

"HYDROLOGICAL AND ECONOMICAL ASSESSMENT OF
WATER HARVESTING STRUCTURES AT ADARSHA
WATERSHED"

Thesis

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SEPTEMBER, 2003

DEDICATED TO



MY

BELOVED PARENTS

CERTIFICATE – I

This is to certify that the thesis entitled "Hydrological and Economical Assessment of Water Harvesting Structures at Adarsha Watershed" submitted in partial fulfillment of the requirements for the degree of "Master of Technology in Agricultural Engineering" of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide work carried out by Shri K. Srinivasa Raju under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

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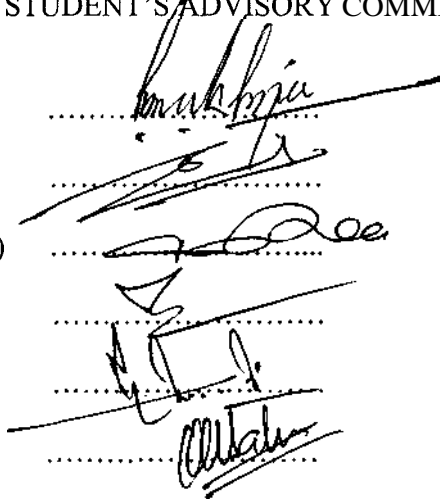
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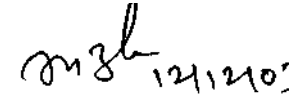
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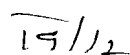
CERTIFICATE - II

This is to certify that the thesis entitled "Hydrological and Economical Assessment of Water Harvesting Structures at Adarsha Watershed" submitted by Shri K. Srinivasa Raju to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirements for the degree of M.Tech.(Agril. Engg.) in the Department of Soil and Water Engineering has been approved by the Student's Advisory Committee after oral examination in collaboration with the external examiner.


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(Place: Raipur

(Date:


(K. Srinivasa Raju)

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LIST OF ABBREVIATIONS AND SYMBOLS

| Abbreviation | - | Expansion |
|---------------------|----------|---|
| ASAE | - | American Society of Agricultural Engineers |
| ASCE | - | American Society of Civil Engineers |
| Agri. Engg. | - | Agricultural Engineering |
| bcm | - | billion cubic meter |
| CRIDA | - | Central Research Institute for Dryland Agriculture |
| CSWCRTI | - | Central Soil and Water Conservation Research and Training Institute |
| cm | - | centimeter |
| cm/h | - | centimeter per hour |
| E | - | East |
| ha | - | hectare |
| ICRISAT | - | International Crops Research Institute for the Semi-Arid Tropics |
| I.G.A.U. | - | Indira Gandhi Agricultural University |
| m | - | meter |
| m ² | - | square meter |
| m ³ | - | cubic meter |
| mm | - | millimeter |
| N | - | North |
| NGO | - | Non-Government Organisation |
| NRSA | - | National Remote Sensing Agency |
| Rs | - | Rupees |

| | | |
|---------------------------|---|--|
| Rs. /m³ | - | Rupees per cubic metre |
| SCS | - | Soil Conservation Service |
| USDA | - | United States Department of Agriculture |

ABSTARCT

by

K. Srinivasa Raju

The hydrological aspects and cost evaluation of different water harvesting structures viz. masonry and **earthern** checkdams and sunken pits, as constructed at Adarsha watershed in Rangareddy district of **Andhra Pradesh**, were investigated

The modified SCS Curve Number runoff model developed by Pathak *et al.*(1987) had been modified to suit the topographic conditions of Adarsha watershed. From the runoff simulation studies over past 15 years, it was observed that there is 59 per cent probability of getting runoff of more than 1,32,000 m³ in an year. Hence, an additional storage capacity of 40,000 m³ can be created, taking into account, the existing capacity of 11,000 m³.

Numerical modeling of tank had been used for making an estimate of artificial groundwater recharge. From the water balance studies of a 255 m capacity check dam, the contribution of water harvesting structures to ground water was assessed as 26,000 m³ and 15,000 m³ in the years 2000 and 2001, respectively.

Analysis of cost and storage capacity of water storage structures at Adarsha watershed revealed that, on an average, one cubic metre of water storage capacity costed Rs.8 for earthen check dams, Rs.27 for sunken pits and Rs.112 for masonry check dams. The high unit costs of masonry check dams outweigh the benefits of durability and stability. On the other hand, sunken pits have the limitation of storage capacity. Earthen check dams prove to be the most cost-effective method, if precautions against overtopping are taken care of. Earthen check dams are simple and easy to construct and hence can be implemented on a large scale, without any hassles resulting in direct benefit to the local community also. However, other aspects such as suitability, equity for harvested water, and the purpose of a particular type of storage structure need to be further considered along with the economic assessment.


Er. A. P. Mukherjee

(Major Advisor)

Place: Raipur

Date:

INTRODUCTION

CHAPTER - I

INTRODUCTION

The rainy season in India spans from three to five months in most parts of the country. Almost 90 percent of the rainfall is received during this part of the year. The rest of the year remains dry. Hence, the conservation and preservation of precipitation occurring in the rainy season are necessary. Water harvesting serves as a means of preserving rainwater for future use.

Rainwater harvesting may be done in a number of ways, both *in-situ* and *ex-situ*, namely- roof water harvesting, ponds, percolation pits, recharge wells *etc.* However, their suitability may vary from one place to another, mainly depending upon the purpose for which the water will be harvested, land topography and utility, soil properties, pattern of rainfall and construction costs.

1.1 Prospects of water harvesting

The scope of water harvesting depends upon the potential for runoff, which in turn is affected by the rainfall characteristics, topography, soil type and its conditions. Scientific investigation is of imperative value in determining the type, size and number of structures to be constructed for the optimum utilization of the runoff.

The simulation of runoff helps a great deal in the assessment of prospects of water harvesting, in the absence of runoff records for a watershed. However, the ability of the runoff model in simulating the complex situation prevailing in the field accurately, determines the efficacy of the model. Therefore, a suitable runoff model has to be developed, taking into account, the typical features of a watershed.

1.2 Groundwater recharge

Groundwater resources have a prominent role in meeting the water requirement of the country. Groundwater supplies over 90 % of drinking water needs and over 50 % of agricultural requirement of the country. Since pumping of underground water is estimated to be double the rate of aquifer recharge from rainfall, the necessity for recharging groundwater cannot be **overemphasized**.

Water harvesting structures contribute to the groundwater by way of seepage from the structure. The proportion of water stored in the structure, leading to the water table depends upon the type of structure, depth of ground water table and characteristics of the soil profile. The assessment of groundwater recharge effected by the water harvesting structures provides an insight into the change in the groundwater regime and thus the efficiency of the structures in artificial ground water recharge.

1.3 Evaluation of structures

Watershed development programmes are being given top priority by the government, in the recent years, leading to the enhanced funding on these programmes. Major share of this expenditure is made on the water harvesting structures in most of the programmes across the country. Hence, an evaluation of the costs made on these structures is also necessary for the effective fund utilization.

The cost-effectiveness of various types of water harvesting structures can be compared so as to assess the viability of different kind of structures. This will serve as a tool in determining the type of structure to be preferred over the other at the time of implementation of watershed programmes.

1.4 Objectives

The present study has been taken up *in lieu* of the above considerations with the following objectives:

- (1) To make modifications to the **runoff** model, to suit the local conditions at Adarsha watershed.
- (2) To ascertain the prospects of additional water harvesting at Adarsha watershed.
- (3) To estimate the quantum of groundwater recharge being contributed by water harvesting structures.
- (4) To assess the cost-effectiveness of various types of water harvesting structures.

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

The principles of water harvesting are not new. These techniques are being used, from as early as 4,500 B.C., by the people in Middle East. In fact, researchers have constructed water-harvesting systems used for runoff farming in Israel's Negev desert 4,000 years ago. India has had a tradition of water harvesting which is more than two millennia old.

However, it can be said that scientific research on water harvesting structures, their economy and potential ground water recharge has been taken up only in the recent times. And, with water shortages reaching crisis proportions in many countries, this aspect of research is becoming the focal point of many a studies.

The following sections enumerate some of the research work related to runoff simulation models, water harvesting structures and their characteristics. The research related to the cost-effectiveness of different types of structures is also given at the end of this chapter.

2.1 Runoff simulation models

Singh (1962) developed a simplified version of conceptual models, only by considering a linear channel of pure translation and two linear reservoirs of different storage coefficients in series. However, this model was developed for simulating the typical conditions of large watersheds only and hence not suitable for small watersheds.

Kulandaisamy (1964) considered the rainfall and runoff relationship by system analysis. The vast computational requirements involved in the application of this model discourage the users from using this model.

Diskin (1975) proposed a model consisting of two parallel cascades of linear reservoirs with four parameters. The unique determination of these parameters remained a difficult task in applying this model.

Pederson *et.al.* (1980) reported a model considering the watershed as a single linear reservoir and observed that the use of this model should be restricted to small flashy watersheds having very small time of concentration.

Helweg *et. al.* (1982) presented an improved model by suggesting a non-linear rainfall-runoff relationship. Multiple linear regression was used to solve the model coefficients from historical values.

Vinod Kumar and Rastogi (1989) developed a mathematical model of the instantaneous unit hydrograph based on time-area hydrograph. The instantaneous unit hydrograph was used for generation of runoff hydrographs. The predicted runoff hydrographs were found to be in good agreement with the observed runoff hydrographs.

Though the above discussed models reveal better accuracy in the prediction of runoff, their complexity, huge data requirement and applicability for various conditions are the major limiting factors. It was observed that neither simple nor complex models are free from failure and simple models also perform satisfactorily in most cases. Hence, application of models should be done based on merit and hydrological data available for the watershed.

2.2 Water harvesting structures

2.2.1 Hydrologic characteristics

Dvoracek *et. al.* (1963) studied water flow characteristics as influenced by the geometry of recharge pit. To study the effect of pit geometry on outflow, Hele-shaw viscous fluid models of recharge pits, simulating conditions of different pit geometry were used. Results showed that changes in depth to impermeable layer effect only 3 to 4 per cent variations in free-water surface location and resultant flow area.

Schiff (1964) had conducted research on the influence of site characteristics on groundwater recharge from a water harvesting site. Determination of the potential of a site for recharge and the prediction of the performance of a site can be based only on the knowledge of relationships between soil and strategic characteristics and water movements.

Eisenhauer *et. al.* (1982) have studied the potential for groundwater recharge from flood-retarding reservoirs in South Central Nebraska. Seepage from these reservoirs potentially increase groundwater recharge by an amount equal to volume seepage after overburden on aquifer is sufficiently wetted to allow additional seepage to reach aquifer.

Reichard and Bredehoeft (1984) observed the performance of local aquifers as influenced by stream transmission losses. Continuous records from a shallow dug well in the aquifer showed a rapid increase in the water level following a surface flow. A subsequent steady decline occurred during periods of no runoff. This showed that the transmission losses from the stream contributed to the groundwater, when the water table levels are shallow.

Dokoozlian *et. al.* (1987) studied the changes in hydraulic conductivity as influenced by continuous flooding in San Joaquin valley of California. An average daily rate of recharge of 80 mm /day for a 32-day period each year for a period of 3 years was achieved through a clay loam soil. There was no substantial change in saturated hydraulic conductivity for the whole period even under continuous flooding.

Hubbard *et. al.* (1989) observed the movement of surface water to ground water in the south-eastern coastal plain of U.S.A. and concluded that the amount of actual recharge may be small compared to the potential available recharge because potential recharge rate generally exceeds the rate at which aquifers can accept and transmit water, but will certainly lead to actual recharge at some point of time later.

Kalita *et. al.* (1992) developed a simulation model to predict the vertical and lateral percolation losses from a ponded site. The vertical percolation losses were almost equal to the saturated hydraulic conductivity values and, in most cases, these losses occurred with deeper water table depths. The lateral percolation losses were relatively small in comparison to vertical percolation losses.

Brian *et. al.* (1997) have made efforts to understand the interactions between groundwater and surface water within the context of watershed management concerns. Groundwater and surface water constituted a single dynamic system in most parts of the Suwannee river basin due to the presence of *karst* features.

Khepar et. al. (1999) took up field study to examine the feasibility of artificial ground water recharge through surface drainage system. The added advantage of providing sequence of pools by constructing sequence of pools by constructing checks across the drain at suitable intervals and recharge shafts under specific **geo-hydrological** conditions to enhance the groundwater recharge was examined. The studies revealed that recharge through surface drainage system along with enhancement of recharge through creating sequence of pools and provision of recharge shafts are technically feasible.

Gore et. al. (2000) have constructed a ground water flow model of the **Wagarwadi** watershed to assess the impact of impounded water in two *nala* bunds and a cement plug structure. They have been simulated as lake interaction in the model. The *nala* bund and cement plug structures were found effectively contributing for artificial recharge through harvested water.

2.2.2 Contribution of losses to groundwater

ICRISAT (1977) Analysis of losses from runoff storage in tanks at **ICRISAT, Patancheru** showed that seepage losses accounted for one-half of the total inflow and losses by evaporation constituted about one-fourth of the total inflow, over a period of **four-and-half** months starting from July. These seepage losses were found to have contributed to the water table which was gauged from the increase in the water level in wells.

Eisenhauer et. al. (1982) have studied the potential for groundwater recharge from flood- retarding reservoirs in South Central Nebraska. The average seepage rate for two reservoirs with watershed of 400 hectares each was 12.7 mm/day and 15.0 mm/day. This amounted to annual seepage volume of 65,000

m^3 and $1,10,000 \text{ m}^3$ respectively, which contributed to the groundwater after overburden on aquifer is sufficiently wetted.

Rama Mohan *et. al.* (1996) has studied the influence of conservation measures on groundwater regime in a semi-arid tract of south India. The predominantly agricultural watershed was treated with soil and water conservation measures such as diversion drains, stone check dams in arable land and rock fill dams, arch weir and *nala* bund across the gully. Hydrological analysis revealed that integrated management of land and water resources consistently improved groundwater regime. Consequently, water levels in the open wells rose by 0.5 to 1.0 m, thereby increasing the area irrigated by wells by 172 % when compared to pre-project period.

Sathpathy *et. al.* (1997) have studied the dugout-cum-embankment type ponds for water harvesting. The study quantified the major hydraulic parameters of water harvesting tanks located in lower reaches of hill slopes using a water balance approach. There was no significant correlation between water depth and seepage. The major portion of pond inflow was lost as seepage and evaporation. And the seepage losses constituted 91 to 96 % of the total losses (evaporation and seepage).

Gaur *et. al.* (1998) have studied the effect of water conservation structures on groundwater recharge in watershed. Generally, it was observed that there was an overall buildup of water levels in the entire watershed due to impounding water. Impact of water conservation structures on ground water regime has been evaluated as 6 ha-m of recharge per year, which is causing a rise of 0.3 to 2.5 meters in water table of different locations.

Mul *et. al.* (1998) have studied the effect of water conservation measures on runoff, soil loss and groundwater recharge in watershed. The water conservation measures are found to be responsible for rising the water table in observation wells on downstream side of *nala* bunds. The water table rose by about 2 metre in the wells located within 200 meters on the downstream side of the *nala* bunds and other wells located adjacent to water conservation structures

Pendke *et. al.* (1998) has studied the effect of watershed management on groundwater potential in Wagarwadi watershed of Parbhani district. Four open wells in treated and two open wells in untreated area of watershed are selected for monitoring groundwater fluctuations. The increase of 40 to 45 per cent in accumulated groundwater potential due to watershed management practices was observed in treated area after the period of two years.

Phadnavis *et. al.* (1998) have studied the impact of water harvesting structures on ground water recharge in Padalsingi watershed in semi-arid Maharashtra. Two *nala* bunds and one percolation tank were selected for this study. The structures resulted in the increase in water table in open wells situated below the structures.

Tiwari *et. al.* (1999) have analyzed different water harvesting structures at Tezpura watershed in Bundelkand region. All kinds of water harvesting structures are found to augment the groundwater. The study revealed that, by constructing 4 check dams on the ephemeral stream, the recharge in dugout wells increased from 2 to 12 hours a day and the number of dugout wells increased from 5 to 35 providing irrigation to about 60 hectares of agricultural land. The water table in wells increased form 3 to 7 m. in different seasons.

Bhuyan (2000) has done the economic analysis of watershed management project at micro-level in Naupada district. Among the soil conservation works undertaken were 35 gully plugging and a water harvesting structure and renovation of two tanks. Average water table depth during summer and rainy seasons had gone down from 30 meter to 10 meter (66.60 %) and 10 meter to 2 meter (80.00 %), respectively.

Bhan (2000) has analyzed the impact of various soil and water conservation practices and concluded that capturing the rainfall at the site of occurrence with its minimum loss through runoff and harvesting excess runoff in dugout ponds, storage tanks, gully control structures, checkdams, bundhi etc. have been found highly successful in augmenting surface water supplies and recharging ground water table apart from substantially improving production of crops in rain-fed areas

Tyagi (2001) has studied the effectiveness of percolation ponds for artificial recharge. Two percolation ponds namely, Uralipatti and Viralipatti in Tamilnadu were studied to assess the recharge aspect of these ponds in quantitative terms. The seepage rates in these ponds are found to vary from 180 to 16.3 m³/day (55.7 to 5.4 mm./day) and 137 to 20.4 m³/day (23.3 to 5.0 mm/day) respectively for storage in these ponds varying between 2700 to 260 m³ and 10,905 to 28.30 m³ respectively. On an average, about 88 % of the total storage loss percolated down and the remaining 12 % was lost through evaporation in Uralipatti tank whereas the seepage and evaporation losses accounted for 66 and 34 % of the total storage loss respectively in Viralipatti tank

Khepar *et. al.* (2001) have studied large number of soil and water conservation works constructed under World Bank Aided Project in **Kandi** area of **Punjab**. The impact of these works on ground water regime has been investigated. The studies have revealed that the water table has been rising on the average 22.6 cm/year during the period 1979-98 as a result of these works. The study emphasized the need for taking up the watershed management works in the upper reaches of declining water table areas on priority basis for reversing the trend of declining water table.

Sastry *et. al.* (2001) have observed the impact of soil and water conservation measures adopted on watershed basis by CSWCRTI, Dehradun and its regional research centers on development of ground water resources and subsequent recharge. The engineering practices that have been found suitable for artificial recharge to augment depleting ground water resources are assessed. The impact of percolation embankments and check dams was assessed by measuring the water level in the open wells inside watershed at the end of monsoon season every year. It revealed that even in low rainfall years, the drop in water table was less than 50% in recharged wells than that in non-recharged wells.

Anonymous (2002) Five water-harvesting structures were identified in the **Antisar** watershed under **Kheda** district of Gujarat to assess their effect on groundwater recharge. Water balance analysis of largest structure with 10 ha-m. Total runoff volume collected in the structure was 44,985 m³, out of which 2,632 m³ water was lost through evaporation. Remaining water, constituting about 94% of collected volume, percolated in the soil to form soil moisture storage and groundwater recharge.

2.3 Cost evaluation of water harvesting structures

Brown (1955) has reviewed the accomplishments in 11 watersheds under Flood control act of 1936. The average cost incurred on these structures per cubic meter of capacity was compared with that of the large dams. It was observed that the **floodwater-retarding** structures were more cost-effective than most of the large dams, as the average unit cost of these structures was considerably less than that of the most large dams.

Merle *et. al.* (1972) had evaluated four types of water harvesting structures *viz.* Steel tank, Butyl rubber tank, Earth tank and Open pond on the basis of the costs involved. The initial cost per unit of storage for steel tank, rubber tank and earth tank are 16, 9 and 4.5 times respectively more than that for Open pond at Colorado, U.S.A. Even though the capacity and cost are highly variable and depend largely on site characteristics, Open ponds turn out to be the cheapest structures.

Doty *et. al.* (1989) compared water storage costs for a stream water level control system (SWLC), which provides underground storage, with storage costs for impoundments and excavated ponds. Water storage in excavated ponds was found to be the most expensive method than the other two methods. And water storage in impoundments provides water storage at less unit cost than SWLC and excavated ponds.

Savadamuthu (1991) studied the construction of percolation ponds taken up under various programs like Rural Landless Employment Guarantee Program in **Tamilnadu**. Percolation ponds are mini storage structures constructed across natural watercourses of small watershed areas to impound rainwater and retain it

for a longer time. It was observed that the construction of mini storage structures on natural water courses reduced the cost of construction considerably.

Mukherjee *et. al.* (1992) have evaluated water harvesting structures such as **coaltar** drum structure, bamboo structure etc. for their cost-effectiveness. **Techno-economic** feasibility of these structures at Indira Gandhi Agricultural University Farm, Raipur was undertaken. The results showed that low cost water harvesting structures made of locally available material should be preferred on account of added advantages like micro-ecological balance, erosion control, *in-situ* water utilization, generation of employment *etc.*

MATERIALS AND METHODS

CHAPTER - III

MATERIALS AND METHODS

This chapter describes the characteristics of the study watershed, data collection and various procedures and techniques used in the study to fulfill the objectives of the project, validation of the modified hydrological model for simulating the runoff. The simulation model along with the flow chart is also described briefly in this chapter.

3.1 Study watershed

The runoff from a watershed depends upon multitude of factors, mainly on basin and storm characteristics. Thus, each watershed is **unique**, and an understanding of the ambience of the watershed is a pre-requisite for evaluating potential for water harvesting. The following sections present basic features of the watershed under study.

3.1.1 General description

Adarsha watershed in Ranga Reddy district of Andhra Pradesh has been selected for the present study where Innovative Farmer Participatory Integrated Watershed Management Model is being implemented under Drought Prone Area Programme of the state government with the technical backstopping of **ICRISAT**, **CRIDA** and **NRSA**, in co-ordination with M.Venkatarangaiya Foundation (NGO) and active participation of the farmers.

