INTEGRATING RAINWATER HARVESTING IN URBAN PLANNING AND DEVELOPMENT CASE STUDY : DEHRADUN

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree
of
MASTER OF URBAN AND RURAL PLANNING

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CANDIDATE'S DECLARATION

I hereby declare that the work that is being presented in the dissertation entitled **"Integrating Rainwater Harvesting In Urban Planning And Development, Case Study: Dehradun"**, in partial fulfillment of the requirements for the award of degree of **Master Of Urban And Rural Planning** submitted in the **Department of Architecture And Planning, University of Roorkee, Roorkee**, is an authentic record of my own work carried out in the past six months from July 2000 to February 2001 under the guidance of **Prof. R. Shankar**, Professor, Department of Architecture and Planning, University of Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Date :27-02-2001

(Ashutosh Kumar Sahu)

Place : Roorkee

This is to certify that the above statement made by candidate is correct to the best of my knowledge.

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CHAPTER-I

OUR WATER RESOURCES AND NEEDS

1.1 INTRODUCTION

Water is basic to the human health, welfare and economic development. It is equally vital for the preservation of wild life and natural environment. Fresh water is a central feature and can be a source of energy, avenue of transportation, means of production and aesthetics. It exerts a major influence on demographic patterns. Water is a finite and limited resource, and thus its efficient and effective use of water resources is necessary for sustainable economic and social development. (Ritu Batra, 1990)

India is one of the few countries in the world endowed with abundant land and water resources. It is the seventh largest country in the world and Asia's second largest country, with an area of 3,287,590 Km^2. Most of the Indian landmass is in the semiarid tropical belt characterized by seasonal rainfall lasting over a period of three to four months. Total population of India was 846 million in 1991(census 1991). It is expected to be one billion in may 2000. The water resources of India are enormous but they are unevenly distributed in space, time and quantity. Due to lack of proper water resources planning and budgeting, famine in the vast tracts of the western and southern peninsula plateau region and floods in northern and eastern India ravage the lives of millions of human and animal population. Famine, especially scarcity of drinking water, is causing havoc in Rajasthan, Gujrat, Maharashtra, Andhra Pradesh, Karnatka, and Tamil Nadu. (A. G. Bobba, V. P. Singh, Lars Bengston, 1997)

1.2 WATER RESOURCES IN INDIA

Average annual precipitation including snowfall over the country is 4000 billion cum.(BCM).in addition, it receives another 200 BCM from river flowing in from other countries. Average annual water resources in various river basins are estimated to be 1869 BCM of which the utilizable volume of water that has been estimated to be 1086 BCM including 690 BCM surface water and 396 BCM of ground water. Rest of water is lost by evaporation by flow into the sea. The utilization of water is expected to be 784 to 843 BCM by the year 2025. "Though the present utilasation level is only about 50% of the total available water resources, the availability of water is highly irregular. It is not available in places of need, at time of need and in required quantities". (D.K. Chadha, C.G.W.B 2000.)

In the major part of the country, rainfall is the only source of water, which is available mainly during monsoon season lasting for less than three months. Due to tropical climate and its geography, the country experiences vast spatial and temporal variations in precipitation. About one third of the county's area is drought prone (D.K Chadha, 2000). The south and western parts comprising the state of Rajasthan, Gujrat, Andhra Pradesh, Madhya Pradesh, Tamilnadu and Karnatka are the drought prone states. On the other hand, north and northeastern region including states of U.P., Bihar, West Bengal and Assam are subjected to periodic flooding. The recent drought that the country has faced has not only created water scarcity but also led to migration of people and cattle from water scarcity areas to adjoining areas causing hardships to them. This has also brought social and economic problem in the areas where they migrate. In such areas women have fetch water from wells, ponds, lakes etc. from long distances which consumes lot of time, energy and affect the women folk. Therefore, concentrated and dedicated efforts are needed not only to harness the rainwater but also to conserve it so that it can be used in the time of needs.

The demand is the maximum during summers when the available water resources dwindle. In the time of crisis, ground water is the most dependable source. The problem is more severe in urban areas where natural recharge is reduced due to reduction in preamble area, consequent to increase in urbanisation. (D. K. Chadha, 2000)

1.2.1 SURFACE WATER RESOURCES

India is endowed with a network of 2.89 million Km^2 of river basin systems and an average annual discharge of 1900 billion m^3 of water (C.W.C. 1996). Indian river basin systems can be classified into four categories:

1. Major rivers, with catchment area of more than 20,000 Km^2 ,
2. Medium rivers, with catchment area of 2000 to 20,000 Km^2,
3. Minor rivers, with catchment area of less than 2000 Km^2,
4. Desert rivers, with flow for some distance, which disappear into desert of Rajasthan

The following figure shows the major river basins in India.

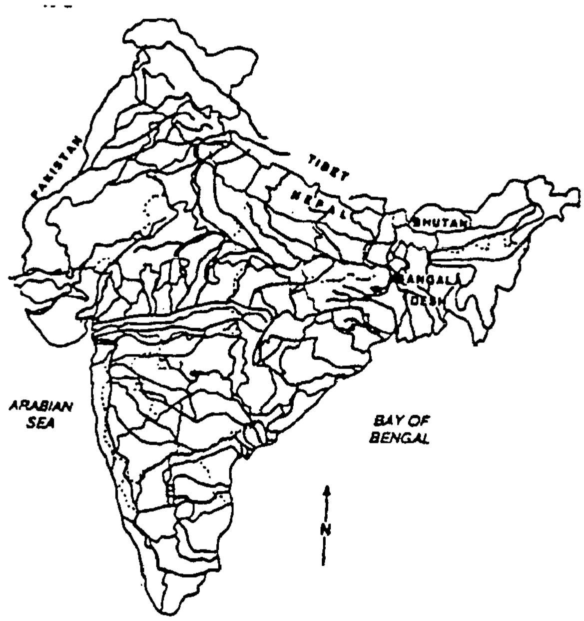


Fig.1 Major river systems in India
Source: Environmental Management, 1997

TABLE # 1 WATER RESOURCES POTENTIAL OF RIVER BASINS OF INDIA

S.NO.	River Basin	Average Annual WR potential Cu.Km.	Availability Per capita Cu.M.	Utilisable Surface Water Cu.Km.	Ground Water Potential Cu. Km.
1	Indus	73.3	1757	46	25.5
2	Ganga-Brahmaputra-Meghna	1110.6	2833	274	201.4
	a) Ganga	525	1473	250	171.7
	b) Brahmaputra	537.2	18417	24	27.9
	c) Barak	48.4	7646		1.8
3	Godavari	110.5	2026	76.3	46.8
4	Krishna	78.1	1312	58	26.6
5	Subernarekha	12.4	1392	6.8	2.2
6	Cauvery	21.4	666	19	13.6
7	Brahmani-Bautarani	28.5	2696	18.3	5.9
8	Mahanadi	66.9	2546	50	21.3
9	Pennar	6.3	648	6.9	5
10	Mahi	11	1057	3.1	7.9
11	Sabarmati	3.8	421	1.9	
12	Narmada	45.6	2855	34.5	11.9
13	Tapi	14.9	10.91	14.5	8.2
14	West flowing rivers	87.4	3194	11.9	9.5
	from Tapi to Tadri				
15	West flowing rivers	113.5	3539	24.3	8.8
	from Tadri to Kanyakumari				
16	East flowing rivers	22.5	919	13.1	22.8
	between Mahanadi & Pennar				
17	East flowing rivers	16.5	383	16.7	20.9
	between Pennar & Kanyakumari				
18	West flowing rivers of Kutch	15.1	631	15	13.9
	&Saurashtra including Luni				
19	Area of inland drainage in	0			
	Rajasthan desert				
20	Minor rivers draining into	31	14616		
	Burma & Bangladesh				
	Total	1869.3	2214	690.3	452.2

Source :- Journal of indian water works association, Oct- Dec, 1998.

The chief characteristic feature of Indian hydrology is the concentration of rain in major parts of the country in some months during the monsoon season. During non-rainy months the river flows dwindle and many of them dry up. There are 14 major rivers in India, covering 2.35 million cum. of basin area with an annual discharge of 1406 BCM.

The total volume of water discharged in a year by all the river systems in India is 1869 Billion m^3 Of this the major river systems contribute 85% while the medium and minor, including desert rivers contribute 7% and 8% respectively (see table-1). More water is carried in the minor rivers than the medium rivers. Table-1 gives the water resources potentials of India. We can see that the Ganga- Brhamaputra basin covers largest potential in river water resources. It is giving basinwise availability of surface water in India along with the per capita availability in the year 1996. It indicates that six of our river basins are under water stress and 14 basins have less than average (for the country) per capita availability of water.

The key information of present status of surface water in India is given below. It shows that per capita availability of surface water is decreasing very rapidly. Hence it shall not be possible to fulfill the demand even if we fully utilize the surface water. Therefore it shall be imperative to use rainwater in future. If we can harvest 20 % of total rainwater available in India it will be enough to fulfill the national demand of water.

Status of Indian Surface Water : Key Information

1- Area of India = 3,287,263 square kilometer

2- Population of India = 846,302,688

(As per 1991 census)

3- Average annual rainfall in India = 1100 mm.

4- annual average precipitation

Including snowfall aver the country = 4000 BCM

5- out of it annual loss as surface runoff = 1150 BCM

6- Rivers flowing in from other countries = 200 BCM

7- Average annual water resource in various river basins = 1869 BCM

8- Utilizable volume of water of (7) = 1186BCM

a) surface water = 690 BCM

b) ground water = 396 BCM

9- loss due to evaporation and flow in sea = 783 BCM

10- Per capita availability of surface water in India. (in year "1991") = 815 cum./year

11- Per capita availability of surface water in India

(In year "2000" as projected by UN) = 675 cum./year

12- Per capita availability of surface water in India

(In year "2010" as projected by UN) = 580 cum./year

13-At present (1997) India's per capita water availability = 1947 cum.

14- Out of 100 countries India's position in per capita water Availability is – 42^{nd}

15- Average per capita availability of water In world in 1991 = 9231 cum.

16- Per capita demand of water in India in 1991 = 649 cum./year

The table-2 shows the demand of water in India for various sectors along with the increase in population. The increasing standard of living and higher aspirations of the common man for getting better quality food, shelter, clothing etc. are also responsible for increasing the per capita demand for water, thereby increasing the total demand on the water resources in all the countries.

According to U.N report, water consumption in the world has risen 6 folds between the year 1900 and 1995.

TABLE # 2 INDIA'S WATER DEMAND IN DIFFERENT SECTORS (BCM)					
S.NO	USE	1990 AD.	2000 AD (Proj.)	2025 AD (Proj.)	2050 AD (Proj.)
1	Irrigation	460	630	770	800
2	Drinking & Domestic	25	33	52	60
3	Industry	15	30	120	130
4	Energy	19	27	71	120
5	Others	33	30	37	40
6	**Total**	**552**	**750**	**1050**	**1150**
7	Total population (in million)	851	1022	1508	1640
8	% of urban population	26.7	30.9	40	50.0
9	Urban population (in million)	227.2	315.8	603	820
10	Per capita demand in India (cum/per) {(6)/(9)}*1000	649	734	696	701

Source: Proceedings of national seminar on water resource management in 21st century, Roorkee, India,1996

1.2.2 GROUND WATER RESOURCES

Ground water as a source of water supply has been utilised in India from time immemorial, mainly for domestic needs and also partly for irrigation. The pattern of its utilisation changed in recent times, nearly 90 % being used for irrigation purposes so much so that groundwater potential is exposed more so often in terms of irrigation potential. The progressive increase of ground water potential can be seen from the table. From time to time, estimates of groundwater potential of India have been made by various agencies. Here the estimates of ground water potentials statewise made by Central Ground Water Board in 1995 is given in table no-4.

The total replenishable ground water in India is 431.88 BCM. Out of this 322 BCM is recoverable through recharge. The total net draft of ground water for irrigation was 115.16 BCM and for domestic and other uses the provision was for 70.93 BCM. in the year 1993. Hence we have the balance of 245.78 BCM for future use.

The key information about status of groundwater in India has been given below. It should be remembered that it is not an unlimited source, it also needs to be recharged. Over exploitation of groundwater, and increasing population both has put tremendous pressure on it made it necessary to recharge through better water management practices and recharge of it through rainwater harvesting and other measures.

Status of Ground Water in India : Key Information

1- Total replenishable ground water in India = 431.884 BCM

2- Per capita availability of ground water in 1991 in India = 510cum. /year

3- Per capita availability of ground water in India = 422cum./ year

(Population projected by UN for year "2000")

4- Per capita availability of ground water in India =363 cum. /year

(Population projected by UN for year "2010")

5- Water supply to rural areas from GW = 90% (approx.)

6- Water supply for urban areas from GW = 50% (approx.)

7- Water supply for agricultural uses from GW = 50% (approx.)

8- Fall of more than 4m. observed in 138 districts of 14 states.

Per capita availability of replenishible water for different year is given in the table-3

TABLE # 3 PER CAPITA WATER AVAILABILITY IN INDIA	
YEAR	WATER AVAILABILITY (IN CU.M)
1947	6000
1955	5277
1997	1970
1999	1947
2017 (PROJ.)	1600
2025 (PROJ.)	1350

Source : journal of water works association

It is evident from the table-3 that per capita water availability is decreasing rapidly due to the increase in population and decrease in groundwater. Groundwater level has gone 4 meters below in many states. Rural water supply is mainly dependent on groundwater sources, this dependency on the groundwater should be reduced and various rainwater harvesting practices should be adopted both for recharge of groundwater and for domestic & other uses.

1.2.3 RAINWATER

There is only one source of fresh water and that is the precipitation, whether it is in the form of snow that makes glaciers or water, which ultimately flows down as streams and rivers and recharges the ground water. Fresh water or that portion of the world's water resources suitable for use by humans is a small portion of the global water supply. For domestic and agricultural ruses, fresh water generally refers to water containing less than 2 mg/l of dissolved solids. The presence of other contaminants such as toxic substances, disease causing organisms, nutrients and oxygen consuming substances and suspended solids also decrease the quality of fresh water for human and environmental uses. Increase in water demand has triggered off over exploitation of water resources, resulting in stress on both, surface and ground water sources. And yet, the rainwater and the floodwater go completely waste, even though the same is available in a large quantity. The absolute shortage of fresh water is further compounded by the fact that rainfall is unevenly distributed geographically and seasonally. Thus, the need for augmentation technologies remains.

An average annual rainfall of 110 cm, for the country's 328 million hectares area is the highest in the world for a comparable geographical area. A perusal of the past 100 years of meteorological data does not show any marked variation. Of course, all rainfall does not become a water resource. After immediate evaporation and transpiration by vegetation, water percolates into the soil and flows as surface water that constitutes the basic water resources. The cycle of water begins with rainfall and ends in evaporation and involves flows going back to the sea. The key to harnessing and harvesting the maximum quantum of water available from rain is to delay the flow of water towards the sea or into the atmosphere. Thus catching the water when it is on land and controlling it by organizational skill is the crux of water planning.

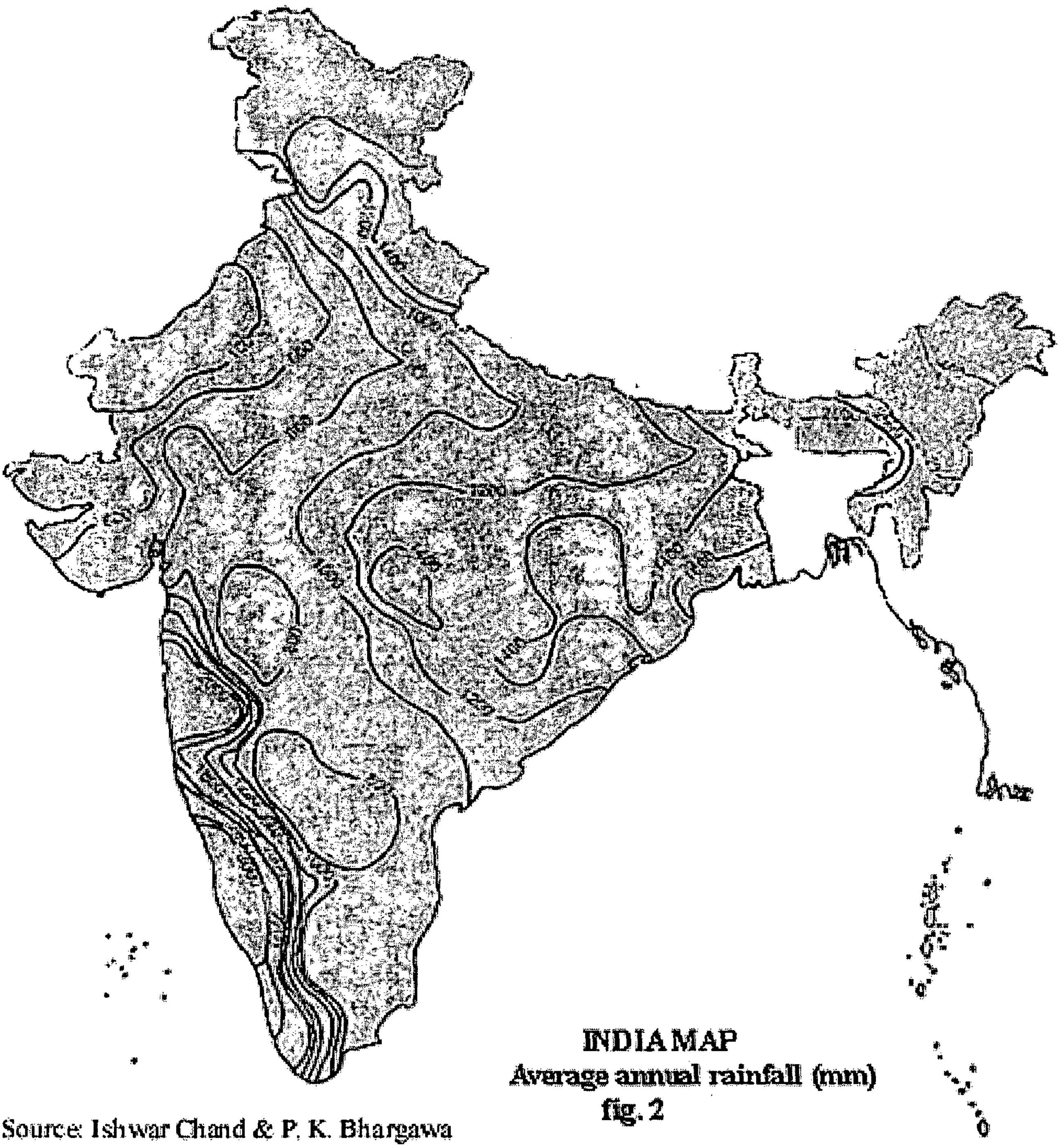
- Total rain water available in India = 3616 BCM
- Per capita availability of rain water in India = 4273Cu.M/year
  (As per 1991 census population)
- Water requirement of the country in year 2000 = 750 BCM.
- Percent of total rainwater needed to harvest to meet the current demand = 20.7%

TABLE # 4 Rain Water Distribution and GW water Potential of India, Statewise

S.No.	state	area in sq. km.	population 1991	avg.annual rainfall in mm	total rainwater in MCM	per capita availability of rainwater in Cu.M. per year	total replenishable GW resources in MCM/yr	provision for domestic industrial/other uses MCM/yr	net draft 1993 MCM/yr	balance for future use MCM/yr	per capita availability of (in Cu.M.	S.No.
1	Andhra Pradesh	275068	66508008	1114.27	306500.0204	4.608467906	35291.64	5293.75	7092.26	22905.63	530.6374535	1
2	Assam	78438	22414322	2380.18	186696.5588	8.329342232	24719.2	3707.89	7092.26	22905.63	1102.830592	2
3	Bihar	173877	86374465	1195.19	207816.0516	2.405989451	33521.66	5028.25	7092.26	22905.63	388.0968756	3
4	Gujrat	196024	41309582	637.18	124902.5723	3.02357386	20376.47	3056.47	7092.26	22905.63	493.2625559	4
5	Haryana	44212	16463648	792.89	35055.25268	2.129251833	8527.51	1279.13	7092.26	22905.63	517.9599321	5
6	Himachal Pradesh	55673	5170877	1637.68	91174.55864	17.63232013	365.81	73.16	7092.26	22905.63	70.74428574	6
7	J&K	222236	7718700	1316.73	292624.8083	37.91115191	4425.84	663.88	7092.26	22905.63	573.3918924	7
8	Karnataka	191791	44977201	1794.09	344090.3152	7.650327445	16185.88	2427.88	7092.26	22905.63	359.8685476	8
9	Kerla	38863	29098518	2582.06	100346.5978	3.448512319	7900.28	1313.48	7092.26	22905.63	271.5011122	9
10	Madhya Pradesh	443446	66181170	1123.71	498304.7047	7.529403071	50889.26	7633.31	7092.26	22905.63	768.9386573	10
11	Maharashtra	307690	78937187	817.78	251622.7282	3.187632316	37867.32	123.91	7092.26	22905.63	479.7145862	11
12	Manipur	22327	1837149	2129.14	47537.30878	25.875587	3154	4.73	7092.26	22905.63	1716.790527	12
13	Meghalaya	22429	1774778	2380.18	53385.05722	30.07985067	539.66	80.95	7092.26	22905.63	304.0718332	13
14	Nagaland	16579	1209546	2129.14	35299.01206	29.18368715	724	109	7092.26	22905.63	598.5716955	14
15	Orissa	155707	31659736	1553.11	241830.0988	7.638411728	20001.33	3000.2	7092.26	22905.63	631.7592162	15
16	Panjab	50362	20281969	871.37	43883.93594	2.163692092	18654.9	1865.5	7092.26	22905.63	919.777562	16
17	Rajasthan	342239	44005990	522.89	178953.3507	4.066567999	12707.6	1994.54	7092.26	22905.63	288.7697788	17
18	Sikkim	7096	406457	2786.76	19774.84896	48.65176134	0	0	7092.26	22905.63	0	18
19	Tamilnadu	130058	55858946	980.64	127540.0771	2.283252482	26391.24	3958.69	7092.26	22905.63	472.4621907	19
20	Tripura	10486	2757205	2129.14	22326.16204	8.097389218	663.41	99.51	7092.26	22905.63	240.6096028	20
21	Uttar Pradesh	294411	139112287	1123.65	330814.9202	2.378042424	83820.85	12573.13	7092.26	22905.63	602.5409531	21
22	West Bengal	88752	68077965	2307.63	204806.7778	3.008415098	23092.32	3463.85	7092.26	22905.63	339.2040288	22
23	Arunachal Pradesh	83743	864558	4323.48	362061.1856	418.7818349	1438.5	215.78	7092.26	22905.63	1663.855982	23
24	Mizoram	21081	689756	2129.14	44884.40034	65.07286684	0	0	7092.26	22905.63	0	24
25	Goa,Daman&Diu	3814	1271379	2676.55	10208.3617	8.029361583	231.24	34.74	7092.26	22905.63	181.8812486	25
	union territories											
26	A&N Island	8249	280661	2598.28	21433.21172	76.36690427	0	0	7092.26	22905.63	0	26
27	Chandigarh	114	642015	792.89	90.38946	0.140790262	29.66	0	7092.26	22905.63	46.19829755	27
28	D&N Haveli	491	138477	773.99	380.02909	2.744348087	42.2	6.33	7092.26	22905.63	304.7437481	28
29	Delhi	1483	9420644	792.89	1175.85587	0.124816931	291.64	178.42	7092.26	22905.63	30.95754388	29
30	Lakshdweep	32	51707	1469.7	47.0304	0.909555766	2.43	0	7092.26	22905.63	46.9955712	30
31	Pondichery	492	807785	980.64	482.47488	0.597281306	28.77	2085.475978	7092.26	22905.63	35.61591265	31
	total	**3287263**	**846302688**	**1100**	**3615989.3**	**4.272690317**	**431884.62**	**60271.95598**	**219860.1**	**710074.53**	**510.3193292**	

Source:- Compendium of environment statistics, 1997

Table-4 gives statewise groundwater potentials and Rainwater distribution in India. It shows the per capita availability of water from both the sources. Per capita availability of rainwater is higher than the per capita need and it is about 9 times greater than total replenishible groundwater. Variability in rainfall is also observable. But even then it is sufficient in



INDIA MAP
Average annual rainfall (mm)
fig. 2

Source: Ishwar Chand & P. K. Bhargawa

quantity in every state to meet the needs of the people of the area. It is very interesting to see that per capita availability of rainwater is high in those areas where per capita availability of ground water is very low. In the figure-2 the average annual rainfall pattern of India is given. It shows the marked variation in rains in India from west to east, from north to south and from plains to coastal areas.

Climatic conditions govern to a great extent the operation of water resources in the country. The Himalayan rivers of India are ice-fed rivers and thus very vulnerable to climate change. Rainfall is governed by the southwest and northeast monsoons. The distribution of rainfall shows great temporal and spatial variations. About 80% of the total rainfall occurs during June to September, and is not spread uniformly over the country, creating pockets of scarcity in some regions. Thus, large water storage facilities are required to meet the demand during the lean periods.

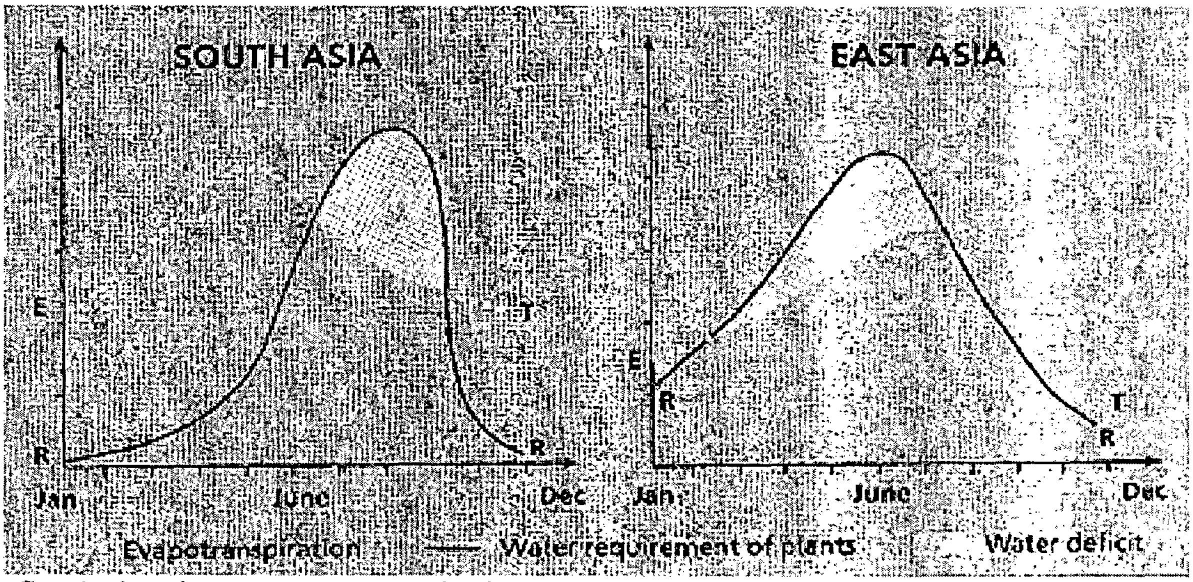
TABLE # 5 POTENTIAL OF WATER HARVESTING TO MEET INDIA'S DRINKING WATER NEEDS

Assumptions				
Population (2000. Proj) : Average annual rainfall : Land area for which land use records are available			1000 million 1100mm 304 million hectare	
Average household water requirements nationwide	*Annual water requirements*	*Water collection efficiency*	*Land requirements*	*% of India's land*
100 litres/day/person (min)	36500 Billion litres (min)	50 %	6.63 million hectares	2.1 %
200 litres/day/person (high)	73000 Billion litres (high)	50%	13.26	4.2 %

Source: Anil Agrawal and Sunita Narain, 1999

If we see the figures of India's rainwater potential (table-5) to meet its drinking water requirement then it is evident that rainwater harvesting on only India's 2 to 3 % land will be sufficient to meet the drinking water requirements. Why then are we forced to live with water scarcity? Rainwater harvesting is an easily available solution for water scarcity in many regions.

Rainfall pattern varies according to geographic location of the area. When compared to East Asia, South Asia has a higher evapotranspiration in practically all seasons, lower average rainfall, and its seasonal concentration is much more pronounced. As a result moisture deficit is also larger, under these conditions, irrigation needs of the dry season can be met only if the surplus water from the monsoon season is stored, either on the surface or underground, for later use. Figure –3 shows the water requirement of the plants of two zones of Asia i.e. south and east and it clearly indicates that there is need of rainwater harvesting in South Asia during rainy seasons. This water can be used in summer season when there is deficit of water in plants.



Graph showing the evapotranspiration rate and water requirement of plants of Asia.

Fig. 3

1.3 RURAL WATER NEEDS

Thousands of Indian villages still do not have any local source of drinking water. Women often have to walk many miles to collect a pot of drinking water of dubious quality. About 2.31 lakh villages or 40% of the villages in the country, were designated ‘problem villages'. by the drinking water mission during sixth plan. Under rural needs mainly two sectors are there. First one is irrigation and second one drinking and livestock. It has been estimated that under irrigation sector the present demand is 630 BCM and by the year 2025 it will increase to 770 BCM. The world's average rural water consumption per capita is only 50 lpcd or about 18 cum. per year.

1.4 URBAN WATER NEEDS

Urban water needs can be divided into various sectors on the basis of the diverse kind of uses. The water demand of a city has two aspects a) Domestic water demand, b) Water demand at city level The following tables from 5 to 7 show various standards for water demand and sectorwise and populationwise breakup.

TABLE # 6 AVERAGE DOMESTIC CONSUMPTION IN AN INDIAN CITY

S.NO	USE	CONSUMPTION (LPCD)
1	Drinking	5
2	Cooking	5
3	Bathing	55
4	Washing of cloths	20
5	Washing of utensils	10
6	Washing and cleaning of houses and residences	10
7	Flushing of latrines	30
	Total	135

Source : Bureau of Indian standards (IS : 1172 – 1971)

The city level demand varies according to the population size. On an average, the per capita demand for Indian cities may vary as shown in the following table. It must be noted that there is a big gap urban and rural demands. As urban demand is about 150 lpcd to 300 lpcd, rural demand is 70 to 100 lpcd. On an average of world's urban water demand is 150 lpcd or about 55 cum per year and average rural water consumption is only 50 lpcd or 18 cum per year.

TABLE # 7 VARIATION IN WATER DEMAND AS PER CITY SIZE

S.NO.	POPULATION SIZE	DEMAND (LPCD)
1	Less than 20,000	110
2	20,000 – 50,000	110 – 150
3	50,000 – 2,00,000	150 – 180
4	2,00,000 – 5,00,000	180 – 210
5	5,00,000 - 10,00,000	210 – 240
6	More than 10,00,000	240 – 270

Source : Bureau of Indian Standards.

TABLE-8 BREAKUP OF CITY LEVEL DEMAND

S.NO.	USE	DEMAND (LPCD)
1	Domestic	135
2	Industrial	50
3	Commercial	20
4	Public	10
5	Waste & Theft	55
	Total	270

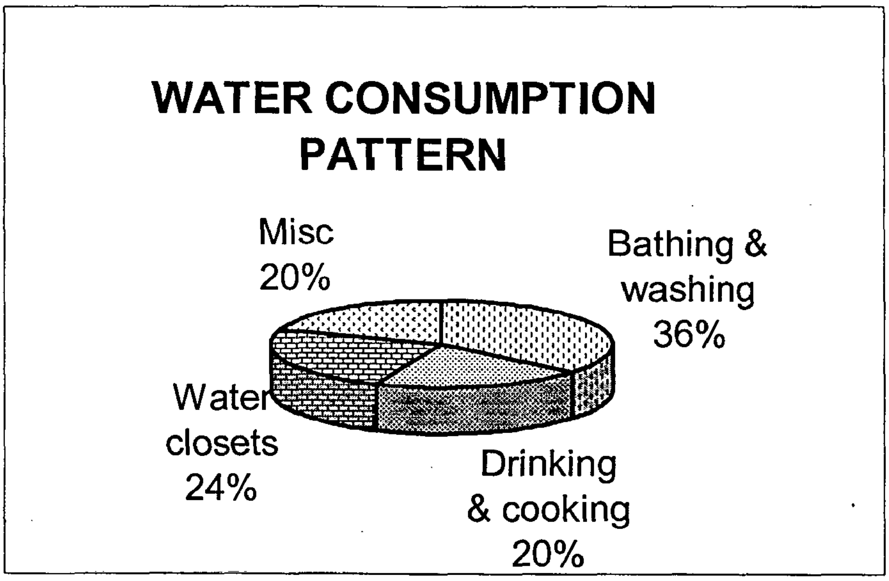
Source : Bureau of Indian Standards

TABLE-9 BREAKUP OF WATER UTILISATION IN DELHI @ 363 LPCD

S.NO.	USE	CONSUMPTION (LPCD)
1	Domestic	225
2	Industrial, commercial & community	47
3	Fire protection (@ 1% of the total demand)	4
4	Gardens (@ 67,000 litres/ha/day)	35
5	For floating population & special uses like embassies & hotels	52

Source: Master plan for Delhi – 2001, DDA.

In the above table the water requirement for the capital Delhi, has been worked out at the rate of 363 lpcd. The consumption of water used for domestic purposes has been worked out at the rate of 225 lpcd. The breakup of the domestic water usage is given in the following chart.



BREAKUP OF DOMESTIC WATER USE PATTERN

CHART- I

1.5 SUMMING UP

The purpose of this chapter is to give an overall picture of the different type of water resources and their pattern of distribution. This also includes the consumption of water and its breakup at city level and national level. From the above mentioned information it is clear that there is no shortage of water as such but there proper management and utilization is of utmost importance. If we don't pay attention to the natural cycle of water then the natural process of recharging of ground water will not take place and will create the water crisis. In fact it is the balanced utilization of the various water resources which is necessary. Presently a huge resource of water that is rainwater is not utilised properly and it going waste as runoff causing inundation in one area and drought in other area. One of the preventive measures for this kind of havoc is rainwater harvesting.

CHAPTER-II

IDENTIFICATION OF THE PROBLEM

2.1 RATIONALE FOR STUDY ON RAINWATER HARVESTING

Water is an essential resource for sustaining life and environment. The available water resources are under pressure due to increased demands and the time is not far when water, which we have always thought to be available in abundance and free gift of nature, will become a scarce commodity. Conservation and preservation of water resources is urgently required to be done. In our villages and cities, down the ages, people have developed a wide array of techniques to harvest rainwater, which are simple, efficient and cost effective. There is a tendency to ignore these traditional water- harvesting systems. We should draw upon the wisdom of our ancient life sustaining system and through better management and planning, conserve our precious water resources.

Despite the advancements in the field of water supply, rapid urbanisation in India has outstripped the supply of this critical resource. As a result of the technique of flood irrigation in the agricultural sector and the further requirement of the growth in agricultural production the irrigation demand has become competing and limiting factor vis-à-vis urban demand (S. P. Sinharay, Y. B. Kausik, D. Chakraborty, 2000). Several of the major river basins have been utilised to the extent of not being left with transferable surplus. The ground water aquifers in several metropolitan areas have been indiscriminately exploited with the help of deep pumping so that their yields are no longer sustainable. The increasing proportion of hard surfaces in urban areas has been matched by proportionate increase in runoff and proportionate decrease in recharge Simultaneously, insufficient supply forces individuals to meet their requirement through groundwater exploitation thereby driving down the water table still further. Furthermore, inability to dispose both solid and liquid wastes appropriately is resulting in their disposal in fresh water bodies leading to the destruction of lakes and low lying areas as well as fresh water aquifers. Thus while urban growth trends are galloping the resource constraint is beginning to inhibit the quality of urban life.

One of the biggest environmental challenges that India faces in the coming decades is that of balancing it's increasing demand of water coupled with the diminishing availability of water. Increase in population along with rapid urbanization, industrialization and agriculture development are, on one hand, leading to an ever increasing demand for water and, on the other hand, a decreased supply of fresh water, especially in the absence of effective mechanisms to regulate pollution. The future scenario is one, characterized by over exploitation of water resources, decreased accessibility to clean water, and increased competition for and potential conflict over water resources.

On the basis of the study of 40 city districts of India (table-10), we find that in the present situation only large cities are facing acute water shortage. It is because the population of those cities has crossed the bearing capacity of the water resources of the city. A city survives on basically on the water resources of the rural hinterland, but in due course of time urban expansion will grab the region and then it will not be easy to augment the water resource for the increased population.

From the table- 10, it is very clear that many cities, which have adequate water supply now, shall be facing water shortage. It is also to be emphasized that if current water supply is not augmented it will not be possible for, even big cites to survive. Due to huge population

TABLE # 10 DRINKING WATER SUPPLY SYSTEM OF 40 CITY-DISTRICTS OF INDIA

(Based on 1991 census of India)

S NO.	name of city district	population in thousands 1991	2011(Proj.)	present Require. in mld	water supply in ref. Year mld	% gap bet. Supply & demand	supply position ref. Year	future water Req. @ 150 lpcd in mld	@ 200 lpcd in mld	% gap (in Year- 2011) @150	@200	SUPPLY POSITION @150	@200
1	HYDERABAD(1995)	3145	6090	1075	675	-37.209302	VI	913.5	1218	-26.11	-44.58	VI	VI
2	PATNA(1995)	3618	5196	135	139	2.96296296	AD	779.4	1039.2	-82.17	-86.62	AC	AC
3	RANCHI(1995)	2214	3120	116	111	-4.3103448	IN	468	624	-76.28	-82.21	AC	AC
4	DELHI(1995)	9420	21605	3413.65	2270	-33.502263	VI	3240.75	4321	-29.95	-47.47	VI	AC
5	AHMEDBAD(1995)	4801	7369	558	455	-18.458781	IN	1105.35	1473.8	-58.84	-69.13	AC	AC
6	GANDHINAGAR(1993)	408	817	50	45	-10	IN	122.55	163.4	-63.28	-72.46	AC	AC
7	RAJKOT(1996)	2514	3627	125	87	-30.4	VI	544.05	725.4	-84.01	-88.01	AC	AC
8	BARODA(1996)	3089	4504	280	250	-10.714286	IN	675.6	900.8	-63.00	-72.25	AC	AC
9	SURAT(1996)	3397	6307	200	200	0	AD	946.05	1261.4	-78.86	-84.14	AC	AC
10	SHIMLA(1993)	617	903	36.4	17	-53.296703	AC	135.45	180.6	-87.45	-90.59	AC	AC
11	SRINAGAR(1993)	860	1198	190	207	8.94736842	SU	179.7	239.6	15.19	-13.61	SU	IN
12	BANGLORE, (1995)	4839	4630	679	680	0.14727541	AD	694.5	926	-2.09	-26.57	IN	VI
13	MYSORE (1960)	3165	4708	85	85	0	AD	706.2	941.6	-87.96	-90.97	AC	AC
14	HUBLI-DHARWAD(1996)	4355	6528	85	85	0	AD	979.2	1305.6	-91.32	-93.49	AC	AC
15	TRIVENDRUM(1995)	720	862		106			129.3	172.4	-18.02	-38.52	IN	IN
16	KOCHI(1995)	1414	1889		170			283.35	377.8	-40.00	-55.00	AC	AC
17	BHOPAL (1996)	1351	3085	288	288	0	AD	462.75	617	-37.76	-53.32	VI	AC
18	INDORE(1996)	1835	3112	300	180	-40	AC	466.8	622.4	-61.44	-71.08	AC	AC
19	BOMBAY	9925	14388		2930								
20	SOLAPUR(1993)	3231	4951	126.8	90	-29.022082	VI	742.65	990.2	-87.88	-90.91	AC	AC

Adequacy level based on percentage gap between supply and demand

+5 and above	SURPLUS	SU
'0 to +5	ADEQUATE	AD
-1 to -20	INADEQUATE	IN
-20 to -40	VERY INADEQUATE	VI
- 40 and below	ACUTE	AC

Source :-Proceedings of International Conference on Habitat & Systaubable Development,N.Delhi,Dec.1997

IMD rainfall Data, Compendium of Evironment Statistics, 1997, Census Book of India 1991,

Contd..

TABLE # 10 DRINKING WATER SUPPLY SYSTEM OF 40 CITY-DISTRICTS OF INDIA

(Based on 1991 census of India)

S	name of	population		present	water sup	% gap	supply	future water Req.		% gap		SUPPLY	
NO.	city district	in thousands		Require.	in ref. Yea	bet. Supp	position	@ 150 lpcd	@ 200 lpcd	(in Year- 2011)		POSITION	
		1991	2011(Proj.	in mld	mld	& deman	ref. Year	in mld	in mld	@150	@200	@150	@200
21	KALYAN(1996)	1015			115								
22	THANE(1996)	5249	12878		235								
23	NASIK(1993)	3851	6383	135.8	82	-39.617	VI	957.45	1276.6	-91.44	-93.58	AC	AC
24	NAGPUR(1996)	3827	8368	368	373	1.3587	AD	1255.2	1673.6	-70.28	-77.71	AC	AC
25	PUNE(1996)	5532	9763	530	600	13.2075	SU	1464.45	1952.6	-59.03	-69.27	AC	AC
26	SHILLONG(1996)	132		33	7.8	-76.364	AC						
27	AIZWAL(1995)	478	944	27	11.25	-58.333	AC	141.6	188.8	-92.06	-94.04	AC	AC
28	JAIPUR(1996)	4722	9001	340	244	-28.235	VI	1350.15	1800.2	-81.93	-86.45	AC	AC
29	JODHPUR(1996)	2153	3591		110			538.65	718.2	-79.58	-84.68	AC	AC
30	KOTA(1993)	2030	3441	120	127	5.83333	SU	516.15	688.2	-75.39	-81.55	AC	AC
31	MADRAS CITY(1995)	3841	5280	605	535	-11.57	IN	792	1056	-32.45	-49.34	VI	AC
32	COIMBATORE(1993)	3508	4610	237.8	75	-68.461	AC	691.5	922	-89.15	-91.87	AC	AC
33	MADURAI(1993)	3449	1994	227.8	60	-73.661	AC	299.1	398.8	-79.94	-84.95	AC	AC
34	LUCKNOW(1995)	2762	5194	540	415	-23.148	VI	779.1	1038.8	-46.73	-60.05	AC	AC
35	KANPUR(1996)	4556	8753	500	300	-40	AC	1312.95	1750.6	-77.15	-82.86	AC	AC
36	ALLAHABAD(1993)	4921	8265	170	190	11.7647	SU	1239.75	1653	-84.67	-88.51	AC	AC
37	VARANASHI(1993)	4680	8380	200	244	22	SU	1257	1676	-80.59	-85.44	AC	AC
38	GORAKHPUR(1993)	3066	2001	105	60	-42.857	AC	300.15	400.2	-80.01	-85.01	AC	AC
39	CALCUTTA CITY (1996	4399	7793	990	990	0	AD	1168.95	1558.6	-15.31	-36.48	IN	VI
40	CHANDIGARH(1995)	640	1288	94.53	65	-31.239	VI	193.2	257.6	-66.36	-74.77	AC	AC

Adequacy level based on percentage gap between supply and demand

+5 and above	SURPLUS	SU
'0 to +5	ADEQUATE	AD
-1 to -20	INADEQUATE	IN
-20 to -40	VERY INADEQUATE	VI
- 40 and below	ACUTE	AC

Note:- poplation of city no 33 & 38 were showing decling trend hence population projected is of 1991 census

Source :-Proceedings of International Conference on Habitat & Systaubable Development,N.Delhi,Dec.1997
IMD rainfall Data, Compendium of Evironment Statistics, 1997, Census Book of India 1991,

INDIA MAP SHOWING WATER SHORT FALL IN SELECTED CITIES

Fig. 4

there is already a lot of pressure on existing water supply. Rapid growth of population and standard of living is also a major factor in demand. From the table it is clear that there is big difference in standards of per capita demand in the country. Like Delhi, Bombay etc. is having very high standard of per capita demand in comparison to the smaller cities. If we take the standard per capita demand of these cities almost 80% of the cities shall come under the category of very acute shortage. But it is not true because the demand of the city varies according to its size and function. There is great need to identify the demand of each city individually, as it is never same. But the basic need of water for domestic use is more or less same in all the cities, but varies in urban and rural context.

If we see the spatial pattern of demand and supply and the shortfall (refer Fig-4) it is clear that the shortfall more is prevalent in the northern and western part of the country. These are the areas where rainfall touches the average annual rainfall of the country except in west Rajasthan. Concentration of population is evenly distributed in four metro cities. But water supply condition in Bombay and Madras is very inadequate, in comparison to their counterparts. Table-11 shows the water availability in four metro cities. One big problem these cities, located in coastal areas, are facing is of seawater intrusion into the fresh groundwater aquifer. The only solution to this problem is groundwater recharge (M. B. Raju, B. Umapati, 2000). Ground water recharge can be done through Rainwater harvesting also and it the cheapest method in comparison to other methods. Aizwal is also facing acute water shortage, besides the fact that it lies in the belt of heaviest rainfall zone. This is because of the geology of the area. Here all the rainwater flows down due to the non-capability of soil to hold the water. In such kind of areas rainwater is of utmost importance and perhaps the only source of water supply.

