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Nature Based Solutions For Climate Resilient Water Security Case Studies On SCC And NACIN. Bengaluru

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ABSTRACT

Trees are recognized as natural solutions for ground water recharge.Environmentally Sound Techniques (EST's) in harnessing storm water by trees and drains are viable tools in the urban ecosystem. Empirical and Field Studies are conducted on ecological niche of trees for two campuses in Bengaluru, India. Trees having 200 mm girth above ground level were chosen for Environmentally Sound Technology at no cost for recharging purposes. Trees with deep root system and canopy included, ***Ficus bengahalensis, Ficus religiosa, Azadirachta indica, Tamarindus indica, Swietienia mahogani and Terminalia arjuna.*** Laboratory studies were conducted, Porosity of soil was recorded as 0.49. The rate of percolation was found to be 3.84*10^-3cm/sec by direct impact test. The average static water levels for the study area for the year 2011 was 30.32m and 32.69 m in 2017. Over all rainfall data for 100 years reveal adequate rainfall for potential harvesting. The ground water yield in the area was 5 liters per second. Climate resilient water security was evident for an integrated deployment of EST of integrating trees and percolating drains as conjunctive means to recycling and rain water harvesting.

Key Words : Trees, Drains, Recharge, EST, Permeability, Climate Resilience

1.0 Introduction

Bengaluru urban region is estimated to host over 1.4 million trees (ENVIS, 2014). Studies using maps and high resolution satellite imagery on Bengaluru urban region over decades reveal irreversible land use. During 1900-1985 urban growth the built up area increased from 6.1% to 40.7 %. (Behera et.al., 1985). Due to rapid urbanization as many as 70 percent of the 262 water tanks in Bangalore have disappeared, drains are choked with garbage leading to flooding of drains and low lying areas (Priya, 2017).

Bengaluru, also has a significant heritage of ecological integrity for Climate Resilience. Very large open space, robust network of lakes and vegetation provided water security for centuries. 2000 open wells in the city during 1900 were an ecological security . They are now endangered to around 50. Bengaluru gets 1,450 million liters of water per day (MLD). By 2031 Bengaluru is projected to be the 19th largest city in the world with over 20 million residents. Water supply augmentation to 3,550 MLD could add another 1.600 MLD by recycling for the city ever growing demands as per BSWWB plans.

Experts suggest, treating waste water and filling lakes in the city and outside as one of the practical steps for water security for both urban and rural. One of the Environmentally Sound Technology option available is decentralized harvesting of rainwater by individual buildings and clusters for potable water. Identifying and recharging groundwater aquifers will also ensure water security. Climate resilient water security in urban can also be ensured by watershed development with intensive afforestation.

Irreversible land use trends are causing rapid increase of runoff in urban settlements. Three categories of failures in storm water drains are reported. The first, runoff exceeding the capacity of the drain, second, velocity exceeding maximum velocity for erosion control and lastly minimum velocity in less than the allowable velocity for deposition control (Ranganathan, 2017). Bangalore has nearly 180 km long primary and secondary storm water drainage system. Rs 45 million was earmarked for flood management at Bangalore in 2017. The flood of 2005 at Bangalore stayed for 7 weeks affecting 20 million people, affecting 14000 homes and damaging more than 350,000 homes and over 200,000 stayed in relief camps.

One of the ten essentials for making cities resilient is to protect ecosystems and natural buffers to mitigate floods, storm surges and other hazards to which any city may be vulnerable. Adapting to climate change by building good risk reduction practices is imminent (UNISDR, 2012). Trees affect the preferential flow and soil infitrability in a given geological formations. Studies reveal that hydraulic re-distributions and trees roots are seasonal and vary (Maizer, 2004). Root systems while spanning soil layers of different moisture content, distributed by water in the direction of the difference in water potential. Stephen et.al. (2001) and Smith et.al.(1999) have estimated the proportion of daily water uptake by lateral roots transferred to deeper soil layers at a maximum of 26%. It was suggested that this might comprise a substantial component of the water balance. The runoff models are useful for designing surface drain network for recharging ground water and for surface water management (Inayathulla, et. 2017). Climate change and urbanization cause definite changes in ground water resources.

