PERFORMANCE EVALUATION OF SOIL AND WATER CONSERVATION STRUCTURES IN DARAKWADI WATERSHED

DISSERTATION

submitted to

Marathwada Agricultural University
in partial fulfillment of the
requirement for the degree of

MASTER OF TECHNOLOGY

(Agril. Engineering)

IN

SOIL AND WATER CONSERVATION ENGINEERING

By

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June - 2005

DEDICATION

DEDICATED TO

My

PARENTS,

BROTHER & SISTERS

CANDIDATE'S DECLARATION

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

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Date : 24/ 06 /2005

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CERTIFICATE-I

This is to certify that the dissertation entitled **"Performance Evaluation of Soil and Water Conservation Structures in Darakwadi Watershed"** submitted to Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the award of the degree of **Master of Technology (Agril. Engineering)** in **Soil and Water Conservation Engineering** embodied the results of the bonafied study carried by **Mr. ABUJ MAHADEV DASHRATHRAO** under my guidance and supervision. I also certify that the dissertation has not previously submitted by him for the award of Degree or Diploma of any University or Institute.

Place : Parbhani.
Date : 24/06 /2005

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CERTIFICATE-II

This is to certify that the dissertation entitled **"Performance Evaluation of Soil and Water Conservation Structures in Darakwadi Watershed"** submitted by **Mr. Abuj Mahadev Dashrathrao** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (Agril. Engg.)** in the subject of **Soil and Water Conservation Engineering** has been approved by the students advisory committee after oral examination in collaboration with external examiner.

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ABBREVIATIONS

Sr.No.	:	Serial number.
m-ha	:	Million hectare.
cm	:	Centimeter.
mm	:	mili meter.
m	:	Meter.
km	:	Kilometer.
ha	:	Hectare.
N	:	North.
E	:	East.
m^3	:	Meter cube.
m^2	:	Meter square.
kg	:	Kilogram.
m/ha	:	Meter per hectare.
t/ha/yr	:	tonnes per hectare per year.
NGO	:	Non-Government organization.
UNICEF	:	United National Children Development Fund.
MLC	:	Member of legislative council.
CCT	:	Continuous contour trenches.
CCD	:	Cement check dam.
GCW	:	Gabion cum wall.
EGP	:	Earthen gully plug.
ENB	:	Earthen nala bund.
CCNB	:	Composite cement nala bund.
P.T.	:	Percolation tank.
T.W.	:	Top width.
B.W.	:	Bottom width
H	:	Height.

gm/cc	:	Gram per cubic centimeter
C/S	:	Cross section
fig	:	Figure
W_1 to W_{12}	:	Well number 1 to Well no. 12
i.e.	:	that is
viz.	:	Namely
J	:	Journal
Agric.	:	Agricultural
Sci.	:	Science.
ISAE	:	Indian Society of Agricultural Engineers
Cons	:	Conservation.
Agril.	:	Agriculture.
et al.	:	and all
m-ha m	:	Million hectare meter.
m^3/sec	:	Meter cub per second.
Rs.	:	Rupees.

INTRODUCTION

CHAPTER-I

INTRODUCTION

Land and water are the most precious heritage and physical base of bio-mass production of life supporting system. The soaring numbers of human and livestock populations of India are escalating the demands on biomass production as well as for non farm uses like industrialization, urbanization etc. The arable land resource is continuously shrinking. Efficient management and utilization of soil and water are very important to increase the crop production and productivity per unit area. One of the principle reasons for low productivity in agriculture is the progressive deterioration of soil due to erosion. The main factors for soil erosion in India are excessive deforestation, over grazing and faulty agricultural practices.

The total land area of India is 329.0 m-ha, out of which 142.2 m-ha is net sown area, forest area is reported as 67.9 m-ha, the cultivatable wasteland and fallow land are reported as 15.9 m-ha and 23.4 m-ha respectively. The area under non-agricultural uses is 21.2 m-ha whereas barren and uncultivable land is 19.7 m-ha. The rest of the area is under pasture, grazing, miscellaneous trees and crops. Out of the total 329 m-ha geographical area of India, about 170.4 m-ha area is threatened by various types of land degradation such as water and wind erosion, salinity and alkalinity, water logging, gullying and shifting cultivation.

