EVALUATION OF RAIN WATER HARVESTING TANKS IN M.A.U., CAMPUS

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DISSERTATION

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IN

SOIL AND WATER CONSERVATION ENGINEERING

By

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JUNE - 2007

DEDICATION

DEDICATED TO

My

PARENTS,

SISTERS & FRIENDS

CANDIDATE'S DECLARATION

I, Hereby Declare that the dissertation or part there of has not been submitted by me to any other University or institution for a degree or diploma.

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CERTIFICATE-II

This is to certify that the dissertation entitled **"Evaluation of Rain Water Harvesting Tanks in M.A.U., Campus"** submitted by **Mr. Kulkarni Vinayak Padmakar** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (Agril. Engg.)** in the subject of **Soil and Water Conservation Engineering** has been approved by the students advisory committee after oral examination in collaboration with external examiner.

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ABBREVIATIONS

Agric.	:	Agriculture
Agril.	:	Agricultural
ASAE	:	Americal Society of Agricultural Engineering
B.C.	:	Before christ
B.W.	:	Bottom width
Cm	:	Centimeter
Cons.	:	Conservation
Dev.	:	Development
E	:	East
et al.	:	and all
Fig.	:	Figure
gm/cc	:	Gram per cubic centimeter
H	:	Height
ha	:	Hectare
ha.m	:	Hectare meter
i.e.	:	that is
ICRISAT	:	International Crop Research Institute for Semi-arid Tropics
ISAE	:	Indian Society of Agricultural Engineers
J.	:	Journal
kg	:	Kilogram
km	:	Kilometer
m	:	Meter
M.A.U.	:	Marathwada Agricultural University
M Hm	:	Million hectare meter
m/ha	:	Meter per hectare.

m^2	:	Meter square
m^3	:	Meter cube
$m^3/p/y$	:	Meter cube per person per year
mm	:	mili meter
N	:	North
Res.	:	Research
Rs.	:	Rupees
Sci.	:	Science
Sr.No.	:	Serial number
T.W.	:	Top width
t/ha/yr	:	tonnes per hectare per year
T_1 to T_6	:	Tank number 1 to 6
viz.	:	Namely
W_1	:	Well number 1
W_2	:	Well number 2

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INTRODUCTION

CHAPTER I

INTRODUCTION

Water is essential for all life and is used in many different ways. It is also a part of the larger ecosystem in which the reproduction of the bio diversity depends. Fresh water scarcity is not limited to the arid climate regions only, but in areas with assured rainfall the access of fresh water is becoming a critical problem. Lack of water is caused by low water storage capacity, low infiltration, larger inter annual and annual fluctuations of precipitation (due to monotonic rains) and high evaporation demand.

The term of water harvesting was probably used first by Geddes of the University of Sydney. He defined it as the collection or storage of any form of water either runoff or creek flow for irrigation use. Meyer's of USDA, USA has defined it as the practice of collecting water from an area treated to increase runoff from rainfall. Recently Currier, USA has defined it as the process of collecting natural precipitation from prepared watershed for beneficial use. Now-a-days water harvesting has become a general term for collecting and storing precipitation as runoff or creek flow, resulting from rainfall in soil profile and reservoirs both over surface and under surface. Previously this was used for arid and semi arid areas, but recently their use has been extended to sub humid / humid region too. In India water harvesting means utilizing the erratic monsoon rain for raising good crops in dry racks and conserving the excess runoff water for drinking and for recharging purposes.

History of Rain Water Harvesting

Water harvesting like many techniques in use today is not new. It was practiced as early as 4500 B.C. While the early water harvesting techniques used natural materials, 20th century technology was made it possible to use artifical means for increasing runoff from precipitation.

Evenari and his colleagues of Israel have described water harvesting system in the Negve desert. The system involved clearing hill sides to smooth the soil and increase runoff and then building contour ditches to collect the water and carry it to lower lying fields where the water was used to irrigate crops. By the time of the Roman Empire, these runoff farms had evolved into relatively sophisticated systems.

The research in India on this subject is recent. Work is taken up at ICRISAT, Hyderabad, Arid Zone Research Institute, Jodhpur, Central Research Institute for Dryland Agriculture (CRIDA). Hyderabad, Agricultural universities and other dry land research centers throughout India.

In Pakistan, in the mountainous and dry province of Balukhistan, bunds are constructed across the slopes to force the runoff to infiltrate. China, with its vast population, is actively promoting rain and stream water harvesting. One very old but still common flood diversion technique is called 'Warping' (Harvesting water as well as sediment).

When water harvesting techniques are used for runoff farming, the storage reservoir will be soil it self, but when the water is to be used for livestock, supplementary irrigation or human consumption, a storage facility of some kind will have to be produced. In countries where land is abundant, water harvesting involves harvesting or reaping the entire rain water, storing it and utilizing it for various purposes. In India, it is not possible to use the land area only to harvest water and hence water harvesting means use in the rainwater at the place where it falls to the maximum and the excess water is collected and again reused in the same area. Therefore the meaning of water harvesting is different in different areas/countries. The methods explained above are for both agriculture and to increase the ground water availability.

The water harvesting for household and for recharging purposes is also in existence for long years in the world. During rainy days, the people in the villages used to collect the roof water in big vessels and use it for household purposes. The people in the rural areas in south east Asian Countries used to collect the roof water by placing four big earthen drums in four corners of their houses. They use this water for all household purposes and only if it is exhausted they go for well water. The main building of the Agril college at Coimbatore was constructed 100 years ago and they have collected all the roof water by pipes and stored in big under ground masonry storage tanks. This rainwater is used for all laboratory, which require pure and good quality water. Using the same principle, all the rainwater falling on the terrace in all the buildings constructed subsequently was collected. Even the surface water flowing in the natural drain in the campus is also diverted by providing obstructions to the abandoned open wells to recharge ground water.

Hence Rain water harvesting is as old as civilization and practiced continuously in different ways for different purposes in the world. Need has come to harvest the rainwater including roof water to solve the water problems everywhere not only in the arid but also in the humid region.

Need For Rain Water Harvesting :

Water is becoming a scarce commodity and it is considered as liquid gold. The demand of water is also increasing day by day not only for Agriculture, but also for household and industrial purposes. It is estimated that water need for drinking and other municipal uses will increase from 3.3 MHm to 7.00 MHm in 2020/25. Similarly the demand of water for industries will increase four fold i.e., from 3.0 MHm to 12.00 MHm during this period. At the same time more area should be brought under irrigation to feed the escalating population of the country, which needs more water.

The perennial rivers are becoming dry and ground water table is depleting in most of the areas. Country is facing floods and drought in the same year in many states. This situation can be controlled to a grate extent through water conservation, harvesting and efficient management.

The rainfall is abundant in the world and in India. But it is not evenly distributed in all places. India being monsoonic country, the rain falls only for 3 to 4 months in a year with high intensity, which results in more runoff and soil erosion. Total rain occurs only in about 100 hours out of 8760 hours in a year. It is also erratic and falls in 3 or 4 years. This is very common in many parts of the country.

If the availability of water is 1700 $m^3/p/y$, there will be occasional water stress, and if it is less than 1000 $m^3/p/y$ it is under water scarcity condition. Though India is not under water stress, there is no need for panic since it is possible to manage this condition as in the case of Israel where the availability is about 450 $m^3/p/y$ by means of water harvesting, water conservation and water management.

Water scarcity/stress is not limited to the arid regions; but it is extended in high rainfall areas also. Chirapunji receives more than 11000 mm of annual rainfall, still the people face drinking water problem before monsoon commences, whereas in Ralegoan Siddhi, in Maharashtra there is no water scarcity problem though the annual average rainfall is only about 450 mm. Hence to mitigate water problem/drought etc., there is an urgent need to follow our ancestral way of water harvesting and the latest technologies adopted in soil and water conservation measures on watershed basis including roof water harvesting etc.

The theme paper on water vision 2050 of India, Water Resources Society (IWRS) has indicated that a storage of 60 MHm is necessary to meet the demand of water for irrigation, drinking and other purposes. But the present live storage of all reservoirs put together is equivalent to about 17.5 MHm which is less than 10 per cent of the annual flow in the rivers in the country. If the project under construction (7.5 MHm) and those contemplated (13 MHm) are added, it comes to only 37.5 MHm and hence we have to go a long way to build up storage structures in order to store 60 MHm.

All the above details indicate the need for water harvesting measures in urban and rural area for the use of Agriculture, drinking and other purposes.

Methods of Water Harvesting in Rural and Urban Areas

There are different/various systems of water harvesting depending upon the source of water supply as classified below.

a) *In situ* Rain water harvesting

- Bunding and terracing
- Vegetative/Stone contour barriers
- Contour trenching
- Contour stone wells
- Contour farming
- Micro catchments
- Tie Ridging methods

b) Direct surface runoff harvesting

- Roof water collection
- Dug out ponds/storage tanks
- Tankas
- Khaduns
- Uranis
- Temple tanks
- Diversion bunds
- Water spreading

c) Stream flow/runoff harvesting

- Gully control structures
- Check dams – temporary, permanent
- Silt detension tanks
- Percolation ponds
- Farm ponds
- Sub surface dams
- Diaphragm dams

d) Micro catchments/watershed

- Inter terrace/inter plot water harvesting
- Conservation bench terrace

e) Runoff inducement by surface treatment

- Use of cover materials – Aluminium foils.
- Plastic sheet, bentonite, Rubber etc.
- Using chemicals for water proofing, water repellent etc.

Runoff harvesting by constructing the reservoir and big size ponds or tanks in the area is one of the long term harvesting technique. The design criterions of these structures are given as under:

1. Watershed should be contributing a sufficient amount of runoff.
2. There should be a suitable collection site, where water can be safely stored.
3. There should be the provision of suitable methods for minimizing the various types of water losses such as seepage and evaporation, during storage and its use in the watershed, and
4. There should also be some suitable method for efficient utilization of the harvested water for maximizing crop yield per unit volume of water available.

To design a runoff harvesting system and its recycling, the proper estimation of water yield from the catchment and the water requirement of the area should be done in the beginning of project formulation. This will help in arriving at the most economical design. The use of too large area or too small catchment area without taking care of the pondage area is always inappropriate as there is danger of safety and life of the structure due to fluctuation of runoff volume.

The main purpose of storing water is to provide irrigation to the cropped area however; suitability of such water storage bodies is justified only if the water is made to store at a specific location for a longer period of time and also prudent use of stored water. Storage changes in surface water sources are affected by a number of factors and, therefore it is necessary to workout the water balance of such bodies to chalk-out the future strategies for efficient, effective and judicious management of available water.

Considering all above view; the project is planned to evaluate rain water harvesting tanks in M.A.U. micro-watershed, with following objectives.

OBJECTIVES :

1. To analyze the rainfall data for runoff estimation.
2. To evaluate rain-water harvesting tanks with respect to the design.
3. To study the evaporation and seepage losses from rain water harvesting tanks.
4. To estimate the area to be irrigated from harvested rain water.
5. To study the effect of rain water harvesting on ground water recharge.

REVIEW
OF
LITERATURE

CHAPTER II

REVIEW OF LITERATURE

This chapter gives a brief review of relevant literature cited to undertake present work on evaluation of rain water harvesting tanks in Marathwada Agricultural University micro watershed. The work most pertinent to the present study has been reviewed and presented in this chapter. The literature on the importance of water harvesting tanks, design parameters, storage losses from tanks, effect of water harvesting on ground water recharge and economic aspects of water harvesting tank along with comprehensive review directly or indirectly relevant to the objectives of the study have also been included in this chapter under the following sub heads.

2.1 Importance of water harvesting tank.
2.2 Parameters in planning tank.
2.3 Essentials requirement of tank.
2.4 Design of tank.
2.5 Storage losses from tank.
2.6 Ground water recharge.
2.7 Economic evaluation.

2.1 Importance of water harvesting tank :

Howard Matson (1943) has studied on needs of farm pond. He narrated that farm pond is chief source of water supply for livestock, irrigation, farmstead uses and fish production. He also explained that a pond which is properly constructed, fertilized, stocked and managed,will produce as much as 500 pounds of fish annually for each acre of surface area. He also studied on planning of farm pond for storing water and considering the variables such as seepage losses.

Sastry *et al.* (1980) has studied the farm ponds for assured protective irrigation for Rabi crops in doon valley. The studies conducted at the Central Soil and Water Conservation Research and Training Institute, Deharadun indicated that the runoff water thus harvested can be recycled with forms an intergral part of successful crop management programme. The limited water available in the farm ponds should be utilized at the earliest opportunity i.e. at presowing stage covering larger area for a given depth of water for optimum yields. It is also stated that farm ponds serve dual purpose of storing water for crop life saving irrigation and at the same time minimize the flood hazard in the downstream.

Mann and Ramrao (1981) showed that, the better rainwater utilization by harvesting and recycling increased the efficiency of available land and water resources. The potential productivity of treated regions appeared to be two to three times higher than what was attained by the traditional system of production.

Gajri *et al.* (1982) worked on rain water harvesting and its recycling for maximization of crop production. Study reflected that water harvesting systems which consists of collecting and storing, in suitable reservoirs, the excess runoff from the catchment and its use as crop life saving irrigation would help increase and stabilize yields in the dryland areas.

Sastry *et al.* (1983) studied on farm ponds and their influence on flood retardance. In this article the effect of land treatment on runoff originating in the land phase and its retardance by locating a farm pond was studied. The study indicates that considerable retardance of volume and peaks can be achieved. He also concluded that watershed treated with graded terraces generates low runoff in the land phase as compared to untreated watersheds. Scope of improving the performance of farm pond through a rational schedule of using available water for crops such as paddy could be further explored.

Verma *et al.* (1984) studied on feasibility of storage of runoff in dugout ponds and its use for supplemental irrigation in Punjab. He suggested that dugout ponds are able to collect at least 8 to 10 cm of runoff even during the drought year, which is sufficient to provide for one supplemental irrigation to the donor area of its equivalent. One irrigation at pre-sowing or 30-40 days after sowing increased wheat yield significantly and gave greater stability of yield over the years.

Srivastava *et al.* (2004) stated that plateau areas of Orissa as well as eastern region, traditional irrigation systems viz. large dams, canal network or deep tube wells, are not feasible due to topographical and geo-hydrological reasons. The Water Technology Centre for Easten Region in Bhubaneshwar has developed a tank cum open dug well system for providing a reliable irrigation source in this area. The system is comprised of tanks and open dug wells in series. While tanks store runoff, which is recycled for irrigation, the open dug wells harvest water seeped from tanks. The system has been evaluated in a field in Keonjhar district with six tanks and five wells in two transects. The total command area of the system was 23 ha and the total irrigation potential was 44.5 ha. The total cost of system was Rs. 7.80 lakh making the cost of irrigation resources creation being Rs.17528/ha, which is much less than approximately Rs.1.00 lakh for major and medium irrigation project in the IX plan. Furthermore, these systems can be constructed and maintained by locally available skills. The returns from the system in the first year for both transects were 20 per cent of the total investment and 58 per cent by second year, indicating that the system can pay off very early with no gestation period. This system can be adopted on a watershed basis having a multi-tanks, multi-well system to create an irrigation potential of more than 30 per cent to bring the whole area under the irrigated area category.