TABLE # 11 WATER AVAILABILITY IN METRO CITIES OF INDIA			
S.NO.	MRTRO CITY	WATER AVILABILITY IN 1994 – 95 IN LPCD	WATER AVILABILITY IN 2000(proj) IN LPCD
1	Delhi	341	257
2	Bombay	192	135
3	Calcutta	200	213 (1991)
4	Madras	90	70

Source: CWC, 1996

Most of the cities have already exploited their natural water resources to such an extent that there is and urgent need to resort for other type of water sources (Ashish Banerjee, Manu Bhatnagar, 2000). If we fail in doing so we can see the effects of population on the water resources. Almost all the major cities of India shall face the acute water shortage. After analyzing the rain water potentials in these cities one can easily say that rain in itself can fulfill the greater part of the demand. Rainwater is pure and little purification makes it of drinking water quality. And at least we can use it for the non-drinking purposes because drinking water requirement is only about 25 lpcd. Table –12 shows the water resources of the 40 city districts in India. On comparing the different resources we see that rainwater has the highest potential and able to meet the water requirements of the cities, then why we are facing acute water shortage in so many cities?. It is only because the sole dependency on groundwater resources and surface water resources. The problem is further aggravated when surface water sources are getting contaminated. Even the ground water source is not intact of pollution. Is rainwater free from pollution? The answer is not entirely; it may also contain bacteria as coming in contact with the atmosphere and contaminated. But only little purification makes it usable for drinking water. So why don't we resort to rainwater resource, which is a free natural gift and distributed freely to everyone.

TABLE # 12 WATER RESOURCES OF 40 CITY-DISTRICTS OF INDIA

S NO.	name of city district	population 2011 (Proj.)	district area sq. km.	avg. annl. rainfall in mm.	Total rain water in a year (MCM)	(proj.) per capita avilability of rain water in cum/year	G. Water availability in MCM/yr	surface water source (Y/N)
1	HYDERABAD	6090	217	758.9	164.6813	27041.26437		Y
2	PATNA	5196	3202	992	3176.384	611313.3179	954.76	Y
3	RANCHI	3120	18266	1482.6	27081.1716	8679862.692	620.62	
4	DELHI	21605	1483	467.1	692.7093	32062.45314		Y
5	AHMEDBAD	7369	8707	625.8	5448.8406	739427.4121	1254.15	Y
6	GANDHINAG/	817	649	625.8	406.1442	497116.5239	122.84	
7	RAJKOT	3627	11203	589.7	6606.4091	1821452.743	1361.67	
8	BARODA)	4504	7794	968.8	7550.8272	1676471.403	1186.47	
9	SURAT	6307	7657	1521.2	11647.8284	1846809.64	1960.21	
10	SHIMLA	903	5131	1528.1	7840.6811	8682924.806		
11	SRINAGAR	1198	2228	783.8	1746.3064	1457684.808	400.41	Y
12	BANGLORE	4630	8005	793.6	6352.768	1372088.121	764.05	Y
13	MYSORE	4708	11954	761.9	9107.7526	1934526.89	812.35	
14	HUBLI-DHAR\	6528	3149	691.1	2176.2739	333375.2911	1039.35	Y
15	TRIVENDRUN	862	2192	2001.6	4387.5072	5089915.545	304.29	
16	KOCHI	1889	2569	1122.9	2884.7301	1527120.222	1035	
17	BHOPAL	3085	2772	1244.8	3450.5856	1118504.246		
18	INDORE	3112	3898	974.4	3798.2112	1220504.884	433	
19	BOMBAY	14388	603	1804.8	1088.2944	75639.03253		Y
20	SOLAPUR	4951	15017	584.3	8774.4331	1772254.716	1468.49	
21	KALYAN							
22	THANE	12878	9558	2477	23675.166	1838419.475	531.46	
23	NASIK	6383	15530	1022	15871.66	2486551.778	1604.4	Y
24	NAGPUR	8368	9931	1176	11678.856	1395656.788	1892.18	
25	PUNE	9763	15642	1150.3	17992.9926	1842977.835	1611.23	
26	SHILLONG							
27	AIZWAL	944	12588	2295.5	28895.754	30609908.9		
28	JAIPUR	9001	14068	548.2	7712.0776	856802.3109	1629	Y
29	JODHPUR	3591	22850	318.7	7282.295	2027929.546	511	Y
30	KOTA	3441	12436	885.6	11013.3216	3200616.565	1222	
31	MADRAS CIT	5280	170	877.1	149.107	28239.96212		Y
32	COIMBATOR	4610	7469	1030.4	7696.0576	1669426.811		
33	MADURAI	1994	12624	854.8	10790.9952	5411732.798		
34	LUCKNOW	5194	2528	959.3	2425.1104	466906.1224	678	Y
35	KANPUR	8753	6176	801.5	4950.064	565527.7048	1498	Y
36	ALLAHABAD	8265	7261	976.4	7089.6404	857790.732	2231	Y
37	VARANASHI	8380	5091	1056.4	5378.1324	641781.9093	1248	Y
38	GORAKHPUF	2001	6272	1364.1	8555.6352	4275679.76	28.96	
39	CALCUTTA C	7793	104	1629.9	169.5096	21751.5206		Y
40	CHANDIGARH	1288	114	792.89	90.38946	70178.15217		Y

Note:- poplation of city no 33 & 38 were showing decling trend hence population projected is of 1991 census

Source :- Proceedings of International Conference on Habitat & Systaubable Development,N.Delhi,Dec.1997
IMD rainfall Data, Compendium of Evironment Statistics, 1997, Census Book of India 1991,
Surface water source is based on the information available with the author

2.2 NEED FOR INTEGRATING RAINWATER HARVESTING IN URBAN PLANNING

Countries such as Thailand, Denmark, Philippines and even the highly urbanized countries such as Japan, China and America are among the few where rain water harvesting is now being practiced to meet the water needs of the growing population (C.S.W.C.R.T.I., 1996). India with its strong tradition of harvesting structures throughout the country developed to suit the requirements of the area and the society is not far behind. We have modern examples like systems of harvesting rainwater in cities of Chennai, Hyerabad, Aizwal, to our credit where these systems have been successful. Rain water that is collected is not used only for domestic needs, but also for artificial recharge of ground water by improved soil and water conservation practices. Such as examples relate to the watershed management practices carried out in Sukhomajri, Ralegan Siddhi, and in Alwar by Tarun Bharat Sangh.

Rain water harvesting can not only provide a source of water to increase water supplies but also involve the public in water management, making water management everybody's business. It will also reduce the demand on the government institutions to meet water needs of the people. It would also help everyone to internalize the full costs of their water requirements, thus encouraging people to be more conscious of their water demand. Water is not something that one can live without thus people would find ways ensure then own water supply. Major institutional, policy and technological initiatives are required to ensure an efficient, socially equitable and environmentally sustainable management of our water resources. Development of water resources must be to an extent, such that it ensures the sustainability of the resource, both for the present and future generations.

When we look at the traditional system of water collection, which has been practiced for centuries we find that these systems were not only very dependable, they were also low-cost, involving mainly people's initiative and community participation in low-cost water collection systems such as rain water harvesting. There is an urgent need of relink urban planning with consideration of the local resource potentials of nature like rainwater.

2.3 OBJECTIVES OF THE THESIS PROJECT

The broad objectives of the thesis project will be as under,

1- To analyze our water resources potentials and the problem of water scarcity in general and of urban areas in particular, and to establish the rationale for rain water harvesting.

2- To study the various traditional rainwater harvesting practices as well as the modern technologies, if any in terms of their appropriateness to diverse situations.

3- To analyze the physical economic, infrastructure and planning implications of integrating rain water harvesting in urban planning and urban water management.

4- To propose feasible water management plan for Dehradun integrating rainwater harvesting and other water conservation methods.

5- To formulate planning policy guidelines and strategies for incorporating rain water harvesting and other water conservation methods in planning and development process.

2.4 SCOPE

The scope of coverage of integrating rainwater harvesting includes not only for drinking purpose but also for all other uses of urban household sectors. While the main purpose will be to deal with urban household sector primarily, the project attempts to cover other sectors of urban water consumption as well. The recommendations will be applicable to meet Indian urban settlement facing water shortage.

The project will be dealt with in two parts. First part studies the water problems & potentials in urban areas. It will also deal with the traditional practices of rainwater harvesting and the new concepts and technologies of rainwater harvesting. Analyzing various aspects of integrating rainwater harvesting in urban planning and development will come in the first part. The second part includes preparation of water management plan for Dehradun integrating rainwater harvesting. The area covered will be that of Dehradun municipality.

2.5 METHODOLOGY

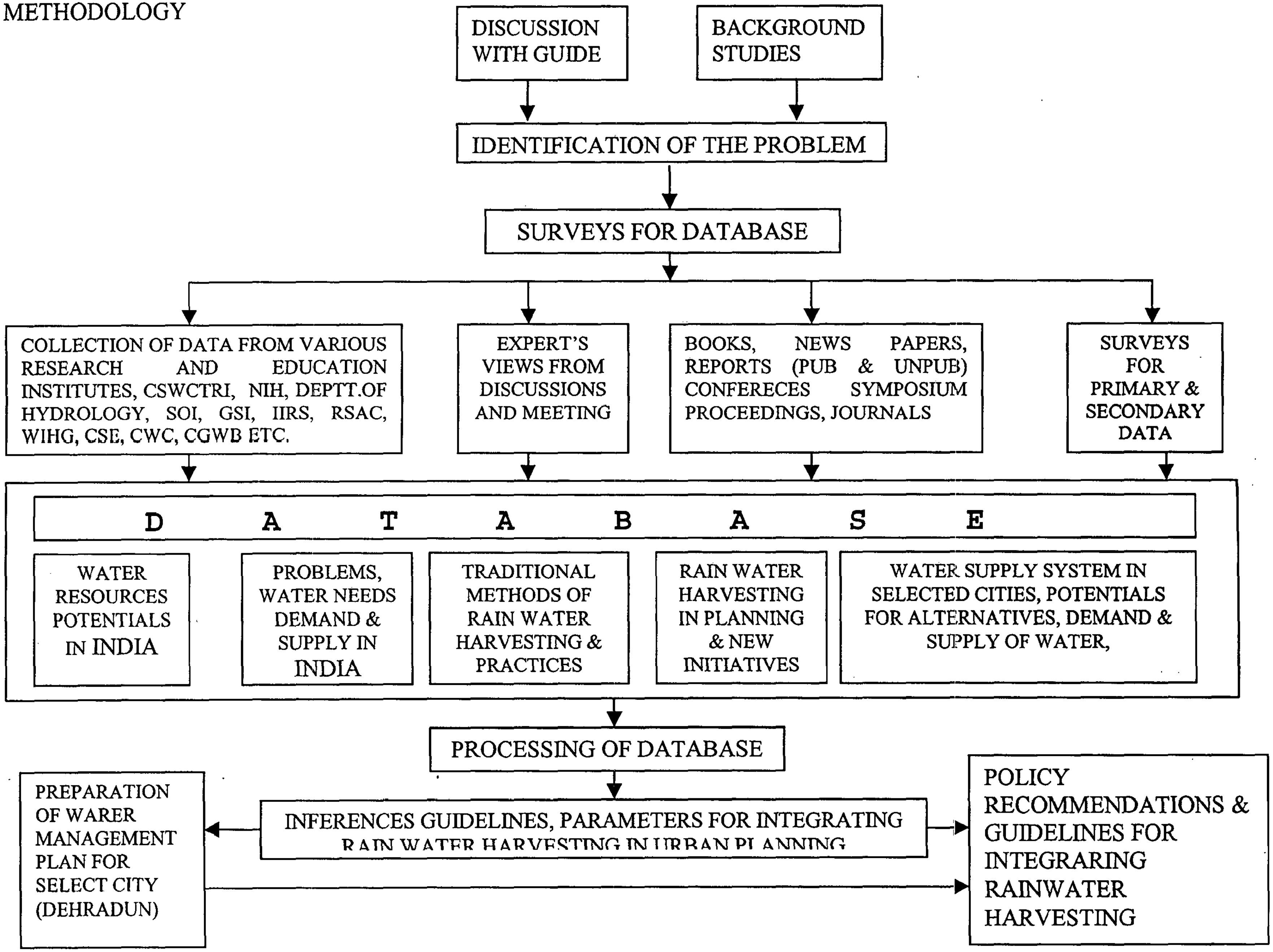
The methodology is given in the form of flow chart on the next page.

2.6 LIMITATIONS

Due to the limitation on time and resources for undertaking necessary studies, the field survey will be limited to cover only the key planning aspects and the bulk of the data will be from reliable secondary official sources. .

As the project is dealing only a small area in the country a lot many possibilities will be left to study. These will be depending upon the geographical, geological and meteorological conditions of the different part of the country. As the problem of water in urban areas is much more rampant hence there is urgent need to go for alternate water resources, but we can't avoid the need of it in rural areas also. The project will thrust the study on rainwater harvesting in terms of spatial planning but there is always a need on a comprehensive approach involving management, and other aspects.

METHODOLOGY



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CHAPTER-III

FUNDAMENTAL S OF RAINWATER HARVESTING

3.1 INTRODUCTION TO RAIN WATER HARVESTING

Water is essential for life on the planet, water resources have been a decisive factor in the growth and development of human civilization in the history. India receives an average annual rainfall of around 1100mm. Which is the highest in the world among countries of comparable size, and should be sufficient enough to satisfy its ever-increasing demand (N.I.H. 1993). But the temporal and spatial distribution of rainfall throughout the country is so erratic that drought and floods occurs frequently and simultaneously. Also the alarming rate of population growth at 2.11 percent has led to increasing pressure on the basic life supporting system. The utilization of water resources in the country has increased over the years.

Quality of rainwater is quite considerable even in drought prone areas. About 10 mm. rainfall in a small farmer's lands of a hectare amounts to 100,000 litres. And effective rainfall or each 100 mm. works out to a million liters, the quantity of which is sufficient not only for drinking purposes but also for selective cropping (J. V. S. Murthy, 1996). These good quantities of rainwater in low rainfall areas could effectively be stored for different purposes through harvesting. Collection of rain as it falls near a house of a small farm is known as catchment, while collection of runoff by minor structures is styled as harvesting.

There are various questions raise in ones mind when we talk of roof top rain water harvesting like how much cost effective it is, how it can be done, what should be the surface finish of how we can store if? In this chapter I have tried to answer all these queries. To show the details I have taken a hypothetical case, but the same may hold good for any other places with the little modifications.

Assumptions:

Average annual rainfall: 2140 mm.

Plot size: 200 sq.m.

Ground coverage: 50%

Average family size: 5

Use zone : residential

Roof top area: 100 sq.m.

Total rainwater collected in a year: 214 cum.

Considering losses made due to:

Evaporation + first wash + shifting due to wind + pits in gutters = 25%

Hence net water available for harvesting from = 160.5 cum / year

Per capita requirement of water for domestic use: 135 lpcd or 50 cum. per year

Per capita availability rainwater: 160 / 5 = 32 cum. per year. Hence it is fulfilling about 60% of water need in a family. It is, when only rooftop area is considered. Table no.13 gives the availability of rainwater through rooftop rainwater harvesting. So one can easily calculate the appropriateness of the harvesting system. This table is also helpful in determining the storage space required and on the basis of that feasibility of the project can be found.

It is obvious from the above figures that rainwater from the rooftop alone is sufficient to fulfill half of the need of the household. It shall be possible to use this rainwater for various domestic purposes. Generally the quality of rainwater is good enough but due to its contact with atmosphere it is advisable to do some treatment for pathogenic bacteria and coliform.

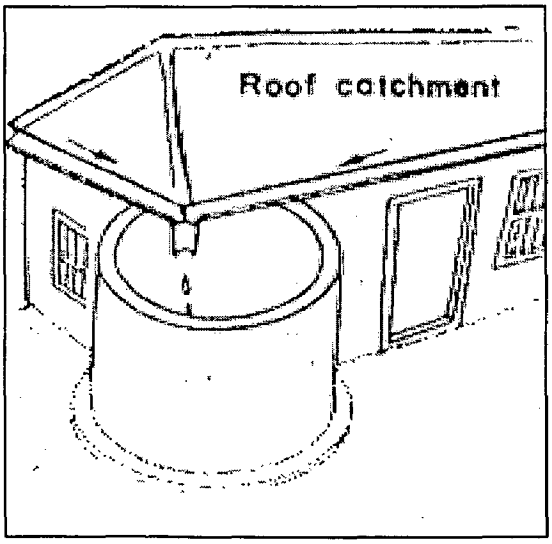
TABLE-13 AVAILABILITY OF RAINWATER FROM ROOFTOP RAINWATER HARVESTING

Rainfall (mm)	100	200	300	400	500	600	800	100	1200	1400	1600	1800	2000
Rooftop area (sq.m.)	Harvested water from rooftop (cum.)												
20	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4	25.6	28.8	32
30	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	33.6	38.4	43.2	48
40	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8	51.2	57.6	64
50	4	8	12	16	20	24	32	40	48	56	64	72	80
60	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2	76.8	86.4	96
70	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4	89.6	101	112
80	6.4	12.8	19.2	25.6	32	38.4	51.2	64	76.8	89.6	102	115	128
90	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	101	115	130	144
100	8	16	24	32	40	48	64	80	96	112	128	144	160
150	12	24	36	48	60	72	96	120	144	168	192	216	240
200	16	32	48	64	80	96	128	160	192	224	256	288	320

250	20	40	60	80	100	120	160	200	240	280	320	360	40(
300	24	48	72	96	120	144	192	240	288	336	384	432	48(
400	32	64	96	128	160	192	256	320	384	448	512	576	64(
500	40	80	120	160	200	240	320	400	480	560	640	720	80(
1000	80	160	240	320	400	480	640	800	960	1120	1280	1440	160(

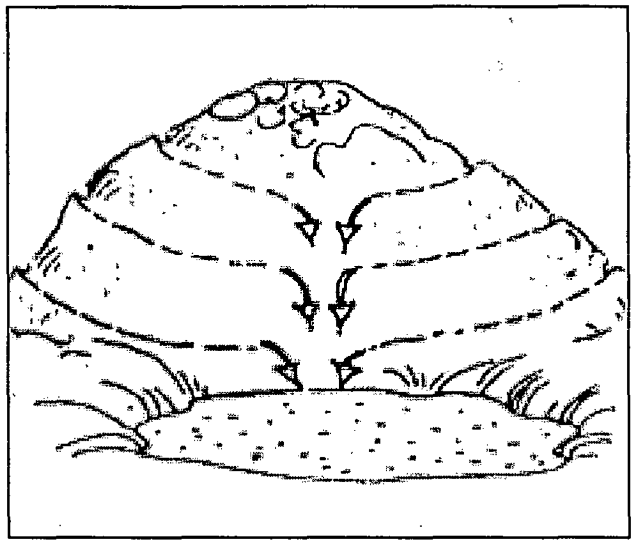
3.1.1 CATCHMENT

Almost all the rainwater is collected in a storage tank till it is filled up. The catchment is either from a roof, compound of a house, or from a small field area. The catchment is done in house basement, separate tanks or well like structures known as Kunds. It would be better to follow these practices for meeting the requirements of households, cattle, schools, gardens and small farms. Rainwater catchment is the most economical means of using rainwater by villagers and farmers.



(ROOF CATCH MENT)

Fig.- 5



(HILL CATCHMENT)

fig- 6

3.1.2 HARVESTING

Rainwater is possible in areas with as little as 50 – 80 mm average annual rainfall (J.V.S. Murthy, 1996.). This seems to be lowest limit, but during an year with only 24 mm of rain, water harvesting in Israel still yielded an usable runoff (J.V.S. Murthy, 1996). Water harvesting is to be planned depending upon the topography, soil, rainfall, and other meteorological parameters. Water harvesting system, once installed , will provide water without motivating power in contrast to ground water exploitation structures. A few of the water harvesting practices are:

- Historical large step wells across streamlets
- Collection of runoff water into ditches
- Harvesting in cisterns from hillsides
- Usage of easily accessible chemical sealants like silicones, latexes, asphalt & wax
- Graded & rolled areas with drains for harvesting
- Large step tanks with storage cells (Sudan)
- Paved tanks with mud & flat stones (Botswana)
- Lime-sealant-surfaces for harvesting open areas
- Covering soil with plastic, butyl rubber & metal foil increases runoff for harvesting.

3.2.3 HARVESTING STRUCTURES

Farm ponds are the common structures in rainwater harvesting. These are very important in utilizing rainwater for drinking as well as irrigation purposes. There are various types of structures with different designs and dimensions. They are constructed mostly, at proper sites with good storage, along stream courses or in low lying areas. The best dimensions are 10 – 30 m lengths, 5 – 20 m width and 2 m depth. This practice proves best because;

- Water is harvested & velocity is reduced
- Low-cost of construction & maintenance
- No scouring action

Storage capacity is around 100 – 500 cum. and cost of the dams is generally limited to RS. 15000.

3.2 TYPES AND METHODS OF RAIN WATER HARVESTING

A. Roof Top Rainwater Harvesting For Drinking Water

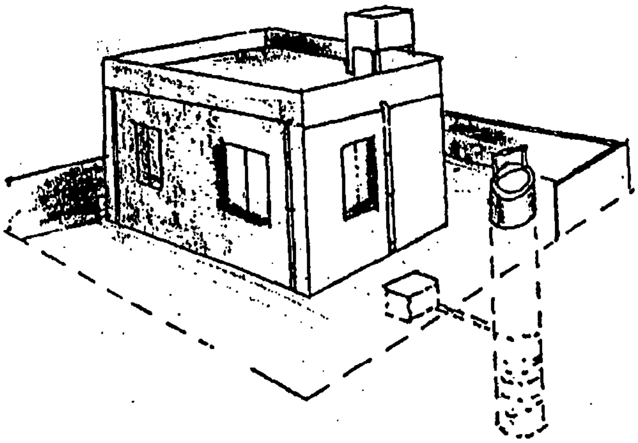
Roof water harvesting is common in areas having high rainfall intensity well distributed in the year e.g. Himalayan areas, Northern States, Andman Nicobar Islands, Rajasthan, and Southern part of Kerla and Tamilnadu.

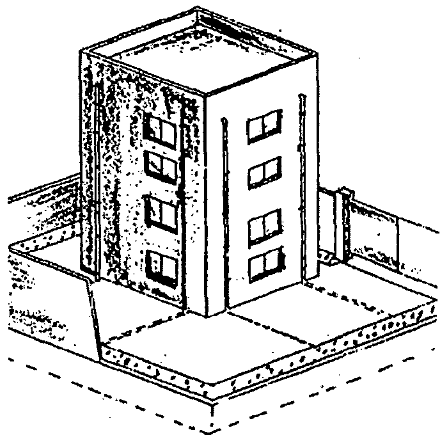
There are many methods available for harvesting rainwater. The method is site specific. following steps are commonly followed in rain water harvesting forms.

1- collection of rain water, 2- separation of first rain flush, 3- filtration of rain water

4- storage of rain water, 5- distribution of water

Before supplying for human consumption the raw water from the pond should be filtered through a sand filter and kept in a PVC tank connected to a hand pump for withdrawal. In spite of certain limitations rainwater harvesting will be beneficial for providing drinking water to human beings as well as cattle in areas lacking alternative sources .

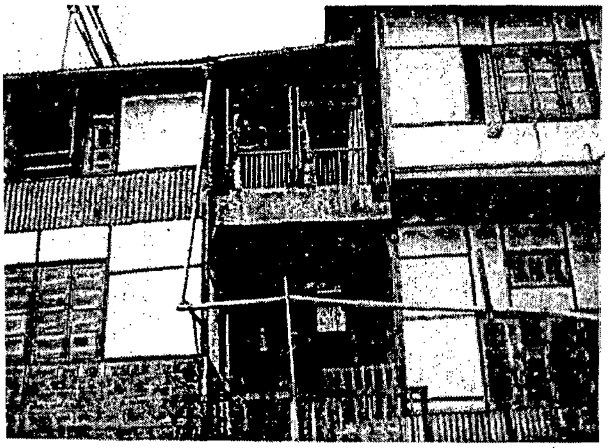




BROKEN BRICK METHOD

fig.-7 (percolation pits for individual house)

fig.- 8



withstanding heavy rain. the people of Mizoram face acute water problems during the dry son because most of them live on hilltops. Hence, they have begun to practice rainwater vesting from rooftops.

fig. 9 Roof top rainwater harvesting in Rajasthan

The Mizoram government took up rainwater harvesting under its public water supply programmes n 1986. As a policy, it is replacing all thatch roofs with galvanised sheet roofs to promote rooftop water harvesting.

fig. 10 Roof top rainwater harvesting in Mizoram

B. Rain Water Harvesting By Ground Catchment And Microcatchments

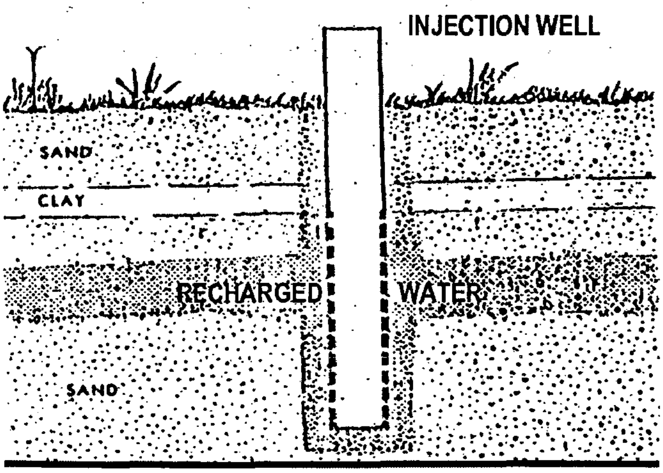
This method can be used to supply water for crops, wild life and livestock as well as for domestic use.

C. **Rain Water Harvesting By Land Treatments (Forestation etc.)**

The conservation of moisture, particularly in arid and semiarid regions is of most importance. In such areas infiltration capacity of the soil is reduced through different land treatments, which can be served for agricultural purpose in drought prone areas.

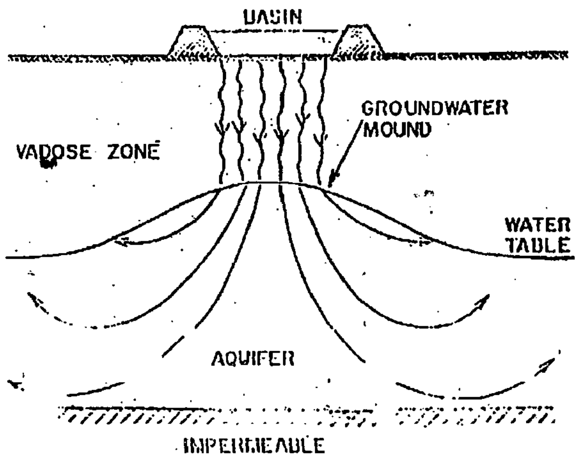
D. **Rain Water Harvesting By Percolation Tanks, Injection Wells And Subsurface Dams**

In areas of declining trend of ground water, the artificial recharge of ground water is of great in water harvesting. GW recharge involves augmenting the natural movement surface water into underground formations by some method of construction, by spreading of water, or by artificially changing natural conditions.



Water harvesting by injection wells.

Fig. 11



Water harvesting by percolation tanks.

Fig. 12

E. **Rain water Harvesting By Mechanical Measures**

Such practices as contour farming and strip cropping are effective in water holding capocity. Level terracing is a good water harvesting practice where the slopes are gentle enough so that the water can spread where a relatively large area.

F. Rainwater Harvesting By Mulch and Farming Practices

Various type of farming practices are there for rainwater harvesting.

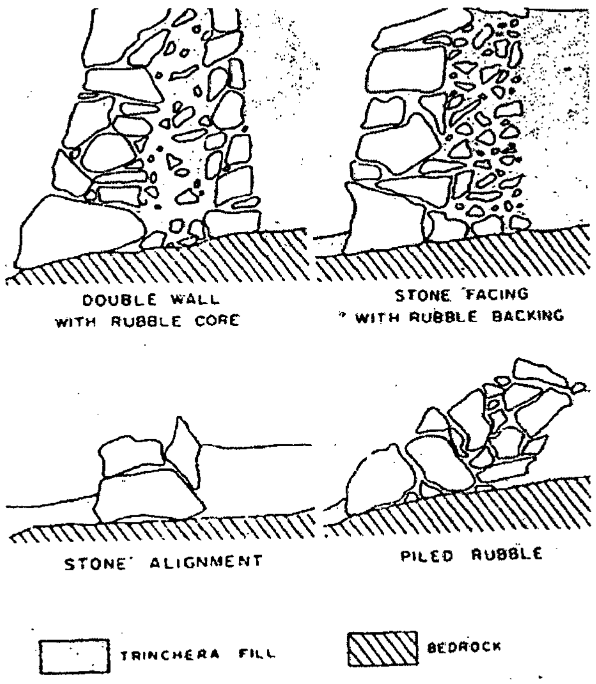
1. Contour farming
2. Strip farming

G. Water Harvesting By Engineering Practices

The important types of water harvesting practices are;

1- **Silt traps (see fig. 13)** : Silt traps are built of stones across the beds of intermitted streams.The

size of silt trap structure varies enormously. In order to asses the adequacy of silt traps one must consider two aspects : first its cost; and second, its effectiveness in harvesting runoff.



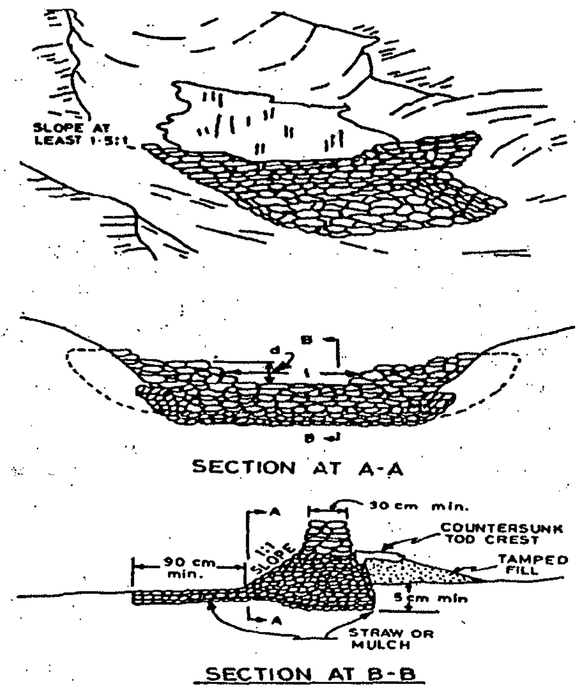


Fig- 13 silt trap structures used for water harvesting

Fig- 14 a woven wire dam for water harvesting

2- **Check dams (see fig. 14)**: Check dams of varying design constructed for the purpose of stabilizing the grade and harvesting runoff water from large catchments, even under arid conditions. Check dams are made of locally available materials like brush, poles, and woven wire: loose rock and plants or slabs. Temporary check dams constructed across the bed of a gully have two uses: (1) to collect enough soil and water to ensure the eventual growth of protective vegetation and (2) to check channel erosion until sufficient stabilizing vegetation can be established.

The life of temporary check dams depends on the quality of the materials and efficient of construction; but under ordinary conditions, they should last from 3 to 8 years. The following are the check dams normally used in small catchments.

- Woven-wire dams
- Brush dams
- Loose rock dams
- Plank or slab dams

3- **Bunds and Terraces (see fig.15) :**

Bunding is by far the most effective and widely practiced field measure for water harvesting. It is the placing of small earthen dams across local streams to collect the rainwater. The reservoirs so formed are called tanks. Tanks are usually shallow and the stored water covers a large area means a relatively large evaporation.

Bench terracing is one of the most popular water harvesting device on sloping and undulating lands. The water either stored in the soil of the cultivated land, or sometimes artificial

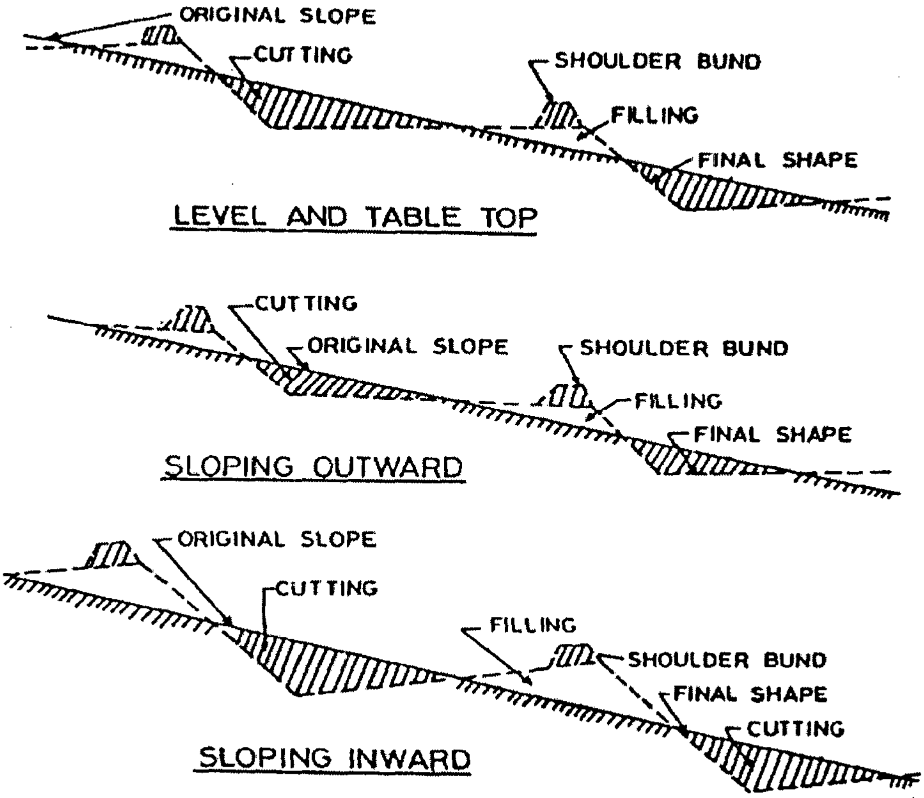


Fig. 15 Type of bench terraces used for water harvesting

storage facilities are provided. Most contour terraces are located on slopes of less than 25 percent. The following type of terraces normally adopted and are shown in fig. 15.

- Level bench terrace
- Inwardly sloping bench terraces
- Outwardly sloping bench terraces

3.3 RAINWATER HARVESTING IN DIFFERENT AGROCLIMATIC ZONES

The department of Rural Development, government of India, under its National Drinking Water Mission Programme (NDWMP), appointed a high-level national committee and a working group comprising experts from various organisations, to collect information about traditional water harvesting structures and suggest modifications for water harvesting in various agroclimatic zone, hydrological setups, and geographic situations; and evaluate the economic viability of these structures.

According to NDWMP, the term 'water harvesting' connotes collection and storage of rainwater and also other activities aimed at harvesting surface water and groundwater, prevention of losses through evaporation and seepage, and all other hydrological studies and engineering interventions aimed at conservation and efficient utilisation of limited water endowment of physiographic unit such as a watershed or geomorphic basin.

Water harvesting can be achieved by various techniques as stated above. These techniques or structures may be known by different names at different places but all of them can be put in the

above categories. Some of the common names used for water harvesting (also used by NDWMP) are as follows.

I. *In situ harvesting* : Nadi, Tanka, Sand-filled reservoirs, Ponds, Rooftop and hilltop collection of water.

II. *Storage of water in aquifers* (artificial recharge of groundwater) : Percolation tanks, Anicuts/Check Dams, Subsurface dams/barriers, Injection wells.

III. *Soil conservation methods* (which help to increase groundwater recharge) : Gully plugging, Contour bunding, Afforestation , Contour trenching, Land levelling and bunding of fields.

IV. *Enhancement of surface runoff collection:* Catchment treament.

V. *Evaporation control:* Chemical films, Hydrophobic coating material, Spreading of thermocole sheet etc

RAINWATER HARVESTING STRUCTURES IN DIFFERENT AGRO-CLIMATIC ZONES

S.NO.	AGRO-CLIMATIC ZONE	STATE OF THE ART	RECOMMENDATIONS
1.	Humid North-Western Himalaya	a) Roof water harvesting b) Diversion of perennial springs & streams in storage structures c) Village pond d) Collection from hill slope	Improvement in roof structures and use of proper material such as corrugated sheets for generating higher run off and with arrangement of foul slush diversion system and proper storage structure for checking water from contamination.
2	Himalyan foothill	a) Collection from hill slope b) Village ponds c) Roof water harvesting	Improvement in roof top harvesting system as above
3.	Humid High Rainfall North Eastern Zone	a) Roof water harvesting b) Diversion of perennial springs & streams in a storage structure (tank)	- do -
4.	Humid Assam Bengal Plains	a) Tank b) Anicut/check dam c) Gully plugging d) Contour bunding	Improved design of tank for minimising evaporation and seepage losses, contr0l of sediment load and water pollution
5.	Sub Humid Satluz Ganga Alluvial Zone	a) Pond b) Check dam c) Fully plugging d) Contour bunding	- do –
6.	North Western Semi arid & Arid Zone	a) Nadi b) Tanka	1- Adoption of improved design of Nadi and Tanka. 2- Sand filled reservoir

		d) Percolation tank e) Anicut f) Gully plugging g) Contour bunding	4- Flat batter tank
7.	Central Semiarid Vindhyan Zone	a) Ponds b) Check dams c) Sub surface dams	- do –
8.	High rainfall High runoff Chhotanagpur Plateau	Same as 4	- do –
9.	Assured Rainfall Deep Black soil Malwa Plateau & Narmada Basin	a) Ponds b) Check dams c) Subsurface dams	Improvement of existing systems
10.	Variable Rainfall South Central Plateau Zone	a) Pond b) Check dam c) Percolation tank d) Bandhara e) Gully plugging f) Sub-surface dam g) Contour bunding	1- Flat batter tank 2- Selection of suitable site and improvement of existing system, better water management
11.	Chattisgarh Plateau Zone	Same as 10	Same as 10
12.	South Eastern Brown/Red Soil Zone	a) Ponds/Tanks b) Percolation tanks c) Sub-surface dams	Improvement of existing system
13.	Southern Variable rainfall, Mixed Soil Zone	a) Pond/Tank/Kunta b) Nadi c) Check Dam d) Percolation tank e) Sub-surface Dam	1- Flat batter tank 2- Selection of suitable site and improvement of existing system foe better water management.

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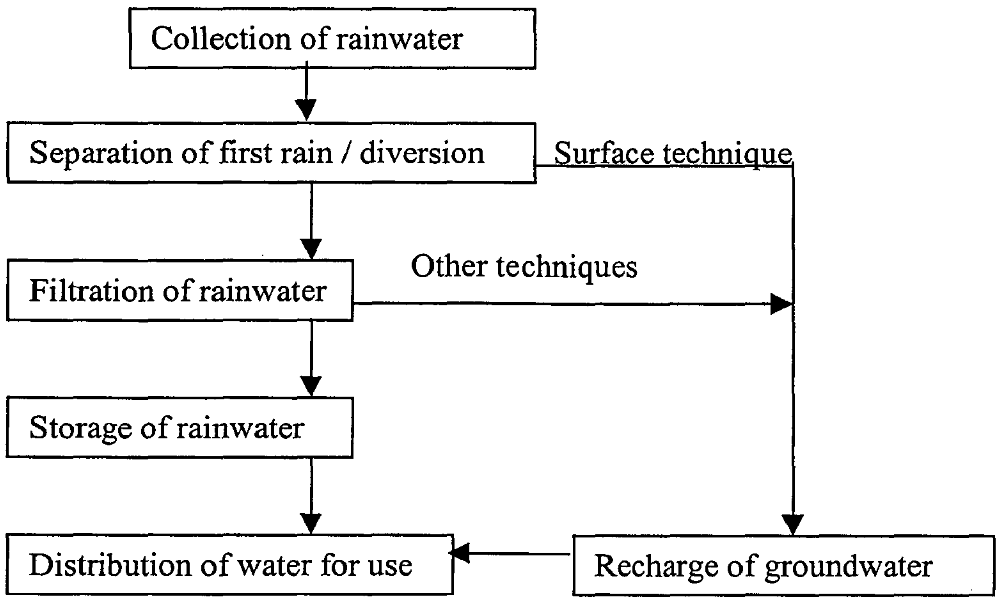
		c) Check Dam d) Percolation tank e) Sub-surface Dam f) Gully plugging	system foe better water management.
14.	Southern bi-modal Rainfall Zone	a) Ponds/Tanks b) Percolation tanks c) Gully plugging d) Contour bunding e) Check dams	Improvement of existing systems
15.	Eastern Coromandal	a) Pond/Tank/Kunta b) Nadi c) Check Dam d) Percolation Tank e) Sub-surface Dam f) Gully plugging	1- Adoption of improved design of Nadi and Tank 2- Selection of suitable sites and improvement of existing system for better water management.
16.	Western Malabar	a) Pond/Tank/Kunta b) Check Dam c) Percolation Tank d) Contour Bunding e) Bandhara f) Kolhapur type Weirs g) Sub-surface Dam	1- Improvement of existing systems, better water management. 2- Construction of structures at suitable sites.

Source: Water Harvesting and Recycling, Indian Experiences; CSWCRTI, Dehradun, 1996.

3.4 ELEMENTS OF ROOF TOP RAINWATER HARVESTING

The basic elements/functional parameters of any roof top rainwater are as follows:



Elements of rooftop rainwater harvesting

CHART-III

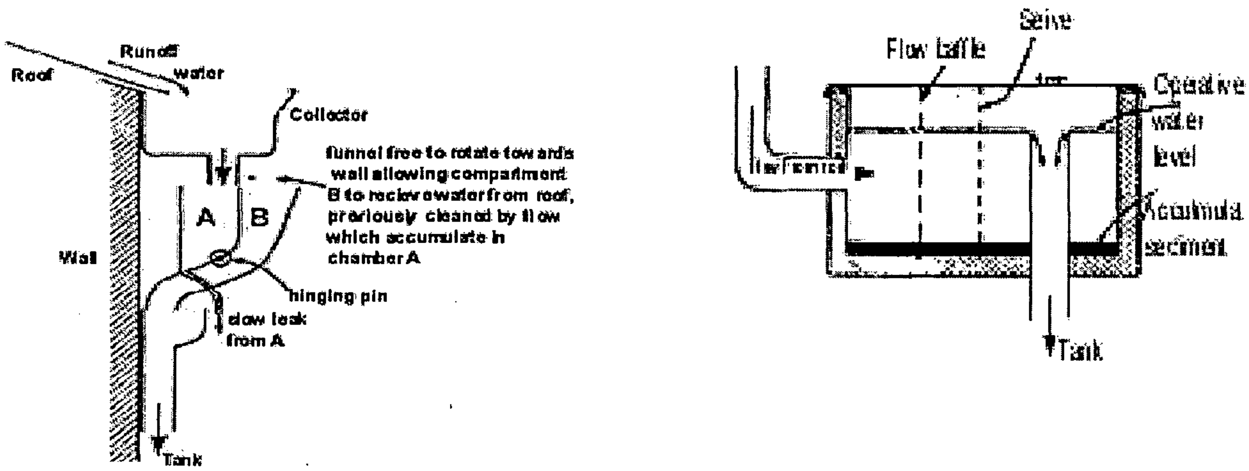
1. Collection of rainwater
2. Separation of first rain / diversion
3. Filtration of rainwater
4. Storage of rainwater
5. Recharge of groundwater
6. Distribution of water

3.4.1 COLLECTION OF RAINWATER

Catchment is the first thing, the rainwater comes in contact with. Hence it is the first thing where one should pay attention very first. The quality and quantity of harvested rainwater depend very much on the type and surface finish of the roof, its size, slope and maintenance etc. sloping roofs have the maximum potential of harvesting rainwater, next comes the flat roofs. Surface finish of the roof is also important. It should not be of any harmful material. Even thatch roof can be used for rainwater harvesting, the only thing is that the water will have some color and odour, which can be avoided by putting the plastic sheet on the roof.

3.4.2 SEPARATION OF FIRST RAIN / DIVERSION

The water from the rooftops can be directed towards an opening by providing mild



slopes. **Fig.-16 Roof water harvesting-A first flash separation and sediment accumulation system.**

This opening connected with a PVC pipe will enable the water to flow down to a tank of a well. If there are many rainwater pipes then they may be joined at some suitable point and the total rainwater can be then directed to the filter section.

3.4.3 FILTRATION OF RAINWATER

Rainwater collected from the rooftops will have lot of impurities in them. It has to be filtered to clear the filth. For this a filtering tank should be made. The collected water should be passed through this filtering tank before being stored. This will enable to harvest good quality freshwater for usage. Various types of filters are available in the market ranging from Rs.300/- to Rs.2400/-.

A filter developed by Devas roof water harvesting filters, Bhujal smvardhan mission, Devas is shown here in the figure- 17 is the outcome of the need of the people of Devas. The filter shall consist of a standard PVC pipe of size 1.2 to 2m. in length. The diameter shall depend upon the roof area. For the roof area up to 1500 sq.ft. The dia of the filter pipe is 6 inches and for the roof area more than 1500 sq. ft. the dia of the filter pipe should be 8 inches (M. Mohan Rao, 2000).

The entire cost of the filter with the filter media and other fittings varies from Rs.800/- to Rs.1200/-.