Adarsha community watershed is located at **Kothapally** village (longitude 78° 5' to 78° 8' E and latitude 17° 21' to 17° 24' N) in Ranga Reddy district, Andhra Pradesh, India (Fig 3.1). It is 40 km south of **ICRISAT** Center,

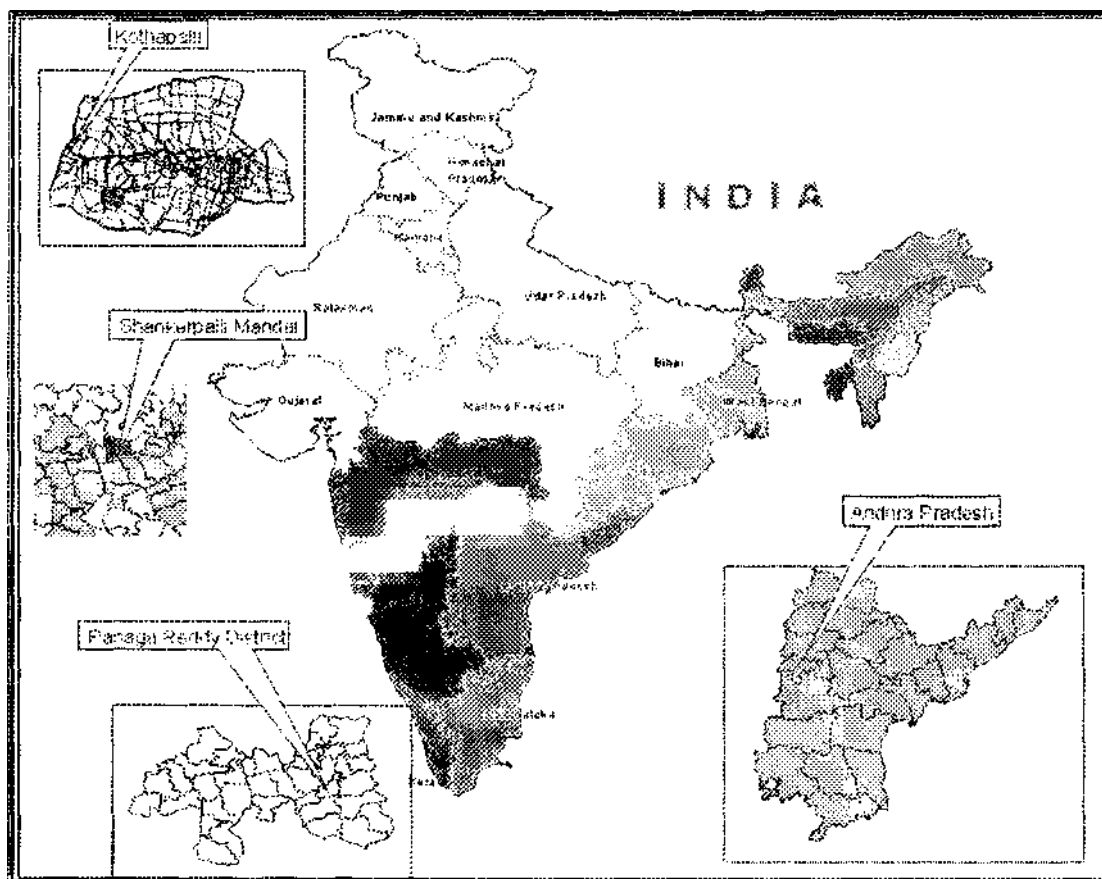


Fig 3.1 Location map of Adarsha watershed

Patancheru and spread over 465 ha, of which 430 ha is cultivable and 35 ha is wasteland. The watershed is characterized by undulating topography with an overall slope of 2.5 %. The vertisols and associated vertic soils occupy 90 % of the watershed area. About 10 % of the watershed area is under alfisols. The soil depth ranges from 30 to 90 cm having medium to low water holding capacity.

3.1.2 Agro-climate

The mean annual rainfall at the watershed is about 800 mm received mainly in June-October (85%). The rainy season, also known as *kharif*, usually begins in June extends up to October. The post-rainy winter season (October-

January) also known as post monsoon or *rabi* is dry and cool and days are short. During this period crops can be grown in **vertisols** on stored profile soil moisture. The hot dry summer season is from February until rains begin in early June

3.2 Runoff simulation

Runoff recorders have been installed in the watershed in the year 1999, with the inception of watershed development programme. Therefore, the observed values of runoff were available for a period of four years (1999-2002). However, the analysis of the runoff for evaluating the prospects of water harvesting require the data for a minimum period of 15 years. Hence, the necessity of a simulation technique was found to be imperative.

A good number of runoff models are available to estimate runoff from small watersheds. The modified SCS curve number runoff model, developed by Pathak *et. al.* (1987), had been chosen for the present study, since the model was developed considering the typical conditions of Semi-Arid Tropics. The flow chart of the model is shown in the Fig. 3.2.

The model was developed from Soil Conservation Service (SCS) runoff model by taking into account, soil moisture accounting procedure to suit small watersheds in the Semi-Arid Tropics. Pathak *et. al.* (1987) tested its validity and soil moisture accounting procedure using hydrological data collected from on-station **vertisol** watersheds at **ICRISAT center**. They reported that the agreement between observed and simulated daily, monthly and annual runoff was good. The **developed** model and the moisture accounting procedure simulated quite accurately runoff for high, low as well as normal rainfall years in the semi-arid environment.

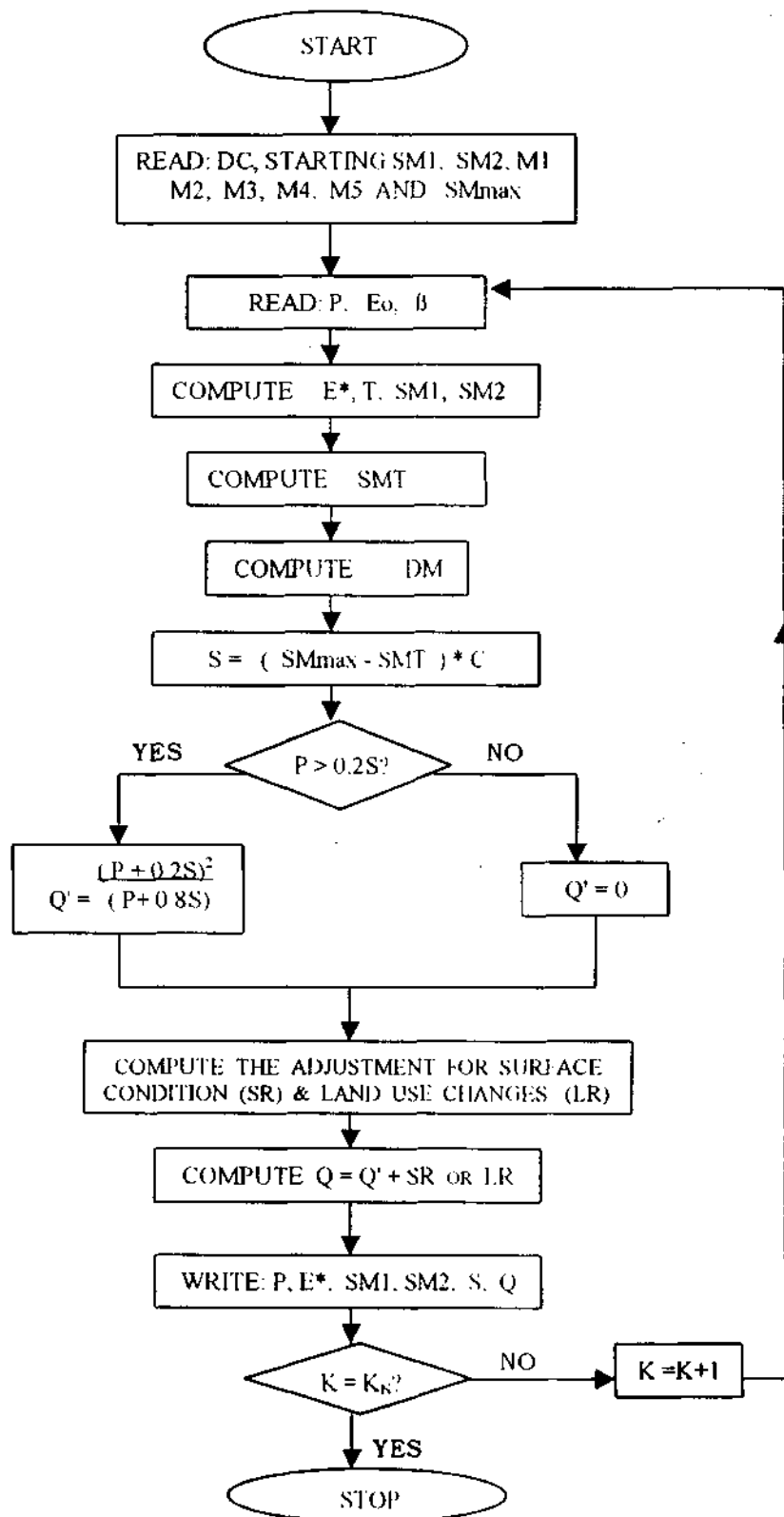


Fig 3.2 Flow chart depicting the runoff model

Flowchart shown in Fig. 3.2 indicated that several parameters (input and output) were used in the runoff model. Decoding of all these parameters are listed below:

| | |
|-------------------|--|
| DC | = Parameter representing soil depth |
| Sr | = Adjustment for cracks |
| Rs | = Adjustment for land smoothness |
| SM1 | = Initial soil moisture of first layer |
| SM2 | = Initial soil moisture of second layer |
| M1 | = Moisture at field capacity in first layer |
| M2 | = Moisture at field capacity in second layer |
| M3 | = Minimum moisture level for evaporation |
| M4 | = Moisture at wilting point in first layer |
| M5 | = Moisture at wilting point in second layer |
| SM _{max} | = Profile moisture at saturation |
| P | = Rainfall |
| E _o | = Pan evaporation |
| P | = Light interception coefficient |
| E* | = Losses by evaporation |
| T | = Transpiration |
| SMT | = Total soil moisture |
| Q | = Simulated runoff |
| S | = Retention parameter |
| DM | = Rainfall excess/ deficit |

- C = Coefficient
- t* = Time factor
- K, K_n = Starting and ending dates
- Q' = Simulated runoff before accounting for Sr and Rs
- D = Deep percolation

3.2.1 Runoff model

The original SCS curve number equation has been used for the determination of runoff

$$Q = (P - 0.2 S)^2 / (P + 0.8 S) \quad P > 0.2S \quad \dots(3.1a)$$

$$Q = 0 \quad P < 0.2S$$

where,

Q = daily runoff

P = the daily rainfall in mm

S = soil retention parameter

However, the formula used for the determination of curve number,

$$S = (25400/CN) - 254 \quad \dots(3.2)$$

where, CN denotes the curve number was discarded, since it was found to attribute discrete relationship between rainfall and runoff leading to unrealistic quantum jumps in calculated runoff.

Following Hawkins (1978), the relationship between S and total water storage, V is

$$V_i = 1.2 S_i \quad \dots (3.3)$$

$$\text{since } \lim_{P \rightarrow \infty} (P - Q) = 1.2S$$

At time t_2 , ($t_2 > t_1$) the total water storage, V_2 is obtained by

$$V_2 = V_1 + ET_1 - (P_1 - Q_1 - D_1) = 1.2S_2 \quad \dots (3.4)$$

Similarly total water storage V_n available at time t_n will be given by

$$V_n = V_{n-1} + (ET)_{n-1} - (P_{n-1} - Q_{n-1} - D_{n-1}) = 1.2S_n \quad \dots (3.5)$$

where, Q_{n-1} , D_{n-1} and $(ET)_{n-1}$ refer to runoff, deep percolation and evapo-transpiration losses between time t_{n-1} and t_n .

The above equation does **not** define clearly the depths of soil profile under consideration. In this model, runoff calculations are based on water status for a particular depth of soil. This provides a logical basis for calculating runoff from different soils, land treatments, and topographic conditions.

Thus, retention parameter, S is calculated using the relationship

$$S = C(SM_{\max} - SMT) \quad \dots (3.6)$$

where,

SM_{\max} = soil moisture at saturation in mm,

SMT = actual soil moisture in mm at any particular time,

C = a coefficient whose value is determined through calibration

Soil moisture accounting procedure

Soil moisture, evapotranspiration and deep percolation are calculated on a daily basis by using a soil moisture accounting procedure. This moisture accounting procedure is based on the assumption that whenever there is rainfall or irrigation, the upper layer is fully recharged before any moisture is transmitted to the lower layer. The soil moisture accounting procedure can simulate the soil moisture of various layers at 50, 100 and 150 mm depth increments. The daily soil evaporation and transpiration are calculated separately using equations-

.(3.7)

$$T = (1-p)E_o \quad \dots(3.8)$$

where,

E_o = daily open pan evaporation

E = daily evaporation form soil

P = light interception coefficient

T = daily transpiration

t^* = time factor

The soil moisture for the first layer is given by,

$$(SM_2)_1 = (SM_1)_1 + \{P_1 - Q_1 - E_1 - T_1 - D_1\} \quad \dots(3.9)$$

where,

$(SM_1)_1$ = the previous day's soil moisture content for the first layer

$(SM_2)_1$ = the soil moisture content of the first layer for the day under consideration

E_1, T_1, D_1 = the evaporation, transpiration and deep percolation losses, respectively from the first layer

The soil moisture for the second layer will be

$$(SM_2)_2 = (SM_1)_2 + \{D_1 - E_2 - T_2 - D_2\} \quad \dots(3.10)$$

where,

$(SM_1)_2$ = the previous day's soil moisture content

$(SM_2)_2$ = the soil moisture content of the second layer for the day under consideration

E_2, T_2, D_2 = the evaporation, transpiration and deep percolation losses, respectively from the second layer

Time delay factor

In clay soils, it was observed that the immediate transfer of excess moisture from top layer to the bottom does not occur, because of low saturated hydraulic conductivity. The concept of time delay factor is based on an assumption that the deep percolation rate from any soil is directly proportional to the excess moisture temporarily held in that layer, so that

$$D = df (S_{Ma} - S_{Mf}) \quad \dots(3.11)$$

where,

D = deep percolation in mm per day

df = time delay factor for that soil layer

S_{Ma} = soil moisture content at the beginning of the day in mm

S_{Mf} = field capacity moisture content for that layer in mm

Runoff correlation for small cracks

The long dry spells in the rainy season was found to increase infiltration and therefore reduce runoff. The model estimates the negative contribution of cracks to runoff by the following equation

$$S_r = \alpha \sum_1^n E^* \quad \dots(3.12)$$

where,

S_r = runoff 'cracking' adjustment factor in mm

E* = total evaporative demand on the soil during an extended rainless period

n = the number of days with no rain or with rainfall less than soil evaporation

Alpha (α) is a function of the amount and type of clay in the soil, and represents soil's inherent tendency to crack. It is determined by calibration with the measured runoff data. This correction for cracking was applied only when the total evaporative demand exceeds 20 mm.

3.2.2 Performance of the original model

The runoff was simulated for four years (1999-2002), so as to compare it with the measured runoff, to check for its accuracy. After careful investigation, it was found that the model was simulating runoff in excess at the initial stages of the monsoon (June/July) and was under predicting at the latter stages (Sept./Oct.).

The study indicated that the model, since developed for small watershed, had not considered surface depression storage and standing water due to field bunds in check basin method of rice cultivation. Storage was found to reduce the runoff at the outlet of the watershed. Hence, amendments had been made to the model to take into account, the water storage on fields and natural depressions, specific to the watershed under study.

3.2.3 Topographic considerations

Field bunds and natural depressions were found to hold water up to a depth of 300 mm, on an average, over the entire watershed. The runoff contribution to a runoff depth of more than 300 mm, was assumed to flow out from the outlet of the watershed. The ponded water was perceived to infiltrate at the rate of 10 mm per day (Wani *et. al.*, 2002) on an average. To accommodate the above assumptions and effect the change in the predicted runoff accordingly, the cumulative runoff of previous 30 days has been considered and following conditions were set:

- If the cumulative expected runoff of previous 30 days is found to be nil, then a value of 300 mm will be deducted from the obtained predicted runoff.
- If the cumulative expected runoff of the previous 30 days is less than 100 mm, then a value of 200 mm will be deducted from the obtained value.
- If the cumulative expected runoff of the previous 30 days is less than 200 mm, then a value of 100 mm, will be deducted from the obtained value.

Considering all the conditions given above, the existing runoff model was modified and used in this study for estimation of runoff. The program listing was done in Turbo Basic as given in Appendix-A

3.3 Scope for future harvesting

On the basis of simulation of runoff for the past 15 years, the probability of obtaining different amounts of runoff was estimated. The past 15 years were categorized into wet, dry and normal years depending on the annual rainfall for the respective years. The probability of a year being wet, dry or normal was calculated based upon Weibull's formula. The probability of occurrence of an event, P(E) is given by

$$P(E) = \frac{m}{n} \quad \dots(3.13)$$

where.

m = number of favourable events

n = total number of events

The average runoff of the three categories was worked out and the probabilities of obtaining the average runoff was calculated.

Thus, the scope for water harvesting has been evaluated and suggestions made regarding the need for additional water harvesting structures. The procedure followed and the outcome of the results are discussed in **Chapter-IV**.

3.4 Artificial **groundwater** recharge

A wide variety of techniques are available for quantifying ground water recharge. The reliability of recharge estimates using different techniques is variable. However, choosing appropriate technique for a particular site depends upon attributes like range, space/time scales and reliability of recharge estimates. The goal of recharge study is also important in selecting the technique to be adopted.

Finally, the hydrologic zone used for making the estimate and the climate of the place should be taken into consideration in deciding the technique to be used. Surface water and unsaturated zone approaches usually provide estimate of potential recharge, whereas ground water techniques generally provide information on actual recharge, because water has reached the water table. Shallow water tables and effluent streams usually characterize humid regions. In contrast, deep water tables and influent streams are common in arid and semiarid regions.

Some of the techniques commonly used are seepage meters, heat tracers, isotopic tracers, watershed modeling, lysimeters, channel water budget, water table fluctuations.

Numerical modeling of water harvesting structure is used to estimate artificial recharge from water harvesting structures. The runoff storage model for small watershed developed by Ajay kumar (1991) at ICRISAT, based upon the

modified SCS curve number runoff model developed by Pathak *et. al.*(1987), has been used in the present study. The flow chart of the water harvesting model is shown in Fig. 3.3.

The model consists of two major components, namely inflows into the structure and outflows from the structure. All inflows accounted by this model include rainfall directly falling on surface of water in the structure, water from sides of the structure, and major component of inflow *i.e.*, runoff from the catchment. In this model, it is assumed that complete runoff resulting from the catchment enters the water harvesting structure. The runoff model does not include the base flow and upward movement of moisture from groundwater. The losses from structure are through seepage and evaporation.

The component of seepage loss from the storage structure is regarded as the contribution to groundwater recharge. The factors that accounted favorably in making the above assumption are-

- (a) Pathak *et. al.*(2002) have studied the groundwater hydrology of Adarsha watershed by continuous monitoring of water level, in 62 open wells at fortnightly interval and made the following conclusions:

Before the watershed development only 52 wells were functional with low yield at high depth, and the decline in ground water level was fast. There was significant improvement in the yield of most of these wells and another 8 wells, which were completely nonfunctional also got water after the construction of check dams and other structures. The water level in the wells was available even for post rainy season crops. The area under cultivation has increased due to availability of additional water for irrigation.

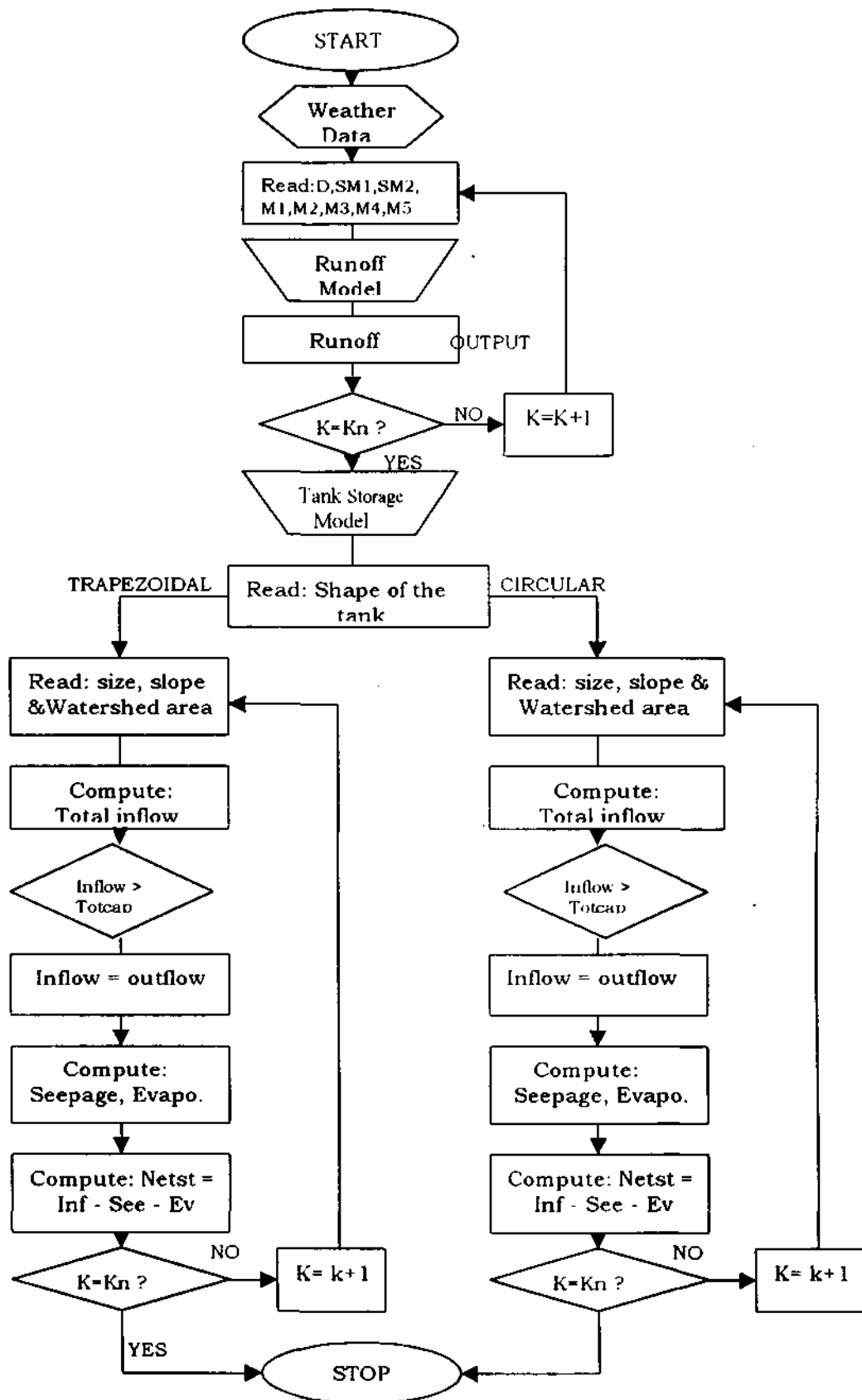


Fig. 3.3 Flow chart of water harvesting model

Prior to the implementation of watershed development programme, water level in the wells was generally 6-12 m, and most of them were seasonal and dried up during the dry season. After the construction of check dams and implementation of other developmental work, the water level and yield in the wells improved significantly, particularly in those wells which were located near the check dams (Fig. 3.4). The water level in these wells was consistently higher (around 3 m) even during normal rainy season, whereas the water level in the wells located away from the check dams was about 6 m deep (Fig. 3.4).

(b) Most of the check dams, earthen embankments and sunken pits were constructed in the *nalas* and other water courses. The depth of the main *nala*, across which check dams of large storage capacities were constructed, varies from 2-5 m at various locations.

From the above observations, it can be said that the watershed has shallow to medium water table depths. Water table had improved significantly with the construction of check dams.

From the Fig. 3.4, it can be said that there is localised build-up of water table near the check dams, i.e. water infiltrating near the check dams is directly reaching the groundwater at the same location without flowing out laterally in the soil or as sub-surface flow.