2.2 Parameters in planning tank

Howard Matson (1943) suggested the following parameters in planning pond

a) Selection of site
b) Size and shape of watershed area together with its physical characteristics
c) Desirable ratio between watershed and storage capacity
d) Probable minimum runoff
e) Expected minimum rate of runoff
f) Types of outlets
g) Spillway or other outlet
h) Loss of evaporation

2.3 Essential requirement of tank

Robert (1947) listed the following essential requirements of pond

a) The tank should meet the essential requirement of water
b) Supply of pond must be of good quality of water
c) The pond must have adequate spillway capacity to maintain the elevation
d) The pond must have an impervious fill and floor

2.4 Design of Water Harvesting Tank

Beasley (1952) has studied on determining the effect of topography and design on the characteristics of farm pond. He suggested that the most efficient pond is one that stores the greatest quantity of water for the least amount of work required in its construction.

He gives factors affecting storage efficiency of ponds as follows.

a) The topography of the area.
b) The radius of curvature of pond dam.
c) The depth of water in the pond.
d) The depth of water stored above the original ground line compared to the depth obtained by excavation.
e) The top width of the dam.
f) The side slopes to be used on the dam and in the excavation.
g) The amount of free board to be provided.

Remson Irwin and Randolph (1958) have worked on design of irrigation ponds using pond as ground water storage. He determines equations and curves to relate the pond discharge and drawdown to pond dimensions and hydrologic properties of the aquifer. They stated that these equations and curves can be used to determine the pond dimensions and drawdown needed to obtain the desired discharge under given hydrologic conditions. The methods given by them are based on consideration of the contributions to pond yield from both pond storage and ground water storage.

Chittaranjan (1982) has studied on water harvesting in farm ponds and recycling of harvested water. Accordingly, water is normally stored in tanks- dugout or impounded or combination of both. He gives storage design considerations points as follows:

a) Catchment and water yield – Their should be a proper relationship between catchment and size of storage based on average expected amount of runoff. It is estimated that water yield works out to 0.5 ha.m for every 10 ha. of catchment.

While selecting the optimum size of storage allowance has to be made for storage losses such as evaporation and seepage are inevitable.

b) Economic storage - Best location in the area that permits the maximum storage with least amount of earthwork i.e. we should aim at greater storage excavation ratio.

c) Dimensions of pond.

Samra and Verma (1990) concluded that the design of water harvesting tanks and supplemental irrigation system is highly location-specific and thus, makes it very difficult to develop a general model, which can be used for all areas. A procedure for the design of water harvesting tanks for rainfed farming in northen Punjab, India was developed which can be modified and used for other rainfed areas. It was observed that the total cost of tank per unit of capacity decreased with increasing tank capacity. For maximum benefit, the tanks should be designed on the basis of lowest assured runoff for presowing irrigation to wheat. The appropriate probability level of lowest assured runoff for tank design increased with increasing catchment area and varies from 40 to 80 per cent. The benefit cost ratio of such tanks varied from 1.60 to 4.56 for catchment areas 1 to 100 ha.

2.4.1 Selection of the site for the tank

Carrekar (1945) suggested that the first consideration in the pond construction is its location and a narrow depression between two opposite slopes with a wide flat area slope generally makes the best side. He also told that to prevent seepage from the pond a core wall should extend down under each dam to impervious material free of roots and other organic matter.

Verma (1981) reported that, the location of the pond should be at lowest point of catchment. An ideal location in the water disposal system. Earthwork verses water storage ratio should be minimum. Site should be such as to have possibility of gravity irrigation.

Sharda and Shrimali (1994) stated that the selection of the suitable water harvesting system for any location depends upon complex and environmental factors. The location of the tank or pond should essentially be at the lowest point of the catchment and where the largest storage volume can be obtained with least amount of earth fill. This generally occurs where valley is narrow, relatively steep and slope of the valley floor permit a large deep basin. In areas where embankment type construction is not feasible owing to topographic considerations, dugout or excavated ponds can be constructed in a relatively flat terrain. Since they can be constructed to occupy minimum exposed area for a given storage capacity, they can be advantageously used in area where evaporation losses are high.

2.4.2 Shape and dimension of the tank

Pottor and Kermyold (1946) stated that high storage efficiencies of pond are desirable. The two major losses components are seepage and evaporation. Seepage losses can be reduced by selecting a proper shape and that gives the ratio of quantity of water stored to the wetted surface area value should be higher. Circular and square shape would give higher value than rectangular, semi circular and horse shoe shapes. Minimum surface area for the same capacity of tank is important factor for minimizing evaporation losses.

Juyal and Gupta (1985) revealed that in the Himalayan region storage tanks locally known as 'tankas' of capacity ranging from 10 cum to 20.4 cum have been successfully constructed at farmer's field level. The top length varying from 5 to 6.5 m and width 3.5 to 5.0 m have been found suitable with side slope of 1:1 and depth 1.6m.

2.4.3 Capacity of the tank

Isgur (1951) studied on computing excavation and capacity of dugout ponds. He concluded that dugout ponds are built with buldozers and have the side slopes at 2:1 and the end slopes at 4:1. Designed storage capacity must be based upon requirements and probability of a reliable supply of runoff. Design of the storage capacity and watershed requirement should take into account both, evaporation and storage losses.

Gupta *et al.* (1974) studied on design considerations of dual purpose ponds. He stated that the dual-purpose dugout ponds fill in a very significant gap in the conventional surface drainage system and offer many advantages. According to him the dugout ponds in a flat country can serve the dual purpose of surface drainage and water storage. He also stated that the capacity of dugout pond increases more and more rapidly with increase in the height of the embankment and that the capital cost of storage decreases with increase in storage to excavation ratio.

Verma (1981) suggested that the capacity of pond should be designed in such a way that the pond is full at the end of monsoon. The depth of tank should be 2 to 5 m. side slopes should be about 1.5:1.

Bhandarkar *et al.* (1993) conducted studies on potential of water harvesting and recycling in rainfed area of Bhopal. They concluded that on an average 30 to 35 cm of water, out of 120 cm of average annual rainfall could be harvested and stored in dugout ponds about 3 m deep and having submergence area of 10 to 15 per cent of the watershed. With the runoff stored in ponds two irrigations could be given to 50 per cent watershed area in the kharif and entire area in rabi. One irrigation during rabi at presowing and another during critical growth stage had increased the grain yield by 51 to 90 per cent in different crops.

Kanetkar and Kulkarni (1999) gives the method of determining the capacity of farm ponds. Accordingly to them the reservoir volumes are determined from contour maps. The area enclosed by each contour line is measured by a planimeter. Knowing the vertical distance between the first and second contour lines and their areas, the volume of water between them may be calculated either by trapezoidal formula or by prismoidal formula.

Trapezoidal formula,

$V = D/2\ (A_1+A_2)$

Prismoidal formula,

$V+ D/6\ (A_1+4A_m+A_2)$

Where,

A_1 = Top area, m^2 , A_2 = Bottom Area, m^2

A_m = The mid area, m^2

D = The contour interval, m

V = volume, m^3

Stephen *et al.* (2005) from the field survey revealed that the storage capacities of existing farm ponds ranged between 30 and 100 m^3, though most of the farm ponds were on the lower range (30-50 m^3). The adequacy of the farm ponds, in terms of size of the catchments, storage capacity and meeting crop water requirements was also evaluated. The results revealed that considering rainfall characteristics, the catchment sizes can generate adequate runoff to meet supplemental irrigation requirement if water losses, especially on sandy soils, were controlled. Water balance analysis showed that evaporation and seepage losses account for 30-50 per cent of the total seasonal water storage in most farm ponds. The evaporation losses ranged from 0.1 to 0.3m^3 day^{-1} and seepage losses from 0.03 to 0.4 m^3 day^{-1} on clay soils and more than 2 m^3 day^{-1} on sandy soils. However, despite the water losses, the seasonal rainfall generated enough runoff for a 50m^3 farm pond, which is adequate to irrigate a kitchen garden of 300-600 m^2. Due to the limited amount of runoff, water use efficient drip irrigation was recommended instead of the current wasteful hand watering application method.

2.5 Storage losses from tank

Seepage and evaporation are the two losses from the pond. Gajri *et al.* (1982) concluded that in order to minimize the seepage and evaporation losses, storage volume should be maximized in relation to the exposed surface area. Because the volume of water stored per unit wetted area increases as the depth of the tank increases in relation to its breadth.

Khandelwal (1985) conducted the experiments for determining the rate of evaporation from the pond surface, rate of seepage and percolation losses through the ponds at village Salkuti at Midnapore district of West Bengal. There are 94 farm ponds with water storage capacity of 174731 ha.cm out of which 1049.62 ha.cm is lost due to the evaporation and seepage losses and 6987.69 ha.cm would be available for irrigation.

Ranade *et al.* (2002) stated that evaporation from water surface of the tank was one of the main factors responsible for depletion of tank water storage. Location having vertisol soil is very much suitable for the construction of water harvesting tank, as the seepage rate is found only one tenth to that of the total storage volume available.

2.5.1 Evaporation loss

Ponds improperly designed and poorly constructed have large losses from evaporation and seepage. These losses may result in the low storage efficiencies. Evaporation losses to be find out from the following linear relationship.

$$E = S + B\,Ep$$

Where,

E = Pond losses, cm

S = Seepage losses, cm

B = A constant which expressing the ratio of pond to the pan evaporation loss.

Ep = USWB class A pan evaporation, cm.

Soil and water division committee suggested that evaporation from the pond should be taken as 70 percent of measured amount from USWB class A pan.

Watlon (1969) reported that evaporation may account for up to 50 per cent of the water losses in open shallow reservoirs and up to 20 per cent in deep reservoirs, liquid chemicals such as aliphatic alcohol, floating of wax, blocks of light weight concrete, polystyrene, wax rubber, plastic have been suggested for suppression of evaporation. He narrated that above suggested material are effective but the initial cost of treatment is high.

Khan (1992) studied that influence of climatic parameters on rate of evaporation from free water surface are described. Air temperature was found to be the principal factor affecting evaporation. Water temperature influenced evaporation directly by conveying radiation energy and was it self effected by evaporation. The effect of the relative humidity of the air seemed to be for out weighted by other climatic factors. At times wind had a effect on evaporative climatic factor under the condition prevailing at the test site complemented each other in either increasing or decreasing evaporation.

Subramanya (1992) gives formula for calculating the evaporation from reservoir.

$V = A\ Ep\ Cp$

Where,

V = Volume of water lost in evaporation, m^3

A = Average reservoir area, m^2

Ep = Pan evaporation loss, m.

Cp = Pan coefficient.

He also gives methods for reduction of evaporation losses as under:

1) Reduction of surface area.
2) Mechanical covers: Permanent roofs over the reservoir, temporary roofs and floating roofs such as rafts and light weight floating particles can be adopted whenever feasible.
3) Chemical films: This method consists of applying a thin chemical film on the water surface to reduce evaporation. Chemicals such as cetyl alcohol and stearyl alcohol are used.

Raghunath (2000) gives measures to reduce reservoir evaporation as under:

1) Storage reservoir of more depth and less surface area
2) By growing tall trees like causerinna on the wind ward side of the reservoir to act as wind breakers.
3) By spraying certain chemical or fatty acids and formation of films e.g. monomolecular layers of cetyl alcohol.
4) By removing water loving weeds and plants like phreatophytes from the periphery of the reservoir.
5) By providing mechanical coverings like thin polytherne sheets to small agricultural ponds and lakes.

6) By developing underground reservoir, since the evaporation from a ground water table is very much less than the evaporation from water surface.
7) If the reservoir is surrounded by huge trees and forest, the evaporation loss will be less due to cooler environment.

Singh (1995) reported that several antievaporants viz., plant residues (Straw, wood bark and straw dust), oil emulsions, fatty alcohols, gum mixtures, polyethylene oxides and cationic, anionic and non ionic chemicals etc. could be used in prevention of evaporation losses in farm ponds. He further told that wax is an unusual, recently tested evaporation suppressant. He concluded that rubber and plastic floats can cut evaporation by about 80 per cent.

2.5.2 Seepage loss

Husenappa *et al.* (1979) worked on trend of storage losses from unlined farm ponds in Doon valley and concluded that the seepage losses from unlined farm ponds are extremely high and these losses must be considered while designing the farm ponds. He further observed from his study that an inverse geometric relationship exists between seepage looses and time and established that seepage loss at any time is directly related to the hydraulic head available in the pond.

Verma (1981) studied water harvesting for life saving irrigation of rainfed crop in Punjab. He suggested many sealing materials like bentoite, Butyl rubber, Concrete bricks, Polythene, soil cement, lime mortar, Bitumen, Latex, Emulsion etc. for seepage control.

Grewal *et al.*, (1982) revealed that the effect of some soil and site properties on seepage losses from three small storage reservoirs developed in the Kalka area of Siwalik region for rain water harvesting and supplemental irrigation was evaluated. It was observed that on an average 16-42 percent of the total stored monsoon rainwater was lost through evaporation and seepage before it is utilized for 'Rabi' crop irrigation. The seepage loss on an average varied from 6.2 to 20.0, 0.4 to 1.2 and 2.0 to 10.1 mm/day in Sukhomajri Reservoir Nos. Sm I, II and III with the corresponding heads varying from 2.0 to 3.4, 8.4 to 9.3 and 2.5 to 4.1 metres respectively the seepage losses decreased with the decrease in hydraulic head in each case.

Sastry *et al.* (1982) has worked on the structural measures for efficient control of seepage from dugout ponds. He concluded that the storage efficiency of the ponds mainly depends on storage losses i.e. seepage, evaporation and evapotranspiration and storage/ excavation ratio. He also observed that the seepage losses tend to stabilize after 8 to 10 years of the construction of the farm ponds.

Verma *et al.* (1984) stated that for lining the tank bottoms 800 gauge polythene film is quite suitable and brick and cement (7.5 cm thick) has been found suitable for lining the sides of the tank. But seepage losses through brick pores are still above the tolerable limits.

Juyal and Gupta (1985) reported that development of water resources play an important role in hilly agriculture. The water storage tanks constructed with cement masonary being costly, low cost LDPE film lined tanks were tried at the operational research project on watershed management at Fakot on farmer's field. The cost of LDPE lined tanks has been founded to be less than half of cement masonry ones cum water stored per year of excepted life period.

Kale *et al.* (1986) has studied on effect of various sealant materials on seepage losses in tanks in lateritic soil in Konkan region of Maharashtra having bulk density 1.02 g/cc, field capacity 34 per cent and permanent wilting point 18 per cent. At the end of his study, he concluded that polythene cement + soil plaster (2:10) and cement + soil plaster (3:10) could be considered for lining purpose in the tanks to reduce the seepage losses in lateritic soils.

Table 2.1 : Seepage rate and losses as influenced by various sealent materials at Dapoli, Dist Ratnagiri (Maharashtra).

Treatment	**Ave. Seepage (l hr^{1})**	**Percentage rate (l hr^{1}) seepage loss over control %**
Control	134.56	100.00
Compaction to maximum bulk density (1.60 g/cc)	71.32	52.96
Cow dung + Paddy husk + Soil plaster (1:1:10)	123.10	91.49
Cement plaste at bottom (1:6)	94.21	69.99
Cement + Soil plaster	6.10	4.53
Cement + Soil plaster (2:10)	5.42	4.04
Polythene lining	2.33	1.72
Paddy husk ash plaster	84.10	62.50
Costal saline soil plaster	39.64	29.47
Fly ash + sand plaster	18.14	13.47
Bentonite clay plaster	87.53	65.03

Sastry and Mittal (1987) studied on water harvesting and its recycling in Doom valley. They reported that lining of dugout ponds with brick and cement mortar was effective in reducing seepage losses by about 20 percent but seepage was dependant on head of water and varied from 0.28 cm/ day to 10.4 cm/ day as the head increased from 0.5 m to 2.0 m.