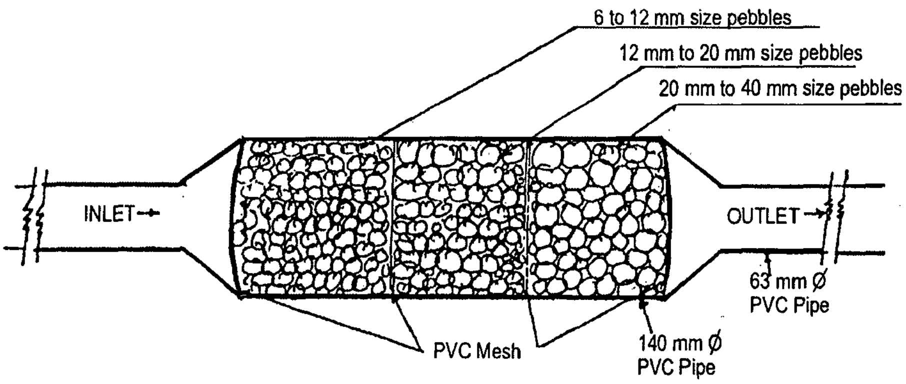


Fig.- 17, Dewas roof water harvesting filter developed by Bhujal Smvardhan Mission, Dewas.

3.4.4 STORAGE OF RAINWATER

After filtering, storage of the rainwater is required. This storage may be of two types. First type consists the storage above the ground level and second type consists the underground storage, which is called recharge of ground water. In the first method the quality of water is likely to deteriorate with time and demand proper treatment for that(C. S Agrawal, Dr. Satyendra Mittal, Himani Goyal, 2000). While in the second type the water remain fresh forever and readily available for use. In the second method the advantage is that it may occupy less space depending on the technique used for recharge. The disadvantage is that withdrawing water needs more energy.

In the storage above ground the storage tank may simply a tin container or a complicated underground tank. Depending upon the need, resources and rainfall the storage may be designed to suit the requirements of the individual household. Tanks of ferrocement and RCC are of permanent nature while the tanks of GCI sheet or galvanised plain iron sheet are having flexibility to place anywhere.

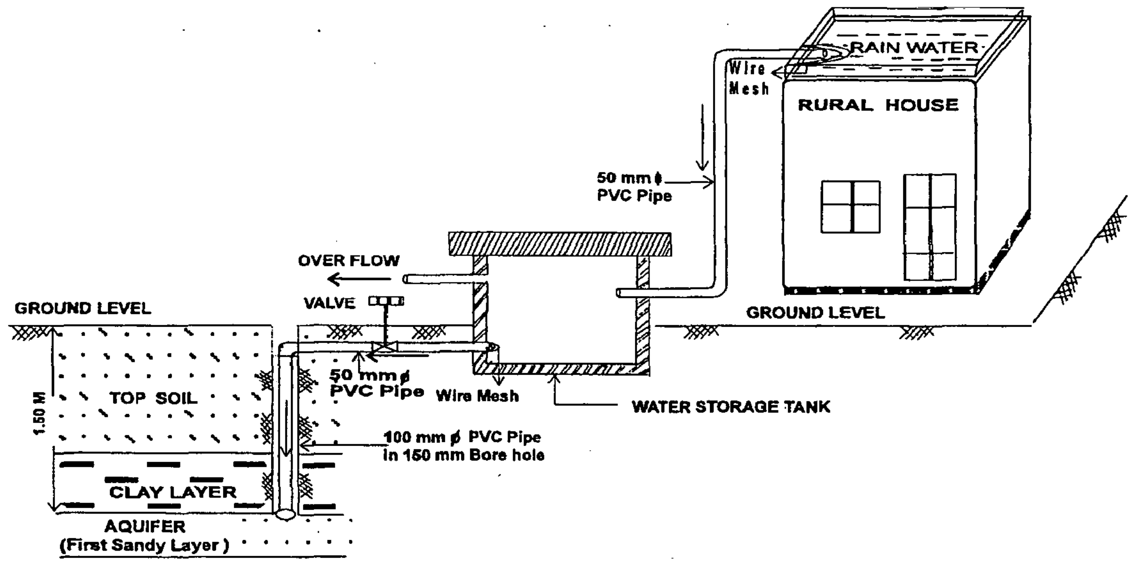


Fig.-18, Rooftop rainwater harvesting showing storage and recharge of rainwater

The capacity of storage tank depends on the following factors:

1 . Average annual rain fall
1. The length of dry season
2. Number of rainy days
3. Number of users per tank
4. Type of the catchment or roof type
5. Maintenance
6. Space available for storage
7. Water requirement

One major aspect of storing water in tank for a long period is the quality. One can put sodium hypo chloride of potassium permanganate into the water so that the bacteria can be checked from time to time. One more thing I would like to mention here that rainwater lacks the necessary minerals, which are generally in the groundwater. Monthly application of chlorine or bleaching powder is considered to be sufficient to check the bacterial growth.

3.4.5 RECHARGE OF GROUNDWATER

Recharging of groundwater through rooftop rainwater harvesting is an important feature. It is suitable in condition where there is no space to store the rainwater like existing and densely built up areas of the town and cities and where groundwater table is very low or quality of groundwater is not good. It is also good in places where seawater intrusion is a problem(Shri . R. Sethuraman, Dr. S. R. Shukla, 2000). Cities like Chennai, Vishakhapattanam etc. are the main example of such cities.

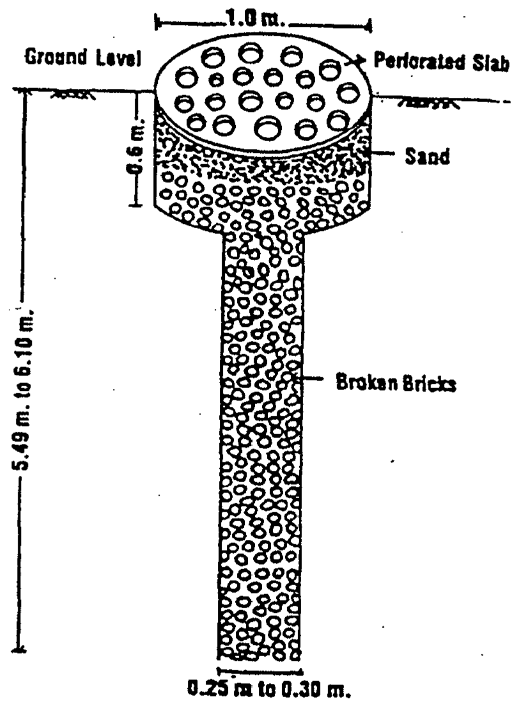


Fig.-19, Rainwater harvesting through defunct borewells

3.4.6 DISTRIBUTION OF WATER:

Distribution of collected rainwater is the utilisation of rainwater is also very important thing. At the household level various uses may need the rainwater. Some of them are following.

- For drinking and cooking purposes after proper treatment

- Flushing of sewers and drains
- Washing of utensils and cloths
- Washing of cars etc.
- Gardening / watering purposes
- Recharging the ground water
- Terrace gardening
- Used for cooler and air conditioner
- Construction of buildings

3.4.7 QUALITY ASPECT

Rainwater is the purest form of water available on the earth. It gets contaminated during the contact with atmosphere. But in areas where pollution is not so much, rainwater can be directly put into use for the domestic use including for drinking purpose also. But the places, where pollution is more it needs careful analysis and treatment for the use of drinking. Various types of filters come in the market to purify the water, which can be used for the same. After filtering water must be chlorinated of some chemical should be done to remove pathogenic bacteria if any. To ensure the purity roof top finish should not be of any harmful material or painted with any such kind of material. It is better to have the roof top of cement concrete or GI or AC sheets etc. if the GI sheet is very old and rusty it should be painted on top with any harmless paint. Even thatch roof can be able to work as rainwater catchment, the only thing is to cover it with any polythene sheet or plastic sheet.

3.5 RECHARGING TECHNIQUES

Ground water is the place where we should put our "fixed deposits" and those who understand that today will be rich in the future.

(Tom Gablier in national seminar on rainwater harvesting)

Aquifer: Aquifers may be scientifically defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells, bore wells etc.

Artificial recharge: It is a process of augmenting aquifer to underground water table by artificial infiltration of rainwater and the surface runoff.

The purpose of artificial recharge is:

1. To arrest ground water declines and improve ground water levels and availability.
2. Beneficiate water quality in aquifers.
3. Arrest seawater ingress.
4. Conserve surface water run-off during monsoon.
5. Enhance availability of ground water at the specific place and time.
6. Reduce power consumption.
7. Conserve urban wastewater.

The rainwater harvesting techniques need to be differentiated based on the final outcome or the product generated from such efforts. One, the most commonly being used is to directly store rainwater in appropriate closed tanks or containers, which can be utilised in time to come. These tanks have no connection with the subterranean ground water resource. The other one is utilising the rainwater to directly or indirectly recharge the ground water and the water so recharges becomes the part of common pool ground water reservoir. The movement and subsequent utilisation of the rainwater harvested in the ground water reservoir which becomes integral part of ground water regime is controlled by the characteristics and behaviour of aquifers wherein the rainwater harvested has been recharged (Dhaneshwar Rai).

Three types of techniques are there:

1- direct surface technique
2- direct subsurface technique
3- indirect technique

3.5.1 DIRECT SURFACE TECHNIQUE

- ***Flooding***: Recommended for the places where the shallow aquifers continue to show deep ground water levels even in post monsoon period.

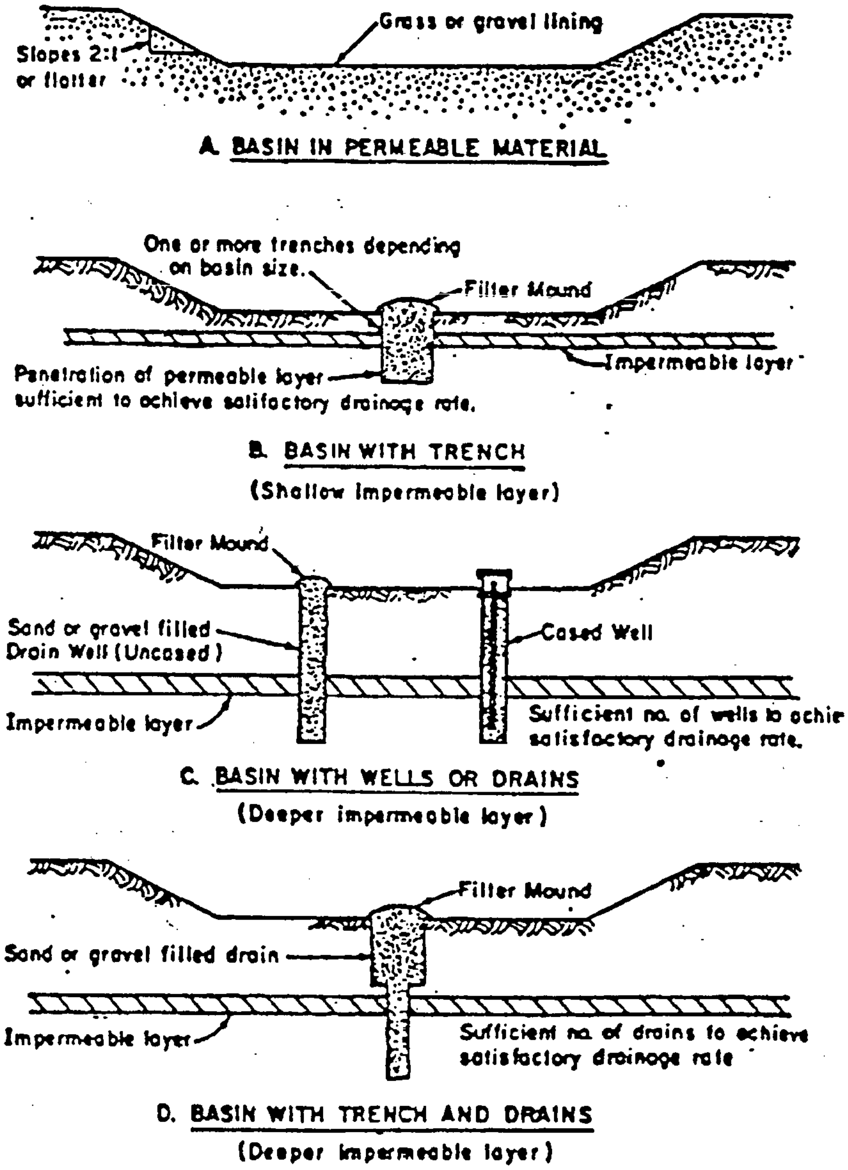
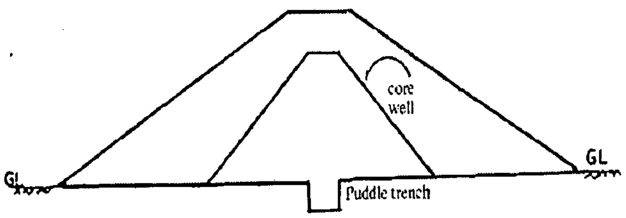


Fig.- 20 Basin and Trench method of recharge

- ***Stream augmentation:*** The natural drainage can be modified with a view to increase the infiltration by increasing the stream bed area and detaining stream flow.

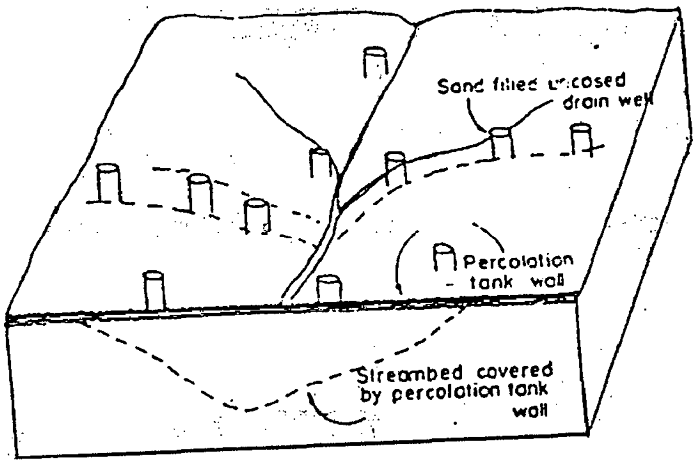
- ***Ditch and furrow system:*** This technique can be used over gentle slopes. In this technique shallow, flat bottomed and closely spaced ditches or furrows, provide larger contact area for ground water recharge from perennial streams or canals.

➢ ***Basin or percolation tank:*** Most prevalent in India to recharge ground water both in alluvial as well as in hard rock terrain. The surface runoff from steep slopes and streams is checked by constructing "Gabion" structures, check dams, weirs, gullies plugs etc. Percolation tanks are more feasible in mountain fronts occupied by talus scree deposits.



CROSS SECTION OF NALA BUNDING

Fig.- 21



front view of percolation tank

Fig.-22

3.5.2 DIRECT SUBSURFACE TECHNIQUES

In this technique the structure is below the ground and directly recharges the ground water.

➢ ***Subsurface dykes or dams:*** The promising sites for construction of such structures are narrow valleys underlying by impermeable rocks at shallow depth. Subsurface dykes or dams or bandharas with impervious material viz. clay, bitumen, tarlet or polythene sheets, arrests subsurface lateral flow of ground water.

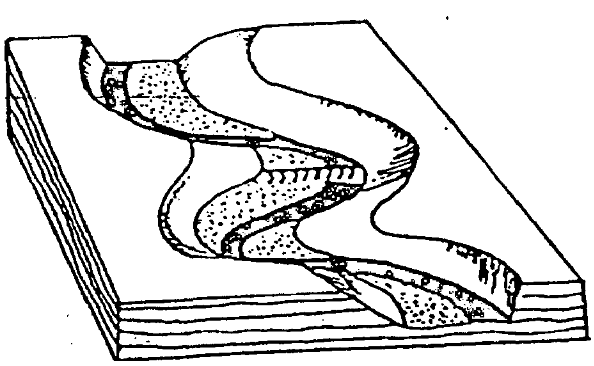
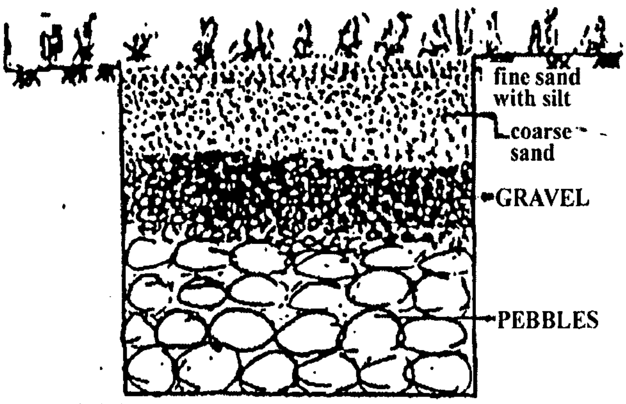


Fig. 23 Underground Bandhara

➢ ***Injection well / recharge well:*** this method is used to replenish semi-confined aquifers at deeper levels, by pumping in treated surface water. These wells can be used as pumping wells during summers.

➢ ***Recharge pits and shafts:*** These are the most effluent and cost effective structures to recharge the shallow aquifers directly. It can be suitable in areas where source of water is perennial in the form of base flow or springs. It can be dug manually at low cost.

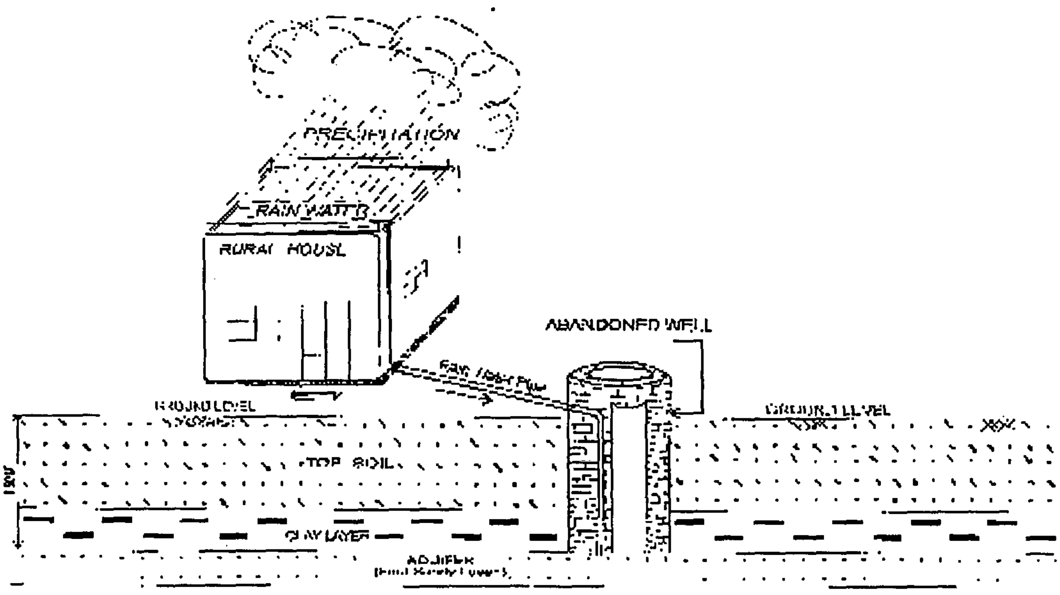


CROSS SECTION OF RECHARGE PIT

Fig.- 24

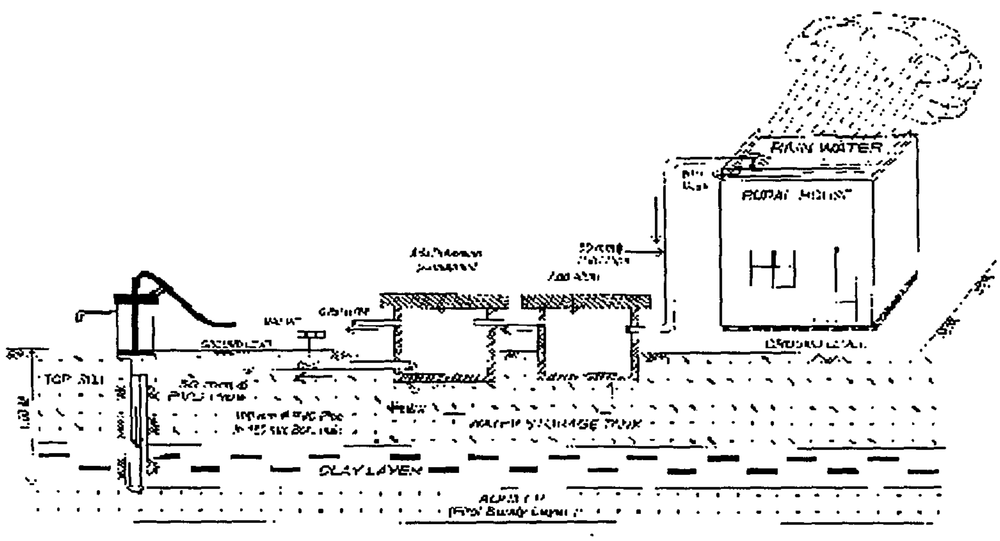
➢ ***Dug well recharge:*** In areas where water levels have declined considerably, most of the dug wells remain dry and non-operational. Such dug wells can be utilised for ground water recharge.

➢ ***Roof top rainwater harvesting:*** this method can be widely used in major towns where, high building density provides large roof top area for collection of rainwater. The source of water for recharge is the roof top rainwater.



RECHARGE THROUGH ABANDONED DUG WELL

Fig.- 25



RECHARGE THROUGH HAND - PUMP

Fig.-26

3.5.3 INDIRECT OR INDUCED RECHARGE

This method involves excessive pumping from shallow aquifers those hydraulically connected with surface water, to induce recharge to ground water reservoir. Cone of depression is also i mportant in this method.

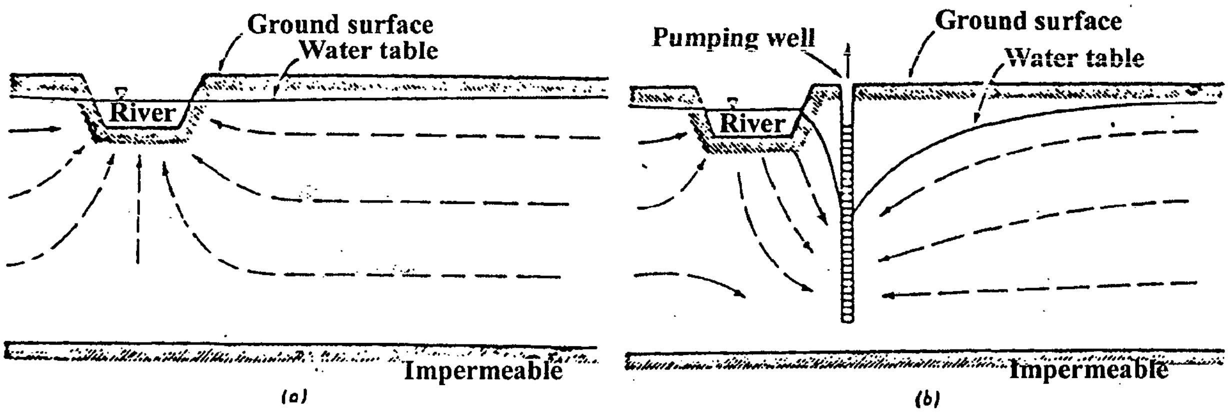


Fig. 27, Induced recharge resulting from a well pumping near river. (a) Natural flow pattern (b) Flow pattern with pumping well.

3.5 ADVANTAGES OF ARTIFICIAL RECHARGE

Following are the advantages of artificial recharge:

a. Enhanced sustainability of water supply projects and structures.

b. Improved well yields and reduced pumping lifts and costs.

c. Improved water supply.

d. Conservation of water lost to run off and evaporation

e. Enhanced well yield in areas where there is overdraft of ground water.

f. Arrest decline in ground water table.

g. Improved quality of ground water through dilution, especially fluoride, nitrate and salinity.

3.7 TECHNIQUES RELEVANT TO URBAN AREAS

a) Recharging through Defunct Open wells, Borewells & Hand pumps:

Due to severe depletion of ground water level, many open wells, bore wells and hand pumps are getting dried. Instead of discharging these wells, they can be converted into useful recharge wells. Roof water and runoff water can be diverted into these wells after filling of the wells with pebbles and river sand. There should be an effective arrangement for desilting before diverting the water into these wells.

b) Rainwater Harvesting through Ponds:

Rainwater collected from terrace of row house buildings may be lead into the nearby ponds (with previous top layer) through pipe lines for recharging the ground water aquifers. Runoff water can also be diverted into this pond after proper desilting arrangements. A production well can be constructed nearby to tap the water recharged.

c) Rainwater harvesting through Ditch and Furrow system:

This type of Ditch system can be designed to suit the topographic and geological conditions that exist at a potential artificial recharge site. This system is particularly advantageous where recharge water contains high loads of suspended sediments.

d) Storm run off collection and recharge:

The run off water generated during monsoon within an area can be well utilized for ground water recharging by diverting it into suitable designed recharge structures in Public parks, Play grounds, Stadiums, Airports, Railway stations, Bus stations, Temple tanks, Artificial Ponds, Huge dug wells etc.

e) Artificial Recharge through Storm water Drains

Storm water drains should be designed in such a way that two separate segments are made so as to accommodate water coming from houses and water coming from the roads. The segment on the side of the road should be covered with perforated slab and should have percolation pit at regular intervals of depth 20 to 50 ft. depending on the soil condition.

f) For Agriculture Lands, Farms etc.

- It is advisable to have numerous percolation pits (pits with deep bore) in Agriculture lands for gradual percolation and recharging of aquifer.

- Construction of small bunds on slope area, slows down the run off water and helps easy percolation.

- Runoff water can be diverted into a large well through a Baby well and Filtering tank to avoid silt depositing in the well.

g) Reclamation of Sewage water:

Huge quantities of sewage water generated from the domestic segment can be separated and reclaimed through Soil Aquifer Treatment (SAT). This treated water can be used for recharging dry rivers and for irrigation purposes.

h) Construction of Bandharas on the River beds:

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

CHAPTER-IV

TRADITIONAL AND CONTEMPORARY PRACTICES OF RAINWATER HARVESTING

4.1 TRADITIONAL PRACTICES OF RAINWATER HARVESTING IN INDIA

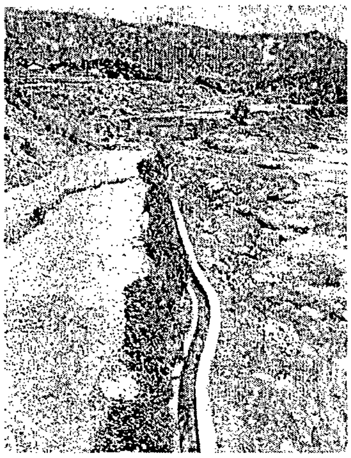
In earlier times the state took care of the water supply to large extent by development and maintenance of several ingenious and indigenous ways of storing rain and floodwaters. The concentration of rainfall in the monsoon season and the variation in extent of precipitation over space compelled the storage of rainwater in order to spread the resource availability into the lean season. It was the "dhrama" of the ruler to support and execute water storage structures. Urban planning took into consideration natural catchments and focussed on enhancing the water harvesting systems. The tank system was so well developed in many watersheds of Karnataka that it was estimated that hardly any runoff water escaped from the catchment. Settlements like Mandu, Jodhpur, Coimbatore were based around their water tanks and their associated catchments. The city of Jodhpur was built around the catchments of 35 tanks and Coimbatore around 24 tanks (Ashish Banarjee & Manu Bhatnagar, 2000).

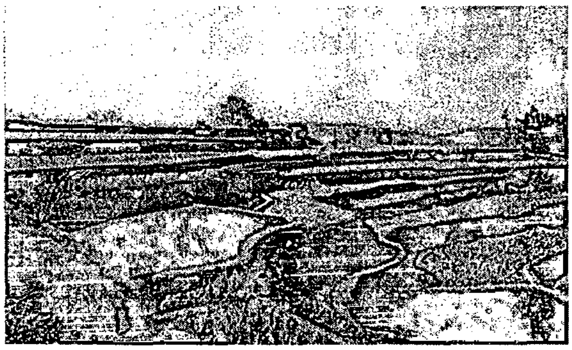
In ancient Rome, residences were built with individual cisterns and paved courtyards to capture rainwater to augment water from the city's aqueduct. There are evidences that even during Harappan period there was very good system of water management as could be seen in latest excavation at Dholvira in Kutch.

The traditional structures varied from State to State and even from different regions of India (S. K. Sharma, 2000). In hilly and high rain fall areas, general practice is rooftop collection and storage by constructing dug cum embankment type of water storage structures on foothills to arrest flow from the springs and streams. In Rajasthan, traditional water harvesting systems are Tankas (underground tanks), Khadins (embankment in plain areas), which are utilised for collection of surface runoff from the micro-catchment. The traditional runoff harvesting structures in southern peninsula ate Bandharas (weirs), Kolhapur type weirs (open well), village ponds and stone lined tanks in Maharastra and Oranies in Tamil Nadu.

4.1.1 Hill And Mountain Region

- Diversion channels leading directly to agricultural fields (e.g. guhls and kuhls of Western Himalaya). About 40 percent of the heavy rainfall is lost as runoff in the Garhwal region. As





Zabo system of Kikruma village in Nagaland

fig. 28 Photograph showing Guhls of Garhwal Region. **Fig. 29**

a result irrigation depends on diversion channels called guhls, which are full during the monsoon but whose discharge gets sharply reduced during the winter.

- Occasionally, the channels first lead into a storage structure so that water can be used in the subsequent dry period, too (e.g. zings of Ladakh).

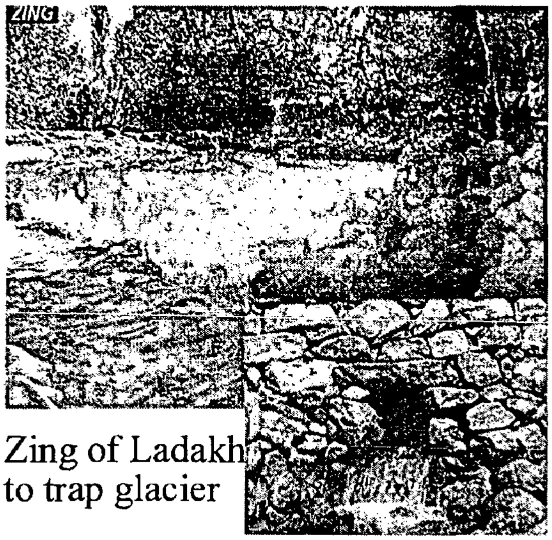


Fig. 30

The entire cultivated area of Ladakh, which stands out like an oasis in cold, rocky desert, depends on assured irrigation from the waters of melting snow through long, winding streams from the upper mountain reaches. Snow and glaciers melt slowly throughout the day and water is available for irrigation in the later evening. This water is collected in tanks, locally called Zings, and used the next day.

- Natural springs were often harvested.
- Rainwater harvesting from rooftops.

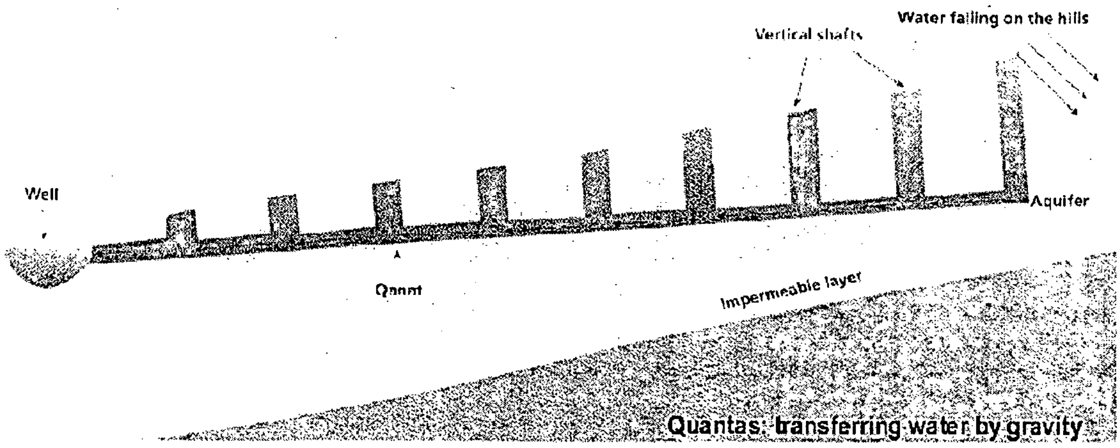


Fig. 31

Quanta's or underground canals that tap an alluvial fan on mountain slopes and carry it over large distances, were one of the most ingenious of ancient hydro-technical inventions. They originated in Armenia around 1000 B. C. and were found in India since 300 B. C.

- In the northeast, spring water is often carried over long distances with the help of bamboo pipes.

Bamboo drip irrigation of Meghalaya
Fig. 32

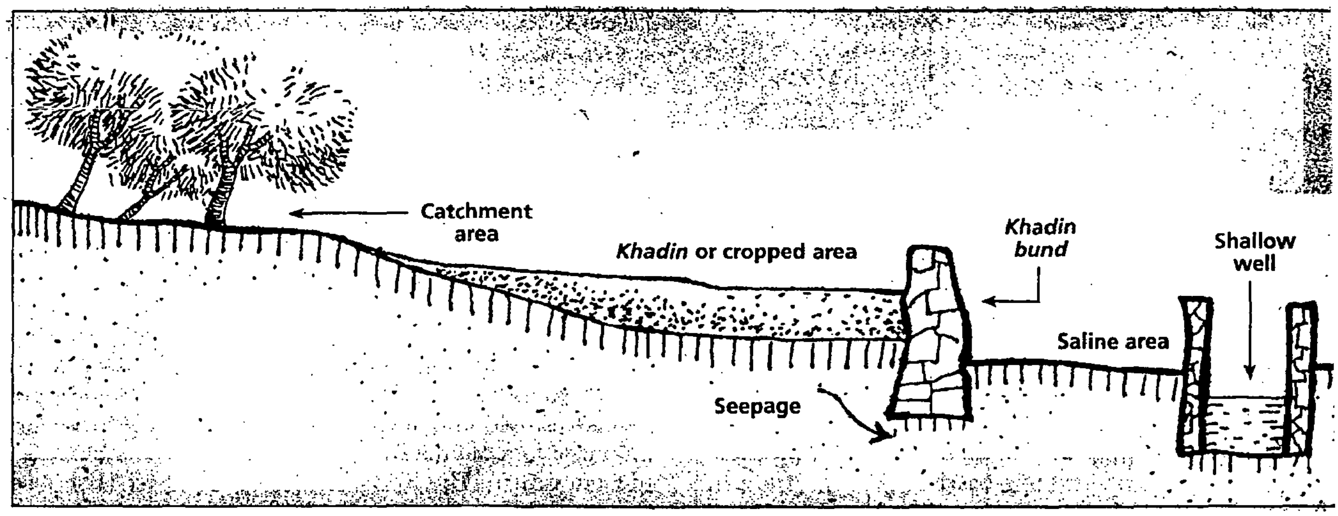
Rooftop rainwater harvesting in Aizwal
Fig. 33

First photo showing Bamboo Drip irrigation system of Meghalaya, which is 200 year old. In this system stream and spring water is tapped by using bamboo pipes. In another photo rooftop water harvesting is shown in Aizwal, Mizoram.

4.1.2 Arid And Semi- Arid Regions

- Rain fed storage structures which provided water for a command area downstream (e.g. tanks).
- Stream or river fed storage structures, sometimes built in a series, with overflow from one becoming runoff for the subsequent one (e.g. system tanks of Tamil Nadu, bandharas of Maharashtra, keres of Karnataka).

- Rain fed storage structures, which allow runoff to stand over and moisten the fertile soil-bed of the storage structure itself, which is later used for growing crops (e.g. khadins of the Jaisalmer district and johads of the Alwar district in Rajasthan).



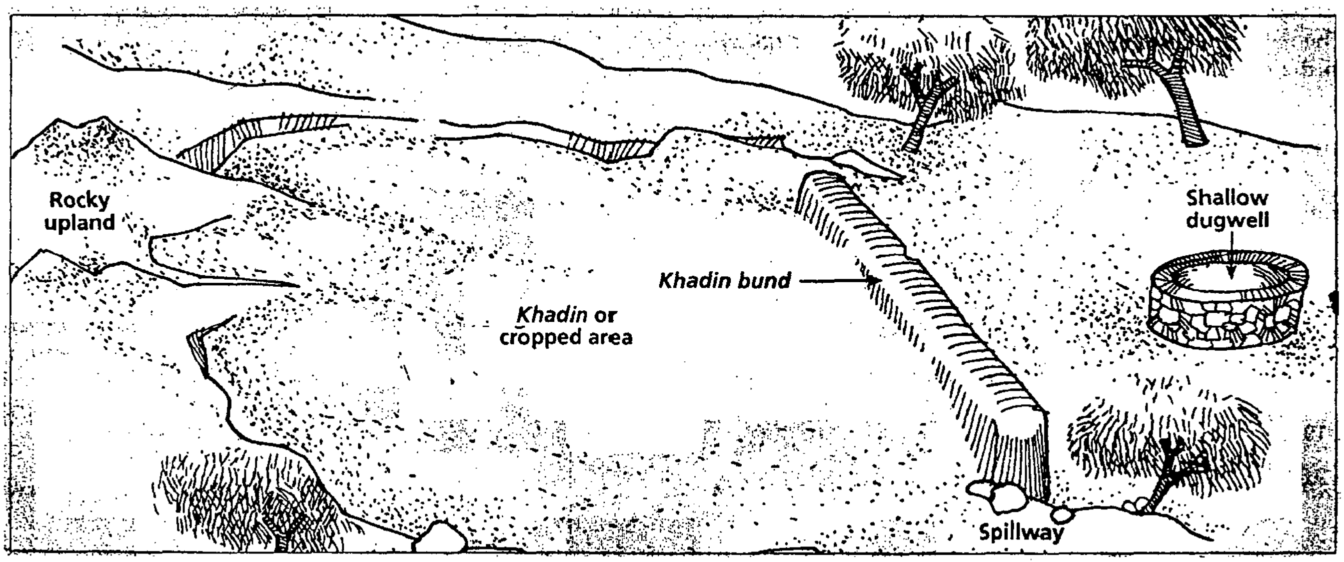
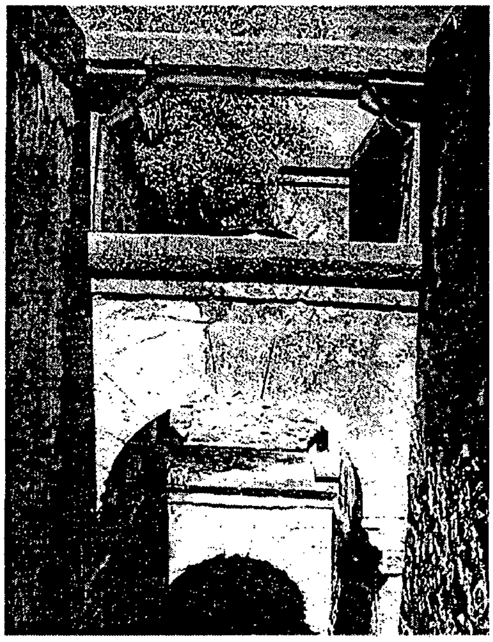


Fig. 34 , Khadin system of Rajsthan

First designed in Rajasthan by Paliwal Brahmins of Jaisalmer in the 15th century, the Khadin system is reminiscent of the agriculture of the Ur civilisation of Iraq and of the Nabateans in West Asia.

- Groundwater harvesting structures like wells and stepwells were built to tap groundwater aquifers (e.g. bavdis of Rajasthan).
- Groundwater harvesting structures like wells and stepwells were invariably built wherever they were possible, especially below storage structures like tanks to collect clean seepage for use as drinking water (e.g. several such structures can he found in the forts of Chittor and Rantharnbhore).



Step wells of Gujrat
Fig. 35

Step wells are unique form of underground wells found in Rajasthan and Gujarat. A long stepped corridor leading down five to six storeys to the well at the far end is an essential feature of a stepwell.

- Rainwater harvesting from rooftops (e.g. tankas of pali).
- Rainwater harvesting using artificially created catchments, which drain water into an artificial well - just about any land, can be used to create such a water harvesting structure (e.g. kunds of Rajasthan).

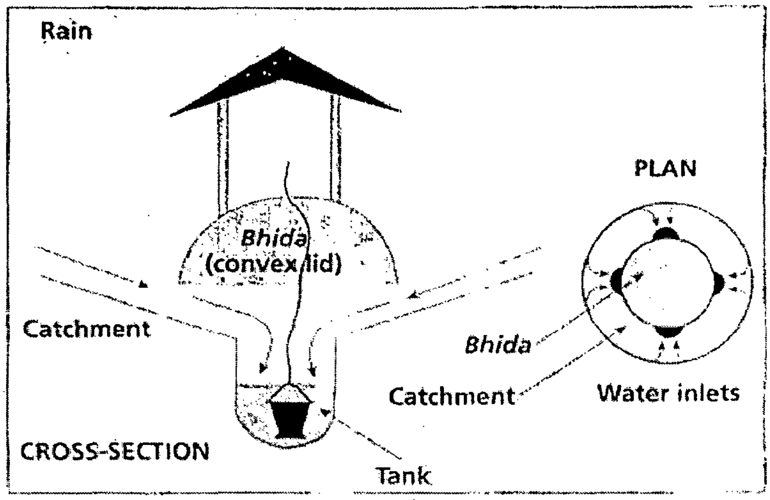


Fig. 36, Cross section of a kund in Rajasthan

Kunds are roughly 6 m deep and 2 m broad. The sides of the pits are plastered with lime and ash. The sketch shows how a kund works.

- Special rainwater harvesting structures which help to keep sweet rainwater from mixing with saline groundwater and, thus, providing a layer of potable water (e.g. virdas of Kutch).

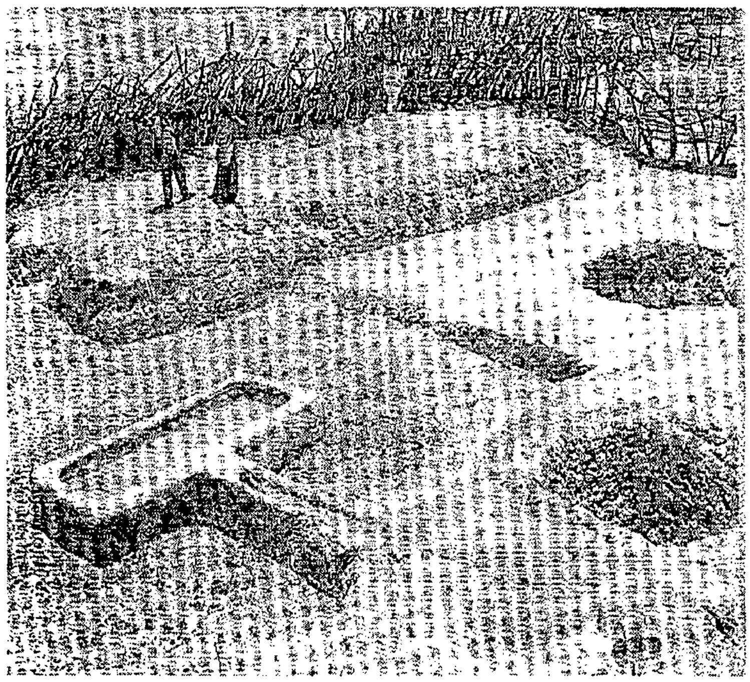


Fig. 37 Water harvesting through Virdas in Gujrat and a closer view of well

Virdas were the principal means of water harvesting by the nomadic Maldharis of Gujrat. Virdas are shallow wells dug in low depressions called jheels (tanks). These are usually connected to a trough with a channel. A fence is put to prevent animals from destroying these troughs. Virdas collect enough rainwater to ensure the availability of fresh water throughout the year. The water can be utilised from 20 days to four months depending upon the use.

- Horizontal wells similar to the quanats of the Middle East to harvest seepage down hill slopes (e.g. surangams of Kerala).

4.1.3 Plains And Flood Plains

- In the flood plains of major rivers, people built inundation channels which allowed floodwater to be diverted to agricultural lands (e.g. flood irrigation system of west Bengal).
- In specific types of soil and cropping regions, people also store rainwater in the agricultural fields by bunding them (e.g. haveli system of Madhya Pradesh).
- Dugwells.

4.1.4 Coastal Areas

- Regulatory systems to control ingress of saline riverwaters, especially during coastal tides, and thus maintain crop productivity in the coastal plains (e.g. khazana lands of Goa).
- Dugwells.

4.1.5 Causes For Decline Of Traditional System

People want 'modern' systems because nobody likes to walk long distances to fetch water from a well or a tank if this facility is available by turning a tap at home. Similarly irrigation water available from a sluice or by switching on a pumpset is considered more desirable. Only when modern systems fall - taps go dry, dams silt up - people think of traditional systems. There are however, large parts of the country where modern systems will never reach because of the sheer costs involved. People in these areas continue to depend on traditional systems for both irrigation and drinking water. Another problem with modern systems is that they have increased the dependence of rural communities on the government agencies, which often fail to meet the, basic needs of the people. Pipes are often laid in election years but water is rarely released in them.