The water stored in the structures, seep laterally into the surrounding soil profile at a depth of 2-5 m from the soil surface. The depth of soil from which evapo-transpiration occurs varies from 500 mm below the surface, during the dormant season to 500 mm below the root zone depth, during the growing season

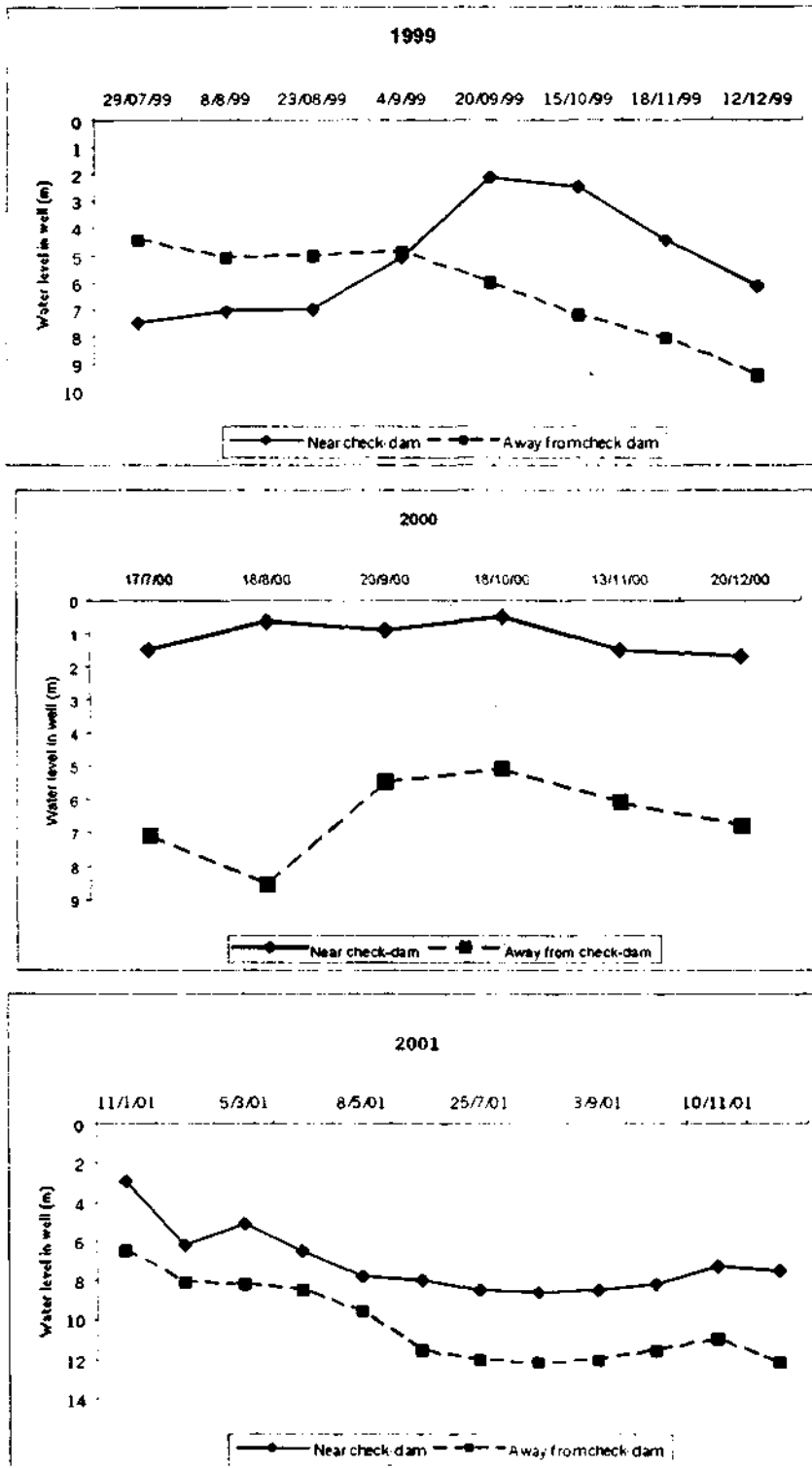


Fig. 3.4 Groundwater levels in open wells at Adarsha watershed
Source: Pathak *et. al.* (2002)

(Anonymous, 1972) This level is at about 3 m below the ground surface (Seytoux, 1984).

Hence, very limited water, entering the soil profile is lost by evapotranspiration. Also, from the observations of water table, it can be said that the thickness of the vadose zone will be only few metres. Therefore, there is little scope for this seepage to contribute to surface flow in streams elsewhere through sub-surface flow. As such, even though there may be time lag between seepage rate and aquifer recharge rate, the water entering the soil profile will reach the ground water ultimately without loss by evapotranspiration or sub-surface flow.

3.5 Data source

3.5.1 Rainfall

The daily rainfall data of Adarsha watershed was available for the years starting from 1999. However, for the years 1988 to 1998, the rainfall data of Shankerpally, at an aerial distance of about 6 km from Adarsha watershed, has been taken. The data has been collected from the agro-climatology department of ICRISAT, Hyderabad

3.5.2 Evaporation

Daily evaporation recorded using a USDA-class A pan evaporimeter at the Meteorological Station, ICRISAT, Hyderabad has been collected for a period from 1988 to 2002.

3.5.3 Runoff

The runoff data available for the Adarsha watershed, since 1999, has been collected from land and water management department of ICRISAT, Hyderabad. Automatic runoff recorders are used for the measurement of runoff.

3.5.4 Soil properties

The data pertaining to the soil *viz.*, initial soil moisture level, maximum moisture holding capacity, minimum moisture level for evaporation and minimum moisture level for transpiration of the two layers has been obtained from the department of land and water management, ICRISAT, Hyderabad.

3.6 Cost evaluation of different structures

Three types of structures (Plate 3.2 & Plate 3.3) *viz.* masonry check dams, earthen check dams and sunken pits were constructed at Adarsha watershed. An effort has been made to compare the cost-effectiveness of these structures. The cost incurred in creating a unit of storage capacity was used as a tool for comparing the cost-effectiveness of structures. This method of evaluation was earlier used by several researchers (Brown, 1955; Merle, 1972 and Doty, 1989).

3.6.1 Storage capacity and costs

The sunken pits are man-made depressions excavated in the *nalas* and low-lying areas. The storage capacity of these pits could be found out easily, with the use of tape, by measuring the length, breadth and height. However, the masonry and earthen check dams were of irregular shape and necessitated the contour survey of the water storage area.

Various procedures have been followed using different instruments for the calculation of storage capacities. For the present study, Nikon field station has been used (Plate 3.1). The electronic equipment coupled with the software package obviates the need for chaining, paper work and manual calculations while developing contour maps and finding volumes, resulting in the accurate determination of storage capacities



Plate 3.1 Nikon field station equipment

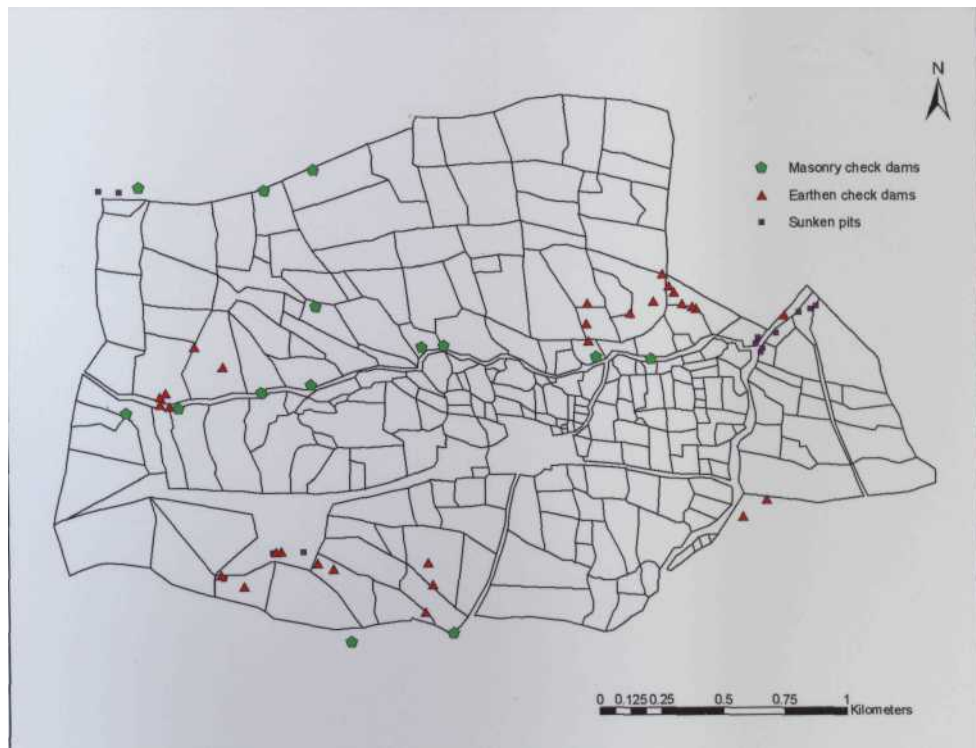


Fig 3.5 Location of water harvesting structures

The location of the existing water harvesting sites was identified with the aid of Global Positioning System (GPS) 12XL 12-channel garmin for obtaining the spatial distribution of the structures across the watershed. The positions of various water harvesting structures in the watershed are given in Fig. 3.6.



(A)



(B)



(C)

Plate 3.2 A view of the water harvesting structures at Adarsha watershed
(A) Masonry check dam (B) Sunken pit (C) Earthen check dam



(A)



(B)



(C)

Plate 3.3 Runoff collected in the water harvesting structures with onset of monsoon
(A) Masonry check dam (B) Sunken pit (C) Earthen check dam

RESULTS AND DISCUSSION

CHAPTER - IV

RESULTS AND DISCUSSION

This chapter deals with the performance of the runoff model after the modifications were made. The procedure followed in assessing the scope for additional water harvesting at Adarsha watershed and potential recharge contributed by the water harvesting structures are described. The field survey of various water harvesting methods has been studied and outcome is given in this chapter.

4.1 Runoff simulation

The runoff model developed for estimation of surface runoff on event basis for small watersheds at ICRISAT, Hyderabad (Pathak *et. al.*, 1987) has been used in this study. However, appropriate amendments were made in the model to account for the water storage due to field bunds in agricultural lands of the watershed.

The original model does not include the factors of natural depression and detention storage in the process of simulation. The topographic features vary from one watershed to another. Therefore, different watersheds have different storage capacities that are **unique**. Hence, any model predicting runoff accurately for a watershed cannot be applied to another watershed directly. To include the above features, a careful investigation of the field conditions was conducted and a few assumptions were made to represent the conditions of the watershed as described in Chapter-III.

4.1.1 Validity of the model

The accuracy of the model for the watershed under study was tested by comparing the values of simulated runoff with those of the measured runoff. The measured values of runoff for the watershed were available, since the inception of watershed development activity in 1999. The runoff prediction for the four years was compared with the measured runoff to test the validity of the model. The rainfall and evaporation data were given as input to the model. And the output obtained from the model for a year is given in Appendix-B. The major rainfall events of the four years (1999-2002), along with their measured and simulated runoffs are given in Table 4.1.

The annual rainfall for the year 1999 was 766.9 mm. The model has predicted runoff of 7.5 mm on 27th May, when the rainfall was 42.0 mm. However, runoff recorded at the outlet of the watershed was only 0.8 mm. For the rest of the major rainfall events, the deviation of simulated runoff from the measured runoff can be termed as acceptable.

The year 2000 received rainfall above normal of 1117 mm. The model has simulated runoff of 4 mm and 13.8 mm on 30 June and 1 July, while runoff was not observed in the field. August 24 has recorded high-intensity rainfall of 300 mm, which have resulted in overflowing of excess water over the bunds. Hence, wide deviation of simulated runoff from the measured can be regarded as an exception. 737 mm of rainfall was recorded in 2001. The runoff from the model was in close accordance with that of the observed on the field. The year 2002 had scanty rainfall of 571 mm. The model was precise in its prediction.

Table 4.1 Measured and simulated runoffs for major rainfall events (1999-2002)

| Year | Date | Rainfall (mm) | Measured runoff (mm) | Predicted runoff (mm) | Deviation (mm) | Percent deviation | R ² |
|-------|-------|---------------|----------------------|-----------------------|----------------|-------------------|----------------|
| 1999 | 26/05 | 98.0 | 0.0 | 0.0 | - | 0 | 0.6435 |
| | 27/05 | 42.0 | 0.8 | 7.5 | 6.7 | 838 | |
| | 16/07 | 34.0 | 0.0 | 0.0 | - | 0 | |
| | 31/08 | 74.0 | 10.1 | 11.4 | 1.3 | 13 | |
| | 01/09 | 8.6 | 0.3 | 0.1 | -0.2 | 66 | |
| | 10/09 | 16.0 | 0.3 | 0.0 | -0.3 | 100 | |
| | 11/09 | 33.4 | 3.3 | 3.2 | -0.1 | 3 | |
| | 13/10 | 25.7 | 1.7 | 0.0 | -1.7 | 100 | |
| Total | | | 16.5 | 22.2 | 5.7 | 34 | |
| 2000 | 07/05 | 86.4 | 0.0 | 0.0 | - | 0 | 0.9935 |
| | 07/06 | 25.1 | 0.0 | 0.0 | - | 0 | |
| | 30/06 | 26.4 | 0.0 | 4.0 | 4.0 | - | |
| | 01/07 | 66.6 | 0.0 | 13.8 | 13.8 | - | |
| | 10/08 | 39.4 | 4.0 | 0.0 | -4.0 | 100 | |
| | 23/08 | 43.5 | 0.0 | 0.0 | - | 0 | |
| | 24/08 | 301.8 | 177.9 | 223.9 | 45.2 | 25 | |
| | 19/09 | 53.3 | 16.1 | 18.0 | 1.9 | 11 | |
| | 26/09 | 43.0 | 20.4 | 19.0 | -1.4 | 7 | |
| Total | | | 218.4 | 278.8 | 60.4 | 27 | |
| 2001 | 04/06 | 17.8 | 0.0 | 0.0 | - | 0 | 0.9987 |
| | 06/09 | 49.1 | 0.0 | 0.0 | - | 0 | |
| | 07/09 | 20.7 | 0.0 | 0.0 | - | 0 | |
| | 28/09 | 23.1 | 0.0 | 0.0 | - | 0 | |
| | 01/10 | 77.2 | 30.4 | 27.6 | -2.8 | 9 | |
| | 08/10 | 16.0 | 0.0 | 1.0 | 1.0 | - | |
| | 11/10 | 7.7 | 0.0 | 0.0 | - | 0 | |
| Total | | | 30.4 | 28.6 | -1.8 | 5 | |
| 2002 | 10/08 | 35.0 | 0.0 | 0.0 | - | 0 | - |
| | 12/10 | 39.1 | 0.0 | 0.0 | - | 0 | |
| | 16/10 | 31.0 | 0.0 | 0.0 | - | 0 | |
| Total | | | 0.0 | 0.0 | 0.0 | 0 | |

As a whole, the model seems to be predicting in excess, in the initial stages of the monsoon and found to be a little short of the actual observations, in the latter stages of the monsoon. However, there was no specific correlation in the trend. Due to influence of complex factors like storm, hydrological, topographic characteristics and unpredictable human interference (application of irrigation), it is very difficult to be very precise in the simulation. It requires extensive study of the watershed characteristics over a longer time span, which is beyond the scope of this study.

The Coefficient of determination (R^2) values of 0.9935 and 0.9987 for the years 2000 and 2001 respectively, indicate good agreement between measured and simulated runoff. The agreement can be termed acceptable for the year 1999, in spite of its comparatively low coefficient of determination (0.6435). Hence, the overall performance of the model can be termed as satisfactory.

4.2 Application of the model

The model was used for the simulation of runoff over the past 15 years, so as to analyze the scope for construction of additional water harvesting structures. On the basis of output of the model, the number of runoff events, depth of runoff and percentage of rainfall contributing to runoff were calculated.

The 15 years were categorized into wet, dry and normal years depending upon the annual rainfall. The mean annual rainfall at Adarsha watershed is 800 mm (Wani *et. al.*, 2002). Hence, the years with annual rainfall in the range, 800 \pm 100 mm were categorized as normal years. The years, with annual rainfall below and above the range as dry and wet years, respectively. The data pertaining

to estimated runoff for the previous 15 years, in their ascending order of annual rainfall, are given in Table 4.2.

Table 4.2 Characteristics of simulated runoff for 15 years (1988-2002)

| Category | Year | Rainfall (mm) | Runoff depth (mm) | Runoff volume (m ³) | Runoff percentage | No. of runoff events |
|--------------|-------|---------------|-------------------|---------------------------------|-------------------|----------------------|
| Dry years | 2002 | 571.2 | 0 | 0 | 0 | 0 |
| | 1997 | 699.1 | 0 | 0 | 0 | 0 |
| Normal years | 1992 | 707.5 | 17.8 | 82,910 | 2.5 | 2 |
| | 1993 | 731.8 | 38.9 | 1,80,885 | 5.3 | 3 |
| | 2000 | 737.2 | 29.0 | 1,34,804 | 3.9 | ~ |
| | 1991 | 747.4 | 42.7 | 1,98,369 | 5.7 | ~ |
| | 1999 | 766.9 | 22.2 | 1,02,998 | 2.9 | 4 |
| | 1994 | 787.8 | 19.6 | 91,047 | 2.5 | 2 |
| | 1988 | 877.8 | 33.2 | 1,54,520 | 3.8 | 9 |
| 1990 | 893.1 | 8.0 | 37,107 | 0.9 | 4 | |
| Wet years | 1996 | 942.2 | 48.9 | 2,27,199 | 5.2 | 7 |
| | 1998 | 1100.8 | 69.8 | 3,24,617 | 6.3 | 16 |
| | 2000 | 1117.4 | 278.9 | 12,96,653 | 25.0 | 5 |
| | 1989 | 1141.2 | 108.0 | 5,02,061 | 9.5 | 10 |
| | 1995 | 1357.8 | 93.0 | 4,32,264 | 6.8 | 20 |

From the Table 4.2, it can be noted that, runoff was not observed in the dry years, with annual rainfall below 700 mm. In the normal years, even though runoff was observed in all the years, there was no correlation between rainfall and runoff, depicted by the percentage of rainfall contributing to runoff. Another noteworthy finding is that the year with maximum annual rainfall in this category

had the least runoff. The runoff events in a year varied from 2 to 4 in general, with the exception of 1988, which recorded nine runoff events. On the basis of above findings, it can be ascertained that the pattern and intensity of rainfall are also crucial along with the cumulative rainfall in determining the runoff.

The effect of magnitude of annual rainfall on runoff was noticeable in the wet years. There was considerable increase in the percentage of rainfall contributing to runoff and the runoff events. Again, the abnormal value of 25 %, in the year 2000, can be attributed to the very high intensity rainfall of 300 mm/day on 24th August, which underscores the effect of intensity and pattern of rainfall.

4.2.1 Probability analysis

The probability of occurrence of dry, wet and normal years were worked out by applying Weibull's formula. The probabilities thus obtained are given in Table 4.3.

Table 4.3 Probability of occurrence of dry, wet and normal years

| Category | Probability | Average runoff (m) |
|-------------|-------------|---------------------|
| Dry year | 13.33 | 0 |
| Normal year | 53.33 | 1,32,000 |
| Wet year | 33.33 | 5,46,000 |

The chance of obtaining different quantum of runoff has been estimated by taking into account, the average runoff obtained under various categories. The

Fig. 4.1 represents the probabilities of getting different amount of runoff. It was seen that there was 95 % probability of obtaining runoff at the outlet of the watershed. At 59 % and 17 % probability levels, there is possibility of getting runoff of more than 1.32 lakh and 5.46 lakh m^3 , respectively.

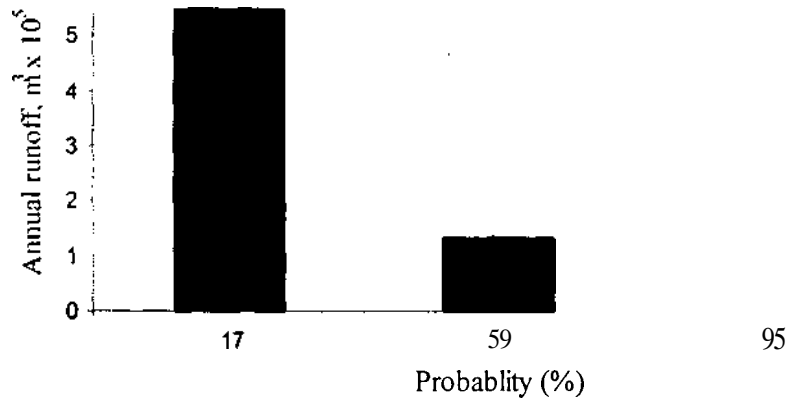


Fig 4.1 Runoff at different probability levels

4.2.2 Scope for additional water harvesting

The present runoff storage capacity under various methods is around $11,000 m^3$. By taking into consideration, the number of times, the structures get filled as 2.5 (from the discussion in section 4.3), the effective capacity of the existing structures comes to around $27,500 m^3$.

Most of the water resource projects are considered to be viable at probabilities above 60 to 70 %. There is 59 % probability of getting runoff of more than $1,32,000 m^3$. From the above considerations, it can be concluded that $1,32,000 m^3$ of runoff can be harvested. Taking into account, the existing

effective capacity of around 28,000 m³, there is scope for harvesting another 1,04,000 m³ of water. Thus, additional water harvesting capacity of 40,000 m³ can be created, by taking into account, fill-factor of 2.5, for a normal year.

4.3 Artificial groundwater recharge

The technique of numerical modeling was used for the estimation of ground water recharge from the water harvesting done at Adarsha watershed. The water harvesting model (Ajay sharma, 1991) was used for assessing the potential recharge from the structures. The accuracy of the model and the rationale behind the selection of the model has been discussed earlier in Chapter-III. The computer program of the model is given in Appendix-C.

4.3.1 Selection of representative structure

Since the estimation of potential recharge contributed by every individual structure require extensive field survey, for the collection of input data and the constraint in the application of the model, a sample structure was taken to be representative of the whole set of structures. Accordingly, an earthen check dam having storage capacity of 249 m³ (typical capacity of check dam at Adarsha) has been selected. The check dam was almost circular in shape. The side slopes of the structure were steep and approximately equal to 1:1. There was not much variation in the depth of the structure and was equal to 1 m on an average. Hence, the structure was found to suit the requirements for the application of the model.

Topographic survey of the catchment area was undertaken for the delineation of the catchment area using Nikon field station. The specifications given as input to the water harvesting model are enlisted below :

| | |
|----------------------------------|----------------------|
| Shape of the structure | = circular |
| Top diameter of the structure | = 19 m |
| Bottom diameter of the structure | = 17 |
| Side slope of the structure | = 1:1 |
| Total depth of the structure | = 1.2 m |
| Spillway height of the structure | = 1 m |
| Capacity of the structure | = 254 m ³ |
| Area of the catchment | = 1.5 ha |

The rainfall and evaporation data of 3 years(2000-2002) was given as input to the model and the output of the model for a year is given in Appendix-D.

4.3.2 Water balance

The water balance prepared from the output of the model is given in Table 4.4. The study shows that a large amount of water has overflown the check dam in the year 2000, whereas there was no overflow during the year 2002. This can be interpreted from the fact that the year 2000 had rainfall in excess of 1100 mm, whereas year 2002 received the lowest rainfall in 15 years. The small amount of runoff was not even sufficient to fill the tank once.

Table 4.4 Water balance for an earthen check dam of 255 m" capacity

| Year | Inflow (m) | | Outflow (m ³) | | Overflow (m ³) |
|------|-------------|--------------|---------------------------|---------|----------------------------|
| | Runoff | Surface rain | Evaporation | Seepage | |
| 2000 | 5171.4 | 336.3 | 1624 | 608.1 | 4732.6 |
| 2001 | 503.5 | 181.2 | 87.1 | 359.1 | 201.4 |
| 2002 | 17.8 | 168.3 | 17.8 | 168.1 | 0 |

Rather than the overflow from the tank, the proportion of water stored in the tank, contributing to soil moisture profile below 2 meters is of greater significance in the present study. The percentage of stored water contributing to seepage is given in the Fig. 4.2. An observation of the Fig. 4.2 indicates that seepage accounted for 79 % of the total water stored in 2000 and 90 % of the total water stored in 2002. The reason behind this trend can be understood from a study of the output obtained from running the model (Appendix-D). The quantity of water in the tank on daily basis indicated that water was present in the tank for longer duration, leading to greater scope for evaporation, whereas due to meager runoff in 2002, water was present for only a short duration, resulting in reduced evaporation.

