WATER BUDGETING STUDIES ON ROOFTOP RAINWATER HARVESTING

Thesis submitted in part fulfillment of the requirements for the Degree of Master of Engineering (Agriculture) in Soil and Water Conservation to the Tamil Nadu Agricultural University, Coimbatore.

BY

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COIMBATORE - 641003

2001

DEDICATED TO

MY

GRAND FATHER

AND NAANI

CERTIFICATE

This is to certify that the thesis entitled **"WATER BUDGETING STUDIES ON ROOFTOP RAINWATER HARVESTING"** submitted in part fulfilment of the requirements for the degree of Master of Engineering (Agriculture) in Soil and Water Conservation to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Er. LALA ISWARI PRASAD RAY** under my supervision and guidance and that no part of this thesis has been submitted for the award of any degree/ diploma/fellowship/other similar titles/ prizes and that the work has not been published in part/full in any scientific/ popular journal/ magazine.

Date: 2-11-2001
Place: Coimbatore

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(LALA ISWARI PRASAD RAY)

Abstract

ABSTRACT

WATER BUDGETING STUDIES ON ROOFTOP RAINWATER HARVESTING

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Degree : Master of Engineering (Agriculture) in Soil and Water Conservation

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In the present era of acute water shortage both in rural areas dealing with agriculture and urban areas dealing with drinking and industrial water needs, rainwater harvesting seems to be a feasible solution to provide for considerable storage of water during rains. The present study aims at the role of rooftop rainwater harvesting to facilitate the local water needs of TNAU Campus. Keeping the Soil and Water Conservation Engineering Workshop Complex as a representative unit of evaluation. The study has revealed encouraging results indicating a good potential for harvesting rainwater. The SWCE Workshop Complex can generate 8.6×10^5 litres of water per annum from its roof top surface during the rainy season and the volume of water collected has been found to cater to the volumetric water requirements of the hydraulics laboratory, drinking water needs, washing water needs and the consumptive water use requirements of the Theme Park. Due to the water harvesting a sum of Rs.46,080/- per annum would be saved which otherwise could be incurred for transporting lorry loads of water to workshop Complex. By the same token extending the RTWH all over the TNAU Campus a water harvesting potential of 1.03×10^5 cum water can be generated there by saving a sum of Rs.1,16,923/- per annum.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	Asbestos
Cm	Centimeter
CM	Cement Mortar
et al.	Co workers
E	East
ha	Hectare
H	Horizontal
i.e	That is
km	Kilo meter
LDPE	Low density poly ethylene
m	Meter
mm	Millimeter
M ha	Million hectare
m^2	Square meter
m^3	Cubic meter
MCWH	Micro Catchment Water Harvesting
MSL	Mean sea level
o	Degree
N	North
%	Percentage
/	Per
PVC	Poly Vinyl Chloride
Rs	Rupees
RWH	Rain Water Harvesting
RTWH	Roof Top Water Harvesting
SW	Stone Ware
SWCE	Soil and Water Conservation Engineering
TNAU	Tamil Nadu Agriculture University
V	Vertical

Introduction

CHAPTER I

INTRODUCTION

Though our country is blessed with abundant land and water resources, acute water shortages are not uncommon due to failure in monsoons. Next to Latin America, our subcontinent gets maximum rainfall. If we save each and every drop of water we can rescue ourselves from this fascinating problem of water scarcity. India receives an annual precipitation of around 4000 billion cubic meters including snowfall. Of this, the seasonal rainfall (June to September) is of the order of 3000 billion cubic meters. Out of this, the average annual flow available in the rivers is around 1869 billion cubic meters. Owing to topographic, hydrological and other constraints, the utilizable surface water is assessed at 690 billion cubic meters in addition to the annual replenishable groundwater resources, which is about 452 billion cubic meters. (Ministry of Water Resources, 1998).

Excessive deforestation has resulted in poor receipt of rainfall and unscrupulous pumping of groundwater has caused drastic depletion in underground aquifer reserves. Extensive urbanization and Industrialization have also contributed to increasing demand for non-agricultural usage of water. Agriculture has always remained a gamble with monsoon, and the situation is further assuming precarious levels due to non-adherence of implementing Water Harvesting strategies. The term `Water Harvesting` was first used in Australia by H.J.Geddes to denote the collection and storage of any farm water, either runoff or creek flow for irrigation use. (Myers, 1975)

Though the concept of Water Harvesting is an `old wine in a new bottle`, it is very much the need of the hour in order to narrow down the supply-demand gaps of water. The demand for water is realised from different fronts such as water for domestic purposes, civic or public purposes, firefighting purposes, evapotranspirative needs in agriculture, industrial water usage and many other purposes. The central idea behind any Water Harvesting strategy should be such that the excess water available during rainy period should be collected and stored for a compensative usage during non-rainy periods. That is the supply-demand gap during non-rainy season can be brought down by supplemental usage of harvested water.

Rainwater harvesting can be done both on a large scale such as watershed planning as well as on a smaller scale like Roof top water harvesting from individual houses. While the large scale water harvesting helps damming on water to sustain agriculture, Rooftop Water Harvesting helps to meet the local needs of community. It is often observed that rainwater draining down from rooftop surface is simply disposed off, through sewage network or stream network wastefully. This often leads to poor ground water recharge due to runoff. Rooftop surfaces offer greater scope for domestic storage of relatively pure water and in addition, augmentation of groundwater table in-situ. Urban areas where a lot of housing colonies and commercial complexes are coming up, Rainwater harvesting from roof top is the only feasible solution to develop water resources in order to meet the local needs of water with self sustainability. Accordingly, suitable hydraulic and structural design of roofs top WaterHarvesting mechanisms need to be developed and type designs to be evolved. Keeping this in view, the present study is contemplated with the following objectives.

i) To take stock of the temporal and spatial water demands for various purposes in the study area. (SWCE Workshop Complex of TNAU)

ii) To analyse the rainfall pattern in order to assess the water harvesting potential.

iii) To investigate the supply-demand relationships on standard week basis through out the year.

iv) To estimate the runoff potential from the rooftop surface of the study area.

v) To design the storage capacity of surface and sub-surface water collection tanks.

vi) To evaluate the economics of components involved in proposing various type designs of Rooftop Water Harvesting mechanisms.

Review of literature

CHAPTER II
REVIEW OF LITERATURE

Over exploitation of available water reserves has lent us to the precarious situation of mining for water- "*the liquid gold*", if not an exaggeration. Prevailing situation of prolonged drought has now forced us to renew the ideas related to Rainwater harvesting- the collection, and storage of rainwater produced as runoff from an area treated to increase runoff. 'Rain Water Harvesting' is itself a very broad term. It can be sliced into different sub-components such as Rooftop Water Harvesting, Micro-Catchment Water Harvesting, Roaded Catchment Water Harvesting, and Runoff Water Harvesting etc.

The comprehensive literature pertaining to the Rain Water Harvesting studies, experiments carried out elsewhere in the world has been reviewed in this chapter.

2.1 Water Harvesting
2.2 Rain Water Harvesting
2.3 Micro-catchment Water Harvesting
2.4 Roaded Catchment Water Harvesting
2.5 Roof top Water Harvesting
2.6 Runoff Water Harvesting

2.1. Water Harvesting

From Vedic times, water harvesting is practised in India. *Rigveda* has mentioned a lot about the rational and judicious use of water from wells, tanks, ponds, etc. For agriculture, domestic and other purposes.

In the 4th century B.C. Kautilya, in his book *Arthasasthra* has entrusted the responsibility of constructing dams, reservoirs, wells and ponds to the king from some perennial source of water.

The grand *anicut* built across the river Cauveri in the 2nd century A.D. was a display of greatest engineering talent in olden times. It was irrigating about 0.24 Mha at that time.

Das (1988) has classified water-harvesting systems depending upon the source of water supply as follows:

a. In-situ rainwater harvesting

(i) Benching and terracing
(ii) Conservation tillage and deep ploughing
(iii) Contour farming
(iv) Contour trenching
(v) Cover crops and mulching
(vi) Land leveling

b. Rain water or direct surface runoff harvesting

(i) Ahar and bandhra
(ii) Khadins
(iii) Tankas

c. Stream flow or runoff harvesting

(i) Check dams
(ii) Nadi
(iii) Nala
(iv) Percolation tanks
(v) Water Harvesting tanks or ponds

d. Sub- surface flow harvesting

i) Sub surface dams
ii) Sub surface bandharas

e. Micro catchment water harvesting

f. Run off inducement by surface treatment

(i) Roaded catchment
(ii) Use of cover materials Plastic sheet, bentonite etc.
(iii) Using chemicals for waterproofing, water repellant etc.

g. Domestic or Roof top water harvesting

2.1.b.i. AHARS AND BUNDHRAS

The Ahars are constructed on very gentle gradients to facilitate large inundation. The bund is of uniform soil without any clay core and usually has 1:2 upstream and downstream slopes. To release excess water a spillway is provided, the crest of which is 1m lower than top of bund. Sluice gates are provided in masonary structures to empty out ahars quickly in time for sowing, through concrete or cast iron pipes, 150-300 mm in diameter pipes are embedded in the bund at intervals of 50-100 m to release water for irrigation.

Bandhras

Bandhras are nothing but concrete walls or impermeable soil, built across the river but below the riverbed at regular intervals. This will act as underground reservoirs and recharge the surrounding areas.

2.1.b.ii. KHADIN

Kolarkar *et al.* (1980) stated that khadin is a system of growing crops on harvested and stored water by constructing an earthen-bund across the general slope of farm in the valley bottom. It was innovated during 15th century. These are generally practised in areas receiving less than 100mm average rainfall, covering a total cultivated area of 12,140 ha.

Kolarkar *et al.* (1983) stated that khadins are generally located near the low eroded hills and ridges of sandstone and limestone which serve as catchments, generating runoff which flows down to relatively flat valley land. Bunds are constructed in valleys where they can collect and hold back the runoff water and the sediments it carries. Since the individual khadin covers an area of several hundred ha, a close co-ordination among the farmers involved is essential for efficient management and operation of khadins.

2.1.b.iii. TANKA

Tanka is the most common rainwater harvesting system in the Indian arid zone and is a local name given to a covered underground tank. Generally constructed for storage of surface runoff. The first known construction of Tanka in India can be traced back during the year 1607 in village Vadi Ka Melan near Jodhpur in Rajasthan. The tanka is constructed by digging a circular hole of 3.00 to 4.25 m diameter and plastering the base and sides with 6mm thick lime mortar or 3mm thick cement mortar. The top is covered with locally available brushwood thorns and dried grass mats. Tankas constructed traditionally suffer due to leakage from bottom as well as sides.

Juyal and Gupta (1985) constructed a series of tankas lined with LDPE film on farmer's field (capacity from $12m^3$ to $20.4\ m^3$) at the Operational Research Project at Faakot in Teheri Garhwal District of Western Himalaya of Utterpradesh. LDPE film with a thickness of 1000 gauge was used. It was found out that the cost of LDPE lined tankas has been less than half of cement masonary of 1:3.

Reddy ***et al.*** (1993) examined the factors contributing to the deterioration of tank irrigation in Andhra Pradesh with particular reference to the drought-prone areas. The first section presents the state of tank irrigation in historical context. The second section discusses the financial starvation to which the system has been subjected over the years. The third section draws attention to certain institutional and technological aspects, which have been a part of the process of the deterioration of tank irrigation. The last section refers to ways in which the problems of the tank irrigation system could be dealt with. The study shows that there has been a rapid increase in well irrigation and decline in tank irrigation, resulting from certain technological and institutional changes. The paper also suggests measures for restoration of tanks in drought-prone areas.

Vangani ***et al.*** (1994) designed an improved tankas of 21cu m capacity to provide adequate drinking water for a family of 6 persons through-out the year. It was estimated that about 10,000 such structures were successfully functioning in the arid regions of Indian during that period.

2.1.c.i. CHECKDAMS

Checkdams are small water storage structures constructed across small streams or nallas to collect and impound the surface runoff from catchments of streams during monsoon rains. These have been found quite effective in storing the water in the nalls to a good length upstream of structure. These structures have been found useful in augmenting groundwater.

Iyer (1995) has studied the benefits of rainwater harvesting system which were constructed under the technical guidance from Vivekananda Research & Training Institute (VRTI) at Bhijipur near Mandvi in kutch Gujrat.18 checkdams were built 7 years ago has increased the percolation through the soil and boosted aquifer recharge. But to maximise harvesting, VRTI constructed recharging tubewells which is slotted PVC pipe 20cm diameter, directly feeding the aquifer with surface water. In addition to check dams and recharging tubewells subsurface dykes were constructed. The effect was that there was a 10m rise in water level in well upto 1-1.5km on either side of checkdams.

Mohapatra (1999a&b) studied the advantages of WaterHarvesting structures namely small earthen checkdams, which has been constructed by the Tarun Bharast Sangh (TBS) of Alwar in the past 13 years At present TBS has 3000 waterharvesting structures in 650 villages of Alwar district and stated that after WaterHarvesting structures were built, there was an additional recharge of groundwater to the tune of 20% making a total of 35% of rainfall recharging ground water. Seasonal runoff has come down from 35% to 10% There has been an increase in soil moisture, extra 5% of rainwater is retained in soil in addition to an original 5%.

2.1.c.ii. NADI

A nadi should be located in areas with lowest elevation to have the benefit of natural drainage and minimum excavation of earth. It consists if 2 components viz. Catchment and water storage area. The Nadis range from 1.5 to 12m in depth, 400 to 7,00,000 cum in capacity and have drainage basin of various shapes and sizes (8 to 2,000 ha).

Dewan (1988) stated that water harvesting includes a wide range of techniques and can be classified by the following criteria such as source of water required, storage duration and the intended use.

Carter ***et al.*** (1991) stated that a water harvesting system in an on-farm macro-catchment was evaluated over three distinctly different seasons in eastern Botswana. Water harvesting improved sorghum grain yield two- to threefold during seasons where rainfall was low or poorly distributed. Larger yields were associated with higher pre-planting soil moisture, higher profile soil moisture, higher water use, and a larger and deeper root system. Storms with a minimum of 20-mm daily rainfall were associated with runoff volume exceeding 1000 cum. The probability of receiving such a storm annually during the growing season was greater than 80%.

Dhyani ***et al.*** (1993) conducted a study in middle Himalayan Region at Fakot in Tehri Garhwal district of UP. A small watershed of 370 ha area was treated with various measures like renovations of bench terraces (27.4ha) construction of cement lined and LDPE tanks of 150 cum. capacity (24nos) landslide control measures (2ha) etc. These measures considerably reduced runoff and soil loss from 42 to 0.7% and 11 to 2.7 ton/ha.

Gupta ***et al.*** (1993) studied the effect of different water harvesting techniques on the establishment of neem (*Azadirachta indica*). There were 8 treatments: (1) control; (2) weed removal; (3) weed removal + intensive soil working (hand ploughing the inter-row space to 10 cm depth); (4) as (3) + water harvesting saucers of diameter 1 m; (5) as (4) but with saucers of diameter 1.5 m; (6) as (5) but with mulching in saucers; (7) water conservation structures (bunding) in a checker board design; and (8) water conservation structures as a 20% inter-row slope. Plants were established as 1- yr.-old nursery stock in 40X40X40 cm pits at 3X2 m spacing in July 1990 and dead plants were replaced in August. Supplementary watering was carried out at intervals and plant growth recorded periodically; data are given on height and girth at 18 months old, and on moisture conservation. Best growth was found in the 20% slope treatment (8), followed by the weed clearing treatment (2) and all the saucer treatments (4-6), that gave similar results. The other treatments gave poorer results but all were better than the control. Moisture conservation (compared with the control) was best in treatment (7) and (8) and least in treatment (3) and (5).

Mittal *et al.* (1993) examined effect of three water-harvesting structures (*anicuts*) on groundwater recharge by monitoring the water level of six wells, four downstream of the *anicut* and two upstream. Results indicate that average groundwater recharge was 1.15-1.25% greater in wells located downstream of the *anicut* than in these located upstream.

Sharda *et al.* (1994) stated that due to erratic and uneven distribution of rainfall, water harvesting is normally recommended for arid and semiarid regions have become essential in humid and sub-humid climates. The Northern hilly region of India, though receiving sufficient average annual rainfall, has temporal and spatial variations that result in moisture stress conditions during critical stages of plant growth. The water harvesting techniques being adopted under different situations in the Northern Hilly regions are reviewed with special emphasis on their design criteria, rainfall-runoff relationships, catchment area-storage capacity ratios and methods to contain storage losses. Studies showed that properly designed dugout-cum-embankment type ponds or reservoirs when used for providing supplemental irrigation, can increase crop yields two- to threefold.

Vangani and Singh (1994) stated that each village in arid zone has one or more nadis depending on the demand of water and availability of suitable sites. Nadis are small-excavated ponds for harvesting precipitation to mitigate the scarcity of drinking water in desert regions. The first recorded masonary nadi was constructed in the year 1520 near Jodhpur.