The term traditional systems do not imply old or decrepit structures. These systems are distinct from large capital intensive, state-managed structures. Modern systems, apart from their high monetary costs, have enormous ecological costs, too. Use of water generated by them usually goes against the basic norms of sound agrocilmatic planning. Mining of groundwater through borewells is now extensive. Many government water agencies do not even understand ecological nature of water source they are tapping and assume that it will be available on a sustained basis. Even the-sociopolitical impacts of modern systems have been adverse. Traditional community-based structures contribute to social cohesion and self-reliance. Often the responsibility of taking decisions and action was left to individuals groups and local communities working together. This encouraged economic independence and optimatisation of local resources at the micro-level. Traditional systems used low cost, user-friendly techniques and were easily kept in good operational condition by local communities. Modern systems broke down the community and increased dependence on the government. The problem is compounded by the fact that modem systems, operating on market economy principles, are far from perfect in terms of their distributional impact. A few are favoured at the cost of many. Corrupt government agencies often fail. to keep modern systems in good working conditions.

Water is a major force in economic growth. If development of water resources has to be sustainable, equitable and community based, traditional systems have to be rejuvenated and developed.

Traditional water harvesting techniques have been severely eroded, thrown into disuse and even eliminated in most parts of the country.. Since Independence, this deterioration has worsened despite the fact that the present system of centralised supply and management of water has failed to meet the needs of a large number of people. There are about 500,000 tanks in the country, mainly used for irrigation. Due to siltation resulting from deforestation and degradation of catchment areas, many of them have become unusable and groundwater recharge has also been affected. Deterioration of percolation tanks and encroachment of tank beds in many parts have led to a sharp fall in the groundwater table and drying up of drinking water open wells. Some of the facts responsible for the decline of traditional systems are:

1. Growth in population and water demand, which could not be met through traditional technologies and systems; and at the same time, availability of modern and more convenient water supply through centralised storage systems like reservoirs and canals because of the official emphasis on them led not only to a halt in the expansion of traditional systems but also to disuse and consequent deterioration of the existing ones;

2. The centralised modem systems were initially installed in good faith to provide the people with more convenient and abundant supply. But, over the years, the government machinery has developed an open bias in flavour of these large complex and costly systems with low capital efficiency ensuring that power and authority stays with the bureaucracy and the community remains bonded to it;

3. The fostering of greater dependence on the state itself for even small matters like maintenance of existing systems and the powers that government agencies have acquired through existing water and land resources laws which provide complete control over these resources, leading to large scale misuse;

4. State promotion of individual beneficiary-oriented schemes and the accompanying decline of active community participation in the maintenance of traditional systems;

5. Commercialisation of agriculture and the large scale cultivation of cash crops alien to local micro-climates, which work well for a short time but with serious problems emerging over the long term;

6. Expectations of quick individual returns, resulting in a general decline in community cooperation;

7. Changes in distribution and concentration of ownership of land and community resources in fewer hands;

8. Emergence of state-sponsored institutions which were largely land-centred in their perspective as compared to traditional water harvesting systems which viewed land in relation to water and thus had a water-centred perspective;

9. Unchanged state investment patterns which were developed during the colonial regime and neglected small water harvesting irrigation systems; and,

10. Inability of government agencies to take a holistic view of water as a product of larger environmental management.

Modern attempts to restore traditional systems must reckon with the causes for their decline. They must also be based on a clear understanding of whether the conditions for their restoration are present today or not. If the 'community' supporting the traditional system no longer exists, it would be futile trying to build the structure first. Initial efforts would have to be made on building up the 'community' once again. Furthermore, social contradictions in some systems developed to the point that they collapsed. These contradictions will have to be carefully considered.

Specifically, some water harvesting systems were caste-based. British policies hardened caste hierarchies. Caste-based institutions became instruments of coercion and control. The British fragmented and divided communities to maximise revenue collection. Community-based systems were an antithesis to the British model of centralised rule. Perhaps, it was factors like these, which contributed to the decline of water harvesting systems in Tamil Nadu. On the other hand, as in the case of the kuhls of Himachal Pradesh and kuhals of Jammu and Kashmir, traditional systems succeeded where the community participated by contrubuting voluntary labour and money to construct and maintain the structures.

4.2 TRADITIONAL WATER MANAGEMENT IN JODHPUR: A Case Study

4.2.1 Introduction

Jodhpur is the second largest city of Rajasthan, and ancient capital of the Marwar clan of the Rajputs. The old capital of the Marwar was shifted from Mandore to Jodhpur for several reasons, one of which was shortage of water. Located on the slopes of a rocky hill, the city of Jodhpur has been dependent on rain and groundwater harvesting for essential water supplies. The whole plateau serves as the water catchment for 50 functional surface water bodies like nadis, talabs, tanks and lakes, and indirectly for about 154 ground water bodies like wells, baoris, and jhalaras. The city of Jodhpur is an excellent example of how an extraordinary water management system has been destroyed in a desert city through unthinking processes of modernization and urbanization.

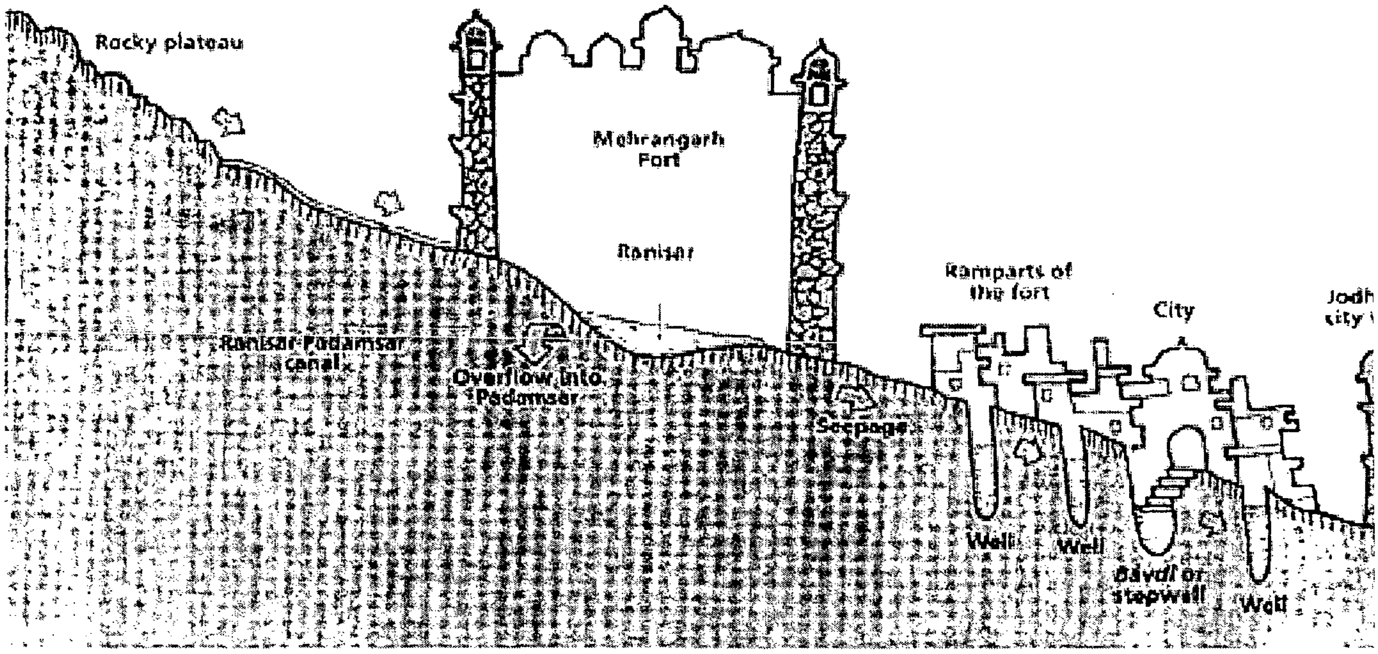


Fig. 38 (Jodhpur once ingeniously captured the runoff from the rocky plateau and also the seepage through wells and stepwells.)

4.2.2 Water supply

The present water requirement of Jodhpur, with an estimated population of 0.9 million in 1991, is 27 million gallons per day (mgpd). This is largely met by surface reservoirs but with an increasing dependence on groundwater. Of the 27 mgpd requirement, 22.4 mgpd is being currently supplied. Surface water reservoirs account for 55-60 percent of the water supply. The major reservoirs, Jawai and Kemavas, in addition to supplying water to Jodhpur, also serve the needs of Pali and Rohit towns as well as the villages of Pali and Jodhpur districts en route. Only 30 percent of water released from Jawai, and 50 percent released from Hemavas goes to Jodhpur. During poor monsoon years , the available water is not sufficient to meet the demands of Jodhpur and all other settlements.

Dependence on groundwater has increased because of the increasing shortage of surface water. During the last few years, groundwater has been the only available source for Jodhpur frim January to the next monsoon. Aquifers in and around Jodhpur are not copious and can not, therefore, meet the requirements of the city. The water table has already reached 45 m. below ground level.

4.2.3 Water sellers

Since 1980-81, water has turned into a saleable commodity in Jodhpur. Although prior to 1980-81, water was being sold for functions and constructions only, but now it is sold for marriages, social functions and domestic use as well. Normally it is sold for Rs. 10/- for one tractor although there have been times when it was sold at the rate of Rs 35/- per tractor.

4.2.4 Water during drought

During drought periods, the local sources have usually played a very important role. In 1985, the water crisis had reached such a stage that the government was at one time thinking of evacuating the city. But local sources like Tapi bavdi, which were cleaned up, supplied 0.25 mgpd of water and saved inhabitants living within a radius of 5 Km from the bavdi. An effort to revive the local sources is, therefore, urgently needed.

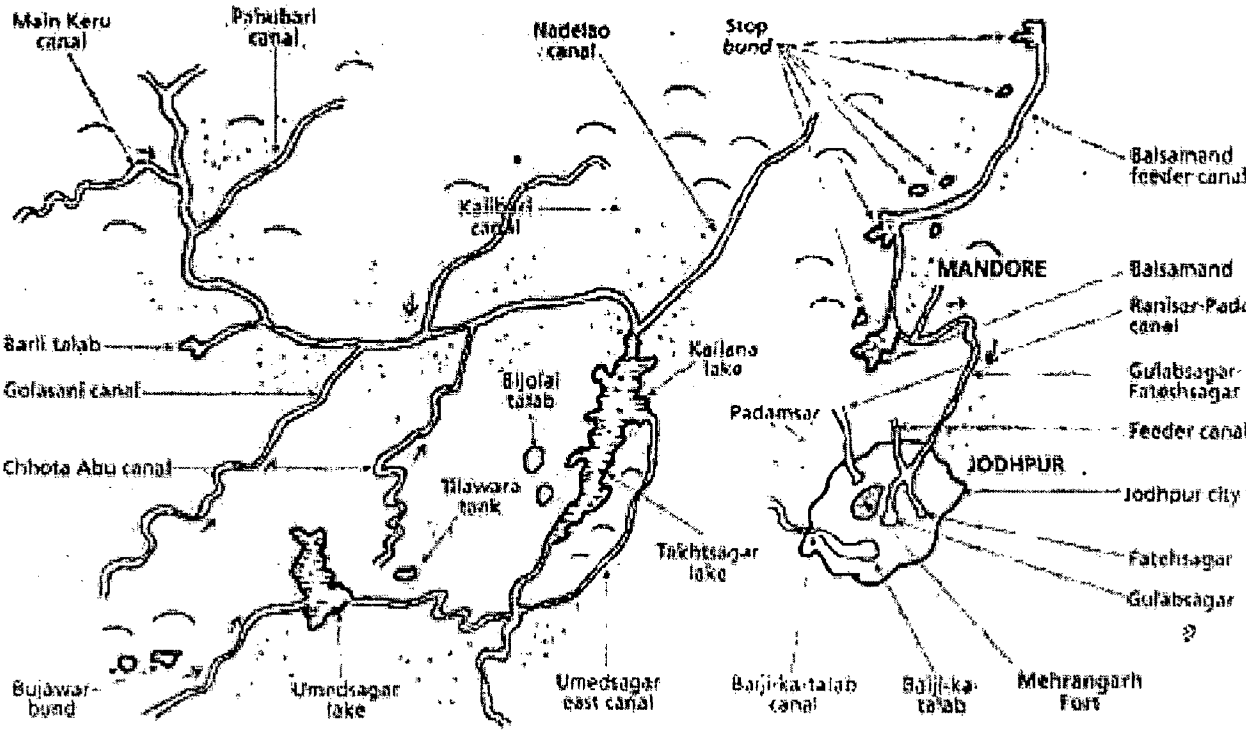


Fig. 39 (A great impetus to water supply schemes of Jodhpur was given during the reign of Mahraja Jaswant Singh ii (1872-95), when Kailana lake was constructed in a famine year. Ranisar bunds were raised, and long canals were constructed to feed the city tanks. The map shows some of the key canals and reservoirs that used to supply water to Jodhpur.)

4.2.5 Various Rainwater Harvesting Structures In Jodhpur

We can divide these structures into two main categories.

4.2.5.1 SURFACE WATER BODIES

The survival of surface water bodies of Jodhpur depends essentially on the survival of its magnificent water catchment – the Chonka-Daijar plateau. Each water body was provided with an extensive catchment, watercourses and canals to trap the precious rainwater.

Nadis : The local name given to a village pond used for storing water from an adjoinging natural catchment during the rainy season, was an ancient system for harnessing rainwater. Most villages had their own nadi, and the site was selected on the basis of available natural catchment its water yield potential. It serves the need of water for two months after the rains.

Talabs : A talab is a popular word used locally for water reservoirs situated in valleys and natural depressions. These talabs have been the main source of water for the human and animal population until recently. Today only Ranisar and Padmsar are safe talabs and still used for drinking and other purposes by the local population.

Tanks : In contrast to talabs, especially those of more recent origin, tanks were constructed in situ with massive masonry walls on four sides and an almost impermeable floor as a standard pattern. Tanks were invariably provided with an efficient system of canals to bring rainwater from the catchment areas on the outskirts of the city. An exclusive catchment area and a system of canals thus supported each tank. Out of five tanks in Jodhpur, Fatehsagar is the oldest one, built in 1780.

Lakes : Jodhpur has five large reservoirs located on the outskirts of the city in a more or less natural setting. The oldest is Balsamand, built in 1126 AD. The total five lakes in the

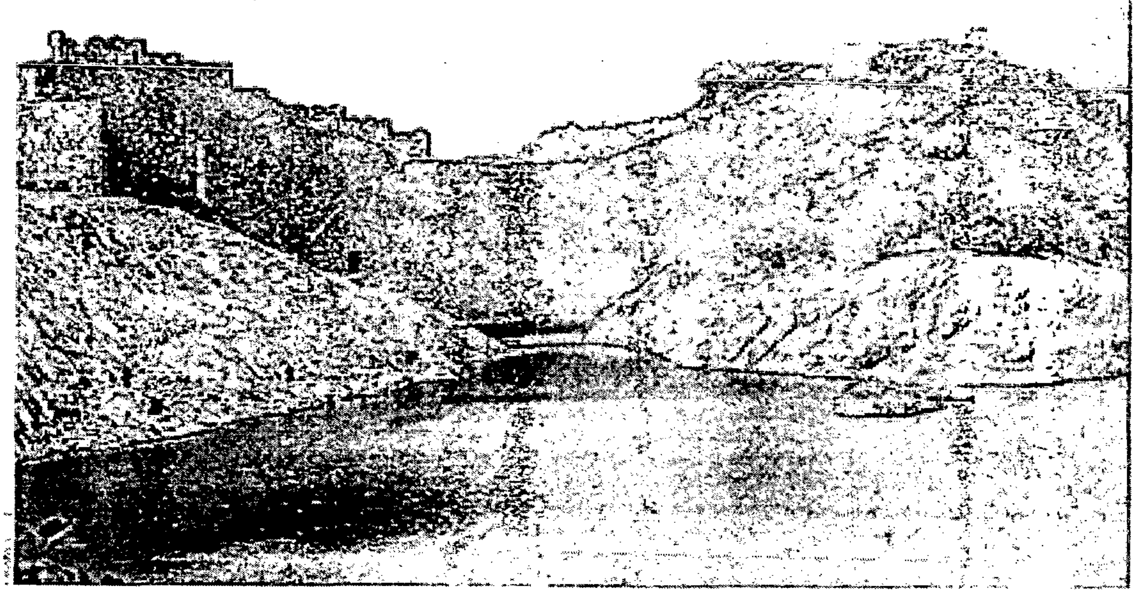


Fig. 40 (The Ranisar lake of Jodhpur, situated inside the Meharangarh fort, was reserved for the use of the nobility. Its water is still used for drinking. The window in the center of the picture is the port through which the overflow from the lake goes into the Padmsar)

city can hold about 700 million cubic feet of water at a given time, which can support 0.8 million people for eight months. Due to poor state of catchments and canals which carry rainwater to them, these lakes do not get adequate water , even during normal rain years.

Canals : Johpur's canal system consists of numerous watercourses, channels and aqueducts to carry rainwater to the city's various nadis and talabs. It is perhaps these canals which led to the construction of large number of nadis and talabs around Jodhpur before tanks came into existence.

Jodhpur is perhaps the only city in the country where an all-out effort was made to conserve every drop of rainwater. To achieve this, every catchment and hillock was drained by canals. Not only did each lake, tank and talab have efficient canal system, there were interconnections between lakes and between lakes and tanks to distribute to distribute water to all parts of the city. The city also had underground canals, which seem to have escaped the attention of most experts.

4.2.5.2 *GROUND WATER BODIES*

A large number of wells, baoris and jhalaras constitute the major groundwater bodies of Jodhpur. These water bodies were built with the sole purpose of ensuring easy and regular water supply to the neighboring areas. They neither have any catchment of their own nor are they connected with any watercourse. However, each one collects the subterranean seepage of a talab or lake located upstream. Their size, shapes, depths, designs, layouts and locations vary a great deal. Minimum space has been used in the construction to save money, time and energy. Wells were dug essentially to enhance drinking water supply while baoris and jhalaras were meant for washing and bathing, a situation which exists to date.

4.2.6 Conclusion

The above case study reveals the fact, that the city, even in desert can survive through better water management practices. The city of Jodhpur is situated in desert area of Rajasthan and is supporting the population of millions only due to the better water management practices and subtle utilization of rainwater through rainwater harvesting. The study also establishes the fact that rainwater harvesting can be incorporated in city/regional level planning. It is the combined effort of the government and people, which brings the prosperity. There are many such practices in India and abroad that need to be studied and incorporated in the planning and management. We have already discussed the various technologies and practices which are or were in practice. Jodhpur is the one example of such tradition.

This study shows that Jodhpur had taken the advantage of natural slopes and drainage patterns to harvest its rainwater, but the current response from people and government has nearly ruined the city and created acute shortage of water. The encroachment upon natural drainage network has badly affected the traditional water storage structures. Hence there is an urgent need to revive such practices and adopt rainwater harvesting in town planning before it is too late to realize the situation.

4.3 CONTEMPORARY PRACTICES AND INDIAN EXPERIENCES

(a) Yaval Taluka region, Jalgaon, Maharashtra – 6 percolation tanks

(b) Mehsana Area – Gujarat

(c) Ghaggar river basin – Haryana

(d) Injection well at Ahmedabad city

(e) On farm rain water Management at Raipur (M.P.)

(f) Percolation tank and check dams in A.P.

(g) Rock fracturing in Deccan Trap (Maharasthra)

(h) Sub surface dyke in Ottapalam Kerala and Kerala Agriculture University.

4.3.1 Central Ground Water Board

NCT of Delhi

1. Artificial recharge through 4 check dams in JNU and IIT created storage of 4,600 to 22,180 cubic metre – Water levels in the wells recorded rise of 0.8 to 9.9 m and area of 75 hectare benefited.

2. Roof top RainWater Harvesting and recharge through two injection wells in IIT campus – Rise of 0.5 m in water levels.

3. On the President's estate, recharging of ground water began recently using water, which would otherwise flow into drains.

Punjab

1. Roof top RainWater harvesting to recharge ground water through injection well in one of the CSIO buildings. Rise of 2m in water level was observed.

2. In Amritsar , water flowing out of golden temple Sarovar is to be used for recharging ground water.

4.3.2 State Governments

Madhya Pradesh

1. District Administration in Dewas made roof top Rain Water Harvesting mandatory for all houses having tubewells and banned tubewell drilling – Improved soil moisture and recharged first aquifer.

Tamil Nadu

1. Chennai Metro Water Board has made roof top RainWater Harvesting mandatory under the city's building regulations. The decision has led to a rise in ground water levels.

2. Central Public Works Department has employed rainwater harvesting techniques in Rajaji Bhawan in Chennai.

Andhra Pradesh

Andhra pradesh government has made it mandatory to have rainwater-harvesting structures in all new constructions in urban areas and for leaving sufficient open area for ground water recharge.

Percolation tanks and check dams constructed chronically drought affected Rayalseema region helped in drought proofing.

Himachal pradesh

In Himachal pradesh the state government has made it compulsory for any new buildings in Shimla to have rainwater harvesting.

4.3.3 Non-Government Organization

Gujarat

1. Rooftop RainWater Harvesting and recharging of wells as a movement in Gujarat by the Saurashtra Lok Manch Trust in Mandlikpur village of Rajkot district prevented drying up of wells.

2. Agakhan Rural Support Programme in Junagadh and Surendranagar districts of Saurashtra harvested rainwater by check dams and percolation ponds involving beneficiary farmers – optimum utilisation of harvested rainwater achieved.

3. Vivekanand Research and Training Institute in Kutch, Bhavnagar, and Amreli districts constructed RainWater Harvesting structures –Helped in improving water quality and controlling the decline in water level.

Rajasthan

1. Tarun Bharat Sangh has taken up desilting and deepening of village ponds and built water harvesting structures and johads with villager's participation in more than 750 villages. The dried up streams have become perennial.

2. In Jodhpur district, Gramin Vigyan Vikas Samiti motivated the resident of 25 villages and built 2000 storage tanks (tankas) – Each house has a tanka (a water collection) structure) lined with lime and alum to keep the water fresh for four to five months.

3. Prayathna Sansthan, Solavata village constructed roof water harvesting tanks firstly on school buildings to provide safe drinking water to children. Remarkably, the attendance in these schools went up. Tanks such constructed have an average capacity of 30,000 liters and being used by village community also.

Central Ground Water Board, New Delhi has selected 3 major buildings in India for rooftop RainWater Harvesting. These buildings are National Institute of Hydrology Roorkee., Brahamputra Board headquarter Guwahati and C.G.W.B. head office in Faridabad.

4.4 THE INITATIVES ABROAD

Water harvesting – collecting natural precipitation from prepared watersheds – has the potential to provide the only source of water in some areas of the world and economical water source in many others. Water harvesting techniques were used in the Middle East as early as 3000 years back.

4.4.1 Runoff farming in the Negev

The Negev desert of Israel, maintained a thriving agriculture in the desert using runoff farming, at least four to five thousand years back. The farming, is diverting runoff from precipitation events to from bigger area to small cultivated area.

4.4.2 Water harvesting on public lands: southeastern Arizona

Twenty water harvesting systems for livestock watering have been constructed on natural resource lands of the Safford district of the Arizona. Precipitation in the area ranges from 150 to 405 mm. the water harvesting systems installed have included catchments of nonreinforced, 0.8mm butyl rubber; fiberglass asphalt and mopped with ½ gal clay asphalt emulsion.

4.4.3 Water harvesting in Hawaii

In Hawaii, to alleviate the water shortage problem, over 300 water storage systems, often combined with catchment facilities, have been installed during the past 15 years. Often water harvesting is competitive with other forms of water supply. Since over 300 water systems have been installed and the frequency of installation continues to be about one per month, this attests to their successful use and indicates that water harvesting systems should be very carefully considered where alternative means of obtaining water supplies are limited.

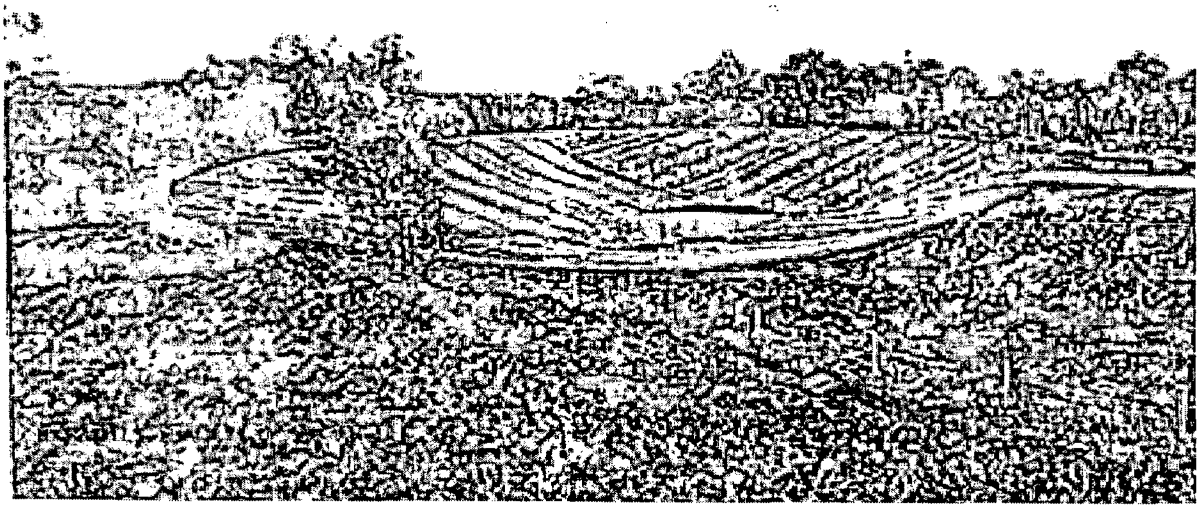


Fig. 41 (3.2 million gallon stock reservoir on the Palani on the Island of Hawaii. Reservoir is lined with 62,000 sq. ft of butyl)

4.4.4 Rainwater catchment and storage – Jamaica

In Jamaica, studies showed supplies were plentiful over much of the area but depth to water was as great as 610 metre. This difficulty lead to consideration of water harvesting catchments and storage facilities to attain the water supply. Storage tank of 10,000 gallon was constructed of metal lined with PVC bag, was built at Cross Keys, Manchester. These are as good at individual household.

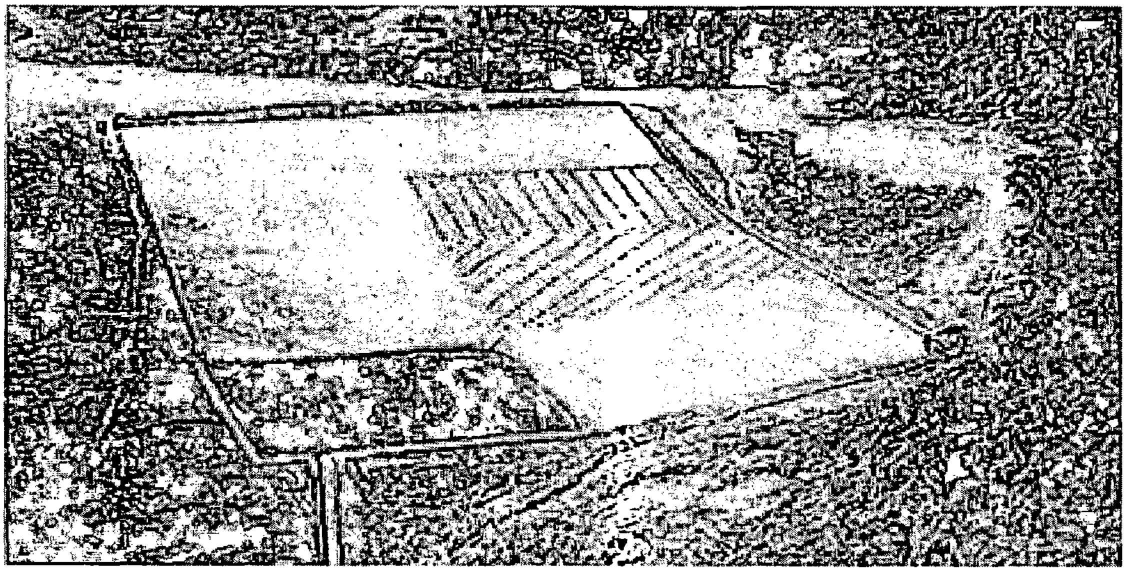


Fig. 42 (large catchment & storage facility, in Jamaica to supply 65000 gal per mainly for domestic need)

4.4.5 Japan

Tokyo is short of water once, every few years. Almost 60% of Tokyo's ground is covered with asphalt and concrete. In Sumida City office provision for roof top rain water harvesting is made, having the capacity of 1000 cum. This water is used mainly for flushing toilets in the buildings. In Ryogoku Kokugikan (sumo wrestling arena) one of the biggest facilities to harvest rainwater has been installed. It's 8400 sq.mt. roof area drains 1000 Cum. water into storage tank. There are many other illustrations where rainwater harvesting has been incorporated.

4.4.6 China

The Chinese have captured rainwater for over 1000 years but the efficiency is too low. 'Rainwater catchment and utilization' (RWCU) were set up aimed at supplying water for drinking and courtyard irrigation. Roof top rain water harvesting, highways, threshing yards and also from seepage controlled fields are some common methods practiced in China for rainwater harvesting

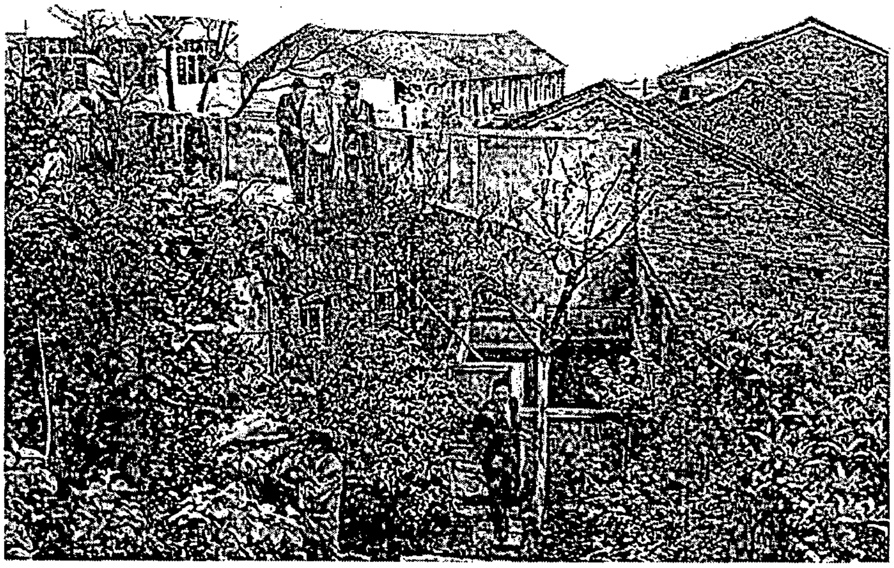


Fig. 43 Rooftop water harvesting , Chengdu, China

4.5 CONCLUSION

Traditional water harvesting systems definitely have relevance in areas where water scarcity 8s acute or where groundwater is either brackish or too deep to obtain cheaply. However, in some areas, a supplementary source may well be necessary. Traditionally, in these areas people have developed cultural practices, which encourage judicious use of water, but now these practices are dying. Water conservation education should be encouraged across the country.

It is clear that the issues involved in the revival of traditional systems are intricate and interlinked these systems are location specific and management-intensive. Planning for their revival must be based on the needs and capacities of the people so as to ensure their sustainability.

4.6 RAINWATER HARVESTING AT VARIOUS LEVEL OF URBAN PLANNING

Thus far planning response has been insensitive to this critical issue of resource management inspite of the growing unsustainability of the resource base and the limitations being thus imposed upon urban growth. Urban expansions and the rampant construction activity in the past have had negative impact on the water systems as the site development had ignored the local hydrological considerations. Planners aim at systematic colonization of the hinterland and leave resource planning to water departments and central water authorities, working on a strictly engineering approach, to deliver water and the constraints in this regard have not come in the way of planning for projected population.

The level of planning that is covered in a city will decide the approach of planners. These can be broadly discussed under following levels of urban planning.

1. HOUSEHOLD LEVEL
2. CLUSTER LEVEL
3. NEIGHBOURHOOD LEVEL
4. SECTOR LEVEL
5. CITY LEVEL

4.6.1 Household Level

At the household level the rainwater various technique of rainwater harvesting can be adopted. Various catchments in the house are rooftop, and open spaces. Rooftop rainwater may provide the rainwater of drinking quality. But the other open spaces also provide the water, which can be used for the purposes other than drinking like gardening, recharging etc. various techniques have been already discussed.

Rainwater harvesting techniques at household level shall differ according to type of housing and location of the house means it is either in densely built up area or in newly well planned area. Let us consider the type of household and possible harvesting measures.

Plotted development:

In the **newly** developed area roof top rainwater harvesting and its storage in tank is possible. Open spaces can also be harvested and the collected rain water can be put into use for recharging and other purposes. In plotted development one can individually install the rainwater harvesting structure.

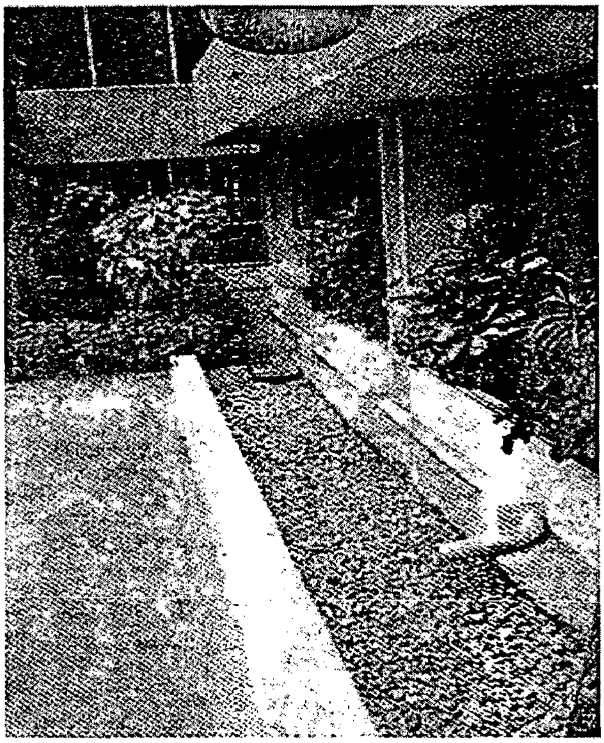


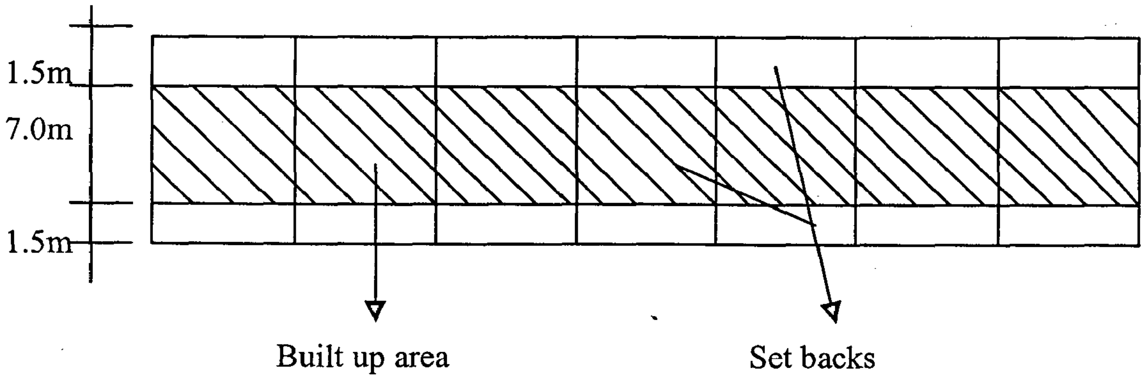
Fig. 44 Rainwater diverted to the percolation trench along the apron of the building in a plotted development area.

In plotted development setbacks play an important role, as they are integral part of the open spaces that receive considerable amount of rainfall. Hence the surface treatment of the open spaces and the diversion of the rainwater is also important. This water can be diverted to recharge the ground water through various measures.

Row houses:

Row houses need special attention for the provision as they are having comparatively less roof area and these houses are occupied by the lower income groups of the society. Hence it shall not be feasible to construct individual rainwater harvesting structure. Another point is that roofs of the houses are joined side by side and buildings are having only front and rear setbacks. It would be a better proposition to group some houses and provide a common rainwater harvesting structure.

Below an assumption has been made to calculate the rainwater from an individual house. In the assumption the plot size has been taken of 50 square metres and the ground coverage of 70 percent.



Total plot area : 50 sq.m.

Built up area : 35 sq.m.

Rain fall : 2140 mm.

Family size : 5

Total rainwater availability : 74.9 cum.

Assuming losses due to various factor : 25%

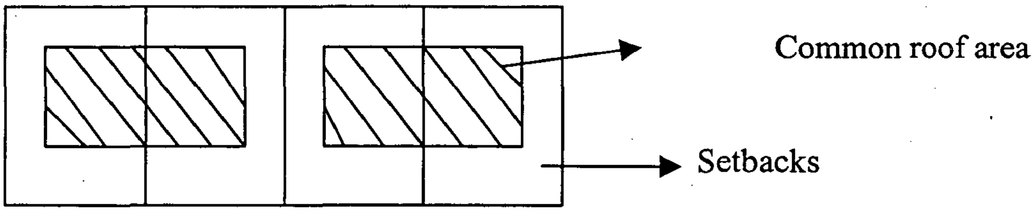
Net available rainwater annually : 56

Per capita availability of rainwater : 30 lpcd

It is clear that this much rainwater is just 20 percent of the minimum per capita requirement i.e.135 lpcd. So it is better to do it in groups of 5 to 10 houses.

Semidetached houses:

In semidetached houses common roof area can be used, hence reducing the cost of rainwater harvesting. A common storage tank and recharge pit can be made on plots. In the same way runoff from the ground can be stored in underground tanks and used for gardening etc.



(Common roof area in semidetached house that can be used for rooftop rainwater harvesting)

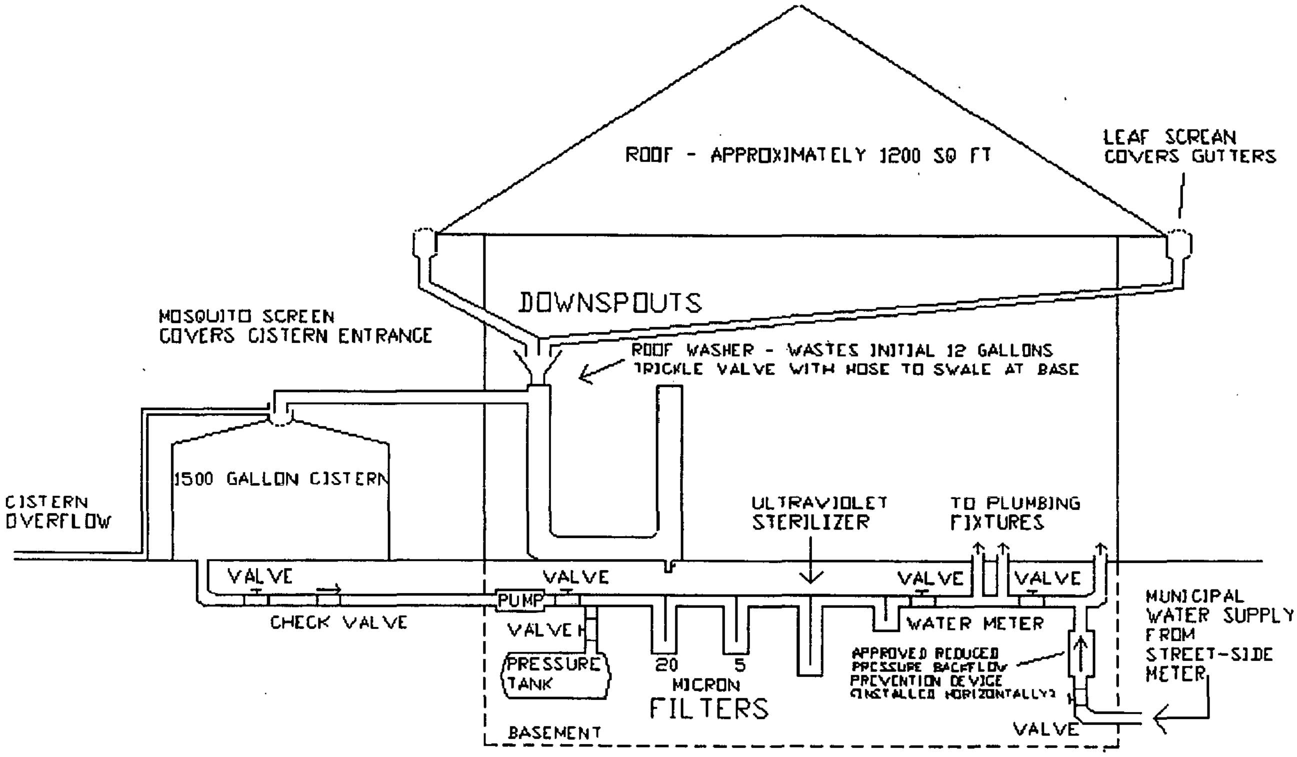


Fig. 45, Showing the plumbing of a house having pitched roof, which is very common in Dehradun and other heavy rainfed areas.

Group housing:

In the group housing most of the services in the building are shared by the inhabitants.

Fig. 46 Photograph showing an apartment building in Chennai and the rainwater harvesting technique adopted in it.

The whole building complex is in one unit of construction. Here management of water supply and other things are done by a group of society. same way runoff from the ground can be stored in underground tanks and used for gardening etc.

Hence rainwater harvesting adopted for such buildings will be different from plotted houses or any other type of housing.

Rooftop area is common hence the system adopted here will he very economical to individuals. But if it is multistoried building then per capita rainwater harvested will be less. In this type of housing the entire roof area can be divided into appropriate sections and each section having its own rainwater storage tank, and that water is supplied to that particular group for their use. That group will be responsible for the maintenance and management of the structure. Similarly recharge well can be made for group of households.

Open areas of the housing complex can have underground rainwater storage tank, water of which can be used for several purposes eg. washing of floors, gardening, car washing etc.

4.6.2 Neighbourhood Level

Cluster is the next level of urban planning. It is very important to see what is the size of the cluster and how many houses are there. This will decide the level of facility they can sustain. Generally a cluster contains a tot-lot, nursery school, park, roads and residences. I have already said the rainwater harvesting measure at the household level. Cluster level rainwater harvesting will involve the community participation, and government intervention.

At the cluster road catchment can divert its water to side storm water drain which should ultimately lead to any recharge structure. Similarly parks may have the recharge structure and storage tank, and park's water needs should be fulfilled from its own water resources as far as possible. Actually when we talk of using one own resource; we talk of self-sustainability. It can be achieved only through proper ecological balance means whatsoever we take from nature we should give it back. Rainwater harvesting at any level is to maintain this water cycle at that level.

When we talk of any project at community level, social and cultural aspects becomes very important to consider. "Even though a society may be local or remote, it is subjected to internal differentiation, stratification, and unequal social and gender relations. Many a time, development efforts may reproduce the status quo and the existing internal inequity. In implementing water-harvesting programs it is essential to look at the issue of equity. Does the program has bridge the gap between the better half and the disadvantaged or does it, as an unintended consequence, escalate the divide?" (Ujjwal Pradhan, 1999)

Dr. Ujjawal Pradhan from Ford Foundation stressed the need to pay attention to promotion of local self-governance and local control for multiple uses of water.

At the neighbourhood level 3 or 4 clusters are grouped together to form a neighbourhood. At the neighbourhood level we can extend the provision of the clusters but on the larger level. At the neighbourhood level rainwater collected from the public places can be used for fire fighting after the filtration. Excess water should be used for ground water recharge and this water can be used to fill the ponds etc. in neighbourhood parks. This pond can be used for fishing and aquaculture etc. Storm water drain should be separate from the sewer line and storm water should be used for recharge of groundwater and other purposes.

4.6.3 Sector Level

Sector level is very important from the geological point of view. Generally the lithology soil condition and groundwater level varies at this level. Hence on the basis on proper survey and information of the hydrological features we can specifically recommend the type and method or rainwater harvesting and recharge techniques.

At the sector there are various land uses, on the basis of which we can further categorize the various rules and regulation related to rainwater harvesting. Like for commercial use the measures and bye-laws will be different that the residential use. In the same way institutional and public buildings may have the common provisions.

Roads, parks and other public open spaces can be used for rainwater harvesting. At this level government and public participation is must. The following general methods can also be adopted using the site condition. Small check dams are suitable for areas in the ridges. Structures like recharge shafts, recharge trenches are suitable for garden parks.
Open ground: Remove the top soil to a depth of 30 cm to 60 cm and place with river sand to allow for slow percolation of the rain water into the soil.

Paved surfaces: Dig 120 cm deep square percolation pits measuring 60 cm each along its length and breadth, fill with small pebbles of river sand and cover with perforated concrete slabs. This is useful on footpaths and paved surfaces of various institutional and government buildings premises.

Outlets: connect wastewater outlets from the bathroom to pits, instead of to the drainage pipes.