According to Bennelt , "Soil without water is desert and water without soil is useless". In fact every kind of farm activity is connected with land and prosperity of nation depends on the judicious management of land resources. Frequent and almost regular occurrence of floods and droughts in different parts of the country are evidences of improper land use in the catchments and inadequate conservation and use rainwater. The flood proves area in the country is estimated to be 40 m-ha, out of which an average 9 m-ha areas affected annually by flood. Total drought prone area in the country is 260 m-ha. Nearly 2/3 of cropped area in the country is rainfed and often subjected to vagaries of nature. The defective land use without necessary conservation in the catchment is causing excessive situation of not only the costly multipurpose reservoirs but also of minor irrigation tanks, village and farm ponds, irrigation and other uses like domestic water supplies, fisheries, etc.

In Maharashtra state 70 per cent of the cultivated land is affected by erosion in varying degrees and 30 per cent of the land has been highly eroded and is no longer cultivable. According to study conducted by the central soil and water conservation research and training institute, Dehradoon, 5334 million tonnes of soils is being eroded annually in India of which 29 per cent is being lost of sea, 10 per cent is deposited in the reservoirs and 61 per cent is displaced from one location to another. As a result 8.4 million tonnes of nutrients are lost annually. The National Commission on Agriculture has estimated food grain requirements of about 225 million tonnes. As the cropped area cannot be significantly increased, major increase in food grain production must come from higher productivity.

It is generally recommended that soil conservation works be planned on a watershed basis. The reason for this approach is that by implementation of the soil and water conservation structures, water and sediment yields could be modified for beneficial purposes. Land management practices for erosion control and water conservation have a significant influence of the hydrological behaviour of watershed. The land management practices could consist of engineering, forestry and agro economical measures. Any of these measures influence the hydrological behaviour of the watershed depending upon the catchment area of the watershed and the extent of each of the measures implemented.

Integrated water management planning is a very complex phenomenon, which involves large number of possible alternate plans, variable nature of hydrologic and economic parameters makes the problems more challenging to arrive at an optimal decision to tackle the problems. Adoption of system approach techniques is essential in many areas, rather low proportions of the average annual rainfall is actually used for crop production because of erratic rainfall and other climatic factors, soil profile characteristics, technological limitations and economic planning aims at increasing net benefits to the farmers as the efficient crop production from the available water resources, considering socio-economic conditions.

India, being a country with tropical and sub tropical climate has potential to grow crops around the year proved adequate water supply is available. Irrigation is necessary because rainfall may not occur according to the needs. The water supplied by rain is not only adequate but uncertain and unevenly distributed. It is observed that 94 per cent of the rainfall received in 4 months in June to September and 6 per cent in the rest of the year under normal conditions. Research in the management practices of soil and water is still lagging by killers and high yielding crop varieties. It can broadly economical if soil and consequently the nutrients are lost due to lack of soil and water conservation measures. This necessitates the research need for integrated and holistic approaches on soil and water conservation measures in order to develop criteria on which sound recommendations can be made.

* Major source of water for dry land agriculture is the rainfall received from South west monsoon during the period from June to September, which is erratic in nature, unevenly distributed and sometime it is inadequate to meet the soil moisture requirement of crops. The average annual rainfall of India is 1140 mm and 360 m-ha m will be available from it, out of which one-third water will be evaporated and from the remaining 247 m-ha m, 167 m-ha m water will be infiltrated. From that 43 m-ha m water will be stored in upper sub strata and only 36 m-ha m will be stored as ground water. If the water resources are exploited for irrigation only 60% of the cropped area can be brought under irrigation and 40% will

remain rainfed. Out of the area under different crops, more than 78% of cotton, 82% of seeds, 96% of sorghum, 98% of millets and as much as 82% of rice and 38% of wheat of country are grown under rainfed conditions. It is estimated that out of total cultivation area (136.18 m-ha) of the country, 68% is rainfed and out of net sown area (178 m-ha) in Maharashtra state, 88% is rainfed. Despite of such situation, 30-40% of rainwater goes as surface runoff. Hence harvesting and reusing the runoff water is very essential.

A watershed is the total land area above a given point on a waterway that contributes runoff to the flow at that point. One of the major objectives of the watershed development programme is to manage the land surface so as to retain as much rainfall as possible and conserve both soil and water. In planning watershed development programme various types of soil and water conservation works such as bunding, terracing, nala bunding, underground diaphragms, diversion ditches, vegetative water ways are taken up according to the availability of site, location and land capability classification.