Agrawal (1995) conducted an experiment in the Banni village in Gujarat and stated that this village has developed a unique Water Harvesting techniques Virdas are shallow wells dug in low depressions called jheels (tanks). Here, the inhabitants collect enough rainwater to ensure the availability of fresh water throughout the year. They build a structure basically reaching down into the upper layer of fresh rainwater. As fresh water is removed, the brackished water zone moves upwards, and accumulates towards the bottom of Virda. The topography of Banni being very flat, it has only few depressions. They have found that after rainfall infiltrated the soil, it was stored at a level above the salty groundwater because of the difference in density. To store more fresh water, they dug many virdas in upper layers of accumulated rainwater up to about 1m above groundwater.

Goyal *et al.* (1995) showed that water harvesting using a farm pond of 271cum capacity coupled with ber *(Ziziphus mauritiana)* in the adjoining area could sustain this system even in very low rainfall situations. The cost-benefit ratio of the system was 1.672 which indicate that, in order to impart stability to agricultural production on rainfed lands in arid and semi-arid areas, farm ponds are a suitable means to achieve this.

Anschutz *et al.* (1997) suggested the basic principles of water harvesting (definition, conditions and inputs for water harvesting) the design of water harvesting systems, selection of water harvesting techniques, contour systems in his book on Water harvesting. Contour systems for improving filtration, measures to improve infiltration and water storage and the reduction of evaporation losses and optimization of the use of soil moisture.

Dijk *et al.* (1997) proposed the achievements of water harvesting in the Headadeib pilot scheme in arid Sudan. Breaching of the earthworks was an important factor contributing to this poor performance. Simple procedures based on soil moisture blocks for assessing moisture contents under cultivated soils were successful and could be used for monitoring and preventing breach damage in water harvesting projects.

Anonymous, (1999b) a workshop on WaterHarvesting in the Himalayas Region was conducted at International Center for Mountain Development (ICIMOD), Kathmandu of March 1999. The Central theme of the workshop was to identify the ways to improve WaterHarvesting system in mountainous areas of Hindukush-Himalayan region. It was found that, from the participating countries like China, Bhutan, India, Pakistan and Nepal except China none of the countries had adequate programmmes to promote waterharvesting systems in the Himalaya regions and needs were stressed.

2.2 Rain Water harvesting

Though the rainfall received in the arid and semi arid regions of our subcontinent is scanty and erratic, high intense showers resulting into sizable runoff are seldom. This provides ample scope for surface rainwater harvesting. Local people have developed various water harvesting systems. 'Rainwater harvesting' structures known as 'tanks' constructed by putting small earthen bunds across ephemeral stream has been an age-old traditional practice in India. A statistics on tank irrigation released during our independence era reveals that there were about half a million tanks under use irrigating about 4.5 Mha over the country.

Bruins ***et al.*** (1986) suggested that Rainwater-harvesting agriculture is a specialized form of rainfed farming that has a significant potential to increase food production in arid zones. Runoff farming and rainwater-harvesting agriculture are considered synonymous terms. There are indications that runoff rainwater was already used for farming during the Neolithic age. Remnants of ancient rainwater-harvesting agricultural systems have been found in many dry regions of Asia, Africa and America. Today, rain is still the cheapest and often only available source of water for agricultural purposes, but not always reliable. In many dry regions there is no alternative to a better and more effective use of rain to increase food production. Hyper-arid zones are usually too dry for runoff farming. Five major types of runoff farming are distinguished, arranged in order of generally increasing geomorphic scale: (1) micro-catchment system; (2) terraced wadi system; (3) hillside conduit system; (4) liman system; and (5) diversion system. The introduction and use of runoff farming in arid zones of a number of African countries is reported. As arid regions are characterized by large yearly fluctuations in the amount of runoff-producing rainfall, droughts have to be taken into account in proper runoff farming management. Forming reserve buffer stockpiles of water and food during the good years for drought periods are considered essential in this respect.

Grewal ***et al.*** (1989) stated excess monsoon rainwater was harvested from 10 contiguous forest watersheds and used for supplemental irrigation in the foothills of North India in an Operational Research Project. The performance of 1 typical reservoir was studied for 10 years (1978-87) with particular reference to the management of agricultural droughts. Rainwater was harvested from a 9.2-ha forest watershed by constructing a 12 m high earthen dam to store 55,600cum of water and to provide supplemental irrigation to 20 ha of rainfed farmland. Drought conditions were observed in 9 out of 20 crop seasons studied. Winter wheat was grown on areas of 18.5, 16.7 and 10.9 ha using 27 960, 24 980 and 16 400 m3 of water in 2 irrigations applied during the severe droughts of 1979-80, 1984-85 and 1987-88. The project cost was recovered from the production benefits of 1 severe drought. It was calculated that 33 000, 35 900 and 23 900 m^3 of water available during the most critical droughts of 1979-80, 1984-85 and 1987-88 had the potential to save crops on 44.0, 47.9 and 31.9 ha with 1 irrigation and on 21.0, 22.9 and 14.9 ha with 2 irrigations. The projected production and monetary benefits of supplemental irrigation are discussed. The project has been extended to more than80 locations in the foothill regions and now farms an important part of all agriculture and forestry development programmes.

Subbaiah (1991) suggested a linear programming technique was formulated and applied to a typical alkali area under reclamation in the western Yamuna canal in Haryana, India. Storage of rainwater in fields of rice in alkali soils was the most cost-effective way of managing rainwater followed by fallow alkali land storage and artificial recharge. Storage of rainwater in aquifers through induced recharge was preferable to storage aboveground in farm ponds. Runoff volume up to 80% could be profitably stored in various rainwater management components.

Mahoo *et al.* (1994) proposed a physically based model of Rainwater Harvesting (RWH) for semiarid areas of Tanzania. RWH is defined as the collection of runoff as sheet flow from a catchment area into an adjacent cropped area without storage other than in the cropped area. The model was formulated to: (i) design the most appropriate system given site characteristics by optimising predicted crop yields; and (ii) act as a tool for technology transfer both from research to the farmer and from location to location. Experimental work was undertaken in 3 of Tanzania's major agro-climatic zones. Runoff was measured directly from 50 and 100sqm catchments on bare soil, bare-compacted soil, natural vegetation and a low-management crop. Soil moisture, infiltration rates and bulk density were monitored throughout the growing season(s). The model is composed of 4 sub-units - a climate generator; a soil water storage model; a crop model and a catchment area rainfall-runoff model. To facilitate the model's intended use in areas where few or no data are available, it represents the important hydrological processes using physical parameters that are readily available or can be easily measured or estimated. Using runoff data from Morogoro, the relationships between rainfall, surface treatment, soil moisture, and runoff are examined. An attempt was made at validating the runoff model by comparing predictions from 'blind' simulations with observed runoff. The problems inherent in validating a model, which is physically based, and therefore not caliberated for a particular situation, are examined.

Gobin (1996) published a paper-describing role that rainwater harvesting plays in meeting the water needs of rural households and its interaction with other available sources of water supply in the rural and urban areas of Enugu State in Southeastern Nigeria. Its importance in four communities of the region, endowed with different water resource environments, is discussed. Rainwater is available at the point of use and is particularly invaluable in meeting household water requirements. The indigenous village knowledge systems were outlined.

Singh ***et al.*** (1994) stated that water management in the arid and semi arid area includes water harvesting and runoff management, storing rain water for protective irrigation, reducing evaporation losses through mulching, growing crops on receding soil moisture, reducing percolation losses by using bentonite and silt to increase soil moisture retention capacity. These areas receiving an annual rainfall ranging from 100-400mm.Problems in the management of irrigation water include an inadequate source of groundwater supply, high evapotranspiration, high rate of percolation in soils, low water use efficiencies, saline irrigation waters, and drainage requirements. Selection of the appropriate irrigation techniques for the area was discussed.

Todd and Vittori (1997) showed that collecting rainwater is not only water conserving, it is also energy conserving, since the energy input required to operate a centralised water system designed to treat and pump water is by passed. Rooftop WaterHarvesting also lessen local erosion and flooding caused by runoff from impervious cover such as pavement and roofs as some rain is instead captured and stored.

Ghosh (1999b) has quoted that K.Raheja Group's Towers was constructed with rainwater harvesting systems A trench along the boundary wall recharges the ground water; and a simple man Ramani, who lives in Korattur, a water starved area that still gets its potable stock from Ambattur Municipality. He has constructed rainwater harvesting system 16 years ago. The terrace has been resurfaced to generate a mild slope to direct rainwater to feeder, which runs the water into a tank. He has used alum to sink the floating sediment and dust particles and has two sets of pipes -one leading to the soak pit and then to the well, the other available on the first floor with a link to the kitchen. The only thing modern is the monobloc pump set and water purifier installed for drinking water. He does not depend on Municipal water supply at all. If properly planned, the whole system will cost just Rs 6,000/-.

2.3. Micro catchment water harvesting

A micro-catchment is a very small watershed designed to collect runoff for the consumptive use of tree.

Evenrai ***et al.*** (1971) gave the design of Micro catchment as a boarder check of about 15cm high raised around each catchment at the lowest point of each catchment an infiltration basin 30-40 cm deep is made and a tree is planted in it. After a heavy rainfall the whole micro-catchment is flooded; a light shower causes ponding only in the basin.

National Academy of Sciences (1974) stated that the micro-catchment water harvesting (MCWH) is practised all over the Asian and African countries like Afghanistan, Australia, India Israel, Mexico, North Africa and Pakistan.

Sharma ***et al.*** (1986) stated that the micro-catchments having different combinations of slopes, slope lengths and contributing areas, aimed at generating runoff supplements of 0 to 400 mm, were studied to determine their runoff yield, soil moisture storage, growth, yield, and long term runoff behavior under hot arid conditions in India. Runoff and soil moisture storage increased significantly with increasing slope, and decreasing slope length and contributing area; the highest being at 10% slope, 5.12 m slope length and 31.5 sqm. per tree contributing area. Similar trends were observed for growth parameters, yield of jujube (*Ziziphus mauritiana*). Jujube yield was a function of the available soil moisture storage. Over a period of seven years the threshold rainfall reduced by half and runoff efficiency doubled due to the formation of a nearly impervious soil crust over the micro-catchment surface.

Gainey (1988) proposed the various micro-water harvesting techniques (micro catchments, semi-circular hoops and trapezoidal bunds) have been established in the Turkana District of northwest Kenya. Larger schemes require much outside input, especially of food or cash to pay for labour. Problems of cultural acceptability and future replicability remain, and any successful technique must take into account the requirements of the people for whom it is built.

Oron ***et al.*** (1987) studied the Micro-catchment water harvesting system and developed a method for predicting the volume of runoff from a flat terrain Micro-catchment subject to rainfall of uniform intensity, and various initial conditions for the upper soil layer. The model was derived from the kinematic overland flow equations and used mannings equation as an approximation of the momentum equations. The modified Green-Ampt equation was adopted for water intake rate in crusted soils. In areas where crop water requirement problem can at least be partially solved by the use of non-conventional water sources, the model will be of application to the design of systems for the Water Harvesting of runoff in micro-catchments.

Gielen (1990) gave the design and methods for micro-basins dug out in April-May, before tree planting in June. The micro basins retain the limited and irregular rainfall so that the trees are able to establish a root system that can survive the ensuing dry season.

Achour ***et al.*** (1994) gave the evaluation of soil moisture under various soil treatments in micro-watersheds. Studied in the semiarid central region of Tunisia. Four treatments to reduce water infiltration rates were studied: (i) control, (ii) soil compaction, (iii) compaction and removal of salt, and (iv) removal of vegetation. These treatments were studied for two types of micro-basins (16 and 64sqm). Soil moisture measurements at different depths (30, 45, 60 and 90 cm) showed that the treatments (iii), (iv) and (ii) increased soil moisture by 8%, 6% and 4% respectively compared with (i).

Arora *et al.* (1994) studied the moisture stress during post monsoon and summer period, in the Doon Valley, India. It appeared to be a major constraint for the economic yield of fruit crops rose in degraded and shallow lands with inherently low water holding capacity. To overcome this, attempts were made to enhance the productivity of lemon, sweet orange and plum orchards through land shaping and in situ moisture conservation through water harvesting. V-shaped micro-catchments with runoff surfaces mulched with grass were effective for yield increases up to two to two half times, with better fruit quality. Such techniques are suited to degraded rainfed lands, where irrigation facilities are not available and supplemental irrigation is also uneconomic. The effect of various moisture conservation treatments on growth parameters, fruit yield quality characteristics and soil moisture was also studied.

Bithu (1994) studied the benefits of micro-catchment water harvesting (MCWH) and soil trap techniques in the loessial soils of the Western *Thar desert*, Rajasthan, India. Under the MCWH system overall surface runoff is reduced by increasing infiltration rates. Root zone soil analyses were conducted from the bare loessial soils and from the sand plains with MCWH. Root soil moisture was greater under the MCWH system and salinity was less compared with the bare soil. Crop yields increased by 40-50% under the MCWH system. Rainfed agriculture and dryland irrigation aided by the MCWH system were environmentally and economically sustainable and were more remunerative than the conventional (canal) irrigated agriculture in the region.

Boers (1994) described a design procedure for a water-harvesting system in micro-catchments that can be used in developing countries. The procedure is based on sheet-flow-runoff models and a soil water balance model, which together predict the water balance of the root zone below the basin area of a micro-catchment. It was illustrated by a prediction of the water supply to windbreaks in Niger and Nigeria. It is concluded that, in arid and semi-arid zones, runoff from small areas such as micro-catchments is an important potential source of water for the establishment, development and growth of trees.

Renner *et al.* (1995) proposed that that micro-catchment water harvesting can act as an important technique for sustainable agriculture in developing countries if important socioeconomic elements are incorporated into its design. The paper discusses some of these socioeconomic design elements, including evaluation and monitoring of the economic benefit and social acceptability of the water harvesting project, local participation, involvement of women, incentives versus need, and appropriate technology.

Suleman *et al.* (1995) stated that micro catchments 4-5 m long with 7-15% slopes increased soil moisture by 59, 63 and 80% at depths of 0-15, 15-30, and 30-45 cm, respectively. Soil moisture increased in late summer and in late winter when precipitation is greatest. Rill erosion increased with micro-catchment length and gradient, with erosion volumes of 14.9-26.3 litres from areas of 120 and 150 m^2.

Oweis *et al.* (1996) conducted experiment on the performance of a small runoff-basin water-harvesting system. It was evaluated under a typical Mediterranean arid environment in Jordan. Rainfall, runoff, catchment area, soil water storage, and crop evapotranspiration were analysed as elements of one system. Three micro-catchment areas (25, 50, and 75 sqm) and three surface treatment methods (natural, plastic cover, and compaction) were used. Runoff efficiency was evaluated for 16 storms. Storage efficiency was evaluated for eight periods by monitoring soil water balance in the crop root zone. The overall efficiency of the water-harvesting system was determined as the ratio of the amount of water stored and used by the crop to the amount of rainfall received in the catchment area. The overall efficiency of the system varied from more than85% to as low as 7% depending on the size of the catchment and the root zone capacity. The required ratio of the catchment area to the cultivated area was strongly related to the root zone storage capacity and the rate of consumptive use as well as rainfall-runoff characteristics.

2.4.Roaded catchment water harvesting

Roaded Catchment Water Harvesting (RCWH) is a viable technique for collecting runoff water going as a waste off the road and using the same to meet the irrigational needs of avenue trees planted on both sides of roads. RCWH is widely practised in Western Australia. Roaded catchment consists of a series of parallel compacted roads with exaggerated camber, which adjoin to make V-shaped channel that discharge into collected drain at the lower end. The roaded catchment were developed from field experiments from which thumb rules for design are produced for gradients of roads and collecting channels to ensure that no series erosion will occur. The size and shape of the roaded catchment layout can be evolved mainly through intuition and by taking into consideration the available construction equipments. Individual roads vary from 50m-300m long and 5m-12m wide crest to crest. The catchment area can be varying up to 10ha. RCWH tends to loose its effectiveness with time because debris collected in the channels. Improved designs may allow the application of gradients that could cause most of the debris to be washed from the catchments. Research is on the anvil to develop methods for calculating the maximum non-erosive gradients of channel and to find the best catchment shape and influence of the catchment design parameters on the runoff yield. One bottleneck is the assessment of the erosion resistance of soil. Observations on several freshly constructed roaded catchments with width up to 24m indicate that riling of side slope may pose the serious problems than the channel erosion. The best possible prospect for impervious performance of roaded catchment seems to be the developed techniques to form mini roads on the sides of main road. The mini roads increase the runoff and also give a wider range of acceptance road making equipment. The essential difference between the roaded catchment and bedding system of drainage to act as a road catchment is that the latter serve only the purpose of collecting the drainage runoff water from the bed along the furrows on both the sides, and to convey the same into a common lateral collected drain towards common outlet. No trees are grown along the furrows, but the beds are planted with crops.

2.5. Roof top water harvesting

This is the method of harvesting rainwater pouring on the rooftop using gutters. Gutters must be properly designed, slopped and installed in order to maximise the quantity of harvested rain. Another problem is simply the weight of the gutter when loaded with water. Gutters will need to be well supported so that they cannot sag or be pulled away from the support. They must be carefully positioned to catch both gushing flows from the roof and also drips. In addition to they need an adequate support slope for their entire flow length so that stagnant pools, which could provide breeding places for mosquitoes are avoided.