Storm water drains: cover the drains existing with the premises and construct small boundary walls around them to a height of 30 to 60 cm to ensure gm that rainwater rushes into the drains and the water stagnates over the ground until it seeps into the soil.

In community schemes larger areas of catchment are used for collection of rainwater runoff in large size underground tanks, fenced reservoirs or by diverting it to large lakes. Treated and protected hill slopes pr protected platform areas or runoff collection from watershed management projects, can be used but the water will need treatment before human consumption. Filtration and chlorination are generally enough for this purpose.

4.6.4 City Level

The runoff water generated in monsoons within an area can be well utillised for ground water recharging by diverting it into suitably designed recharge structures in public parks, play grounds, stadiums, airports, stations, temple tanks etc.

Storm water drains should be designed in such a way that two separate segments are made so as to accommodate water coming from house and water coming from the rocks. The segment on the side of the road should be covered with perforated slabs and should have percolation pits of depth 20 to 50 ft. depending on the soil condition at regular intervals.

Huge quantities of sewage waters generated from the domestic segment can be separated and reclaimed through soil aquifer treatment (SAT). This treated water can be used for recharging dry rivers for irrigation purpose.

There are various factors, which should be taken care while planning for new cities like there should be enough for afforestation and green areas, which can work as natural infiltration areas for rainwater. The planners must take care of natural drainage pattern of the site and preserve the catchment and water shed areas. Every effort should be made to check the runoff water. The whole city can have the network of canals and ponds and reservoirs. Existing ponds and tanks must be preserved.

The cities like Dehradun that are having the advantage of high gradient can have the system of water supply, which work on gravity. Runoff water collected on the high catchment areas can feed the low-lying areas. And the series of this kind of supply will necessitate the supply of the highest areas to be fed by other means. This supply will be through gravity and no power of very little power will be required to supply the low-lying area.

Several seasonal streams become activated during monsoons providing the outlet to floodwater as well as local runoff. This water should be stored on the channel itself. The water can be detained through construction of appropriately located regulators. Deepening and widening wherever possible can enhance the storage capacity of channels. Naming few are Bindal River, Rispna Rao, and its attributeries. Storm water channels can be enlarged to form on channel lakes at locations conductive to recharge.

As all storm water can not be stored on channel, possibilities exist for off-channel storage. It is useful device for storing water for lean season. In the same way we can store storm water in lakes and depressions. This depression may be of Quarries prevalent in the area of Dehradun. Several small or large check dams are possible and these should be used not so much for surface withdrawal but for recharging the falling groundwater. Deepening and cleaning of tanks, construction of new tanks, percolation pits, cleaning of dug wells, etc. are some important measures to adopt.

From the study of various techniques of rainwater harvesting and their applicability following recommendations are made for different building types. These building types have been further grouped under various landuse zones. These recommendations are of general nature and the technique should be adopted by considering other factors such as rainfall pattern, soil condition, geology etc. The following list of recommendation shall prove useful while designing for rainwater harvesting structures in any building of campus.

LIST OF RAINWATER HARVESTING STRUCTURES RECOMMENDED FOR DIFFERENT BUILDING TYPES

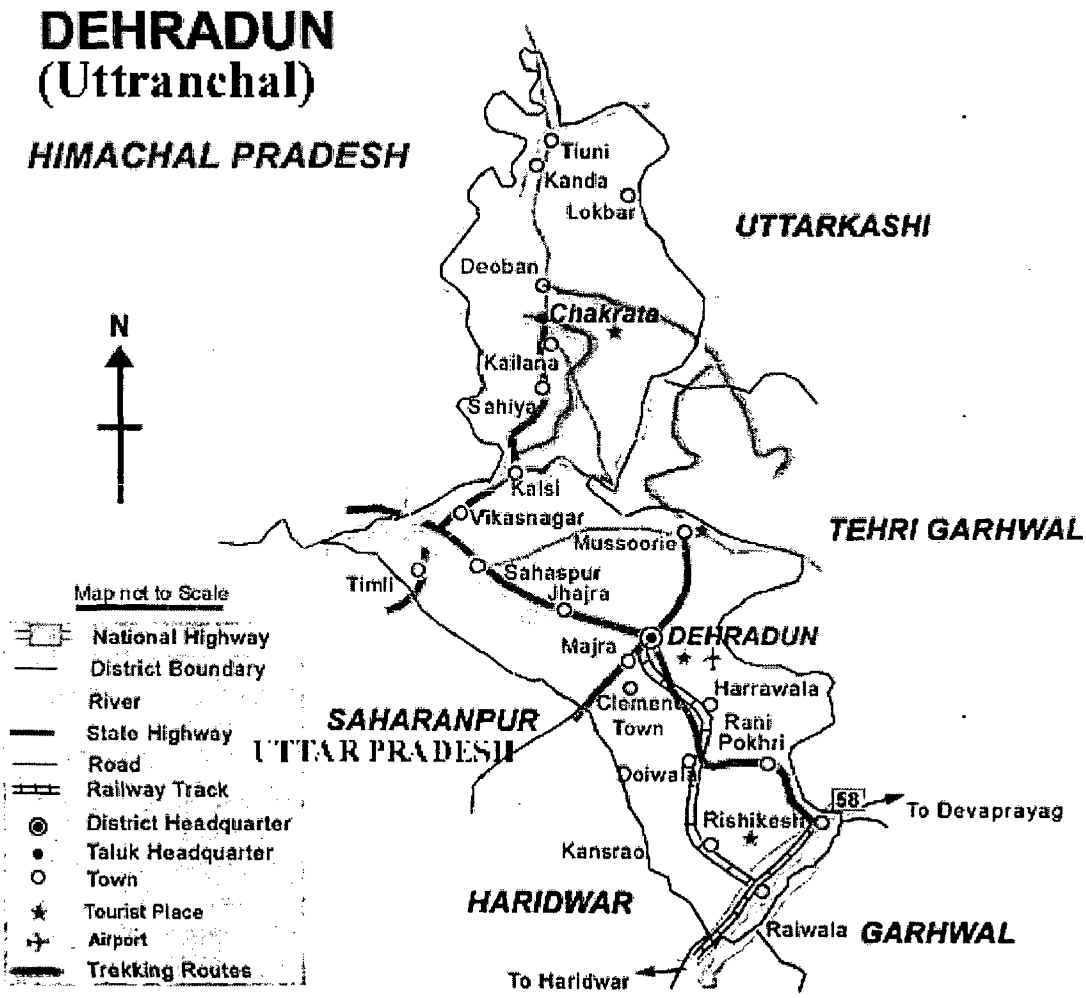
LANDUSE	RESIDENTIAL					COMMERCIAL			INSTITUTIONAL			
BUILDING TYPE	PLOTTED DEVELOPMENT			GROUP HOUSING		EXISTING HOUSES	SHOPPING COMPLEX		GOVERNMENT		PRIVATE	
	detached	semidetach	row house	upto G+3	above G+3	no setbacks	row	multistoried	Resi.	non-Resi	Resi.	non-Resi.
1. ROOF TOP RWH	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
2. RECHARGE PIT	✓	✓		✓	✓			✓	✓	✓	✓	✓
3. PERCOLATION PIT	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
4. PONDS/RESERVOIR									✓			
5. SOIL AQUIFER TREATMENT									✓			
6. AFFORESTATION									✓		✓	✓
7. CHECK DAMS									✓		✓	✓
8. BUNDING												
9. DUGWELL	✓			✓	✓				✓	✓	✓	✓
10. BOREWELL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11. PERFORATED PAVEMENT	✓	✓		✓	✓				✓	✓	✓	✓
12. TRENCHING	✓	✓		✓	✓				✓	✓	✓	✓
13. WATER SPREADING									✓		✓	
14. BANDHARA												
15. SUBSURFACE DYKE												
16. RECHARGE WELL				✓	✓				✓			
17. INJECTION WELL												
18. RECHARGE SHAFT					✓				✓			

CHAPTER- V

WATER RESOURCES AND NEEDS OF DEHRADUN

5.1 REGIONAL SETTING OF DEHRADUN:-

The Doon Valley lies Between latitudes 29°55'N and 30°30'N,and longitudes 77°35'E and 78°24'E. Dehradun city, the district headquarter of Dehradun district, is in the southern part of the state of Uttaranchal (map-I). The city is surrounded by river Song on the east, river Tons on the west, Himalayan Ranges on the north and Sal forests in the south. It is the largest city in the hilly region of U.P. and well connected by rail road and air transport. Dehradun urban area consists of Dehradun municipal area, Forest Research Institute, Adhoiwala outgrowth, Dehradun Cantonment, Clement Town Cantonment and Raipur town.



MAP-I Regional map of Dehradun (not to scale)

5.2 LOCATION OF THE STUDY AREA

The Dehradun city is situated in the south central part of Dehradun district in Doon Valley. It lies at 30°19'N and 78°20'E. The Dehradun Municipal area is 38.04 square kilometer and is divided into 34 wards according to 1991 census. Recently this number of wards was reduced to 33. Physical limit of the Dehradun municipal boundary is limited by two intermittent rivers namely Bindal river and Rispana river. Map-II shows the ward map of Dehradun municipal boundary.

5.3 LINKAGE

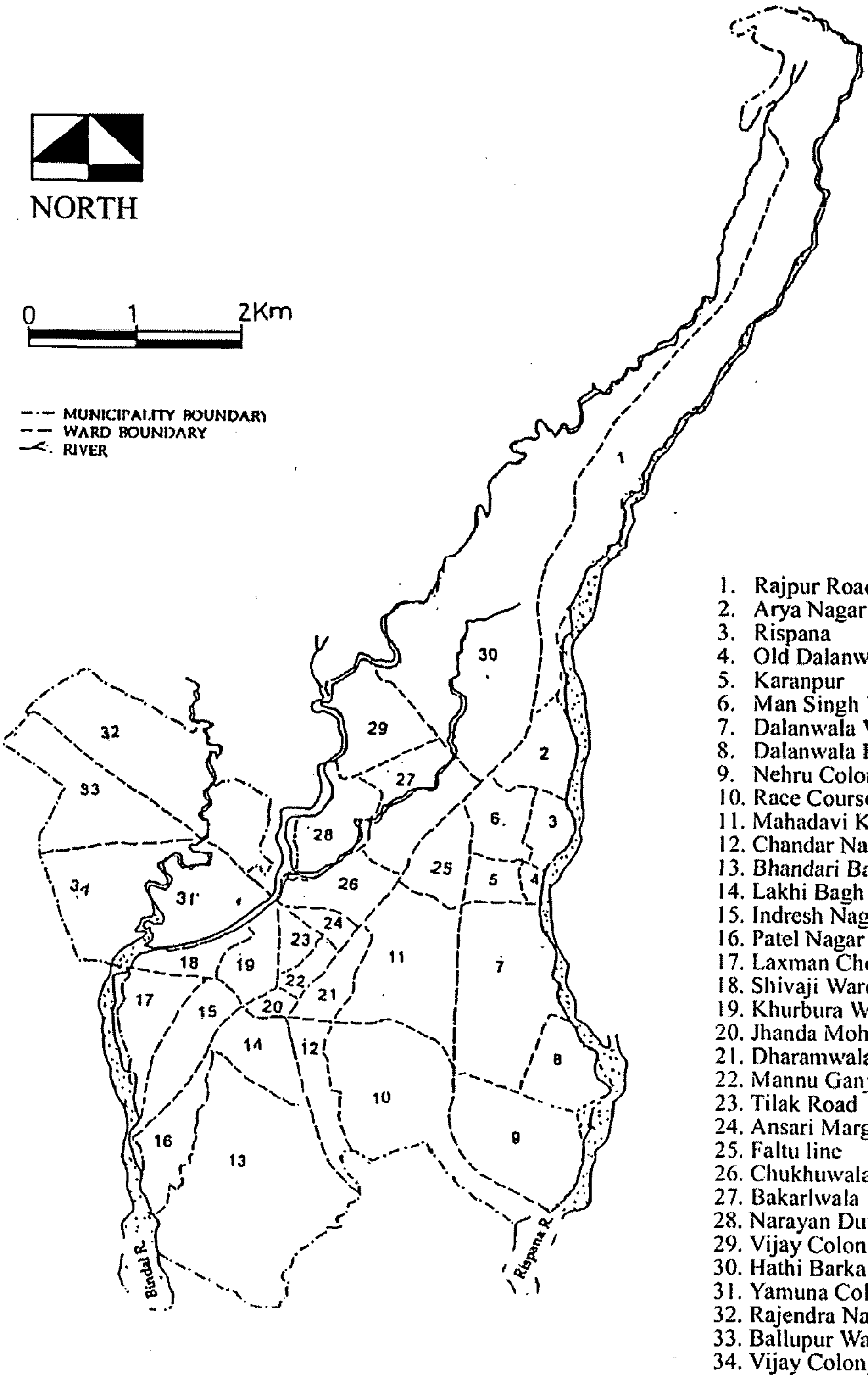
Dehradun is well connected to Delhi, Amritsar, Lucknow and Allahabad by road enroute Haridwar. The major trade routes connecting Dehradun with the plains is the Roorkee – Raipur – Mussoorie road. Dehradun is also connected to Rishikesh and Paonta Sahib by road.

5.4 BRIEF HISTORY OF THE DEHRADUN

Dehradun is composed of two words 'Dehra' and 'Dun'. Dehra is the corruption of word dera of Hindi and it means camp. Similarly Dun in Sanskrit and Hindi means elongated valley.

History of Dehradun lies back in the period of Ashoka, when it was the part of Kedar Khand in 3rd century B.C. Later on it became the part of Garhwal Kindom. From 1803 to 1814 the city was under the reign of Gorkhas. The hill station of Mussoorie and Landour have been established in 1827-29 .The spurt in growth and development was observed due to the establishment of two military cantonment in 1872 and 1908. After the second world war, a new cantonment named Clement Town, an Ordinance factory, Indian Institute of Petroleum, Indian Institute of Remote Sensing, and Oil and Natural Gas Corporation, and other many institutions, offices were set up which further accelerated the growth and physical expansion of the city. The increasing population and urban expansion put tremendous pressure on the existing infrastructure and water supply system of the city.

WARD MAP OF DEHRADUN M.B.



1. Rajpur Road
2. Arya Nagar
3. Rispana
4. Old Dalanwala
5. Karanpur
6. Man Singh Wala
7. Dalanwala West
8. Dalanwala East
9. Nehru Colony
10. Race Course
11. Mahadavi Kanya Pathshala
12. Chandar Nagar
13. Bhandari Bagh
14. Lakhi Bagh
15. Indresh Nagar
16. Patel Nagar.
17. Laxman Chowk
18. Shivaji Ward
19. Khurbura Ward
20. Jhanda Mohalla
21. Dharamwala
22. Mannu Ganj
23. Tilak Road
24. Ansari Marg
25. Faltu line
26. Chukhuwala
27. Bakarlwala
28. Narayan Dutt Dangwal
29. Vijay Colony
30. Hathi Barkala
31. Yamuna Colony
32. Rajendra Nagar
33. Ballupur Ward
34. Vijay Colony Ward

MAP-II

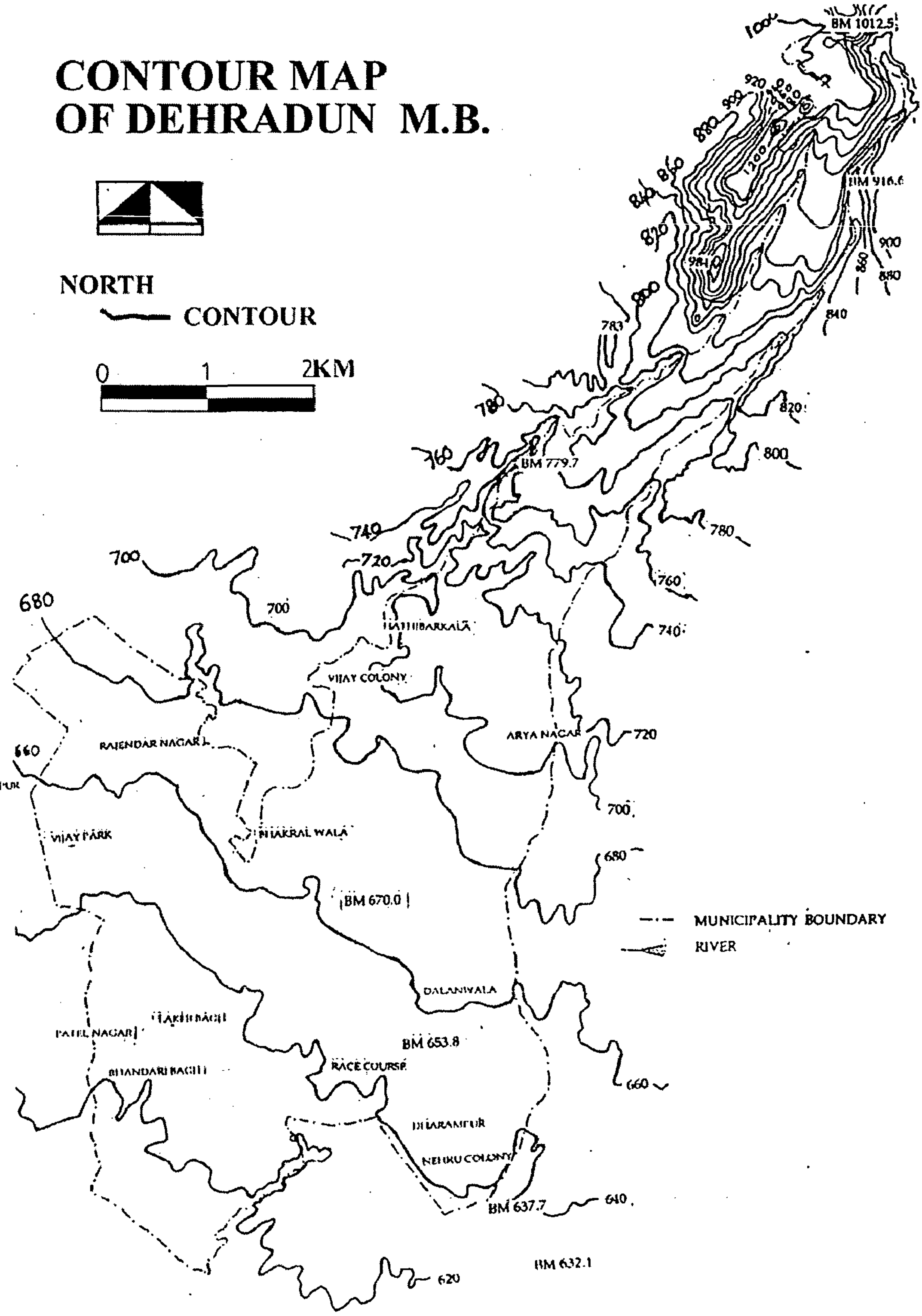
5.5 DEHRADUN AS CAPITAL OF UTTRANCHAL

The recent change in the status of Dehradun is that it has got the status of capital of state of Uttranchal. The decision came after a long struggle of people of hill areas of UP. This change will certainly spur the growth of Dehradun in all aspects on the one hand it may increase the prices of the commodity imported from other states, and on the other due to accelerated growth of population land may be at a premium. As far as Dehradun is concerned it was earlier the 12^{th} largest city of Uttar Pradesh and now it is the largest city in the new state. Hence the growth of the city due to new developments will be in all horizons. New ministry, new departments, new offices and institutions will invite the people from the different parts of the state. In that case the floating population coming to Dehradun will increase manifold and residential population will also increase at a higher rate. The city will require a lot of input in the infrastructure along with the water supply. Hence peoples participation is must to tackle the problem and rainwater harvesting is one of the methods to involve the people in the water management of the city.

5.6 PHYSIOGRAPHY AND TOPOGRAPHY

The city is located at an altitude of 640 meters above mean sea level. The lowest altitude is 600 meters in the southern part, where as highest altitude is 1000 meters on the northern part. Map-III shows the contour plan of Dehradun Municipal boundary. The site of the city slopes gently from north to south and south west having gradient 1:37.5 and is heavily dissected by a number of seasonal streams and nallas which are locally known as Khalas. The drainage of the city is borne by two rivers namely Bindal and Rispana Rao. The direction of flow of streams and nallas in the eastern part is north to south and in the western part it is north to southwest. Dense patches of forests exists along the outer limits of regulated area which include area of Dehradun municipal board and the areas falling within 5 miles radius beyond municipal limit. The physiography of the city is marked by undulations and has strictly governed the physical growth and surface water availability.

CONTOUR MAP OF DEHRADUN M.B.



MAP - III

5.7 GEOMORPHOLOGY AND GEOLOGY

Nakata(1972) identified four levels of geomorphic surfaces in the Doon Valley. These are:

1- *Hill top surfaces* :- This is recognised on the top of the Siwalik hills such as the Rajpur, Golwari and Kalanga hills in the northern part of the Doon valley. The surface is composed of thick boulder gravel beds including huge boulders as large as 2 meter across near top.

2- *Upper Doon surface* :- The upper Doon surface is best exposed between the Rajpur and the Golwari hills as undulating surface characterised by red soil. It is composed of thick deposits comprising of small, angular to subangular gravels of sandstone, phyllite and limestone.

3- *Middle Doon surface* :- The deposits of Middle Doon surface covers the upper Doon surface(UDS), and the red soil on top of the UDS marks the unconformity between the deposits of two Doon surfaces. This consisting of less consolidated and weathered gravel beds. This younger surface is the most extensively developed in the northern part of the Doon valley.

4- *Lower Doon surface* :- The lower Doon surface is recognised as the lowest alluvial fan of the major tributaries of the Ganga and Yamuna rivers in the central part of the Doon. The surface is composed of boulder gravel beds that cover the finer deposits of the middle doon surface. The deposits are not thick, less than 10 meter, but the surface is quite extensive. Dehradun town is located on this wide Doon surface.

5.8 CLIMATE

In general, the climate is temperate. The period may be divided into four seasons. The period from about the middle of November to February is the cold season. The hot season, which follows, continues up to about the end of June. The monsoon season is from July to about the third week of September. The following period, till the middle of November is the post-monsoon or transition season. (see table-14)

5.8.1 Temperature

The maximum average temperature is 36+6° C and the minimum is 5+2° C. In summers, maximum temperature is 36+6° C and the minimum is 16+7° C whereas in winter it varies from 23+4° C and 5+2° C respectively. In summers the heat is often so intense and on individual day, the maximum temperatures raises to over 42° C January is generally the coldest month and the minimum temperature sometimes falls down to about a degree below the freezing point of water. Inversion of temperature is a conspicuous phenomenon, owing to the location of the city in valley.

TABLE # 14 CLIMATIC DATA FROM PRIMARY STATION DEHRADUN

Station Dehradun Lat 90°30' Long 78°02' E Alt. 682m

Months	Mean temp °C	Humidity %age	Rainfall mm	No. of rainy Days 02mm	No. of rainy Days 2 mm	No. of days without Traces of rain	No. of moisty days	% of total rainfall
January	12.7	64.5	58.9	6	3.9	2.1	0.3	2.725716
February	14.3	61	62.7	7	3.8	3.2	0.9	2.901569
March	19.2	45.5	32	4	2.7	1.3	0	1.480864
April	24.5	33.5	16.5	4	1.7	2.3	0	0.763571
May	28.3	35	36.8	5	3	2	0	1.702994
June	28.8	55	217.2	13	9.4	3.6	0.1	10.05137
July	26.7	80.5	668	26	20.3	5.7	0.2	30.91305
August	25.9	83	731.3	26	21.3	4.7	0.7	33.84238
September	25	75	268.7	15	10.9	4.1	0.1	12.43463
October	22	62	32	2	1.6	0.4	0	1.480864
November	11.1	55	4.3	0.8	0.9	0	0.7	0.198991
December	7.8	55	35	3	2.6	0.4	4	1.619695
Total mean annual	21.5	60.5	2160.9	112	81	30.7	2	

Source: Climatological data of Dehradun for the year 1995.

5.8.2 Rainfall

The average annual rainfall of Dehradun City is 2183.5 millimeters. About 87% of the rainfall is through monsoon and is received during the months from June to September, July and August being the rainiest. Number of rainy days in Dehradun is highest in comparison to other surrounding areas like Roorkee, Saharanpur and Haridwar.

5.8.3 Humidity

The relative humidity is high during the monsoon season normally exceeding 70% on an average. The mornings are generally more humid than the afternoons. The driest part of the year is during the summer season, with the relative humidity becoming less than 45 percent.

5.8.4 Prevailing Winds

The winds are mostly from direction between southwest and northwest throughout the year except in October and November. The annual mean wind speed is 3.2 km/hour. Mountain and valley winds are common throughout the year.

5.9 BASIC NATURAL RESOURCE

5.9.1 Vegetation

Dehradun bears the mixed moist deciduous type of vegetation and contains the following type of main tree species (table-15).

TABLE. # 15 IMPORTANT TREE SPECIES IN DEHRADUN

Common name	Botanical name	Common name	Botanical name
Sal	Shorea robusta	Ber	Zizyphus jujuba
Silver oak	Grevillia roubusta	Phaldu	Cassia fistula
Khair	Acacia catecheu	Amaltas	Mitragyna parviflora
Sandan	Ougeinia oogeinensis	Sain	Terminalia tomentosa
Jamun	Shyzium cuminii	Buddhas coconut	Sterculia alata
Rohini	Mallotus philipopinensis	Shishum	Dalbergia sissoo

Source: J. S. Pandey, S. Khan, A. K. Gupta & P. Khanna (NEERI), 1995

Apart from minerals, many types of forests with different varieties of trees are found in Dehradun district. Sal is the main species along with other like chir, deodar, jamun, khair – sissoo, semal, tun, bamboo and eucalyptus forests. The best quality of wheat and rice is grown here and sugarcane, onions, tobacco and strawberries also grow abundantly.

5.9.2 Soil

Unstratified mixed pebbles, boulders and clay with very little matrix cover the Doon valley proper. A thin mantle of soil covers the Doon gravels of the Pleistocene age, except in the riverbeds. These gravels are highly pervious with poor underground eastern reservoir capacity, except in the eastern Doon, which was a vast swampland in the 19th century.

The hinterland of Dehradun is richly endowed with natural resources like minerals (especially limestone), forests and fertile agriculture land. The important minerals constitute limestone, gypsum, tufa, copper, marble, slates and quartzite. Availability of these minerals has set a pace for industrialization in Dehradun.

5.9.3 hydrology

The boulder, gravel and pebble – beds of the drainage channels provide the underground course for most streams originating in the Himalayas. Many of these disappear deep into the boulder and shingle beds for long stretches and reappear near the edges of the plateau where they find impermeable clay formations (fig.-47).

5.9.3.1 Surface Water Resource

Doon valley is an intermontane piedmont plain between the northern Mussoorie and the southern Siwalik Foothills range. It is composed of alluvial fans and river terraces and traversed by seasonal braided streams/rivers. The underlying deposits are the 'Doon Gravels'.

Dehradun forms a low water-divide in the valley with the song river and its tributaries flowing south-east and eastwards to join river Ganga in the east of the valley, whereas Asan river and its tributaries flow westwards to join river Yamuna in the western Doon. The streams are mostly seasonal, and flow rapidly for sometime after rains. Runoff is quite high during peak rains. Channel-bed infiltration takes place along braided river courses. Along, river Song and river Asan base flows occur in downstream reaches whence they flow perennially.

5.9.3.2 Ground Water Resource

Doon valley is endowed with very productive groundwater bearing aquifers within the 'Doon Gravels' formations, which constitute alluvial fill in Doon Valley. Tube wells have tapped aquifers (sand, gravels, and pebble-boulder horizons) down to depths of 130-170 metres or a little more. Aquifer zones are alternated by layers of reddish clay, clay-boulder etc. Rain recharge potential is good. From the map – IV it is evident that depth of water table is very high in areas of high population density hence demanding ground water recharge.

Hydromorphogeologic Mapping for targeting groundwater prospective zones has greatly helped in exploration and location of successful tube wells in Doon Valley. Heavy-duty tube wells discharging around 100,000 litres per hour of usable water occur in different parts of the valley, with water levels ranging 25 to 70 metres below ground level (at places even shallower to near surface). Few springs and seepage occur e.g. near Manduwala table and along lower reaches of Asan river valley respectively (see fig.-48). The aquifers are mainly under water table semi-confined conditions. Locally perched aquifers also occur. Although good rainfall recharge to groundwater, yet due to excessive groundwater withdrawal by numerous tubewells in Dehradun city area, the lowering of water levels by about 1.5 metres or more has been reported during the last decade.

Water harvesting plans for UP hills
The Times of India News Service Wednesday 22nd march, 2000
DEHRADUN: An ambitious scheme is afoot for rain water harvesting in the 11 hill districts of western UP which often face water shortage, especially in the summer months. Stating this here on Friday, BJP MP from Pauri Garhwal B.C. Khanduri said that a high-powered committee of the Central Ground Water Harvesting Authority had been asked by the Union government to prepare a blueprint of the scheme.

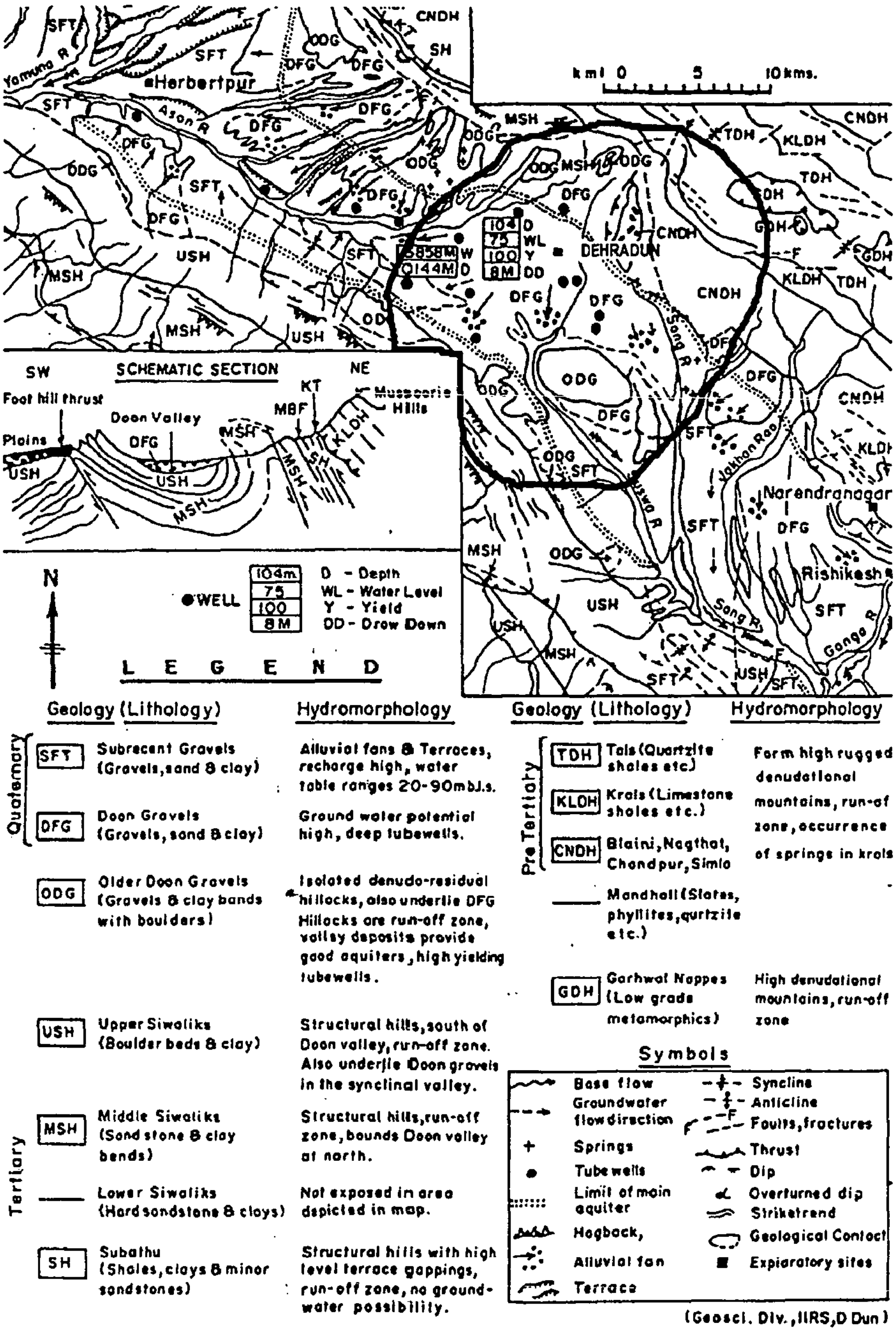
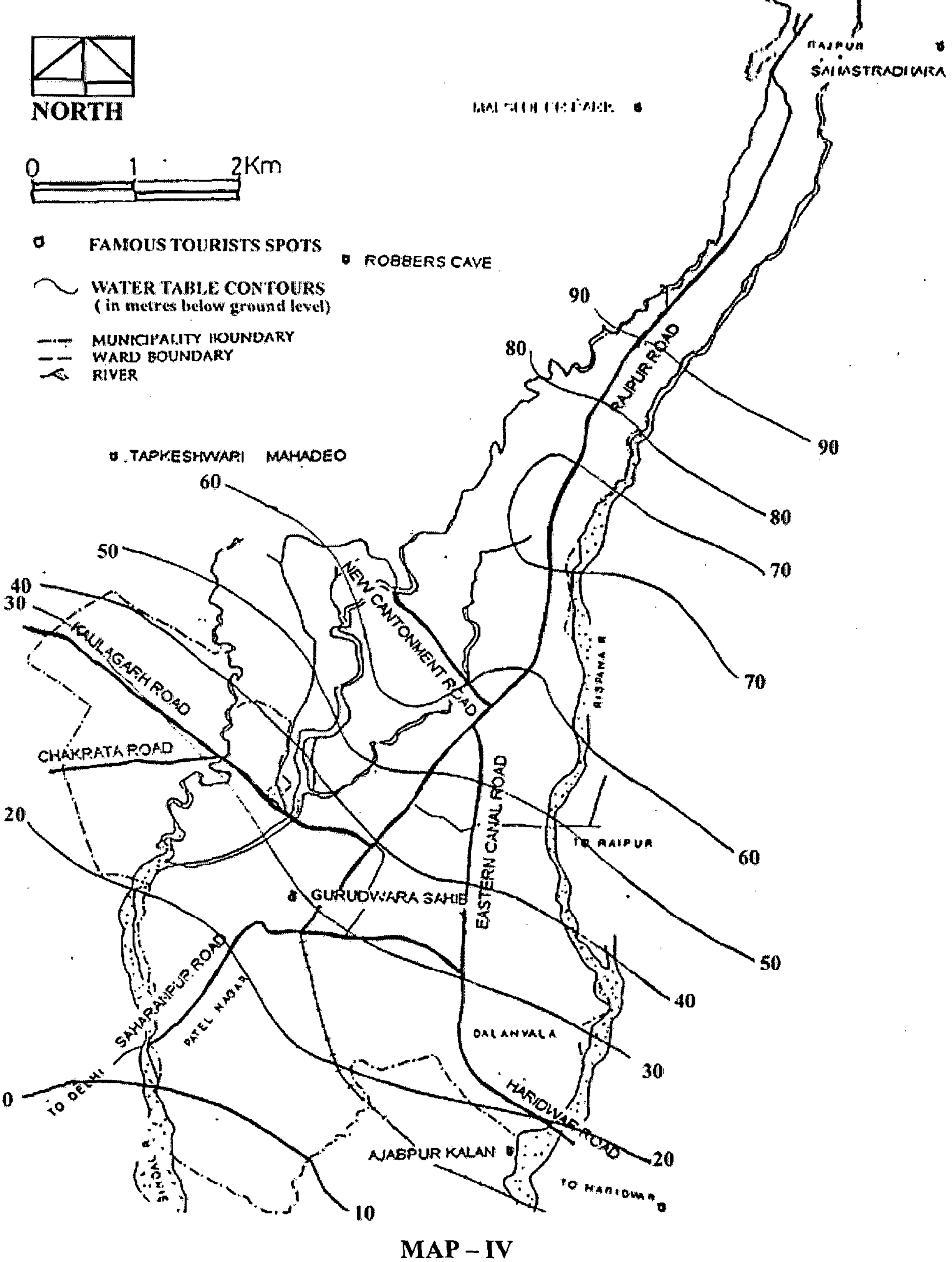


Fig.47, Hydromorphogeological map of Doon Valley

5.9.4 Minerals

The hinterland of Dehradun is richly endowed with natural resources like minerals (especially limestone), forests and fertile agriculture land. The important minerals constitute limestone, gypsum, tufa, copper, marble, slates and quartzite. Availability of these minerals has set a pace for industrialization in Dehradun.

G.W. WATER TABLE CONTOUR MAP OF DEHRADUN M.B.



MAP – IV

5.10 DEMOGRAPHY

Dehradun was twelfth largest city among class I cities of Uttar Pradesh according, to size of population and largest in the state of Uttranchal. The total population of Dehradun urban agglomeration is projected as 4,96,871 persons in 2001 and that of municipal area is 3,28,902 persons according to 1991 census (table-16). For the projection of the population of U.A. growth rate has been taken as 34.99 % and that of municipal area as 27.78 %. As per the new status of Dehradun it is expected that the growth rate will be as high as 50% for U.A and 35% for municipal area. According to this assumption of growth the population of Dehradun U.A will be 7,45,306 persons and that of municipal area will be 4,44,017 persons in the year 2011.

TABLE # 16 POPULATION OF DEHRADUN URBAN AGGLOMERATION AND MUNICIPAL CORP. AREA

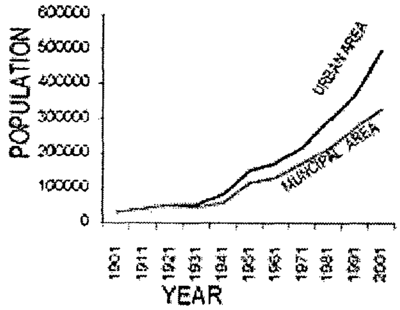
YEAR	*1901*	*1911*	*1921*	*1931*	*1941*	*1951*	*1961*	*1971*	*1981*	*1991*	*2001*
U.A	30995	42568	50858	52927	80580	151936	172478	220571	293010	368053	496871
M.C	30995	42568	50858	43206	59535	116404	129764	169827	211416	270159	328902

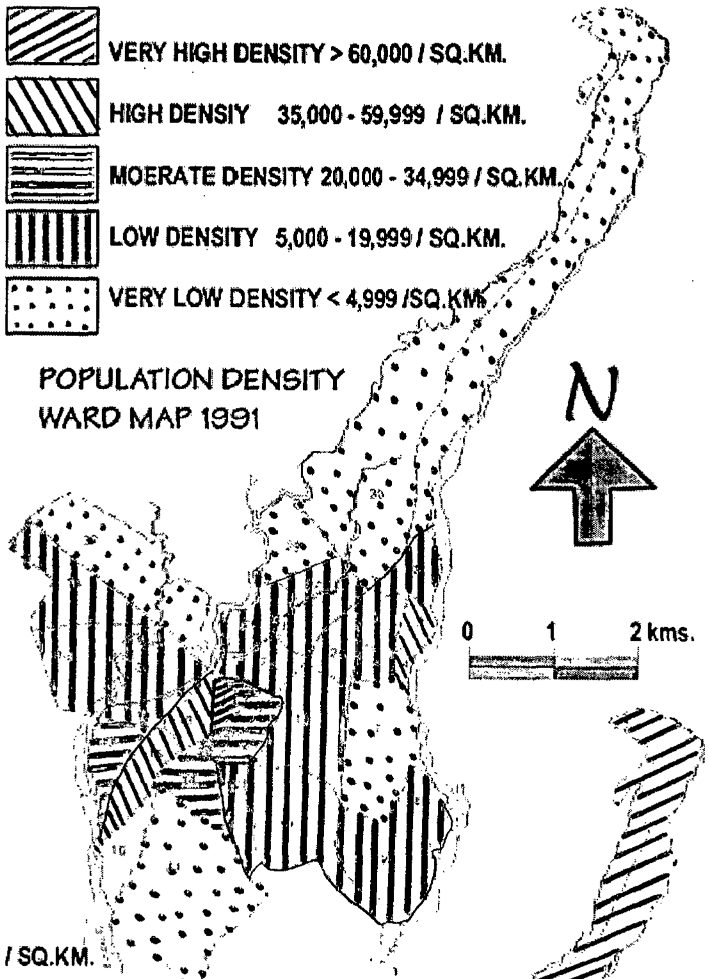
Source: census of Dehradun 1991

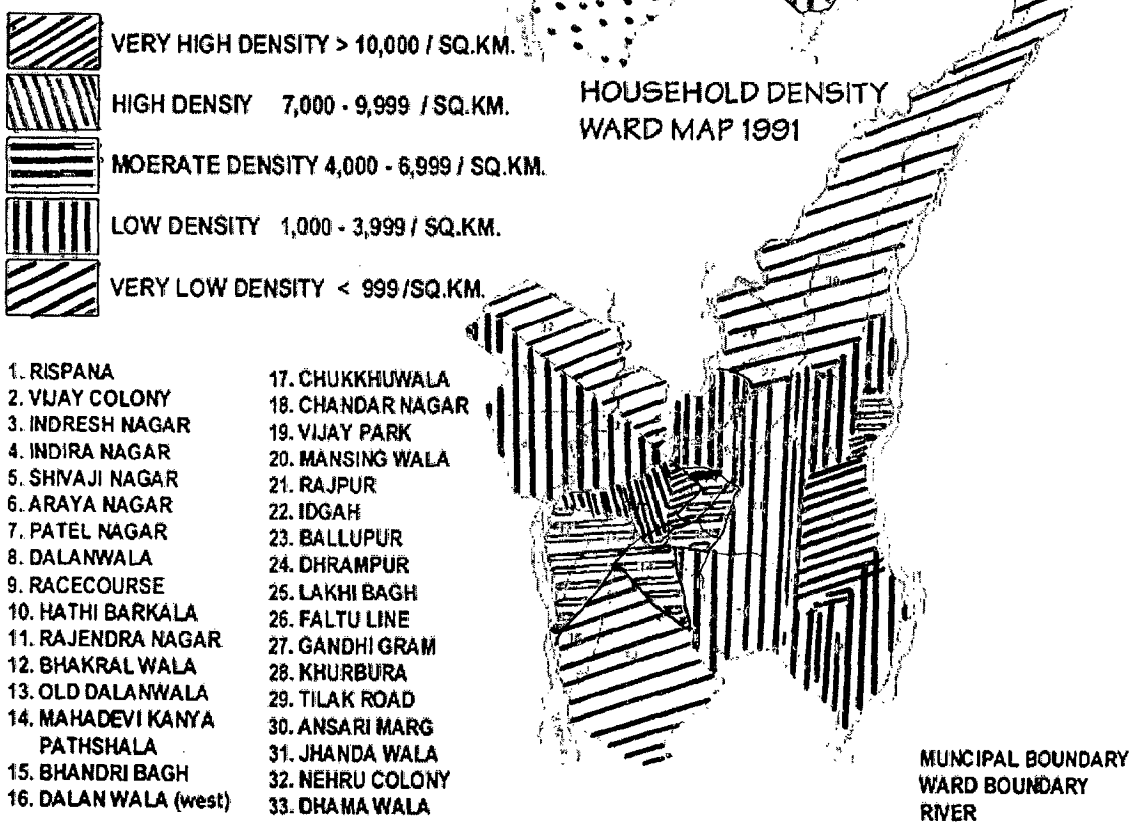
It is clear from the map – V that the entire population of municipal boundary of Dehradun is very unevenly distributed over the area. The reason behind this is the topography of the area and process of settlement from core area towards the fringe area. From the table no-17 it is clear that population density of the wards vary from 60020 persons/sq.km. in Tilak road ward to 1526 persons/sq.km in Hathibarkala. Household density of the wards vary from 11130 HH/sq,km. in Tilak road to 343 HH/sq.km in Rajpur ward.