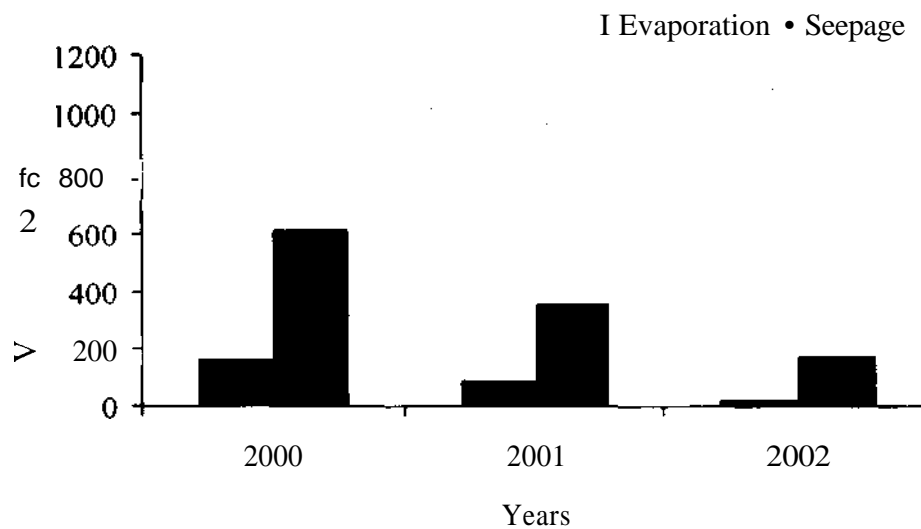


Fig. 4.2 Contribution to evaporation and seepage from check dam

4.3.3 Potential recharge

Based on the water balance study of 255 m³ capacity check dam, an effort has been made to estimate the potential recharge from water harvesting

structures. Seepage factor, ratio of amount of seepage to the total capacity, was taken into account in the process of estimation. The check dam considered for the study of water balance was a structure of average capacity and the soil properties were almost uniform over the entire watershed. Hence, pattern of seepage and evaporation losses from the other structures was considered to be similar to the one under study with only little variations, because of shape and size. Therefore, seepage factor was used for the estimation of artificial groundwater recharge in the watershed. The calculations pertaining to the potential recharge are given in Table 4.5.

Table 4.5 Estimates of artificial ground water recharge

| Year | Seepage (m ³) | Seepage factor | Potential recharge (m ³) |
|------|---------------------------|------------------|--------------------------------------|
| 2000 | 608.1 | $608.1/255=2.4$ | $11000 \times 2.4 = 26400$ |
| 2001 | 359.1 | $359.1/255= 1.4$ | $11000 \times 1.4 = 15400$ |

It can be seen from the Table 4.5 that the year 2000 had seepage factor of 2.4, whereas 2001 had seepage factor of 1.4. The wide difference can be interpreted from the intensity and pattern of rainfall and cumulative rainfall of corresponding years. Thus, the contribution of water harvesting structures to the groundwater in the years 2000 and 2001 was estimated to be around 26,400 and 15,400m³, respectively.

The year 2002 was not considered for the estimation of artificial ground water recharge because both the rainfall simulation studies and runoff recorders indicated that there was no runoff at the outlet of the watershed. Hence, the runoff

would have collected in a natural depression, in the downstream, even in the absence of the earthen check dam. Therefore, the check dams were not considered to have affected the groundwater regime during the year 2002.

4.4 Cost analysis

The analysis of costs involved in different types of water harvesting methods *viz.*, masonry check dams, earthen check dams and sunken pits were considered. The advantages and disadvantages associated with various methods are observed and suitable recommendations were made, based on the findings of the current study.

4.4.1 Masonry check dams

The data obtained from the field survey of masonry check dams is presented in Table 4.6. The masonry check dams constructed at Adarsha watershed had capacities ranging from 1477 m³ to 38 m³. The water spread area also varied widely, with as high as 2190 m² to relatively small extent of 100 m². Obviously, the large difference in water spread areas of different structures was due to their varying capacities and topography. However, the water spread area can be varied for a given capacity, depending on the location of the structure. The average depth of water stored in various structures, which is the ratio of storage capacity to water spread area, is indicative of the efficiency of site selection. Greater average depth represents more water stored per unit area, which in turn results in reduced evaporation losses and greater head of water, aiding in increased infiltration.

Table 4.6 Details of masonry check dams

| S. No. | Storage capacity (m) | Water spread area (m ²) | Average depth (m) | Total cost (Rs.) | Unit cost (Rs./ m ³) |
|--------|-----------------------|-------------------------------------|-------------------|------------------|----------------------------------|
| 1 | 1476.3 | 2189.6 | 0.67 | 78,172 | 53.0 |
| 2 | 1071.8 | 1941.0 | 0.55 | 75,420 | 70.4 |
| 3 | 821.1 | 1029.4 | 0.80 | 46,597 | 56.7 |
| 4 | 735.2 | 1480.0 | 0.50 | 83,500 | 113.6 |
| 5 | 428.5 | 1401.0 | 0.31 | 68,507 | 159.9 |
| 6 | 366.3 | 749.3 | 0.49 | 50,000 | 136.5 |
| 7 | 283.4 | 622.0 | 0.46 | 38,000 | 134.1 |
| 8 | 193.8 | 494.9 | 0.39 | 49,857 | 257.3 |
| 9 | 186.9 | 447.2 | 0.42 | 47,856 | 256.1 |
| 10 | 137.4 | 448.2 | 0.31 | 35,120 | 255.6 |
| 11 | 90.9 | 228.7 | 0.40 | 52,234 | 574.6 |
| 12* | 37.9 | 100.1 | 0.38 | 28,671 | 756.5 |
| Total | 5829.5 | - | - | 6,53,934 | 112.1767** |

* Check dam built for the measurement of runoff

** Average unit cost

The effective utilization of financial resources should receive due attention in the implementation of watershed programmes. From the Table 4.6, it can be inferred that relatively large amounts of expenditure has been made, to the tune of Rs.6.54 lakh, on the construction of various masonry check dams. Rather

than the total cost incurred on individual structures, their unit costs (total cost incurred per m^3 of storage capacity), serve as a tool in making cost evaluation among them. It can be observed that there is wide variation in their unit costs, from Rs. 52 = 00 per m^3 to Rs 756 = 00 per m^3 . However, the check dam with 38 m^3 of storage capacity can be treated as exception, since the main purpose of its construction is to record the runoff, apart from harvesting water. In spite of the above consideration, the structures with unit costs of Rs.575 and those around Rs.200 prove to be expensive in comparison to the rest. Hence, it can be concluded that some of these check dams with larger unit costs could have been located at more suitable locations or avoided.

However, the long durability of masonry check dams and greater mechanical strength associated with them prove to be the advantages of masonry check dams. But the large unit costs, necessitates preliminary survey to be conducted for selection of suitable site. The economic viability should also be carefully ascertained.

4.4.2 Sunken pits

Sunken pits, artificial depressions made on the *nala* beds and low-lying areas, were also used as a method of water harvesting. Depressions of rectangular shape have been made to store the runoff. The details regarding their capacities and costs are given in Table 4.7. The capacities are very small, ranging from 10 to 45 m^3 . The total costs are almost proportional to their capacities. The typical feature of these pits is their uniform unit cost. This can be understood from the fact that, the costs involved in this method is only the manual labour cost, as no

Table 4.7 Details of sunken pits

| S. No. | Storage capacity (m ³) | Cost (Rs.) | Unit cost (Rs./m ³) |
|--------|------------------------------------|------------|---------------------------------|
| 1 | 45.7 | 1,216 | 26.6 |
| 2 | 45.0 | 1,197 | 26.6 |
| 3 | 44.6 | 1,170 | 26.2 |
| 4 | 44.4 | 1,181 | 26.6 |
| 5 | 39.6 | 1,053 | 26.6 |
| 6 | 32.1 | 807 | 25.1 |
| 7 | 29.9 | 558 | 18.7 |
| 8 | 23.5 | 665 | 28.4 |
| 9 | 23.2 | 616 | 26.6 |
| 10 | 22.6 | 623 | 27.6 |
| 11 | 14.7 | 521 | 35.4 |
| 12 | 12.2 | 638 | 52.5 |
| 13 | 1 1.3 | 435 | 38.4 |
| 14 | 9.8 | 259 | 26.6 |
| Total | 398.5 | 10,939 | 27.4* |

*Average unit cost

other raw material is required for their construction work and labour charges are paid basing on the extent of earth excavated.

Eventhough their unit costs were economical when compared with that of the masonry check dams, their serious limitation is the capacity. Only limited amount of water can be stored and hence, cannot serve the purpose of water harvesting to meet the needs. Also, the small capacity can be hampered by siltation.

4.4.3 Earthen check dams

The earthen check dams are almost similar to masonry check dams, with the exception of the construction material. These have been taken up on a large scale in the Adarsha watershed as a means for harvesting water. These are nothing but earthen embankments made by replacement of cement and concrete material in the masonry check dam with the earth excavated. The method of construction is also simple. The soil on the upstream side of the *nala* or watercourse is excavated and spread across the flow, which serves as embankment. An outlet is provided for the safe disposal of excess water. Stone pitching is done on the embankment to reduce erosion of soil and prevent piping. Special variety of plants that withhold the soil can be grown on the embankment so as to prevent washing away of soil.

The details of the check dams at Adarsha watershed are presented in Table 4.8. Total storage capacity of around 5,000 m³ has been created with the construction of these dams, with an amount of just Rs 40,000. The water spread area varies from one structure to another. However, careful study of shape and size of the watercourse will enable the selection of suitable location to reduce water spread area and increase average depth. These factors help in reduction of

Table 4.8 Details of earthen check dams

| S. No. | Storage capacity (m ³) | Water spread area (m ²) | Average depth (m) | Cost (Rs.) | Unitcost (Rs./m ³) |
|--------|------------------------------------|-------------------------------------|-------------------|------------|--------------------------------|
| 1 | 694.9 | 1165.4 | 0.60 | 3,309 | 4.8 |
| 2 | 481.8 | 950.4 | 0.51 | 1,793 | 3.7 |
| 3 | 315.6 | 623.5 | 0.51 | 1,579 | 5.0 |
| 4 | 288.4 | 547.4 | 0.53 | 1,170 | 4.1 |
| 5 | 246.7 | 285.2 | 0.87 | 2,551 | 10.3 |
| 6 | 243.3 | 335.3 | 0.73 | 1,027 | 4.2 |
| 7 | 242.4 | 595.7 | 0.41 | 6,533 | 27.0 |
| 8 | 238.2 | 478.6 | 0.50 | 1,380 | 5.8 |
| 9 | 216.4 | 592.7 | 0.37 | 618 | 2.9 |
| 10 | 210.2 | 343.7 | 0.61 | 2,600 | 12.4 |
| 11 | 193.6 | 282.9 | 0.68 | 486 | 2.5 |
| 12 | 182.0 | 327.8 | 0.56 | 1,995 | 11.0 |
| 13 | 178.9 | 291.9 | 0.61 | 438 | 2.4 |
| 14 | 166.3 | 267.4 | 0.62 | 1,353 | 8.1 |
| 15 | 148.4 | 288.1 | 0.52 | 1,945 | 13.1 |
| 16 | 139.0 | 312.6 | 0.44 | 624 | 4.5 |
| 17 | 127.6 | 571.4 | 0.22 | 421 | 3.3 |
| 18 | 102.3 | 198.9 | 0.51 | 709 | 6.9 |
| 19 | 88.0 | 169.7 | 0.52 | 2,174 | 24.7 |
| 20 | 85.7 | 143.1 | 0.60 | 2,164 | 25.3 |
| 21 | 80.3 | 184.6 | 0.43 | 1,804 | 22.5 |

| | | | | | |
|-------|--------|-------|------|--------|------|
| 22 | 61.0 | 118.3 | 0.52 | 670 | 11.0 |
| 23 | 49.2 | 102.3 | 0.48 | 798 | 16.2 |
| 24 | 42.7 | 83.6 | 0.51 | 509 | 11.9 |
| 25 | 37.5 | 71.6 | 0.52 | 560 | 14.9 |
| 26 | 33.8 | 63.4 | 0.53 | 695 | 20.6 |
| 27 | 33.5 | 64.9 | 0.52 | 571 | 17.0 |
| 28 | 27.0 | 67.6 | 0.40 | 332 | 12.3 |
| Total | 4954.7 | - | - | 40,808 | 8.2* |

* Average unit cost

evaporation losses. The comparison of unit costs indicated that storage capacities can be created even with a low cost of Rs. 2 - 50 per m . However, with the escalation of costs in other structures, the average unit cost for earthen check dam work out to be around Rs. 8 = 00 per m .

4.4.4 Evaluation

The unit costs of various water harvesting structures were compared to evaluate their cost-efficiency. From the Fig. 4.3, the curve of masonry check dams is striking It depicts the exorbitant costs of these structures and the wide variation among them. In contrast, earthen check dams and sunken pits have relatively uniform unit costs and found to be economical.

From the larger perspective of water harvesting methods as a whole, earthen check dams prove to be most economical method of water **harvesting**

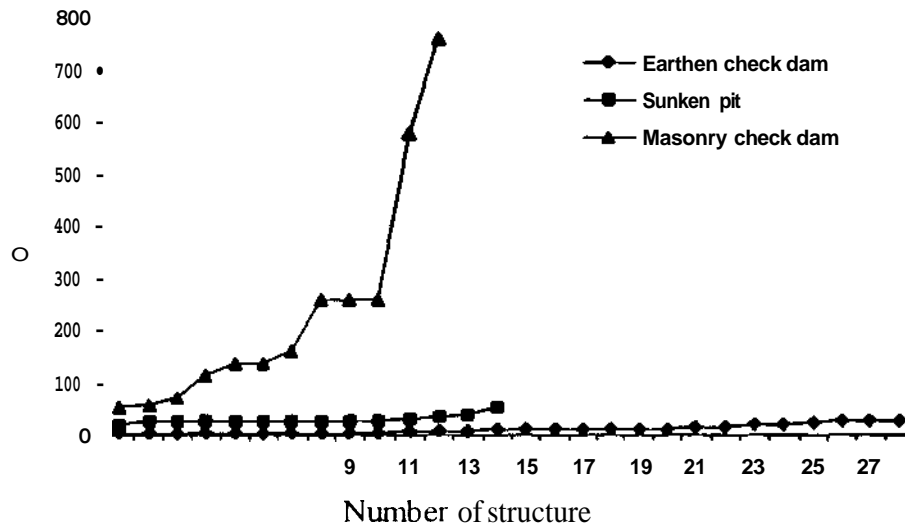


Fig 4.3 Comparison of unit costs of earthen check dams, sunken pits and masonry check dams

Even if the life of the structure was taken into account, with the assumption that the life of earthen check dams is 5 years and that of the masonry check dams as 10 years, the effective unit cost of earthen check dams (Rs. 16 = 00 per m³) is too less than that of the masonry check dams (Rs. 112 = 00 per m³). Sunken pits exclusively, are not a viable option, because of the limitation of creating storage capacity, in spite of their medium unit costs

The present study revealed that almost equal amounts of storage capacities are created by earthen and masonry check dams, but with incomparable costs of Rs. 41,000 and 6,54,000, respectively. Hence, more number of earthen structures could have been constructed, if some of the smaller capacity masonry check dams were replaced by earthen check dams.

Hence, the earthen check dams are preferred over masonry check dams due to the following advantages:

- (1) Simple and easy to construct
- (2) Little technical expertise required
- (3) Suitable for small agricultural watersheds
- (4) Obviates the need for raw material like cement and concrete
- (5) Contractors and middlemen can be eliminated.
- (6) Provides work for agricultural laborers in lean months of agricultural activity and prevents migration.

However, the limitation of the earthen check dams is the ability of the earthen structure to withstand hydraulic force. To overcome this limitation, larger capacity earthen structures should be avoided to reduce the risk of getting washed away. Instead, relatively small embankments can be made at more number of locations along the watercourse. Masonry check dams can be constructed in tandem, on the upstream side, so as to reduce the flow rate and risk of breaching and subsequent cascading effect on the downstream side, which may lead to the total failure of the whole series of structures at the time of floods.

The findings of this study were in close accordance with the results reported by earlier researchers (Merle. 1972; Doty, 1989 and Mukherjee, 1992), which proved that the harvesting structures built of locally available material along the water course provide the cheapest means of water harvesting.

SUMMARY AND CONCLUSIONS

CHAPTER - V

SUMMARY AND CONCLUSIONS

The spatial and temporal availability of water is a cause of concern in many parts of India. Rainwater harvesting provides an effective solution. Water harvesting can be done in a number of ways like ponds, check dams, percolation pits and recharge wells. In view of the significance associated with water harvesting, the hydrological assessment and cost evaluation of water harvesting structures at Adarsha watershed in Ranga Reddy district of Andhra Pradesh was taken up.

The SCS Curve Number (CN) model developed by **Pathak *et. al.* (1987)** was considered taking into account, its accuracy in simulating the conditions of Semi-Arid Tropics. However, the model was found to have been ignoring the aspects of topography in predicting the runoff. Modifications were made to the model accordingly to suit the conditions at Adarsha watershed. The chance of obtaining runoff from the watershed at different probability levels was estimated basing upon the simulated runoff for the past 15 years. Thus, runoff that can be expected in a normal year, on an average has been worked out. The effective capacity of the existing harvesting structures was found out from the field survey. From the difference between the existing capacity and expected runoff, the scope for additional water harvesting was determined.

The groundwater recharge being effected by the water harvesting structures at Adarsha watershed was estimated by considering the water balance studies of a typical check dam at Adarsha watershed. Numerical modeling of water harvesting structure was used as a tool in studying the water balance

studies of structure. The water going out from the structure, as seepage was taken to be the potential recharge to the ground water.

The storage capacities and costs of the water harvesting structures at Adarsha watershed was determined by field survey. The cost involved in creating a unit of storage capacity for various structures was calculated and compared for cost-effectiveness. The advantages and disadvantages associated with different structures were studied carefully and efficient method of water harvesting was proposed.

The findings from the study are enumerated below:

- (1) The performance of the modified runoff model for Adarsha watershed was found to be satisfactory.
- (2) The total capacity of various water harvesting structures is around 11,000 m³, with an effective capacity of 27,500 m³ in a normal year.
- (3) There is 59% probability of getting 1,32,000 m³ of runoff from Adarsha watershed.
- (4) Additional water harvesting structures, having a capacity of 40,000 m³, can be constructed.
- (5) The contribution of water harvesting structures to groundwater is nearly 26,400 m³ and 15,400 m³, in the years 2000 and 2001, respectively
- (6) The main advantage of the masonry check dams is their greater durability and scope for harvesting greater quantity of water. However, comparatively high unit costs (around 14 times that of the earthen check dams) act to their detriment. Hence, they can be used, preferably, for storing large volumes of water and on the upstream side of the *nalas*.

- (7) Sunken pits can store only small volumes of water and hence do not meet the water harvesting demands. They can be used as supplementary to the check dams.
- (8) Earthen check dams prove to be the most efficient and economical method of water harvesting. They are simple and easy to construct and provide employment opportunity to local communities in the lean months of agricultural activities. It does not require expensive raw material like cement and concrete and avoids middlemen in construction process.
- (9) The earthen check dams can be taken up along the *nalas* as a means of water harvesting in small agricultural watersheds. However, they are not recommended on watercourses having large flow rates due to susceptibility of getting washed away.

SUGGESTIONS FOR FUTURE WORK

On the basis of the present study and existing conditions, it can be suggested that this work can be taken up in future also as an extension of the present study. Some of the suggestions are given below:

- (1) The cost-effectiveness of the dams and water harvesting structures can be compared

After independence, India has embarked on a large number of major and medium irrigation projects. The cost-benefit analysis prepared before the initialization of the projects, have under-estimated the costs and over-estimated the benefits, in most cases (**Patil, 1986**) Follow-up studies have to be

undertaken and the actual cost-benefit analyses have to be compared with that of the water harvesting structures to check out for their economic viability.

(2) The benefits of water harvesting can be compared with that of the micro-irrigation methods.

Availability of water is not a problem in most parts of India. The real issue is about the storage of water for the needs of the dry season. From the present study, it can be observed that- with a comparatively paltry sum of Rs. 40,000 , around 5,000 m³ of storage capacity can be created.

The Drip and Sprinkler method of irrigation might be economically viable in countries like Israel, where the rainfall is scanty. The case need not be the same in country like India, averaging annual rainfall of around 1200 mm. If focus is shifted on efficient water harvesting, there might be bountiful of water available throughout the year. Hence, a study can be conducted comparing the subsidies given by the government for taking up micro irrigation, with the benefits accruing by taking up low-cost water harvesting structures.