The collection and disposal of the first flush of water from roof, is of particular concern if the collected rainwater is to be used for human consumption, since the first flush picks up to most of the dirt, debris and contaminants such as bird droppings that have collected on the roof and in the gutter downspout located at the head of the downspout from gutter to cistern. Most of these types of roof washers extended from the gutter to the ground where they are supported. Rather than wasting the water, the first flush can be used for non-portable uses such as for lawn or garden for irrigation.

In Thailand, people have stated using a device for holding back first flush water. It consists of a length of large diameter pipe suspended along the side of the rainwater a tank. This is sealed at the bottom with a plug. When rain begins to fall, this length of pipe must fill before any water can enter the tank. It will thus retain any sediment carried by the first flush water. After each storm the plug is removed and pipe is cleaned.

Other than the roof which is an assumed cost in most building projects; the storage tank represents the largest investment in a rainwater harvesting system. To maximise the efficiency of our system, the building plan should reflect decisions about optimal placement, capacity and material selection for the cistern.

Tanks are available in range of materials, sizes large and small to accommodate our system design and budget. For small installations, locally available barrels, drums and troughs can be used as storage tanks. For large installations many options like concrete, plastic. Fiberglass, polythene, metals and wooden storage tanks are available.

In Chennai, water scarcity is the order of the day. Chennai's water scarcity is as comical as the plight of a man who searches madly for his key that rest on the table. Chennai is blessed with an annual average of 128cm of rainfall. The downpour, at times heavy leaves more than mere puddles against for hours, in some areas, for days. This mismatch of paucity and plenty is because of various factors at least one of which within our control. The Chennai Metropolitan Development Authority notified in 1993 those ordinary building, special building group developments, multi-storied building must conserve rainwater in their premises.

One of the famous rainwater harvesting companies in Madurai says that it would cost around Rs. 25,000/- for constructing a rainwater harvesting system in an eight-apartment complex. Another rainwater harvesting consultant, Paneer Selvam of Pal Promoters, Madurai has said that rather than spending cores on storm water drains soaks pits could be built on road to absorb rainwater. There is need for people to invest in the system.

Farrar (1974) gave a typical example of catchment area being both roof and ground, which is adopted in a number of houses in Botswana Each house has two rainwater tanks. One stands on the ground and collects water directly from the roof to provide water for drinking and cooking. The other is an excavated tank filled by overflows from the first tank as well as runoff from hard ground near the house. This tank is used to provide small amount of water for the garden as well as some water for washing.

Mc Dowell (1976) stated that in tropical areas, the high intensity of rainfall that occurs hence the gutters must be larger than in temperate regions, if they are not to overflow. In general gutters with a cross sectional area of 200sqcm will be able to cope with all but the heaviest rain when attached to small roof, which implies approximately 200mm width for gutters off semi circular section. However, local materials such as bamboo are used. The way in which gutters are actually supported must depend very much on the construction of house. As to the construction of gutter one of the simplest methods is to nail ceder or other planks together in V-shape. The joint is sealed with tar or any other suitable locally available resinous material Metal gutters can sometimes be made locally, and both metal and plastic (PVC) guttering may be available for purchase. Several appropriate technology centers in Nairobi have demonstrated halved tin cans riveted together used as gutters. But the most widely used and important form of guttering from local materials is that made from bamboo.

Norieku (1980) stated that troughing below the eaves but near to ground level has been used to collect rainwater in small containers. Such troughing may be particularly appropriate for thatched roofs and could be used to fill a larger permanent tank or just at a low level, perhaps constructed in a shallow excavation.

Fricke (1982) stated that in Khon Kaen province of Thailand, houses were raised with wooden platforms and have iron roofs. Here the houses have bamboo reinforced concrete rainwater tanks and the gutters and usually attached to only one slope of the roof.

Hall (1982) had designed some gutters for rainwater collection from thatched roof. The cost of conventional guttering is often said to be small with the cost of a tank.

Waller (1982) stated that guttering seems to be a difficulty for many householders where there are practical obstacles in installing conventional gutters, one option may be to discuss ways of collecting water from roofs without them, In Bermuda thesis achieved by means of slanting ridges on the roof surface known as `glides` They are formed of lengths of stone cut to triangular shape or else precast in concrete and are bedded on the limestone roof slates with cement mortar. This method is only practicable where roof surfaces are smooth and it would not be satisfactory with corrugated iron.

Kaufman (1983) had reported that the most of people of rural Indonesia follow a similar design of using an extra length of guttering. Guttering can also involve an complex array of down pipes as prescribed by the Institute of Rural Water (1982) But in view of the need to keep costs low and avoid maintenance problem, the simpler approach is clearly preferable.

Omwenga (1984) conducted a Survey in Kissi, Kenya and showed that 33% of households collected water in oil drums compared with 17% which had permanent tanks Most of the remaining families collected some runoff from roofs in pots, pans, buckets placed under eaves during storms. The oil drums used for rainwater collection had a capacity of 2000liters.

Gould (1996) suggested the potential in household rainwater collection systems for improving water supplies in rural Botswana. The possibilities for supplementing community supplies are demonstrated through pilot projects using roof catchments and large ferro-cement rainwater tanks at rural schools and clinics. The paper also notes the benefits of using surface runoff for livestock, trees and crops, projects that have run since 1990. It was noted that adoption of these techniques was slow in spite of various government subsidies. Reasons for the limited diffusion include the relatively high initial capital costs of systems, and poor design or maintenance of systems at many institutions.

Ghosh (1999a) stated that if all the water could be trapped and stored all the people in Chennai could get 940 liter per head per day nearly fivefold the revised estimate of 200 liters suggested for domestic consumers by the Chennai Metro Water Board.

Ghosh (1999c) stated that if every resident tapped rainwater at his house, if each builder complied with the rules, Metro Water would not have to set up a Rs 530core water treatment plant to process 530 million liters a day at Chemberambakkam by December 2001.

2.6 Run-off water harvesting

This is the usual procedure for harvesting rainwater. Generally it is practised in almost all the rural areas. This run-off rainwater is stored in Percolation and Farm Ponds. Indirectly they recharge the ground water.

Prasad (1979) conducted a study for runoff water collection in which runoff water is collected behind an earthen bund 3m in height and running along contour over a sizable distance and hooked up at appropriate points. Length of ponds varies from 100m to 10Km or more depending on the rainfall, watershed etc. The submergence may vary from 0.5to 100 ham.

Frasier (1987) suggested that water-harvesting or runoff-farming techniques are technically feasible methods of supplying water for animals, households, and growing plants. Some water-harvesting systems have been outstanding successes, others total failures. Despite use of proper materials and design, many systems have failed because social and economic factors were not adequately integrated into the systems. There will be a higher probability of system failure when funds are available for construction at no obligation to the user unless there is a clear understanding of who is responsible for maintenance. A successful water-harvesting system must be: (a) technically sound, properly designed, and maintained; (b) socially acceptable to the water user and his method of operation; and (c) economically feasible in both initial cost and maintenance at the user level.

Proud (1988) proposed that runoff harvesting is the interception and concentration of rainfall runoff and its storage in the soil profile for crop production. The technique is used in semi arid areas where there is high storm intensity and poor infiltration of water into the soil. Design parameters were defined and explained. The construction techniques to maximize runoff and minimise erosion are indicated.

Materials and methods

CHAPTER III

MATERIALS AND METHODS

This chapter covers the methods used to collect Rooftop rainwater and its harvesting techniques. It also furnishes the specification and construction details of the structures used for filtering the rainwater. A detailed procedure to work out the water budgeting for the SWCE Workshop Complex is also illustrated.

3.1. Experimental site

A field study has been taken up in the western side of Soil and Water Conservation Workshop Building of TNAU, Coimbatore. The TNAU Campus is located at Latitude of 11°N and Longitude of 77°E and an Altitude of 426.72m (MSL).

3.2. Season and weather conditions

Coimbatore has a subtropical, semi-arid climate with hot summer. The mean annual rainfall is 674mm distributed in 49 rainy days. Coimbatore is having a salubrious climate with an average rainfall intensity of 11cm/hr. the maximum and minimum intensity is 30cm/hr and 5cm/hr respectively. The mean maximum and minimum temperature ranges between 29.2°C to 35.2°C and 17.9°C to 23.8°C respectively. The mean relative humidity ranges between 40.6 to 61 percent (25 years mean).

3.3. Description of the Experimental Set up

The Soil and Water Conservation Workshop Building has a structural framework in the form of Northlight shell roof type, with an inclination of 30° with the horizontal. There are six rainwater gutters, which are provided at both the sides east and west at downstream end of shell roof. The gutter is in the form of trapezoidal shape sloping towards both the directions (i.e.) east and west direction. The gutter receives rainfall from shell roof in which half of the amount is carried towards the eastside and other half towards west side.

PLATE 3.1. ROOF SURFACE WITH GUTTER

PLATE 3.2. THROUGH WITH DOWN PIPE CONNECTION

PLATE 3.3. LAYOUT OF STONEWARE PIPE CONNECTION

PLATE 3.4. SUMP IN THE MICROCATCHMENT LAYOUT

3.4. Rooftop rainwater Harvesting Mechanism

The amount of rainfall on the shell roof is safely carried towards the outlet of gutter, which is having a gentle slope of 1-1.5%. From the outlet end, the rainwater is allowed to pass through the asbestos down pipe and later through stoneware pipe. The fast moving rainwater is then detained in a detention basin to reduce the velocity of rainwater. After that the rainwater is allowed to pass through the filtering basin. The pure rainwater is eventually collected at the out-let of filtering basin by providing necessary connection to the storage tank.

3.5. Lay out of the Structures

The various components involved in the Rooftop rainwater harvesting experiment are as follows:

1. Roof top surface area
2. Gutter to harness run-off water
3. Down pipe
4. Stone ware pipe
5. Detention basin
6. Filtering basin
7. Collecting basin
8. Storage tank

3.5.1. Roof top Surface area

The features of roof top area differ from building to building. The roof area and their design also depend on climatic conditions. The study roof top surface area is of asbestos type with a projected area of 39m × 32m. (Plate 3.1.)

3.5.2. Gutter to Harness run-off water

The gutters receive the rain falling on the roof surface and direct them towards the down pipe. Generally asbestos type gutters are used for their easy transportation and durability, in case of asbestos roof. Of course in concrete roof this is not at all needed. On concrete roof surface, rainwater is diverted directly to down pipe by providing necessary slope. For experiment purpose asbestos gutters were used. (Plate 3.1.)

3.5.3. Down Pipe

These pipes generally receive the rainwater gushing out from the out-let end of gutter. These pipes deliver the rainwater vertically down and then diverted towards a safe collecting basin through stoneware pipes. Depending on the height of the roof, the length of the down pipe required is calculated. The pipes are available in different sizes. For moderate to heavy rainfall areas the down pipe of 15cm diameter is sufficient. The joining of the down pipe with gutter end and necessary bends is done by jute and cement paste. The down pipes are clamped at safe points. If needed the down pipes can be joined with suitable length. Asbestos pipes of 15cm diameter were installed at the experimental site. (Plate 3.2.)

3.5.4. Stone ware Pipe

These pipes are very cheap and available in standard length with different diameters. The horizontal diversion of rainwater to the detention basin is well done with the help of these pipes. The SW pipes are available in 2.0ft length. The fixing of SW pipes is done by using jute and cement paste end-to-end. The well-packed SW pipes are given a suitable gradient to drain the collected rainwater towards the detention tank. 15cm diameter 2.0ft length SW pipes were used. A bed slope of 1 in 80 was provided to the SW pipe for safe disposal of rainwater. (Plate3.3.)

3.5.5. Detention Basin

It was constructed at the experimental site by using brick masonary. The purpose of this basin was to reduce the speed of rainwater that comes out from the outlet of SW pipe. The detention basin was constructed below the ground level and was plastered inside. In case of intense rain this structure got a great utility in decipating the speed of rainwater coming out of the SW pipes. (Plate3.5.)

PLATE 3.5. FILTERING UNIT UNDER CONSTRUCTION

PLATE 3.6. LAYING OUT OF PCC IN STORAGE TANK PIT

PLATE 3.7. INLET PIPE TO STORAGE TANK

3.5.6. Filtering Basin

This component has been designed to filter the rainwater. Though rainwater is clear for drinking purpose it has to be filtered taking safety into account. Fine sand and gravel filter has been constructed at the experimental site to treat the rainwater. Filtration process removes bacteria, colour, taste etc. so for domestic consumption this component is essential for treating the rainwater. (Plate3.5.)

3.5.7. Collecting Basin

The basin was constructed to reduce the cost of excavation for the storage tank. As the out let of the filtering basin out let was below the ground the inlet of the storage tank is up to that height apart from the own height below the ground. Thus a small basin adjacent to filtering basin was constructed with brick masonary, and plastered inside. The sole purpose of this was to raise the depth of filtered rainwater up to at least the ground level and then discharge the same by outlet towards the storage tank. This small provision was a great help in reducing the earth work excavation and maintaining the level surface of the storage tank. (Plate3.5.)

3.6. Storage Tank

PVC storage tank is used. It has got a life cycle of 20-25 years. For installing the PVC storage tank, earthwork excavation was carried out and after providing proper platform, the tank was placed on it. The upper part of the tank was connected with a pipe from collecting basin. The capacity of the tank was 2,000litres. Incase of excess filtered rainwater on intense rainfall the excess amount can be diverted easily by providing necessary pipe arrangement to a near by sump which is of adequate dimension in side the Laboratory. (Plate3.6.and 3.7.)

3.7. Gravel used for filtering basin:

Gravel is used as the base material in the filtering basin. 40mm, 25mm and 15mm size gravel was used for the filtering basin at the experimental site. 40mm size was laid at