M.C. POPULATION

YEAR	POPULATION	%GROWTH
1901	30,995	----
1911	42,568	37.34
1921	50,858	19.47
1931	43,206	- 15.05
1941	59,535	37.79
1951	1,16,404	95.52
1961	1,29,674	11.58
1971	1,69,827	30.87
1981	2,11,416	29.86
1991	2,70,159	27.78
2001	3,28,902	27.78







MAP – V

TABLE # 17 WARDWISE DISTRIBUTION OF POPULATION

WARD	WARD NAME	AREA	HOUSE HOLD	POPULATION			POPUL- -ATION	SCs	STs	LITER- -ATES
No.		SQ. KM.		P	M	F	AGE 0-6			
1	Rajpur	6.51	2236	10697	5934	4763	1358	662	8	7459
2	Aryanagar	0.52	1839	9501	4930	4571	1275	3178	8	6768
3	Rispna	0.22	1530	8145	4363	3782	1214	3445	58	5358
4	Old Dalanwala	0.11	1110	5258	2816	2442	734	760	24	3811
5	Karanpur	0.36	952	4502	2302	2200	590	182	13	3605
6	Mansingh wala	0.84	1175	5333	2766	2567	556	243	6	4300
7	Dalanwala west	1.7	1078	6055	3154	2901	675	453	16	4861
8	Dalanwala east	1.13	1909	9879	5397	4482	1517	1444	11	6489
9	Nehru colony	1.16	3126	14880	7855	7025	2059	472	6	10892
10	Race course	1.17	2838	14097	7553	6544	2180	1566	11	9785
11	Mahadevi Kanya Pathshala	0.6	636	3599	1806	1793	483	158	3	2718
12	Chandra nagar	0.84	1913	9812	5332	4480	1400	958	25	6212
13	Bhandaribagh	2.68	923	4641	2521	2120	773	351	0	2832
14	Lakhibag	0.59	2576	13391	7314	6077	2421	936	31	7848
15	Indresh nagar	0.16	1080	6029	3179	2850	903	2490	5	4004
16	Patel nagar	0.72	1237	6288	3342	2946	900	108	3	4694
17	Laxman chowk	0.62	2669	13906	7451	6455	2344	1389	25	8899
18	Shivaji marg	0.44	1196	7375	4032	3343	1350	1755	5	3293
19	Khurbura	0.3	2197	11109	5832	5277	1610	773	0	7760
20	Jhanda ward	0.28	1234	6138	3301	2837	790	89	13	4566
21	Dhama wala	0.3	1177	6791	3583	3208	958	43	0	4671
22	Mannu ganj	0.18	741	4200	2236	1964	564	122	0	3042
23	Tilak Road	0.1	1113	6002	3127	2875	821	128	0	4585
24	Ansari marg	0.24	1078	5432	2767	2665	685	282	11	4351
25	Faltu line	0.51	755	3650	1925	1725	397	182	38	2926
26	Chukhoo wala	0.6	1774	9131	4838	4293	1173	984	42	6842
27	Bakral wala	0.57	932	4454	2274	2180	484	199	13	3522
28	Dungwal marg	0.96	2406	12600	6654	5946	1900	3441	124	8351
29	Vijay colony	0.74	714	3663	1904	1759	447	823	23	2710
30	Hathibar Kala	7	2455	10682	5882	4800	1284	1289	109	7716
31	Yanuna nagar	1.06	2249	10590	5611	4979	1437	640	29	8056
32	Rajendra nagar	2.27	1818	8593	4723	3870	1201	674	30	6674
33	Ballu pur	0.72	1332	6646	3321	3325	790	356	64	5107
34	Vijay park	0.97	1440	7090	3780	3310	1030	656	31	5111
	TOTAL	37.17	53438	270159	143805	126354	38303	31231	785	189818

Source: Census of Dehradun, 1991.

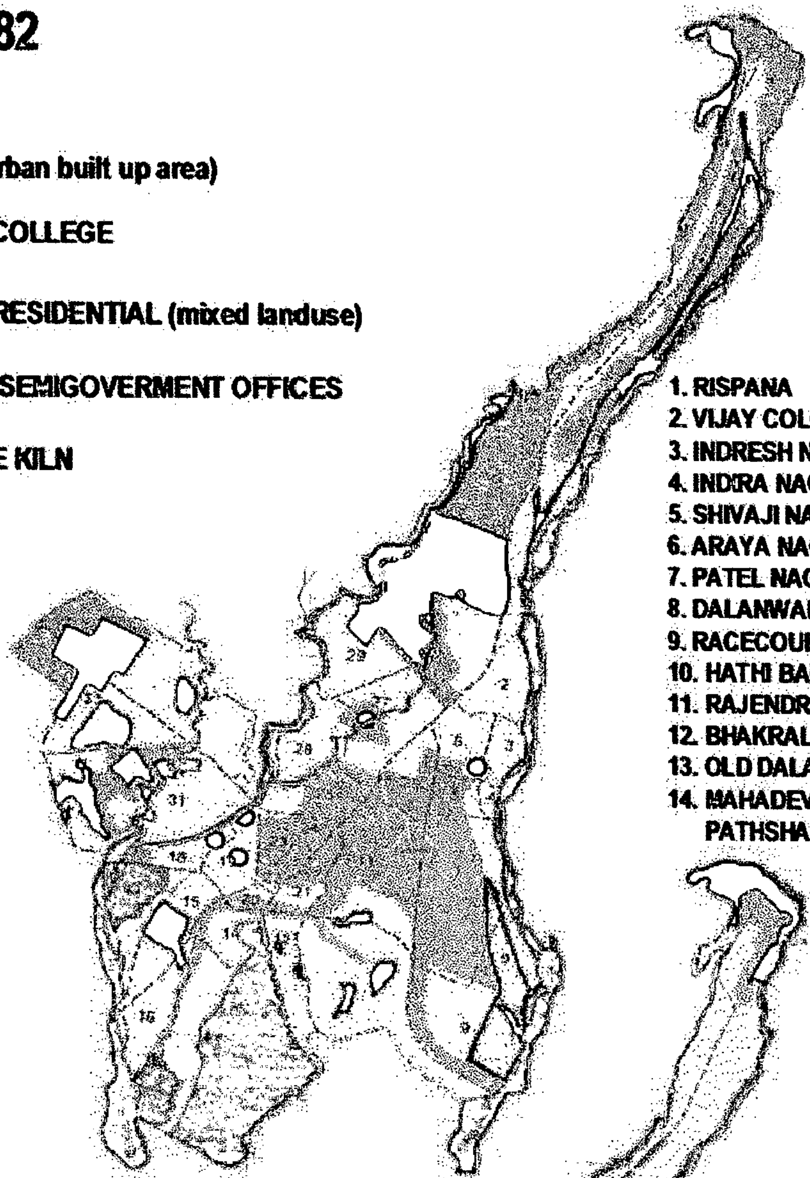
5.11 LANDUSE

Dehradun just as other cities, has also developed from a group of townships over the decades to form an urban agglomeration. The Dehradun town alongwith it's urban out growths, cantonments and census towns forms the urban agglomeration.

LANDUSE MAP 1982

- RESIDENTIAL (urban built up area)
- INTERMEDIATE COLLEGE
- COMMERCIAL / RESIDENTIAL (mixed landuse)
- GOVERNMENT / SEMIGOVERMENT OFFICES
- INDUSTRY / LIME KILN
- GREEN SPACE
- VACANT LAND
- AGRICULTURE
- RIVER
- UNKNOWN

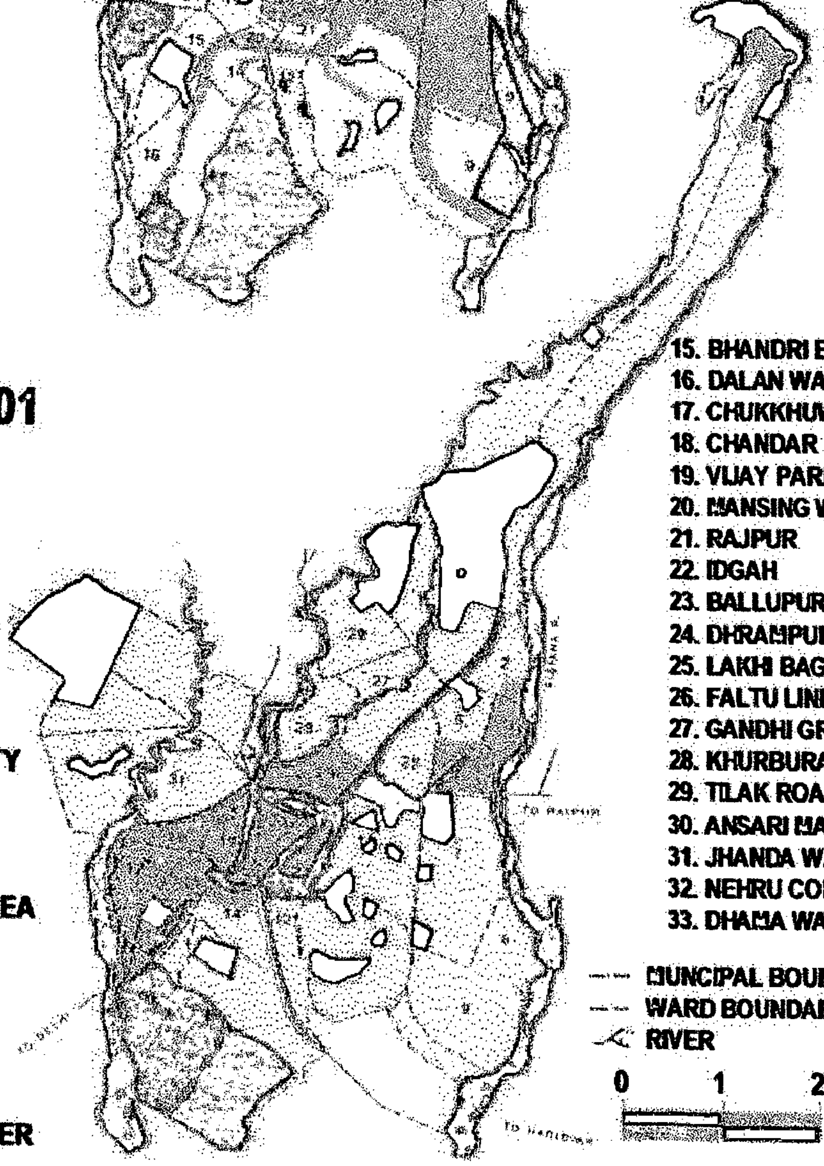
N



1. RISPANA
2. VIJAY COLONY
3. INDRESH NAGAR
4. INDIRA NAGAR
5. SHIVAJI NAGAR
6. ARAYA NAGAR
7. PATEL NAGAR
8. DALANWALA
9. RACECOURSE
10. HATHI BARKALA
11. RAJENDRA NAGAR
12. BHAKRAL WALA
13. OLD DALANWALA
14. MAHADEVI KANYA PATHSHALA
15. BHANDRI BAGH
16. DALAN WALA (west)
17. CHUKKHUWALA
18. CHANDAR NAGAR
19. VIJAY PARK
20. MANSING WALA
21. RAJPUR
22. IDGAH
23. BALLUPUR
24. DHRAMPUR
25. LAKHI BAGH
26. FALTU LINE
27. GANDHI GRAM
28. KHURBURA
29. TILAK ROAD
30. ANSARI MARG
31. JHANDA WALA
32. NEHRU COLONY
33. DHAMA WALA

LANDUSE MAP 2001

- COMMERCIAL
- INDUSTRIAL
- OFFICES
- HIGH DENSITY
- MEDIUM DENSITY
- LOW DENSITY
- DEVELOPED AREA
- FOREST
- GARDEN
- AGRICULTURE
- DRAINAGE / RIVER



MUNCIPAL BOUNDARY
WARD BOUNDARY
RIVER

0 1 2 kms.

TABLE # 18 LANDUSE OF DEHRADUN U.A. 1981

S. NO.	LANDUSE	AREA (SQ.KM.)	% OF TOTAL AREA
1	Residedntial	15.89	41.78939617
2	Commercial	0.81	2.130233537
3	Industrial	1.134	2.982326951
4	Public & semipublic	8.01	21.06564275
5	Govt.& semi-govt. offices	2.67	7.021880917
6	Parks, open spaces	1.56	4.102671997
7	Orchard & Gardens	2.06	5.41763097
8	Circulation	2.03	5.338733432
9	water bodies	3.31	8.705028403
10	Undefined uses	0.55	1.446454871
TOTAL		38.024	100

Source: TCPD, 1982

Table-18 gives the detail picture of the landuse in the Dehradun during year 1981. According to the existing landuse distribution around 41% of the land is under residential use. Land under public & semipublic use and offices is very high because most of the organisations have set their headquarter in Dehradun. Various educational institutions are also here which are of international fame and occupy a large chunk of land adding to this landuse type.

In the map – VI Landuse pattern shows great variation in the use pattern. Residential and semipublic uses seem to grab most of the forestland of Dehradun. Other uses do not show major variation in their share percentwise in the landuse pattern. The two-increased landuse reflects the rapid growth in population.

5.12 INFRASTRUCTURE

5.12.1 Power

The basic infrastructure of any city consists of Power, water supply, waste disposal and transport. The main source of electricity for Dehradun city and its adjoining area is met from the Hydel power stations. At present the Roorkee, Moradabad, Lucknow, Rishikesh nodes supply the electricity needs of Dehradun city and adjoining areas through the main grid installed in Majra where from it is distributed by the U.P. Electricity Board. The total number of connections under Northern division and Southern division that includes domestic, industrial, commercial and road lighting points is 41,002 and 48,751 respectively.

5.12.2 Transport

The transportation network is predominantly road based, the railway's role in meeting the commuters travel needs is almost insignificant. The major roads are Delhi – Mussoorie road and Dehradun – Rishikesh road State Highway, and other roads are Dehradun – Chakrata, Dehradun – Sahastradhara, Dehradun – Raipur. Dehradun Municipal Road maintains 305.14 km. and 79 km of road network in the Cantonment area was maintained by Cantonment Board. The public works department maintains the 15 km stretch of State Highway and 75.6 km of Municipal roads within Municipal limit. Majority of city roads is narrow and less in width ranging between 6 to 8 meters except a few.

5.12.3 Solid Waste Management

The main source of solid waste comes from households, institutional commercial establishments, and industrial operations, in general, and in few tourist places tourist may also he considered to some extent as a source. In general, Solid waste contains putrescible organic matter such as kitchen refuse, combustible matter such as paper, textiles, oil and grease, and plastics, and inert materials such as metals, soil and ash. The wastes generated from hospitals, dumping of wastes and faeces in drains/canals have greater potential for causing epidemics.

The present arrangement for collection and disposal of solid waste is inadequate and in many areas inefficient. Presently, the garbage is piled up on the sides of the roads, from where it off-loaded into handcarts and later into garbage containers. However, the wastes are removed regularly only from very selected places like Railway Station - Exit point, Arrant Bazaar, Patel Road - Old Change, Ketuchery Road. Municipal Corporation estimates about 140-150 tonnes of garbage is generated in the town everyday of this only 65-70 tonnes are collected by them.

Dehradun has been divided into 7 zones and further these zones are subdivided into 25 civic circles for the purpose of smooth and efficient Sanitation Management. The Chief Sanitary officer heads these zones. Besides these, there are approximately 800 "Safai Karamacharis" on pay rolls of the corporation. Each one is entrusted with a specific area of operation, for the collection of solid wastes. Among them 645 are on permanent basis and remaining are employed on daily/wages basis Corporation has 80 Dustbins 2 Dumpers, 2 trailer, 11 tractors. Only 7 are on road and additionally a refuse collector serves the Race Course area.

5.13 WATER SUPPLY

No city could exist without an adequate supply of safe water that is fit for human consumption. In urban context besides drinking, water has other, purposes such as washing, industrial use, fire fighting & air conditioning sprinkling lawns, dairy farms etc. The most concerned public facilities of all large cities have been with their water supplies.

The large cities during their expansion found the local sources of supply from wells, springs and brooks that were inadequate to meet drinking and sanitary demands of growing population. Building aqueducts that could bring water from distances solved this problem of cities.

The Water Supply Systems of this kind are constructed and operated by the Municipal Corporation (privatised in some of the developed countries), elected by the citizens. Dehradun city was no different and exceptional from other cities. In olden days people of Dehradun met their day to day water requirement from the dug wells, natural springs and canals. Later, as city grew to meet the demands of increasing population amid seasonal tourist, Piped Water Supply System was introduced connecting the perennial springs. Subsequently the surface water was brought from River Bandal through gravity main and with this a proper water works department with facilities of filtration came into existence at Dila Ram Bazaar. Pipe -lines were also laid for conveying water to the town's population.

5.13.1 Local Bodies

Under the Status and the existing set-ups and until few of the Jal Sansthan (Water and Sewage Boards) came up with power to levy water and drainage tax, its realization and also the responsibility of establishing a protected water supply vested with the Local Bodies representing the community. Obviously the responsibilities of establishing a Water Supply

> The mounting water crisis is he foremost of all problems of this region. Adequate scientific data and expertise are locally available to suggest remedies. Short and long term solutions should be drawn up and tackled on a war footing.
>
> S. Ghosh, The friends of the Doon (1995)

and promotion of protected Water Supply in Dehradun, became the responsibility of the Dehradun Municipality.

5.13.2 Increasing Population & Growing Demand Of Water

With the urbanisation and industrial growth the demand started increasing unprecedantly. The new areas on all sides of town were inhabited and so the limits of Dehradun across municipality extended demanding the civic facilities to newly formed settlements. The existing water supply from springs and rivers became inadequate and tapping new sources for augmenting the water needs and also extension of distribution system to new colonies became essential. The table –19 shows the present supply and demand statement of the city. Presently there is the shortfall of about 20 mld and this gap is expected to widen in the next decade. Hence corrective measures are necessary to fill the gap. Rainwater if harvested can be useful to a great extent in filling the gap.

To meet this ever increasing demand under several new and reorganisation schemes as many as 30 tubewells have been drilled and along with other operational works to make the system responsive to the needs of the community (table-19).

About 84.9% of total water supply is met from the tubewells that are scattered almost all over the area of the town. There are 11 overhead tanks each of varying capacity in order to supply the elevated areas. Table-20 shows the list of tubewells and overhead tanks). The ground water level of the water varies from 20- 90 metres.

5.13.3 Population & Area Covered - Present Water Supply System

The present water supply systemic of Dehradun town is catering the needs of a 2.89 lakhs in the Municipal limits and a population of nearly 0.86 lakhs in the areas adjoining the Municipal limits. Besides this population that is permanent it also serves the tourists and the students who are considered to be floating population.

Water harvesting plans for UP hills
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DEHRADUN: An ambitious scheme is afoot for rain water harvesting in the 11 hill districts of western UP which often face water shortage, especially in the summer months. Stating this here on Friday, BJP MP from Pauri Garhwal B.C. Khanduri said that a high-powered committee of the Central Ground Water Harvesting Authority had been asked by the Union government to prepare a blueprint of the scheme.

As the tourist inflow in Dehradun is only seasonal, it is estimated that the city water supply system serves a total population of 4 lakhs covering an area of 33.08 sq. km through a piped distribution of 689 kms in length on March 31st 1994. For the efficient running of water works system and equal distribution the water supply department works from four zones within the City viz., Upper Zone, Rajendar Nagar Zone, Dharampur Zone and Niranjanpur Zone. Out of 46,261 connections there are 36,115 domestic connection, 6,465 non-domestic and 1789 commercial metered connections. There are 134 bulk connections given for industrial and institutional requirements. To the economically weaker section of the society there are 1758 connections given by water works through stand post which are unmetered. Later on metered to cheek unauthorised multiplication of more taps, besides 822 Public Stand Posts mostly serving needs of the poor.

Despite there being a supply of 66.64 mld, the supply situation becomes grim every summer. Except the few areas the rest of the city has problems in getting drinking water. The areas that are facing acute water scarcity are Clock Tower, Hathi Barkala, Rest Camp, Tyagi road, Chander Road, Kaulagarh Road, and General Mahadeo Singh Road. The water scarcity in these zones is because of the rapid commercialization, new shopping complex demands a high supply of water. The floating population in the city also consumes the water supplied partly. The water demand projected does not include the need of this population. The storage capacity of the Overhead Tanks and number of tubewells within Dehradun City is less in number to meet the demands of the people.

The problem of water pressure in the pipes remains in the areas of higher elevation. This problem clearly indicates the lack of research during the planning for constructing the Overhead Tanks. ' Apart from the above reasons, the limited economic resources, the cost involved in drilling tube well (approx. Rs.18-20 lacs) and the shortage of man-power are also strong reasons for the crippled operational system of Water works. Summing up the above issues, it was inferred that a holistic study needs to be conducted to locate new potential sites, keeping in mind the future requirements of the growing population.

> The most limiting factor for further development is the shortage of water and, therefore, it is important that water-intensive industries must not be located in the valley.
>
> Prem K. Thandani, 1993

TABLE # 19 TABLE SHOWING WATER SUPPLY SENARIO OF DEHRADUN

POPULATION COVERED BY EXISTING WATER SUPPLY

MUNICIPAL POPULATION	- 3.29 Lacs
ADJOINING POPULATION	- 0.86 Lacs
TOTAL POPULATION	- 4.15 Lacs

SOURCE, SUPPLY, DEMAND AND GAP OF WATER SUPPLY

		Withdrawal (m.l.d)	Current Supply (m.l.d)	Current Demand (m.l.d.)	Gap (m.l.d.)
MAJOR SOURCES	Bandal River	8.0	68.64	87.15 (@ 210 lpcd)	18.15
	Mossy Falls	2.0			
	Rajpur Canal	2.0		99.60 (@ 240 lpcd)	30.96
	30 Tubewells	56.64			

TOTAL CONNECTIONS REGISTERED WITH W.W.D.

Type of connection	Type of consumers	No. of connections	%age of total connections
METERED	Domestic	36,115	78.06
	Non – Domestic	6,465	13.97
	Commercial	1,789	3.8
	Bulk	134	0.29
Sub Total		44,503	96.2
UNMETERED	Public Stand Post	1,758	3.8
GRAND TOTAL		46,261	100%

FUTURE AUGEMENTATION PLAN (2011)

Projected population	No. of Tubewells	Expected supply	Other Sources and their Proposed supply
5,60,117	5	10 m.l.d	Laying of pipe lines is under progress to augment the Mossy Fall supply from 2 to 14 m.l.d. it is also proposed that water supplied from Rajpur Canal will be augmented from 2 to 11.5 m.l.d.

FUTURE DEMAND, EXCEPTED SUPPLY AND GAP OF WATER SUPPLY IN YEAR 2011

Supply	Demand @ 210 lpcd	Demand @ 240 lpcd	Gap @ 210 lpcd	Gap @ 240 lpcd	%age Shortfall @ 210 lpcd	%age Shortfall @ 240 lpcd	Availability of rainwater @ 50% of total in M.C.
100.5 m.l.d.	117.6 m.l.d.	134.4 m.l.d.	17.1 m.l.d.	33.9 m.l.d.	9.70	20.99	**109 m.l.d** 81% of high demand in 2011.

Source: Water Works Department, Dehradun

Below the chart-IV shows the categorywise water supply connection from Water Works Deptt, Dehradun. Maximum connections are under the domestic use. Hence the input is highest in domestic category. This is where the enforcement of rooftop rainwater harvesting can supplement the existing water supply.

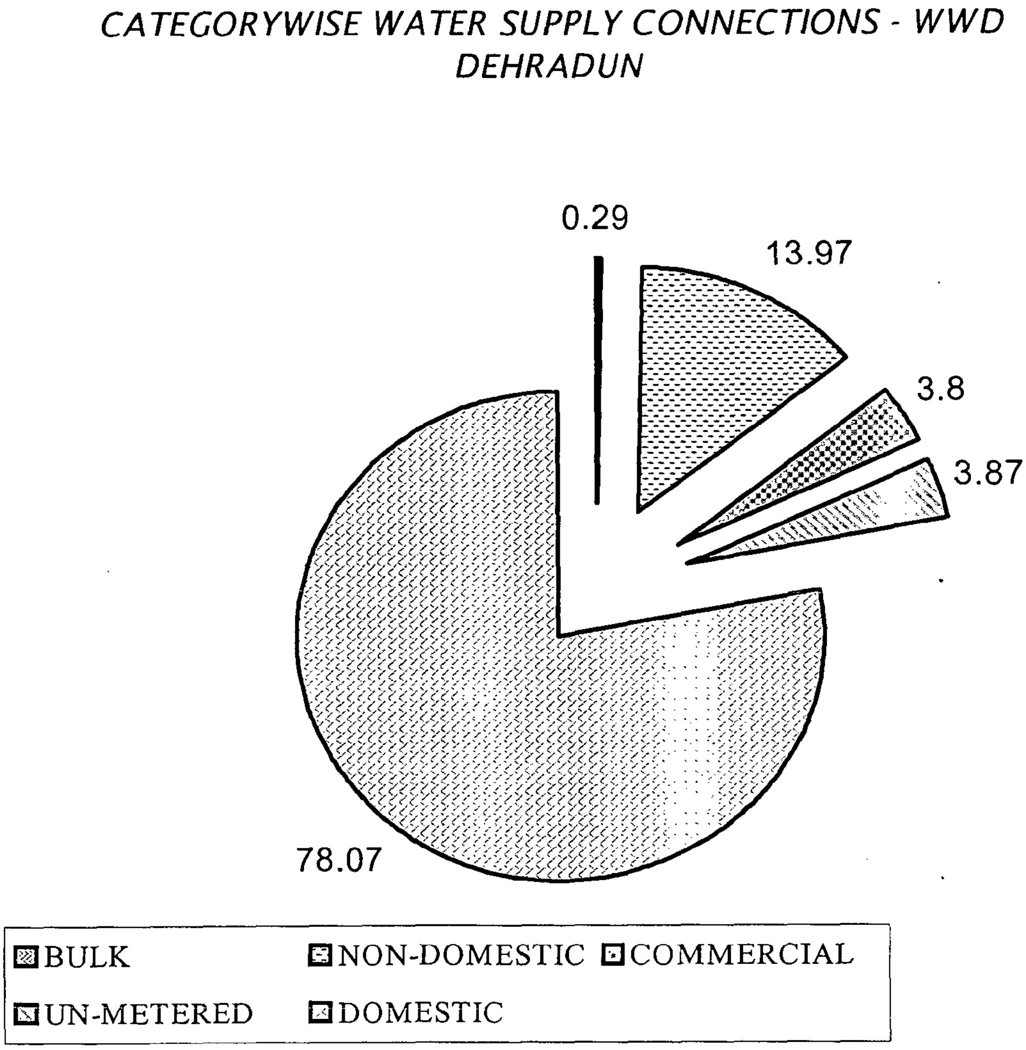


CHART- IV

The hill people have made Gools, Bawries and ditches in the hill slopes and dug up ponds for river water harvesting. The focus needs to shifted to these areas, the small individual needs could also be met with proper and scientific rainwater harvesting systems, polythene tanks, solar pumps and these could be run on water mills which can be transformed into mini electric plants. The Hindustan Times, 11th August, 1999.

TABLE # 20 DETAILS OF OVERHEAD TANKS			
S. NO.	NAME OF OHT/CWR/SUMP	CAPACITY (KL)	STAGING
1.	(A) OVERHEAD TANKS		
	1. Hathi Barkala	300	12
	2. City Board	900	16
	3. Kaulagarh Road TW No.2	450	14
	4. Rajendra Nagar Street No.8 TW no. 1	900	18
	5. Vijay Park near O.N.G.C.	550	16
	6. Jhanda Tank	900	13
	7. Kanwali Tank	900	14
	8. Nehru Colony Tank TW NO. 3	225	16
	9. Parade Ground Survey Chowk	900	16
	10. Water Works	1800	18
	11. Dobhalwala	1250	20
2.	(B) CLEAR WATER RESERVOIRS		
	1. Hathi Barkala	500	Semi Sunk
	2. Dilaram Bazar W/W Campus	--	--
	Tank No. 1	730	Underground
	Tank No. 2	730	Underground
	Tank No. 3	1248	Underground
	Tank No. 4	2250	Underground
3.	(C) SUMPS		
	1. Dharampur Booster P/Stn.	125	Semi sunk
	2. Niranjanpur TW No. 1	75	Semi sunk
	3. Niranjanpur TW No. 2	75	Semi sunk
	4. Survey Chowk Booster P/Stn.	75	Semi sunk
	5. Kaulagarh TW No. 2	75	Semi sunk
Source: Water Works Department, Dehradun.			

There is great and urgent need in Dehradun for

a) Water management including demand management
b) Water conservation
c) Artificial recharge measures based on further necessary surveys, specially in the river valley, as well as a few selected check dams in upstream areas etc.
d) Rainwater harvesting e.g. roof-top water collection/ storage with suitable designs.
e) Water recycling and reuse

A. K. Roy, I.I.R.S. Dehradun (1995)

5.13.4 Tariff For Domestic And Non-Domestic Consumers

Water is sold to the domestic consumers at Rs. 2.50 per thousand litres and non-domestic rate of supplying water is Rs 12/- per thousand litres. Besides the existing tariff rate for consumption of water, a minimum service charge of Rs. 12.50/- plus Rs.2/- for meter rent is collected monthly. This however holds good for consumers who are drawing water through metered connections, but there is a section of people who do not have either metered or unmetered connections on flat rates, but enjoy and draw water from Municipal Mains. To extend the tax base to this section of population and also to have a minimum assured income from the Water Supply System, a water tax @ 12.5% of the rental value of the property is levied on all houses and properties except houses belonging to the weaker section of the society, irrespective of whether that property has a water connection or not and also whether or not water is consumed at such premises. However all those properties which are having metered water connections enjoy a monthly fixed non chargeable quantity of water in lieu of the water Tax paid, but all consumption over the fixed monthly limits all chargeable. If in any case the monthly consumption fall short of the non chargeable limit the balance is not carried forward and it lapse. The present tariff structure for water consumption is presented in the table-21.

TABLE # 21 PRESENT TARRIF STRUCTURE FOR WATER CONSUMPTION WWD (Circular dated 06-09-1994)

TYPE OF CONNECTION		TARIFF Rs./1000 lit.	MIN. SERVICE CHARGE (Rs.)	METER RENT (Rs.)
Domestic	Metered	2.50	40.00	5.00
	Unmetered	2.50	45.00	5.00
Non-domestic	* Spl. Cate. & Industries	15.00	200	5.00
	Other Commercial Inst.	12.00	150	5.00
	Govt. and Semi-govt.	7.50	100	5.00
	Multi purpose M.C points	2.50	45	5.00
	Cantt. Board	4.00	75	5.00

* Star Hotels, Nursing Homes, Cold Storage, Ice cream/Ice factories, Bottling Plant, Petrol Pumps, Garage, Service Stations etc.

Source: Water Works Department, Dehradun

CHAPTER – VI

AN INTEGRATED PLAN FOR WATER RESOURCES MANAGEMENT FOR DEHRADUN

Inadequate recharge resulting in lesser discharge of the springs and wells and increased demand of water is creating scarcity of water in the township of Dehradun. The groundwater play an important role in solving this periodic water crisis and it also serves as a source of uncontaminated water. More than 50 tubewells and 250 dugwells are in existence in the valley. In the decade between 1972 and 1982 groundwater level in the Dehradun, city has dropped by more about 30 metres (Prem K. Thadhani, 1985) and overexploitation of groundwater may lower the water table further and reduce the saturated thickness of the aquifer. Landuse changes are considered to have contributed largely to the reduced recharge and consequently reduced discharge of the natural springs.

6.1 ANALYSIS OF PRESENT WATER SUPPLY SCHEMES FOR DEHRADUN BY JAL SANSTHAN

Population of Dehradun is around 3,28,900 (approximately 65,780 households). Besides, the city also harbours three groups of floaters as well; seasonal immigrant labourers settling in the slums, tourists and students. This escalatesS the city's population to more than 3,60,900 and adds to Dehradun's water demand at the driest time of the year. The city of Dehradun is spread over 38 square kilometres and its sources of water are 30 odd tubewells, with a maximum capacity of 56.64 MLD, and the Bindal river, providing up to 8 MLD. A total supply of 68.64 MLD should, therefore, is expected during regular season. This is equivalent to 153 litre per capita per day for the total population of 4,46,900 (3,60,900 in Dehradun and 86,000 in the adjoining areas).

Based on their pumping rate of 59,550 lpm the total regular season capacity of the city's 30 tubewells should be 64 MLD. One of the tubewells is however abandoned since 1986 and most of all suffer from deficiencies in pressure gauges, depth gauges or booster pumping stations. Electric breakdowns during the dry season further affect the output.

Low water pressure and rudimentary sanitation lead to infiltration of sewage into damaged water mains. Though most of Dehradun's residents are connected to the municipal water system, only 25% are served by a sewer. Diarrheal diseases and kidney problems arising from dissolved salts in the water are a significant health problem, especially in the dry season. The low water pressure is partly a consequence of a gravity-fed system and partly a result of the practice of leaving taps open to catch whatever water is available.

On an average the tubewells of Dehradun are 120 m deep with the depth of groundwater around 70 m during the regular season and 110-m. during the dry season. Four of the tubewells are however less than 60 m deep, and are therefore, inoperable during the dry season. This alone constitutes 7 per cent loss of daily production during the dry season.

Four water treatment facilities are operational in Dehradun, but their capacity totals only 40 MLD, well short of the daily water production. Only six of the tubewells have working chlorinators. A large population is, therefore served untreated water.

Water is distributed from the city's 11 overhead tanks for six hours a day during the regular season. But in reality it supplies only for four and half hours a day in most of the part of the city.

The sewer line serves a quarter of the city's population. Most of the residents (66%) discharge their wastewater into open. The existing five sewage pumping stations supposedly pump sewage to a nearby river; however, three out of five pumping stations do not function properly. To add to it all, the city does not have any wastewater treatment facility. The lack of proper sewage lines cause groundwater contamination and sewage infiltration into low-pressure water supply lines.

Following rains, water starts percolating down through the weathered material and saturate pore spaces in soils and rocks. The recharge of groundwater tends to increase the amount of groundwater storage and raises the pressure in primary and secondary pores. This results in increase in the discharge of water through springs, and thus its quick outflow. High rates of discharge lower the water table and its gradient and reduce pressure in pore spaces. This alteration of recharge and discharge is the cause of seasonal, local and short-term fluctuations.

Because of Dehradun's altitude and stratigraphy, maintaining an individual groundwater source in the city is expensive. Most consumers have no access to water other than through the municipal piped system. Some large institutions operate their own tubewells, which they also use to serve their employees' residences. Dehradun does not have a commercialized water vending activity, except some occasional tanker supply by the municipal water department (Dehradun Water Works Department: WWD) on request.

According to the WWD, its annual physical losses are 22%. This figure is considerably lower than what is reported in studies of other water supply systems both in India and other developing countries. Losses are typically 40 to 50%; these usually include administrative losses. Based on the survey result (conducted by USAID & WASH, 1997), the unaccounted-for-water in Dehradun would be approximately 30%; i.e., the difference between the average water consumption (107 lpcd) and the designed capacity (153 lpcd).

The shortage of piped water supply is due to the inefficient management of the existing capacity, which can be elaborated as:

(a) Inadequate capacity of the pumping main

(b) Insufficient storage capacity of clear water reservoir

(c) Irregular and inadequate power supply to filtration plants and pump houses

(d) Old and inadequate distribution system affecting different areas of the city in varying degrees

(e) Shortage of fund for maintenance

(f) As the supply of water in Dehradun is primarily through tubewells, depth of some tubewells is not adequate to tap the groundwater because it is rapidly depleting.

(g) Due to its topography it is not feasible to serve all with piped water connections

(h) Proximity of overhead tanks

(i) Regulated water supply compels consumers to left their taps open to tap whatever is available causing decrease in pressure and absence of water at the tail.

The general picture to emerge is that the problem is far more serious in the dry season when the main storage tanks are discharged into the mains for a limited period each day. Since 95% of meters are inoperative and accurate billing based on consumption a rarity; taps are just left open to catch whatever is available. Some consumers' topography and connections allow them to use copious quantities of water in their gardens, while others, less fortunate, receive less than the recommended bare-minimum rations of 20 lpcd. Users pay no additional charge for each additional unit of water they consume, and the pricing regime is effectively one of a free marginal cost of water once fixed charges are paid with intermittent and random availability. Billing amount is not consistent with the consumption amount, which causes revenue losses as well as frequent billing disputes.

Constantly open taps lower water pressure contributing to high calcium deposits. Even though water is supposedly discharged regularly from the overhead tanks, the flow of water at the consumers' taps become uneven depending on the supply of electricity, topography and the proximity to overhead tanks. Regulated supply hours are the results of multiple reasons; high fuel costs to run pumps, limited volume of storage tanks, dependency on electric supply, and of course not enough revenue to cover the operation of continuous supply.

The WWD has difficulty tracking down unpaid bills and unbilled water consumption, because it has not registered all its consumers, nor has it automated its billing process. According to the survey (USAID and WASH, 1997) 14% of households did not receive a bill in the year 1996. Revenue is essentially determined by the zeal with which collection campaigns are pursued. Unaccounted for water was estimated to be 33% (the combined effect of non-payment and leakage).

Almost all revenues are used to pay personnel salaries and little remains for repairs and maintenance. Revenues never actually cover costs and debts accumulate – the WWD reconciles its cash flow position by simply not paying its electricity bill (the state utility, which is run like the water department, will not cut off supply and is itself unable to ensure regular supplies or charge an economic tariff.) The WWD's financial system operates according to political cycles and is driven by the overarching goal of meeting the payroll each month. Kyeong and Robert (Kyeong Ae Choe and Robert C. G. Varley, 1997) estimated that to cover the real costs of water in Dehradun would require an average tariff of twice the current level (RS. 2.50 per cum.).

6.1.1 Coping Strategies Of People

Ways of coping with an unreliable water supply include increasing their household's water-holding capacity (quantity), enhancing water pressure (reliability), and purifying water (quality) via water tanks, electric pumps, and water filters, respectively. When there is a water crisis during the dry-season, coping costs reveal a high demand or willingness to pay for marginal consumption. When supply is very low (*at least* 25 percent lower than during the regular season, maybe as much as 50%), an enormous excess demand emerges at the zero price for marginal consumption. In the dry season, the only way users can obtain more water is to spend money on storage capacity or time queuing, to get a bigger share of the available supply. This, however, is self-defeating for the community as a whole, since supply is fixed.

6.2 POTENTIAL OF RAINWATER TO MEET THE CITY DEMAND

The city of Dehradun can be divided on the basis of its development and built up areas. It is important because when we talk of catchment land and its use comes first. Hence on the basis on built up area in each ward Dehradun has been divided into three categories of development. First one is densely developed area where the built up area is more than 50% of the total ward area. Second is moderately developed area where the built up area is in between 20% to 50% of the total ward area. Third and last is the sparsely developed area where the built up area is less than 20% of the ward area. Table-22 shows the areas under different type of wards. From the table it is clear that most of the area in the city is sparsely built up and there is further scope of development in the city. Hence it can accommodate the increased population up to a certain extent. The quantity of sparsely developed area is high also because of the topography of the city.

TABLE # 22 AREA UNDER DIFFERENT DEVELOPMENT TYPES IN DEHRADUN.

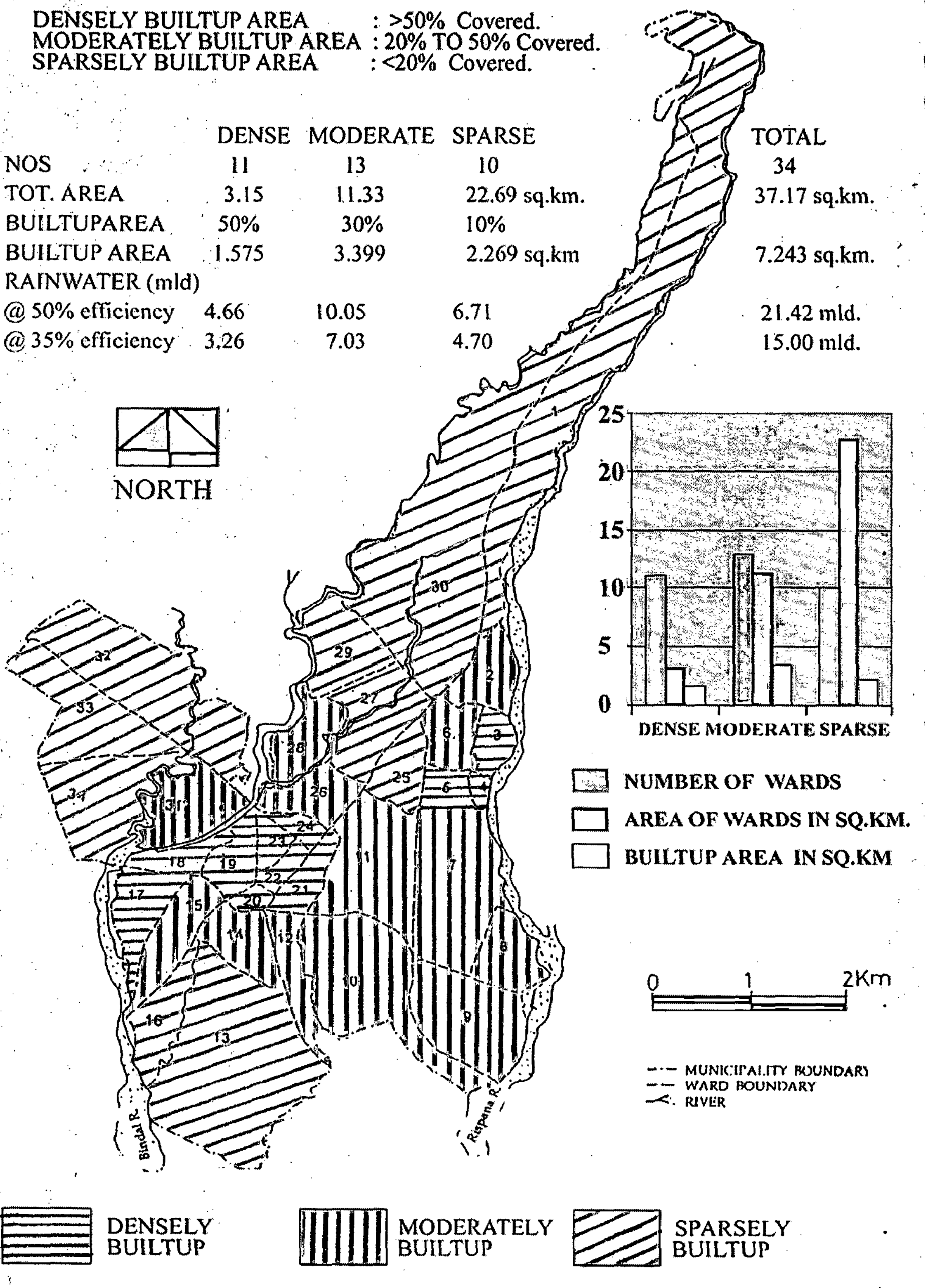
	DENSE	MODERATE	SPARSE
no of wards	11	13	10
Total area of wards sq. km.	3.15	11.33	22.69
Built up area (%)	50	30	10
Built up area sq.km.	1.575	3.399	2.269
Dense wards = built up area >50%			
Moderate wards = built up area 20% - 50%			
Sparse wards = built up area < 20%			

WARD MAP OF DEHRADUN M.B.

SHOWING THE BUILTUP AREA

DENSELY BUILTUP AREA : >50% Covered.
MODERATELY BUILTUP AREA : 20% TO 50% Covered.
SPARSELY BUILTUP AREA : <20% Covered.

	DENSE	MODERATE	SPARSE	TOTAL
NOS	11	13	10	34
TOT. AREA	3.15	11.33	22.69 sq.km.	37.17 sq.km.
BUILTUPAREA	50%	30%	10%	
BUILTUP AREA	1.575	3.399	2.269 sq.km	7.243 sq.km.
RAINWATER (mld)				
@ 50% efficiency	4.66	10.05	6.71	21.42 mld.
@ 35% efficiency	3.26	7.03	4.70	15.00 mld.



Builtup area means the sum of roof area and paved area.

MAP-VII

When we compare the total built up area of the city with its total area it comes very low of just about 20% in year 1981. But the pace of growth since then was very high and presently this ratio may be as high as about 30% of the total city area. The question raises that when this much city area is left open why then recharge of ground water is not sufficient or at least equal to the withdrawal.

There are 11 wards, which are densely built up. Thirteen wards are moderately built up. And only ten wards are sparsely built up. (Chart-V)

The area under sparsely built up wards is highest because these wards are of larger area and latest developed (see map-VII). Major wards under this category are Rajpur, Patel Nagar, Vijay Nagar, Rajendra Nagar, Hathibarkala and Ballupur. Under this category of wards large institutions big offices and government offices, which are having large premises. Survey of India and Indian Institute of Remote Sensing in Hathibarkala, Wadia Institute of Himalayan Geology in Ballupur and Oil and Natural Gas Corporation, Central Soil and Water Conservation Research and Training Institute, and Geological Survey of India in Rajendra Nagar on Kaulagarh road are few to name the large and international level institutions.

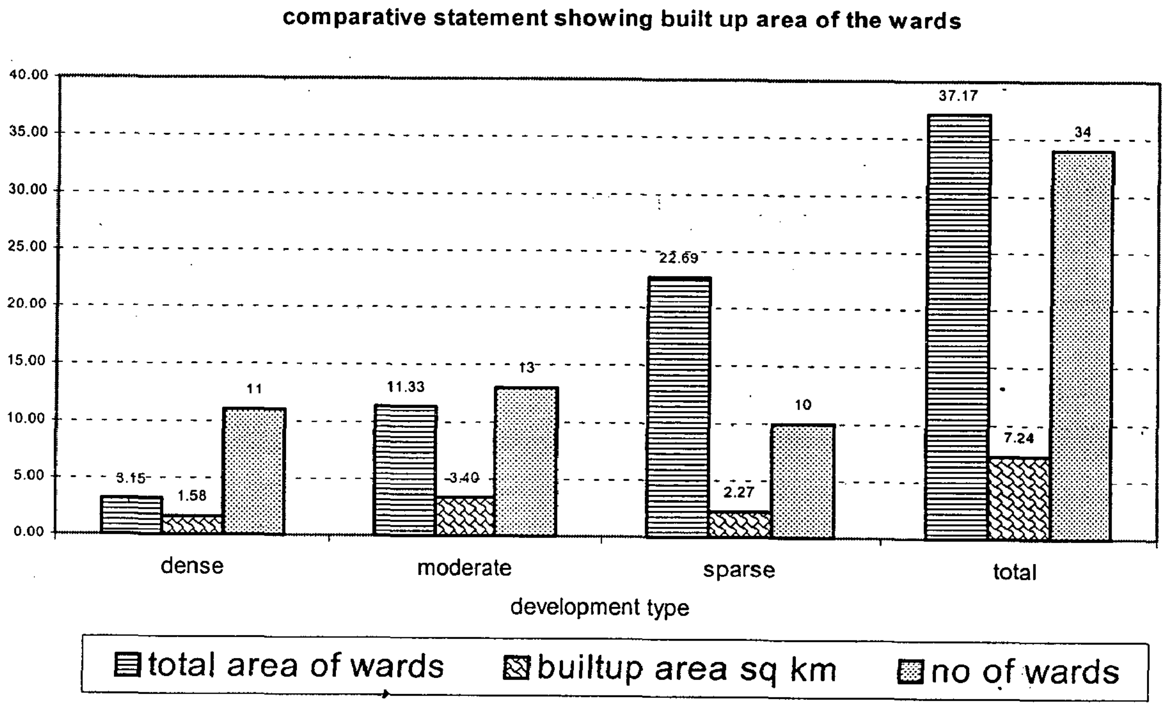


CHART-V

Strategy of water management and rainwater harvesting should be distinct for each type of development. Landuse is also very different in each type of development. In densely built up wards major activities are of residential and commercial. While some government organisations and schools can be attributed to these wards.