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APPENDICES

APPENDIX-A

Modified runoff model

```
1000 CLS
1050 L$= "MM MM ###.## ###.## ##.### ##.## ## ###.### #####.#####.## ###.##"
1060 REM SWB FOR SOIL OF TWO LAYERS
1061 REM DIM Z(1000,10)
1062 DIM DTE(11000),RAIN(11000),PAN(11000),RO(11000),BEETA(11000)
1065 DATA 12.27.52.77,102
1066 LOCATE 13,14:INPUT "ENTER THE DATA FILE NAME "; FILE$
1067 LOCATE 13,14:PRINT "
1070 OPEN FILE$ FOR INPUT AS #1
1075 WHILE NOT EOF(1)
1080 'LOCATE 13,14: PRINT USING "READING THE DATA ### ";K
1085 LINE INPUT #1,DAT$
1095 K= K+1
1096 DTE(K) = VAL(MID$(DAT$,1,4))
1097 RAIN(K) = VAL(MID$(DAT$,5,7))
1100 PAN(K) = VAL(MID$(DAT$,12,6))
1105 RO(K) = VAL(MID$(DAT$,18,7))
1106 BEETA(K) = VAL(MID$(DAT$,26,6))
1116 WEND
1118 CLOSE #1 :CLS
1150 INPUT "ENTER A NAME FOR OUTPUT FILE";M$
1160 OPEN M$ FOR OUTPUT AS #4
1170 'INPUT "ENTER THE STARTING AND ENDING DATES SEPERATED BY COMMAS":N1,N2
1180 INPUT "ENTER THE STARTING SM1,SM2";S1,S2
1190 INPUT "ENTER THE DEPTH VALUE";D1
1200 INPUT "ENTER THE VALUES OF M1,M2,M3,M4,M5":M1,M2,M3,M4,M5
1210 INPUT "ENTER THE VALUES OF X3":X3
1220 'PRINT #2." ***** LAND AND WATER MANAGEMENT SOIL WATER BALANCE FOR
SOIL OF TWO LAYERS *****"
1230 'PRINT #2." STARTING SM1,SM2 = ":S1,S2;" DEPTH VALUE IS = ":D1:PRINT #2, " "
1240 'PRINT #2." M1,M2,M3,M4,M5,X3 VALUES ARE = ":M1.M2,M3,M4,M5,X3:PRINT #2." " :
PRINT #2,STRING$(132,42)
1250 PRINT #4." ROW DATE RAIN EVAP RUNOFF BEETA T E* ET DM
SM1 SM2 SMT S PQ"
1390 D2=D1 -30
1395 M2=D2*M2
1396 M5=D2*M5
1400 G1=0: G8=0
1410 J=1
1420 R1=0:R2=0:C=0
1430 E5=0
1440 T=0:U=6:D2(0)=1.5:O=2
1450 FOR L=1 TO K
1460 'NCO= NCO+1
1470 T6=RAIN(L)
1480 IF T6>0 THEN 1500
1490 NEXT L
1500 A1=0
1510 A2=0
1520 FOR I = 1 TO K
```

```

1530 T6=RAIN(I):T7=PAN(I)
1540 NCO= NCO+1
1550 D=T6 - T7
1560 IF I=L THEN 1670
1570 IF T6=0 THEN A1=0 : GOTO 1590
1580 GOTO 1610
1590 IF A2=1 THEN A2=0 : GOTO 1640
1600 T=T+1 : GOTO 1640
1610 IF D>0 THEN A2=1 : GOTO 1670
1620 IF A1=1 THEN T=1:E2=T7/T : GOTO 1700
1630 E2=T7/T : GOTO 1700
1640 IF T>10 THEN T=10
1650 IF T=0 THEN T=1 : E2=T7/T : GOTO 1700
1660 E2=T7/T : GOTO 1700
1670 IF A1=0 THEN T=0:E2=T7/0:A1=1 : GOTO 1700
1680 T=1 : E2=T7/T
1690 S7=S6
1700 GOSUB 1740
1710 J=J+1
1715 NEXT I
1720 GOTO 2740
1740 T8=RO(I)
1750 S=S1+S2
1770 B=BEETA(I):E3=(1- B)*T7
1780 E2=E2*B
1790 D5=T6-T8-E2-E3
1800 S5=D2*X3+144:P2=1.2*(S5 -(M1+M2))
1810 P3=P2+4
1820 IF D5<=0 THEN 1890
1830 S1=S1+D5
1840 IF S1>M1 THEN S5=S1-M1:S1=M1:GOTO 1860
1850 S5=0
1860 S2=S2+S5
1870 IF S2>M2 THEN S2=M2
1880 GOTO 1980
1890 IF S1<M4 THEN S1=S1 -E2 : GOTO 1930
1900 S1=S1 -.3*E3
1910 IF S1<M4 THEN S1=M4
1920 S1=S1 -E2
1930 IF S1<M3 THEN S1=M3
1940 IF S2<M5 THEN S2=M5 : GOTO 1970
1950 S2=S2 -.7*E3
1960 IF S2<M5 THEN S2=M5
1970 IF S2>M2 THEN S2=M2
1980 S5=D2*X3+144
1990 S6=(S5-S)*1.2
2000 G2=0
2010 P9=0
2020 G8=0
2030 R=R1+R2
2040 IF T6>20 THEN 2050 ELSE 2060
2050 'IF R>=8 THEN S6=35 : GOTO 2090
2060 IF T6<=20 THEN 2070 ELSE 2120
2070 'IF R>=8 THEN S6=15 : GOTO 2090
2080 GOTO 2120

```

```

2090 P1=(T6 -.1*S6)^2/(T6+.9*S6)
2100 IF T6<.1*S6 THEN P1=0
2110 GOTO 2160
2120 P9=P1
2130 G8=0
2140 IF T6<.2*S6 THEN E4=T8:P1=0 : GOTO 2160
2150 P1 = (T6 -.2*S6)^2/(T6+.8*S6)
2160 IF B=1 THEN 2170 ELSE 2290
2170 IF T6>=20 THEN 2180 ELSE 2230
2180 C1=I -1:G8=RAIN(C1)
2190 IF G8>=10 THEN 2200 ELSE 2230
2200 P1 = (T6 -.04*S6)^2/(T6+.96*S6)
2210 IF T6<.04*S6 THEN P1 = 0
2220 GOTO 2290
2230 C1=I -4:C2=I -1
2240 IF C1<0 THEN C1=1
2250 FOR J9=C1 TO C2
2260 IF PAN(J9)>RAIN(J9) THEN 2290
2270 NEXT J9
2280 GOTO 2200
2290 C1=I -60
2300 C2=I -1
2310 IF C1<0 THEN C1=1
2320 IF C2<=0 THEN C2=1
2330 FOR J9=C1 TO C2
2340 G8=G8+RAIN(J9):NEXT J9
2350 ' IF G8<8 THEN P1=P1 -8 : GOTO 2430
2360 'C1=I-4:C2=I-1
2370 'IF C1<0 THEN C1=1 :IF C2<0 THEN C2=1
2380 'G8=0
2390 'FOR J9=C1 TO C2
2400 'G8=G8+RAIN(J9)
2410 'NEXT J9
2420 IF G8=0 THEN P1=P1 -35 :GOTO 2540
2421 IF G8<150 THEN P1=P1-30 :GOTO 2540
2422 'IF G8<150 THEN P1=P1-25 :GOTO 2540
2423 IF G8<200 THEN P1=P1-15 :GOTO 2540
2424 IF G8<300 THEN P1=P1-5 :GOTO 2540
2425 IF G8>500 THEN 2426 ELSE 2540
2426 IF RAIN(I)>20 THEN P1=P1+15 :GOTO 2540
2430 IF P1<=0 THEN P1=0 : GOTO 2540
2440 IF P9=0 THEN 2540
2450 IF P9>=3 THEN 2460 ELSE 2480
2460 IF P9<=6 THEN 2470 ELSE 2480
2470 IF P1>0 THEN P1=P1+1 : GOTO 2540
2480 IF P9>6 THEN 2490 ELSE 2510
2490 IF P9<=15 THEN 2500 ELSE 2510
2500 IF P1>0 THEN P1=P1+2 : GOTO 2540
2510 IF P9>15 THEN 2520 ELSE 2540
2520 IF P1>0 THEN P1=P1+4 : GOTO 2540
2530 IF T6<=8 THEN P1=0
2540 IF T6<=8 THEN P1=0
2541 IF P1<=0 THEN P1=0
2550 E4=T8 - P1:C=0
2560 IF R<=10 THEN C=R

```

```
2570 IF R>10 THEN 2580 ELSE 2590
2580 IF R<=25 THEN C=12 : GOTO 2600
2590 IF R>25 THEN C=17
2600 R2=R - C
2610 R1=T6 - P1+S -309
2620 IF ABS(E4)<=.5 THEN E4=0
2630 IF T6<=4 THEN R1=0
2640 IF R1<0 THEN R1=0
2650 IF R2<0 THEN R2=0
2660 IF ABS(E4)<=.5 THEN E4=0
2670 E5=E5+E4
2680 IF D5<0 THEN D5 = 0
2710 PRINT #4. USING L$: I,DTE(I),T6,T7,T8,B,T,E2,E3,D5,S1,S2,S,S6,P1
2720 G1=G1+1
2730 RETURN
2740 CLS
2750 LOCATE 12,18 : PRINT "JOB IS OVER"
2760 END□
```

APPENDIX-B

Output obtained from the modified runoff model for the year 1999

|)W | DATE | RAIN | EVAP | RUN OFF | BEE TA | T | E* | ET | DM | SM1 | SM2 | SMT | S | PQ |
|----|------|------|------|------------|-----------|-----------|-------------|----|----|------|-----|------------|--------|----|
| 1 | 101 | 0 | 3.6 | 0 | 1 | 1 | 3.6 | 0 | 0 | 54.4 | 118 | 176 | 192 | 0 |
| 2 | 201 | 0 | 3.4 | 0 | 1 | 2 | 1.7 | 0 | 0 | 52.7 | 118 | 172.4 | 196.32 | 0 |
| 3 | 301 | 0 | 3.6 | 0 | 1 | 3 | 1.2 | 0 | 0 | 51.5 | 118 | 170.7 | 198.36 | 0 |
| 4 | 401 | 0 | 3.6 | 0 | 1 | 4 | 0.9 | 0 | 0 | 50.6 | 118 | 169.5 | 199.8 | 0 |
| 5 | 501 | 0 | 3.7 | 0 | 1 | 5 | 0.74 | 0 | 0 | 50 | 118 | 168.6 | 200.88 | 0 |
| 6 | 601 | 0 | 3.1 | 0 | 1 | 6 | 0.517 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 701 | 0 | 4.3 | 0 | 1 | 7 | 0.614 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 801 | 0 | 4.3 | 0 | 1 | 8 | 0.538 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 901 | 0 | 3.2 | 0 | | 9 | 0.356 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 10 | 1001 | 0 | 3.2 | 0 | | 10 | 0.32 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 11 | 1101 | 0 | 5 | 0 | | 10 | 0.5 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 12 | 1201 | 0 | 4 | 0 | | 10 | 0.4 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 13 | 1301 | 0 | 3.5 | 0 | | 10 | 0.35 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 14 | 1401 | 0 | 3.7 | 0 | | 10 | 0.37 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 15 | 1501 | 0 | 4.2 | 0 | 1 | 10 | 0.42 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 16 | 1601 | 0 | 3.7 | 0 | 1 | 10 | 0.37 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 17 | 1701 | 0 | 4 | 0 | | 10 | 0.4 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 18 | 1801 | 0 | 4.1 | 0 | 1 | 10 | 0.41 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 19 | 1901 | 0 | 4.2 | 0 | | 10 | 0.42 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 20 | 2001 | 0 | 3.8 | 0 | 1 | 10 | 0.38 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 21 | 2101 | 0 | 4.1 | 0 | 1 | 10 | 0.41 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 22 | 2201 | 0 | 4.6 | 0 | 1 | 10 | 0.46 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 23 | 2301 | 0 | 4.5 | 0 | 1 | 10 | 0.45 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 24 | 2401 | 0 | 4.8 | 0 | | 10 | 0.48 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 25 | 2501 | 0 | 4.5 | 0 | 1 | 10 | 0.45 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 26 | 2601 | 0 | 3.6 | 0 | | 10 | 0.36 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 27 | 2701 | 0 | 4.4 | 0 | 1 | 10 | 0.44 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 28 | 2801 | 0 | 4.9 | 0 | 1 | 10 | 0.49 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 29 | 2901 | 0 | 5.1 | 0 | 1 | 10 | 0.51 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 30 | 3001 | 0 | 4.8 | 0 | 1 | 10 | 0.48 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 31 | 3101 | 0 | 6 | 0 | 1 | 10 | 0.6 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 32 | 102 | 0 | 5.6 | 0 | 1 | 10 | 0.56 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 33 | 202 | 0 | 6 | 0 | 1 | 10 | 0.6 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 34 | 302 | 0 | 6.5 | 0 | 1 | 10 | 0.65 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 35 | 402 | 0 | 7.6 | 0 | 1 | 10 | 0.76 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 36 | 502 | 0 | 5.8 | 0 | 1 | 10 | 0.58 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 37 | 602 | 0 | 6.3 | 0 | | 10 | 0.63 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 38 | 702 | 0 | 6.6 | 0 | | 10 | 0.66 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 39 | 802 | 0 | 7.4 | 0 | | 10 | 0.74 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 40 | 902 | 0 | 4.8 | 0 | | 10 | 0.48 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 41 | 1002 | 0 | 5.5 | 0 | | 10 | 0.55 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 42 | 1102 | 0 | 6 | 0 | | 10 | 0.6 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 43 | 1202 | 0 | 6 | 0 | | 10 | 0.6 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 44 | 1302 | 0 | 6.4 | 0 | | 10 | 0.64 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 45 | 1402 | 0 | 7 | 0 | | 10 | 0.7 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 46 | 1502 | 0 | 7 | 0 | | 10 | 0.7 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 47 | 1602 | 0 | 7 | 0 | 1 | 10 | 0.7 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 48 | 1702 | 0 | 6.4 | 0 | 1 | 10 | 0.64 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |

| | | | | | | | | | | | | | |
|----|---|------|---|---|----|-------|---|------|-------|-----|--------|--------|---|
| 4 | 0 | 6.8 | 0 | | 10 | 0.68 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5 | 0 | 7.2 | 0 | | 10 | 0.72 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5 | 0 | 8.1 | 0 | | 10 | 0.81 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5 | 0 | 7.2 | 0 | | 10 | 0.72 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5 | 0 | 8.1 | 0 | | 10 | 0.81 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5- | 0 | 6.4 | 0 | 1 | 10 | 0.64 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5 | 0 | 6.4 | 0 | 1 | 10 | 0.64 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5< | 0 | 6.4 | 0 | 1 | 10 | 0.64 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5 | 0 | 6.2 | 0 | | 10 | 0.62 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5: | 0 | 7.2 | 0 | 1 | 10 | 0.72 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 5' | 0 | 8.2 | 0 | 1 | 10 | 0.82 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 7.6 | 0 | | 10 | 0.76 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 7.8 | 0 | | 10 | 0.78 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 7.4 | 0 | | 10 | 0.74 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 7.7 | 0 | 1 | 10 | 0.77 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 8 | 0 | | 10 | 0.8 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 7.4 | 0 | | 10 | 0.74 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 8.5 | 0 | | 10 | 0.85 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 8.9 | 0 | 1 | 10 | 0.89 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 8 | 0 | 1 | 10 | 0.8 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 6 | 0 | 6.9 | 0 | | 10 | 0.69 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 8 | 0 | | 10 | 0.8 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 9.1 | 0 | | 10 | 0.91 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 8.8 | 0 | 1 | 10 | 0.88 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 7 | 0 | | 10 | 0.7 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 7.4 | 0 | 1 | 10 | 0.74 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 9 | 0 | | 10 | 0.9 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 9.9 | 0 | | 10 | 0.99 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 9.3 | 0 | 1 | 10 | 0.93 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 8.5 | 0 | | 10 | 0.85 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 7 | 0 | 8.2 | 0 | | 10 | 0.82 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 8.5 | 0 | 1 | 10 | 0.85 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 6.8 | 0 | | 10 | 0.68 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 6.8 | 0 | | 10 | 0.68 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 7.5 | 0 | 1 | 10 | 0.75 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 4 | 5.7 | 0 | | 0 | 2.85 | 0 | 1.55 | 51.55 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 8.6 | 0 | | 1 | 8.6 | 0 | 0 | 50 | 118 | 169.55 | 199.74 | 0 |
| X | 0 | 8.8 | 0 | | 2 | 4.4 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 9 | 0 | | 3 | 3 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 9.7 | 0 | | 4 | 2.425 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 8 | 0 | 9 | 0 | | 5 | 1.8 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 9.3 | 0 | | 6 | 1.55 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 10.3 | 0 | | 7 | 1.471 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 9.6 | 0 | 1 | 8 | 1.2 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 11.2 | 0 | | 9 | 1.244 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 10.2 | 0 | | 10 | 1.02 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 11.4 | 0 | 1 | 10 | 1.14 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 9.5 | 0 | | 10 | 0.95 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 9.5 | 0 | | 10 | 0.95 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 9.9 | 0 | 1 | 10 | 0.99 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 9 | 0 | 10 | 0 | 1 | 10 | 1 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 10 | 0 | 11 | 0 | 1 | 10 | 1.1 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 10 | 0 | 9.7 | 0 | 1 | 10 | 0.97 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |

| | | | | | | | | | | | | | | |
|------------|------|------|-------------|---|---|----|-------|---|----------|--------|--------|--------|--------|------|
| 102 | 1204 | 0 | 10.5 | 0 | 1 | 10 | 1.05 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 103 | 1304 | 0 | 10.4 | 0 | 1 | 10 | 1.04 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 104 | 1404 | 0 | 12.2 | 0 | 1 | 10 | 1.22 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 105 | 1504 | 0 | 12.8 | 0 | 1 | 10 | 1.28 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 106 | 1604 | 0 | 11.8 | 0 | 1 | 10 | 1.18 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 107 | 1704 | 0 | 9.9 | 0 | 1 | 10 | 0.99 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 108 | 1804 | 0 | 12.1 | 0 | 1 | 10 | 1.21 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 109 | 1904 | 0 | 10.8 | 0 | 1 | 10 | 1.08 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 110 | 2004 | 0 | 10.7 | 0 | 1 | 10 | 1.07 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 111 | 2104 | 0 | 11.1 | 0 | 1 | 10 | 1.11 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 112 | 2204 | 0 | 10.4 | 0 | 1 | 10 | 1.04 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 113 | 2304 | 0 | 7.2 | 0 | 1 | 10 | 0.72 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 114 | 2404 | 0 | 10 | 0 | 1 | 10 | 1 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 115 | 2504 | 0 | 9.4 | 0 | 1 | 10 | 0.94 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 116 | 2604 | 0 | 10.2 | 0 | 1 | 10 | 1.02 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 117 | 2704 | 0 | 10.5 | 0 | 1 | 10 | 1.05 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 118 | 2804 | 0 | 11.8 | 0 | 1 | 10 | 1.18 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 119 | 2904 | 0 | 12.6 | 0 | 1 | 10 | 1.26 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 120 | 3004 | 0 | 12 | 0 | 1 | 10 | 1.2 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 121 | 105 | 0 | 14 | 0 | 1 | 10 | 1.4 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 122 | 205 | 0 | 14.5 | 0 | 1 | 10 | 1.45 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 123 | 305 | 0 | 11.5 | 0 | 1 | 10 | 1.15 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 124 | 405 | 0 | 12.5 | 0 | 1 | 10 | 1.25 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 125 | 505 | 3.2 | 13.7 | 0 | 1 | 10 | 1.37 | 0 | 1.83 | 51.83 | 118 | 168 | 201.6 | 0 |
| 126 | 605 | 0 | 11.5 | 0 | 1 | 10 | 1.15 | 0 | 0 | 50.68 | 118 | 169.83 | 199.4 | 0 |
| 127 | 705 | 0 | 6.2 | 0 | 1 | 10 | 0.62 | 0 | 0 | 50.06 | 118 | 168.68 | 200.78 | 0 |
| 128 | 805 | 0 | 12.2 | 0 | 1 | 10 | 1.22 | 0 | 0 | 50 | 118 | 168.06 | 201.53 | 0 |
| 129 | 905 | 0 | 11 | 0 | 1 | 10 | 1.1 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 130 | 1005 | 0 | 11.4 | 0 | 1 | 10 | 1.14 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 131 | 1105 | 0 | 11.2 | 0 | 1 | 10 | 1.12 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 132 | 1205 | 19.4 | 13 | 0 | 1 | 0 | 6.5 | 0 | 12.9 | 62.9 | 118 | 168 | 201.6 | 0 |
| 133 | 1305 | 0 | 6.2 | 0 | 1 | 1 | 6.2 | 0 | 0 | 56.7 | 118 | 180.9 | 186.12 | 0 |
| 134 | 1405 | 0 | 9 | 0 | 1 | 2 | 4.5 | 0 | 0 | 52.2 | 118 | 174.7 | 193.56 | 0 |
| 135 | 1505 | 0 | 6.5 | 0 | 1 | 3 | 2.167 | 0 | 0 | 50.03 | 118 | 170.2 | 198.96 | 0 |
| 136 | 1605 | 0 | 9.6 | 0 | 1 | 4 | 2.4 | 0 | 0 | 50 | 118 | 168.03 | 201.56 | 0 |
| 137 | 1705 | 0 | 10.1 | 0 | 1 | 5 | 2.02 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 138 | 1805 | 0 | 8.4 | 0 | 1 | 6 | 1.4 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 139 | 1905 | 0 | 9.6 | 0 | 1 | 7 | 1.371 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 140 | 2005 | 0 | 12.2 | 0 | 1 | 8 | 1.525 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 141 | 2105 | 0 | 11.6 | 0 | 1 | 9 | 1.289 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 142 | 2205 | 0 | 10.7 | 0 | 1 | 10 | 1.07 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 143 | 2305 | 0 | 10.4 | 0 | 1 | 10 | 1.04 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 144 | 2405 | 0 | 9.5 | 0 | 1 | 10 | 0.95 | 0 | 0 | 50 | 118 | 168 | 201.6 | 0 |
| 145 | 2505 | 5.6 | 7.6 | 0 | 1 | 10 | 0.76 | 0 | 4.84 | 54.84 | 118 | 168 | 201.6 | 0 |
| 146 | 2605 | 98 | 6 | 0 | 1 | 0 | 3 | 0 | 95 | 110 | 157.84 | 172.84 | 195.79 | 0 |
| 147 | 2705 | 42 | 5.5 | 0 | 1 | 1 | 5.5 | 0 | 36.5 | 110 | 160 | 267.84 | 81.79 | 7.45 |
| 148 | 2805 | 0 | 5 | 0 | 1 | 1 | 5 | 0 | 0 | 105 | 160 | 270 | 79.2 | 0 |
| 149 | 2905 | 0 | 8.5 | 0 | 1 | 2 | 4.25 | 0 | 0 | 100.75 | 160 | 265 | 85.2 | 0 |
| 150 | 3005 | 0 | 11 | 0 | 1 | 3 | 3.667 | 0 | 0 | 97.08 | 160 | 260.75 | 90.3 | 0 |
| 151 | 3105 | 0 | 11 | 0 | 1 | 4 | 2.75 | 0 | 0 | 94.33 | 160 | 257.08 | 94.7 | 0 |
| 152 | 106 | 0 | 10.2 | 0 | 1 | 5 | 2.04 | 0 | 0 | 92.29 | 160 | 254.33 | 98 | 0 |
| 153 | 206 | 0 | 11.6 | 0 | 1 | 6 | 1.933 | 0 | 0 | 90.36 | 160 | 252.29 | 100.45 | 0 |
| 154 | 306 | 0 | 12 | 0 | 1 | 7 | 1.714 | 0 | 0 | 88.65 | 160 | 250.36 | 102.77 | 0 |