The process of hydraulic redistribution in sap flow in roots of trees cause fluctuation in water content below. With increasing temperature as a result of global warming, leaf area index (LAI) decreases. This is found to cause higher rates of infiltration in the soil and less interception within the leaf itself. It is a direct result of increasing infiltration into soil at elevated rates of ground water recharge (Crosbie et.al., 2010). Research reports shows that the ground water recharge can be up to ten times higher in urban areas compared to rural areas (Allison, 1994). Various Physical methods of estimation of ground water recharge are available (Bond, 1998).

In the recent two decades microwave remote sensing has proven successful for estimation of dielectric properties of soil .This is based on land surface resistivity leading to Soil moisture estimation (Mohanty et. al.,2017). Near surface moisture is further extended to the root zone(top 1m) using process based models and data set for long term climate research.

` In the management of urban floods, urban streams are used extensively for disposal of urban run off , over flow from sewer systems, potable and non-potable water supply and ground water recharge {Novotny,et.al. 2001). Field investigations are reported on the effect of trees in the runoff of two small watersheds (Rosen, 1984). Runoff from land is established as a function of precipitation, evapotranspiration and the water storage capacity of the soil. Van-dose zone below plant roots cause recharge as a flux to the ground water table. Direct and indirect physical methods are used for estimation of recharge. In deep recharges Isotopic tracer or chloride recharge can be arrived at by numerical models such as HYDRUS ID available on line (Allison, 1978). This is found to cause higher rates of infiltration in the soil and less interception within the leaf itself. A direct result of increasing infiltration into soil is elevated rates of ground water recharge (Crosbie et.al. 2010).

Further, on the functional role of roots of trees literature survey reveal interesting evidences. Surface of the root system concealed in the soil can be greater than the surface of the leaves (Russel, 1973). Roots of large woody trees grow horizontally through the soil and are perennial. They are predominantly located in the top 30 cms of soil and do not normally extend to depth greater than 1 to 2 m (Perry,1982). Roots are the most abundant and trees grow best in light, clay –loamy soils about 80 cm deep (Coile, 1937) . Root depth studies indicate tree roots up to 10 m deep. One report of a tree growing roots up to 53 meters is available (Marritz, 2012). Current Space Technology Services also provide soil moisture and soil temperature at 1 km spatial resolution in near real time as much as a few hours latency at soil depths and vegetation root zones (Das, et.al. 2018).

Richards equation gives the basis for describing the moisture profile development in soil properties under unsaturated conditions. Researchers hypothesized that water movement could be described by the diffusion equation. This led to the diffusion form of the Richard's equation with a soil-water diffusibility dependent on water content. This was the beginning of the theoretical calculation of moisture profile developments from Richard equation (Youngs, 2005).Studies on the uptake of water by plant roots does takes place as the flux at the soil-root interface and at macroscopic scale is represented by a sink term in the volumetric mass balance (Boat, 2007)

Modelling and Simulation Hydrus-ID is an extensively used numerical model with computer modeling and simulation over two decades. One of the recent version Hydrus 2D/3D include a flexible reservoir boundary condition, expanded root growth features and new graphical capabilities of the graphical user inference (GUI) (Simunek, 2018). Hydrus –ID model is used to simulate coupled water as a simulation tool. In this model water a theoretical case is simulated for water movement in soil to approximate the fluxes of water across the gradient in a median having roots of trees(Simunek et.al.2008).

Development of a high resolution imageries for soil moisture for precision aquaculture are reported (Das et.al., 2018). Further, in microwave remote sensing, the shorter microwave signal (X-band, -3cm) interact mainly with the top of the canopy cover. C-band (-8cm) travel more than X band at vegetation canopy. Longer wavelengths (L-band,-24cm) are able to penetrate further into canopy and reflect from soil surface. An inventory of Urban tree species mapping is therefore very useful for ecological benefits. Tree canopy features extraction and species classification using satellite imageries are reported (Li et.al., 2016).