PLATE 3.8. COARSE AGGREGATE INFILTERING BASIN

PLATE 3.10. FILTERING SAND FILL ABOVE THE BASE MATERIAL

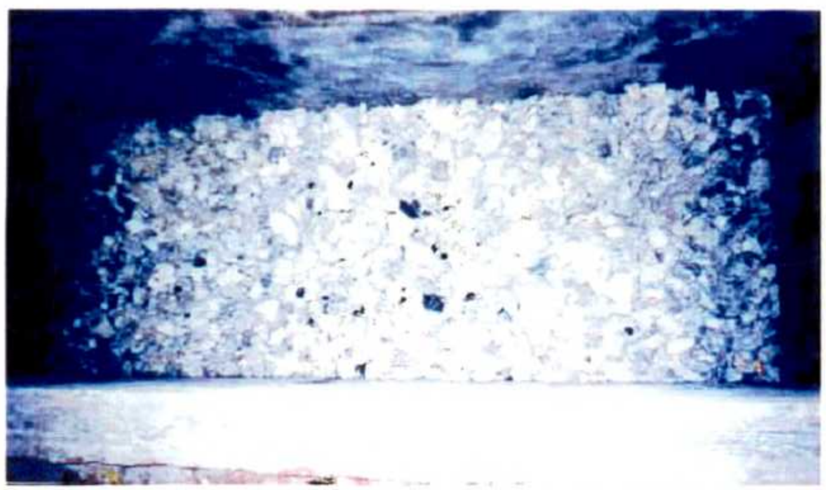


PLATE 3.9. MEDIUM SIZE AGGREGATE ABOVE THE COARSE AGGREGATE

PLATE 3.11. MICROCATCHMENT LAYOUT IN THEME PARK

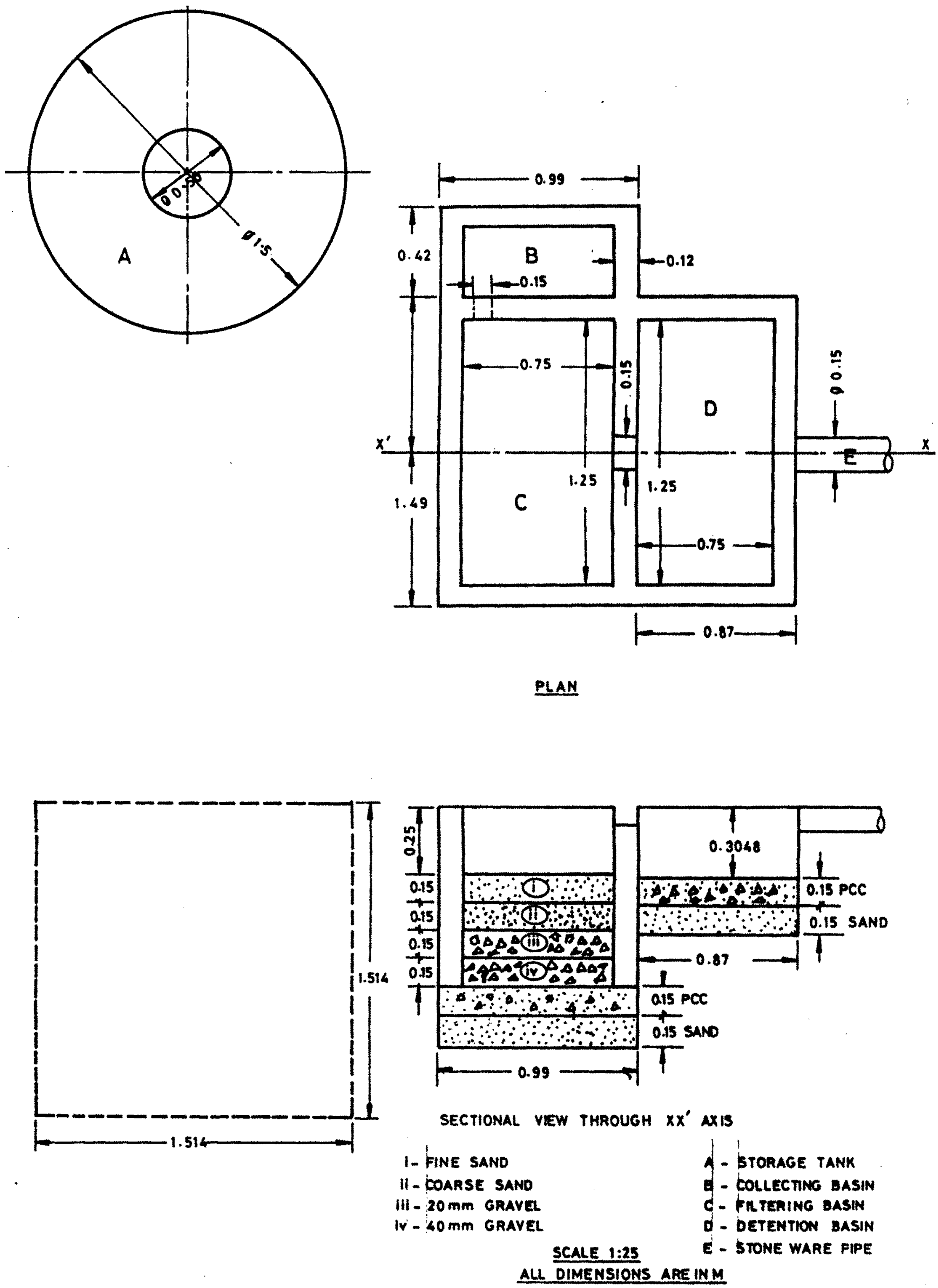


Fig. 3·1. PLAN AND ELEVATION OF FILTERING UNIT AND STORAGE TANK the bottom up to 15cm height, 25mm size up to 15cm height and 15mm up to 20cm height chronologically from bottom to top of the filtering basin. (Plate3.8.and 3.9.)

3.8. Sand used for filtering basin:

River sand is used for the filtering basin. Coarse sand was used just on the gravel layer up to 15cm over which fine sand was laid up to 15cm depth. (Plate3.10.)

3.9. Lay out and Construction details of the Structure

The storage tank and the filtering basin along with other accessories were installed near the workshop building. The asbestos gutters were provided to carry the rooftop rainwater and direct them towards the down pipes with the help of asbestos bends. All the joints were fixed tightly by using jute and cement paste. From the down pipes the stone ware (SW) pipes were fixed end to end with the help of the asbestos bends by the same manner. The lining of these SW pipes were provided on a horizontal land with 1 in 78 bed slope for easy passage of rain water.

The construction of filtering basin, detention basin, and collecting basin took place at one corner end of the Laboratory building. Earthwork excavation was done for the storage tank up to a proper depth of 6.0 ft. for foundation settlement 15.0 cm layer sand and 15.0 cm layer concrete foundation (1:4:8) was laid, to avoid shrinkage. The storage tank was placed on the platform below the ground level.

II class chamber brickwork in cement mortar (1:5) of a brick wall thickness was carried out on the foundation surface. The inner walls were plastered by 1:4 CM of 12.5 mm thickness for all the three basins. (Detention basin, filtering basin, collecting basin) The bed of the filtering basin was given a slope for the filtered rainwater to drain out. The collecting basin was connected by a PVC pipe of 4-inch diameter to the storage tank for storing filtered rainwater. A rectangular weir was constructed on the detention basin for easy disposal of rainwater towards the filtering basin. The filtering basin was later filled with coarse gravel, middle coarse gravel, and small gravel up to a depth of 15cm each.

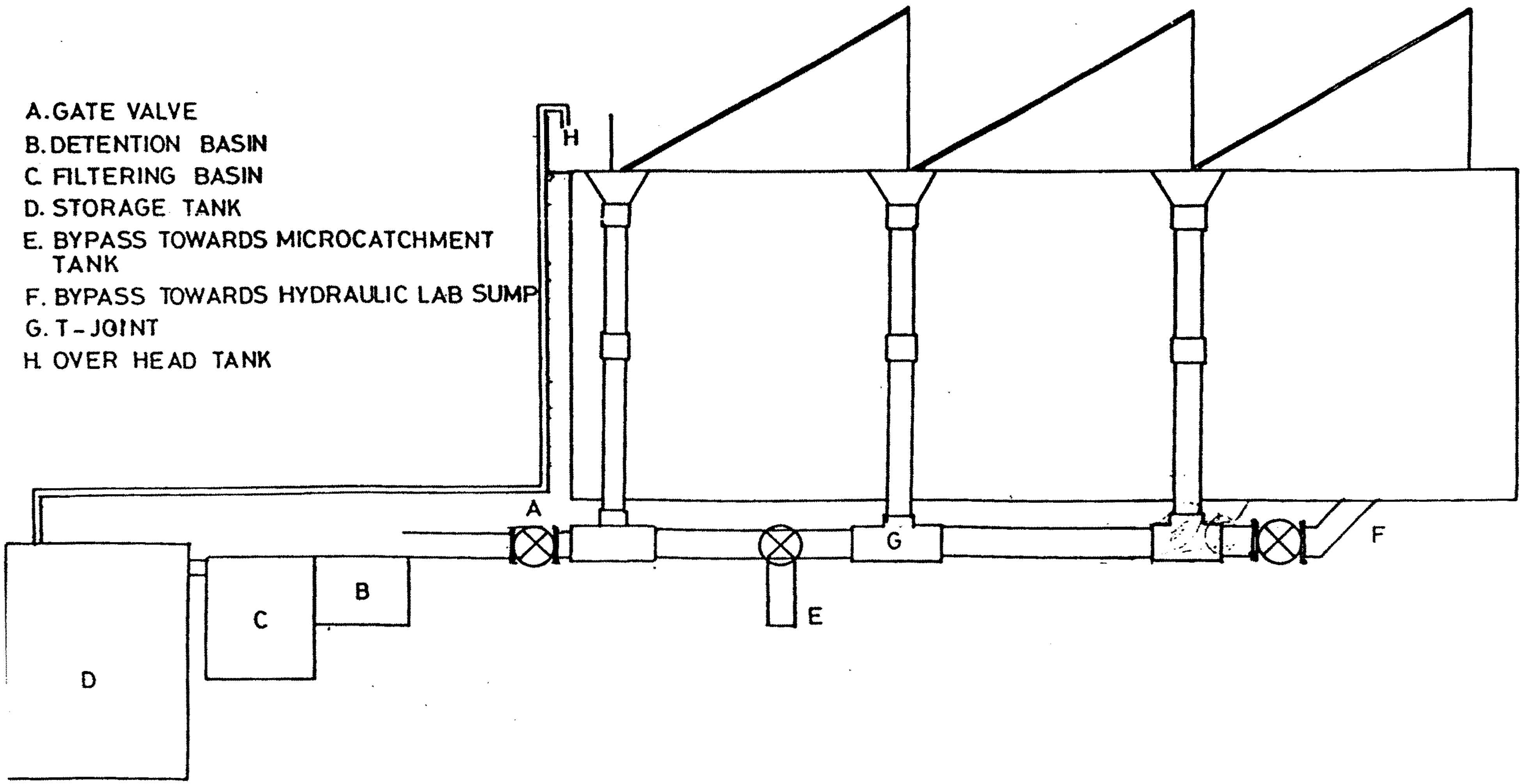
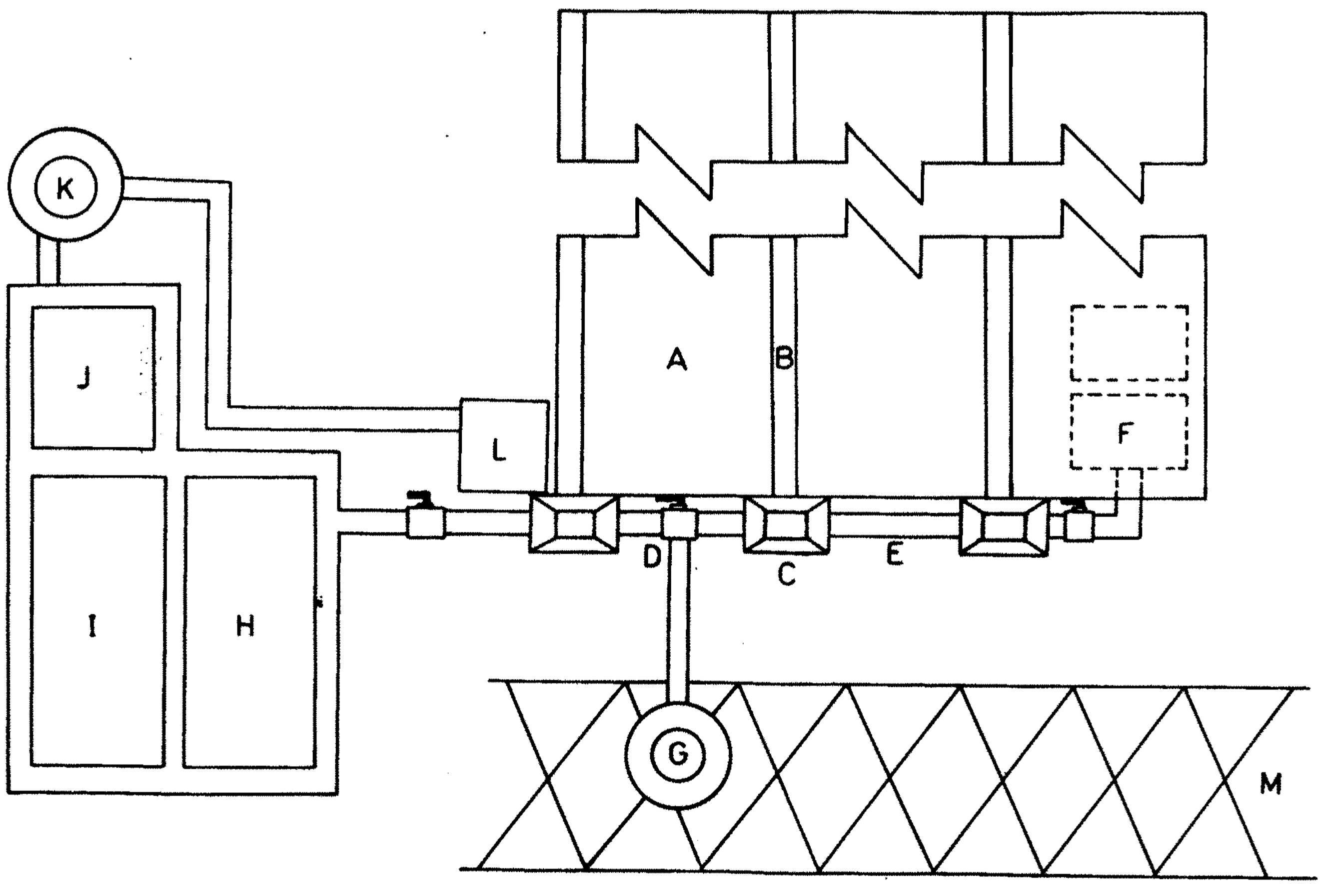


FIG. 3·2.i SECTIONAL VIEW OF ROOFTOP RAINWATER HARVESTING SYSTEM



A. ASBESTOS ROOF SURFACE
B. TRAPEZOIDAL GUTTER
C. TROUGH
D. GATE VALVE
E. STONEWARE PIPE
F. HYDRAULIC LAB SUMP
G. MICRO-CATCHMENT STORAGE TANK
H. DETENTION BASIN
I. FILTERING BASIN
J. COLLECTING BASIN
K. STORAGE TANK
L. OVER HEAD TANK
M. MICRO-CATCHMENT BASIN

FIG. 3.2.ii. SECTIONAL PLAN OF ROOF-TOP RAIN-WATER HARVESTING SYSTEM

Coarse sand and fine sand was filled to a depth of 15cm. Above the sand layer about 30.0 cm was kept for the treatment of rainwater.

A pipe arrangement was provided at the storage tank to spill out the excess amount of filtered rainwater to the collecting sump in-side the Laboratory.

The detailed plan and elevation of the filtering unit and its components are given in the Figure 3.1.The sectional view of Rooftop rainwater harvesting system is shown in the Figure 3.2.

3.10. Design of the components involved in rooftop rainwater harvesting

The Tank design, Trapezoidal gutter design, Pipe design and the filter basin design of the system component are narrated as follow.

3.10.1. Tank design

Total projected area of the workshop complex $=39\times32$

$=1248$sqm

Taking maximum monthly rainfall (from 25 years rainfall data)

$= 663.9$mm $= 0.66$m

The volume of run-off assuming no losses $= 1248 \times 0.66 = 823.68$cum

Runoff over the A.C. Sheet accounting 3% loss (observed data from Meteorology) $= 823.68 \times 0.97$

$= 799$ cum

Runoff one end of gutters $= 799\div2 = 399.5$ cum

Runoff on monthly basis $= 399.5$cum

Maximum weekly rainfall occurs on 45^{th} week $= 57.91$mm

Runoff collected on one side $= (1248 \times 57.91)/1000$

$= 36.135$cum

Runoff collected from AC sheet accounting 3% loss $= 36.135 \times 0.97$

$= 35.1$cum

The capacity of the water tank need not be designed based on maximum monthly and weekly rainfall, because the design will give a bigger dimensional tank, which is not economical. To economise the cost of the tank, and also the water is used daily for different purposes, maximum one day rainfall (24hours) will be considered for the design of collection tank.

Assuming, rainfall in 24 hours = 5.4 mm

Total runoff occurring on one side of the roof $= (1248\times5.4) \div(1000\times2)$

$= 3.369$cum

Taking 3% loss into account the accumulated actual runoff over the roof on one side $= 3.369 \times 0.97$

$= 3.268$cum

A tank capacity of 3268 liters is required but the capacity of available tank is 2000liter. The excess amount 1268 litre can be diverted safely to the existing sump near by whose capacity is 4800 litre.

3.10.2.Trapezoidal gutter design

Total runoff collected on daily basis on the projected area (Q)=3.369 cum

Assuming uniform distribution over the roof and yielding equal runoff through **three trapezoidal sections provided at a gradient (S) =1.5%, side slope of the section is** 1:2 (V: H).

For Economic cross-sectional area

$R=d/2$; $b = d \tan\theta/2$; $\tan\theta = 1/2, \Rightarrow \theta = 26.56°$

Runoff in one trapezoidal section $= 3.369/3$

$= 1.123$cum

$Q = a \times v$

Manning's velocity, $v = 1/n\, R^{2/3}\, S^{1/2}$

Where:

n = Manning's constant = 0.011

R = Hydraulic radius = $d/2$

S = Slope of the bed = 1.5%

$$1.123 = d\,(b+d)(1/0.011)(d/2)^{2/3}\,(0.015)^{1/2}$$

$$= 7.014(1.414)\, d$$

$$\Rightarrow d = 0.44\text{m};$$

$$\therefore b = 0.18\text{ m}$$

Therefore the cross section of the trapezoidal section will be 18cm width and 44cm depth; by providing a free board of 3 cm, the depth of the section becomes 47 cm.

3.10.3. Pipe design

Rooftop-rain water can be collected through down pipes.

By considering uniform distribution over the roof area.

Quantity of runoff flowing through one pipe is calculated as follows

$Q_1 = 3.369/3 = 1.123\text{m}^3$

$Q_1 = a_1 \times v_1$

$a_1 = \Pi\ /4\, (d^2\, l)$ $\qquad$ $v_1 = 1/n\, R^{2/3} S^{1/2}$

Where

d = diameter of the pipe

l = total length of the pipe

R = hydraulic radius

S = bed slope

$$1.123 = \Pi /4\, d^2 \times 32\, (1/0.011)\, (d/2)^{2/3}\ (0.015)^{1/2}$$

Diameter, d = 0.15m

The diameter of the down pipe and stoneware pipe is 15 cm.

3.10.4. Filter bed design

Discharge per day = 3.268 cum

= 3.3cum

Rate of filtration for the filtering medium = 200l/h/m^2 (Garg. S.K.,1987)

Total surface area required = Maximum discharge / Rate of filtration

= 3.3/4.8 = 0.6875sqm--------(i)

Assuming one filtration unit is adopted and the length is 1.5 times the width.