The conservation structures are an integral part of soil and water conservation programmes and is important component of the watershed development and management programme. Conservation structures not only control the erosion and conserve water but also help in meeting the socio-economical demands in various ways.

In the State of Maharashtra, nala bunding works are being carried out since 1969. The soil and water management activities in the state are being carried out as an integrated manner on watershed basis since 1983. It is estimated that about 169.95 lakh ha of area is bunded in Maharashtra state up to 1988-89 .

The socio-economic growth of the country particularly in the respect of rural area depends primarily on the continuous preservation and effective utilization of the land and water resources. The pattern of land and water resources development for various beneficial uses however, differs from area to area depending upon its climatic, and physiographic condition and socio-economic development.

In order to maximize the net cultivable area, importance is now given to the soil conservation work in our country. In the first five year plan, the urgency has been given for making the nation wide policy, dealing with various existing problems, which resulted into the reorganization of soil and water conservation work plan. In the first five year plan (i.e. 1954 to 1956) the soil conservation schemes were approved in three heads, these are the immobilizing of desert, bunding and terracing on hilly land and afforestation of ravines and severely eroded areas. In which about 2.8-lakh hectares land were used for bunding and terracing practices in the first five year plan (Suresh, 1998).

With the ever growing population the need for water is also increasing many fold, but the chief source of water i.e. rainfall is almost constant. So a more scientific approach involving various factors that really govern the movement and occurrence of water both on the surface and underground is necessary for judicious planning and management of water resources. The hydrologic cycle is complex phenomenon involving the precipitation on land or snowmelt, evapotranspiration, percolation into ground, runoff as stream flow, storage in surface etc. for efficient water management system, all the above aspects needs to be studied together and their linkages have to be established.

Soil conservation works should start at the head of topography units (watershed) and proceed in the same way the water flows down stream. One of the first principles in the watershed development programme is to manage the land so as to get as much as the rainfall to soak in as possible.

Water harvesting system consists of collecting and storing the excess runoff from the catchment area of a watershed in a suitable reservoir and its subsequent use for irrigation of crops. It can be achieved by gully plugging, construction of structures like farm ponds, small check dams, nala bunds, percolation tank etc. These structures are integral part of soil and water conservation activity and are important component of watershed development and management programme.

Water is the most essential input to agricultural production. There has been an impressive growth in annual food grain production in the country over the years. With the limited scope of development of irrigation potential rain water management plays an important role to supplement the surface water for domestic, irrigation and industrial uses. Therefore efficient conservation and scientific management of harvested water is crucial for optimum utilization for crop production.

Watershed development is the only way to make efficient and judicious use of rainwater.

Major activities, which are undertaken in watershed management programme to conserve the natural resources namely soil and water, includes various soil and water conservation measures. Watershed area is treated from ridge to valley. In non-agricultural land with steep slope, soil and water conservation measures like contour trenching, gully plugging, bench terracing, afforestation, development of pasture etc. are undertaken. Contour bunding graded bunding, broad base and narrow base terracing and contour farming are adopted in agricultural land. Along the drainage line, construction of nala bund, cement nala bund, farm pond and other permanent structures are undertaken to control the runoff water. Among the various soil conservation measures, cost incurred on the structures like earthen nala bund, cement nala bund, semi permanent structures like gabion wall, gabion cum impermeable wall is comparatively more.

Now a days many Government and non-Government agencies implemented many watershed development programme and invested a huge amount of money on soil and water conservation for enhancing the problem of water scarcity and achieving the standard of living of human being. But there is necessity to evaluate these implemented projects to know, how much positive impact was gained from that particular project and on the basis of it we can made further improvement and proper plan for future.

Considering this fact "Performance evaluation of soil and water conservation structures in Darakwadi watershed" has been undertaken. Darakwadi watershed is situated in the Aurangabad District. This project is implemented by "Dilasa Janvikas Pratisthan" Aurangabad with the support of United Nation Children Development Fund (UNICEF) Mumbai and Member of Legislative Council (MLC) during the year 2002-03. Thus attempt has been made to evaluate the watershed development programme and its impact on rural community and crop production with respect to soil and water conservation structures at Darakwadi watershed with the following specific objectives.

1) To determine silt deposition in various soil and water conservation structures in Darkawadi watershed.
2) To study the existing dimensions of the soil and water conservation structures in Darakwadi Watershed.
3) To study the effect of various water harvesting structures on ground water recharge in Darakwadi watershed.
4) To study socio-economic impact of soil and water conservation structures.