| | | | | | | | | | | | | | |
|-----|------|------|------|---|-----|-------|-------|------|--------|--------|--------|--------|---|
| 155 | 406 | 6.5 | 6.1 | 0 | 0 | 3.05 | 0 | 3.45 | 92.1 | 160 | 248.65 | 104.83 | 0 |
| 156 | 506 | 0 | 8.1 | 0 | 1 | 8.1 | 0 | 0 | 84 | 160 | 252.1 | 100.69 | 0 |
| 157 | 606 | 0 | 9.6 | 0 | 2 | 4.8 | 0 | 0 | 79.2 | 160 | 244 | 110.41 | 0 |
| 158 | 706 | 0 | 12 | 0 | 3 | 4 | 0 | 0 | 75.2 | 160 | 239.2 | 116.17 | 0 |
| 159 | 806 | 0 | 9 | 0 | 4 | 2.25 | 0 | 0 | 72.95 | 160 | 235.2 | 120.97 | 0 |
| 160 | 906 | 0 | 11 | 0 | 5 | 2.2 | 0 | 0 | 70.75 | 160 | 232.95 | 123.67 | 0 |
| 161 | 1006 | 1.8 | 10.5 | 0 | 5 | 2.1 | 0 | 0 | 68.65 | 160 | 230.75 | 126.31 | 0 |
| 162 | 1106 | 0.25 | 7 | 0 | 5 | 1.4 | 0 | 0 | 67.25 | 160 | 228.65 | 128.83 | 0 |
| 163 | 1206 | 3.3 | 6.2 | 0 | 5 | 1.24 | 0 | 2.06 | 69.31 | 160 | 227.25 | 130.51 | 0 |
| 164 | 1306 | 0.25 | 6.6 | 0 | 5 | 1.32 | 0 | 0 | 67.99 | 160 | 229.31 | 128.03 | 0 |
| 165 | 1406 | 0 | 5.9 | 0 | 6 | 0.983 | 0 | 0 | 67 | 160 | 227.99 | 129.62 | 0 |
| 166 | 1506 | 0 | 8.4 | 0 | 7 | 1.2 | 0 | 0 | 65.8 | 160 | 227 | 130.8 | 0 |
| 167 | 1606 | 3.3 | 2.2 | 0 | 0 | 1.1 | 0 | 2.2 | 68 | 160 | 225.8 | 132.24 | 0 |
| 168 | 1706 | 6.9 | 3.9 | 0 | | 3.9 | 0 | 3 | 71 | 160 | 228 | 129.6 | 0 |
| 169 | 1806 | 7.4 | 2.5 | 0 | | 2.5 | 0 | 4.9 | 75.9 | 160 | 231 | 126 | 0 |
| 170 | 1906 | 12.2 | 2.8 | 0 | | 2.8 | 0 | 9.4 | 85.3 | 160 | 235.9 | 120.12 | 0 |
| 171 | 2006 | 1 | 6.7 | 0 | | 6.7 | 0 | 0 | 78.6 | 160 | 245.3 | 108.84 | 0 |
| 172 | 2106 | 1.8 | 7.5 | 0 | | 7.5 | 0 | 0 | 71.1 | 160 | 238.6 | 116.88 | 0 |
| 173 | 2206 | 0 | 7.5 | 0 | 1 | 7.5 | 0 | 0 | 63.6 | 160 | 231.1 | 125.88 | 0 |
| 174 | 2306 | 0 | 7.1 | 0 | 2 | 3.55 | 0 | 0 | 60.05 | 160 | 223.6 | 134.88 | 0 |
| 175 | 2406 | 3 | 4.8 | 0 | 2 | 2.4 | 0 | 0.6 | 60.65 | 160 | 220.05 | 139.14 | 0 |
| 176 | 2506 | 4.8 | 4.7 | 0 | 0 | 2.35 | 0 | 2.45 | 63.1 | 160 | 220.65 | 138.42 | 0 |
| 177 | 2606 | 0 | 7.5 | 0 | 1 | 7.5 | 0 | 0 | 55.6 | 160 | 223.1 | 135.48 | 0 |
| 178 | 2706 | 0 | 8 | 0 | 1 | 4 | 0 | 0 | 51.6 | 160 | 215.6 | 144.48 | 0 |
| 179 | 2806 | 2 | 8.5 | 0 | 1 | 2 | 4.25 | 0 | 50 | 160 | 211.6 | 149.28 | 0 |
| 180 | 2906 | 0 | 7.3 | 0 | 1 | 3 | 2.433 | 0 | 50 | 160 | 210 | 151.2 | 0 |
| 181 | 3006 | 0 | 8 | 0 | 1 | 4 | 2 | 0 | 50 | 160 | 210 | 151.2 | 0 |
| 182 | 107 | 0 | 7.7 | 0 | 0.8 | 5 | 1.232 | 1.54 | 50 | 158.92 | 210 | 151.2 | 0 |
| 183 | 207 | 0 | 9 | 0 | 0.8 | 6 | 1.2 | 1.8 | 50 | 157.66 | 208.92 | 152.49 | 0 |
| 184 | 307 | 0 | 9 | 0 | 0.8 | 7 | 1.029 | 1.8 | 50 | 156.4 | 207.66 | 154.01 | 0 |
| 185 | 407 | 0 | 9.3 | 0 | 0.8 | 8 | 0.93 | 1.86 | 50 | 155.1 | 206.4 | 155.52 | 0 |
| 186 | 507 | 4.8 | 8.6 | 0 | 0.8 | 8 | 0.86 | 1.72 | 52.22 | 155.1 | 205.1 | 157.08 | 0 |
| 187 | 607 | 3 | 4.6 | 0 | 0.8 | 8 | 0.46 | 0.92 | 53.84 | 155.1 | 207.32 | 154.42 | 0 |
| 188 | 707 | 5.1 | 7.1 | 0 | 0.8 | 8 | 0.71 | 1.42 | 56.81 | 155.1 | 208.94 | 152.47 | 0 |
| 189 | 807 | 23.4 | 5 | 0 | 0.8 | 0 | 2 | 1 | 77.21 | 155.1 | 211.91 | 148.91 | 0 |
| 190 | 907 | 0 | 3.3 | 0 | 0.8 | 1 | 2.64 | 0.66 | 74.37 | 154.64 | 232.31 | 124.43 | 0 |
| 191 | 1007 | 0 | 5.8 | 0 | 0.8 | 2 | 2.32 | 1.16 | 71.7 | 153.83 | 229.01 | 128.39 | 0 |
| 192 | 1107 | 0 | 5.1 | 0 | 0.6 | 3 | 1.02 | 2.04 | 70.07 | 152.4 | 225.53 | 132.56 | 0 |
| 193 | 1207 | 6.1 | 4.5 | 0 | 0.6 | 0 | 1.35 | 1.8 | 73.02 | 152.4 | 222.47 | 136.24 | 0 |
| 194 | 1307 | 5.6 | 5 | 0 | 0.6 | 1 | 3 | 2 | 73.62 | 152.4 | 225.42 | 132.7 | 0 |
| 195 | 1407 | 0 | 3.8 | 0 | 0.6 | 1 | 2.28 | 1.52 | 70.89 | 151.33 | 226.02 | 131.98 | 0 |
| 196 | 1507 | 2.8 | 6 | 0 | 0.6 | 1 | 3.6 | 2.4 | 66.57 | 149.65 | 222.22 | 136.54 | 0 |
| 197 | 1607 | 34 | 5 | 0 | 0.6 | 0 | 1.5 | 2 | 97.07 | 149.65 | 216.22 | 143.74 | 0 |
| 198 | 1707 | 5.1 | 4.7 | 0 | 0.6 | | 2.82 | 1.88 | 97.47 | 149.65 | 246.72 | 107.14 | 0 |
| 199 | 1807 | 0 | 4.3 | 0 | 0.6 | | 2.58 | 1.72 | 94.37 | 148.45 | 247.12 | 106.66 | 0 |
| 200 | 1907 | 4.1 | 3.8 | 0 | 0.6 | 0 | 1.14 | 1.52 | 95.81 | 148.45 | 242.82 | 111.82 | 0 |
| 201 | 2007 | 7.1 | 5.8 | 0 | 0.6 | | 3.48 | 2.32 | 97.11 | 148.45 | 244.26 | 110.09 | 0 |
| 202 | 2107 | 2.3 | 4.6 | 0 | 0.2 | | 0.92 | 3.68 | 95.09 | 145.87 | 245.56 | 108.53 | 0 |
| 203 | 2207 | 11.9 | 4.1 | 0 | 0.2 | | 0.82 | 3.28 | 102.89 | 145.87 | 240.96 | 114.05 | 0 |
| 204 | 2307 | 6.9 | 4.3 | 0 | 0.2 | | 0.86 | 3.44 | 105.49 | 145.87 | 248.76 | 104.69 | 0 |
| 205 | 2407 | 0.8 | 5.9 | 0 | 0.2 | | 1.18 | 4.72 | 102.89 | 142.57 | 251.36 | 101.57 | 0 |
| 206 | 2507 | 8.4 | 5.6 | 0 | 0.2 | 1 | 1.12 | 4.48 | 105.69 | 142.57 | 245.46 | 108.65 | 0 |
| 207 | 2607 | 4.6 | 6.6 | 0 | 0.2 | 1 | 1.32 | 5.28 | 102.79 | 138.87 | 248.26 | 105.29 | 0 |

| | | | | | | | | | | | | | |
|------------|-------------|------|-----|---------------|---|--------------|-------|--------|--------|--------|---------------|---------------|-------------|
| 208 | 2707 | 2 | 5.2 | 0 0.2 | 1 | 1.04 | 4.16 | 0 | 100.5 | 135.96 | 241.66 | 113.21 | 0 |
| 209 | 2807 | 1 | 6.1 | 0 0.2 | 1 | 1.22 | 4.88 | 0 | 97.81 | 132.55 | 236.46 | 119.45 | 0 |
| 210 | 2907 | 0.25 | 4.3 | 0 0.2 | 1 | 0.86 | 3.44 | 0 | 95.92 | 130.14 | 230.36 | 126.77 | 0 |
| 211 | 3007 | 0 | 6.6 | 0 0.2 | 1 | 1.32 | 5.28 | 0 | 93.02 | 126.44 | 226.06 | 131.93 | 0 |
| 212 | 3107 | 0 | 5.3 | 0 0.1 | 2 | 0.265 | 4.77 | 0 | 91.32 | 123.1 | 219.46 | 139.85 | 0 |
| 213 | 108 | 26 | 4.1 | 0 0. | 0 | 0.205 | 3.69 | 22.105 | 110 | 126.53 | 214.43 | 145.89 | 0 |
| 214 | 208 | 15.2 | 4.3 | 0 0. | 1 | 0.43 | 3.87 | 10.9 | 110 | 137.43 | 236.53 | 119.36 | 0 |
| 215 | 308 | 9.2 | 3.3 | 0 0. | 1 | 0.33 | 2.97 | 5.9 | 110 | 143.33 | 247.43 | 106.28 | 0 |
| 216 | 408 | 0 | 4.5 | 0 0. | 1 | 0.45 | 4.05 | 0 | 108.34 | 140.5 | 253.33 | 99.2 | 0 |
| 217 | 508 | 0 | 4 | 0 0. | 2 | 0.2 | 3.6 | 0 | 107.06 | 137.98 | 248.83 | 104.6 | 0 |
| 218 | 608 | 0 | 5.2 | 0 0. | 3 | 0.173 | 4.68 | 0 | 105.48 | 134.7 | 245.03 | 109.16 | 0 |
| 219 | 708 | 11 | 4.5 | 0 0. | 0 | 0.225 | 4.05 | 6.725 | 110 | 136.9 | 240.18 | 114.99 | 0 |
| 220 | 808 | 0 | 3.2 | 0 0. | 1 | 0.32 | 2.88 | 0 | 108.82 | 134.89 | 246.9 | 106.92 | 0 |
| 221 | 908 | 0 | 3.2 | 0 0. | 2 | 0.16 | 2.88 | 0 | 107.79 | 132.87 | 243.7 | 110.76 | 0 |
| 222 | 1008 | 6 | 3 | 0 0. | 0 | 0.15 | 2.7 | 3.15 | 110 | 133.81 | 240.66 | 114.41 | 0 |
| 223 | 1108 | 9 | 4.8 | 0 0. | 1 | 0.48 | 4.32 | 4.2 | 110 | 138.01 | 243.81 | 110.63 | 0 |
| 224 | 1208 | 0 | 4 | 0 0. | 1 | 0.4 | 3.6 | 0 | 108.52 | 135.49 | 248.01 | 105.59 | 0 |
| 225 | 1308 | 0 | 5.9 | 0 0. | 2 | 0.295 | 5.31 | 0 | 106.63 | 131.77 | 244.01 | 110.39 | 0 |
| 226 | 1408 | 0 | 5 | 0 0. | 3 | 0.167 | 4.5 | 0 | 105.12 | 128.62 | 238.41 | 117.11 | 0 |
| 227 | 1508 | 0 | 4.4 | 0 0.1 | 4 | 0.11 | 3.96 | 0 | 103.82 | 125.85 | 233.74 | 122.71 | 0 |
| 228 | 1608 | 42.5 | 5.1 | 0 0.1 | 0 | 0.255 | 4.59 | 37.655 | 110 | 157.33 | 229.67 | 127.6 | 0 |
| 229 | 1708 | 0 | 2.8 | 0 0.1 | 1 | 0.28 | 2.52 | 0 | 108.96 | 155.56 | 267.33 | 82.41 | 0 |
| 230 | 1808 | 0 | 4 | 0 0.1 | 2 | 0.2 | 3.6 | 0 | 107.68 | 153.04 | 264.53 | 85.77 | 0 |
| 231 | 1908 | 7.7 | 4.5 | 0 0.1 | 0 | 0.225 | 4.05 | 3.425 | 110 | 154.15 | 260.73 | 90.33 | 0 |
| 232 | 2008 | 0 | 4.4 | 0 0. | 1 | 0.44 | 3.96 | 0 | 108.37 | 151.38 | 264.15 | 86.22 | 0 |
| 233 | 2108 | 0 | 4.1 | 0 0. | 2 | 0.205 | 3.69 | 0 | 107.06 | 148.8 | 259.75 | 91.5 | 0 |
| 234 | 2208 | 0 | 3.4 | 0 0. | 3 | 0.113 | 3.06 | 0 | 106.03 | 146.65 | 255.86 | 96.17 | 0 |
| 235 | 2308 | 0 | 4.8 | 0 0. | 4 | 0.12 | 4.32 | 0 | 104.61 | 143.63 | 252.68 | 99.98 | 0 |
| 236 | 2408 | 0 | 5.9 | 0 0. | 5 | 0.118 | 5.31 | 0 | 102.9 | 139.91 | 248.24 | 105.31 | 0 |
| 237 | 2508 | 0 | 5.2 | 0 0. | 6 | 0.087 | 4.68 | 0 | 101.41 | 136.64 | 242.81 | 111.82 | 0 |
| 238 | 2608 | 0 | 4 | 0 0. | 7 | 0.057 | 3.6 | 0 | 100.27 | 134.12 | 238.05 | 117.54 | 0 |
| 239 | 2708 | 0 | 5.1 | 0 0. | 8 | 0.064 | 4.59 | 0 | 98.83 | 130.9 | 234.39 | 121.93 | 0 |
| 240 | 2808 | 24 | 3.3 | 0 0.1 | 0 | 0.165 | 2.97 | 20.865 | 110 | 140.6 | 229.74 | 127.52 | 0 |
| 241 | 2908 | 0 | 4.8 | 0 0.1 | 1 | 0.48 | 4.32 | 0 | 108.22 | 137.58 | 250.6 | 102.48 | 0 |
| 242 | 3008 | 0 | 2.9 | 0 0.1 | 2 | 0.145 | 2.61 | 0 | 107.3 | 135.75 | 245.8 | 108.24 | 0 |
| 243 | 3108 | 74 | 3.9 | 0 0.1 | 0 | 0.195 | 3.51 | 70.295 | 110 | 160 | 243.05 | 111.54 | 11.4 |
| 244 | 109 | 8.6 | 4.5 | 0 0.15 | 1 | 0.675 | 3.825 | 4.1 | 110 | 160 | 270 | 79.2 | 0 |
| 245 | 209 | 0 | 5.7 | 00.15 | 1 | 0.855 | 4.845 | 0 | 107.69 | 156.61 | 270 | 79.2 | 0 |
| 246 | 309 | 0 | 5.2 | 00.15 | 2 | 0.39 | 4.42 | 0 | 105.98 | 153.51 | 264.3 | 86.04 | 0 |
| 247 | 409 | 0 | 6.6 | 00.15 | 3 | 0.33 | 5.61 | 0 | 103.96 | 149.59 | 259.49 | 91.81 | 0 |
| 248 | 509 | 0 | 5 | 00.15 | 4 | 0.188 | 4.25 | 0 | 102.5 | 146.61 | 253.55 | 98.94 | 0 |
| 249 | 609 | 0 | 7.4 | 00.15 | 5 | 0.222 | 6.29 | 0 | 100.39 | 142.21 | 249.11 | 104.26 | 0 |
| 250 | 709 | 26 | 6.7 | 00.15 | 0 | 0.502 | 5.695 | 19.802 | 110 | 152.4 | 242.6 | 112.08 | 0.11 |
| 251 | 809 | 0 | 4.4 | 0 0.15 | 1 | 0.66 | 3.74 | 0 | 108.22 | 149.79 | 262.4 | 88.32 | 0 |
| 252 | 909 | 14 | 5.4 | 00.15 | 0 | 0.405 | 4.59 | 9.005 | 110 | 157.01 | 258 | 93.6 | 0 |
| 253 | 1009 | 16 | 5.4 | 00.15 | 1 | 0.81 | 4.59 | 10.6 | 110 | 160 | 267.01 | 82.79 | 0 |
| 254 | 1109 | 33.5 | 3.5 | 00.15 | 1 | 0.525 | 2.975 | 30 | 110 | 160 | 270 | 79.2 | 3.22 |
| 255 | 1209 | 0 | 3.2 | 00.15 | 1 | 0.48 | 2.72 | 0 | 108.7 | 158.1 | 270 | 79.2 | 0 |
| 256 | 1309 | 0 | 4.1 | 00.15 | 2 | 0.308 | 3.485 | 0 | 107.35 | 155.66 | 266.8 | 83.04 | 0 |
| 257 | 1409 | 0 | 3.5 | 00.15 | 3 | 0.175 | 2.975 | 0 | 106.28 | 153.57 | 263.01 | 87.59 | 0 |
| 258 | 1509 | 0 | 4.8 | 0 0.15 | 4 | 0.18 | 4.08 | 0 | 104.88 | 150.72 | 259.86 | 91.37 | 0 |
| 259 | 1609 | 0 | 6.3 | 00.15 | 5 | 0.189 | 5.355 | 0 | 103.08 | 146.97 | 255.6 | 96.48 | 0 |
| 260 | 1709 | 0 | 6.6 | 00.15 | 6 | 0.165 | 5.61 | 0 | 101.24 | 143.04 | 250.05 | 103.14 | 0 |

| | | | | | | | | | | | | | |
|-----|-------------|------|-----|--------|----|-------|-------|-------|---------------|---------------|--------|---------------|---|
| 261 | 1809 | 0.25 | 6.3 | 0 0.15 | 6 | 0.158 | 5.355 | 0 | 99.47 | 139.29 | 244.28 | 110.07 | 0 |
| 262 | 1909 | 0 | 5 | 0 0.15 | 7 | 0.107 | 4.25 | 0 | 98.09 | 136.32 | 238.77 | 116.68 | 0 |
| 263 | 2009 | 0 | 4.8 | 0 0.15 | 8 | 0.09 | 4.08 | 0 | 96.78 | 133.46 | 234.41 | 121.91 | 0 |
| 264 | 2109 | 0 | 5.5 | 0 0.8 | 9 | 0.489 | 1.1 | 0 | 95.96 | 132.69 | 230.24 | 126.91 | 0 |
| 265 | 2209 | 0 | 4.5 | 0 0.8 | 10 | 0.36 | 0.9 | 0 | 95.33 | 132.06 | 228.65 | 128.82 | 0 |
| 266 | 2309 | 0 | 3.4 | 0 0.8 | 10 | 0.272 | 0.68 | 0 | 94.85 | 131.59 | 227.39 | 130.33 | 0 |
| 267 | 2409 | 0 | 3.4 | 0 0.8 | 10 | 0.272 | 0.68 | 0 | 94.37 | 131.11 | 226.44 | 131.47 | 0 |
| 268 | 2509 | 0 | 4.7 | 0 0.8 | 10 | 0.376 | 0.94 | 0 | 93.72 | 130.45 | 225.49 | 132.62 | 0 |
| 269 | 2609 | 2.5 | 2.2 | 0 0.8 | 0 | 0.88 | 0.44 | 1.18 | 94.9 | 130.45 | 224.17 | 134.2 | 0 |
| 270 | 2709 | 0.3 | 4 | 0 0.8 | 1 | 3.2 | 0.8 | 0 | 91.46 | 129.89 | 225.35 | 132.78 | 0 |
| 271 | 2809 | 0 | 4.6 | 0 0.8 | 1 | 3.68 | 0.92 | 0 | 87.5 | 129.25 | 221.35 | 137.58 | 0 |
| 272 | 2909 | 20.6 | 3.7 | 0 0.8 | 0 | 1.48 | 0.74 | 18.38 | 105.88 | 129.25 | 216.75 | 143.1 | 0 |
| 273 | 3009 | 3.3 | 2 | 0 0.8 | 1 | 1.6 | 0.4 | 1.3 | 107.18 | 129.25 | 235.13 | 121.04 | 0 |
| 274 | 110 | 0 | 4.1 | 0 0.7 | 1 | 2.87 | 1.23 | 0 | 103.94 | 128.39 | 236.43 | 119.48 | 0 |
| 275 | 210 | 0 | 5 | 0 0.7 | 2 | 1.75 | 1.5 | 0 | 101.74 | 127.34 | 232.33 | 124.4 | 0 |
| 276 | 310 | 0 | 4.8 | 0 0.7 | 3 | 1.12 | 1.44 | 0 | 100.19 | 126.33 | 229.08 | 128.3 | 0 |
| 277 | 410 | 0 | 5.4 | 0 0.7 | 4 | 0.945 | 1.62 | 0 | 98.76 | 125.2 | 226.52 | 131.38 | 0 |
| 278 | 510 | 0 | 6 | 0 0.7 | 5 | 0.84 | 1.8 | 0 | 97.38 | 123.94 | 223.95 | 134.45 | 0 |
| 279 | 610 | 0 | 4.9 | 0 0.7 | 6 | 0.572 | 1.47 | 0 | 96.37 | 122.91 | 221.31 | 137.62 | 0 |
| 280 | 710 | 2 | 3 | 0 0.7 | 6 | 0.35 | 0.9 | 0.75 | 97.12 | 122.91 | 219.27 | 140.07 | 0 |
| 281 | 810 | 0.3 | 3.6 | 0 0.7 | 6 | 0.42 | 1.08 | 0 | 96.37 | 122.15 | 220.02 | 139.17 | 0 |
| 282 | 910 | 4.1 | 4.6 | 0 0.7 | 6 | 0.537 | 1.38 | 2.183 | 98.56 | 122.15 | 218.52 | 140.97 | 0 |
| 283 | 1010 | 0 | 5 | 0 0.7 | 7 | 0.5 | 1.5 | 0 | 97.61 | 121.1 | 220.71 | 138.35 | 0 |
| 284 | 1110 | 0 | 6 | 0 0.4 | 8 | 0.3 | 3.6 | 0 | 96.23 | 118.58 | 218.71 | 140.75 | 0 |
| 285 | 1210 | 0 | 5.8 | 0 0.4 | 9 | 0.258 | 3.48 | 0 | 94.92 | 116.14 | 214.81 | 145.43 | 0 |
| 286 | 1310 | 25.7 | 3.7 | 0 0.4 | 0 | 0.74 | 2.22 | 22.74 | 110 | 123.81 | 211.07 | 149.92 | 0 |
| 287 | 1410 | 1.5 | 5.9 | 0 0.4 | 1 | 2.36 | 3.54 | 0 | 106.58 | 121.33 | 233.81 | 122.63 | 0 |
| 288 | 1510 | 0 | 4.8 | 0 0.4 | 1 | 1.92 | 2.88 | 0 | 103.79 | 119.31 | 227.91 | 129.71 | 0 |
| 289 | 1610 | 11.9 | 4.3 | 0 0.4 | 0 | 0.86 | 2.58 | 8.46 | 110 | 121.57 | 223.11 | 135.47 | 0 |
| 290 | 1710 | 0 | 4.2 | 0 0.4 | 1 | 1.68 | 2.52 | 0 | 107.56 | 119.8 | 231.57 | 125.32 | 0 |
| 291 | 1810 | 0 | 4.4 | 0 0.4 | 2 | 0.88 | 2.64 | 0 | 105.89 | 117.96 | 227.37 | 130.36 | 0 |
| 292 | 1910 | 0 | 4.6 | 0 0.4 | 3 | 0.613 | 2.76 | 0 | 104.45 | 116.02 | 223.85 | 134.58 | 0 |
| 293 | 2010 | 0 | 5.2 | 0 0.4 | 4 | 0.52 | 3.12 | 0 | 102.99 | 113.84 | 220.48 | 138.63 | 0 |
| 294 | 2110 | 0 | 5.9 | 0 0.4 | 5 | 0.472 | 3.54 | 0 | 101.46 | 111.36 | 216.84 | 143 | 0 |
| 295 | 2210 | 0 | 5.5 | 0 0.4 | 6 | 0.367 | 3.3 | 0 | 100.1 | 109.05 | 212.82 | 147.81 | 0 |
| 296 | 2310 | 0 | 6.2 | 0 0.4 | 7 | 0.354 | 3.72 | 0 | 98.63 | 106.45 | 209.16 | 152.21 | 0 |
| 297 | 2410 | 0 | 5.7 | 0 0.4 | 8 | 0.285 | 3.42 | 0 | 97.32 | 104.05 | 205.08 | 157.1 | 0 |
| 298 | 2510 | 0 | 4.6 | 0 0.4 | 9 | 0.204 | 2.76 | 0 | 96.29 | 102.12 | 201.38 | 161.55 | 0 |
| 299 | 2610 | 0.3 | 4 | 0 0.4 | 9 | 0.178 | 2.4 | 0 | 95.39 | 100.44 | 198.41 | 165.1 | 0 |
| 300 | 2710 | 4.8 | 4.9 | 0 0.4 | 9 | 0.218 | 2.94 | 1.642 | 97.03 | 100.44 | 195.84 | 168.2 | 0 |
| 301 | 2810 | 0 | 3.5 | 0 0.4 | 10 | 0.14 | 2.1 | 0 | 96.26 | 100 | 197.48 | 166.23 | 0 |
| 302 | 2910 | 0 | 4.9 | 0 0.4 | 10 | 0.196 | 2.94 | 0 | 95.19 | 100 | 196.26 | 167.68 | 0 |
| 303 | 3010 | 0.3 | 6.5 | 0 0.4 | 10 | 0.26 | 3.9 | 0 | 93.76 | 100 | 195.19 | 168.98 | 0 |
| 304 | 3110 | 0 | 6.6 | 0 0.4 | 10 | 0.264 | 3.96 | 0 | 92.3 | 100 | 193.76 | 170.69 | 0 |
| 305 | 111 | 0 | 6.2 | 0 1 | 10 | 0.62 | 0 | 0 | 91.68 | 100 | 192.3 | 172.43 | 0 |
| 306 | 211 | 0 | 6.6 | 0 1 | 10 | 0.66 | 0 | 0 | 91.02 | 100 | 191.68 | 173.18 | 0 |
| 307 | 311 | 0 | 4.7 | | 10 | 0.47 | 0 | 0 | 90.55 | 100 | 191.02 | 173.97 | 0 |
| 308 | 411 | | | | 10 | 0.5 | 0 | 0 | 90.05 | 100 | 190.55 | 174.53 | 0 |
| 309 | 511 | 0 | 5.6 | | 10 | 0.56 | 0 | 0 | 89.49 | 100 | 190.05 | 175.13 | 0 |
| 310 | 611 | 0 | 4.8 | | 10 | 0.48 | 0 | 0 | 89.01 | 100 | 189.49 | 175.81 | 0 |
| 311 | 711 | 0 | 5.2 | | 10 | 0.52 | 0 | 0 | 88.49 | 100 | 189.01 | 176.38 | 0 |
| 312 | 811 | | | | 10 | 0.3 | 0 | 0 | 88.19 | 100 | 188.49 | 177.01 | 0 |
| 313 | 911 | 0 | 5.6 | 0 1 | 10 | 0.56 | 0 | 0 | 87.63 | 100 | 188.19 | 177.37 | 0 |