In this paper trees and drains as two ecologically sustainable options for improving soil moisture and ground water recharge for two campuses - NACIN and SCC at Bengaluru are reported. Trees and percolating storm water drains are considered for ensuring urban water security in the context of climate resilience.

2.0 Materials and Methods

2.1: Study Area

The study areas are located in North of Bengaluru Urban in the State of Karnataka. Bengaluru City has GPS location 12^{o} 58^{i} 20.7912^{ii} North and 77^{o} 34^{i} 50.3148^{ii} East. The average rainfall of the city is 923 mm, the average rainfall in the area for 100 years is 807 mm. Bengaluru city receives rain during both southwest and northeast monsoon. The Two campuses are at a distance of 5 km by road.

2.2 : Trees survey

The Survey of trees in the two campuses was done by physical counting the number of trees. Identification of species was done by using flora and consulting taxonomists. Trees having 200 mm diameter girth were measured 1000 mm above ground level. In this simple method, circular trenches of about 300 mm wide and 600 mm deep were dug by leaving a 300 mm of soil around the tree trunk. A gentle slope 1 : 100 around the tree was maintained by gentle soil leveling. Rain water was drained by gravity to these pits from the road side and natural landscape. Thus, adjacent to road and open space water was ensured to stagnate before reaching the storm water drains or evaporation or natural outlet of the campus.

2.3 : Storm water drains

Existing Storm water drains, soil drains without side pitching, V and rectangular shaped granite drains at SCC Campus and plain cement concrete PCC drains at NACIN were considered for rainwater drain recharge. Over 600 meters open and granite slab drains at SCC Campus were identified for recharge purpose. About 300 meters of Granite slab drains were considered for erection of check walls within the drains. The bottom slab at granite drains at every 3 to 5 meters was removed and a pervious area was created. Locally available rocks and stone metals were filled in the bottom pervious area. Removed bottom granite slab served as a check wall with sides filled to hold three fourth of the drain depth with rainwater. NACIN campus had over 460 meters long Plain Cement Concrete drains 450 mm X 450mm and 300 to 1200 mm depth were cleaned and storm water was directed to ground water sump adjacent to bore well in the Sewage Treatment Plant area.

2.4. Soil porosity and permeability laboratory tests:

Samples from gravely clayey sandy soil were collected from NACIN campus. Soil studies conducted during construction by 8 Bore Holes were available. Bengaluru Urban district is having red loamy and sandy soil and laterite soil (CGWB, 2013). As per standard procedures laboratory tests were conducted for soil porosity and permeability. Soil tests were conducted at civil engineering laboratory facilities at UVCE, Bangalore University. Permeability of the soil sample was found out by head test method. Darcy's law was used for Permeability test.

Q=KIA Darcy's Law

Where q= rate of flow

K= coefficient of permeability

I= hydraulic gradient

A= Area of cross section of soil

In soil mass its area is comprised of soil solids and void spaces. For permeability entire soil and cross section area is considered but the seepage/passage of water takes place through the void spaces only. Hence, the actual cross sectional area is only area of void spaces. If only cross section area of void is taken into account then this seepage of water is called as percolation.

Relationship between permeability and percolation

Percolation = Permeability/Porosity

Experimental procedure: 2.5 kg Sample was thoroughly mixed, and placed in the mould and weighed. The sample was compacted for required density. Porous disc was saturated and filter paper was placed on the disc. The water reservoir was connected at the base, water was allowed to flow upwards till the sample got saturated. 100mm water depth on the top of sample was ensured. The empty portion of the mould was filled with water without disturbing the soil. The reservoir was disconnected from the outlet of the bottom. Water is allowed to flow through the soil specimen. Soil is ensured to be completely saturated.