Srivastva and Bhatnagar (1989) studied on LDPE film lined conveyance channel for hilly irrigation system, they told that LDPE film lined channel was found to be stable with negligible seepage losses. They concluded that the cost of lining a conveyance channel with stone masonry and LDPE film was worked out to be Rs. 144.00 and Rs. 27.00 per meter respectively. In this study the lined channel was constructed with a rectangular cross section and a side wall or R.R. (Random Rubble) dry stone masonry (12.5 cm thick with cement pointing (1:3).

Kale and Deshmukh (1990) used black LDPE polythene (1000 gauge) as a lining materials under lateritic soil conditions. They reported that lining of only beds of big dugout farm ponds was found inadequate in significantly reducing the seepage losses. They concluded that the average specific percolation loss of 5.14 l/hr/sqm under unlined condition was reduced to only 3.88 l/ hr/ sqm i.e. by 24.5 per cent after lining the bed of farm pond.

Ranade *et al.* (1993) in a comprehensive study evaluated the performance of different sealants in dugout pond (8 x 8m top , 2 x 2m bottom and 1.5 m depth size) constructed in black clay soils of Indore region of Madhya Pradesh. It was observed that silpaulin plastic film was most effective in controlling seepage followed by LDPE film and straw, cow dung paste.

Table 2.2 : Seepage rate ($l/m^2/hr$) from different lined dugout farm ponds under various heads.

Head m	Bentonite	Control	LDPE	Soil + Straw + cow dung	Soil cement	Silpaulin
1.45	18.40	16.00	2.20	3.10	9.50	0
1.30	13.00	12.90	2.20	2.40	9.00	0
1.15	10.40	11.10	2.20	2.20	6.40	0

2.6 Ground water assessment :

Khillare and Kulkarni (1990) studied effect of soil conservation practices on ground water in micro watershed of 118.1 ha located in solapur district. Data on water level in 5 wells before and after provision of soil conservation structures indicated the rise in water table in all the 5 wells measured by 14.3, 13.2,17.7, 17.9 and 10.10 per cent respectively.

Mathuria (1990) stated that about 30 per cent of the Dinderi block with an area of 1200 square km of Mandul district (M.P.) was available for cultivation, to adopt the programme approach for estimation of dynamics recharge in cultivable, valley plains only by utilizing water levels fluctuation data of key observation wells. They suggested that a few artificial recharge structures viz. percolation tanks, sub-surface dykes, berries and collector with recharge wells and their effect be monitored in the ground water regime of the micro-basins.

Reddy and Khybri (1991) observed that the ground water level in the open wells and bore wells started rising from the end of June till the end of September and later declining till the first week of June.

Phadnis *et al.* (1998) studied the impact of water harvesting structures on ground water recharge in semi-arid region of Maharashtra, Recharge of ground water due to construction of percolation tank and two nala bunds were observed through open wells below water harvesting structure. Level of water in the wells from surface was maximum during May 1991 in all the wells under study. The range of water level fluctuations varied from 1.1 m to 4.0 m in all well, during August while in September it varied from 0.0 m to 7.3 m.

Janardhan *et al.* (2006) reported that declining water level trends and yields of well, deterioration of ground water quality and drying up of a shallow wells are common in many parts of India. This is mainly attributed to the recumence of drought years, over exploitation of ground water increase in the number of ground water structures and explosion of population. In the sub continent, saving of water has to be done on the days it rains. India receives much of its rainfall in just 100 hr, in year mostly during monsoon period. If this water not captured or stored, the rest of the year experience a precarious situations manifest in the water scarcity. The objective behind the construction of surface dams in the Swarnmukhi river basin was to harvest base flow infiltrating into sandy alluvium as waste to the sea and there by to increase ground water potential for maching future water demand. An analysis of hydrograph of piezometer of four subsurface dam, monitored during October 2001-December 2002 reveals that there as an average rise of 1.44 m in post monsoon and 1.80 m in pre monsoon period after the subsurface dam were constructed further during free monsoon month of June, much before construction of subsurface dams in October 2001, the water level was found fluctuating in range of 3.1-10 m, in contrast to the fluctuation period following construction of dam hence planning of rain water harvesting entails identified most suitable location for sub surface dam.

2.7 Economic evaluation

Tejwani and Rambabu (1982) discussed the case studies with respect to economics of various soil and water conservation programs in the country. In the studies B/C ratios has more than 1.06, which justified the economical worthiness of the programs.

Narayan *et al.* (1987) studied on the evaluation of supplemental irrigation through farm ponds on drylands. The study analyses the economics of utilization of farm pond water in medium deep black soils in dryland areas based on crop response obtained at the research station Bijapur. The cost of unit quantity of water stored has been estimated by amortization of the investment cost as well as the annual cost. He suggested that the cost of irrigation per hectare was Rs. 784 for giving one protective irrigation and Rs. 1694 for giving two protective irrigations. The study suggested to aim at economizing the use of water by standardizing the number of irrigation's techniques and timing of irrigation, so that higher out put per unit quantity of water is achieved.

Agnihotry *et al.* (1986) stated that at village Nada in Shiwalik foot-hills, three homogeneous earth fill dams were constructed in three independent watersheds having catchment areas of 25 ha, 22 ha and 11.7 ha, respectively. The storage capacities of the dams were 7.65, 5.9 and 6.12 ha-m, respectively. Supplemental irrigation through underground PVC pipelines system has significantly increased the wheat yield from by 253 to 280 per cent and maize yield by 114 to 161 per cent. Over all B:C ratio of the project with 30 years project life was calculated as 1.07 at 15 per cent discount rate.

Rana, *et al.* (2006) studied on economic evaluation of four water harvesting structures under integrated watershed development project in HP, he revealed that the productivity of crops was increased and the cropping pattern was changed due to availability of irrigation water. Beneficiaries shifted to high value crops like tomato, ginger, garlic, onion, French bean etc. which in turn increased the per capita income in the command areas. The rearing of fish from two structures at Samur Khurd and Lahar further increased the income of the user groups. Berseem production resulted in higher milk yield by one litre per lactating animal per day. There were large numbers of intangible benefits like saving in land from degradation due to excessive runoff, increased vegetative cover and production of bhabar grass from the catchments due to closure. All the projects were found economically viable as the benefit : cost ratio (BCR) was more than unity both at 10 and 12 per cent discount rates. Net present worth (NPW) was higher for Lahar and least for Nanowal. Though full benefits are yet to be harvested, yet even at this production level, only increase in area under cultivation has worked as magic in increasing the income of the farm families and building confidence in the people as well as the govt. agencies for investing in water harvesting projects for judicious use of scarce water resources.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

To meet the objectives of the present research project on evaluation of rain water harvesting tanks was conducted in Marathwada Agricultural University Campus. This chapter deals with the experimental details materials used and methods following during the course of investigation.

3.1 General features of M.A.U. Micro-watershed :

3.1.1 Location

The jurisdiction of Marathwada Agricultural University, Parbhani encompasses 17°36' to 20°38', N latitude and 74°37', E longitude and at 405.8 m from mean sea level. Area comes under assured rainfall zone. The soils are medium deep to deep black and mostly clay in texture with bulk density 1.30 gm/cc and pH 7.5 and production is assured in this zone.

3.1.2 Climate

The average rainfall of the Parbhani region is around 900-950 mm with average number of rainy days 48. South-West monsoon is the major source of rainfall for the region. The region falls under semi-arid tropics having highest temperature of 43°C during month May. While the lowest temperature of 11°C during December. The rainfall is uneven erratic and varies from year to year.

3.1.3 Description of M.A.U. Micro-watershed

A micro-watershed named as Demonstration field was developed in Marathwada Agricultural University campus, Parbhani. The main objectives of the site development were to convert the bare land under the cultivation. Make a showcase for demonstrating all types of plants varieties as a live demonstration.

To develop the land, it was treat by different soil and water conservation practices like opening of dead furrows, compartmental bunding, ridges and furrow, contour cultivation and water harvesting tanks. Total area of watershed 25.93 ha.

3.2 Water harvesting tank :

3.2.1.1 Data collection and analysis

The daily rainfall data for the years 1985-2006 have been collected from Meteorological Station, MAU, Parbhani. The rainfall data was analysed and grouped as weekly and fortnightly manner.

Similarly, the daily pan evaporation data was also collected for a period 1985-2006 and analyzed to obtain the average values for Meteorological weeks.

3.2.1.2 Determination of runoff by curve number techniques

In order to determine runoff, following steps are followed.

1) First the hydrological soil group of catchment is determined according to infiltration rate of soil.
2) CN for AMC-II condition was determined according to land use, treatment given, hydrological condition and hydrological soil group.
3) CN for AMC-I and AMC-III had been obtained by using Table 3.2.
4) Potential maximum retension (s) was determined by using equation.

$$CN = \frac{25400}{254 + S} \qquad 3.1$$

5) AMC has been determined using five day antecedent moisture condition using table 3.1.

6) Then runoff Q is determined using formula.

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \qquad 3.2$$

Where,

Q = runoff, mm.

P = rainfall, mm.

Table 3.1 Rainfall limits for estimating Antecedent moisture condition (AMC)

AMC	5 day antecedent rainfall (cm)	
	Dormant season	Growing season
I	Less than 1.25	Less than 3.5
II	1.25 to 2.75	3.5 to 5.25
III	Over 2.75	Over 5.25

Table 3.2 Multiplying factor for converting AMC II to I or III condition in curve number method.

CN	Factors to convert CN for conditions it to	
	Condition I	Condition III
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

3.2.1.3 Design evaluation of rain water harvesting tank.

Site survey :

Contour grid survey with the help of Automatic leveling instrument had been undertaken to insure the proper existence of the tanks according to land slope and determined the catchment

T-5310

Plate 1 Grid survey using dumpy level.

Plate 2 Measurement of depth of water harvesting tank.

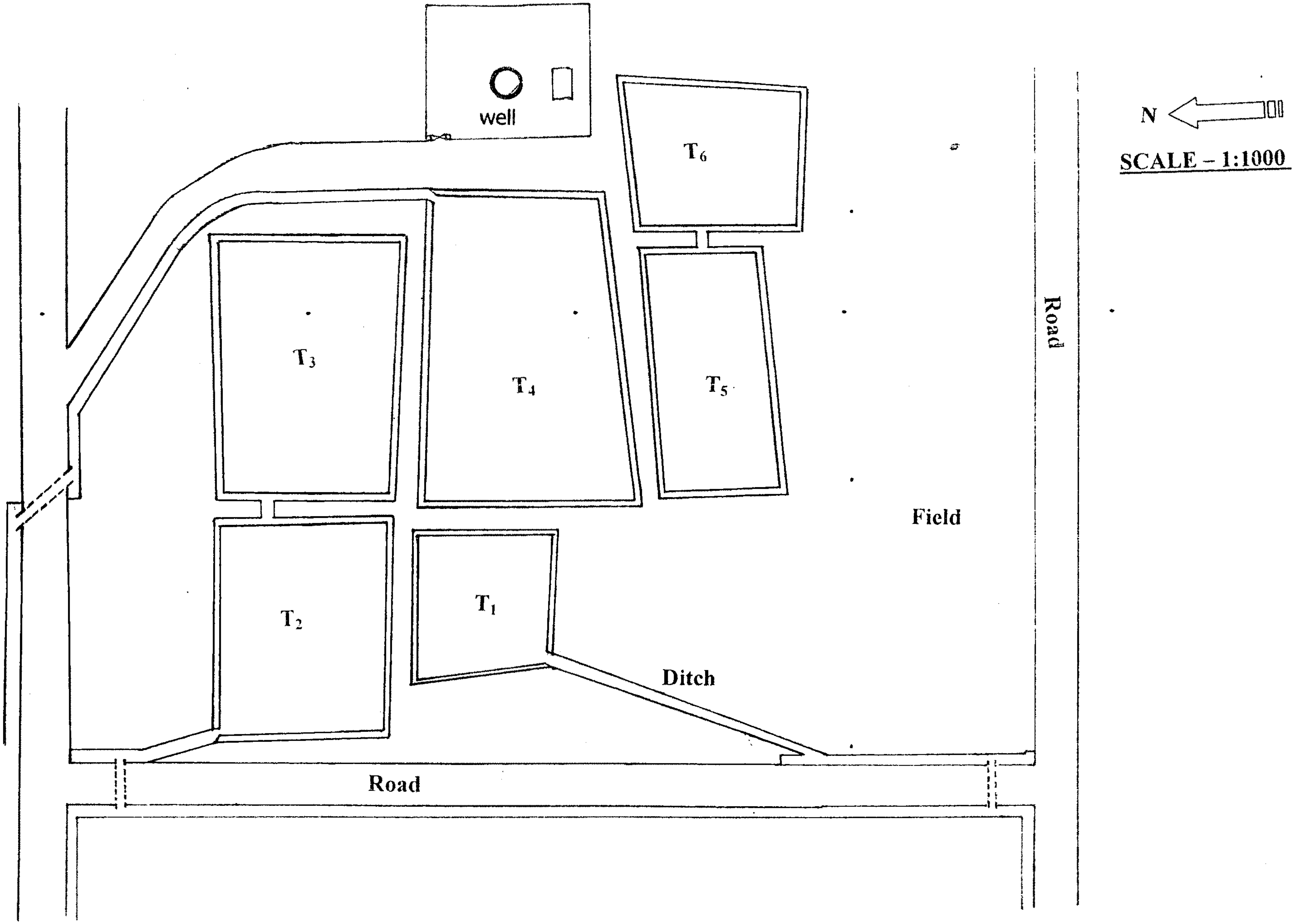

Fig. 3.1 : Site map of rainwater harvesting tanks in MAU, Campus.

area contributing runoff towards tanks. The photograph of grid survey is given in plate no.1

All dimensions of tanks will be measured by metallic tape, average depth of the tanks has been measured by leveling staff at five different locations in tank. The photograph of measurement of depth of tank is given in plate no.2. The capacity of the tanks has been calculated using trapezoidal formula.

$$V = \frac{A_1+A_2}{2} \times D \qquad 3.3$$

Where,

V = Volume of tank, m^3.

A_1 = Top area, m^2.

A_2 = Bottom area, m^2.

D = Depth, m.

Evaporation and seepage losses :

Tank evaporation and seepage are the two major losses. To study evaporation losses from the tank, daily open pan evaporation data for the year 2006-07 was collected from the Meteorological station, MAU, Parbhani. Then losses were calculating considering pan co-efficient as 0.70.

Seepage measurement can be carried out by three methods viz. ponding, seepage meter and inflow-outflow method. It identifies ponding as the reliable of the three methods to obtain realistic estimate of seepage losses (Weller and Mcateer 1993). Hence for calculating seepage losses water level reduction in all tanks has been measured daily with respect to fixed reference point by tape. The daily record of pan evaporation taken as actual evaporation from the tank surface. This value subtracted from daily loss of water level in the tank to obtain seepage loss.

Plate 3 View of water harvesting tank before rainy season.

Plate 4 View of water harvesting tank in rainy season.