APPENDIX-C

Water harvesting model

```
1060 REM SWB FOR SOIL OF TWO LAYERS
1061 REM DIM Z(1000,10)
1062 DIM D2(1200), RAIN(1200), PAN(1200), BEETA(1200), DTE(1200), RO(1200), P1(1200),
NETSTORE(1200)
1063 DIM RAINVOL(1200), TS(1200), SURFRAIN(1200), RUNVOL(1200), D(1200), EL(1200),
OVERFL(1200)
1065 DATA 12,27.52,77,102
1066 LOCATE 13,14:INPUT "ENTER THE DATA FILE NAME "; FILES$
1067 LOCATE 13,14:PRINT "
1070 OPEN FILES$ FOR INPUT AS #1
1075 WHILE NOT EOF(1)
1080 LOCATE 13,14: PRINT USING "READING THE DATA ### ";K
1085 LINE INPUT #1.DATS$
1095 K= K+1
1100 DTE(K) = VAL(MID$(DAT$,1,4))
1105 RAIN(K) = VAL(MID$(DAT$,5,7))
1110 PAN(K) = VAL(MID$(DAT$,12,6))
1112 RO(K) = VAL(MID$(DAT$,18,7))
1115 BEETA(K) = VAL(MID$(DAT$,25,6))
1116 WEND
1118 CLOSE #1 :CLS
1120 'OPEN "BEETA TXT" FOR INPUT AS #2
1122 'K = 0
1123 'WHILE NOT EOF (2)
1124 'K = K+1
1125 'INPUT #2. DAT.BEETA(R)
1126 WEND
1128 'CLOSE #2
1130 'OPEN "ICRIPE.PEN" FOR INPUT AS #3
1132 'K = 0
1134 WHILE NOT EOF (3)
1135 'K = K+1
1136 'INPUT #3. DUM.PAN(R)
1137 WEND
1138 'CLOSE #3
1140 'INPUT "ENTER THE NUMBER OF RECORDS IN YOUR DATA FILE "; NR
1150 'INPUT "ENTER A NAME FOR OUTPUT FILE";M$
1160 'OPEN M$ FOR OUTPUT AS #4
1170 'INPUT "ENTER THE STARTING AND ENDING DATES SEPERATED BY COMMAS";N1,N2
1180 INPUT "ENTER THE STARTING SM1,SM2";S1,S2
1190 INPUT "ENTER THE DEPTH VALUE";D1
1200 INPUT "ENTER THE VALUES OF M1,M2,M3,M4,M5";M1,M2,M3,M4,M5
1210 INPUT "ENTER THE VALUES OF X3";X3
1220 'PRINT #2," ***** LAND AND WATER MANAGEMENT SOIL WATER BALANCE FOR
SOIL OF TWO LAYERS *****"
1230 'PRINT #2," STARTING SM1,SM2 = ";S1,S2;" DEPTH VALUE IS =; D1:PRINT #2," "
1240 'PRINT #2," M1.M2,M3,M4,M5,X3 VALUES ARE = ";M1,M2,M3,M4,M5,X3:PRINT #2," " :
PRINT #2,STRING$(132,42)
1250 REM PRINT #2." ROW DATE RAIN EVAP RUNOFF BEETA T E* ET DM
SM1 SM2 SMT S";
```

```

1260 REM PRINT #2," PQ ER"
1270 REM PRINT #2,STRING$(132,42)
1390 D2=D1 -30
1395 M2=D2*M2
1396 M5=D2*M5
1400 G1=0: G8=0
1410 J=1
1420 R1=0:R2=0:C=0
1430 E5=0
1440 T=0:U=6:D2(0)=1.5:O=2
1450 FOR L=1 TO K
1460 'NCO= NCO+1
1470 T6=RAIN(L)
1480 IF T6>0 THEN 1500
1490 NEXT L
1500 A1=0
1510 A2=0
1520 FOR I = L TO K
1530 T6=RAIN(I):T7=PAN(I)
1540 'NCO= NCO+1
1550 DD=T6 - T7
1560 IF I=L THEN 1670
1570 IF T6=0 THEN A1=0 : GOTO 1590
1580 GOTO 1610
1590 IF A2=1 THEN A2=0 : GOTO 1640
1600 T=T+1 : GOTO 1640
1610 IF DD>0 THEN A2=1 : GOTO 1670
1620 IF A1=1 THEN T=1:E2=T7/T : GOTO 1700
1630 E2=T7/T : GOTO 1700
1640 IF T>10 THEN T=10
1650 IF T=0 THEN T=1 : E2=T7/T : GOTO 1700
1660 E2=T7/T : GOTO 1700
1670 IF A1=0 THEN T=0:E2=T7/O:A1=1 : GOTO 1700
1680 T=1 : E2=T7/T
1690 S7=S6
1700 GOSUB 1740
1710 J=J+1
1715 NEXT I
1716 GOSUB 2800
1717 PRINT #2,"
1718 PRINT #2, "Date Rain Panev RO Evap Scep RO RVOL SVOL Netstore
Overflow"
1719 PRINT #2, " (mm) (mm) (mm) (cum) (cum) (cum) (cum) (cum) (cum) (cum)"
1720 PRINT #2, "
1721 FOR N = 1 TO K
1722 PRINT #2, USING "####.###.# ###.# ###.# ##.# ##.# ####.# ####.# ##.# ####.# ####.#" :
DTE(N),RAIN(N),PAN(N),P1(N),EL(N),TS(N),RUNVOL(N),RAINVOL(N),SURFRAIN(N),
NETSTORE(N),OVERFL(N)
1724 'PRINT #2, " "
1725 NEXT N
1728 CLS : LOCATE 18,21 : PRINT "JOB IS OVER"
1730 END
1740 T8=RO(I)
1750 S=S1+S2
1760 T9=DTE(I)

```

```

1770 B=BEETA(I):E3=(1- B)*T7
1780 E2=E2*B
1790 D5=T6-T8-E2-E3
1800 S5=D2*X3+144:P2=1.2*(S5 -(M1+M2))
1810 P3=P2+4
1820 IF D5<=0 THEN GOTO 1890
1830 S1=S1+D5
1840 IF S1>M1 THEN S5=S1-M1:S1=M1:GOTO 1860
1850 S5=0
1860 S2=S2+S5
1870 IF S2>M2 THEN S2=M2
1880 GOTO 1980
1890 IF S1<M4 THEN S1=S1 -E2 : GOTO 1930
1900 S1=S1 -.3*E3
1910 IF S1<M4 THEN S1=M4
1920 S1=S1 -E2
1930 IF S1<M3 THEN S1=M3
1940 IF S2<M5 THEN S2=M5 : GOTO 1970
1950 S2=S2 -.7*E3
1960 IF S2<M5 THEN S2=M5
1970 IF S2>M2 THEN S2=M2
1980 S5=D2*X3+144
1990 S6=(S5-S)*1.2
2000 G2=0
2010 P9=0
2020 G8=0
2030 R=R1+R2
2040 IF T6>20 THEN GOTO 2050 ELSE GOTO 2060
2050 IF R>=8 THEN S6=35 : GOTO 2090
2060 IF T6<=20 THEN GOTO 2070 ELSE GOTO 2120
2070 IF R>=8 THEN S6=15 : GOTO 2090
2080 GOTO 2120
2090 P1(I)=(T6 -.1*S6)^2/(T6+.9*S6)
2100 IF T6<.1*S6 THEN P1(I)=0
2110 GOTO 2160
2120 P9=P1(I)
2130 G8=0
2140 IF T6<.2*S6 THEN E4=T8:P1(I)=0 : GOTO 2160
2150 P1(I) = (T6 -.2*S6)^2/(T6+.8*S6)
2160 IF B=1 THEN 2170 ELSE 2290
2170 IF T6>=20 THEN 2180 ELSE 2230
2180 C1=I -1:G8=RAIN(C1)
2190 IF G8>=10 THEN 2200 ELSE 2230
2200 P1(I) = (T6 -.04*S6)^2/(T6+.96*S6)
2210 IF T6<.04*S6 THEN P1(I) = 0
2220 GOTO 2290
2230 C1=I -4:C2=I -1
2240 IF C1<0 THEN C1=1
2250 FOR J9=C1 TO C2
2260 IF PAN(J9)>RAIN(J9) THEN 2290
2270 NEXT J9
2280 GOTO 2200
2290 C1=I -10
2300 C2=I -1
2310 IF C1<0 THEN C1=1

```

```

2320 IF C2<=0 THEN C2=1
2330 FOR J9=C1 TO C2
2340 G8=G8+RAIN(J9):NEXT J9
2350 IF G8<8 THEN P1(I)=P1(I) -8 : GOTO 2430
2360 C1=I-4:C2=I-1
2370 IF C1<0 THEN C1=1:IF C2<0 THEN C2=1
2380 G8=0
2390 FOR J9=C1 TO C2
2400 G8=G8+RAIN(J9)
2410 NEXT J9
2420 IF G8<8 THEN P1(I)=P1(I) -5
2430 IF P1(I)<=0 THEN P1(I)=0 : GOTO 2540
2440 IF P9=0 THEN 2540
2450 IF P9>=3 THEN 2460 ELSE 2480
2460 IF P9<=6 THEN 2470 ELSE 2480
2470 IF P1(I)>0 THEN P1(I)=P1(I)+1 : GOTO 2540
2480 IF P9>6 THEN 2490 ELSE 2510
2490 IF P9<=15 THEN 2500 ELSE 2510
2500 IF P1(I)>0 THEN P1(I)=P1(I)+2 : GOTO 2540
2510 IF P9>15 THEN 2520 ELSE 2540
2520 IF P1(I)>0 THEN P1(I)=P1(I)+4 : GOTO 2540
2530 IF T6<=8 THEN P1(I)=0
2540 IF T6<=8 THEN P1(I)=0
2550 E4=T8 - P1(I):C=0
2560 IF R<=10 THEN C=R
2570 IF R>10 THEN 2580 ELSE 2590
2580 IF R<=25 THEN C=12 : GOTO 2600
2590 IF R>25 THEN C=17
2600 R2=R - C
2610 R1=T6 - P1(I)+S -309
2620 IF ABS(E4)<=.5 THEN E4=0
2630 IF T6<=4 THEN R1=0
2640 IF R1<0 THEN R1=0
2650 IF R2<0 THEN R2=0
2660 IF ABS(E4)<=.5 THEN E4=0
2670 E5=E5+E4
2680 IF D5<0 THEN D5 = 0
2720 G1=G1 + 1
2730 RETURN
2800 REM PROGRAM FOR CALCULATING TANK WATER STORAGE
2820 REM DEVELOPED ON JAN 1991, ICRISAT. PATANCHERU, HYDERABAD
2840 CLS
2860 REM
2880 REM DEFINITION OF VARIABLES
2900 REM RAIN ()..... RAINFALL DATA ARRAY
2920 REM RO ()..... RUNOFF DATA ARRAY
2940 REM PAN ()..... PAN EVAPORATION DATA ARRAY
2960 REM CUBRUN..... RUNOFF IN CUBIC METERS ARRAY
2980 REM D ()..... DEPTH OF WATER IN TANK ARRAY
3000 REM DTE$ ()..... DATE ARRAY
3020 REM WSA..... WATERSHED AREA ( Sqm )
3040 REM SEEP..... SEEPAGE
3060 REM
3100 LOCATE 12,7:PRINT "-----"
3120 LOCATE 14,7:PRINT "-----"

```

```

3660 REM THIS PROGRAM CALCULATES INFLOW
3680 LOCATE 13,14:INPUT " Enter the type of the tank ";TYPES$
3700 LOCATE 13,14:PRINT "
3720 IF TYPES$ = "CIRCULAR" OR TYPES$= "circular" THEN
3725 GOSUB 3960
3730 GOTO 6550
3735 END IF
3740 IF TYPES$ = "TREPEZOIDAL" OR TYPES$= "trepezoidal" THEN
3742 GOSUB 5240
3750 GOTO 6550
3755 END IF
3960 LOCATE 13,14:INPUT "Enter the watershed area (in ha ) ;AW
3980 LOCATE 13,14:PRINT "
4000 LOCATE 13,14:INPUT "Enter the bottom diameter of the tank (mts)";BD
4020 LOCATE 13,14:PRINT "
4040 LOCATE 13,14:INPUT "Enter the total depth of the tank (mts) ":H
4060 LOCATE 13,14:PRINT "
4080 LOCATE 13,14:INPUT "Enter the spillway height from bottom (mts)";SH
4100 LOCATE 13,14:PRINT "
4120 LOCATE 13,14:INPUT "Enter the seepage rate ( lits/sqm/day ) ":S
4140 LOCATE 13,14:PRINT "
4160 LOCATE 13,14:INPUT "Enter the evaporation coefficient ";EV
4180 LOCATE 13,14:PRINT "
4200 LOCATE 13,14:INPUT "Enter the side slope of the tank ":SS
4220 LOCATE 13,14:PRINT "
4240 ' LOCATE 13,14:INPUT "Enter the irrigation efficiency ":EFF
4260 ' LOCATE 13,14:PRINT "
4280 ' LOCATE 13,14:INPUT "Enter the area to be irrigated (in ha) ":IA
4300 FOR N = 1 TO K
4320 LOCATE 13,9:PRINT "CALCULATING NET STORAGE AND DEPTH OF THE TANK FOR
THE DATE ";N
4340 TD = BD+2*SS*H
4360 RUNVOL(N) = P1(N)*AW*10
4380 RAINVOL(N) = (RAIN(N)*((22/7)*(TD)^2)/4)/1000
4400 SURFRAIN(N) = 0.00
4420 RAINWT = RAINVOL(N)+SURFRAIN(N)
4440 TOTINF = RUNVOL(N)+RAINWT
4460 ' TV = (((22/7)*(1/3)*D(N-1))/4)*((BD+2*SS*D(N-1))^2+(BD+2*SS*D(N-1))*BD+(BD)^2)
4480 TOTVOL = TOTINF+TV
4500 TOTCAP =((1/12)*(22/7)*SH*((BD+2*SS*SH)^2+(BD+2*SS*SH)*BD+(BD)^2))
4510 IF (NETSTORE(N-1)+TOTVOL)>= TOTCAP THEN
4520 OVERFL(N) = NETSTORE(N-1)+TOTVOL-TOTCAP
4525 ' TOTVOL = TOTCAP
4530 END IF
4540 REM CALCULATION OF THE DEPTH FOR THE DAY
4541 'L=2*BD*SS
4542 'M=BD^2
4543 'O=-28*(NETSTORE(N-1))/22
4544 'P=(-(L^2)/3)+M
4545 'Q=(2*((L/3)^3))-(L*M/3)+O
4546 'R=(P/3)^3+(Q/2)^2
4547 'A=(-Q/2+R^(1/2))^(1/3)
4548 'B=(-Q/2-R^(1/2))^(1/3)
4549 'TOD=A+B-(L/3)
4560 FOR VD = 0 TO SH STEP 0.001

```

```

4580  TEMPVOL =(1/12)*(22/7)*VD*((BD+2*SS*VD)^2+(BD+2*SS*VD)*BD+(BD)^2))
4600    IF (NETSTORE(N-1)-TEMPVOL)<=0.001 THEN
4610      TOD = VD
4620      GOTO 4640
4622    END IF
4625    NEXT VD
4640  WSA = (22/7)*((BD+2*SS*TOD)/2)^2
4660  RR = ((SS*TOD)^2+(TOD)^2)^(1/2)
4680  WA = (1.5708*(RR)*((BD+2*SS*TOD))+BD)+((22/28)*(BD)^2)
4700  REM CALCULATION OF SEEPAGE AND EVAPORATION LOSSES AND IRRIGATION
4720  TS(N) = (S/1000)*WA
4740  EL(N) = (EV*PAN(N) * WSA)/1000
4760  ' IRRI(N) = (IRR(N)*IA*10)/EFF
4780  TOTOUT = TS(N)+EL(N)
4800  NETSTORE(N) =NETSTORE(N-1)+TOTVOL-TOTOUT-OVERFL(N)
4820  IF NETSTORE(N) <= 0.0 THEN
4821    NETSTORE(N) = 0.0
4822    TS(N)=0.0
4823    EL(N)=0.0
4824    ' STORAGE(N)=0.0
4825    END IF
4826  IF NETSTORE(N)>= TOTCAP THEN
4827    NETSTORE(N)= TOTCAP
4828    ' STORAGE(N) = (NETSTORE(N))/10
4830    END IF
4840  ' FOR VD = 0 TO SH STEP 0.001
4860  ' TEMPVOL =1/12*(22/7)*VD*((BD+2*SS*VD)^2+(BD+2*SS*VD)*BD+(BD)^2))
4880    'IF (ETSTORE(N)-TEMPVOL)<=0.001 THEN
4881      'D(N) = VD
4882      'GOTO 4920
4885      ' END IF
4900  ' NEXT VD
4920  NEXT N
4940  LOCATE 13,8:PRINT "
4960  LOCATE 13,9:INPUT "Enter the output filename to store depth and storage ":TANK$
4980  LOCATE 13,9:PRINT "Writing output to the file Please wait.. "
5000  OPEN TANK$ FOR OUTPUT AS #2
5020  PRINT #2, "MODEL FOR WATER COLLECTION AND NETSTORAGE IN THE TANK"
5040  PRINT #2 *****
5060  PRINT #2, "SHAPE OF THE TANK      =";TYPES$
5080  PRINT #2, "TOP DIAMETER OF THE TANK  =";TD;"METRES"
5100  PRINT #2, "BOTTOM DIAMETER OF THE TANK =";BD;"METRES"
5120  PRINT #2, USING "SIDE SLOPE OF THE TANK  = # : 1":SS
5140  PRINT #2, "TOTAL DEPTH OF THE TANK    =";H;"METRES"
5160  PRINT #2, "SPILLWAY HEIGHT OF THE TANK   =";SH;"METRES"
5180  PRINT #2, USING " CAPACITY OF THE TANK    = ####.## CUBIC
METRES";TOTCAP
5200  PRINT #2 *****
5220  RETURN
5240  LOCATE 13,14:INPUT "Enter the watershed area ( in ha )...   ":AW
5260  LOCATE 13,14:PRINT "
5280  LOCATE 13,14:INPUT "Please enter bottom length of tank (mts)  ":A
5300  LOCATE 13,14:PRINT "
5320  LOCATE 13,14:INPUT "Enter the bottom width of the tank (mts)  ":B
5340  LOCATE 13,14:PRINT "