2.4 Rainfall and Static Ground Water : Hydrograph

Both the campuses of the study area are in the Bengaluru north division of the Ground Water Division, Govt. of Karnataka. Static water level and rainfall data for 8 rainfall gauges in Bangalore north for the period 2013 and 2018 were collected from the ground water division, GOK.

3.0 **Results and Discussions**

3.1 Study Area : NACIN campus, Jalahally, Bangalore LA 13.043 LONG 77.538

Total area of the NACIN campus is 12,305 sqm with 60% of open space. A total of 9.13 MLD is the present water demand and is projected to be 13.79 MLD by 2030. A domestic ground level reservoir of capacity 1,25.000 liters is provided. There is a fire fighting ground level reservoir of 58 cubic meter capacity and a treated waste water sump of capacity 10 cubic meter. Rain water collection from roof is by 1,25,000 liters ground level reservoir. Static ground water level is found to be varying from 28.12 m to 36.0 m during the period 2011 and 2017 respectively. Average annual rainfall measured in the nearby rain gauge station at Chikkabanavara is recorded as 937 mm. Recycling of waste water is by a ground level soil wetland plant of 40 KLD capacity. There is no electrical power used in this treatment method. NACIN daily water demand is 18,000 Liters. This is met by tapping one of the two bore wells in the campus.Table 3.1.1 provides the summary of NACIN Campus, land use, water supply and demand, Soil details, rainfall, ground water yield, and rain water harvesting methods adopted.

The strategies proposed for climate resilient water security for NACIN campus are

- Conservation of water at consumer level in office, toilets, canteen, hostel and other facilities.
- Recycling of waste water for non potable uses, gardening and toilet flushing.
- Rain water harvesting by roof top rainwater collection and storage at ground level, soil enrichment using drains and trees..

3.1.2 Satellite Control Centre , ISTRAC, Peenya, Bangalore LA 13.0353 N LONG 77.5124 E

Total area of SCC Campus is 77,150 sq m with 11.52 percent built up area. Daily average water requirement of the facility is 2000 KLD. Fire fighting overhead tank of 1 Lakh liters capacity and 2 Lakh liters capacity ground water tank for domestic purpose is provided. The terrain of the campus slopes towards north east with a fall of over 10 meters. There were three bore wells before 1985 and later seven bore wells were drilled till 1995. As the yield of bore wells and water level fell very low, bore wells water sources was not feasible. Based on the bore log data of past 10 bore wells since 1988 the diminishing ground water sources were evident, The deepest bore well was 125 m and shallow one was 51 m drilled in 1985. The yield of these 10 bore wells since 1985 have been 2 to 3 inches. After switching over to municipal water sources from BWSSB, the daily water demand of 2000 KLD has been the primary source of water. Soil profile details of the campus based on bore log details were collected. The soil composition is found as red mix clay soil 1 to 2 m below ground level and weathered soil 2 to 18 m. Fractured rock are estimated at 18-24 m. Casing pipes for the earlier 10 number of bore wells were provided up to 24 to 26 m. There is one 10 KLD extended aeration Sewage Treatment Plant working since 1985. Oxidation ditch, coagulation, plate settler and dual media pressure filter are used for tertiary treated waste water. Treated waste water is used for gardening purposes only. Table 3.1.1 provides the salient features of SCC campus with soil, land use, and water resources management using rain water, ground water, recycled and external municipal supply. The monthly bill for external water supply was Rs 1,20,000 during the period of study.

Strategies proposed for water security in SCC campus is to evolve a decentralized rain water harvesting system for each building. During 2015 and onwards over 1016 trees and 300 m granite slabs are deployed as eco initiative. A large ground level reservoir of 100 cubic meter for storing Rain Water was constructed in 2017.

