed a model of rainwater harvesting operated with solar panels. The solar powered water pump automatically switches on or off according to the level of the water in the tank. On the basis of contamination present in the water the water is recycled for various purposes such as impure water being utilised in fields. The micro controller is programmed using the arduino programming language. The sensed values are monitored using the android apps. Since it is an open source platform everyone can easily access the system. Users can save the energy and water by sensing and analysing the information via mobile applications as soon as the user receives the notification from sensors. The project helps in reducing the labour cost and provides real time monitoring in field by easy monitoring and controlling the water management system.
5. Kumar, G. P. (2019). *JASC : Journal of Applied Science and Computations ISSN NO : 1076-5131 Volume VI , Issue I , January / 2019 Page No : 2523 JASC : Journal of Applied Science and Computations ISSN NO : 1076-5131 Volume VI , Issue I , January / 2019 Page No : 2524*. *VI*(2523), 2523–2528. https://www.ijsdr.org/papers/IJSDR1809001.pdf
The author describes various IoT based smart technologies helping in water management such as smart water sensors, smart leak detectors, remote water monitoring etc. the various requirements for the IoT based smart water management are detailed out which talks about functions, operations and description of various physical components required. Interoperability and various applications such as GIS and databases containing information on soil condition and climatic condition etc. The papers comes to an conclusion that if implemented in an effective & conceivable aspect, it can mitigate the effects of depleting ground water levels and fluctuating climate conditions. The future scope of IoT based water management technology are being highlighted as productive and efficient in terms of water conservation.
6. Verma, G. (n.d.). *Low Cost Smart Ground System for Rainwater Harvesting for Indian Houses Using IoT Technology rainwater harvesting for indian houses*. https://www.researchsquare.com/article/rs-531034/v1
The author has proposed layout of the self-sustainable low cost rainwater harvesting system. The ground system is using the IoT technology for communication and powered using the solar panel to make it efficient. The IoT based quality analysis for rainwater harvesting is been done in various projects on Ghaziabad, Noida and further they have provided comparative on the basis of results obtained from case studies mentioning cost and efficiency of the projects. The projects have simple Arduino as microcontroller and sensors such as LDR or turbidity connected to it. The sensed values of the sensor are given to Arduino Nano and NodeMCU for performing their respective actions. On the basis of the data obtained the water is stored and utilised at site for various purposes such as horticulture, road or car washing etc. Proposed system becomes one of the smart solutions to address the modern problem of rainwater harvesting with water quality management in low cost.
7. Vatsala Sharma. (2020). Arduino based Smart Water Management. *International Journal of Engineering Research And*, *V9*(08), 652–656. https://doi.org/10.17577/ijertv9is080239
The author has proposed a design of automated rainwater harvesting through Arduino micro controlled processing information from various sensors through internet. The ultrasonic sensor sense the level of water in the tank/pit. The information being visualised on the smart phone. The automatic turning on/off of tank gate will done by the user ones the information is updated on the phone. When water reaches near high level of underground tank, motor will be turned on through Blynk application on smartphone to transfer the water in the ground tank to main tank and when main tank is about to fill up it will turn off automatically. To minimize losses such as time consumption, cost and to address mounting concerns about drought, flooding, and water quality, the water industry is now adopting advanced sensor and communications solutions designed specifically for "smart" Internet of Things (IoT) water management.
8. NBC, 2016. (2016). *National building code, volumne 2, 2016* https://archive.org/details/nationalbuilding02
The volume 2, Part 9 of NBC deals with plumbing design. The provisions for drainage and water supply are being provided which helps in design of rainwater harvesting. It provides all the necessary data regarding runoff coefficient for various surfaces, calculation of quantity analysis. The design and consideration for recharge pits are being specified along with all the necessary provisions which have to be taken while designing rainwater harvesting. Further the design of various plumbing layouts such as drains and sewers are also given. The necessary data for the initial design of various structures of recharge pits is acquired from NBC.

9. Chandrika Kota, V. S. P., Annepu, C. R., Dusarlapudi, K., Sreelatha, E., & Tiruvuri, C. S. (2020). Smart approach of harvesting rainwater and

monitoring using IoT. *Journal of Advanced Research in Dynamical and Control Systems*, *12*(2), 91–100. https://doi.org/10.5373/JARDCS/V12I2/S202010011
This paper deals with the effective way of monitoring the rain water and analyse the data using IoT(internet of things). Rain collected from the roofs of homes, tents and native establishments will build a very important contribution to the supply of potable. The rain water harvest home (RWH) system as a prototype is analysed as a various supply of water at K L University in the state of Andhra Pradesh, India. The expected outcome of the study is that the development of rainwater harvesting system for catchment area. The developed system satisfies the social necessities and may be enforced in rural areas by considering most the technical side. The proposed model is solar based rainwater harvesting monitoring using IOT, uses the solar panel to charge the battery via charge controller. IOT (internet of things) is adopted to visualize the data over the cloud. Thingspeak website is to use cloud platform to collect the whole data of the rainwater aimed to increase the ground storage capacity.

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The research focuses on smart rainwater harvesting by interpolation between the stored rainwater and the municipal supply. The automatic valve is placed between tank and municipal pipeline, which helps in regulating the supply of municipal supply when the stored rainwater supply falls. The system is operated with the help of solar panel supply which helps in providing power to the system. The system is run with the help of Arduino UNO, which acts as a micro-controller and ultrasonic sensors. Ultrasonic sensors helps in knowing the level of water in the tank from time to time. The supply of stored rainwater is done for recycling of various potable and non-potable uses. The city of Azrou could reduce the demand of water on the ground water sources with the help of this system being implemented on the Atlas villa, through roof top rainwater harvesting.

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