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

This chapter deals with the review of literature related to the present investigation. The research conducted was reviewed and presented under the following subheads.

2.1 Evaluation of soil and water conservation structures:

Grewal *et al.* (2002) evaluated the erosion control structures in Shiwalik watershed. Study was carried out during the year 1999-2000 in which 19 drops structures of varifying dimensions were evaluated on the basis of the structural stability and functional efficiency criteria. Ninety percent of the structures evaluated were in perfect condition and placed in A grade, ten percent with minor defects were placed in B grade. They found that structures constructed in main gullies having more efficient than those made on gullies having more slope. They suggested that proper site should be selected to economize cost and increase the functional efficiency of erosion control structures.

Singh *et al.* (2001) reviewed the research related to soil and water conservation measures were found successful in semi arid region of Rajasthan. They found that the Soil conservation measures such as graded bunds, gully control structures are suitable in semi-arid region and it minimized erosion and maximized production of arable lands. Graded bunds had reduced the runoff from 20 to 4.8 percent and soil loss from 24 to 4.12 t/ha/year.

Gore *et al.* (2000) studied the qualitative performance of soil conservation structures in Wagarwadi watershed. The major works undertaken were nala bunding, cement plug, loose boulder dams, gabion structure, contour trenches, contour bunding and graded bunding. About 1622.58 tonnes soil was found deposited under various structures. Qualitative performance indicated the reduction of 3 to 24.66 per cent in cross sectional area of loose boulder dam and 75 percent of siltation in contour trenches and no measurable charge in other structure.

Rana (1998) evaluated the mechanical and vegetative measures in Kandi region of Himachal Pradesh. He found varied performance of loose boulders, gabion and brush wood check dams. The gabion check dams were found to be much efficient than loose boulders or brush wood check dams. The brush wood dams were least efficient as they decayed and were subjected to termite attach. Grasses like vertiver, succharum munja, bushes were found suitable for the region.

Pendke (1997) from the studies conducted on stability and performance studies of soil and water conservation structures at Ghodegaon watershed Tq. Khultabad district, Aurangabad. Reported that cross section dimensions of loose boulder dam reduced by 2.33 to 24.66 percent in 1996-97 compared with original cross sectional area. The length of loose boulder dam reduced by 3.78 to 14.0 percent. Insufficient hydraulic capacity, curved gully structures, improper section of stones for dam and loose packing were the reasons responsible for failure of loose boulder dam in short period of year.

Satapathy (1997) studied nine small watersheds with areas ranging from 0.52 to 3.8 ha. He developed simple linear rainfall-runoff models for planning hilly watershed projects. He found that surface runoff from undisturbed hilly watershed was very small, large intense rainfall events with high moisture content in soils generated most of runoff from the undisturbed and treated watersheds. Mixed land use system with appropriate soil conservation measures namely bench terraces, contour trenches etc. water most effective in retaining 90 to 100 per cent annual rainfall and simulated the effect of natural forest.

Rana, R.S. and Goyal, N.L. (1994) at HPKVV, Regional Research Station, Dhuala Kauan, Sirmour revealed that the annual soil loss was found to be 55.3 t/ha taking average soil density as 1.5 gm/cm^3 and dividing annual loss with density. It is observed that about 3.7 mm of surface soil is being washed annually.

Kale *et al.* (1993) reported that soil loss due to erosion is one of major problem in Konkan region having lateritic soil and heavy rainfall. They found that contour bunding was most effective in reducing soil loss followed by bench terraces, graded bund in comparison with control. Similarly, contour bunding was found most effective in reducing runoff than control but it showed narrow differences.

Jallawar (1993) evaluated cement nala plug in selected watershed of Akola district in the year 1992-93 and concluded that seepage and percolation from the area of ponding of nala plug contributed to the ground water recharge.

Nambiar and Meena (1992) conducted study on evaluation of contour bund and gully plugs with respect to cross section and height. Their results indicated that in the newly constructed bunds (year 1989) more reduction in height (43.33 per cent) and cross section (54.3 per cent) was observed as compared to old bunds.

Kale (1990) revealed that soil loss in watershed with soil conservation measures and kept as fallow was 5.41 t/ha and it was found 17.45 times more as compare to treated watershed (0.31 t/ha) with different soil and water conservation measures like bench terraces, staggered trenches, farm ponds etc.