Table 3.1 Summary of Study Area : NACIN Jalahally and SCC Peenya Campuses, Bengaluru

SL	Attribute	NACIN, since 2017	SCC , Since 1985
1	Location	LA 13.043 LON 77.538	LA 13.053 LON77.5124
2	Total Area	12,305 Sq M	77,150 Sq M
3	a) Built up area b) Open space area	7694 Sq M 4610 sq M, 37.46 %	8590 Sq M 68560 Sq M, 86.86%
4	Water Management a) Supply b) Demand : Domestic	Domestic GLR 88.5 Cum Fire Fighting GLR 58.0 Cum Treated Sump GLR 10.0 Cum 9.13MLD(2020) 13.79 MLD(2030) 2 Bore wells	Domestic GLR 200 Cum Fire Fighting 100 Cum Treated Sump 40 Cum 2000 KLD Rs 1.2 Lakhs/month Water bill
5	Soil details Porosity Percolation of Soil	Gravelly Clayey Sandy 0.49 3.84X10^-3cm/sec	Red Mix Clayey Soil Weathered Soil 2M Fractured rock 18 M
6	Rainfall, Average, Annual	937 mm	929 mm
7	Static ground water, Average Ground water yield	30.32 M(2013) 33.99 M (2012) 32.69 M(2017) 5 liters per second Two active bore wells	1982 (57 M) shallowest 2015 (240M) deepest Total 10 Bore wells Disengaged since 1995 Only BWSSB source
8	Trees Focused	75 species, 236 numbers	40 species, 1016 numbers
9	Drains	460 M	600 M
9	Rainwater Harvesting Technologies adopted	Roof Water, Storage below GL	Rs 55 Lakhs RWH working
10	Recycling, capacity and method	Soil- filtration Wetland STP 40 KLD	10 Cu.M GLR, 10 KLD Extended aeration STP
11	Proposed additional strategy for climate resilient water security	Trees as Recharge Points 236 nos, Storm Water drains 92 nos Check Wall 5000 mm C/C proposed	Trees as Recharge Points 1016 Trees, 120 Nos Storm Water Drains 5000 mm C/C

Note : 1. Water demand for NACIN present and future is based on TERI : 2) Static water levels and ground water yield for the areas of study as per CGWB : 3) Over Rs 1.2 Lakhs per month BWSSB water bill for SCC Campus 2) Soil studies at Soil Lab, Civil Engg UVCE Bangalore University 3) Rain fall data as per annual averages for the urban region and campuses 4) Data from NACIN and SCC Maintenance, 2017

1

3.2 Trees Survey

Over 286 trees measuring 200 mm girth size above ground level were identified for enriching the soil moisture and ground water recharge at NACIN. The trees as simple and cost free eco- option were implemented in 2015 at SCC campus and in 2018 at NACIN campus. Table 3.2.1 Provides a list of 40 tree species at SCC ISTRAC Campus. Some of the trees with good canopy and deep root system included, *Ficus bengahalensis, Ficus religiosa, Azadirachta indica, Tamarindus indica, Swietienia mahogani and Terminalia arjuna..* Over 1016 trees measuring 200 mm girth above ground level were identified and utilized for enriching the soil moisture and ground water recharge at SCC and 286 trees at NACIN Campus for this purpose.. Figs. 3.2.1 and 3.2.2 shows the recharge pits around the trees at SSC campus and NACIN campus respectively.

The trees as rain water recharge points were considered without any additional expenses. Existing external environmental maintenance manpower were utilized. No extra machinery, material and labor was necessary. Thus, over 3 years of ecological operations of recharging rainwater through trees, recuperated ground water in defunct bore wells. Ten bore wells were dug during 1985 till 1995 at SCC Campus. The maximum depth of bore wells were 245 M. They were not yielding adequate water and hence were not used. During 2018, while drilling new bore wells for new building construction purposes water was struck at half the depth of existing bore wells.