Ground Water Recharge :

a) Water level fluctuation

To evaluate the influence of water harvesting in tanks on ground water recharge, water levels in the wells were recorded. For these, two wells were selected. One is located near the water harvesting tanks under the influence of tanks and other approximate 400 m from the tanks i.e. out of zone. Water level in each well were measured with the help of 30 m metallic tape having small stone attached to open end of the metal ring. Water level measured with respect to the fixed reference point marked at the top of each well by fly leveling. The water levels in wells were recorded before the start of pump. The photograph of measurement of water table depth in well is given in plate no.5.

b) Estimation of ground water recharge

The rise of ground level (Karanth, 1987) can be expressed as

$$h = Pi/Sy \qquad (3.4)$$

Where,

h = rise of water level (cm)

Pi= Portion of precipitation that percolate to the water table i.e. recharge to ground water (cm).

Sy= Specific yield

The rise of water level were obtained from the water table fluctuation data, specific yield was estimated as 0.015 for the watershed area by conducting a long duration pumping tests.

Thus precipitation infiltrated to ground water.

$$Pi = h \times Sy \qquad (3.5)$$

Further the recharge in terms for percent corresponding rainfall of two wells were also estimated.

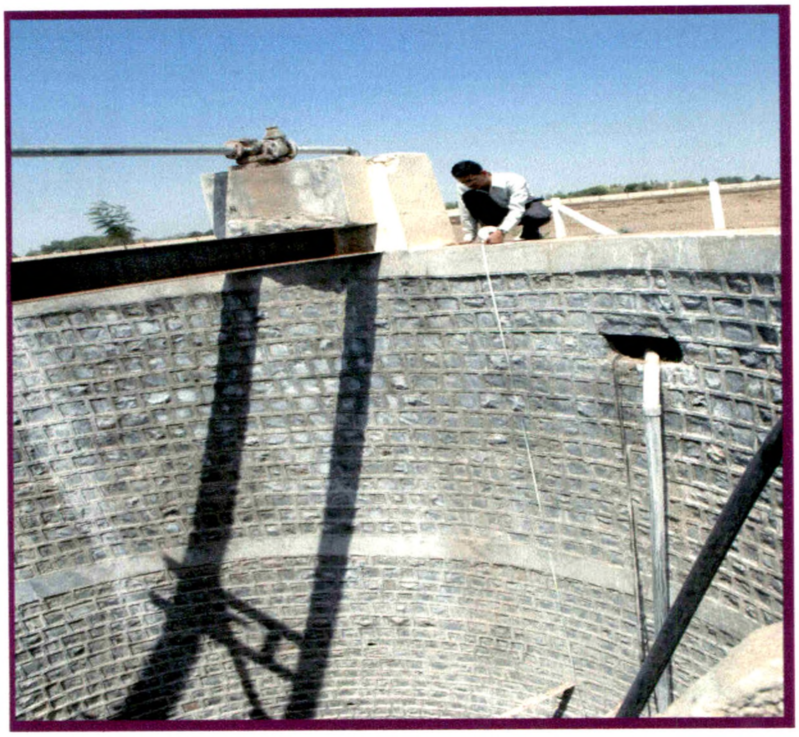

Plate 5 Water level measurement in well.

Plate 6 Supplementary irrigation from tank.

Recycling of Harvested Water :

The harvested water in tanks can be efficiency utilized for supplemental irrigation during lean periods to boost crop production. The volume of water utilized for supplementary irrigation in total storage period had been estimated. The water application/reuse had been monitored for the year 2006.

RESULTS AND DISCUSSION

CHAPTER IV

RESULT AND DISCUSSION

Study on "Evaluation of Rain Water Harvesting Tanks in M.A.U., Campus" was carried out during the year 2006-07. In the present study rain-water harvesting tanks were evaluated with respect to catchment area and design. Evaporation and seepage losses from rain water harvesting tanks were studied. Area to be irrigated from harvested rain water was estimated. Effect of rain water harvesting on ground water recharge was also studied. Results of present study have been discussed in this chapter.

4.1 Rainfall analysis :

The daily rainfall data during the monsoon season from 1985-2006 was collected and analysed. The runoff for the above period was estimated by CN technique. Considering the AMC and the runoff curve number, the runoff for each rainfall event was estimated and presented in Annexure-I.

The hydrological soil group of this region is found to be group 'D' which includes mostly clay of high swelling percent and highest runoff potential. According to the land use treatment, hydrological condition and hydrological soil group, the curve number for AMC-II condition is found to be 82. On the basis of this the curve number, for AMC-I and III had been obtained by using the multiplying factor 0.80 and 1.15, and found to be 65 and 95 respectively.

Potential maximum retention(s) is calculated for all the AMC using equation and which is found to be 136.76, 56.76 and 13.36 for AMC-I, II and III respectively. The rain storm above 5 mm was considered for runoff estimation. The AMC had been determined using 5 days rainfall and moisture conditions for the estimation of runoff.

The data on annual rainfall, runoff and percent runoff is presented in the Table 4.1. During the study period, the highest rainfall was recorded during the year 1988 with a runoff 674.5 mm (43.10 per cent). Out of the 21 years during seven years the rainfall received more than the average annual rainfall producing about 32 to 43 per cent of runoff. Similarly 14 years received less than average annual rainfall resulted into less than 30 per cent runoff. Average rainfall is 987.3 mm with the average runoff 309.35 mm which is 30.03 per cent of annual rainfall.

Table 4.1 : Percent runoff from 1985 to 2005.

Year	Rainfall(mm)	Runoff(mm)	% Runoff
1985	684.0	187.2	27.30
1986	641.0	72.58	11.30
1987	819.0	250.18	30.54
1988	1564.9	674.5	43.10
1989	1344.0	531.4	39.50
1990	1711.0	653.6	38.19
1991	742.0	307.6	41.45
1992	822.7	182.9	22.23
1993	792.7	162.1	20.4
1994	790.3	100.7	12.74
1995	848.7	173.4	20.43
1996	995.9	320.0	32.13
1997	970.3	165.7	17.07
1998	1463.0	571.41	39.05
1999	952.8	362.77	38.07
2000	953.0	380.4	39.91
2001	1123.0	409.2	36.43
2002	864.6	200.58	23.19
2003	767.4	219.4	28.59
2004	575.2	48.5	8.43
2005	1308.0	522.58	39.85
Average	987.3	309.35	30.03

Table 4.2 Rainfall and Runoff data for the year 1985 to 2005

Year	Ra.	Ru.	Ra.	Ru.	Ra.	Ru.	Ra.	Ru.	Ra.	Ru.	Ra.	Ru	Ra.	Ru.	Ra.	Ru.	Ra.	Ru.	Ra.	Ru.	Rainfall	runoff
	1-15 June		16-30 June		1-15 July		16-31 July		1-15 Aug.		16-31 Aug.		1-15 Sept		16-30 Sept		1-15 Oct		16-31 Oct			
1985	26.8	0	112.2	47.5	--	--	125.2	47.88	60	29.7	--	--	--	--	28.0	4.0	134.1	58.2	--	--	486.3	187.2
1986	50	4	19.2	1.2	--	--	142.4	48.04	56.4	19.34	--	--	--	--	--	--	--	--	--	--	268.0	72.58
1987	--	--	119.4	37.68	84.4	19.6	--	--	203.1	67.64	137.6	71.7	--	--	--	--	86.0	53.5	--	--	630.55	250.18
1988	60.8	25.8	144.4	54.2	--	--	410.4	200.15	--	--	370.1	200.9	172.0	93.7	224.8	93.87	15.0	6.0	--	--	1397.5	674.5
1989	--	--	242.8	127.5	33.4	1.2	381.5	164.82	--	--	467.9	237.85	--	--	--	--	--	--	--	--	1125.6	531.4
1990	324.6	173.1	53	19.5	--	--	129.3	56	161.2	47.65	329.7	182.85	--	--	142.2	60.75	138.8	60.0	123.2	52.9	1402.0	653.6
1991	226.2	125.6	59.6	18.4	244.2	149.8	63.4	13.5	--	--	--	--	--	--	--	--	--	--	--	--	593.4	307.3
1992	--	--	97	48.14	--	--	--	--	107.4	37.2	30	9	75.8	48.4	--	--	92.0	40.15	--	--	402.2	182.9
1993	46.4	1	105	52	82.5	20.4	174.4	69.5	19.7	5	--	--	--	--	55.2	14.2	--	--	--	--	483.2	162.1
1994	46.2	0.5	--	--	30.2	5	29.6	4.8	--	--	--	--	242.5	90.4	--	--	--	--	--	--	348.5	100.7
1995	--	--	138.8	51	42	11	57.6	21	--	--	42.6	18.9	82.0	38.0	43.0	21.0	--	--	29.1	12.5	435.1	173.4
1996	23.4	3	--	--	24	0.5	--	--	--	--	173.2	94.3	190.1	95.02	103.9	64.8	98.8	44.0	57.4	18.4	1187.4	320.0
1997	--	--	--	--	40.4	4.6	23.4	2.8	23.5	0.0	79.0	26.5	102.4	43.39	54.0	14.7	--	--	148.4	73.5	471.4	165.7
1998	25.0	0.0	99.1	33.52	--	--	330.8	134.7	164.2	95.63	148.8	87.0	122.2	84.0	132.0	60.5	51.6	7.0	105.2	69.0	1178.9	571.4
1999	64.0	23.5	47.4	34.0	101.4	47	--	--	125.7	49.5	50.0	37.0	251.2	144.1	44.8	0.0	62.0	27.9	--	--	746.6	362.7
2000	161.2	98.2	42.0	29.0	137.0	50.3	--	--	185.9	90.4	257.2	112.5	--	--	--	--	--	--	--	--	783.3	380.4
2001	92.1	34.5	--	--	--	--	39.0	9.0	325.8	173.9	8.2	1.6	--	--	--	--	382.4	190.4	--	--	847.5	409.5
2002	--	--	259.9	105.3	--	--	53.6	6.0	30.6	5.0	114.4	35.73	121.6	48.2	--	--	--	--	--	--	577.1	200.5
2003	34.0	7.0	--	--	213.2	115.6	192.2	72.33	--	--	90.6	24.5	--	--	--	--	--	--	--	--	530.1	219.4
2004	--	--	--	--	--	--	107.4	34.0	--	--	--	--	91.2	14.5	--	--	--	--	--	--	198.6	48.5
2005	--	--	--	--	214.9	107.2	590.6	281.2	22.3	12.0	20.0	2.0	--	--	99.6	45.13	133.2	75.0	8.2	2.0	1088.0	522.2
Total	1180.7	495.9	1539.8	659.04	1247.7	532.24	2961.4	1165.7	1360.0	633.15	2176.0	1142.98	1451.0	700.1	930.5	378.9	1193.0	563.0	47.1	228.0	--	--
Avg.	56.22	23.6	73.3	31.3	59.4	25.3	141.0	55.5	64.78	30.15	103.4	54.3	69.1	33.33	44.3	18.04	56.8	26.8	22.4	10.8	--	--

The weekly and fortnightly rainfall and runoff data for the month of June to the end of October is presented in Table 4.2. Data revealed that during June 7-15, the average rainfall of 56.22 mm occurred which produce the average runoff of 23.6 mm. In second fortnight of June the 21 years average rainfall was found to be 73.3 mm resulted into 31.3 mm of runoff.

The highest rainfall and runoff during the monsoon season was recorded in the second fortnight in the month of July 16-31. During this period, 141 mm of rainfall occurred resulted into 55.5 mm of runoff. The second highest, runoff producing period was recorded as August 16-31. However, the low runoff was observed in the second fortnight of October.

The weekly and fortnightly rainfall and runoff data for month of June to the end of October for year 2006 is presented in Table 4.3. Data revealed that during August 1-15, highest rainfall and runoff occurred. However there is no runoff during August 16-31 and Sept 1-15. Data of 2006 indicate that only one fortnight August 1-15 produced significant quantity of runoff out of total monsoon season.

Table 4.3 : Rainfall and Runoff data for the year 2006

Month	Day	Rainfall (mm)	Runoff (mm)
June	7-15	0.0	0.0
	16-30	130.4	20.69
July	1-15	72.0	35.52
	16-31	34.7	0.0
Aug.	1-15	443.4	378.53
	16-31	3.2	0.0
Sept.	1-15	27.8	0.0
	16-30	125.28	29.12
Oct.	1-15	50.20	5.0
	16-31	0.0	0.0

4.2 Analysis of evaporation data :

The daily pan evaporation data of 22 years was collected and analysed. The weekly/fortnightly evaporation data for the period June-October for every year since 1985-2006 is presented in Table 4.4. The lowest evaporation rate was observed in the month of July-August and the highest evaporation rate was found to be in the first fortnights of June and in the October. The evaporation data was used for calculation of evaporation losses from the rain water harvesting tank.

4.3 Design evaluation of rain water harvesting tank :

4.3.1 Survey of catchment area.

Grid survey was undertaken with the help of Automatic leveling instrument and accordingly the catchment area for network of tanks was worked out. The catchment area was found to be 4.79 ha from where runoff water could be collected and harvested for storage in tanks. Slope of the land at site found to be 1 per cent which is considered as gentle slopy land. Contour map of M.A.U. micro watershed is presented in Fig. 4.1.

All the dimensions of tanks were measured with tape and average depth of all tanks was calculated by measuring depth at five different locations in tank with the help of leveling staff. The capacity of the tanks was calculated using trapezoidal formula. All dimensions and capacity of individual tank tabulated in Table 4.5

Table 4.4 : Observed weekly evaporation (mm) for Parbhani (1985-2006)

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Ave. Evap.
7-15 June	53.2	65.9	76.3	48.5	62.3	29.4	23.3	67.4	73..7	41.7	83.9	59.6	59.9	60.0	45.3	27.4	31.5	57.0	68.1	46.4	69.3	63.0	54.80
16-30 June	77.7	56.4	82.5	64.5	72.3	52.7	35.0	44.5	80.1	52.9	56.1	125	65.9	42.8	49.5	51.9	78.0	52.7	66.1	76.6	71.8	68.2	64.08
1-15 July	72.6	97.4	52.3	56.4	63.9	72.8	32.1	89.3	50.4	47.8	49.9	74.1	55.4	41.0	45.9	40.8	59.2	76.6	47.9	64.1	39.7	51.1	58.58
16-31 July	46.2	49.9	74.9	42.0	49.7	63.9	54.8	67.0	58.1	59.5	54.8	56.9	70.4	42.3	43.7	57.6	49.3	62.2	42.9	51.6	35.1	45.2	53.97
1-15 Aug.	48.4	42.5	58.1	42.4	58.6	49.8	63.1	38.1	54.6	51.4	63.5	47.6	60.9	28.6	34.6	43.0	28.8	46.2	37.8	46.8	34.5	31.0	46.66
16-31 Aug	69.2	46.3	44.8	42.4	60.3	40.4	55.0	51.1	58.2	54.8	69.5	36.4	54.1	41.7	50.3	53.7	31.8	45.2	47.4	54.1	44.8	48.3	51.52
1-15 Sept	76.0	42.2	72.9	45.5	53.7	56.2	63.8	57.1	66.6	45.4	53.0	41.0	45.7	33.0	30.0	54.3	47.3	47.9	53.8	48.3	46.4	48.5	54.41
16-30 Sept	56.2	76.3	85.4	43.3	60.3	61.9	71.2	75.8	44.4	62.6	59.6	47.3	40.9	30.6	48.9	51.7	49.4	61.9	51.8	49.0	43.7	37.2	56.27
1-15 Oct	45.4	77.6	85.4	53.2	53.7	58.0	74.8	65.4	61.0	59.4	66.1	56.0	49.4	40.6	43.8	61.7	27.4	63.2	61.1	52.7	52.3	44.5	57.57
16-31 Oct	72.8	85.8	64.2	73.3	68.4	77.2	65.6	62.3	52.5	62.0	45.4	42.5	38.6	54.4	62.5	50.9	55.6	65.7	65.7	89.7	45.9	56.3	61.98