Suraj Bhan and Tripathi, R.Y. (1988) reported that the application of nitrogen resulted in reduced splash of soil. Increase plant or crop canopy due to increasing levels of nitrogen reduced the direct impact of raindrops on soil ultimately resulted in lesser soil splashing. That is resulted in reduced total soil loss.

Dhurva Narayana (1987) reviewed that in Western Ghats at Ooty with 20% slope under potato crop, the runoff under up and down cultivation was 4% as against 2.1 and 1.1% under potato with graded bund and bench terraces respectively. The soil loss of 39.3 t/ha was observed under up and down cultivation as against only 1.4 to 0.1 t/ha under graded bund and bench terraces respectively.

Patil and Bangal (1987) conducted experiments to study the effect of different conservation practices on runoff and soil loss. The graded and contour ridges were laid out at 5.0 m horizontal interval. They concluded that contour ridges absorbed more rainfall compared to graded ridges. Graded and contour ridges reduced soil loss by 52.1 per cent and 81.7 per cent respectively compared to ridge treatment along the slope cultivation. The contour ridges and graded ridges across the slope cultivation recorded more moisture retention in the soil and reduced the runoff and thereby increased the yield.

Bharadwaj, S.P. (1984) revealed that the increase in vertical interval from 100 to 133 cm and grade from 0.4 to 0.6% decreased the runoff but the soil loss varied from 10 to 14 t/ha in plots having bunding and strip cropping while contour sowing and cultivated fallow produced 32 and 54 t/ha soil loss respectively. The bunding and strip cropping retained more sediment as compared to contour cultivation having some of slightly lesser runoff.

Singh (1979) stated that while planning for permanent control measures, selection of proper structure for any location is a factor for effective and economic control of erosion and runoff. Generally degree of protection or control and size of the catchment are basic considerations in selection of proper structures. He also reported that drop spillway are costlier structures, where the required discharge capacity is less than 2.83 m^3/sec and total drop is more than 3m.

Kamannavar *et al.* (1977) reported that rate of reduction of bund section increased with the increase in size.

Reduction rate in cross section area and height of bund was found as 253, 324, 493 cm^2/year and 1.71, 2.53, and 2.93 cm/year for 0.74, 0.93 and 1.28 m^2 cross section respectively. Expected life of bund of above section was found as 23, 20 and 19 years respectively. They opinioned that there could be possibility of using lower cross section of bund, which will reduce the cost of bunding to greater extent.

Ram babu (1976) concluded that bunding in small agricultural watershed of 54.6 hectare reduced the monthly runoff and peak rate to extent of 62% and 40% respectively and reduced the soil loss upto 48%.

2.2 Effect of water harvesting structures on ground water recharge :

Lavarale (2003) studied the effect of various soil and water conservation structures on ground water table in Kacchighati watershed located in Aurangabad district. It was reported that water table in the wells, which were located at the downstream side of cement nala bund, earthen nala bund and semi permanent structures was found to be increased by 5.85, 4.86 and 2.63 m respectively in the year 2002-03 over the pre development stage.

Gaur and Lal (2001) estimated ground water recharge of small watershed having area 1381 ha. He concluded that the net annual draft from 350 shallow dug wells was predicted as 1.89 million cubic meter (MCM) while the net annual recharge came around 2.058 MCM leaving a ground water balance of 0.1687 MCM. Maximum ground water draft (gross value: 2.02 MCM) were experienced in non monsoon period. The major fraction of annual recharge (gross value: 1.91 MCM) was contributed from monsoon rainfall. The existing stage of ground water development was found to be safe and satisfactory still having scope for its further enrichment.

Gore *et al.* (1998). Studied on ground water modeling in wagarwadi watershed by monitoring 16 observation wells and analyzing the water balance components. The aquifer parameters have been estimated by pumping test. The ground water flow model was developed using rested square meshes of size 160x160m and the steady state condition have been simulated in the model water table configuration of June 1992 assume to be an equilibrium condition incorporating additional seepage from water harvesting structures.

Kumar and Warsi (1998) studied the impact of soil and water conservation measures on ground water recharge in Yamuna ravine watershed. They noticed increase in ground water recharge from 0.77 m in 1995 to 2.05 m in 1996. Increase in ground water recharge was attributed on continuity in functional operation of soil and water conservation measures adopted in watershed area.