Table : 3.2.1 List of trees species at ISTRAC, Bangalore

Sl	Name of the tree species	Common Name	No	Sl	Name of the tree species	Common Name	No
1	*Acacia auriculiformis*	*Australian wattle*	20	21	*Jacaranda mimisifolia*	*Blue jacaranda*	20
2	*Albizia lebbeck*	*shirish*	20	22	*Lagestroemia indica*	*Pride of India*	30
3	*Araucaria coockii*	*Cook's pine*	25	23	*Michelia champaca*	*Champak*	25
4	*Anthocephalus cadamba*	*Burflower tree*	20	24	*Milingtonia hortensis*	*Tree jasmine*	25
5	*Azadirachta indica*	*Neem*	15	25	*Millettia ovalifolia*	*Moulmein rosewood*	27
6	*Bauhinia rosea*	*Bidi leaf tree*	30	26	*Muntingia calabura*	*West Indian cherry*	25
7	*Bignonia megapotamica*	*Taruma*	30	27	*Peltophorum ferrugineum*	*Copperpod tree*	20
8	*Brassica actinophylla*	*Australian umbrella tree*	20	28	*Peltophorum vogelianum*	*horsebush*	30
9	*Callistemon lanceolatus*	*Bottle brush*	25	29	*Polyalthia longifolia var pendula*	*Devadari*	25
10	*Cassia siamea*	*Yellow cassia*	25	30	*Pongamia glabra*	*Pongam oil tree*	60
11	*Casuarina equisetifolia*	*Australian pine tree*	25	31	*Roystonia regia*	*Royal palm*	25
12	*Colvillea racemosa*	*Colville glory*	18	32	*Samanea saman*	*Rain tree*	30
13	*Dalbergia latifolia*	*Indian rosewood*	15	33	*Santalum album*	*Sandal wood*	30
14	*Delonix regia*	*Gulmohar*	26	34	*Spathodea campanulata*	*African tulip tree*	25
15	*Dolichandrone platycalyx*	*Nile trumpet*	30	35	*Sterculia colorata*	*Scarlet sterculia*	25
16	*Eugenia jambolana*	*Malabar plum*	25	36	*Tabubia argentia*	*Golden bells*	20
17	*Ficus benghalensis*	*Banyan tree*	20	37	*Tabebuia avellandae*	*Pink tabebuia*	20
18	*Ficus elastica*	*Indian rubber plant*	30	38	*Tamarindus indica*	*tamarind*	35
19	*Ficus religiosa*	*Peepal tree*	35	39	*Tectona grandis*	*teak*	25
20	*Gliricidia maculata*	*Quick stick*	25	40	*Terminalia catapa*	*Country almond*	20

Total Number of 40 species Individual trees : 1016

3.3 Storm water drains

There are over 600 meters of granite slab drains in the SCC Campus. These percolating natural drains facilitated the rain water recharge and provided a cooler surrounding for the offices and laboratory at SCC Campus. Fig 3.3.1 shows the typical cross section of modified granite storm water drain at SCC Campus.. At, NACIN, over 460 meters of plain cement concrete storm water drains are provided for storm water disposal These drains were proposed to serve as rainwater recharge points.

Fig 2.1.2 Recharge Trees at SCC Campus

Fig.2.2.2 Recharge Trees at NACIN

3.4 Soil Studies

In NACIN Campus Porosity of soil was found out by laboratory tests as 0.49. Coefficient of permeability was found by direct impact test as 1.88*10^-3 cm/sec. Considering a 4.5 m deep gravel clayey sand silt soil , the rate of percolation is found to be 3.84*10^-3cm/sec. The Experimental procedure, observation and calculations are at Enclosure 3.4.

ENCLOSURE : 3.4 : SOIL STUDIES

AIM : To determine the Percolation of the soil for NACIN at Jalahally, Bengaluru

OBJECTIVE : To conduct laboratory test for permeability by Falling head test for the soil sample.

THEORY :

Coefficient of Permeability is an indirect measure of coefficient of percolation. Permeability is a property of a porous material which permits the passage of water.Permeability is the property of saturated soils.