Table 4.5 : Dimensions and capacity of rain water harvesting tanks

Tank No.	Tank average depth (m)	Top area (m^2)	Bottom Area (m^2)	Capacity (m^3)
T_1	1.40	650	306	670
T_2	1.00	1428	945	1187
T_3	0.90	1800	1395	1438
T_4	1.50	2174.50	1960	3098
T_5	1.32	1104	860	1297
T_6	1.50	1029.5	793	1367
Total		**8186**	**6259**	**9057**

4.3.2 Design of rain water harvesting tank :

The design of rain water harvesting tank is based on the weekly / fortnightly rainfall and runoff. Runoff volume for the proposed catchment area was calculated. Considering the 80 per cent of the runoff volume in the tank, total runoff harvested from catchment area was worked out. The storage volume of water in different depths in tank is calculated and presented in Table 4.6

Table 4.6 : Storage volume at different height

Height (m)	Storage volume (m^3)
0.2	1261.27
0.4	2541.74
0.6	3841.63
0.8	5161.15
1.0	6500.53
1.2	7859.97
1.4	9239.69

and its graphical representation is shown in Fig. 4.2. Surface area of ponded water is obtained by using the graph of storage volume in tank at different heights Fig.4.2. The evaporation losses from tank are worked out by multiplying surface area of ponded water with open pan evaporation of the corresponding week/fortnight. The seepage looses were calculated by multiplying seepage rate of corresponding week/fortnight by surface area. Seepage rate of 10 mm/day was worked out for calculating seepage loss for that week/fortnight

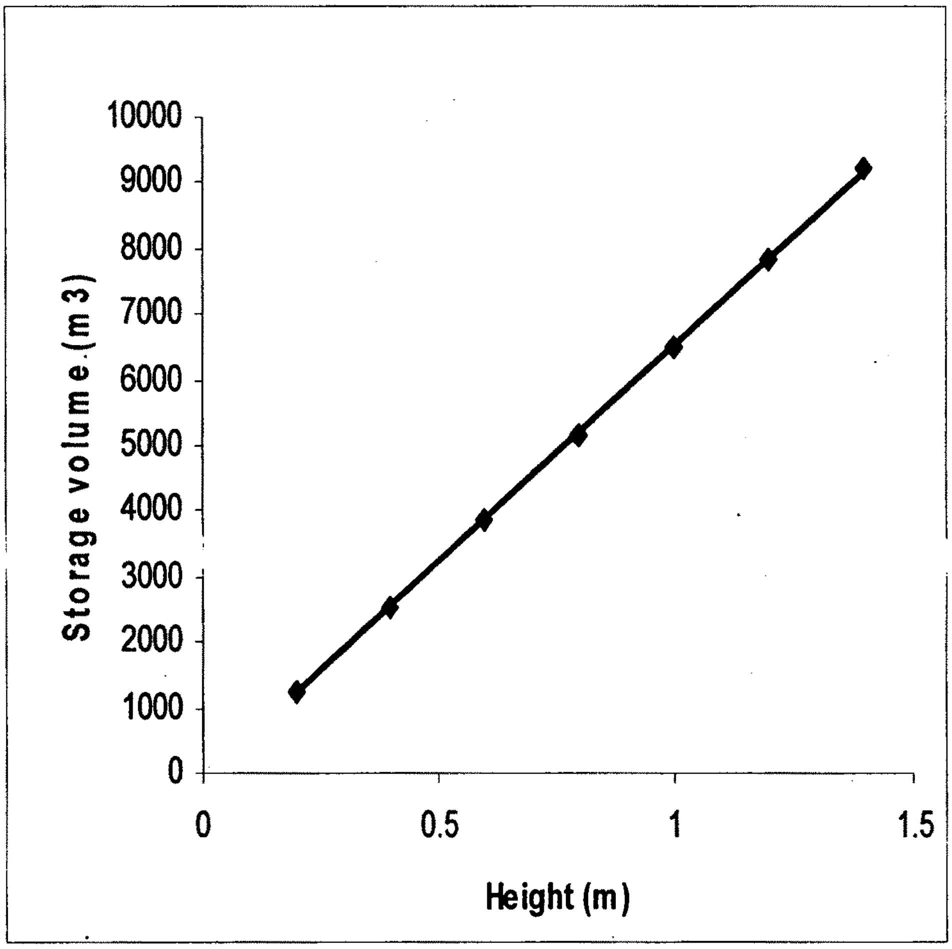

Fig. 4.2 : Storage volume at different heights.

Table 4.7 : Design of Water Harvesting Tank for area 4.79 ha.

Month	Duration	Rainfall (mm)	Runoff (mm)	Runoff volume (m^3)	80% of runoff volume (m^3)	Rainfall in tank (m3)	Total Runoff volume (m^3)	Tank Evapo. (m^3)	Seepage losses (m^3)	Runoff volume at end of period(m3)	Cumulative Runoff volume (m^3)
June	7-15	56.22	23.6	1130.44	904.35	460.22	1364.57	348.71	527.69	443.17	443.17
	16-30	73.32	31.38	1503.10	1202.48	600.19	1802.67	412.06	964.57	426.04	869.21
July	1-15	59.40	25.34	1213.79	971.03	486.25	1957.28	377.07	965.53	114.68	983.89
	16-31	141.0	55.51	2658.93	2127.14	1154.23	3281.37	355.45	1053.76	1872.16	2856.05
Aug.	1-15	64.78	30.15	1444.19	1155.35	554.84	1710.19	308.49	991.45	410.25	3266.3
	16-31	103.6	54.39	2605.28	2084.22	848.07	2932.29	347.10	1077.94	1507.25	4773.55
Sept.	1-15	69.1	33.33	1596.51	1277.21	565.65	1842.86	368.45	1015.74	458.66	5232.21
	16-30	44.30	18.04	864.12	691.29	362.69	1053.93	379.50	1011.63	-337.2	4895.01
Oct.	1-15	56.85	26.08	1249.23	999.38	465.37	1464.75	388.60	1012.50	63.65	4958.66
	16-31	22.40	10.87	520.67	416.54	183.37	599.91	414.46	1069.92	-884.47	4074.19

As per the survey conducted the catchment area was found to be 4.79 ha from where runoff water could be collected and harvested for storage tank.

It is found that, from 4.79 ha catchment area 5232.21 m^3 runoff volume was harvested from Sept 1-15 which is maximum as presented in Table 4.7. This volume is less than the capacity of tank 9057 m^3. It is also revealed that, at the end of October harvested runoff volume remains in the tank is 4079.19 m^3. This is concluded that only one irrigation up to 3 ha area with 6 cm depth could be possible and tank will not be useful for protective irrigation in rabi season. Hence from the design it is concluded that for catchment area of 4.79 ha, the tank capacity is excess or the runoff from 4.79 ha is insufficient to fulfill the capacity of tank.

Thus, the possibility was exploited for increasing the catchment area. The topography was studied and an additional catchment area of 2.44 ha was jointed to previous area to divert the runoff water. Thus catchment area was increased to 7.23 ha. considering now, the total catchment area of 7.23 ha, again design was checked. Previous catchment area and additional area is shown Fig. 4.1.

For 7.23 ha catchment area, the cumulative runoff volume at the end of each fortnight was worked out and presented in Table 4.8.

The cumulative runoff volume by the end of July was found to be 5416.47 m^3. Considering the irrigation of 6 cm depth to 3.6 ha area with 90 per cent irrigation efficiency i.e. 2400 m^3 runoff volume used and balance remained in the tank was 3016.47 m^3.

Table 4.8 : Design of Water Harvesting Tank for area 7.23 ha.

Month	Duration	Rainfall (mm)	Runoff (mm)	Runoff volume (m^3)	80% of runoff volume (m^3)	Rainfall in tank (m^3)	Total runoff volume (m^3)	Tank Evapo. (m^3)	Seepage losses (m^3)	Runoff volume at end of period (m^3)	Cumulative Runoff volume (m^3)	Remark
June	7-15	56.22	23.6	1706.2	1365.03	460.22	1825.25	350.59	575.78	898.88	898.88	
	16-30	73.32	31.38	2268.77	1815.02	600.19	2415.22	417.31	976.84	1021.06	1919.94	
July	1-15	59.40	25.34	1832.08	1465.66	486.25	1951.91	384.09	983.32	584.5	2504.44	
	16-31	141.0	55.51	4013.37	3210.69	1154.23	4364.92	366.46	1086.43	2912.03	5416.47	Irri. of 6cm depth to 3.6 ha area
Aug.	1-15	64.78	30.15	2179.85	1743.88	554.84	2274.17	313.80	1008.80	963.22	3979.69	
	16-31	103.6	54.39	3932.39	3145.92	848.07	3993.99	373.94	1109.92	2539.21	6518.90	Irri. of 6cm depth to 3.6 ha area
Sept.	1-15	69.1	33.33	2409.76	1927.80	565.65	2493.45	374.69	1032.97	1109.62	5228.52	
	16-30	44.30	18.04	1304.29	1043.43	362.64	1406.07	387.50	1032.97	9.28	5237.80	
Oct.	1-15	56.85	26.08	1885.58	1508.47	465.37	1973.84	412.33	1074.34	558.78	5796.58	
	16-31	22.40	10.87	785.90	628.72	183.37	812.09	439.39	1134.28	-690.64	5105.93	

Similarly, at the end of August, the cumulative runoff volume of 6518.90 m^3 is found in the tank. Again by providing one irrigation of 6 cm depth with a same area is possible. At the end of October lowest runoff volume of 812.09 m^3 can be harvested and cumulative runoff volume remain is 5105.93 m^3 which can be used for irrigation to crop in rabi season.

4.4 Estimation of area to be irrigated by rainwater harvesting tanks :

Total volume of water stored in the tanks found to be 9905.94m^3 for 7.23 ha catchment area. From this total volume, three irrigation of 6 cm depth considering 90 per cent irrigation efficiency could be given to 3.6 ha area. The ratio of area irrigated to the catchment area found to be 50 per cent and area of tanks to the catchment area is 11.33 per cent.

4.5 Water budgeting of rain water harvesting tanks :

Rainwater harvesting tanks were fulfilled of their maximum capacity during the first week of August. For estimating seepage losses from water harvesting tanks water level had been measured daily with respects to fixed reference point by the means of tape. Daily evaporation and rainfall data collected from meteorological department, situated near to the experiment site. Using these parameters water budget of each tank was calculated and presented in Table 4.9 to 4.14.

Table 4.9 : Water budget of rain water harvesting tank T_1.

Date	Initial R.L. of water surface in T1	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
9/8/2006	410.862	80	3.6	76.4	-	410.782
10/8/06	410.782	80	4.1	75.9	-	410.702
11/8/06	410.702	60	4.2	55.8	-	410.642
12/8/06	410.642	60	4.6	55.4	2.0	410.584
13/8/06	410.584	50	4.0	46.0	-	410.534
14/8/06	410.534	50	3.8	46.2	-	410.484
15/8/06	410.484	40	4.2	35.8	--	410.444
16/8/06	410.444	40	4.0	36.0	1.6	410.404
17/8/06	410.404	40	3.8	36.2	-	410.365
18/8/06	410.365	30	4.0	26.0	-	410.335
19/8/06	410.335	30	3.6	26.4	-	410.305
20/8/06	410.305	30	3.8	26.2	-	410.275
21/8/06	410.275	40	4.6	35.4	-	410.235
22/8/06	410.235	30	4.8	25.2	-	410.205
23/8/06	410,205	40	4.0	36.0	1.6	410.165
24/8/06	410.165	30	4.0	26.0	-	410.136
25/8/06	410.136	40	4.4	35.6	-	410.096
26/8/06	410.096	40	5.2	34.6	-	410.056
27/8/06	410.056	40	5.0	35.0	-	410.016
28/8/06	410.016	30	4.4	25.6	-	409.986
29/8/06	409.986	20	4.8	15.2	-	409.966
30/8/06	409.966	20	5.0	15.0	-	409.946
31/8/06	409.946	20	3.6	16.4	-	409.926
1/9/06	409.926	20	3.8	16.2	-	409.906
2/9/06	409.906	20	3.2	16.8	-	409.886
3/9/06	409.886	20	4.2	15.8	3.0	409.869
4/9/06	409.869	20	4.8	15.2	-	409.849
5/9/06	409.849	10	5.0	5.0	-	409.839
6/9/06	409.839	10	4.4	5.6	13.6	409.843
7/9/06	409.843	20	4.8	15.2	-	409.823
8/9/06	409.823	20	5.6	14.4	-	409.803
9/9/06	409.803	20	6.0	14.0	-	409.783
10/9/06	409.783	10	4.6	5.4	3.6	409.777
11/9/06	409.777	10	5.4	4.6	-	409.767
12/9/06	409.767	10	4.6	5.4	1.0	409.843

Date	Initial R.L. of water surface in T1	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
13/9/06	409.758	10	4.8	5.2	2.0	409.750
14/9/06	409.750	10	4.5	5.5	2.0	409.742
15/9/06	409.742	10	3.6	6.4	2.6	409.735
16/9/06	409.735	10	2.5	7.5	5.5	409.730
17/9/06	409.730	10	3.8	6.2	-	409.720
18/9/06	409.720	10	2.0	8	1.3	409.711
19/9/06	409.711	10	3.3	6.7	2.0	409.703
20/9/06	409.703	10	4.5	5.5	37.6	409.731
21/9/06	409.731	-20	4.4	-	2.0	409.753
22/9/06	409.753	00	4.0	-	5.8	409.755
23/9/06	409.755	10	3.5	6.5	5.4	409.750
24/9/06	409.750	10	2.7	7.3	3.2	409.743
25/9/06	409.743	10	2.6	7.4	32.6	409.743
26/9/06	409.743	10	3.8	6.2	25.8	409.782
27/9/06	409.782	00	4.2	-	-	409.778
28/9/06	409.778	00	4.8	-	-	409.773
29/9/06	409.773	10	3.2	6.8	4.0	409.767
30/9/06	409.767	10	3.9	6.1	0.8	409.757
1/10/06	409.757	10	3.2	6.8	30.4	409.777
2/10/06	409.777	00	2.8	-	1.0	409.776
3/10/06	409.776	10	2.8	7.2	-	409.766
4/10/06	409.766	10	3.6	6.4	-	409.756
5/10/06	409.756	10	3.9	6.1	-	409.746

Data presented in Table 4.9 revealed that maximum seepage loss observed during initial period was 76.4 mm on 9/8/06. Seepage loss went on decreasing as the time elapsed and after a month it was nearly constant, ranged from 6 to 7 mm per day. Initial reduced level of water surface was 410.862 m and final reduced level was observed 409.746 m. Total seepage loss observed was 1113.4 mm. On 5/10/06 tank was dry because of dry spell observed in next days.