A = L X B

Where

A = Area of the filtering basin

L = Length of the filtering basin

B = Breadth of the filtering basin

The area = $1.5B \times B = 1.5\, B^2$---------(ii)

Equating Eq. (i) and Eq. (ii) we have

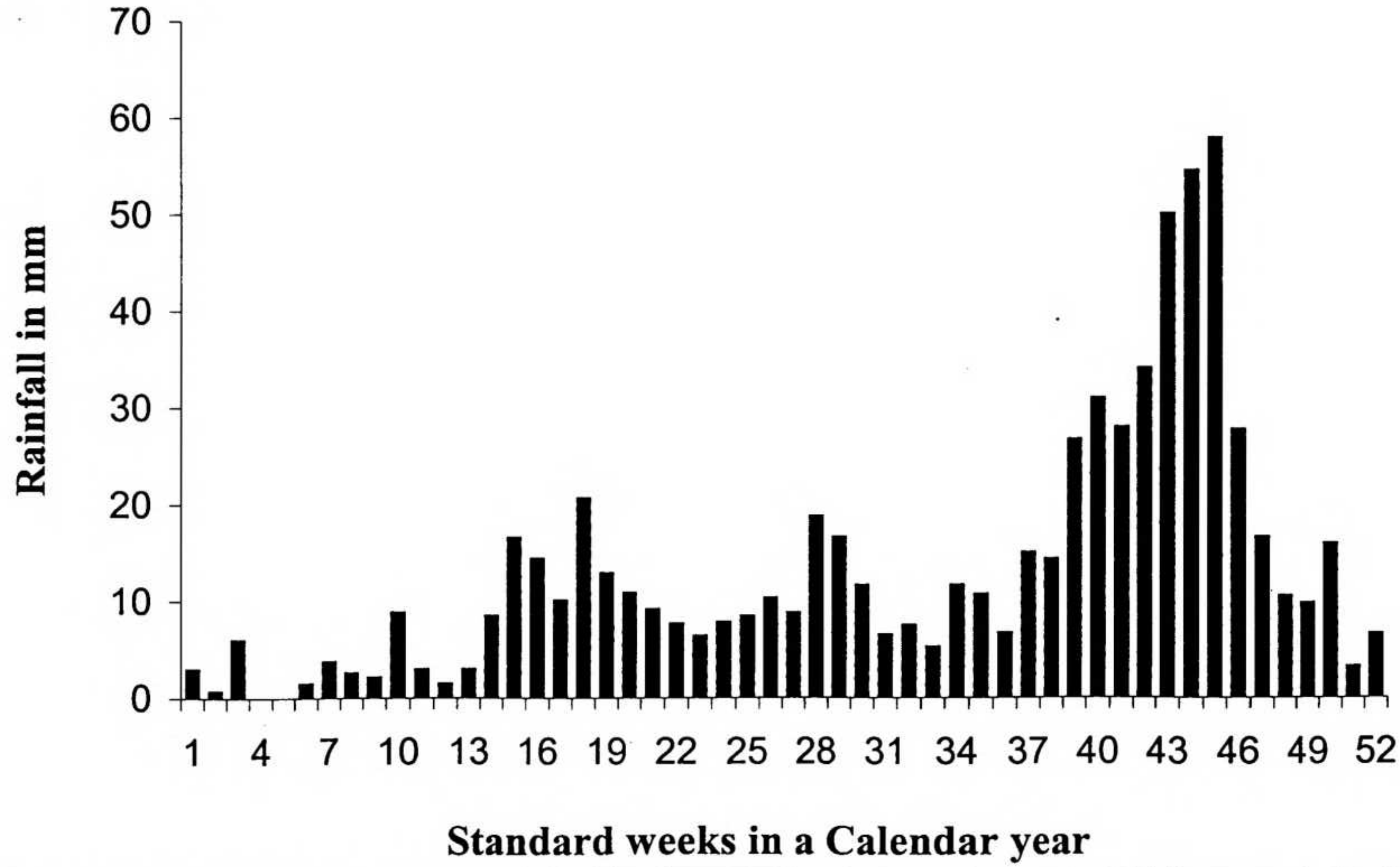
$1.5B^2 = 0.6875$

$\Rightarrow B^2 = 0.458 \Rightarrow B = 0.67m$

$\cong 0.75m$

Length (L) = 1.5 (0.75) =1.125m ≅1.25m

Fig. 3.3. Average Weekly Rainfall Distrinution



Assuming 6 hr of filtration the depth (d) can be calculated as

d = (Volume/ day) x 6 ÷(L X BX 24)

Depth of the filter bed (d) = $(3.3\times 6)\div(1.25\times 0.75\times 24) = 0.88$m

So, B = 0.75m, L = 1.25m and d = 0.88m

3.11. Water budgeting studies

For water budgeting analysis of SWCE complex the weekly demands and supplies have been arrived at during the study period. The different components of water demand and water supply have been finalised for estimating the water budgeting. The various components of water demand are drinking water need, washing, toilet needs and water requirement for the Theme Park. The supply constitutes the runoff collected from micro-catchment layout of Theme Park and rooftop surface of SWCE Workshop Complex using established system components.

3.11.2. Demand

Physical observations were carried out to assume the approximate values of drinking water need, washing need and toilet needs. During the physical observation the average number of persons working per day in the workshop premises were observed. The total drinking water demand was then calculated by multiplying the water requirement per person and the number of person working per day. Similarly washing needs were worked out by multiplying the number of buckets of water used for washing instruments with the capacity of each bucket of water.

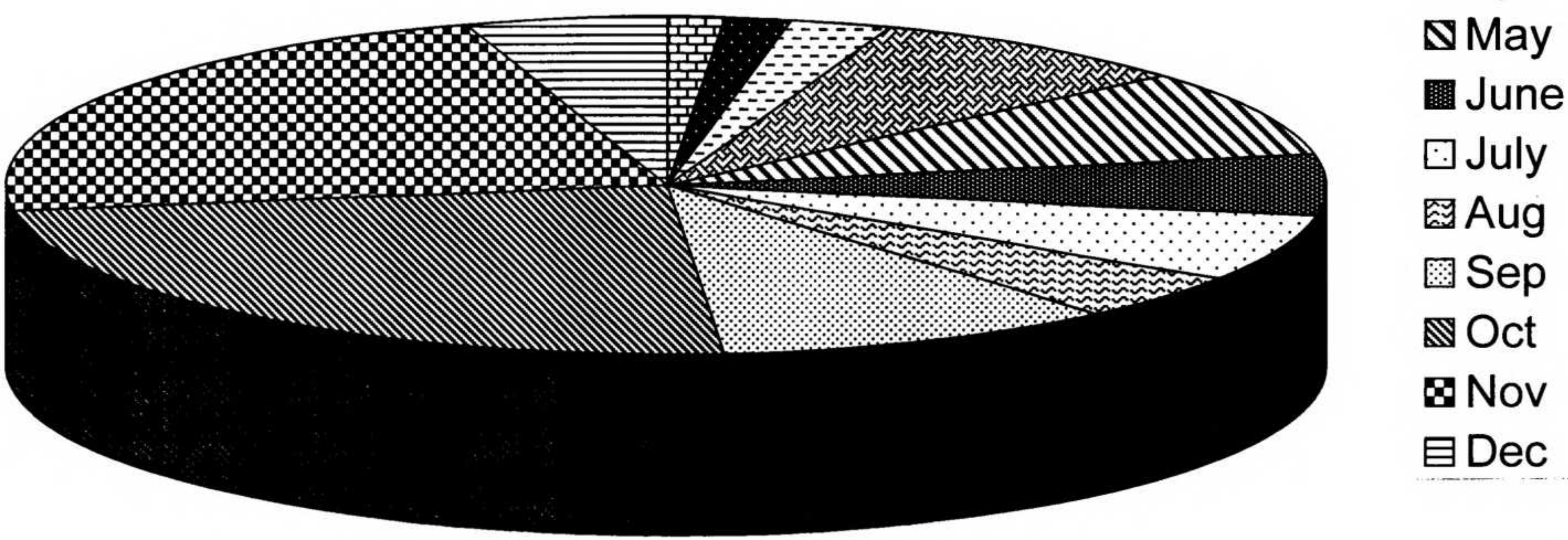
For estimating the evaporative water requirement for the Theme Park, the weekly Pan evaporative data were collected from the Meteorological Department of TNAU campus. The total depth of evaporative water requirement can be calculated as follows.

WR = Ep x Vp x Kc

Where

WR - Depth of evaporative Water requirement
Ep - pan evaporation
Kp - pan coefficient
Kc - crop coefficient

Fig. 3.4. Average monthly Rainfall Distribution



The total volume of evaporative water demand per standard week was then calculated by multiplying the Theme Park area with the depth of evaporative water requirement.

3.11. Supply calculation

The rainfall, which is the only source of supply is harvested by the roof top rain water harvesting system components and the Run off falling on the micro-catchment area of the Theme Park. The weekly rainfall data for the study area were collected from the Meteorological Department or TNAU campus. Average monthly rainfall distribution was shown in figure 3.4. Figure 3.3. shows the average weekly rainfall distribution. The volume of rainwater collected from rooftop has been calculated of assuming 30% losses; during collection. For further analysis of the amount of water that can be collected from the roof area of the whole campus this experimental results have projected.

3.12. Cost benefit analysis

The total cost incurred in the installation process of the rooftop rainwater harvesting for SWCE workshop building has been compared with the domestic corporation water supply of the Coimbatore district. The comparison cost was analysed. SWOT Analysis was made for the designed Rooftop rainwater harvesting system. SWOT analysis was made for the designed Rooftop Rainwater Harvesting System.

Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The Roof Water Harvesting technique has been used in the SWCE Workshop Complex in TNAU Campus. The workshop roof surface has the configuration of North light shell roof having a projected surface area of 39m x 32m. However, for the study purpose the projected area works out to 624 sqm. This collected rainwater is planed to be used for meeting the different demands in different seasons described as below.

4.1. Supply - Demand analysis for water harvesting needs

The water needs of Soil and Water Conservation Engineering workshop Complex has been categorised as follows:

4.1.1. Drinking water needs

The workshop complex is supposed to accommodate at least 60 persons per day including the students attending practical classes, the teachers handling the classes and the workers assisting the practicals. By physical observation the drinking water demand has been arrived at as 5 litres per day per person or 300 litres per day or 1500 litres per week.

4.1.2. Washing water needs

The Laboratory equipments pertaining to surveying, soil mechanics and water management practicals, need to be washed after the classes. The washing needs also cover for floor washing, hand washing etc. and has been physically observed to be around 50 litres per day or 250 litres per week.

4.1.3. Toilet needs

As the persons moving around the Laboratory complex during practical hours need to use the toilets and bathrooms, at least 3000 litres of water need to be stored in an overhead tank per a single week.

4.1.4. Water Harvesting Theme Park needs

The SWCE workshop complex also maintains a Theme Park on Rainwater Harvesting demonstration on Micro catchment water harvesting, Roaded catchment water Harvesting and other in situ water harvesting techniques (Plate 3.4). The area under the Theme Park works out to 37.4 sqm and the evaporative water demands are to be met out. The weekly evaporation from the Theme Park area has been found to range from 25 mm to 60 mm depending on the season viz. Pre monsoon season or South-West Monsoon or North-East monsoon season. Accordingly the weekly water demand has been worked out for the Theme Park. To accommodate a drip irrigation system for micro catchment layout a sump of diameter 1.5 m and depth of 2.7 m has been installed. The volume of the sump works out to 4800 litres which should be filled by diversion from the water harvested from rooftop during intensive rain.

4.1.5. Hydraulics lab water needs

The hydraulics and hydraulic machinery lab require water to be circulated from an underground sump with a storage capacity of 50,000 litres. It is proposed to fill the tank during intensive rains by filtered water collected from the rooftop. Normally the tank is cleaned twice a year and re-filled. This quantum of water cannot be distributed week wise and hence analysed separately.

The supply of water to the laboratory complex is at present done by transporting water from the Estate office of TNAU. It is proposed to meet all the water demand only by harvesting rainwater from rooftop, so that no water can be transported from outside.

Towards this end, rainfall data over a period of 25 years (1976 - 2000) has been analysed and the weekly distribution of rainfall as the input has been arrived at. It is important to note that a certain fraction of incident rainfall needs to be discarded as it may contain lot of impurities. Runoff coefficient of 0.7 is assumed for the present analysis accounting for 30% of losses due to wastage.

Table 4.1. WATER BUDGETING FOR SWCE WORKSHOP COMPLEX

Season	Standard week	Water demand in (litre)					Total demand in litre	Rain fall cm	Supply in litre			Deficit in litre	Excess in litre
		Drinking water	Washing	Toilet	Theme Park water requirement								
					Pan evaporation in mm	Theme Park (WR) evaporative			rooftop collection	theme park collection	total		
North east monsoon	1.	1500	250	3000	3.8	9948.4	14698.4	0.30	1310.40	1122	2432.4	12266	
	2.	1500	250	3000	3.9	10210.2	14960.2	0.07	305.80	261.8	567.6	14392.6	
	3.	1500	250	3000	4.2	10995.6	15745.6	0.61	2664.50	2281.4	4945.9	10799.7	
	4. Jan	1500	250	3000	4.6	12042.8	16792.8	0	0	0	0	16792.8	
Pre monsoon season	5.	1500	250	3000	5.1	13351.8	18101.8	0	0	0	0	18101.8	
	6.	1500	250	3000	4.7	12304.6	17054.6	0.15	655.20	561	1216.2	15838.4	
	7.	1500	250	3000	5.4	14137.2	18887.2	0.38	1659.80	1421.2	3081.0	15806.2	
	8. Feb	1500	250	3000	4.8	12566.4	17316.4	0.26	1135.70	972.4	2108.1	15208.3	
	9.	1500	250	3000	5.7	14922.6	19672.6	0.21	917.30	785.4	1702.7	17969.9	
	10.	1500	250	3000	6.0	15708.0	20458.0	0.88	3843.84	3291.2	7135.04	13322.96	
	11.	1500	250	3000	6.1	15969.8	20719.8	0.30	1310.40	1122	2432.4	18287.4	
	12. Mar	1500	250	3000	6.8	17802.4	22552.4	0.15	655.20	561	1216.2	21336.2	
	13.	1500	250	3000	6.8	17802.4	22552.4	0.30	1310.40	1122	2432.4	20120	
	14.	1500	250	3000	6.2	16231.6	20981.6	0.85	3712.8	3179	6891.8	14089.8	
	15.	1500	250	3000	6.4	16755.2	21505.2	1.66	7250.88	6208.4	13459.28	8045.92	
	16.	1500	250	3000	6.3	16493.4	21243.4	1.44	6289.92	5385.6	11675.52	9567.88	
	17. Apr	1500	250	3000	6.6	17278.8	22028.8	1.10	4804.8	4114	8918.8	13110.0	
	18.	1500	250	3000	6.0	15708.0	20458.0	2.10	9172.8	7854	17026.8	3431.2	
	19.	1500	250	3000	5.8	15184.4	19934.4	1.30	5678.4	4862	10540.4	9394.0	
	20.	1500	250	3000	7.6	19896.8	24646.8	1.10	4804.8	4114	8918.8	15728.0	
	21. May	1500	250	3000	6.8	17802.4	22552.4	0.92	4018.56	3441	7459.56	15092.9	

Contd....