In the moderately built up wards main landuse is residential but the development is somewhat planned. The main wards constituting the area are Aryanagar, Yamuna Nagar, Dalanwala East and West, Mahadevi Kanya Pathshala, Race Course. Residences are having large plot area and most of them are having gardens within the site. Gardening is very popular and everyone in Dehradun wants to have his own home garden. These sites can be very good for rainwater harvesting and recharge of groundwater the only thing is to make some small provisions within the area. This zone of development contains large educational institutions of national and international fame like Doon school and others. These institutions are having large roof areas and a large quantity of rainwater can be harvested from rooftop area of these institutions. Many institutions are residential campus type. Hence the strategy of rainwater practice from management point of view shall be different than that of individual house or institutions without residential campus.

The third category of development is densely built up areas. Rispna, Tilak Road, Ansari Marg, Jhanda Ward, Khurbura and Shivaji Marg are the main wards in the area. The area under these wards is least but the population is highest and development is very high in the area. These wards need special attention as there is very less area or no area left open even of minimum standard. But the development in the area is of contiguous type providing large continuous stretch of roof area that can be effectively utilized for rainwater harvesting. Mixed type of development gave rise to the high population density during daytime. Hence water requirement in these areas is not only of the permanent residents of the area but of the working people and persons coming for shopping and other activities also add to the requirement of the water in the area. Another character of the area is that large number tenant population which lives in the rented houses. This population does not have any property rights in the area but utilize all the infrastructure facility of the area. Hence care should be taken to involve this population in the water management of the area at the local level. Generally the entire area is having pucca roads, but open drainage channel and inefficient sewer system. People in the area used to divert the rainwater of the house along with the sewage in the same drain. Hence this aspect should also be kept in mind while preparing the water management plan for the area. Social interaction in the area is very high hence there is great possibility of community driven approach to be successful.

6.2.1 Potential According To Development Type

Although rain falls equally on all the places of the Dehradun municipal area as it is very small area to face any variation in rainfall pattern. But the potential of rainwater harvesting differs according to development type and topography of the area and landuse. On the basis of development type the entire municipal boundary is divided into three types of developments viz. dense, moderate and sparse. The built up area taken constitutes the rooftop area and paved surfaces. Built up area is pucca area, which does not allow water to percolate into the ground hence maximum rainwater is generated as runoff water. The losses from the runoff mainly due to the evaporation of the water from the surface. Rainwater from open area generates less runoff as compare to the built up area, due to the percolation of water into the ground. Soil of Dehradun is alluvial and it is of Doon gravels which allows high percolation. Due to the terrain of the city speed of runoff generated is very high and the time of contact between ground and water reduces. It is because of it that rate of infiltration or recharge is very less in comparison to the withdrawal of groundwater leading to depletion of groundwater in many areas of the city. The potentials of rainwater harvesting from different development types are given in the table no-23. Harvested water from the moderately developed area is highest due to its highest share of land under built up area in the city. This is the zone where from maximum water is expected to harvest through various type of rainwater harvesting techniques.

TABLE # 23 POTENTIAL OF RAINWATER HARVESTING IN DIFFERENT DEVELOPMENT TYPES OF DEHRADUN

Type of development	Dense	Moderate	Sparse	Total
Built-up area	1.575	3.399	2.269	7.243
Harvested rainwater from built-up area (million litre)	3400.9	7339.46	4899.45	15640
@ 50% collection efficiency harvested water (million litre)	1700.45	3669.73	2449.73	7819.9
@ 35% collection efficiency harvested water (million litre)	1190.31	2568.81	1714.81	5473.9
Availability of RW @ 50% efficiency (mld)	4.65876	10.0541	6.71158	21.424
Availability of RW @ 35% efficiency (mld)	3.26113	7.03784	4.6981	14.997
Note: average annual rainfall of Dehradun city has been taken as 2159.3mm				

Total built up area in Dehradun municipal area is 7.2 sq. km. from where 15.5 thousand million litre of rainwater can be harvested. This quantity of rainwater is collected when we all the rains which falls in the built up area. But it is never possible because of various factor like evaporation, and loss surface runoff and due to the very reason which states that any system cannot be 100 percent efficient in practical. In this case due to various practical hurdles, it may not be possible to harvest more than 70 percent of total rainwater. For the purpose of calculation and assuming that this is the beginning in this field, efficiency may not be more than 50 percent. According to the collection efficiency of 50 % we shall be able to collect about 7.8 thousand million litres and at the collection efficiency of 35% this quantity comes to be 5.5 thousand million litres. This quantity of rainwater is collected from a year. If we see the per day availability of the rainwater then it comes 21 million litre per day at the rate of 50% collection efficiency and 15 million litre per day at the rate of 35% collection efficiency.

Table no-24 illustrates the figures of rainwater harvesting capacity of unbuilt or open areas. Area under open areas is highest in sparsely developed wards. From open area of around 30 sq. km. we can collect maximum of 64.6 thousand million litres of rainwater. While at the collection efficiency of 50% availability is 32 thousand million litres and at

TABLE # 24 CAPACITY OF RAINWATER HARVESTING FROM OPEN AREAS

Type of development	Dense	Moderate	Sparse	Total
Unbuilt (open) area of wards Sq. km.	1.575	7.931	20.421	29.927
Harvested rainwater from open areas (million litre)	3400.9	17125.4	44095.1	64621
@ 50% collection efficiency harvested water (million litre)	1700.45	8562.7	22047.5	32311
@ 35% collection efficiency harvested water (million litre)	1190.31	5993.89	15433.3	22617
Availability of RW @ 50% efficiency (mld)	4.65876	23.4595	60.4042	88.522
Availability of RW @ 35% efficiency (mld)	3.26113	16.4216	42.2829	61.966
Note: average annual rainfall of Dehradun city has been taken as 2159.3mm				

35% it is 22.6 thousand million litres. 88 mld and 62 mld is harvested at the 50% and 35% collection efficiency respectively. The water demand of the city at present is 87.15 mld @ 210 lpcd(chart-VI). The total supply of water from all sources by Jal Sansthan is only 68.64 mld. Hence there is a big gap of 18.15 mld. After completion of the ongoing project of augmenting the water supply this is expected to supply maximum of 100.5 mld. The future projected demand in 2011 is calculated 117.6 mld at the rate of 210 lpcd. But as the population grows the standard of water supply changes and as per the standard this should be about 240 lpcd. If we take this standard then future demand projected is 134.4 mld in the year 2011. So it is clear that in near future there will be acute problem of water shortage. Now if we see the figures of rainwater harvested from the city it presents a quite satisfactory picture of water supply. Table – 25 shows the capacity of rainwater to fulfill the demand of city water. It is clear from the table that the rainwater from only the built up area can fill the gap between demand and supply in future if the total rainwater is harvested.

TABLE # 25 CAPACITY OF RAINWATER TO FULFILL THE CITY DEMANDS

	Harvested rainwater	Capacity of RW to fulfill the demand		
		Demand	@ 210 lpcd	@ 240 lpcd
water demand @ 210 lpcd (mld)		117.60		
water demand @ 240 lpcd (mld)		134.40		
@ 100% efficiency from built-up area (mld)	42.85		36.44	31.88
@ 50% efficiency from built-up area (mld)	21.42		18.22	15.94
@ 35% efficiency from built-up area (mld)	15.00		12.75	11.16
@ 100% efficiency from open areas (mld)	177.04		150.55	131.73
@ 50% efficiency from open areas (mld)	88.52		75.27	65.86
@ 35% efficiency from open areas (mld)	61.97		52.69	46.11
@ 100% efficiency from total area (mld)	219.89		186.98	163.61
@ 50% efficiency from total area (mld)	109.95		93.49	81.81
@ 35% efficiency from total area (mld)	76.96		65.44	57.26

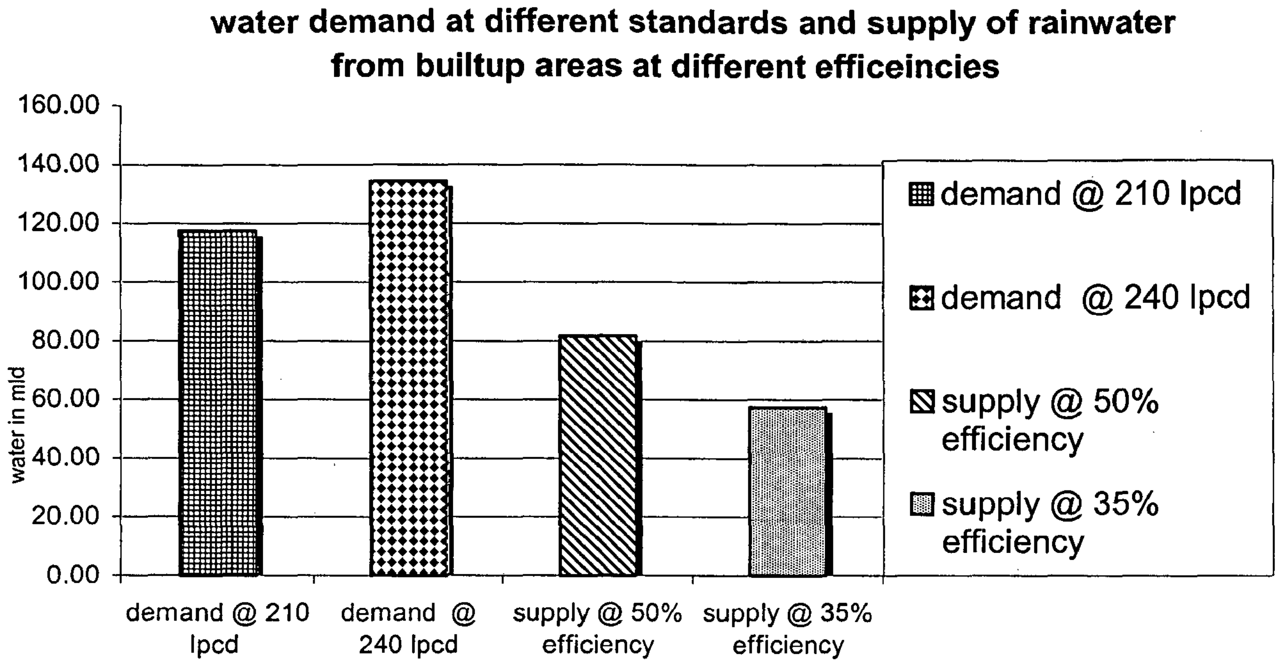


CHART-VI

It can fill the present gap of 18 mld at the collection efficiency of just 50%. Hence if we make the rooftop rainwater compulsory in all the buildings then at least we shall be able to collect 50 % of total rainwater from built up areas, which can contribute to some extent to reduce the shortfall. Even if we can harvest only 35 % of rain from roofs, it will reduce the shortfall considerably. It is clear from the chart-V also. This harvested water alone is sufficient to serve a big number of population. In the table- 26 the number of population at the most, which can be serve through rainwater harvesting from built up area is about 1.12 lakhs and at least 78 thousand from the same area.(chart-VII) But if we see the total rainwater harvested from the entire city then it is capable of serving 52 lakhs, which is equal to the 93% of the total population in year 2011. Hence we can say that if rainwater is harvested then population ranging between 60% to 90% can be served by rainwater alone.

TABLE # 26 POPULATION SERVED THROUGH RAINWATER

	Population that can be served through rainwater		%age of population that can be served through rainwater	
	@ 210 lpcd	@240 lpcd	@210 lpcd	@240 lpcd
RW @ 50% efficiency from built-up area	112190	98166	20.00%	17.50%
RW @ 35% efficiency from built-up area	78547	68729	14.00%	12.27%
RW @ 50% efficiency from total area	523809	458333	93.50%	81.80%
RW @ 35% efficiency from total area	366666	320833	65.50%	57.29%

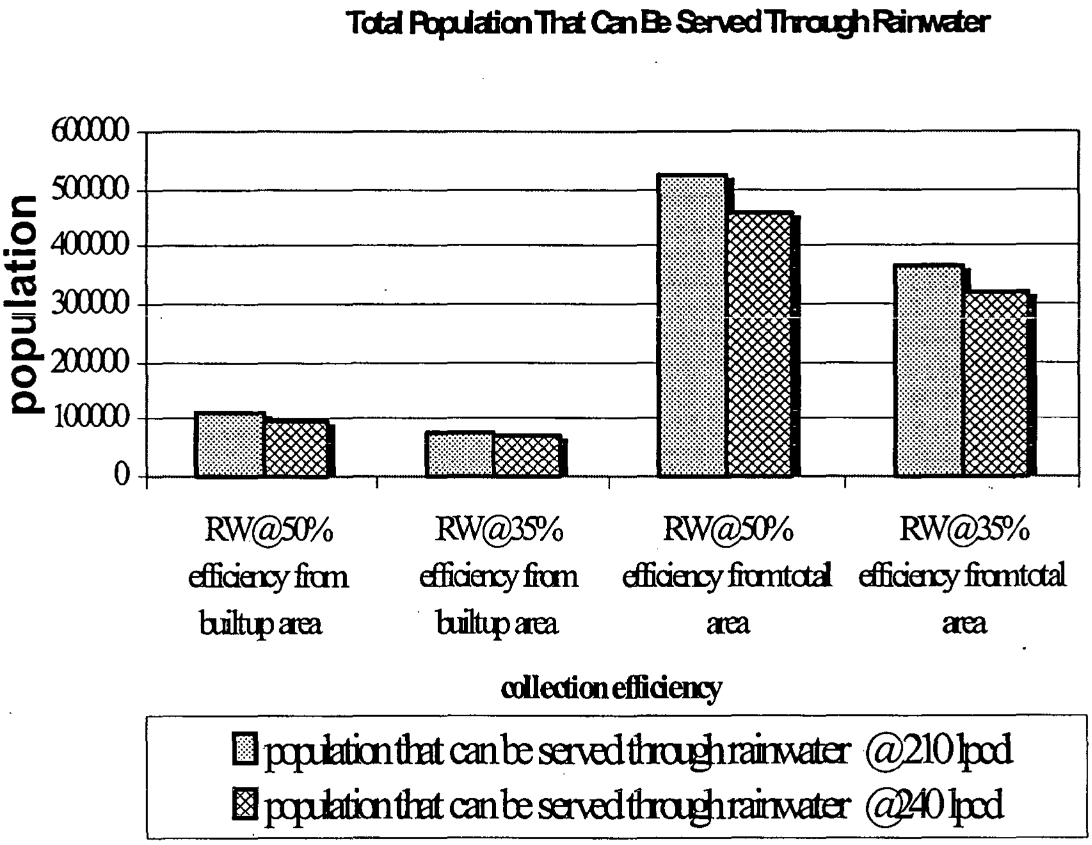


CHART-VII

Table-27 indicates that at the different efficiency of collection of rainwater we obtain different figure that can supplement the existing water supply of the city. At most the total water, which falls on the ground, if collected, will provide 16.3.6 million litre per day of supply. And if the least is collected that is one third of the total rainfall then it will provide 57.2 million litre per day of water. Taking the minimum amount we can fetch around 40% to 50% of city demand of water.

TABLE # 27 EFFICIENCY OF RW TO SUPPLEMENT EXISTING WATER SUPPLY

			Capacity of RW to fulfill the demand	
	Harvested rainwater	Demand	@ 210 lpcd	@ 240 lpcd
Water demand @ 210 lpcd (mld)		117.60		
Water demand @ 240 lpcd (mld)		134.40		
@ 100% efficiency from built-up area (mld)	42.85		36.44	31.88
@ 50% efficiency from built-up area (mld)	21.42		18.22	15.94

@ 35% efficiency from built-up area (mld)	15.00		12.75	11.16
@ 100% efficiency from open areas (mld)	177.04		150.55	131.73
@ 50% efficiency from open areas (mld)	88.52		75.27	65.86
@ 35% efficiency from open areas (mld)	61.97		52.69	46.11
@ 100% efficiency from total area (mld)	219.89		186.98	163.61
@ 50% efficiency from total area (mld)	109.95		93.49	81.81
@ 35% efficiency from total area (mld)	76.96		65.44	57.26

6.3 NEED FOR INTEGRATING RAINWATER HARVESTING

Water resources consist and important part of the wealth of any settlement. History reveals that all the major civilization has grown along the course of water. It is only the increasing population, and unwise exploitation of water which has led the water crisis. Dehradun is also among those cities, which are facing the water shortage not because that it does not have the resource but because of its imprudent use and human intervention in the natural cycle of water. There is need to reconcile the water use with the natural cycle of water and this cycle consist of Groundwater, Surface water and Rainwater. Actually all the waters that we use come from precipitation. Hence it is important to take care of precipitation.

There is and urgent need to integrate rainwater harvesting with our water resource management. Following are some are the reasons, which compelled me to resort for rainwater harvesting in Dehradun.

- It is difficult in many areas where water table has gone down too much below the ground level, to have individual borewell. And in those areas populace is dependent on municipal water supply, which is very unreliable, hence rainwater is the only available source to exploit.

- Water supply in Dehradun is mainly through tubewells. This has caused groundwater depletion. To arrest it, it is necessary to harvest rain and recharge groundwater.

- Some of the areas, which are not served by municipal water supply, are facing acute water scarcity. Rainwater is boon for those areas.

- Due to high gradient soil erosion is very rampant. To stop this, it is important to check the runoff and harvest it.

- Increased urbanisation has led to increased demand, reduced recharge of groundwater due to paved surfaces and inadequate supply of water and increased runoff.

- Rainwater harvesting is a best and most economical method for Dehradun scenario, where there is scarcity for drinking and domestic water in spite of very good rainfall. This method is also eco-friendly and economical.

- The rainfall pattern of Dehradun is best suited for this because rains spread over year, with precipitation almost in each month.

6.4 AN EXAMPLE OF RAIN WATER HARVESTING: Proposals for cpwd office, Dehradun

The office building of CPWD is located in the heart of Dehradun City near Clock Tower. The complex is presently served through the municipal water supply. It often faces problems of water during summers. The depth of water level at this place is about 50 meters. And goes down during summers to the extent of 60 meters. If we can harvest the rainwater in the building and the campus it is expected that it will be able to serve at least 30 percent of the water need of the building and augment the water level of the area.

The office complex consists of four building blocks and three of them are three storied high having considerable ground coverage. Roads surround the triangular site on its two sides and buildings on its third side. The particulars of the complex are as given below.

Total site area	**6015** sq.m.
Area of block A	580.65 sq.m.
Area of block B	44.00 sq.m.
Area of block C	167.80 sq.m.
Area of Annexe building	287.00 sq.m.
Total covered area	1079.45 sq.m.
Say	**1080** sq.m.
Area left open	4935 sq.m.

6.4.1 General Considerations

The building is used for the office purpose only and hence the requirement of water per capita is taken as 45 litres per capita per day for the computation purpose of water demand. The number of workers in the office is taken 350 persons including the visitors. It is also assumed that in case of office building water requirement does not vary seasonally. Hence average per capita requirement remain consistent throughout the year. The average annual rainfall of Dehradun has been taken of the year 1995. Number of working days in case of central government office has been taken into account for the calculation purpose.

TABLE # 28 COMPARATIVE STATEMENT OF RAINWATER AVAILABILITY AND WATER DEMAND IN OFFICE BUILDING OF CPWD, DEHRADUN

A	B	C	D	E	F	G
Month	*Rainfall*	*water req.*	*RW from rooftop*	*RW from total area*	*D-C*	*E-C*
	mm	cu.m	cu.m	cu.m	cu.m	cu.m
jan	58.90	346.5	62	354	-237.25	7.5
feb	62.70	299.25	67	377	-295.25	77.75
mar	32.00	315	34	192	-296.75	-123
apr	16.50	299.25	18	99	-328.5	-200.25
may	36.80	362.25	40	221	-306.5	-141.25
june	217.20	330.75	237	1306	-78	975.25
july	668.00	346.5	721	4018	390.25	3671.5
aug	731.30	346.5	789	4398	458.25	4051.5
sept	268.70	315	290	1616	-9.25	1301
oct	32.00	330.75	34	192	-3541.3	-138.75
nov	4.30	330.75	5	26	5	-304.75
dec	35.00	299.25	38	210	38	-89.25
TOTAL	*2163.40*	*3575.25*	*2335*	*13009*	2335	9433.8

Water demand as such does not vary seasonally but supply of it from municipality varies a great deal. This variation in supply causes the water scarcity in the office and the entire city also. At the local level we can cope with this problem through rainwater harvesting. Table-28 gives the availability of rainwater from rooftop and from the total site. Total water collected from the site in a year is around two four times of the total demand in a year. In the above table water demand for garden, car washing etc are not included. But the distribution of rainwater is not homogenous throughout the year hence causing a gap between demand and supply. This enforces us to resort for the storage of rainwater for use in lean periods. It is clear from the table that water is in excess, in july and august as far as roof top rainwater is concerned and, in june, july, August and September when we see the water from the entire site. This water can be stored and used in the months ahead.

6.4.2 Storage Of Rainwater

All the rainwater, which falls on the roof and the ground, can not be stored due to various reasons. For the calculation purpose I assume that about 75% rooftop rainwater and 50% rainwater from the site can be harvested.

75% of roof top rainwater = 4308 cu.m. /year

50% of rainwater from the open areas = 5337 cu.m. /year

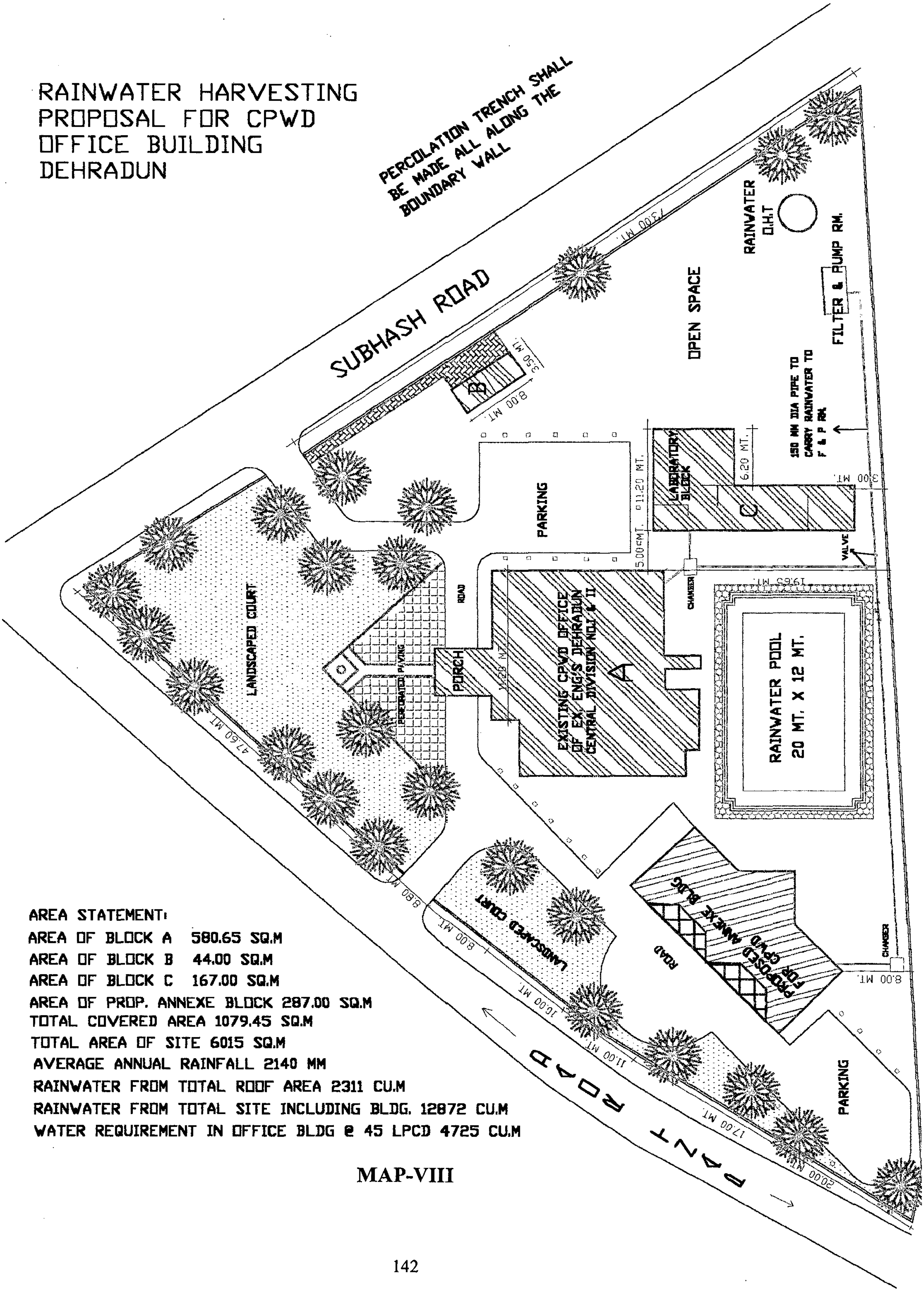
We know that excess water falls in only selected months. Hence for rooftop rainwater we need to store only 156 cu.m. plus average daily rainfall over the roof in July and august that comes to be 186 cu.m. and for open areas we need to store excess water of four months i.e. June, July, August and September. Priority has been given to rooftop rainwater for use then we use rainwater from open areas. Hence excess water comes to be 4263 cu.m. during these four months if only 50% of the total rainwater from open space is taken into account.

Storage reservoir for rainwater from open space = 4250 cu.m. (Say)

Storage tank for rooftop rainwater = 180 cu.m.

6.4.3 Distribution System

Distribution of water shall consist of two parts, one for the building and other for the site. Site uses include the fire fighting, watering of trees and road washing etc. Building uses includes two parts first for drinking and second for all other uses. For this there shall be two supply lines one exclusively for drinking purpose and other for all other purpose. Rooftop rainwater shall be stored on the specially located and designed tank. There will be another tank on the ground floor that will add to the beauty of the landscape and will serve as a water reservoir. The design proposals are shown in map-VIII. It is shown in the that the rooftop rainwater shall be diverted to a common collection chamber from there it will be diverted to directly F & P room or to the rainwater pool. Rainwater will be stored in two places, in the RW pool and OHT for rainwater. Pond will contain untreated water while OHT will contain purified rainwater, ready to be used for supply.



AREA STATEMENT:

AREA OF BLOCK A 580.65 SQ.M
AREA OF BLOCK B 44.00 SQ.M
AREA OF BLOCK C 167.00 SQ.M
AREA OF PROP. ANNEXE BLOCK 287.00 SQ.M
TOTAL COVERED AREA 1079.45 SQ.M
TOTAL AREA OF SITE 6015 SQ.M
AVERAGE ANNUAL RAINFALL 2140 MM
RAINWATER FROM TOTAL ROOF AREA 2311 CU.M
RAINWATER FROM TOTAL SITE INCLUDING BLDG. 12872 CU.M
WATER REQUIREMENT IN OFFICE BLDG @ 45 LPCD 4725 CU.M

MAP-VIII

There will be separate distribution pipe for the drinking and non-drinking use of water. There will be an over head storage tank for rainwater. Rainwater will be given first priority in use then comes municipal water. Before the rainwater from rooftop gets accumulated in the tank it will pass through a filter.

Additional rainwater that is not possible to store due to any reasons should be diverted to the underground water table or aquifer. To allow the rainwater to percolate into the ground numbers of percolation pits are to be made in the campus at suitable locations. Wherever the pavement is there it shall be perforated. Paving should be avoided in open spaces and if it is to be there it should be perforated. Trenching will be done all along the boundary wall of the campus. Size of it will be 60 cm. X 60 cm having depth of 60 cm. The trench will be first filled with 20 cm thick layer of coarse aggregates and next 30 cm thick layer of pebbles and then remaining top cover of sand. This will filter the rainwater before percolation.

6.4.4 Implications At City Level

The above example of rainwater harvesting in CPWD office building if implemented in every government and private institutions it will be able to enhance the groundwater table to a great extent. Suppose an institute is capable of recharging 5000 cum. per annum, and about 100 of big or small institutions implement it, then it computes to be 5 lacs cum. of rainwater per year. Similarly if only 35% of houses make provision for rainwater harvesting and recharge, it will reduce the burden over Jal Sansthan to one forth of existing water supply. Therefore it is reiterated that the rooftop rainwater harvesting should be made mandatory in all building designs.

Of course the rainwater harvesting proposal is not to eliminate the existing water supply system but to supplement it and take over the charge gradually from it up to certain extent. Arresting rainwater means reducing runoff in the city and reduction of pressure over storm water drains.

6.5 RWH PROPOSALS FOR THE CITY

6.5.1 Strategies For Implementation

1. Rooftop rainwater harvesting should be made mandatory for all the new construction with the municipal limit of Dehradun.
2. In old areas or densely built up areas community level structures for harvesting rain should be constructed and the rights of the water should be given to the community itself.
3. No boring should be permitted without prior permission of the Subdivisional Magistrate.
4. At least 10 percent of the area in every house and building should be left unpaved. And should be made compulsory.
5. There should be separate storm water pipe network, which can collect the runoff and should lead to any pond and reservoir. It should be then treated and supplied for non-drinking purpose. Hence there should be two separate water supply lines one to supply drinking water and other for non-drinking water.
6. Supply of drinking water should be for regulated hour and of non-drinking water it should be continuous supply.
7. Some of Water harvesting structures at city level can be given to the private sectors to construct maintain and supply the collected water at reasonable price to different sectors.
8. Most of the big institutions, government and private, in Dehradun are having their own water supply system from their own tubewells and resources. They are just withdrawing the water from ground and not contributing in its replenishment. It should be made mandatory in the building bye-laws for all the institution to harvest rain and recharge the groundwater. The ground water should not be seen as a commodity for granted. They must pay for it and participate in its enhancement.
9. In the densely built up wards community recharge pits and storage tanks are proposed which will collect the rainwater from the rooftops of the buildings in the area. The runoff water in excess can be diverted to other open areas, where recharge facility should be provided.

10. In moderate development existing buildings should make provision for harvesting of rainwater within their plot.

11. Tariff on present water supply is Rs.2.5 per thousand litres for domestic use. But the actual cost of it has been worked out as Rs. 5 per thousand litres. Hence the tariff should be increased to Rs.5 per thousand litres.

12. Effort should be to provide every household with municipal water connection. But if any household is not having any rainwater harvesting structure or not contributing in enhancement of water resources of the area he must be surcharged for the loss the rainwater, which he could be otherwise harvesting, at the rate of municipal water supply.

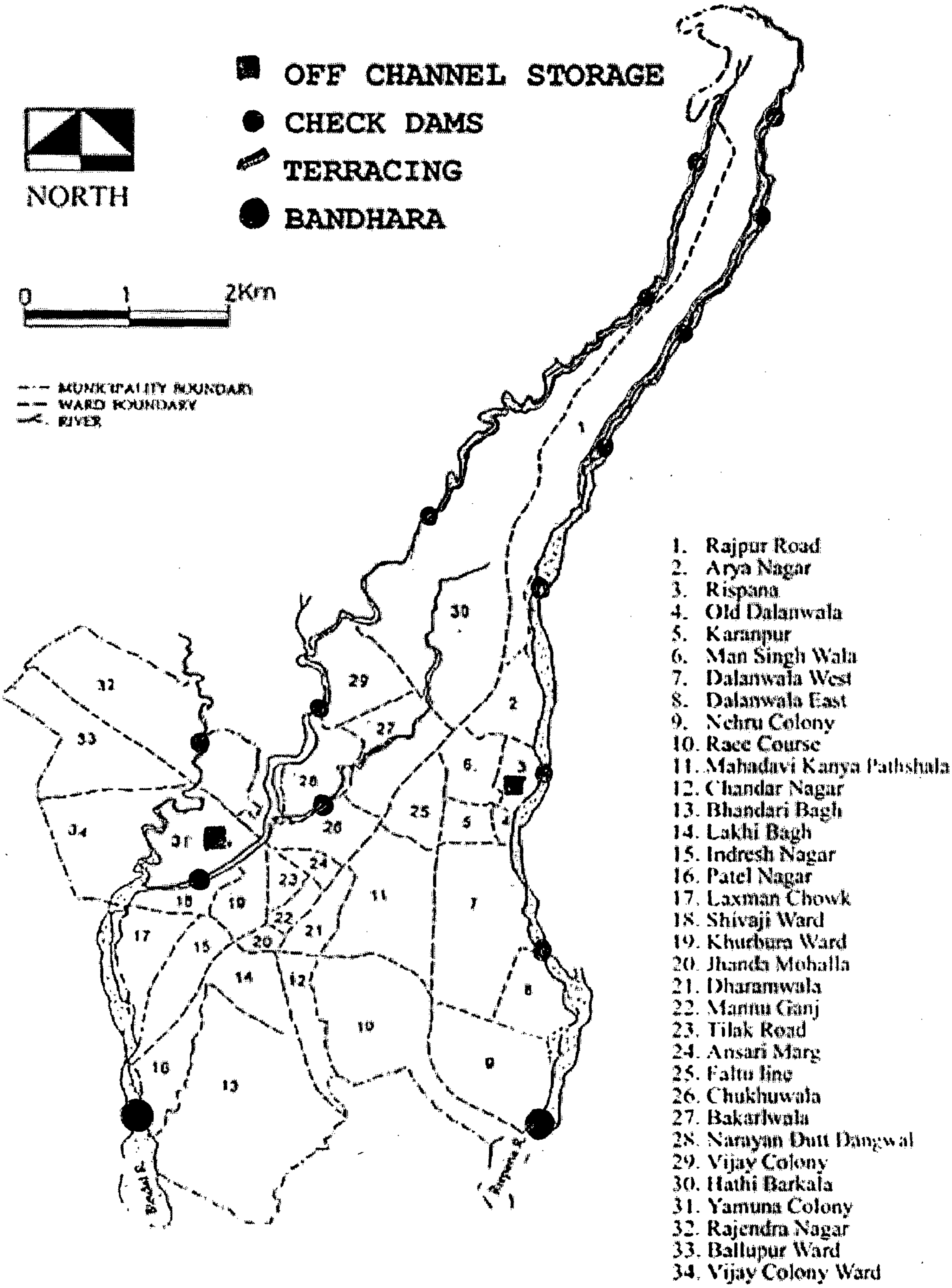
13. At present large amount of sewerage is disposed in the natural drainage due to the lack of proper sewer system in the city. These pollute the groundwater resource and the water in the channels. Ban on disposing the sewer into these natural drainage channels is recommended.

14. In Dehradun people are fond of living in large garden houses. At present water used for gardening purpose is from municipal water supply. This is just the wastage of such an important resource, which is treated for drinking use. All the households having their private garden must use rainwater for this very purpose and it use of municipal water for gardening should be banned.

6.5.2 Planned Locations of Rainwater Harvesting System

1. Where soil condition is less favorable, a network of contour bunding and check dams should be constructed. The sites for this are the seasonal drainage channels. Location of these sites is shown in the map-IX. Mainly these sites fall on the edge of the municipal boundary but there are many areas in the city itself where check dams, should be constructed.

WARD MAP OF DEHRADUN M.B.
PROPOSED WATER HARVESTING STRUCTURES



MAP-IX

2. Percolation tank and recharge pits should be constructed along the paved roads at a suitable interval and the maintenance of these structures should be entrusted to the municipality.

3. Off channel storages are provided in Rispana andYamuna Colony wards. These storage reservoirs shall have the purification and treatment plant for runoff water. After purification it will be supplied to the households.

4. Check dams should be constructed in the seasonal streams and nallas that are locally known as Khalas. The dams are proposed at the place where the depth of the stream bed is at least 2m. below the surrounding land.

5. Two Bandharas are proposed at the lowest parts of the rivers in the municipal boundary. one of them is located on Bindal river at the boundary of Bhandari Bagh ward and other in the Nehru colony ward. Municipality will take care of these Bandharas.

6. Rajpur Road and Hathi Barkala wards have very slopy land. In these wards terracing is proposed to increase the contact of rainwater with the surface of ground to increase the percolation of rainwater into the ground.

6.5.3 Implementation Guidelines

1. Management of the small check dams should be in the hand of the ward committee and the peoples participation must be ensured.

2. There should be increment of tax base in the city. Effort should be on bringing all the households under metered connections.

3. There should be the afforestation programme at the city level and plantation along the roadside is necessary.

4. Along the major roads ditches and furrows should be constructed.

5. New development should take care of natural drainage pattern and watershed areas. No construction activity should be allowed in water shed areas.

6. Preservation of existing ponds, reservoirs and lakes. should be taken up seriously.

7. Artificial recharge measures based on further necessary surveys, specially in the Asan river valley (Jhajra Sahaspur Sector and Bindal) and Rispna Rao River valley as well as a few selected check dams in upstream areas etc.

8. Water recycling and reuse. should be encouraged by suitable incentives.

9. Based on existing information on Groundwater, it is suggested that a properly located, spaced and integrated 'battery' of tubewells in Jhajra and Harrawala sectors of Doon Valley could be taken up in near future for augmenting water supply to Dehradun (new master water supply scheme) and its expanding peripheries. Action should be taken for this. Water budget has to be worked out for the Doon (A. K.Roy, 1995).

10. NGOs should encourage formation of community associations and networking which should in turn influence water policy of the region.

11. Small institutions which are used in only during day times and their water needs are very low can divert excess rain water to the nearby population and should be paid for that. They can also recharge the groundwater if it is not possible to divert to the other localities.

12. A forum at the District level is recommended with representatives from various departments and people representatives, NGOs etc. for overall water conservation and management and evolves a policy for water harvesting structures.

CHAPTER – VII

GUIDELINES FOR URBAN PLANNING AND DEVELOPMENT

7.1 INTRODUCTION

Urban planning so far has been based on assumption that the colossal need of water of the fast growing population of our cities would be 'somehow' served by the groundwater. It has not happened the water supply scenario for all our metropolis is very grim and we can hope to overcome the problems of water scarcity only by taking all necessary step toward harvesting rainwater at the individual house, community and city levels.

Necessary Acts and bylaws need to be enacted by the states and local self-governments to incorporate rainwater harvesting as mandatory part of building design and city development.

The following are some guideline policy recommendations and strategies to get maximum benefits from rainwater harvesting in future.

7.2 TECHNO-ECONOMIC ASPECTS

- Rainwater harvesting should be adopted as a national programme with the objective of increasing ground water storage, except the quantum required for maintaining the river ecology.
- The rainwater harvesting schemes should be based on scientific approach wherein the twin essential elements of source water availability for recharge and suitable hydrological situations to create sub-surface reservoirs are given prime importance. Multidisciplinary

approach including hydrogeological, hydrological and geophysical aspects need to be adopted for designing rainwater-harvesting schemes.

- Model rainwater harvesting projects in different hydrological setups should be implemented on larger scale so that these could act as 'Demonstration Projects' for replication in similar environment.

- The areas with high rate of groundwater development, especially "over exploited" blocks metro and highly urbanised areas should get priority for implementing the rainwater harvesting schemes.

- Although on a macro scale, major areas suitable for rainwater harvesting have been identified, micro-level studies in critical areas to draw detailed plans for ground water resource management are also required before implementation of new operational projects.

- Development of cheaper alternatives for rainwater harvesting and conservation methods like clay sub-surface dykes, various designs of recharge shafts, surface spreading methods and also other combination methods is a major thrust area for scientists and engineer-planners.

- Regional Aquifer System Analysis should also be taken up on a larger scale for future development and management of ground water resources including rainwater harvesting. Central Government, State Governments, Institutes and private organisations are required to make joint efforts to achieve it.

- Tech-economic evaluation of rainwater harvesting schemes should be taken up to assess the benefits. A part of the component of the financial assistance from institutional finance agencies, including NABARD, must be set for recharge schemes and extended for the purpose.

- A suitable pricing mechanism need to be adopted for water so as to recover the cost of rainwater harvesting and management of water resources. It shall also help in promoting conservation of water resources.

- Rainwater harvesting projects should be taken up in coastal areas to prevent the sea water ingress.

- Traditional rainwater harvesting techniques, which have severely eroded, should be revived with a mix of modern techniques to provide sustainability to water resources.

7.3 PLANNING AND MANAGEMENT ASPECTS

- Clear delineation of rights of individual, community, state and centre over ground water in an area need to be defined by the planners and legal experts if maximum benefits are to be reaped though rainwater harvesting. Role of central, state and local bodies is also to be defined clearly in construction and maintenance of rainwater harvesting structures.
- People's participation and social acceptance is essential for success of rainwater harvesting projects. There is no alternative to mass awareness for popularizing water resources management practices; otherwise all such programmes may not be successful without people's participation.
- All the rainwater harvesting techniques should reach to the Panchayat/Municipality level since these local bodies will be more effective in the management of groundwater resources of their area. The participatory association of scientists, engineers and beneficiaries would definitely go a long way in proper and overall development and management of ground water resources.
- Rooftop rainwater harvesting offers a good scope for recharging the ground water reservoir in urban areas. Creating such facilities with the construction of buildings be made mandatory and included in the building byelaws in urban areas.
- It should be responsibility of the urban municipal bodies to harvest the storm runoff from the existing drainage system, which can be effected investing little amount of funds.
- Funds for rainwater harvesting being released under various schemes such as water management, rural development etc. CGWB can be designated as nodal agency for technical

vetting of schemes. It shall ensure technical viability of artificial recharge schemes including gainful utilization of funds.

- Till recently, rainwater harvesting has been government's effort. Off late some NGOs and VOs are also coming forward and have done commendable word. A mechanism should be evolved so that continuous process of interaction among central/state government agencies, local bodies, NGO's, VO's and community exists for optimal development and management of ground water resources. Government organisations should come forward for providing technical and financial support through NGOs and Vos who in turn will ensure optimum utilization of funds for deriving maximum benefits from rainwater harvesting schemes. This mechanism will also generate additional employment opportunities for local populace.
- Co-ordination between various ventral and state government agencies institutions and community in funding and implementing rainwater harvesting schemes is the core issue, if maximum benefits are to be obtained from such schemes. Projects/schemes be evaluated and success stories should be disseminated through media (T. V., Radio, Internet, Newspaper etc.) so that the same may be replicated.

7.4 COMMUNITY PARTICIPATION ASPECTS

From the experience of Pani Panchayat working in Purandhar tehsil of Maharastra, we can learn various lessons, which can be directly implemented in other areas as well. The following recommendations shall be useful at the community level.

- There should be a committee in each ward, which should take care of the water management of local area and maintain the local water harvesting structures.
- For any proposal only group scheme should be taken, which fosters a community spirits.
- Water should be shared on the basis of the number of family members and not size of landholding. In this way we can incorporate the principle of equity.

- Water right should not accompany land rights. If the land is sold, the water rights revert to the group.

- Beneficiaries must share, in cash, a total of 20 percent of the capital cost of any water harvesting project in the area according to their water share, before the commencement of the project. People's participation is thus ensured. The balance 80 percent should be given by the Government and other agencies as an interest free loan to be paid in five years.

- Project beneficiaries should administer, manage and operate the scheme. This recognizes the leadership capability and skills of the community people.

- Uses other than residential should not be permitted in the area, which consume more water.

- Landless people and poor and slum resident should also get a share of the water so that they can share the labour in the project. This helps them to get employment in the area itself and checks unemployment.

7.5 SOME ISSUES FOR DECISION MAKING AND IMPLEMENTAION

- Countrywide demonstration projects in selected areas to provide useful information and ideas for rainwater harvesting and wastewater utilization.

- The scope of incorporating water harvesting in a micro-watershed basis and equitable use of this water in a way that it increases production and employment per unit of water as a basis of regional planning.

- The need for correcting the current use of surface waters by forming a grid of small watersheds of individual wards and of major and minor industrial, institutional and other water uses.

- The potential of replacing landuse planning with a combined landuse-wateruse planning for developments.

- The need for adopting participatory planning in city planning process to involve the community at household level with regard planning for basic needs and services, like water supply and solid waste management.