Table 4.10 : Water budgeting of rain water harvesting tanks T2

Date	Initial R.L. of water surface in T2	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
9/8/2006	410.862	90	3.6	86.4	-	410.772
10/8/06	410.772	80	4.1	75.9	-	410.692
11/8/06	410.692	80	4.2	75.8	-	410.612
12/8/06	410.612	60	4.6	55.4	2.0	410.554
13/8/06	410.554	60	4.0	56.0	-	410.496
14/8/06	410.496	50	3.8	46.2	-	410.444
15/8/06	410.444	40	4.2	35.8	--	410.404
16/8/06	410.404	40	4.0	36.0	1.6	410.364
17/8/06	410.364	40	3.8	36.2	-	410.325
18/8/06	410.325	30	4.0	26.0	-	410.295
19/8/06	410.295	30	3.6	26.4	-	410.265
20/8/06	410.265	20	3.8	16.2	-	410.245
21/8/06	410.245	20	4.6	15.4	-	410.225
22/8/06	410.225	30	4.8	25.2	-	410.195
23/8/06	410.195	30	4.0	26.0	1.6	410.165
24/8/06	410.165	40	4.0	26.0	-	410.137
25/8/06	410.137	40	4.4	35.6	-	410.097
26/8/06	410.097	40	5.2	34.8	-	410.057
27/8/06	410.057	30	5.0	25.0	-	410.027
28/8/06	410.027	30	4.4	25.6	-	409.997
29/8/06	409.997	20	4.8	15.2	-	409.977
30/8/06	409.977	20	5.0	15.0	-	409.957
31/8/06	409.957	20	3.6	16.4	-	409.937
1/9/06	409.937	20	3.8	16.2	-	409.917
2/9/06	409.917	20	3.2	16.8	-	409.897
3/9/06	409.897	20	4.2	15.8	3.0	409.880
4/9/06	409.880	10	4.8	5.2	-	409.870
5/9/06	409.870	10	5.0	5.0	-	409.860

The water budgeting of rain water harvesting tank T2 is presented in Table 4.10. It was found that maximum seepage loss observed during first fortnight of August was 86.4 mm to 36.0 mm then it decreased upto 5 mm/day. Tank was dried after 5/9/2006.

Table 4.11 : Water budgeting of rain water harvesting tank T_3

Date	Initial R.L. of water surface in T_3	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
9/8/2006	410.862	90	3.6	86.4	-	410.772
10/8/06	410.772	90	4.1	85.9	-	410.682
11/8/06	410.682	80	4.2	75.8	-	410.602
12/8/06	410.602	70	4.6	65.4	2.0	410.534
13/8/06	410.534	60	4.0	56.0	-	410.474
14/8/06	410.474	50	3.8	46.2	-	410.424
15/8/06	410.424	40	4.2	35.8	--	410.386
16/8/06	410.386	40	4.0	36.0	1.6	410.344
17/8/06	410.344	30	3.8	26.2	-	410.316
18/8/06	410.316	30	4.0	26.0	-	410.286
19/8/06	410.286	20	3.6	16.4	-	410.266
20/8/06	410.266	20	3.8	16.2	-	410.246
21/8/06	410.246	20	4.6	15.4	-	410.226
22/8/06	410.226	25	4.8	20.2	-	410.201
23/8/06	410.201	30	4.0	26.0	1.6	410.171
24/8/06	410.171	30	4.0	26.0	-	410.143
25/8/06	410.143	35	4.4	30.6	-	410.108
26/8/06	410.108	30	5.2	24.8	-	410.078
27/8/06	410.078	20	5.0	15.0	-	410.058
28/8/06	410.058	20	4.4	15.6	-	410.038
29/8/06	410.038	20	4.8	15.2	-	410.018
30/8/06	410.018	20	5.0	15.0	-	409.998
31/8/06	409.998	20	3.6	16.4	-	409.978
1/9/06	409.978	10	3.8	6.2	-	409.968

Data presented in Table 4.11 revealed that initial seepage loss i.e. first fortnight of August observed to be 86.4 mm and it reduced to 6.2 mm. Total seepage loss observed was 890.9 mm in tank T_3 during total storage period.

Table 4.12 : Water budgeting of rain water harvesting tank T_4

Date	Initial R.L. of water surface in T_4	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
9/8/2006	410.862	100	3.6	96.4	-	410.762
10/8/06	410.762	90	4.1	85.9	-	410.672
11/8/06	410.672	90	4.2	85.8	-	410.582
12/8/06	410.582	80	4.6	75.4	2.0	410.504
13/8/06	410.504	70	4.0	66.0	-	410.434
14/8/06	410.434	60	3.8	56.2	-	410.374
15/8/06	410.374	40	4.2	35.8	--	410.334
16/8/06	410:334	40	4.0	36.0	1.6	410.294
17/8/06	410.294	40	3.8	36.2	-	410.256
18/8/06	410.256	30	4.0	26.0	-	410.226
19/8/06	410.226	30	3.6	26.4	-	410.196
20/8/06	410.196	30	3.8	26.2	-	410.166
21/8/06	410.166	20	4.6	15.4	-	410.146
22/8/06	410.146	30	4.8	25.2	-	410.116
23/8/06	410.116	20	4.0	16.0	1.6	410.096
24/8/06	410.096	30	4.0	16.0	-	410.078
25/8/06	410.078	30	4.4	15.6	-	410.058
26/8/06	410.058	30	5.2	24.8	-	410.028
27/8/06	410.028	40	5.0	35.0	-	409.988
28/8/06	409.988	40	4.4	35.6	-	409.948
29/8/06	409.948	40	4.8	35.2	-	409.908
30/8/06	409.908	30	5.0	25.0	-	409.878
31/8/06	409.878	30	3.6	26.4	-	409.848
1/9/06	409.848	30	3.8	26.2	-	409.818
2/9/06	409.818	20	3.2	16.8	-	409.798
3/9/06	409.798	20	4.2	15.8	3.0	409.781
4/9/06	409.781	20	4.8	15.2	-	409.761
5/9/06	409.761	20	5.0	15.0	-	409.741
6/9/06	409.741	20	4.4	15.6	13.6	409.735
7/9/06	409.735	20	4.8	15.2	-	409.715
8/9/06	409.715	20	5.6	14.4	-	409.695
9/9/06	409.695	30	6.0	24.0	-	409.665
10/9/06	409.665	20	4.6	15.4	3.6	409.649
11/9/06	409.649	20	5.4	14.6	-	409.629
12/9/06	409.629	20	4.6	15.4	1.0	409.610

Data presented in Table 4.12 revealed that seepage loss in tank T_4 observed initially was 96.4mm on 9th August 2006 and reduced to 15.4mm by the end of the first fortnight September. Total seepage loss observed was 1126.1mm.

Table 4.13 : Water budgeting of rain water harvesting tank T5

Date	Initial R.L. of water surface in T5	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
9/8/2006	410.862	90	3.6	86.4	-	410.772
10/8/06	410.772	80	4.1	75.9	-	410.692
11/8/06	410.692	70	4.2	65.8	-	410.622
12/8/06	410.622	60	4.6	55.4	2.0	410.564
13/8/06	410.564	50	4.0	46.0	-	410.514
14/8/06	410.514	40	3.8	36.2	-	410.474
15/8/06	410.474	40	4.2	35.8	--	410.434
16/8/06	410.434	30	4.0	26.0	1.6	410.404
17/8/06	410.404	30	3.8	26.8	-	410.376
18/8/06	410.376	30	4.0	26.0	-	410.346
19/8/06	410,346	30	3.6	26.4	-	410.316
20/8/06	410.316	30	3.8	26.2	-	410.286
21/8/06	410.286	20	4.6	15.4	-	410.266
22/8/06	410.266	30	4.8	25.2	-	410.236
23/8/06	410.236	20	4.0	16.0	1.6	410.216
24/8/06	410.216	20	4.0	16.0	-	410.198
25/8/06	410.198	20	4.4	15.4	-	410.178
26/8/06	410.178	30	5.2	24.8	-	410.158
27/8/06	410.158	30	5.0	25.0	-	410.128
28/8/06	410.128	30	4.4	25.8	-	410.098
29/8/06	410.098	30	4.8	25.0	-	410.068
30/8/06	410.068	30	5.0	25.6	-	410.038
31/8/06	410.038	20	3.6	16.4	-	410.018
1/9/06	410.018	20	3.8	16.2	-	409.998
2/9/06	409.998	20	3.2	16.8	-	409.978
3/9/06	409.978	20	4.2	15.8	3.0	409.961
4/9/06	409.961	30	4.8	25.2	-	409.931
5/9/06	409.931	30	5.0	25.0	-	409.901
6/9/06	409.901	20	4.4	15.6	13.6	409.895
7/9/06	409.895	20	4.8	15.2	-	409.875
8/9/06	409.875	30	5.6	24.4	-	409.815
9/9/06	409.815	30	6.0	24.0	-	409.789
10/9/06	409.789	30	4.6	25.4	3.6	409.769
11/9/06	409.769	20	5.4	14.6	-	409.750
12/9/06	409.750	20	4.6	15.4	1.0	409.750

13/9/06	409.750	20	4.8	15.2	2.0	409.732
14/9/06	409.732	20	4.5	15.5	2.0	409.714
15/9/06	409.714	20	3.6	16.4	2.6	409.697
16/9/06	409.697	20	2.5	17.7	5.5	409.683
17/9/06	409.683	20	3.8	16.4	-	409.663
18/9/06	409.663	10	2.0	8.0	1.3	409.654
19/9/06	409.654	10	3.3	6.4	2.0	409.646

Water budget of tank T_5 is presented in Table 4.13. From the table it is found that initial seepage loss in tank T_5 was 86.4mm and reduced to 6.2mm by the end of monsoon period. Total seepage loss observed was 1059.6mm during the total stored period.

Water budget of the tank T_6 is presented in Table 4.14. The data presented in Table 4.14 revealed that initial seepage loss i.e. first fortnight of August was observed to be 76.4 mm and it reduced to 14.4 min on 9th Sept. 2006 supplementary irrigation given to the soybean crop from tank T_6 and reduction in water level was observed to be 410 mm on that day. The total seepage loss was observed to be 816.7 mm before pumping.

From the water budgeting data, seepage losses in mm/day from each tank is calculated in weekly/fortnightly manner. Relative loss of water through seepage is presented in Table 4.15.

From data presented in Table 4.15 it was revealed that seepage loss is maximum during initial period of storage. Mean value of seepage loss initially found to be 58.78 mm/day and it decreased to 6.6 mm/day.

Table 4.14 : Water budgeting of rain water harvesting tank T_6

Date	Initial R.L. of water surface in T_6	Reduction in water level (mm)	Evaporation loss (mm)	Seepage loss (mm)	Rainfall (mm)	Final R.L. of water surface
9/8/2006	410.862	80	3.6	76.4	-	410.782
10/8/06	410.782	60	4.1	55.9	-	410.722
11/8/06	410.722	50	4.2	45.8	-	410.672
12/8/06	410.672	40	4.6	35.4	2.0	410.634
13/8/06	410.634	30	4.0	26.0	-	410.604
14/8/06	410.604	30	3.8	26.2	-	410.574
15/8/06	410.574	30	4.2	25.8	--	410.544
16/8/06	410.544	30	4.0	26.0	1.6	410.514
17/8/06	410.514	20	3.8	16.2	-	410.496
18/8/06	410.496	20	4.0	16.0	-	410.476
19/8/06	410.476	30	3.6	26.4	-	410.446
20/8/06	410.446	30	3.8	26.4	-	410.416
21/8/06	410.416	20	4.6	15.4	-	410.396
22/8/06	410.396	30	4.8	25.4	-	410.366
23/8/06	410.366	15	4.0	11.0	1.6	410.351
24/8/06	410.351	25	4.0	21.0	-	410.328
25/8/06	410.328	30	4.4	25.6	-	410.298
26/8/06	410.298	30	5.2	24.8	-	410.268
27/8/06	410.268	40	5.0	35.0	-	410.228
28/8/06	410.228	30	4.4	25.6	-	410.198
29/8/06	410.198	40	4.8	35.2	-	410.158
30/8/06	410.158	40	5.0	35.0	-	410.118
31/8/06	410.118	20	3.6	16.4	-	410.016
1/9/06	410.016	20	3.8	16.2	-	410.014
2/9/06	410.014	20	3.2	16.8	-	410.012
3/9/06	410.012	20	4.2	15.8	3.0	409.996
4/9/06	409.996	30	4.8	25.2	-	409.966
5/9/06	409.966	30	5.0	25.0	-	409.936
6/9/06	409.936	20	4.4	15.6	13.6	409.916
7/9/06	409.916	20	4.8	15.2	-	409.896
8/9/06	409.896	20	5.6	14.4	-	409.876
9/9/06	409.876	410	6.0	-	-	409.466

Table 4.15 Relative loss of water through seepage in rainwater harvesting tanks

Tank No.	Seepage loss (mm/day)				
	Aug.1-15	**Aug.16-31**	**Sept.1-15**	**Sept.16-30**	**Oct. 1-1**
T_1	55.93	28.18	10.05	6.745	6.625
T_2	61.64	25.03	11.08	Dry	Dry
T_3	64.50	21.31	6.2	Dry	Dry
T_4	71.64	26.31	16.97	Dry	Dry
T_5	57.36	22.59	18.74	12.075	Dry
T_6	41.64	23.81	18.025	Dry	Dry
Mean	58.785	24.622	13.63	9.41	6.625

4.6 Status of rain water harvesting tanks during year 2006.

Status of rainwater harvesting tanks during 2006 was studied by taking various observations are tabulated in Table 4.16. Weekly /fortnightly rainfall data for year 2006 was used for calculating runoff from catchment area. Tank evaporation and seepage losses were recorded for year 2006 and considered for design.

Data presented in Table 4.16 revealed that maximum runoff collected from catchment area during August 1-15 is 21894.18 m^3 which is excess than capacity of tanks. This excess runoff volume was diverted as overflow through tanks.

Supplementary irrigation to the 2.19 ha area of 503.48 m^3 was given in Sept. 1-15. Runoff volume 1255.17 m^3 remained in the tank at the end of month October but this volume was spread in depressions and could not be used for further irrigation.

Total runoff volume collected from catchment area was 17918.73 m^3 out of 13251.65 m^3 runoff volume lost through seepage. Seepage loss found to be 73.97 per cent of total runoff volume collected. It is estimated that 2941.73 m^3 of volume evaporated which accumulated for 16.42 per cent of total runoff collected.

Table 4.16 Status of Rain Water Harvesting Tank in year 2006.

Month	Duration	Rainfall (mm)	Runoff (mm)	Runoff volume (m^3)	80% of runoff volume (m^3)	Rainfall in tank (m^3)	Total runoff volume (m^3)	Tank Evapo. (m^3)	Seepage losses (m^3)	Runoff volume at end of period (m^3)	Cumulative Runoff volume (m^3)	Remark
June	7-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	16-30	130.4	20.69	1495.89	1196.71	1067.45	2264.16	428.31	1835.85	0.0	0.0	
July	1-15	72.0	35.52	2568.10	2054.48	589.39	2643.87	330.58	2313.29	0.0	0.0	
	16-31	34.7	0.0	0.0	0.0	284.05	284.05	284.00	0.0	0.0	0.0	
Aug.	1-15	443.4	378.53	27367.72	21894.18	3629.67	9057	138.93	2865.65	6052.42	6052.42	
	16-31	3.2	0.0	0.0	0.0	26.10	26.20	324.96	2650.45	-2949.21	3103.21	
Sept.	1-15	27.8	0.0	0.0	0.0	227.57	227.57	315.97	1331.69	-1420.09	1683.12	Irrigation to 2.19 ha area
	16-30	125.22	29.12	2105.38	1684.30	1025.54	2701.89	384.84	923.53	1435.47	2618.33	
Oct.	1-15	50.20	5.0	361.5	289.2	410.94	700.14	371.54	647.19	-318.58	2299.75	
	16-31	0.0	0.0	0.0	0.0	0.0	0.0	362.57	682.00	-1044.57	1255.17	

4.7 Effect of rainwater harvesting tanks on ground water potential :

4.7.1 Water table fluctuation in wells.

To study the effect of rain water harvesting tanks on ground water table, two wells were monitored. Wells are located in watershed area in which one is in the zone of influence and another out of influence of tanks. Water levels in the wells were recorded fortnightly. Water column depth was interpolated and compared the water levels in two wells. The data on water column depth in two wells are presented in Table 4.17.