DARCY LAW

For a laminar flow condition, in a saturated soil the rate of flow or discharge is directly proportional to hydraulic gradient

q=KIA

Where q= rate of flow

K= coefficient of permeability

I= hydraulic gradient

A= Area of cross section of soil

In soil mass its area is comprised of soil solids and void spaces. For permeability entire soil and cross section area is considered but the seepage/passage of water takes place through the void spaces only. Hence, the actual cross sectional area is only area of void spaces. If only cross section area of void is taken into account then this seepage of water is called as percolation.

RELATIONSHIP BETWEEN PERMEABILITY AND PERCOLATION PERCOLATION =

PERMEABILITY/POROSITY

EXPERIMENTAL PROCEDURE

The falling head permeability test procedure is discussed below.

1. Remove the collar of the mould. Measure the internal dimensions of the mould. Weigh the mould with dummy plate to the nearest gram for the permeability test of soil.

2. Apply a little grease on the inside to the mould. Clamp the mould between the base plate and the extension collar, and place the assembly on a solid base.

3. Take about 2.5 Kg of the soil sample, from a thoroughly mixed wet soil, in the mould. For permeability test of soil compact the soil at the required dry density using compacting device.

4. Remove the collar and base plate. Trim the excess soil level with the top of the mould.

5. Clean the outside of the mould and the dummy plate. Find the mass of the soil in the mould.

6. Take a small specimen of the soil in a container for the water content determination.

7. Permeability test of soil is determined by saturating the porous disc(stones).

8. Place a porous disc on the drainage base and keep a filter paper on the porous disc.

9. Remove the dummy plate and place the mould with soil on the drainage base after inserting a washer in between.

10. Clean the edges of the mould.Apply grease in the grooves around them.

11. Place a filter paper, a porous disc and fix the drainage cap using washers.

12. Connect the water reservoir to the outlet at the base, and allow the water to flow upwards, till it has saturated the sample. Let the free water collect for a depth of

about 100 mm on top of the sample.

13. Fill the empty portion of the mould with desired water without disturbing the soil.

14. Disconnect the reservoir from the outlet at the bottom.

15. Connect the stand pipe of suitable diameter to the inlet at the top. Fill the stand pipe with water.

16. Open the stop cock at the top and allow the water to flow out till all the air in the mould is removed.

17. Close the stop cock and allow the water from the stand pipe to flow through the soil specimen.

OBSERVATIONS AND TABULATION

Length of the Specimen = 12 Cm Diameter of the Specimen
= 10 Cm Volume of the Specimen = 981.75 cc Water content
= 13.4 %

Diameter of stand pipe =10 mm Area of stand pipe =
0.785 sq cm Specific gravity of solids = 2.65

Sl	Observation and Calculations	Unit	Sample No		
			1	2	3
OBSERVATIONS					
1	Mass of the empty mould with base plate	grams	8030	8030	8030
2	Mass of mould, soil and base plate	grams	9290	9290	9290
3	Initial head,h1	cm	150	136	150
4	Final head,h2	cm	140	126	140
5	Head,h1-h2	cm	10	10	10
6	Time Interval	sec	2.3	5.12	4.5

7	Mass of Soil = (2) -(1)	grams	1260	1260	1260
8	Bulk density	g/cc	1.53	1.53	1.53
9	Dry density	g/cc	1.35	1.35	1.35
10	Void ratio		0.96	0.96	0.96
11	K=Ql/Aht	cm/sec	1.628x10^-3	1.88x10^-3	1.88x^-3

Result :

The result of falling head permeability test i

Coefficient of permeability test of soil =1.88x10^-3 cm/see

Porosity = 0.49

Coefficient of percolation of soil =permeability /porosity

PERCOLATION OF SOIL = 3.84X10^-3 cm/sec

Note :

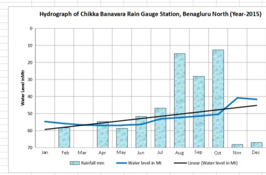
1. **Soil completely saturated in falling head metho**
2. **Soil sample : NACIN Campus, Jalahally, Bengaluru**
3. **Soil is Gravelly clayey sandy soil**
4. **Date of Testing : 2018**
5. **Lab : Civil Engg Soil Lab, UVCE, Bangalore University**

In case of SCC Campus, the bore log details of the campus for bore wells dug since 1985 revealed that the soil profile is red mix clay soil up to 2 m below ground level, weathered soil up to 20 m and fractured rock up to 30 m. Casing pipes are inserted to protect caving of soil up to 30 m deep. Thus, up to 30 m the soil and weathered rock are considered potential zones for recharge using percolating drains at top and in deeper zones by the roots of trees.