```

```

5360 LOCATE 13,14:INPUT "Enter the side slope of the tank ";SS
5380 LOCATE 13,14:PRINT "
5400 LOCATE 13,14:INPUT "Now enter the total depth of tank (mts)";H
5420 LOCATE 13,14:PRINT "
5440 LOCATE 13,14:INPUT "Enter the spillway height from bottom(mts)";SH
5460 LOCATE 13,14:PRINT "
5480 LOCATE 13,14:INPUT "Enter the seepage rate (lits/sqm/day).. ";S
5500 LOCATE 13,14:PRINT "
5520 LOCATE 13,14:INPUT "Enter the Evaporation coefficient ";EV
5540 LOCATE 13,14:PRINT "
5560 ' LOCATE 13,14:INPUT "Enter the irrigation efficiency ";EFF
5580 ' LOCATE 13,14:PRINT "
5600 ' LOCATE 13,14:INPUT "Enter the area to be irrigated (in ha) ";IA
5620 FOR N = 1 TO K
5640 LOCATE 13,9:PRINT "CALCULATING NET STORAGE & DEPTH OF THE TANK FOR
THE DATE ";N
5660 RUNVOL(N) = P1(N)*AW*10
5680 CL = 0.65
5700 SURFRAIN(N) = (CL*RAIN(N)*2*SS*(H-D(N-1))*(A+B+2*SS*(H+D(N-1))))/1000
5720 RAINVOL(N) = (RAIN(N)*(A+2*SS*D(N-1))*(B+2*SS*D(N-1)))/1000
5722 IF RAIN(N) < 5.0 THEN
5724 RAINWT = RAINVOL(N)
5725 SURFRAIN(N) = 0.0
5726 GOTO 5760
5730 END IF
5740 RAINWT = RAINVOL(N) + SURFRAIN(N)
5760 TOTINF = RUNVOL(N) + RAINWT
5780 TV = (1/3)*D(N-1)*(((A*B)+(A+2*SS*D(N-1))*(B+2*SS*D(N-1)))+((A*B)*
(A+2*SS*D(N-1)) *(B+2*SS*D(N-1)))^(1/2)))
5800 TOTVOL = TOTINF + TV
5820 TOTCAP = (1/3)*SH*((A*B)+(A+2*SS*SH)*(B+2*SS*SH))+((A*B)*(A+2*SS*SH)*
(B+2*SS*SH))^(1/2))
5840 IF TOTVOL >= TOTCAP THEN
5842 OVERFL(N) = TOTVOL - TOTCAP
5845 TOTVOL = TOTCAP
5850 END IF
5860 REM CALCULATION OF DEPTH FOR THE DAY
5880 FOR TD = 0 TO SH STEP 0.001
5900 TEMPVOL = (1/3)*TD*(((A*B)+(A+2*SS*TD)*(B+2*SS*TD)
+((A*B)*(A+2*SS*TD)*(B+2*SS*TD))^(1/2)))
5920 IF (TOTVOL - TEMPVOL) <= 0.001 THEN
5922 TOD = TD
5925 GOTO 5960
5930 END IF
5940 NEXT TD
5960 WSA = ( A + 2 * SS * TOD ) * ( B + 2 * SS * TOD )
5980 SD = TOD*(1+(SS)^2)^(1/2)
6000 WA = ( A * B ) + ( 2 * SD * ( A + B + 2 * SS * TOD ) )
6020 REM CALCULATION OF SEEPAGE & EVAPORATION LOSSES (OUTFLOW LOSSES)
6040 TS(N) = ( S/1000 ) * WA
6060 EL(N) = ( EV * PAN(N) * WSA )/1000
6080 'IRRI(N) = (IRR(N)*IA*10)/EFF
6100 TOTOUT = TS(N) + EL(N)
6120 NETSTORE(N) = TOTVOL - TOTOUT
6140 IF NETSTORE(N) < 0.00 THEN

```

```

6142     NETSTORE(N) = 0.00
6144     ' STORAGE(N) = 0.0
6146     END IF
6150     IF NETSTORE(N) >= TOTCAP THEN
6152         NETSTORE(N) = TOTCAP
6154         ' STORAGE(N) = (NETSTORE(N))/10
6155     END IF
6160     FOR TD = 0 TO SH STEP 0.001
6180         TEMPVOL = (1/3)*TD*((A*B)+(A+2*SS*TD)*(B+2*SS*TD) + ((A*B)*
            (A+2*SS*TD)*(B+2*SS*TD))^(1/2)))
6200         IF (NETSTORE(N) - TEMPVOL) <= 0.001 THEN
6210             D(N) = TD
6212             GOTO 6240
6215         END IF
6220     NEXT TD
6240 NEXT N
6260 LOCATE 13,8:PRINT "
6280 LOCATE 13,9:INPUT " Enter the output filename to store depth & storage ";TANK$
6300 LOCATE 13,9:PRINT " Writing output to the the file. Please wait .."
6320 OPEN TANK$ FOR OUTPUT AS #2
6340     PRINT #2, "Model for Water collection and netstorage calculation in the Tank"
6360     PRINT #2  "*****"
6380     PRINT #2, "SHAPE OF THE TANK =";TYPE$
6400     Print #2, "Bottom length of the tank  =":A:"metres"
6420     PRINT #2, "Bottom width of the tank  =":B:"metres"
6440     PRINT #2,USING "Side slope of the tank    = # : 1":SS
6460     PRINT #2, "Total depth of the tank    =":H:"metres"
6480     PRINT #2, "Spillway height of the tank =":SH:"metres"
6500     PRINT #2,USING "Capacity of the tank    = ####.## Cubic meters";TOTCAP
6520     PRINT #2  "*****"
6540     RETURN
6550     RETURN
G

```

APPENDIX-D

Output obtained form the water-harvesting model for the year 2000(May-December)

| DATE | RAIN (mm) | PANEV (mm) | RO (mm) | EVAP (cum) | SEEP (cum) | RO (cum) | RVOL (cum) | SVOL (cum) | NETSTORE (cum) | OVERFLOW (cum) |
|------|--------------|---------------|------------|---------------|---------------|-------------|---------------|---------------|-------------------|-------------------|
| 105 | 0 | 13.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 205 | 0 | 14.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 305 | 2 | 13.3 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 |
| 405 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 505 | 0 | 12.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 605 | 120.2 | 12.5 | 15 | 1.8 | 2.9 | 226 | 35.5 | 0 | 250.1 | 6.2 |
| 705 | 0 | 3.4 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 246 | 0 |
| 805 | 0 | 7.4 | 0 | 1.4 | 3.4 | 0 | 0 | 0 | 241.2 | 0 |
| 905 | 0 | 4.8 | 0 | 0.9 | 3.4 | 0 | 0 | 0 | 237 | 0 |
| 1005 | 0 | 6.6 | 0 | 1.2 | 3.4 | 0 | 0 | 0 | 232.3 | 0 |
| 1105 | 0 | 8.3 | 0 | 1.5 | 3.4 | 0 | 0 | 0 | 227.5 | 0 |
| 1205 | 0 | 9.3 | 0 | 1.7 | 3.4 | 0 | 0 | 0 | 222.4 | 0 |
| 1305 | 0 | 10 | 0 | 1.8 | 3.4 | 0 | 0 | 0 | 217.2 | 0 |
| 1405 | 0 | 10.8 | 0 | 1.9 | 3.4 | 0 | 0 | 0 | 211.9 | 0 |
| 1505 | 0 | 10 | 0 | 1.8 | 3.4 | 0 | 0 | 0 | 206.8 | 0 |
| 1605 | 0 | 11.4 | 0 | 2 | 3.3 | 0 | 0 | 0 | 201.4 | 0 |
| 1705 | 0 | 9.9 | 0 | 1.8 | 3.3 | 0 | 0 | 0 | 196.3 | 0 |
| 1805 | 0 | 11.8 | 0 | 2.1 | 3.3 | 0 | 0 | 0 | 190.9 | 0 |
| 1905 | 0 | 11 | 0 | 1.9 | 3.3 | 0 | 0 | 0 | 185.7 | 0 |
| 2005 | 0 | 11.5 | 0 | 2 | 3.3 | 0 | 0 | 0 | 180.4 | 0 |
| 2105 | 0 | 11 | 0 | 1.9 | 3.3 | 0 | 0 | 0 | 175.2 | 0 |
| 2205 | 0 | 11.6 | 0 | 2 | 3.3 | 0 | 0 | 0 | 169.9 | 0 |
| 2305 | 0 | 8.8 | 0 | .5 | 3.3 | 0 | 0 | 0 | 165.1 | 0 |
| 2405 | 0 | 9.7 | 0 | .7 | 3.3 | 0 | 0 | 0 | 160.2 | 0 |
| 2505 | 0 | 10.8 | 0 | .8 | 3.2 | 0 | 0 | 0 | 155.1 | 0 |
| 2605 | 0 | 7.1 | 0 | .2 | 3.2 | 0 | 0 | 0 | 150.6 | 0 |
| 2705 | 0 | 6.6 | 0 | .1 | 3.2 | 0 | 0 | 0 | 146.3 | 0 |
| 2805 | 0 | 9 | 0 | .5 | 3.2 | 0 | 0 | 0 | 141.5 | 0 |
| 2905 | 0 | 10.9 | 0 | .8 | 3.2 | 0 | 0 | 0 | 136.5 | 0 |
| 3005 | 0 | 11.1 | 0 | .9 | 3.2 | 0 | 0 | 0 | 131.4 | 0 |
| 3105 | 18 | 10.9 | 0 | .8 | 3.2 | 0 | 5.3 | 0 | 131.7 | 0 |
| 106 | 0 | 8.4 | 0 | .4 | 3.2 | 0 | 0 | 0 | 127.2 | 0 |
| 206 | 0 | 7.5 | 0 | .2 | 3.2 | 0 | 0 | 0 | 122.7 | 0 |
| 306 | 22.1 | 6.8 | 0 | .1 | 3.2 | 0 | 6.5 | 0 | 125 | 0 |
| 406 | 0 | 7 | 0 | 1.2 | 3.2 | 0 | 0 | 0 | 120.6 | 0 |
| 506 | 1 | 6.1 | 0 | 1 | 3.2 | 0 | 0.3 | 0 | 116.7 | 0 |
| 606 | 27.3 | 3.9 | 0.2 | 0.6 | 3.2 | 3.3 | 8.1 | 0 | 124.3 | 0 |
| 706 | 27.3 | 2.6 | 5.5 | 0.4 | 3.2 | 82.9 | 8.1 | 0 | 211.6 | 0 |
| 806 | 0 | 5.7 | 0 | 1 | 3.4 | 0 | 0 | 0 | 207.3 | 0 |
| 906 | 0 | 4 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 203.2 | 0 |
| 1006 | 0 | 6 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 198.8 | 0 |
| 1106 | 0 | 6.6 | 0 | 1.2 | 3.3 | 0 | 0 | 0 | 194.3 | 0 |
| 1206 | 37.1 | 6.3 | 0 | 1.1 | 3.3 | 0 | 11 | 0 | 200.9 | 0 |
| 1306 | 0 | 2 | 0 | 0.4 | 3.3 | 0 | 0 | 0 | 197.2 | 0 |
| 1406 | 0 | 7.5 | 0 | 1.3 | 3.3 | 0 | 0 | 0 | 192.5 | 0 |

| | | | | | | | | | | |
|-------------|------|------------|------|-----|-----|-----|------|---|--------------|-------|
| 1506 | 0 | 9 | 0 | 1.6 | 3.3 | 0 | 0 | 0 | 187.7 | 0 |
| 1606 | 0 | 7.4 | 0 | 1.3 | 3.3 | 0 | 0 | 0 | 183.1 | 0 |
| 1706 | 0 | 6.1 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 178.7 | 0 |
| 1806 | 0 | 6.3 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 174.3 | 0 |
| 1906 | 0 | 4.1 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 170.3 | 0 |
| 2006 | 0 | 4.1 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 166.4 | 0 |
| 2106 | 7.1 | 2.3 | 0 | 0.4 | 3.3 | 0 | 2.1 | 0 | 164.8 | 0 |
| 2206 | 0 | 6.4 | 0 | .1 | 3.3 | 0 | 0 | 0 | 160.4 | 0 |
| 2306 | 28.4 | 6.3 | 0 | .1 | 3.2 | 0 | 8.4 | 0 | 164.5 | 0 |
| 2406 | 0 | 4.4 | 0 | 0.8 | 3.3 | 0 | 0 | 0 | 160.5 | 0 |
| 2506 | 0 | 7.8 | 0 | .3 | 3.2 | 0 | 0 | 0 | 155.9 | 0 |
| 2606 | 0 | 8.8 | 0 | .5 | 3.2 | 0 | 0 | 0 | 151.2 | 0 |
| 2706 | 0 | 6.9 | 0 | .2 | 3.2 | 0 | 0 | 0 | 146.8 | 0 |
| 2806 | 0 | 7 | 0 | 1.2 | 3.2 | 0 | 0 | 0 | 142.4 | 0 |
| 2906 | 16.3 | 2.4 | 0 | 0.4 | 3.2 | 0 | 4.8 | 0 | 143.6 | 0 |
| 3006 | 96.8 | 2 | 50.7 | 0.3 | 3.2 | 761 | 28.6 | 0 | 251.3 | 678.2 |
| 107 | 0 | 2.6 | 0 | 0.5 | 3.4 | 0 | 0 | 0 | 247.4 | 0 |
| 207 | 0 | 5.2 | 0 | 1 | 3.4 | 0 | 0 | 0 | 243 | 0 |
| 307 | 0 | 4.6 | 0 | 0.8 | 3.4 | 0 | 0 | 0 | 238.7 | 0 |
| 407 | 2.1 | 3.2 | 0 | 0.6 | 3.4 | 0 | 0.6 | 0 | 235.4 | 0 |
| 507 | 0 | 3.9 | 0 | 0.7 | 3.4 | 0 | 0 | 0 | 231.3 | 0 |
| 607 | 0 | 3.2 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 227.3 | 0 |
| 707 | 4.3 | 3.3 | 0 | 0.6 | 3.4 | 0 | 1.3 | 0 | 224.6 | 0 |
| 807 | 21.5 | 2.5 | 0 | 0.5 | 3.4 | 0 | 6.4 | 0 | 227.1 | 0 |
| 907 | 9.4 | 3.1 | 0 | 0.6 | 3.4 | 0 | 2.8 | 0 | 226 | 0 |
| 1007 | 0 | 4.8 | 0 | 0.9 | 3.4 | 0 | 0 | 0 | 221.7 | 0 |
| 1107 | 0 | 3.5 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 217.7 | 0 |
| 1207 | 20.3 | 1.6 | 0.1 | 0.3 | 3.4 | 1.2 | 6 | 0 | 221.3 | 0 |
| 1307 | 0 | 1.1 | 0 | 0.2 | 3.4 | 0 | 0 | 0 | 217.7 | 0 |
| 1407 | 0 | 3.2 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 213.8 | 0 |
| 1507 | 0 | 5.1 | 0 | 0.9 | 3.4 | 0 | 0 | 0 | 209.5 | 0 |
| 1607 | 0 | 5.4 | 0 | 1 | 3.3 | 0 | 0 | 0 | 205.2 | 0 |
| 1707 | 0 | 6 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 200.8 | 0 |
| 1807 | 0 | 3.4 | 0 | 0.6 | 3.3 | 0 | 0 | 0 | 196.9 | 0 |
| 1907 | 0 | 1.3 | 0 | 0.2 | 3.3 | 0 | 0 | 0 | 193.3 | 0 |
| 2007 | 0 | 3 | 0 | 0.5 | 3.3 | 0 | 0 | 0 | 189.5 | 0 |
| 2107 | 0 | 6 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 185.1 | 0 |
| 2207 | 0 | 6 | 0 | 1 | 3.3 | 0 | 0 | 0 | 180.8 | 0 |
| 2307 | 0 | 5.4 | 0 | 0.9 | 3.3 | 0 | 0 | 0 | 176.6 | 0 |
| 2407 | 0 | 6.3 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 172.2 | 0 |
| 2507 | 0 | 5.2 | 0 | 0.9 | 3.3 | 0 | 0 | 0 | 168 | 0 |
| 2607 | 0 | 4 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 164.1 | 0 |
| 2707 | 0 | 3 | 0 | 0.5 | 3.3 | 0 | 0 | 0 | 160.3 | 0 |
| 2807 | 0 | 4.5 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 156.3 | 0 |
| 2907 | 0 | 5 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 152.2 | 0 |
| 3007 | 0 | 4.6 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 148.2 | 0 |
| 3107 | 0 | 4 | 0 | 0.7 | 3.2 | 0 | 0 | 0 | 144.3 | 0 |
| 108 | 0 | 5.4 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 140.1 | 0 |
| 208 | 0 | 5.7 | 0 | 1 | 3.2 | 0 | 0 | 0 | 136 | 0 |
| 308 | 0 | 5.5 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 131.8 | 0 |
| 408 | 0 | 6.4 | 0 | 1.1 | 3.2 | 0 | 0 | 0 | 127.6 | 0 |
| 508 | 0 | 4.6 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 123.6 | 0 |
| 608 | 0 | 5 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 119.6 | 0 |

| | | | | | | | | | | |
|------|-------|-----|-------|-----|-----|------|------|---|-------|--------|
| 708 | 0 | 5.5 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 115.6 | 0 |
| 808 | 0 | 2.6 | 0 | 0.4 | 3.2 | 0 | 0 | 0 | 112 | 0 |
| 908 | 12.7 | 2.1 | 0 | 0.3 | 3.2 | 0 | 3.8 | 0 | 112.2 | 0 |
| 1008 | 54.2 | 2.7 | 1.7 | 0.4 | 3.2 | 25.8 | 16 | 0 | 150.4 | 0 |
| 1108 | 13 | 0.5 | 0 | 0.1 | 3.2 | 0 | 3.8 | 0 | 151 | 0 |
| 1208 | 0 | 2.6 | 0 | 0.4 | 3.2 | 0 | 0 | 0 | 147.3 | 0 |
| 1308 | 0 | 3.8 | 0 | 0.6 | 3.2 | 0 | 0 | 0 | 143.4 | 0 |
| 1408 | 0 | 4.3 | 0 | 0.7 | 3.2 | 0 | 0 | 0 | 139.5 | 0 |
| 1508 | 0 | 2.3 | 0 | 0.4 | 3.2 | 0 | 0 | 0 | 135.9 | 0 |
| 1608 | 0 | 4 | 0 | 0.7 | 3.2 | 0 | 0 | 0 | 132 | 0 |
| 1708 | 0 | 5 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 128 | 0 |
| 1808 | 0 | 5.6 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 123.9 | 0 |
| 1908 | 13.6 | 3.4 | 0 | 0.6 | 3.2 | 0 | 4 | 0 | 124.2 | 0 |
| 2008 | 0 | 1.5 | 0 | 0.2 | 3.2 | 0 | 0 | 0 | 120.7 | 0 |
| 2108 | 6 | 2.8 | 0 | 0.5 | 3.2 | 0 | 1.8 | 0 | 118.9 | 0 |
| 2208 | 7.5 | 1.7 | 0 | 0.3 | 3.2 | 0 | 2.2 | 0 | 117.7 | 0 |
| 2308 | 200 | 1 | 109.3 | 0.2 | 3.2 | 1639 | 59.1 | 0 | 251.5 | 1560.8 |
| 2408 | 195.3 | 0.8 | 162.2 | 0.1 | 3.4 | 2433 | 57.8 | 0 | 251.3 | 2487.4 |
| 2508 | 0 | 2 | 0 | 0.4 | 3.4 | 0 | 0 | 0 | 247.5 | 0 |
| 2608 | 0 | 2.9 | 0 | 0.5 | 3.4 | 0 | 0 | 0 | 243.5 | 0 |
| 2708 | 11.5 | 2 | 0 | 0.4 | 3.4 | 0 | 3.4 | 0 | 243.1 | 0 |
| 2808 | 0 | 2.9 | 0 | 0.5 | 3.4 | 0 | 0 | 0 | 239.2 | 0 |
| 2908 | 4.4 | 2.3 | 0 | 0.4 | 3.4 | 0 | 1.3 | 0 | 236.7 | 0 |
| 3008 | 0 | 2.7 | 0 | 0.5 | 3.4 | 0 | 0 | 0 | 232.8 | 0 |
| 3108 | 0 | 2.7 | 0 | 0.5 | 3.4 | 0 | 0 | 0 | 228.9 | 0 |
| 109 | 0 | 2.8 | 0 | 0.5 | 3.4 | 0 | 0 | 0 | 225 | 0 |
| 209 | 0 | 3.5 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 221 | 0 |
| 309 | 0 | 3.4 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 217 | 0 |
| 409 | 0 | 3.6 | 0 | 0.6 | 3.4 | 0 | 0 | 0 | 213 | 0 |
| 509 | 0 | 3.7 | 0 | 0.7 | 3.4 | 0 | 0 | 0 | 209 | 0 |
| 609 | 0 | 4 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 204.9 | 0 |
| 709 | 0 | 3.9 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 200.9 | 0 |
| 809 | 0 | 4 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 196.9 | 0 |
| 909 | 0 | 4.2 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 192.8 | 0 |
| 1009 | 0 | 4.2 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 188.8 | 0 |
| 1109 | 0 | 5 | 0 | 0.9 | 3.3 | 0 | 0 | 0 | 184.6 | 0 |
| 1209 | 0 | 4.7 | 0 | 0.8 | 3.3 | 0 | 0 | 0 | 180.5 | 0 |
| 1309 | 0 | 4.9 | 0 | 0.9 | 3.3 | 0 | 0 | 0 | 176.3 | 0 |
| 1409 | 0 | 6.5 | 0 | 1.1 | 3.3 | 0 | 0 | 0 | 171.9 | 0 |
| 1509 | 0 | 5 | 0 | 0.9 | 3.3 | 0 | 0 | 0 | 167.8 | 0 |
| 1609 | 0 | 5.3 | 0 | 0.9 | 3.3 | 0 | 0 | 0 | 163.6 | 0 |
| 1709 | 0 | 5.8 | 0 | 1 | 3.3 | 0 | 0 | 0 | 159.3 | 0 |
| 1809 | 0 | 3.8 | 0 | 0.7 | 3.2 | 0 | 0 | 0 | 155.5 | 0 |
| 1909 | 50.4 | 1.6 | 0 | 0.3 | 3.2 | 0 | 14.9 | 0 | 166.8 | 0 |
| 2009 | 0 | 3.4 | 0 | 0.6 | 3.3 | 0 | 0 | 0 | 163 | 0 |
| 2109 | 0 | 4 | 0 | 0.7 | 3.3 | 0 | 0 | 0 | 159.1 | 0 |
| 2209 | 0.6 | 4 | 0 | 0.7 | 3.2 | 0 | 0.2 | 0 | 155.3 | 0 |
| 2309 | 0 | 5.3 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 151.2 | 0 |
| 2409 | 0 | 4.9 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 147.1 | 0 |
| 2509 | 0 | 5.1 | 0 | 0.9 | 3.2 | 0 | 0 | 0 | 143 | 0 |
| 2609 | 43.6 | 4 | 0 | 0.7 | 3.2 | 0 | 12.9 | 0 | 152 | 0 |
| 2709 | 0 | 4.8 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 148 | 0 |
| 2809 | 0 | 4.7 | 0 | 0.8 | 3.2 | 0 | 0 | 0 | 143.9 | 0 |

| | | | | | | | | | | |
|-------------|---|-------|-------|-------|------|-------|---|---|---|--------|
| 2111 | 0 | 4.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2211 | 0 | 4.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2311 | 0 | 4.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2411 | 0 | 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2511 | 0 | 4.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2611 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2711 | 0 | 4.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2811 | 0 | 5.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2911 | 0 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3011 | 0 | 5.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 112 | 0 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 212 | 0 | 3.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 312 | 0 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 412 | 0 | 5.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 512 | 0 | 5.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 612 | 0 | 5.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 712 | 0 | 4.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 812 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 912 | 0 | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1012 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1112 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1212 | 0 | 5.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1312 | 0 | 4.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1412 | 0 | 5.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1512 | 0 | 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1612 | 0 | 5.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1712 | 0 | 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1812 | 0 | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1912 | 0 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 0 | 5.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2112 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2212 | 0 | 5.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2312 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2412 | 0 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2512 | 0 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2612 | 0 | 4.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2712 | 0 | 5.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2812 | 0 | 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2912 | 0 | 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3012 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3112 | 0 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1137 | | 344.7 | 162.4 | 608.1 | 5171 | 336.3 | 0 | | | 4732.6 |