Season	Standard week	Water demand in (litre)					Total demand in litre	Rain fall cm	Supply in litre			Deficit in litre	Excess in litre
		Drinking water	Washing	Toilet	Theme Park water requirement: Pan evaporati on in mm	Theme Park water requirement: Theme Park (WR) evaporative			rooftop collection	theme park collection	total		
South west monsoon	22.	1500	250	3000	6.3	16493.4	21243.4	0.77	3363.36	2880	6243.36	15000.04	
	23.	1500	250	3000	7.0	18326.0	23076.0	0.64	2795.52	2394	5189.52	17886.48	
	24.	1500	250	3000	7.0	18326.0	23076.0	0.78	3407.04	2917.2	6324.24	16751.76	
	25.June	1500	250	3000	6.9	18064.2	22814.2	0.84	3669.12	3141.6	6810.72	16003.48	
	26.	1500	250	3000	7.0	18326.0	23076.0	1.10	4804.8	4114	8918.8	14157.2	
	27.	1500	250	3000	6.1	15969.8	20719.8	0.88	3843.84	3291.2	7135.04	13581.76	
	28.	1500	250	3000	6.0	15708	20458.0	1.90	82992.2	7106	15405.2	5052.8	
	29.	1500	250	3000	6.7	17540.6	22290.6	1.70	7425.6	6358	13783.6	8507.0	
	30. July	1500	250	3000	5.7	14922.6	19672.6	1.20	5241.6	4488	9729.6	9943.0	
	31.	1500	250	3000	6.9	18064.2	22814.2	0.66	2882.88	2468.4	5351.28	17462.92	
	32.	1500	250	3000	5.8	15184.4	19934.4	0.75	3276	2805	6081.0	13853.4	
	33.	1500	250	3000	5.7	14922.6	19672.6	0.53	2315.04	1982.2	4297.24	15375.36	
	34.Aug	1500	250	3000	6.3	16493.4	21243.4	1.20	5241.6	4488	9729.6	119562	
	35.	1500	250	3000	5.1	13351.8	18101.8	1.10	4804.8	4114	8918.8	9183.0	
	36.	1500	250	3000	5.6	14660.8	19410.8	0.67	2926.56	2506	5432.56	13978.2	
	37.	1500	250	3000	5.3	13875.4	18625.4	1.51	6595.68	5647.4	12243.0	6382.32	
	38.	1500	250	3000	5.5	14399.0	19149.0	1.43	6246.4	4226.2	10472.6	8676.4	
	39.Sep	1500	250	3000	5.8	15184.4	19934.4	2.70	11796.3	10098.0	21894.6		1959.2
North east monsoon	40.	1500	250	3000	4.7	12304.6	17054.6	3.10	13540.8	11594.0	25134.8		8080.2
	41.	1500	250	3000	4.3	11257.4	16007.4	2.80	12230.4	10472.0	22702.4		6695.0
	42.	1500	250	3000	3.7	9686.6	14436.6	3.40	14851.2	12716.0	27567.2		13130.6
	43.Oct	1500	250	3000	3.5	9163	13913.0	5.00	21840.0	18700	40540.0		26627.0
	44.	1500	250	3000	3.1	8115.8	12865.8	5.45	23805.6	20383.0	44188		31322.8
	45.	1500	250	3000	2.8	7330.4	12080.4	5.80	25334.4	21692.0	47026.4		34946
	46.	1500	250	3000	3.1	8115.8	12865.8	2.80	12230.4	10472.0	22702.4		9836.6
	47.Nov	1500	250	3000	2.6	6806.8	11556.8	1.70	7425.6	6358.0	13783.6		2226.8
	48.	1500	250	3000	3.4	8901.2	13651.2	1.05	4586.4	3927.0	8513.4	5137.8	
	49.	1500	250	3000	3.5	9163.0	13913.0	0.98	4280.64	3665.2	7945.84	5967.1	
	50.	1500	250	3000	3.9	10210.2	14960.2	1.60	6988.8	5984.0	12972.8	1987.4	
	51.	1500	250	3000	3.6	9424.8	14174.8	0.32	1397.76	1196.8	2594.56	11580.24	
	52.Dec	1500	250	3000	4.2	10995.6	15745.6	0.66	2882.88	2468.0	8350.88	10394.7	

The cumulative weekly water demands and water supply have been plotted to find out the supply, demand gap (Fig. 4.1). The water demands for hydraulics lab could not be distributed week wise due to its one time collection during the rains only. The supply demand analysis would furnish the extra amount of water available during rain that can be distributed for filling Hydraulic lab tanks and the micro catchment water storage sump.

4.2. Water needs during the pre-monsoon season

From the Table 4.1 it is reckoned that for the pre-monsoon period extending from February through May, the total water demand excluding that of the hydraulics laboratory sumps and the Theme Park water storage sump, works out to 80,750 litres. This demand needs to be met from the excess rain harvested during the South West and North East monsoons using the rooftop water harvesting system.

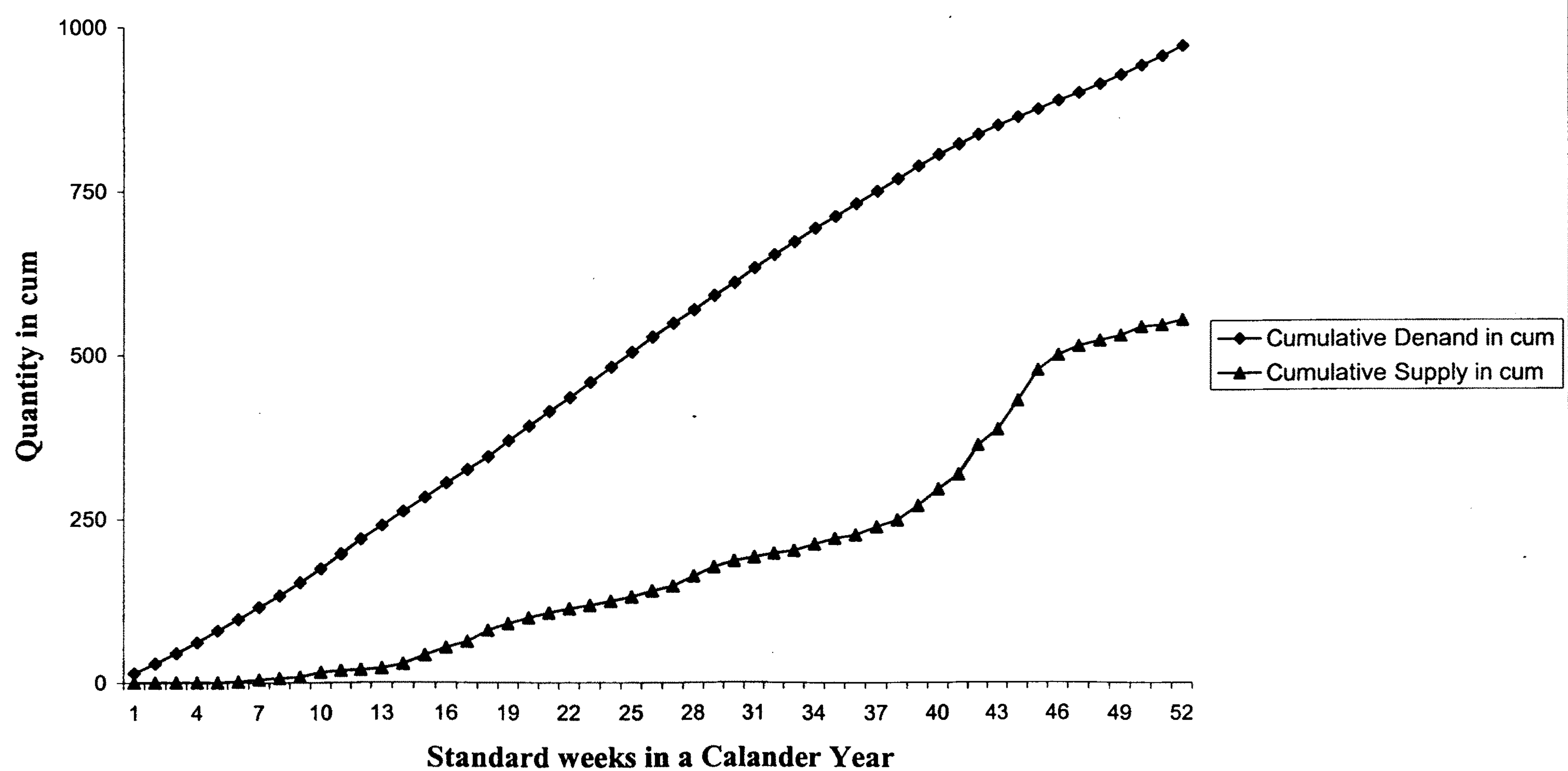
4.3. Water demand and water harvesting potential during South West monsoon

Normally 29% of total rainfall is received during the South West monsoon extending from June through September. From the Table 4.1, assuming 30% wastage and diversion of impurities, the harvestable rainwater potential accounts for 2.8×10^5 litres from the rooftop water harvesting system and 0.72×10^5 litres intercepted by the Theme Park water harvesting structures. Generally the evaporative demand decline during rainy seasons. The total demand for water towards drinking, washing, toilets and Theme Park water requirements amount to 3.2×10^5 litres. Over and above this requirement, the harvestable rainwater amounts to 80,000 litres considering proposed total roof area of SWCE Workshop Complex from the rooftop. The first priority of filling is given to the Theme Park water storage sump where storage capacity in 4800 litres. The remaining volume of harvestable water 75,200 litres in excess of the collection tank storage can be diverted to fill, a part of Hydraulics. lab storage sumps.

4.4. Water demand and water harvesting potential during North East monsoon.

In Tamil Nadu region a lion's share is taken by North East monsoon towards the supply of rainwater. In the study area 52% of rainwater is available during this season extending from October through January. From the Table 4.1, for an assumed runoff

Fig 4.1.Cumulative Supply Demand Curve



coefficient of 0.70 (30% losses) the harvestable rainwater amounts to 1.6×10^5 litres. The total demand for drinking washing, toilet and Theme Park evaporative water requirements amount to 1.11×10^5 litres. The storage sump of the Theme Park need not be filled up as it is already done during South West monsoon. Hence the excess volume of rainwater harvested amounting to 98,000 litres can be fully diverted to fill the hydraulics lab. Sumps considering the proposed roof area of SWCE Workshop Complex. The storage capacity of these sumps amounts to 50,000 litres or water. Any water in excess of this capacity can be diverted to the Pond available as a water harvesting structure at southern end of SWCE workshop premises. This pond, if lined with plastic sheets, can be used as a farm pond for supplemental irrigation of trees in the MCWH layouts, otherwise the pond can serve the purpose of recharging ground water table in the vicinity of SWCE workshop complex, so that a well can be drilled to facilitate consumptive use of ground water during non rainy seasons.

It should be remembered that in most part of Coimbatore district, the ground water table has gone beyond 100.0m, forcing the farmers and other water users to resort to mining even up to 300.0m to get water either for agricultural or for industrial purposes. Under such circumstances gradual delivery of excess rainwater available from the rooftop and through runoff from Theme Park can be beneficially used for raising up the water table.

4.5. Enhancement of Rooftop water harvesting potential.

The present study involves only 50% of the rooftop area draining rainwater towards the western side of SWCE workshop Complex, an equal amount of rain water flows towards the eastern side due to the provision of a crown at the middle at the gutter facilitating equal longitudinal gradient on both sides. If similar system components are provided at eastern side of Workshop Complex the Water Harvesting potential will be doubled thereby doubling the benefit cost proportion too. The additional water thus available can be stored in under ground sumps and by using a Drip or Sprinkler irrigation layout an aesthetic landscaping can be done all around the workshop complex.

4.6. Economic analysis or the Rooftop Rainwater Harvesting system developed.

The total cost involved towards the layout of rooftop water harvesting system components works out to Rs 14,000/-. The benefit accrued out of this system is realised in the form of collection and storage of the significance proportion a rainfall replacing the water needs which are normally met by transporting cart loads or lorry loads of water to the workshop complex. In Coimbatore region a lorry load at water (2000-3000 litre) would cost around Rs. 450/- per load. The total annual water demand for SWCE Workshop Complex can be reckoned from Table 4.1 including the hydraulics lab and Theme Park water storage sump as 8.6 x 10^5 litres which requires 43 lorry loads of water costing around Rs.3840/-. Assuming that the designed rooftop water harvesting system function satisfactorily for over 25 years cost proportion have been worked out. The average cost involved works at to Rs.130/- only. But the benefit accrued per year by of saving water from rainfall against the lorry loads of water works out to approximate Rs 320/- for month that is three times the benefit cost proportion per year is found to be around 36:1 indicating that rainwater harvesting brings in more benefit if we don't mind for the initial cost involved. The cost comparison Table 4.2 also suggest that rooftop water offers high level of benefit in comparison to the burden of expenses incurred by way at transporting lorry or cart loads of water.

Table 4.2. Cost Comparison Table

Items	Corporation water supply (A)	Cart load water supply (B)	Rooftop rainwater supply designed (C)
1. Initial cost of investment	Rs. 12,000/-	-	14,000/-
2. Life cycle	25	-	25
3. Monthly water tax	Rs. 65/-	Rs. 400-Rs. 500	-
4. Maintenance cost per month 1% annually	$= \frac{120}{12} =$ Rs. 10.0/-	-	1% annually = Rs. 11.67/-
5. Overhead cost per month including 10% interest on the fixed cost	Rs. 65/- + Rs. 100/- + Rs. 10.0/- = Rs. 175/-	Rs. 450/-	Rs. 116.67 + Rs. 11.67/- = Rs. 128/-

4.6.1. SWOT analysis

The SWOT analysis has been made to compared the potential capacity of the designed rooftop water harvesting system. SWOT stands per Strength Weakness Opportunities and Thrust.

Strength

(i) Environment friendly

(ii) Re use or Recycling of water is possible

(iii) Investment cost is not so high

(iv) Collection of good quality of water

Weakness

(i) Poor rainfall

(ii) Unequal distribution of erratic / distribution of rainfall

(iii) Lack of awareness and motivation

Opportunities

(i) To meet the ever increasing needs and requirements of population

(ii) Restricted availability domestic water

(iii) Good quality water

(iv) Yawning gap between domestic demand and supply

Thrust

(i) Poor acceptance rate

(ii) Easy availability of municipal water

4.7. Future thrust

The foregoing analysis on exploring the feasibility of rooftop rainwater harvesting yields encouraging results for transposing the water harvesting design for the entire TNAU campus if all the rooftop surfaces ranging from the Office building to Housing complexes can be profitably used to harvest rainwater. At present it is observed during intense rains that surface runoff generated within the campus including water derived from rooftop surface is simply gone as wastage without providing any storage facility. From the Table 4.1 it can be reckoned that from an average rainfall intensity of 10 cm/hr over one hour and at a runoff coefficient of 0.70 the total volume of harvestable rainwater from all roof surface of TNAU campus works at to 1.33×10^6 litres of water. The total rooftop area of TNAU campus is given in Annexure I. This harvestable quantum of rainwater with suitable treatment can be beneficially used for scientific lab. purposes, supplemented irrigation, drinking water needs of human beings and animals and other categories of water usages within the campus.

This case study has been limited only to the SWCE Workshop Complex as a sample and serves the purpose a stepping stone to take up an extensive study to compute the overall water balance and water budgeting for the entire TNAU campus.

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was taken up considering a roof surface area of 624 sqm. in the SWCE Workshop Complex of TNAU campus. Though the roof area is small it gives a fair conclusion of the potential of harvesting rooftop rainwater. The water demands of the Workshop Complex including the evaporative water requirements of the micro-catchment layout in the Theme Park have been worked out on standard week basis. Considering rain as the only source of water supply through out the year. Rainfall received during the pre-monsoon, Northeast and Southwest monsoon is 19%, 29% and 52% respectively for the study area.

The study was carried out to take the stock of the temporal and spatial water demands for various purposes in SWCE workshop complex. The average weekly rainfall was calculated from 25 years (1976-2000). Weekly rainfall data was considered as the source of supply for the workshop complex. The runoff water harvested in microcatchment areas of Theme Park as well as the evaporative needs of the Theme Park area were arrived at.

Two hydraulic Lab. sumps of capacity 26,000 and 24,000 litres are proposed to fill during the North East monsoon when the rainfall is intensive. The excess rooftop rainwater is diverted towards the micro-catchment sump during South West monsoon. It helps in irrigating the trees in the micro-catchment basin by a drip irrigation layout during the lean period.

The stagnated water in the Hydraulic lab sumps can be diverted towards the Pond at southern side of Workshop Complex to recharge the ground water. By lining the pond with polythene sheets the stored water can be used for supplemental irrigation to the Theme Park and can be used for piciculture also.

Considerable quantity of rainwater around two times can be stored to meet the demands by installing the similar system at eastern side or Workshop Complex.

The system components involved in the Rooftop Rainwater Harvesting have been designed as per the requirements. The filtering basin was designed to handle the rooftop rainwater. Sand and Gravel filter is effective in filtering the rain water and make it drinkable. Detention basin has been constructed to slow down the velocity rainwater, Collecting basin served the purpose of effective draining and diverting water towards the storage tank. Down pipes and StoneWare pipes of 15 cm diameter has been used for suitable draining of rainwater.

The total cost involved in the installation of rooftop rainwater harvesting system components is approximate Rs.14,000/- (Annex IV). The benefit accrued out of this system is realised in the form of collection and storage of the significance proportion of rainfall replacing the water needs which are met by transporting cart load or lorry loads of water to the workshop complex. The lorry loads of water works out to be Rs.450/- monthly, thus the benefit cost ratio is found to be around 36:1 per year. Providing similar system components at eastern side of the workshop complex the benefit can be double.

The total roof surface area at the TNAU campus works out to be (1.9 ha) (Annex. I). For an average rainfall intensity of 10 cm/ha over one hour duration at a runoff coefficient of 0.70 the total volume of harvestable rainwater from all roof surface of TNAU campus works out to 1.9×10^6 litres of water. This quantum of water with suitable treatment can be beneficially used for scientific lab requirements, supple mental irrigation, drinking water needs of human and animals and other categories of water usage within the campus.

References

REFERENCES

Achour,H., A. Zairi and N. Ben Mechlia. 1994. Water harvesting system: evaluation of soil moisture under micro-basins following various soil treatments. International Conference on Land and Water Resources Management in the Mediterranean Region., Valenzano., Bari, Italy 4-8 September 1994. No.(4),: 1159-1174.

Agrawal,R. 1995. Water of life. **Down to Earth Nov.15**,pp:49-50.

Anonymous.1999.Waterharvesting. **Down to Earth.May,31**,pp:19.

Anschutz, J., A. Kome, M. Nederlof, De R. Neef and De van T. Ven. 1997. Water harvesting and soil moisture retention. **Agrodok. 1997, No. 13**,pp: 92.