Table 4.17 : Water column depth (m) in wells during year 2006-07.

Month	**Water level (m)**	
	Well 1 in the influence	**Well 2 out of influence**
May-06	2.00	0.6
June-06	2.50	0.8
July-06	2.80	2.1
August-06	11.59	10.4
Sept-06	15.40	12.20
October-06	16.79	11.90
Nov-06	16.74	10.78
Dec-06	13.26	8.0
January-07	11.80	5.2
February-07	9.50	3.5
March-07	4.70	2.9
April-07	4.00	2.4

The water column depth in wells with respect to the month is also shown graphically in Fig.4.3.

The well hydrograph revealed that the water column start rising since June and sudden rise in depth observed in month of August in both wells however peak depth was observed in the month of October in case of W_1 and in September in case of W_2. After that, the water table starts declining in W_2 while water table in W_1 was maintained at nearly constant level up to the month of

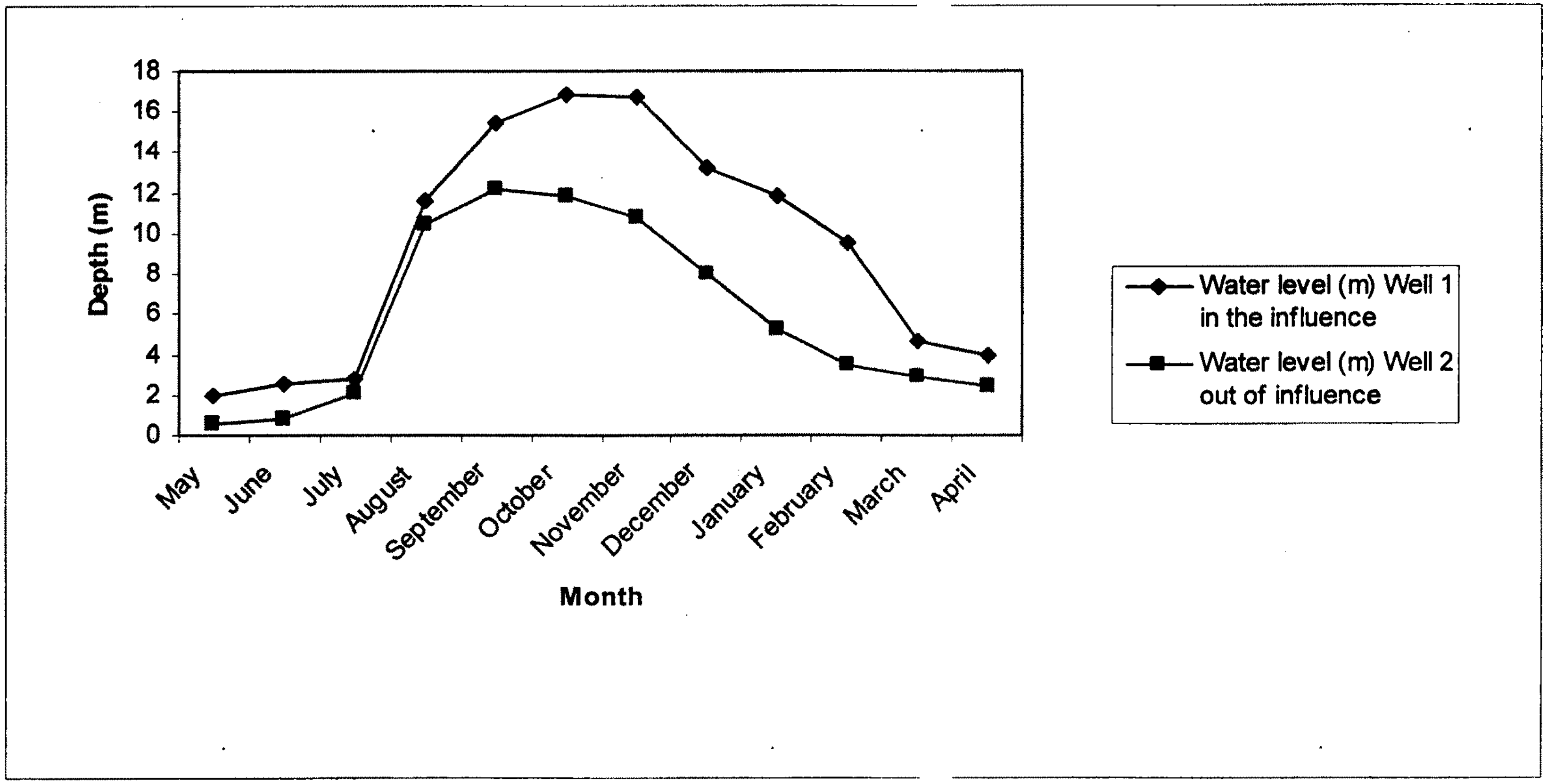

Fig. 4.3 : Water column depths in wells.

February. The constant water column depth in W_1 is a impact of stored water in harvesting tanks of the watershed area.

4.7.1 Estimation of ground water recharge:

Considering the rise in water level and specific yield of wells, the depth of rain water recharge and its percentage with respect to rainfall was worked out for the both wells. The data represented in Table 4.18 and 4.19 for well W_1 and W_2 respectively.

Table 4.18 : Estimation of ground water recharge in well W_1.

Sr. No.	Month	Rainfall (cm)	Well number W_1		
			H (cm)	Pi (cm)	% R
1.	June	13.04	50	0.75	5.75
2.	July	10.67	30	0.45	4.22
3.	August	44.66	879	13.18	29.52
4.	September	15.31	381	5.715	37.33
5.	October	5.02	139	2.058	41.53
		Annual average recharge			**23.67**

Well W_1 is located at the downstream side of water harvesting tanks. Data revealed that the maximum recharge to the ground water was estimated as 41.53 per cent in the month of October, though the maximum rainfall occurred in the month of August. This was because of harvested water take a time to percolate in the soil strata and join to the ground water table. The minimum ground water recharge was estimated as 4.22 per cent in the month of July. The overall average annual recharge to the ground water was found to be 23.67 per cent in the well W_1.

Table 4.19 : Estimation of ground water recharge in well W_2.

Sr. No.	Month	Rainfall (cm)	Well number W_2		
			h (cm)	Pi (cm)	% R
1.	June	13.04	20	0.3	2.3
2.	July	10.67	130	1.95	18.27
3.	August	44.66	830	12.45	27.88
4.	September	15.31	180	2.7	17.64
5.	October	5.02	30	0.45	8.96
		Annual average recharge			**15.01**

Well No. W_2 is located approximately 400 m from the water harvesting tanks. Data revealed that the maximum recharge to the ground water was estimated as 27.88 per cent in the month of August followed by September. The minimum ground water recharge was estimated as 2.3 per cent of the rainfall received in the month of June. The overall average annual recharge of the ground water was found to be 15.01per cent in the well No. W_2.

Comparison of ground water recharge in both the wells indicate that, the water harvesting tanks have definite effect on ~~increase in ground water recharge on deputed from data of W_1. Thus~~ water harvesting structure have a dual benefit i.e. recycling of water for supplemental/ protective irrigation also to increase the ground water recharge. This resulted in increase of ground water potential.

4.8 Cost estimation of rain water harvesting tank :

The cost estimation of rainwater harvesting tank includes cleaning of site, digging of soil/excavation of soil, transportation and lifting and construction of inlet and outlet. Cost estimates for individual tank based on latest D.S.R. values are presented in Table 4.20 to 4.25. The cost of construction for the tank T_1 is estimated as Rs. 31607.55. Tank T_2 and T_3 the depth of excavation is 1 m hence lifting cost excluded. Their estimated costs are Rs. 50673.96 and Rs.61472.46 respectively. For the tank T_4, T_5,

T_6 construction costs estimated as Rs. 145634.91, Rs. 59069.84, Rs. 64178.94 respectively.

Table 4.20 Estimation of cost of construction for tank T_1.

Sr. No.	Particulars	Depth (m)	Excavated volume	Rate (Rs)	Cost (Rs)
1.	Cleaning cost	--	650 m^2	2/m^2	1300.00
2.	Digging cost	0-1	523 m^3	39/m^3	20397.00
		1-14	147 m^3	43/m^3	6321.00
3.	Lifting cost	1-1.4	147 m^3	5.6	823.2
4.	Transportation	1-1.4	147 m^3	6.6	970.2
5.	Inlet 25mx1mx0.5		12.5	19.9	248.95
				Total	30060.15
6.	Supervision cost 3% of total cost			Total	31607.55

Table 4.21 Estimation of cost of construction for tank T_2

Sr. No.	Particulars	Depth (m)	Excavated volume	Rate (Rs)	Cost (Rs)
1.	Cleaning cost	--	1428 m^2	2/m^2	2856.00
2.	Digging cost	0-1	1187 m^3	39/m^3	46293.00
3.	Inlet 5mx1mx0.5		2.5	19.9	49.75
				Total	49198.00
	Supervision cost 3% of total cost				50673.96

Table 4.22 Estimation of cost of construction for tank T_3

Sr. No.	Particulars	Depth (m)	Excavated volume	Rate (Rs)	Cost (Rs)
1.	Cleaning	--	1800 m^2	2/m^2	3600.00
2.	Digging cost	0-1	1438 m^3	39/m^3	56082.00
				Total	59682.00
3.	Supervision cost 3% of total cost				61472.46

Table 4.23 Estimation of cost of construction for tank T_4

Sr. No.	Particulars	Depth (m)	Excavated volume	Rate (Rs)	Cost (Rs)
1.	Cleaning cost	--	2174.50	2/m^2	4349.00
2.	Digging cost	0-1	2115.06	39/m^3	82487.34
		1-1.5	982.94	43/m^3	42266.42
3.	Lifting cost	1-1.5	982.94	5.6	5504.46
4.	Transportation	1-1.5	982.94	6.6	6487.40
5.	Inlet 25mx1mx0.5		15.0	19.9	298.5
				Total	141393.12
6.	Supervision cost 3% of total cost				145634.91

Table 4.24 Estimation of cost of construction for tank T_5

Sr. No.	Particulars	Depth (m)	Excavated volume	Rate (Rs)	Cost (Rs)
1.	Cleaning cost	--	1104 m^2	2/m^2	2208.00
2.	Digging cost	0-1	1015.62 m^3	39/m^3	39609.18
		1-1.5	281.38 m^3	43/m^3	12099.34
3.	Lifting cost	1-1.35	281.38 m^3	5.6	1575.73
4.	Transportation	1-1.35	281.38 m^3	6.6	1857.11
				Total	57349.36
5.	Supervision cost 3% of total cost				59069.84

Table 4.25 Estimation of cost of construction for tank T6

Sr. No.	Particulars	Depth (m)	Excavated volume	Rate (Rs)	Cost (Rs)
1.	Cleaning cost	--	1029.5	$2/m^2$	2059.00
2.	Digging cost	0-1	938.75	$39/m^3$	36611.25
		1-1.5	428.25	$43/m^3$	18414.75
3.	Lifting cost	1-1.5	428.25	5.6	2398.2
4.	Transportation	1-1.5	428.25	6.6	2826.45
				Total	62309.65
5.	Supervision cost 3% of total cost				64178.94

Table 4.26 Storage cost of runoff volume in different tanks.

Tank No.	Storage volume	Cost Rs.	Cost $/m^3$ Rs.
T_1	670 m^3	31604.55	47.18
T_2	1187 m^3	50673.96	42.69
T_3	1438 m^3	61472.46	42.75
T_4	3098 m^3	145634.91	47.00
T_5	1297 m^3	59069.84	45.54
T_6	1367 m^3	64178.94	46.95
Total	9057 m^3	412634.66	45.56

The storage cost of different tank with respect to their storage capacity are presented in table. 4.26. Data presented in table revealed that, the cost of storage per capacity range from Rs.42.69/m^3 to Rs. 47.18/m^3.

SUMMARY AND CONCLUSIONS

CHAPTER V

SUMMARY AND CONCLUSION

Study on Evaluation of rain water harvesting tanks was carried during 2006-07 in Marathwada Agricultural University campus. Network of six rain water harvesting tanks were evaluated as per their design. To insure the proper existence of the tanks, grid survey with dumpy level was undertaken. Catchment area and land slope were determined. As per the topographic survey the present site of tanks suitable for construction of rain water harvesting tank. Site located down slope of watershed and land slope at site is one percent, which is considered as gentle sloppy land. All dimensions of tank were measured and storage capacity was calculated. Tanks were designed for the catchment area. The rainfall data and evaporation data of last 21 years from 1985 to 2005 are collected from Meteorological Station, Parbhani and considered for designing of tank. Area to be irrigated from rain water harvesting tank was estimated and area irrigated from tank in the year 2006 was monitored. Water levels in tanks were monitored to calculate seepage loss from tanks. Water budget of each tank was recorded for year 2006. From the study of status of rain water harvesting tank for year 2006 is found that only one fortnight, August 1-15 produced significant quantity of runoff out of total monsoon season and fulfilled the capacity of tank. Two wells located at micro watershed, one in the zone of influence of tank and another out of influence were monitored for water table fluctuation study. The effect of rain water harvesting tanks on ground water recharge was attributed for wells. Cost of construction of the tanks was estimated and storage cost per cubic meter was also estimated. Cost of storage per cubic meter ranges from Rs.42.69/m^3 to Rs.47.18/m^3 and average cost estimated Rs.45.56/m^3.

Conclusion :

The research study leads to following conclusions.

1. The catchment area from where runoff water could be collected and harvested for storage in tanks, found to be 4.79 ha. From design it was concluded that the runoff for 4.79 ha is insufficient to fulfill the capacity of tank. Thus, the possibility was exploited for increasing the catchment area. The topography was studied and an additional catchment area 2.44 ha joined to previous area to divert the runoff water. Thus area was increased to 7.23 ha.

2. Top surface area of the tank is found to be 8186 m^2 which is 11.33 percent of catchment area. Storage capacity of tank is found to be 9057 m^3.

3. As per design area to be irrigated from rain water harvesting tank was estimated as 3.6 ha. Considering three irrigations at 6 cm depth with 90 percent irrigation efficiency could be given to 3.6 ha area. The ratio of area irrigated to catchment area is found to be 50 percent. However, this year supplementary irrigation to the 2.19 ha area of 503.48 m^3 was given in September 1-15.

4. From the water budgeting of the tank it was revealed that maximum seepage loss is observed at initial period of storage i.e. first week of August; mean value found to be 58.78 mm/day. Seepage loss goes on decreasing to 6.6 mm/day.

Total runoff volume collected from catchment area was 17918.73 m^3 out of which 13251.65 m^3 percolate in the soil as the seepage loss. Seepage loss found to be 73.97 percent of total runoff volume collected. It is estimated that out of the total runoff volume collected, 2941.73 m^3 was evaporated and evaporation loss found to be 16.42 percent of total runoff volume collected.

Hence it is concluded that in present site water loss through seepage are maximum hence effective sealant material like plastic lining etc. recommended to use for control seepage.