7.6 CONCLUSIONS

To sum up it may be said that the last few decades of the 20th century have focused our attention to the problems of water shortage which we are likely to face in the next few decades. Luckily the science and technology has made it possible for the human beings to find solutions to the problems provided the people take advantage of it. It must be our endeavour to protect our flora and conserve water to meet our needs. With the technologies available it should not be difficult to sustain our life by incorporating all the technologies to harvest rainwater.

APPENDIX - I

CRITERIA FOR SELECTION OF DENSITY PATTERN
SPARSELY DEVELOPED : BUILTUP AREA <20%
MODEREATELY DEVELOPED : BUILTUP AREA = 20% - 50%
DENSELY DEVELOPED : BUILTUP AREA > 50%

DETAILS OF SPARSELY DEVELOPED WARDS IN DEHRADUN MUNICIPAL AREA (census of Dehradun, 1991)

WARD NUMBER	WARD NAME	AREA SQ. KM.	HOUSEHOLD	POPULATION P	M	F	POPULATION AGE 0-6	SCs	STs	LITERATES
1	Rajpur	6.51	2236	10697	5934	4763	1358	662	8	7459
13	Bhandaribagh	2.68	923	4641	2521	2120	773	351	0	2832
16	Patel nagar	0.72	1237	6288	3342	2946	900	108	3	4694
25	Faltu line	0.51	755	3650	1925	1725	397	182	38	2926
27	Bakral wala	0.57	932	4454	2274	2180	484	199	13	3522
29	Vijay colony	0.74	714	3663	1904	1759	447	823	23	2710
30	Hathibar Kala	7	2455	10682	5882	4800	1284	1289	109	7716
32	Rajendra nagar	2.27	1818	8593	4723	3870	1201	674	30	6674
33	Ballu pur	0.72	1332	6646	3321	3325	790	356	64	5107
34	Vijay park	0.97	1440	7090	3780	3310	1030	656	31	5111
	TOTAL	**22.69**	**13842**	**66404**	**35606**	**30798**	**8664**	**5300**	**319**	**48751**

CRITERIA FOR SELECTION OF DENSITY PATTERN
SPARSELY DEVELOPED : BUILTUP AREA <20%
MODEREATELY DEVELOPED : BUILTUP AREA = 20% - 50%
DENSELY DEVELOPED : BUILTUP AREA > 50%

DETAILS OF MODERATELY DEVELOPED WARDS IN DEHRADUN MUNICIPAL AREA (census of Dehradun, 1991)

WARD	*WARD NAME*	*AREA*	*HOUSEHOLD*	*POPULATION*			*POPULATION*	*SCs*	*STs*	*LITERATES*
NUMBER		*SQ. KM.*		*P*	*M*	*F*	*AGE 0-6*			
2	Aryanagar	0.52	1839	9501	4930	4571	1275	3178	8	6768
6	Mansingh wala	0.84	1175	5333	2766	2567	556	243	6	4300
7	Dalanwala west	1.7	1078	6055	3154	2901	675	453	16	4861
8	Dalanwala east	1.13	1909	9879	5397	4482	1517	1444	11	6489
9	Nehru colony	1.16	3126	14880	7855	7025	2059	472	6	10892
10	Race course	1.17	2838	14097	7553	6544	2180	1566	11	9785
11	Mahadevi Kanya Pathshala	0.6	636	3599	1806	1793	483	158	3	2718
12	Chandra nagar	0.84	1913	9812	5332	4480	1400	958	25	6212
14	Lakhibag	0.59	2576	13391	7314	6077	2421	936	31	7848
15	Indresh nagar	0.16	1080	6029	3179	2850	903	2490	5	4004
26	Chukhoo wala	0.6	1774	9131	4838	4293	1173	984	42	6842
28	Dungwal marg	0.96	2406	12600	6654	5946	1900	3441	124	8351
31	Yanuna nagar	1.06	2249	10590	5611	4979	1437	640	29	8056
	TOTAL	**11.33**	**24599**	**124897**	**66389**	**58508**	**17979**	**16963**	**317**	**87126**

CRITERIA FOR SELECTION OF DENSITY PATTERN
SPARSELY DEVELOPED : BUILTUP AREA <20%
MODEREATELY DEVELOPED : BUILTUP AREA = 20% - 50%
DENSELY DEVELOPED : BUILTUP AREA > 50%

DETAILS OF DENSELY DEVELOPED WARDS IN DEHRADUN MUNICIPAL AREA (census of Dehradun, 1991)

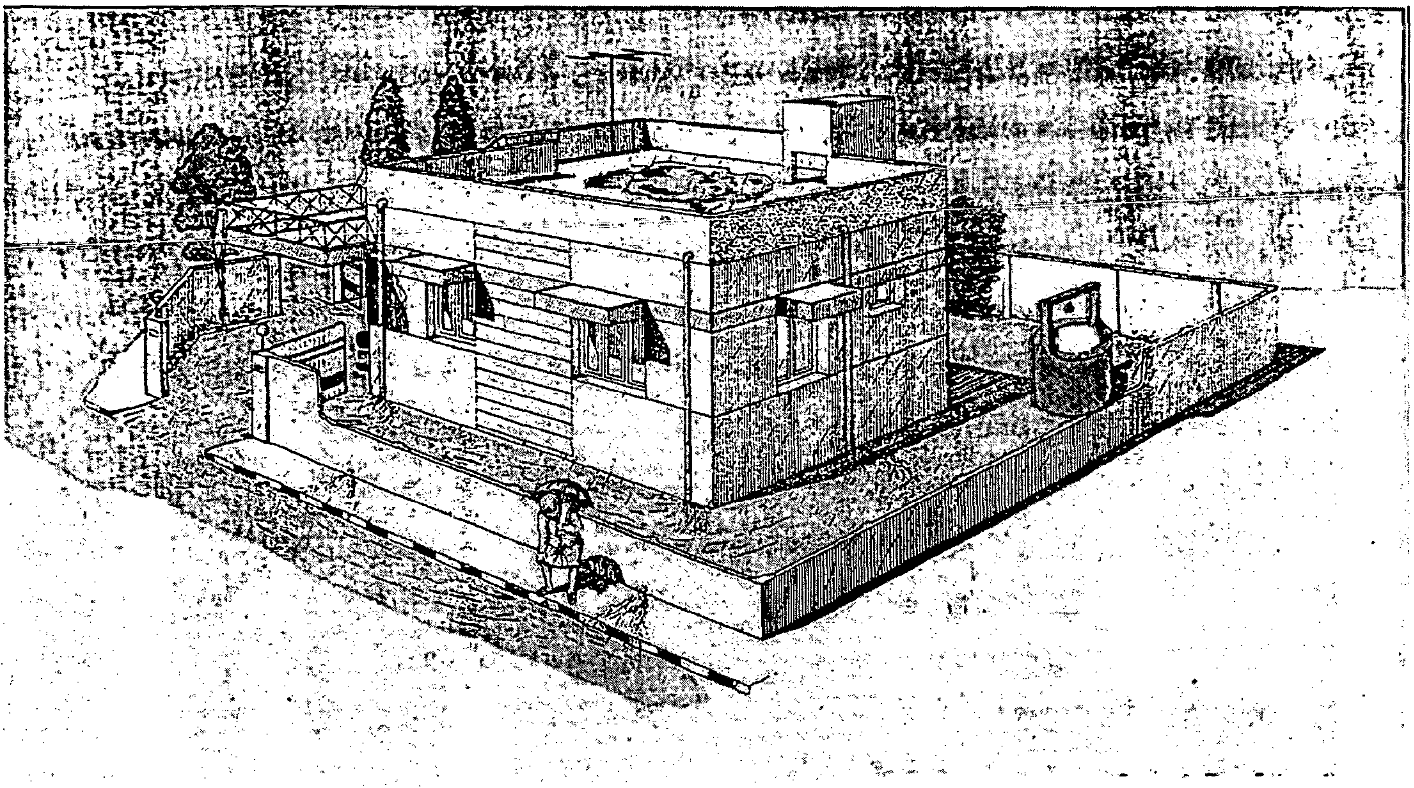
WARD	*WARD NAME*	*AREA*	*HOUSEHOLD*	*POPULATION*			*POPULATION*	*SCs*	*STs*	*LITERATES*
NUMBER		*SQ. KM.*		*P*	*M*	*F*	*AGE 0-6*			
3	Rispna	0.22	1530	8145	4363	3782	1214	3445	58	5358
4	Old Dalanwala	0.11	1110	5258	2816	2442	734	760	24	3811
5	Karanpur	0.36	952	4502	2302	2200	590	182	13	3605
17	Laxman chowk	0.62	2669	13906	7451	6455	2344	1389	25	8899
18	Shivaji marg	0.44	1196	7375	4032	3343	1350	1755	5	3293
19	Khurbura	0.3	2197	11109	5832	5277	1610	773	0	7760
20	Jhanda ward	0.28	1234	6138	3301	2837	790	89	13	4566
21	Dhama wala	0.3	1177	6791	3583	3208	958	43	0	4671
22	Mannu ganj	0.18	741	4200	2236	1964	564	122	0	3042
23	Tilak Road	0.1	1113	6002	3127	2875	821	128	0	4585
24	Ansari marg	0.24	1078	5432	2767	2665	685	282	11	4351
11 wards	**TOTAL**	**3.15**	**14997**	**78858**	**41810**	**37048**	**11660**	**8968**	**149**	**53941**

APPENDIX - II

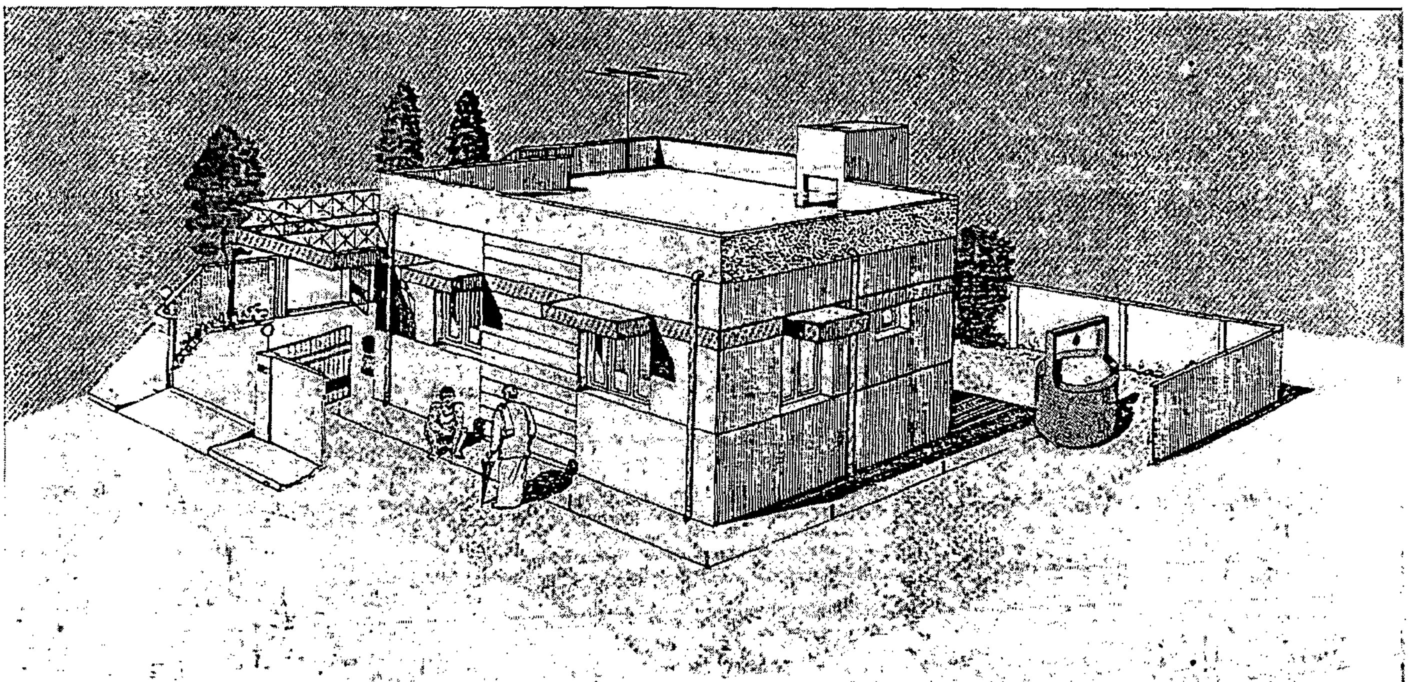
PRIMARY WATER QUALITY CRITERIA

S.NO.	Desinated Best Use	Class Of Water		Criteria
1	Drinking water source without	A	1	Total coliforms organisms
	conventional treatment but			mpn shall be 50 or less
	after disinfection		2	Ph = 6.5 to 8.5
			3	DO = 6 mg/l or less
			4	BOD = 5 days, 200C, 2 mg/l or less
2	Out door bathing (organised)	B	1	Total coliforms organisms
				mpn shall be 500 or less
			2	Ph = 6.5 to 8.5
			3	DO = 5 mg/l or less
			4	BOD = 5 days, 200C, 3 mg/l or less
3	Drinking water source	C	1	Total coliforms organisms
				mpn shall be 5000 or less
			2	Ph = 6 to9
			3	DO = 4 mg/l or less
			4	BOD = 5 days, 200C, 3 mg/l or less
4	Propogation of wildlife	D	1	Ph = 6.5 to 8.5
			2	DO = 4 mg/l or less
			3	Free ammonea 1.2 mg/l or less
5	Irrigation, Industrial cooling	E	1	Ph = 6.5 to 8.5
	Controlled waste			
	Source:- Compodium Of Environment Statistic, 1997			

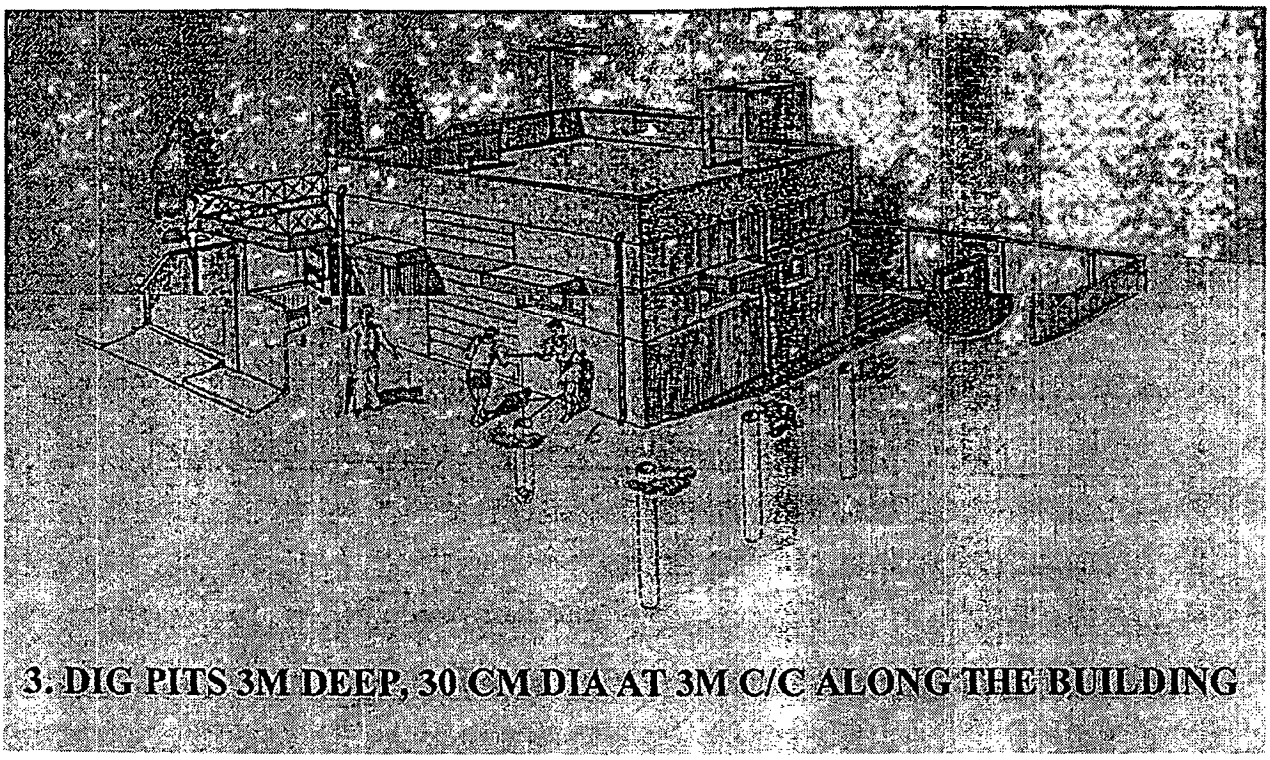
VARIOUS STEPS OF IMPLEMENTING RAINWATER HARVESTING TECHNIQUE IN A HOUSE

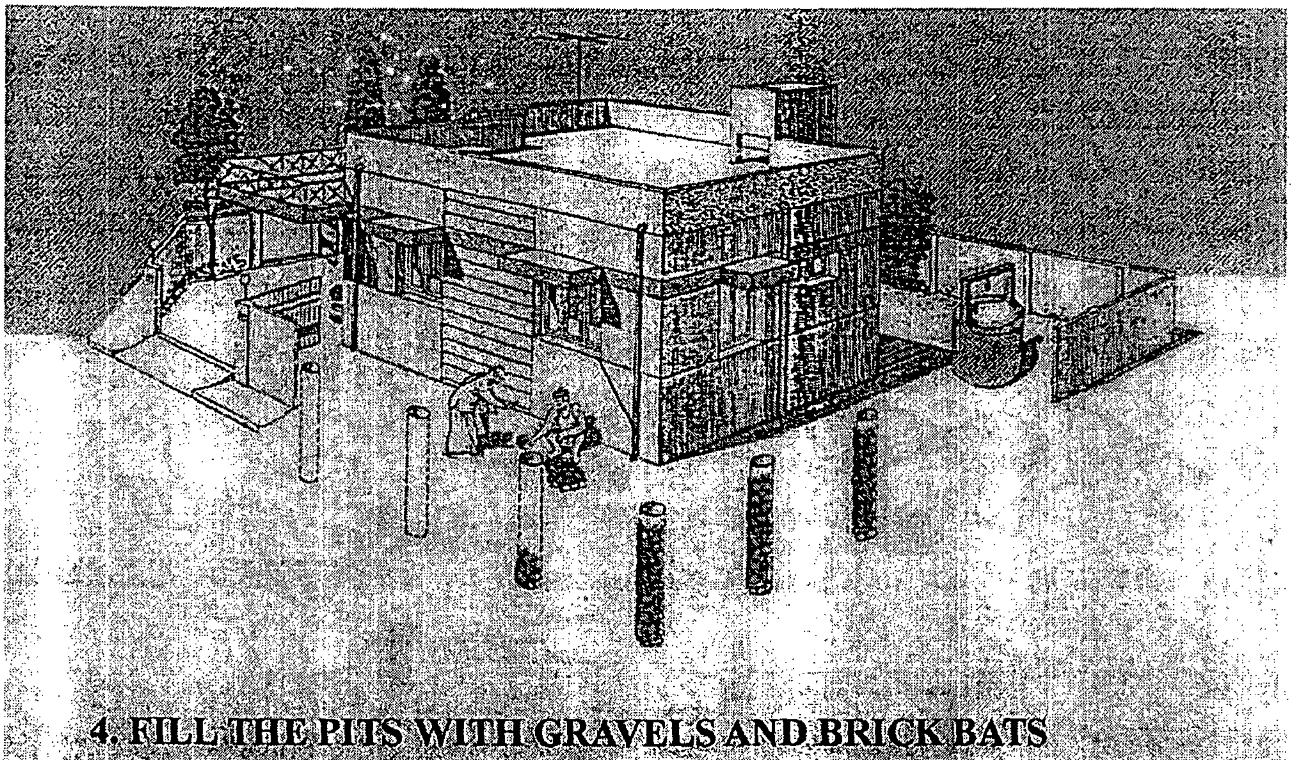


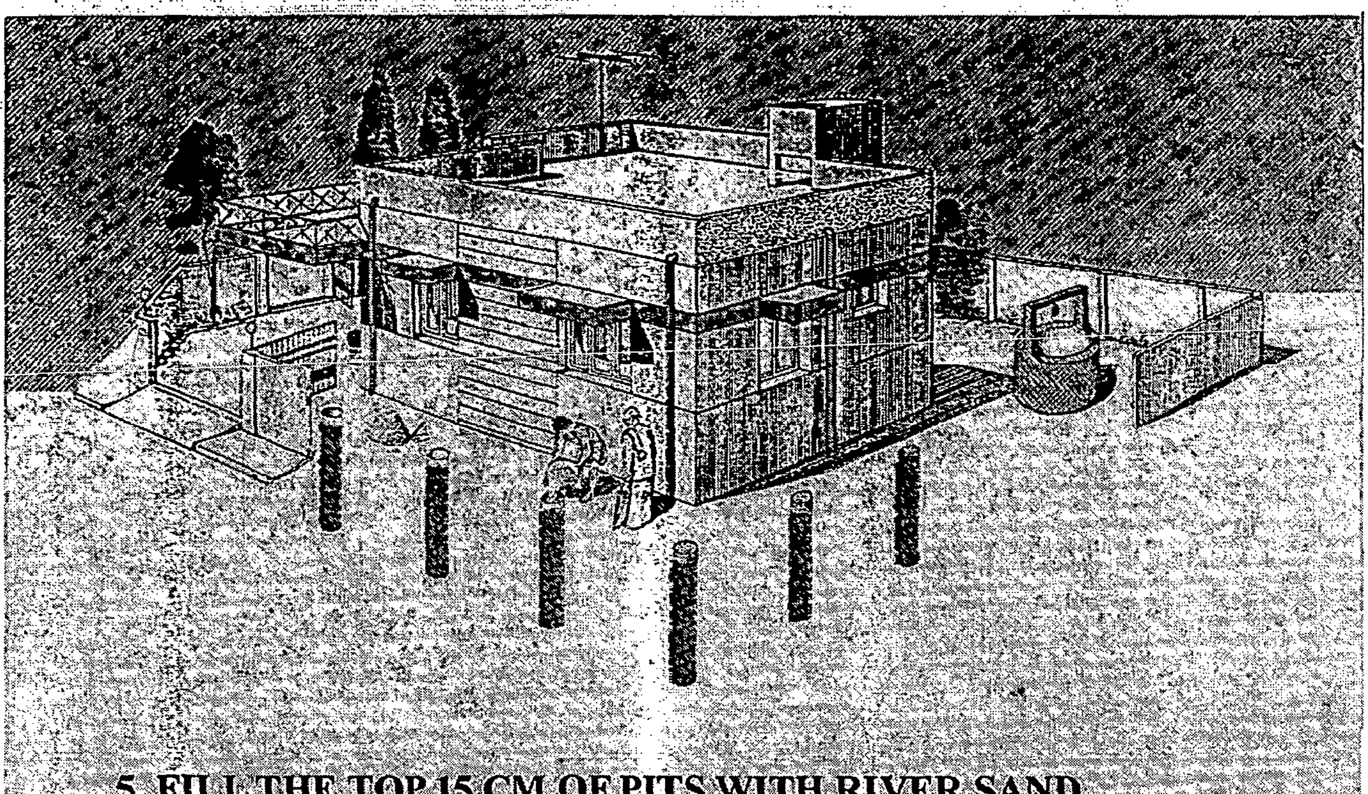
1. FIGURE SHOWS HOW RAINWATER IS WASTED



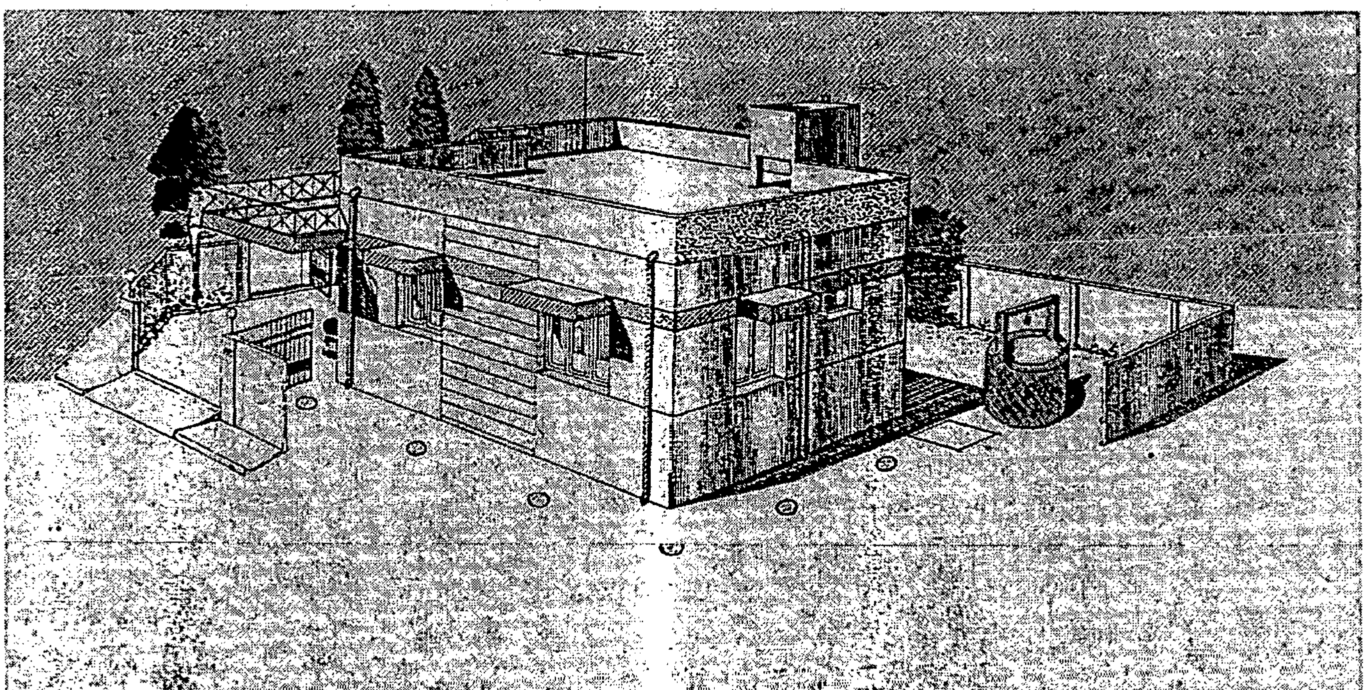
2. MARK AT 3 M INTERVAL 1 M AWAY FROM BUILDING ON GROUND


3. DIG PITS 3M DEEP, 30 CM DIA AT 3M C/C ALONG THE BUILDING

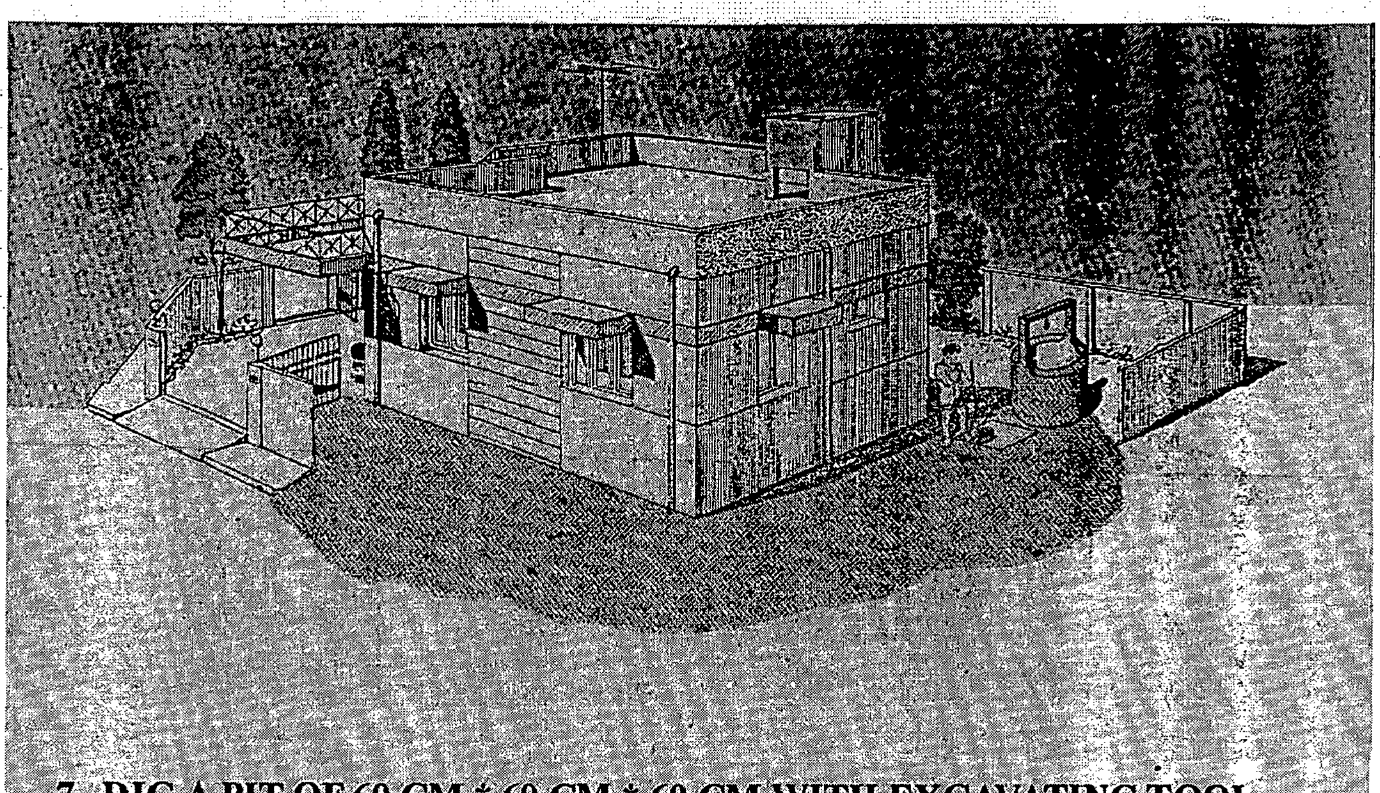

4. FILL THE PITS WITH GRAVELS AND BRICK BATS



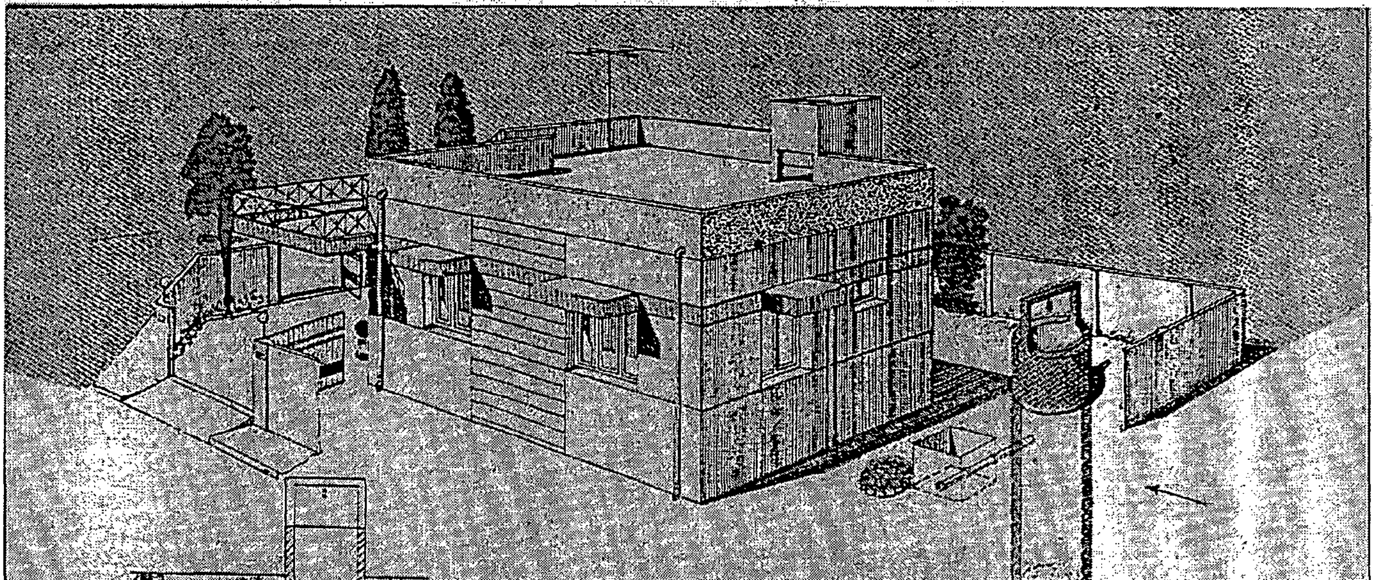
5. FILL THE TOP 15 CM OF PITS WITH RIVER SAND



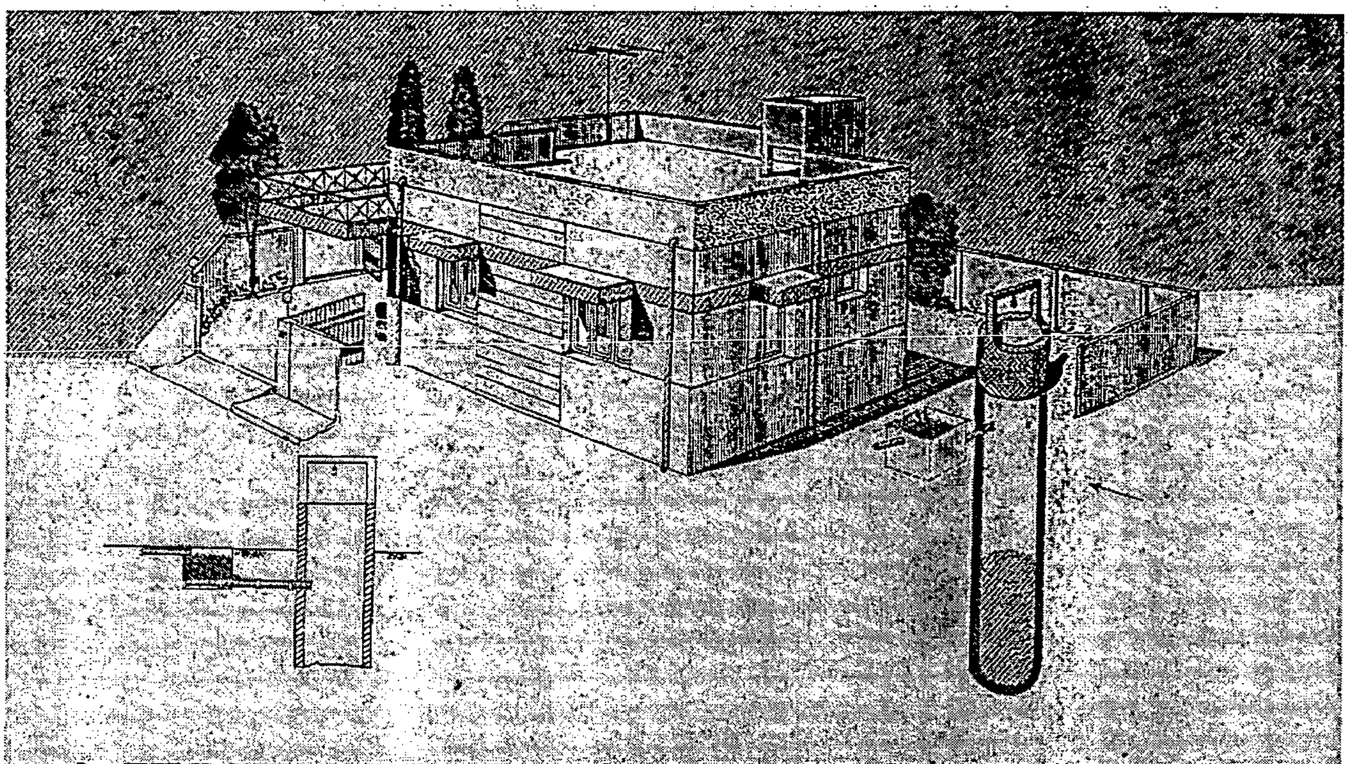
6. FLATTEN THE GROUND AND MARK A SQARE OF SIZE 60 * 60 CM ON GROUND



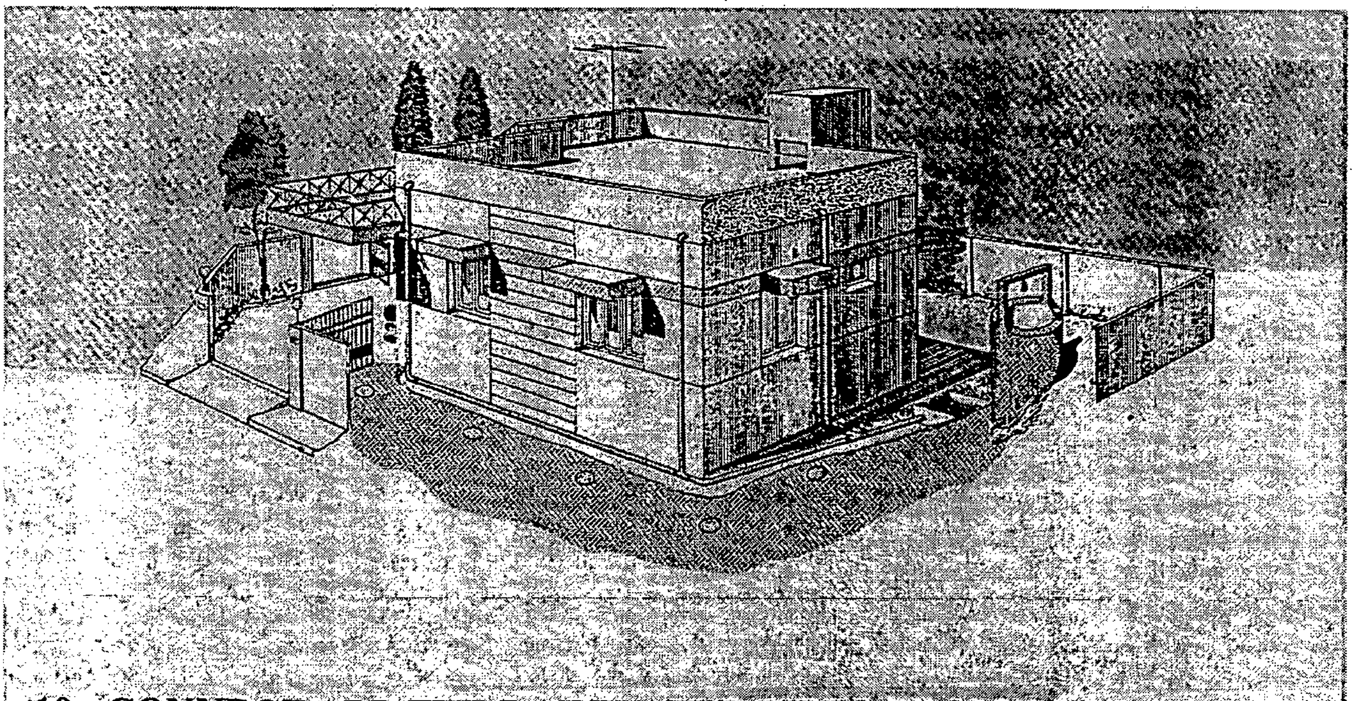
7. DIG A PIT OF 60 CM * 60 CM * 60 CM WITH EXCAVATING TOOL



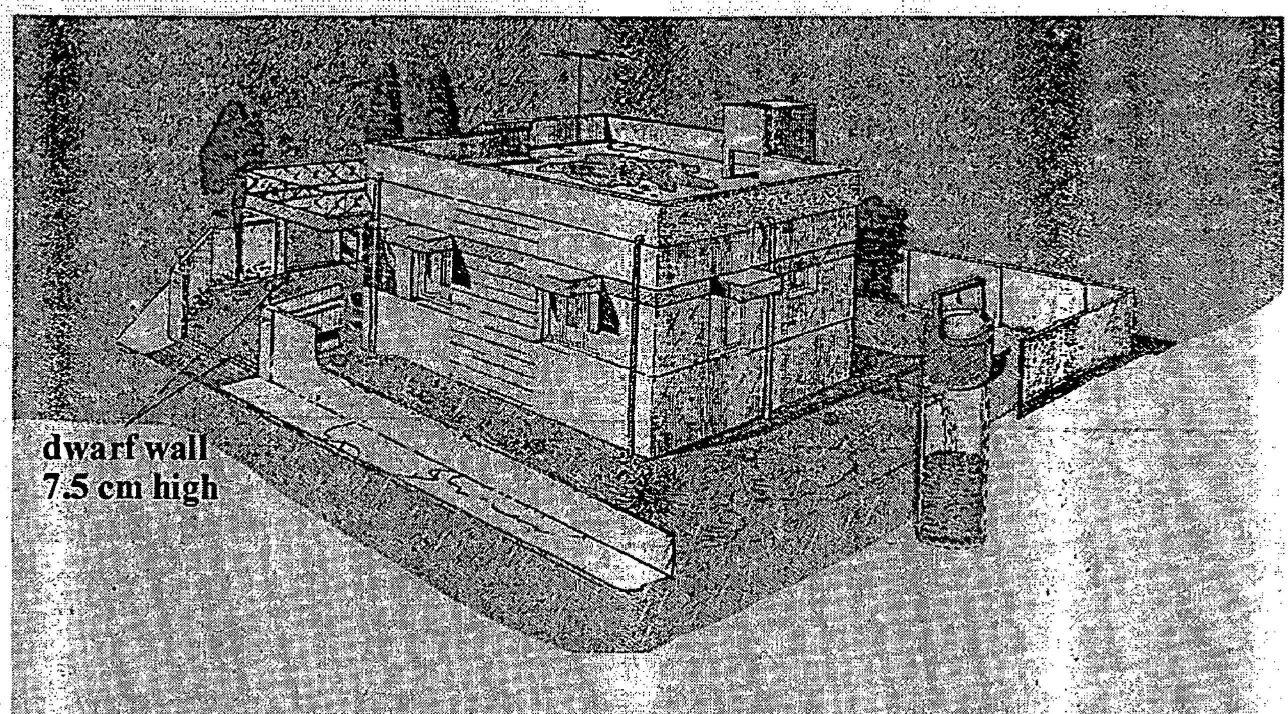
8. CONNECT THE PIT WITH WELL THROUGH 10 CM DIA PVC PIPE



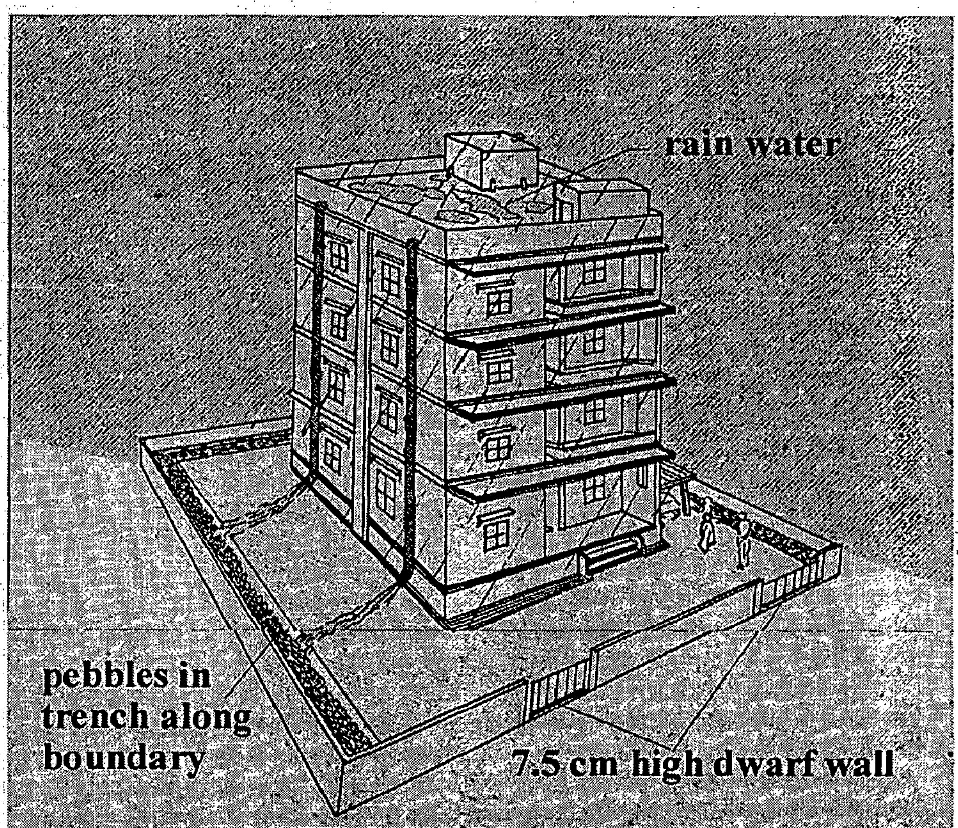
9. FILL THE PIT WITH BRICK BATS AND GRAVELS



10. CONNECT ALL THE RAINWATER PIPES FROM ROOF AT PROPER GRADIENT TO THE PIT WHICH WORKS AS FILTER



11. ERECT A DWARF WALL TO CHECK RUNOFF FROM THE PLOT AND DIVERT THIS WATER TO THE WELL



1 M * 1.5 M TRENCH ALONG THE BOUNDARY

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