Arora, Y .K. and S.C. Mohan. 1994. Water harvesting and in-situ moisture conservation practices for fruit crops in Doon Valley. **Indian Journal of SoilConservation. 1994, (22)**, pp: 1-2,pp and: 63-71.

Bithu, B. D. 1994. Micro-catchment rain water harvesting in Western Thar desert, India, **ODI-Irrigation-Management-Network-Paper. No. 31**,: 20-27.

Boers, T. M. 1994. Rainwater harvesting in arid and semi-arid zones. ILRI, Netherlands. Publication 55,: 5.

Bruins, H. J., M. Evenari and U. Nessler. 1986. Rainwater-harvesting agriculture for food. **Applied Geography. 6, (1)**: 13-32.

Carter, D. C. and S. Miller.1991.Three years experience with an on-farm macro-catchment water harvesting system in Botswana. **Agricultural Water Management. 19 (3)**,: 191-203.

Das,D.C.1988. Water harvesting for water conservation in catchment and command area. **Proceedings of National Seminar on Water Conservation in Drought.II/WCM,** pp:1-32.

Dewan, M. L. 1988. Water harvesting, **Indian Journal of Soil Conservation. Vol.15,(1),**: 30-34.

Dhyani, B. L.,Ram Babu, Sewa Ram, V. S. Katiyar, Y. K. Arora, G. P. Juyal, and M.K. Vishwanathanan.1993.Economic analysis of watershed management programme in Outer Himalayas-A case study of ORP Fakot. **Indian Journal of Agricultural Economics.48(2)** :237-245.

Dijk, J. A., Van and J .A. Van Dijk. 1997. Simple methods for soil moisture assessment in water harvesting projects. University College Dublin, **Irish Republic.Journal of Arid Environments. (3),**: 387-394.

*Evenari, M., L. Shanan and N.H.Tadmor.1971.The Nager: The Challenge of a desert. **Harvad University Press.Camb. Mass.**PP: 345.

*Farrar, D. M. 1974. Aspects of water supply and conservation in some semi-arid regions of Africa. Ph.D. Thesis, University of Manchester Institute of Science and Technology, U. K.,pp:115-132.

Frasier, G. W. 1987. Water harvesting for collecting and conserving water supplies in Southwest Rangeland Watershed..ICRISAT. Patancheru, A. P. pp: 67-77

Fricke, T. B.1982, Bamboo- reinforced concrete rainwater collection tanks in Thailand Washington, D. C.. **International Working paper**.pp: 1-18.

Gainey, V. 1988. Water harvesting in Kenya's dry north-west. **Water and Irrigation Review. 8(3),**: 22-25.

Ghosh, G. 1999a. Hidden vessel holds the key. Appeared in **The Hindu ,Magazine section,June20,** pp:I-VIII.

Ghosh, G. 1999b. We look for what we have. Appeared in **The Hindu,Magazinesection, June 27,** pp:IV.

Ghosh,G.1999c. Scarcity to plenty is a matter of will. Appeared in **The HinduMagazine section,July 4,** pp: IV.

*Gielen, H. 1990. Water harvesting for trees. The practice of microbasins in Tahoua, Niger. AT Source. 18(2),: 14-17.

Gobin, A .M. L., P. Campling, J. Feyen and F.I. Idike. 1996. The role of rainwater harvesting for rural water supply in Enugu state in South-Eastern Nigeria. Belgium. **Science Technology and Development. 14 (3),**: 88-106.

Gould, J. E.1996. Rainwater utilisation in Botswana: problems and possibilities.Botswana. **Science Technology and Development. 14(3),**: 72-87.

Goyal, R. K., P. R. Ojasvi and T.K. Bhati. 1995. Economic evaluation of water harvesting pond under arid conditions. Indian Journal of Soil Conse-rvation. 23(1),: 74-76.

Grewal, S.S., S.P. Mittal, Y. Agnihotri, and L. N. Dubey.1989. Rainwater harvesting for the management of agricultural droughts in the foothills of northern India. **Agricultural Water Management. 16(4),**: 309-322.

Gupta, G.N., K.R. Choudhary, B. Singh and A. K. Mishra. 1993. Neem establishment in arid zone as influenced by different techniques of rain water harvesting, Rajasthan India. **Indian Forester. 119(11),**: 914-919.

Hall, N. 1982. Water Collection from thatch. **Water lines vol.1** London, pp:1.

Iyer, M. 1995.Water in the sand. **Down to Earth. May31,** :22-23.

Juyal. G. P. and R.K. Gupta.1985. Construction of LDPE film linked TANKAS in hills- A case study. **Indian Journal of Soil Conservation.Vol13,(1),** pp:10-13.

Kaufman, M.1983. From Ferro to Bamboo: a case study and techical manual. Yogyakarta Indonesia Yayasan Dian Desa.pp:34-51.

Kolarkar, A. S., K. N. K. Murthy, and N.Singh.1980. Water harvesting and runoff farming in arid Rajasthan. **IndianJournalof Soil Conservation. Vol8.**:113-119.

Kolarkar, A. S., K. N. K. Murthy, and N. Singh .1983. Khadin- a method of harvesting water for agriculture in Thar Desert, **Journal of AgriEnvironments.Vol6,** : 59-66.

Mahapatra, R. 1999a Coming bak to life. **Down to Earth. Vol.7,** pp:19.

Mahapatra, R. 1999b,Waters of life. **Down to Earth. Vol.7,** pp:19.

Mahoo, H., J. W. Gowing, N. Hatibu, B. Kayombo, D.A.N. Ussiri and C. Lungu. 1994. A rainfall-runoff model for rainwater harvesting design in Tanzania: comparison and validation of an empirical and a physical model. **SADC-land and water management research programme, Harare, Zimbabwe, 10-14 October, 1994.** pp: 105-118.

Mc Dowell, J.1976. Village Technology in East Africa. Nairobi UNICEF Regional Office. Publication .pp: 23.

Ministry of Water Resources.1998. Utilisation of Rainwater, Bhagirath.July-Sept.pp:166.

Mittal, H. K.., J. Singh, R.N. Chowdhury and M. Sivakumar . 1993. Effect of waterharvesting structure on groundwater recharge-a case study.**Proceedings of International Conference Wollongong, New South Wales, Australia, 8-11 February**, pp: 461-465.

Myers, L. E. 1975. Recent advances in water harvesting. **Journal of Soil and Water Conservation, May -June,**: 95-97.

National Academy of Sciences, 1974. More water for arid lands. **National Academy of Sciences, Washington, D.C.** pp: 154.

Norieku, E. 1980. Rainfall Harvesting Techniques in Ghana,Accra, Water Resources Research Unit, **Council of Scientific and Industrial Research**.

*Omwenga, J.M.1984. Rainwater harvesting for domestic water supply in Kisii,Kenya. PhD. Thesis. Tamper University of Technology.pp:36-77.

Oron,G. and G. Enthoven. 1987. Stochastic considerations in optimal design of amicro-catchment layout of runoff water harvesting. Israel. **Water-Resources Research. 23(7)**,: 1131-1138.

Oweis, T. Y. and A.Y.Taimeh.1996. Evaluation of a small basin water-harvestingsystem in the arid region of Jordan, Syria. **Water Resources Management. 10(1)**,: 21-34.

Prasad, R. 1979. Rural technologies for utilising surface waters. LectureNo 8. Bangalore, Dept. of Civil Engg. IIS. **Extracts appear in UNEP 1983**, pp: 183. pp:149-157 .pp:160-164.

*Proud, K.R.S. 1988. Water harvesting or run-off agriculture. Proceedings of the 1938-1988 Jubilee Conference of the Institution of Agricultural Engineers, co-sponsored by the Fellowship of Engineering, Robinson College, Cambridge, 12-15 September 1988. pp: 11-12.

Reddy, D.N., B.C. Barah and T. Sudhakar. 1993. Decline of traditional water harvestingsystems: tanks in the drought prone areas of Andhra Pradesh. **Indian Journal of Agricultural Economics. 48(1)**,: 76-87.

Renner, H. F. and G. Frasier. 1995. Microcatchment water harvesting for agricultural production. **Range lands. 17(3)**,: 79-82.

Sharma, K.D., O.P. Pareek and H.P.Singh. 1986. Microcatchment water harvesting for raising jujube orchards in an arid climate. **Transactions of the ASAE. 29(1)**,: 112-118.

Sharda, V. N. and S.S. Shrimali. 1994.Water harvesting and recycling in northern hillyregions. **Indian Journal of Soil Conservation. 22(1)**, pp:1-2,pp: 84-93.

Singh, A., S. Singh and R. P. Singh. 1994. Problems of water management in the Indian arid zone, Sustainable-development-of-the-Indian-arid-zone:-a-research-perspective.Volume dedicated to the memory of Dr.H.S. Mann. 133-137.

Subbaiah, R. 1991. Decision support for managing rainwater - A case study.**Indian Journal of Agricultural Engineering. (1)** . **1**,: 59-65.

Suleman,S., M.K. Wood., B.H. Shah and L. Murray. 1995. Development of a Rainwater harvesting system for increasing soil moisture in arid rangelands of Pakistan **Journal of Arid Environments. 31(4)**,: 471-481.

*Todd and Vittori. 1997. Texas Guide to Rainwater Harvesting, Texas WaterDevelopment Board in cooperation with the centre for maximum potential building systems, second edition, Austin, Texas.pp:118-126.

Vangani, N. S. and S. Singh.1994. Surface of water of the Indian zone. Sustainable Development of the Indian Arid Zone. pp: 33-42.

Waller, D.H. 1982. Rainwater as a water supply source in Bermuda. Rainwater Cistern Systems.pp: 55-71.

* Originals are not seen

Annexures

ANNEXURE-I

ROOFTOP AREA OF THE TNAU CAMPUS

A) Academic Buildings:

Sl No.	Name of the building	Roof area in m^2
1	Chemistry Sericulture House	191.37
2.	Insectary Building	189.70
3.	Microbiology Pot culture House	109.16
4.	Implement Shed (PBS)	10.00
5	Farm office and Seed Store room	91.88
6.	Cholam Lab (MBS)	193.60
7.	Farm Manager Office	77.38
8.	Implement Shed (MBS)	88.90
9.	Ragi Thiami Store(ICBS)	57.81
10.	Insectary No. 2	135.91
11.	Ginning and Capper Room	75.00
12.	Mitting Shed	154.00
13.	Kappa Store room	57.00
14.	Store Room	25.00
15.	Seed Store (PBS)	102.87
16.	Research Engineers Workshop	717.47
17.	Implement Shed No.2	10.00
18.	Insectary Shed	1929.00
19.	Gas House Building	86.86
20.	Diary Building	342.00
21.	Carriage and Food shed	109.44
22.	Central Store and Control Farm	367.90
23.	Student Implement Shed at Central Farm	367.90
24.	Diary Office Building	72.00
25.	Seed Store in (CT)	49.00
26.	Farm Office Building in (CT)	269.36
27.	Superintendent Office Central Farm	40.96
28.	Big Store Room (CT)	49.00
29	Seed room in M.B.S.	50.00
30.	Kappa Store Room No.3 (C.B.S.)	100.00
31.	Agro meteorological Observatory	10.00
32.	Office cum Store in Botanical Garden Lavatory in Botanical Garden	157.00 4.00
33.	Isolation Shed	45.00
34.	Store Room No.2 in Insectary	47.00
35.	Malt Factory Building	144.37
36.	Vargu and Seed Store	193.60
37.	Central Office Building	144.00
38.	Orchard Main Building	52.00
39.	Constructing Lecture hall in FTC	555.00
40.	Orchard Store Building	28.80
41.	Isolation Ward	90.00
42.	Seed Technology Building	600.00
43.	Soil and Water Conservation Block	168.00

44.	Animal Nutrition Building	878.00
45.	Additional Building for Seed Technology	122.00
46.	Service Station	27.00
47.	Guest House	261.00
48.	Farm Power Block	270.00
49.	Shed Godown at C.B.S. Construction of Godown at M.B.S.	220.00 67.31
50.	Seed Test Lab. In Seed Technology	210.00
51.	Seed Storage Godown at P.B.S.	138.39
52.	Insectary Building	643.00
53.	Seed Godown at P.B.S.	138.00
54.	A wet house for entomology	47.50
55.	Water closet Room at wet land	10.00
56.	Incubator cum Office cum Equipment Room	33.27
57.	All India Coordinate improvement Glass House	62.00
58.	Work Shop Building	1157.00
59.	Soil and Water Conservation Building	168.00
60.	Water Technology Building	2137.15
61.	Strength of Material Lab.	93.82
62.	Implement Shed in Engineering Lavatory	61.00 7.00
63.	Tiffin Shed in Malt Factory	20.63
64.	Insectary cycle Shed	39.00
65.	Oil Seed Lab.	222.00
66.	Fumigation Insectary	131.00
67.	Store Room No.1 in Insectary	47.00
68.	Coraya Room	47.00
69.	Cycle Shed Central Office	36.00
70.	Sound Proof Room	15.00
71.	Cold room near Green House	5.00
72.	Store Room in Wet land	200.00
73.	Samiyana in B.G.	75.00
74.	Lab for Minor millet (P.B.S.)	96.39
75	Latrine in Green House	12.00
76.	Flushed latrine in C.B.S.	12.00
77.	Seed Technology Lab in ACPI	303.00
78.	Plant physiology filed Lab.	213.00
79.	Pesticide Testing Lab.	467.00
80.	O/A Farm	13.00
81.	Office Building in Central Room	30.00
82.	Additional Lab. C.B.S.	160.00
83.	Radio isotope Lab	426.00
84.	Hydraulic Lab for Minor Irrigation	100.00
85.	Microbiology Building at ACRI	427.38
86.	Pollination Chamber	9.00
87.	Threshing Floor	197.00
88.	Museum Building	183.11
89.	Construction of Lab. For Biological Research	52.00
90.	Pesticide Toxicology Lab.	106.00
91.	Examination hall, Mushroom Lab, Bio control Lab.	478.00

TOTAL = 19231.22m^2

B) Administrative Building:

Sl. No.	Name of the Building	Roof area in m^2
1.	RI Building	3659.00
2.	Freeman Hall Building	3762.00
3.	Golden jubilee Building	3700.00
4.	PG Building	4000.00
5.	Ramasamy Sivam Building	4570.00
6.	Ramasamy Sivam Block Professional course Building	4760.00
7.	Basic science Building	920.00
8.	Horticultural Building	920.00
9.	Agricultural Engg. College Building	3750.00
10.	Central Administrative Building	655.00

TOTAL = 30,696. 00m^2

C) Hostels Building :

Sl. No.	Name of the Building	Roof area in m^2
1.	Rest House	502.00
2.	Dinning Hall in Long Block	115.45
3.	Combined Pavilion Reading room Students Club	102.00
4.	Hostel Block 1 to 6	376.25
5.	Hostel Block 14 to 15	254.36
6.	Ladies Club	71.35
7.	Reading Room for Students Stadium	237.00
8.	Bathroom in 11,14,15 Hostel Block	914.14
9.	Latrine	950.00
10.	New Hostel	5704.00
11.	Dinning Block for Agri Engg. College	1400.00
12.	Ladies Hostel	1052.00
13.	Canteen for Student	102.00
14.	Office Mess	15.00
15.	Fuel Shed at Hostel	12.00
16.	Teachers' Hostel	500.00
17.	Hostel for Minor Irrigation	337.00
18.	P.P.C. Hostel	59.00
19.	Tiffin Shed in Central Office	13.00
20.	Ladies Hostel p1 to p11	400.00
21.	P20 to p21	1311.7
22.	P26 to p29	600.00
23.	Construction of Student Hostel	591.00
24.	Trainees' Hostel	123.00
25.	Additional Dinning Hall for Teachers' Hostel	163.00
26.	Ladies Hostel	1450.00
27.	Pounding Kitchen for Ladies Hostel	63.00
28.	Common Additional Guest room	190.00
29.	Trainees' Hostel for Water Technology	321.00
30.	Kitchen cum dinning Hall for Ladies Hostel	123.00

TOTAL =16,740. 55m^2

D) **Staff Quarters :**

Sl No.	Name of the Building	Roof area in m^2
1.	A- Grade Bungalow A_1 to A_4	2820.00
2.	A-Type Qrs. $A_{1\ to}\ A_7$	1183.00
3.	B-Type (Tiled) $B_1$to B_{27}	3013.00
4.	C-type (Tiled) 1 to 59	5251.00
5.	C-type (Tiled) 61 to 63	267.00
6.	C-type (Pcc) 64 to 67	240.00
7.	D-type (Tiled) 1 to 53	3922.00
8.	D-type (Tiled) 55 to 58	296.00
9.	E Type (Tiled) 1	24.00
10.	E-type (Tiled) 2 to 6	120.00
11.	F-type (Tiled) 1 to 18	504.00
12.	F-type (Tiled) 20 to 40	500.00
13.	Throtile (tiled) 1to 10	170.00
14.	Throtile (Tiled) 11 to 14	108.00
15.	Sanitary Qrs. 1 to 8	240.00
16.	Drivers Qrs.1 to 6	300.00
17.	A- type (twin floor) 8 to 11	360.00
18.	Associate professors Qrs. 1 to 50	750.00
19.	Associate professors Qrs. 25	100.00
20.	AP Qrs.1 to 4	1680.00
21.	Hostel to irrigation	338.00
22.	Canteen	396.00
23.	South House	418.00
24.	Officers' Mess	70.00
25.	Art House	86.00
26.	Professors' Qrs	70.00
27.	Asso. Prof. Qrs. G.F.& F.T.	789.36
28.	Asso. Prof Qrs.1 to 4	636.00
29.	Subsidiary building for married scholars	160.00
30.	Subsidiary building for Teaching Staffs	117.00