3.5 Hydrograph of Bengaluru North Taluk

There are 8 Rain Gauge stations in Bengaluru North Taluk. Graph 3.5.1 provides an Hydrograph for one of the rainfall gauge Chikkabanavara located at the area of study Major ground water problems listed in the district are 1) degradation of ground water quality due to industrial and sewage pollution 2) High nitrate in ground water and 3) over exploitation of ground water sources (CGWB, 2013).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water level in Mt	54.74	55.93	56.79	57.03	56.9	56.44	53.18	52.41	51.57	50.48	40.83	41.71
Rainfall mm	0	57.7	0	76.2	56.6	91.8	115.9	275.7	208.8	286.2	8.9	15.1



4.0 Conclusion

Climate resilient urban water security is essential for sustainable urban development. Integrated water resource management includes, ground water, surface water and rainwater and recycling options. 1016 trees and over 600 M granite storm water drains at SCC Campus, ISTRAC ISRO, Peenya Bengaluru and 286 Trees and 460 M Plain Cement Concrete storm water drains are deployed for better water resources management.

Fairly good porosity and permeability of the soils in both the campus has helped rain water natural percolation. This could be seen physically percolating through each trees. Over three years there has been a significant improvement in the soil moisture content of the campus. It is observed that some of the trees were not shredding foliage in dry periods of the year. Bore wells which were dry and with no yield have started providing water. There was no extra cost involved in this method. The existing trees and storm water drains and existing labor for external environment maintenance have been effectively utilized.

During 2018, a similar effort of trees recharging defunct bore wells took place at Navoodaya Residential school situated in a 42 acres land at a distance of about 15 Kms from the Mysuru City. There were 10 bore wells in the campus which were totally dried up for reasons of ground water depletion. The Deputy Commissioner requested the first author to come out with a viable solution for water problem. Few visits were made and the water supply and demand were listed. The campus had over hundreds of trees which were above 200 mm girth size measured 1000mm above ground level. .Over 50 trees were chosen to recharge ground water. These trees were in the upper reaches of the campus near to main building. 21 high school students of Navoodaya school volunteered. SCC and NACIN Campus experiences was used to convert 50 trees as recharge points. Continuous rains and trees facilitated a rapid reclamation of bore wells. The reverted dependence on ground water saved external water supply expenses to the extent of Rs.1.2 Lakhs per month.

100 years of rainfall data for Bengaluru region reveal a very easily available source of natural rainfall.The present assessment of ground water categorization for Bengaluru is bad . This necessitates, an immediate review of macro and micro water security policy. Bengaluru Urban region is one of the active urban economic hub in Rain Water harvesting and recycling waste water. Now, in the perspective of essential planning need for Climate Resilient water security new ESTs are very much necessary. Over 207 cities all over world have already embarked for climate resilient planning, design and structural changes. In addition, to Climate change and Pandemics are additional risks affecting normal life. Here, a cost effective approach is appropriate. Storm water drains as percolating places and trees as ground water recharge points for the two facilities at NACIN and SCC campuses are found to be ecologically feasible options for improving soil moisture and ground water recharge. This paper is an outcome of an water security exercise carried out for NACIN and a documentation of a routine and no cost eco practice at SCC Campus. These cost free methods as routine maintenance activities can provide climate resilient to water security in the two campuses. If these eco friendly options are employed in other institutions and industries of the city, climate resilient to water security can be achieved for Bangalore urban region .

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