5. The rain water harvesting tank has definite effect on increase in ground water table. Ground water recharge in well located at downstream side of tank found to be 23.67 percent where well located out of zone of influence found to be 15.01 percent.

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APPENDICES

APPENDIX I

Table : Estimation of runoff for the year 1985-2005.

Year 1985

Day	Rainfall	Runoff
07 June	26.8	0.0
18 June	50.0	22.5
27 June	28.6	4.0
28 June	33.6	21.0
26 July	40.8	1.0
27 July	66.4	29.88
31 July	18.0	8.0
15 Aug	66.0	29.7
19 Sept	28.0	4.0
03 Oct	53.5	17.5
04 Oct	32.0	20.0
05 Oct	21.4	10.5
06 Oct	8.0	2.0
07 Oct	19.2	8.2
	Total	**187.2**

Year 1986

Day	Rainfall	Runoff
05 June	27.0	4.0
14 June	23.0	0.0
16 June	19.2	1.2
16 July	19.2	1.2
18 July	95.2	42.84
22 July	22.0	2.0
23 July	25.2	3.2
06 Aug	13.4	0.0
08 Aug	43.0	19.35
10 Aug	30.0	0.0
	Total	**72.58**

Year 1987

Day	Rainfall	Runoff
16 June	74.4	33.48
17 June	10.8	3.0
18 June	6.0	1.2
29 June	27.0	0.0
06 July	42.0	11.0
07 July	4.0	0.0
09 July	14.2	5.6
13 July	24.2	3.0
08 Aug	70.0	31.5
09 Aug	21.5	10.5
14 Aug	57.0	25.65
16 Aug	2.4	0.0
17 Aug	2.4	0.0
18 Aug	11.4	3.5
21 Aug	52.0	39.0
24 Aug	11.4	3.5
25 Aug	5.4	1.0
04 Oct	55.0	42.0
05 Oct	19.0	9.0
06 Oct	5.0	1.0
08 Oct	7.0	1.5
	Total	**250.78**

Year 1988

Day	Rainfall	Runoff
12 June	54.0	24.3
13 June	6.8	1.5
18 June	36.0	0.5
20 June	31.0	19.0
21 June	13.2	4.2
22 June	28.0	16.0
23 June	21.2	10.0
24 June	13.0	4.5
26 June	2.0	0.0
19 July	29.0	17.0
20 July	2.2	0.5
21 July	21.0	10.0
22 July	109.0	49.05
24 July	19.2	9.0
25 July	7.0	1.5
26 July	56.0	25.2
27 July	15.4	6.3
28 July	3.6	0.5
30 July	50.0	37.0
31 July	98.0	44.1
16 Aug	25.2	0.0
19 Aug	46.2	33.3
20 Aug	35.5	22.2
21 Aug	17.0	7.2
02 Sept	30.0	17.5
03 Sept	70.0	31.5
07 Sept	24.2	13.0
08 Sept	44.4	31.2
10 Sept	3.4	0.5
17 Sept	28.4	1.2
19 Sept	21.8	11.0
20 Sept	44.0	31.0
22 Sept	22.0	11.0
28 Sept	88.2	39.6
01 Oct	15.0	6.0
	Total	**674.5**

1989

Day	Rainfall	Runoff
14 June	2.3	0.0
23 June	75.2	33.84
26 June	35.0	22.0
27 June	3.4	0.5
28 June	30.2	18.0
29 June	59.0	46.0
30 June	17.0	7.2
01 July	6.4	1.2
10 July	27.0	0.0
17 July	49.0	15.0
22 July	82.5	37.12
23 July	15.0	7.0
24 July	235.0	105.75
17 Aug	140.0	63.0
18 Aug	12.8	4.6
20 Aug	47.0	34.0
20 Aug	14.0	5.0
21 Aug	23.5	12.0
22 Aug	11.0	3.0
23 Aug	6.6	1.5
30 Aug	80.0	55.0
31 Aug	133.0	94.6
	Total	**531.4**

1990

Day	Rainfall	Runoff
05 June	50.2	23.62
06 June	41.4	27.2
09 June	78.4	35.28
13 June	80.0	55.0
14 June	70.0	31.5
15 June	4.6	0.5
16 June	7.2	1.3
17 June	20.0	9.0
18 June	15.0	6.0
19 June	10.8	3.0
28 July	58.0	26.1
24 July	42.0	18.9
25 July	29.3	11.0
07 Aug	34.0	0.5
08 Aug	15.6	0.5
09 Aug	21.0	10.0
12 Aug	63.0	28.35
13 Aug	12.6	4.3
14 Aug	10.0	3.0
15 Aug	5.0	1.0
16 Aug	50.0	37.0
17 Aug	51.0	22.95
18 Aug	5.5	1.0
20 Aug	7.0	1.5
26 Sept	8.0	2.0
27 Sept	9.2	2.5
08 Oct	9.2	66.0
09 Oct	11.4	3.5
10 Oct	10.2	2.9
13 Oct	24.0	1.3
25 Oct	102.0	45.9
26 Oct	14.0	5.0
27 Oct	7.2	2.0
	Total	**653.6**

Year 1991

Day	Rainfall	Runoff
07 June	65.0	51.0
08 June	3.0	0.5
09 June	2.2	0.4
10 June	116.0	52.2
11 June	9.0	2.5
12 June	31.0	19.0
23 June	49.6	15.4
24 June	10.0	3.0
05 July	64.0	51.0
08 July	25.4	14.0
09 July	16.0	7.0
11 July	77.0	52.0
12 July	54.6	24.57
13 July	7.2	1.6
17 July	36.4	8.4
18 July	27.0	5.1
	Total	**307.6**

1992

Day	Rainfall	Runoff
16 June	67.0	30.15
19 June	30.0	18.0
2 Sept	72.4	48.0
3 Sept	3.4	0.4
10 Oct	87.0	39.75
08 Oct	5.0	1.0
03 Aug	25.5	0.0
09 Aug	40.0	27.0
10 Aug	4.4	0.7
11 Aug	34.0	21.0
14 Aug	28.4	16.2
21 Aug	30.0	5.0
	Total	**182.9**

1993

Day	Rainf all	Runoff
13 June	28.4	0.0
15 June	18.0	1.0
19 June	77.0	52.0
30 June	28.0	0.0
01 July	23.5	2.4
04 July	10.0	3.0
14 July	26.0	4.0
15 July	23.0	11.0
28 July	27.4	4.2
30 July	144.0	64.8
31 July	3.0	0.5
01 Aug	2.2	0.0
02 Aug	10.0	3.0
03 Aug	7.6	2.0
25 Sept	44.0	12.0
27 Sept	6.2	1.2
28 Sept	5.0	1.0
	Total	**162.1**

Year 1994

Day	Rainfall	Runoff
09 June	29.0	0.0
10 June	17.2	0.5
03 July	30.2	5.0
24 July	29.6	4.8
05 Sept	36.0	8.0
06 Sept	40.0	18.0
12 Sept	166.5	74.925
	Total	**100.7**

1995

Day	Rainfall	Runoff
15 June	38.0	1.0
21 June	25.2	14.0
23 June	14.6	0.0
25 June	23.0	12.0
30 June	28.0	25.0
11 July	42.0	11.0
23 July	28.6	4.0
24 July	29.2	17.0
30 Aug	42.0	18.9
02 Sept	39.2	27.0
03 Sept	17.8	8.0
14 Sept	25.0	3.0
16 Sept	43.0	21.0
17 Oct	22.6	11.0
18 Oct	6.5	1.5
	Total	**173.4**

1996

Day	Rainf all	Runoff
11 June	23.4	3.0
09 June	24.0	0.5
16 Aug	80.0	55.0
19 Aug	7.0	1.5
20 Aug	8.0	2.0
25 Aug	19.0	1.2
28 Aug	33.2	20.5
29 Aug	26.2	14.4
07 Sept	34.4	7.2
08 Sept	48.4	35.0
09 Sept	4.8	1.0
12 Sept	34.0	21.0
13 Sept	68.5	30.82
16 Sept	32.0	19.0
17 Sept	31.2	18.6
19 Sept	40.4	27.2
02 Oct	64.0	28.8
03 Oct	19.0	9.0
04 Oct	15.8	6.2
27 Oct	35.2	7.4
29 Oct	22.2	11.0
	Total	**320.0**

Year 1997

Day	Rainfall	Runoff
04 July	26.4	4.0
05 July	14.0	0.6
31 July	23.4	2.8
15 Aug	23.5	0.0
21 Aug	51.8	16.0
22 Aug	18.0	8.0
23 Aug	9.2	2.5
07 Sept	86.2	38.79
08 Sept	12.0	4.0
09 Sept	4.2	0.6
21 Sept	27.2	4.2
23 Sept	20.0	9.0
24 Sept	6.8	1.5
20 Oct	45.6	13.0
22 Oct	42.0	29.0
23 Oct	36.2	23.0
24 Oct	12.6	4.5
27 Oct	12.0	4.0
	Total	**165.7**

1998

Day	Rainfall	Runoff
15 June	25.0	0.0
16 June	55.6	25.02
17 June	10.5	3.0
20 June	9.0	2.5
25 June	24.0	3.0
24 July	50.0	16.0
25 July	64.8	29.16
26 July	13.0	5.0
28 July	24.0	13.0
29 July	97.0	38.8
30 July	82.0	32.8
02 Aug	60.0	36.63
03 Aug	22.8	12.0
11 Aug	81.4	36.63
23 Aug	26.5	4.0
25 Aug	67.5	53.0
26 Aug	28.4	16.0
27 Aug	26.4	14.0
07 Sept	95.0	69.0
09 Sept	27.2	15.0
20 Sept	22.0	2.0
21 Sept	56.0	25.2
22 Sept	43.0	30.0
25 Sept	11.0	3.0
08 Oct	25.0	3.0
11 Oct	26.6	4.0
14 Oct	25.0	3.0
15 Oct	74.0	50.0
16 Oct	31.2	19.0
	Total	**571.41**

1999

Day	Rainfall	Runoff
11 June	36.4	8.0
15 June	27.6	15.2
19 June	47.4	34.0
07 July	29.4	0.0
08 July	26.0	14.0
09 July	46.0	33.0
02 Aug	74.6	33.57
03 Aug	11.0	3.0
04 Aug	25.0	13.0
30 Aug	50.0	37.0
02 Sept	90.0	40.50
08 Sept	71.4	47.6
09 Sept	48.5	35.6
11 Sept	26.5	14.5
12 Sept	15.0	6.0
22 Sept	29.4	0.0
25 Sept	15.4	0.0
13 Oct	62.0	27.9
	Total	**362.77**

Year 2000

Day	Rainfall	Runoff
02 June	40.2	33.2
04 June	30.0	18.0
06 June	5.6	1.0
07 June	22.4	11.0
08 June	15.0	6.0
11 June	42.0	29.0
01 July	33.6	21.0
03 July	13.0	5.0
07 July	44.0	12.0
09 July	15.4	6.3
11 July	13.0	5.0
12 July	18.0	1.0
07 Aug	36.0	8.0
10 Aug	54.0	41.0
11 Aug	77.2	34.74
12 Aug	15.2	6.2
13 Aug	3.5	0.5
21 Aug	15.0	0.0
24 Aug	125.0	50.0
25 Aug	34.0	21.0
27 Aug	27.2	15.0
28 Aug	10.0	3.0
29 Aug	21.6	11.0
30 Aug	24.4	13.0
	Total	**380.4**

2001

Day	Rainfall	Runoff
11 June	27.7	0.0
13 June	30.0	18.0
14 June	27.0	15.0
15 June	7.4	1.5
29 July	39.0	9.0
05 Aug	82.4	37.08
06 Aug	65.6	52.0
07 Aug	40.2	18.09
08 Aug	3.0	0.0
10 Aug	37.0	24.0
11 Aug	17.6	8.3
12 Aug	3.0	0.0
13 Aug	50.0	22.5
14 Aug	4.0	0.5
15 Aug	23.0	12.0
16 Aug	4.4	0.7
17 Aug	3.8	0.6
01 Oct	165.0	116.0
02 Oct	97.0	43.65
03 Oct	16.4	7.0
07 Oct	44.4	31.0
	56.0	43.0
	Total	**409.2**

2002

Day	Rainfall	Runoff
24 June	21.4	0.0
25 June	84.0	37.8
26 June	135.0	60.75
27 June	15.6	6.3
30 June	3.9	0.5
24 July	26.6	4.0
26 July	17.6	2.0
28 July	9.4	0.0
05 Aug	30.6	5.0
24 Aug	32.0	0.0
25 Aug	79.4	35.73
02 Sept	38.4	9.0
03 Sept	9.2	2.5
06 Sept	50.0	37.0
	24.0	0.0
	Total	**200.58**

2003

Day	Rainfall	Runoff
15 June	34.0	7.0
02 July	50.0	37.0
03 July	27.6	15.8
05 July	29.4	17.4
06 July	10.6	3.0
11 July	37.6	8.3
13 July	25.8	14.4
15 July	32.5	20.0
16 July	38.4	17.73
18 July	31.4	19.0
19 July	11.5	9.0
20 July	36.9	16.60
21 July	7.5	2.0
22 July	11.6	3.6
24 July	13.4	4.5
23 Aug	44.0	12.0
24 Aug	23.6	12.5
30 Aug	23.0	0.0
	Total	**219.53**

2004

Day	Rainfall	Runoff
26 July	38.2	9.0
27 July	13.4	0.0
28 July	16.0	6.5
29 July	22.0	11.0
30 July	17.8	7.8
06 Sept	38.2	9.0
07 Sept	15.4	0.5
08 Sept	3.6	0.0
09 Sept	3.0	0.0
11 Sept	31.0	5.0
	Total	**48.5**

Rainfall for the year 2005

Day	Rainfall	Runoff
9 July	24.2	0.0
10 July	53.2	40.0
11 July	28.3	16.4
12 July	24.0	12.5
15 July	85.2	38.3
16 July	45.2	32.4
23 July	18.7	1.0
25 July	17.5	0.5
26 July	177.8	80.01
27 July	242.9	109.39
28 July	41.6	26.5
29 July	1.9	0.0
31 July	44.3	31.5
01 Aug	23.1	12.0
05 Aug	12.9	0.0
07 Aug	13.7	1.0
23 Aug	20.0	2.0
21 Sept	80.3	36.123
22 Sept	19.30	9.0
14 Oct	51.0	16.0
15 Oct	82.5	57.0
16 Oct	8.2	2.0
	Total	523.65

Rainfall for the year 2006

Day	Rainfall	Runoff
24 June	31.2	5.3
25 June	6.8	0.97
27 June	7.0	1.06
29 June	27.2	3.58
30 June	20.0	9.78
4 July	24.0	2.41
5 July	46.0	33.10
5 Aug	153.6	138.64
6 Aug	234.0	218.67
7 Aug	33.2	21.22
20 Sept	37.6	8.51
25 Sept	32.6	5.96
26 Sept	25.8	14.65
1 Oct	30.4	5.0
	Total	468.85

APPENDIX-II

Water level fluctuations with reference to reduced levels (m) in wells

Month	Water level (m)	
	Well 1 in the influence	Well 2 out of influence
May	393.72	393.82
June	394.22	394.02
July	394.52	395.32
August	403.31	403.82
September	407.12	405.42
October	408.51	405.12
November	408.46	404.00
December	404.98	401.22
January	403.52	398.42
February	401.22	396.72
March	396.42	396.12
April	395.72	395.62