TOTAL = 24,988. 36m^2

E) **Library Building:**

Sl. No.	Name of the Building	Roof area in m^2
1.	Old Library Building	650.00
2.	New Library Building	872.00

TOTAL=1522. 00m^2

F) **Health Facilities:**

Sl. No.	Name of the Building	Roof area in m^2
1.	Additional Sludge Plant	174.25
2.	University Dispensary	375.00
3.	Gymnasium Building	780.00
4.	Indoor Games Hall	70.00
5.	Sanitary Section	59.00
6.	Swimming Pool Office Building	240.00

TOTAL= 1698. 25m^2

G) **Cattle Shed Building:**

Sl. No.	Name of the Building	Roof area in m^2
1.	Cattle Shed at (P.B.S.)	12.00
2.	Cattle Shed at Implement Shed	91.00
3.	Cattle Shed at (M.B.S.)	64.00
4.	Cattle Food Store(P.B. S.)	10.00
5.	Cattle Shed at (C.B.S.)	50.00
6.	Cattle Shed at (C.B.S.)	64.00
7.	Cattle Shed at (C.T.)	141.75

TOTAL =432. 75m^2

H) **Other Buildings:**

Sl. No.	Name of the Building	Roof area in m^2
1.	Green House and Glass House	200.00
2.	Green House For Radiation genetics	200.00
3.	Pot-culture house for Sericulture	191.00
4.	Tuff-lib Glass House in Botanic Garden	104.00
5.	Glass House at PBS	258.50
6.	Screen House at Orchard	56.00
7.	Field Lab Glass House for Horticulture	89.00
8.	Green House in Botanic Garden	142.50
9.	Construction of Green House for Pathology Plant	200.00
10.	Construction of Green House in Botanic Garden	120.00
11.	Green House No.2 in Garden	259.00
12.	Field Lab. In WetLand, Cycle Shed, Pump House, Engine Shed etc.	7000.00
13.	Buildings in Botanic Garden	180.00
14.	Seed processing Building	180.00
15.	Threshing building	531.00
16.	Communication center Building	410.00
17.	Generator Room	388.00
18.	Mushroom Building	15.50
19.	Screen House for Entomology	34.50

20.	Recreation Hall for Students	200.00
21.	Gas Cylinder room	100.00
22.	Add.	14.00
23.	Crop field lab. For Nursery Technology	40.00
24.	Crop Field Lab for Forestry Complex	103.00
25.	Construction of Wood Technology Lab for Forestry crop	180.00
26.	Pollination Chamber	180.00
27.	Paddling Pool	39.00
28.	Threshing Floor	369.00
29.	Threshing Floor in Orchard	262.00
30.	Toilet Block for Farm Labors	4.30
31.	Vehicle Shed	177.00
32.	Construction of labor Toilet	8.04
33.	Bio-control Lab Building	389.00
34.	Cycle Shed for Vaigai Hostel	65.00
35.	Cycle Shed for Forestry and co--	65.00
36.	Dinning hall cum bit for Community Hall	109.00
37.	Pollination Chamber	42.00
38.	Mist Chamber	52.00
39.	Pord in Botanic Garden	52.00
40.	Gas Room	124.00
41.	Gas cylinder Room	6.60
42.	Net House for Microbiology Lab.	45.00
43.	Green House at Garden	59.00
44.	Office Building and Store to the Garden	74.00
45.	Mist Chamber near CPMB Building	26.00
46.	Staff Club	37.00
47.	Screen House in Botanic Garden	137.00
48.	Mist Chamber in Botanic Garden	38.07
49.	Generator Room in Botanic Garden Building	71.00
50.	Const. Of propagation storage room to RI& HC	54.00
51.	Construction of Veterinary Dispensary Block	85.00
52.	Mushroom Building	24.00
53.	Hardening Chamber	15.00
54.	Generator room for TNAU	7.00

TOTAL = 13,592. 00m^2

Source: Estate Office, TNAU, CBE-3.

ANNEXTURE II

CORPORATION DOMESTIC WATER SUPPLY CHARGE

S.No.	Item	Description	Quantity	Rate per Quantity Rs.
1.	Road cutting charge	B.T. Surface Over semidense surface Asphaltic surface	Per sqm Per sqm Per sqm	815 1022 1511
2.	Mason/fitter charge	-	Per one person	150
3.	Labour charge	-	Per one person	150
4.	Service charge	-	Per total life cycle	3000
5.	Water deposit charge	-	Per total life cycle	1000
6.	Meter box	-	One	80
7.	Water meter	-	One	450
8.	PVC/AC saddle	-	One	80
9.	Stop cork	-	One	75
10.	Accessories			
	(i) Tap	-	One	130
	(ii) GI Entrance	-	One	190
	(iii) Regulator valve	-	One	250
	(iv) GI elbow	-	One	20
	(v) GI Reducer	-	One	20
	(vi) GI union	-	One	160
	(vii) Pipe	GI pipe	Per meter length	170
		PVC pipe	Per meter length	110
		CI pipe	Per meter length	107
11.	**Cart load drinking water supply** Approximate cost per 100 l = Rs.150/- Lorry or cart load supply including transportation charge (10,000 litre) = Rs.20/-			

Source: Corporation Office, Dept of water supply, Coimbatore.

ANNEXURE III

COST ANALYSIS FOR DOMESTIC WATER SUPPLY

A. Fixed cost

(i) Road cutting charge

An average change for road cutting
Taking a mean value of all the road cutting

$$\text{Mean road cutting charge} = \frac{814 + 1022 + 1511}{3}$$

= Rs. 1115.66
= Rs. 1116.0/- (avg.)

Assuming an avg. length of road cutting = 8 cm
Width of road cutting = 0.5 cm

Area excavated = 8.0 x 0.50
= 4.00 sqm

Avg. road cutting charge per sqm = Rs. 1116.0
Road cutting charge for 4.0 sqm = 1116.0 x 4 = Rs. 4464.0/-

(ii) **Labour charge**

One labour charge	= Rs. 150/-
Assuming two labour	= 150 x 2 = Rs. 300/-
One fitter charge	= Rs. 150/-
Assuming one fitter	= Rs. 150/-
Total labour and fitter charge	= Rs. 300 + 150 = Rs. 450/-

(iii) Corporation deposit	= Rs. 1000/-
(iv) Service charge	= Rs. 3000/-
(v) Water meter	= Rs. 450/-
(vi) Meter Box	= Rs. 80/-

Total fined cost = Rs. 4464 + 450 + 1000 + 3000 + 450 + 80
= Rs. 9444/-

B. Accessories cost

(i) Pipe charge

Pipe length = 8.0 m
1 m length GI pipe cost = Rs. 170/-
cost of 8.0 m length pipe = 170 x 8
= Rs. 1360/-

(ii) G.I. Entrance

Assuming 1 GI entrance.
Cost of GI entrance = Rs. 190/-

(iii) Regulator value

Assuming 1 Regulator value
Cost or one regulator vlaue Rs. 250/-

(iv) Tap

Assuming 2 tap connection
Cost per one tap connection = Rs. 130/-
Total Cost of tap connection = 130 x 2 = Rs. 260/-

(v) GI union

Assuming 2 GI union
Cost of one GI union = Rs. 160/-
Cost of GI onion = 160 x 2 = Rs. 320/-

(vi) Elbow

Assuming five elbow
Cost of one elbow = Rs. 20/-
Total cost of the elbow = 20 x 5 = Rs. 100/-

(vii) GI reducer

Assuming five G1 reducer
Cost of one reducer = Rs. 20/-
Total cost of G1 reducer = 20 x 5 = Rs. 100/-

Total accessories cost

= 1360 + 190 + 250 + 260 + 320 + 100 + 100
= Rs. 2580/-

Total cost of the system

= Fined cost + Accessories cost
= 9444 + 2580 = **Rs. 12,024/-**

Monthly water charge

Monthly water charge for 10,000 litre = Rs.25/-
Mean monthly consumption for a family = 25,000 litres

$$\text{Avg. monthly water charge} = \frac{25}{10,000} \times 25,000$$

= 62.5/-
= Rs. 65/- (approximate)

Source: Corporation Office, Dept of water supply, Coimbatore.

ANNEXURE IV

COST ANALYSIS FOR ROOF TOP WATER HARVESTING SYSTEM

1. Diameter of AC drain pipe = 15.0 cm

   Standard length of one commercial pipe = 3.048 m

   (Length of pipe to be provided from roof to ground level = 4.3 m)

   Number of pipes required = 6

   Cost of one pipe = Rs 244/-

   $\therefore$ Cost of 6 pipes = 244×6 = Rs 1464/-

2. Diameter of AC bend = 15.0 cm

   Number of bends required = 6

   Cost of one AC bend = Rs 62/-

   $\therefore$ Cost of 6 bends = 62×6 = Rs 372/-

3. Diameter of Stone ware pipe = 15.0 cm

   Length of one stone ware pipe = 0.61 m

   Laying and fixing of SW pipe = Rs. 75/-

   Cost of one stone ware pipe for 25 m length = Rs 60/-

   $\therefore$ Cost of 45 SW pipes = 60×45 = Rs 1875/-

4. Cost of one PVC storage tank of capacity 2000 litters = Rs 6,100/-

5. **Earth work excavation**

   (a) For Storage tank

   Depth of the pit = 2.12m

   Diameter of the pit = 1.828m

   $\therefore$ Quantity of earth work excavated = $\Pi/4\ (1.828)^2\ (2.12) \cong 5.6$cum

   (b) For Stilling basin

   Length of the stilling basin =1.49 m

   Breadth of the stilling basin = 0.91 m

   Depth of the stilling basin = 0.6048m

   $\therefore$ Quantity of earthwork excavated = $149 \times 0.99 \times 0.6048 \cong 0.90$ cum

(c) For filtering basin

Length of filtering basin = 1.49 m

Breadth of filtering basin = 0.99 m

Depth of filtering basin = 1.15 m

∴ Quantity of earthwork excavated = $1.49 \times 0.99 \times 1.15 \cong 1.7$ cum

(d) For collecting basin

Length of collecting basin = 0.99 m

Breadth of collecting basin = 0.55 m

Depth of collecting basin = 1.15 m

∴ Quantity of earthwork excavated = $0.99 \times 0.55 \times 1.15 \cong 0.63$ cum

∴ Total quantity of earthwork excavated = 5.6+0.9+1.7+0.63

= 8.83 cum

Cost of earth work per cum = Rs 51.50/-

∴ Total cost of earth work excavation = $51.50 \times 8.83 \cong$ Rs 454.75/-

6. **Quantity of Sand**

Provide 0.15 cm thick bed of sand above the foundation

(a) For PVC storage tank :

$$\Pi/4\,(1.828)^2\,(0.15) \cong 0.39\text{cum}$$

(b) For stilling basin:

$$1.49 \times 0.99 \times 0.15 \cong 0.22 \text{ cum}$$

(c) For filtering basin:

$$1.49 \times 0.99 \times 0.15 \cong 0.22 \text{ cum}$$

(d) For collecting basin:

$$0.99 \times 0.55 \times 0.15 \cong 0.08 \text{ cum}$$

∴ Total quantity of sand required = 0.39+0.22+0.22+0.08 = 0.91 Cum

Cost of one cum of sand = Rs 646.30/-

∴ Total cost of sand filling = $646.30 \times 0.91 \cong$ Rs 588.00/-

7. Plain cement concrete in foundation (1:4:8)

0.15 m depth cement concrete is to be laid.

(a) For tank pit:

$$\Pi/4\ (1.828)^2\ (0.15) \cong 0.39\text{cum}$$

(b) For stilling basin:

$$1.49\times 0.99\times 0.15 \cong 0.22 \text{ cum}$$

(c) For filtering basin:

$$1.49\times 0.99\times 0.15 \cong 0.22 \text{ cum}$$

(d) **For collecting basin**:

$$1.21\times 0.55 \times 0.15 \cong 0.08 \text{ cum}$$

$\therefore$ Total quantity of concrete required = 0.39+0.22+0.22+0.08

= .91 cum

Cost of one cum of cement concrete (1:4:8)= Rs 1519.20/-

$\therefore$ Total cost involved in cement concrete foundation construction =

1519.20 ×0.91 = Rs1382.50/-

8. II class chamber B.W. in cement mortar 1:5 half of a brick wall thickness

(a) For stilling basin:

Length of stilling basin = 1.37 m

Breadth of stilling basin = 0.87 m

Depth of stilling basin = 0.3048 m

$\therefore$ Volume of B.W.= $(1.37\times2+0.87\times 2)\ (0.3048) \times 0.12$

$\cong 0.16$ cum

(b) For filtering bed:

Length of filtering bed = 1.37m

Breadth of filtering bed = 0.87m

Depth of filtering bed = 0.85m

$\therefore$ Volume of B.W.= $(1.37\times2+0.87\times 2)\ (0.85) \times 0.12$

$\cong 0.46$ cum

Side brick wall volume = 1.37x0.3048x0.12=0.05 cum

$\therefore$ Net Volume of B.W = 0.46-0.05 = 0.41 cum

(c) For collecting basin:

Length of collecting basin = 0.87m

Breadth of collecting basin = 0.4248m

Depth of collecting basin = 0.85m

$\therefore$ Volume of B.W. = $(0.87\times2+0.4248\times 2)(0.85)\times 0.12$

$\cong 0.26$ cum

Side brick wall volume = 0.87x0.85x0.12=0.08 cum

$\therefore$ Net Volume of B.W = 0.26-0.08 = 0.18 cum

$\therefore$ Total Volume of B.W. = 0.16+0.41+0.18= 0.75 cum

Cost for I St class B.W. masonary = Rs 1972.60/-

$\therefore$ Total cost of B.W. = 1972.60×0.75 = Rs 1479.50/-

9. Plastering the B.W. using C.M. 1:4, 12.5 mm thick

Area to be plastered inside the stilling basin

= 2(1.25+0.75)(0.3048)= 1.22 sqm

Area to be plastered inside the filtering basin

= 2(1.25+0.75)(0.85)= 3.4 sqm

Area to be plastered inside the collecting basin

= 2(0.3048+0.75)(0.85) = 1.8 sqm

$\therefore$ Total area to be plastered = 1.22+3.40+1.8 = 6.42 sqm

Cost per square meter of 12.5 mm thick plastering (1:4) = Rs57.20/-

$\therefore$ Total cost of plastering the brick wall using C.M. (1:4), 12.5mm thick = 57.20×6.42 = Rs 367.20/-

10. **Total Installation cost:**

(i) Cost of AC drain pipes = Rs 1464/-

(ii) Cost of AC bends = Rs 372/-

(iii) Cost of SW pipes = Rs 1875/-

(iv) Cost of PVC storage tank = Rs 6,100/-

(v) Cost of Earthwork excavation = Rs 454.75/-

(vi) Cost of Sand filling = Rs 588.0/-

(vii) Cost of Cement concrete foundation (1:4:8)= Rs 1382.50/-

(viii) Cost of Ist class B.W.(1:5)
half of brick wall thickness = Rs 1479.50/-

(ix) Cost of plastering the B.W. using 1:4 C.M. 12.5 mm thickness
= Rs 367.20/-

∴ Total installation cost = **Rs 14083/-**

Source: Estate Office, TNAU, CBE-3

ANNEXURE V

PWD SCHEDULE OF RATE (2000-2001)

S.No.	Item	Description	Quantity	Rate per Quantity
1.	Earth work Excavation	-	Per cum	Rs.51.50
2.	Sand filling	-	Per cum	Rs.646.30
3.	Plain cement concrete (PCC) in foundation	1:4:8 1:5:10	Per cum Per cum	Rs.1519.20 Rs.1426.00
4.	IInd class chamber (a) brick masonary work	1:3 (below ground foundation work) 1:5 - (do) -	Per cum Per cum	Rs.2155.20 Rs.1978.00
	(b) 11.5 cm partition wall	1:3	Per sqm	Rs.261.00
5.	Plastering of wall (a) 12.5 mm thick	1:3 1:4	Per sqm Per sqm	Rs.63.90 Rs.57.20
	(b) 20.0 mm thick	1:3 1:4	Per sqm Per sqm	115.60 106.10
6.	Laying and fixings of SW pipe 15.0 cm dia	-	Per m length	Rs.75.00
7.	RCC with 20 mm gravel; 7.5 cm thick	-	Per cum	Rs.2620.00

Source: Estate Office, TNAU, CBE-3.