Bainade (1997) studied the effects of soil conservation measures like nala bund, contour trenches, loose bolder dam and percolation tank on water tale in Ghodegaon watershed in Aurangabad district. He observed that different soil conservation measures were found to be effective in increasing the water table. In the wells located under downstream side of nala bund, the water table fluctuation was in range of 0 to 13.11 m.

Goel, P.K. and H.B. Singh (1996) studied an integrated watershed development programme and came to the conclusion that annual rise in water table is highly correlated to annual rainfall. Increase in availability to irrigation water in wells has resulted in 83 per cent increase in rabi cropped area and almost doubled the productivity of rabi and kharif crops.

Narayan Pethkar *et al.* (1993). Observed that the conventional methods of determination of the transmissivity and storability cannot be applied in hard rock areas because of their anisotropy and therefore developed mathematical equation defining in flow of recuperation was also developed and it was recommended that well parameters should be determined using pumping test data of open wells in hard rock areas.

Shende (1992) conducted studies on evaluation of soil and water conservation structures in selected watersheds of Akola district. He concluded that the water table was found lowest in the month of June and highest in the month of August. Therefore the ground water table decreased gradually. He has reported that the annual sinusoidal fluctuation of water level in the vicinity of underground diaphragm structure was on an average of the amplitude of 1.37 m and 2.16 m during pre-development period respectively. He also reported that annual sinusoidal fluctuation of water level in the vicinity of nala bunding activity was on an average of the amplitude of 9.65 m.

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

Patil (1990). Studied the behaviour of water table condition in Manjara, Sina and Godavari basin in Beed, district by fixing 47 hydrological stations (open wells), out of 47 open wells, Sina, Manjra and Godavari basin comprises 8,7 and 32 open wells respectively. The rainfall data from 1973 to 1987 was studied. From the study, it revealed that water level fluctuations of wells falling in Manjra, Sina and Godavari basin was comparatively high, comparatively moderate and moderate to low respectively. It was also observed that water level fluctuations were more in high elevated area where as wells which are located to lower elevation showed opposite trend. Again it was concluded that the water table fluctuations were controlled by morphological aspects irrespectively of the amount of precipitation in the area.

Taley and Kohale (1990) monitored 23 open wells located of central research station P.K.V., Akola, during the year 1988-89 for computation of ground water potential. The data revealed that the average cumulative water fluctuations were maximum in the month of September 1988 (576.23 cm). The difference between monthly ground water levels observed to be maximum (388.70 cm), in July 1988 followed by 44.35 cm in the month of August. The annual sinusoidal fluctuation of water level in the watershed was observed with average amplitude of 5.23 m.

Padmanabhan and Hanumanthappa (1989). Conducted study on influence of conservation structures on ground water table. Eight dug wells were selected for observation and the water level in the selected wells were recorded from 1987 to 1989. They concluded that the rise in water table in some of the wells in the watershed area range from 1.14 to 4.61 m, between 1987 and 1988 and from 0.21 to 2.19 m between 1988 and 1989, with this respective mean values of 3.15 m and 0.8 m. This attributed to the conservation measure adopted in the watershed.

Malikarjunappa and Maurya (1988). Studied chandkavate watershed in Sindogin Tq. of Bijapur Dist. in Northern region to evaluate nala bunding in shallow black soil in semi-arid-region. They found that nala bunding recharge underground aquiver due to construction of nala bunds as observed through open wells situated below the nala bund was studied. The range of water table depth was 5.8 m to 10.2 m. during August for the wells under nala bund. The corresponding figures for central wells varied from 7.7 m to 8.0 m respectively. The average depth of water table for wells under nala bund during August was slightly higher than that of central wells.

Anonymous (1987), reported that the nala bunds contributed to the increased rate of recharge of ground water in the neighboring areas and prevented washing of rich top soils. The average increase in water level in the selected wells in the command area was 2.04 m and 1.56 m in non-command areas.

Singh (1984). Analysed water table fluctuations for H.A.U. Farm, Hissar during the year from 1973-1978 to observe changes in the ground water regime. He concluded that water table was rising on an average rate of 4 per cent per year over the entire area approximately 10 per cent of the area was under less than 1 m water table depth during July 1982 and appreciable quantity of water getting lost through capillary rise from shallow water table area.

Pawade (1981) carried out a study on optimum utilization of water mainly based on the data of ground water table fluctuations observed in 23 open wells and 5 piezometers located over the entire central Research station farm during the period from May, 1980 to April 1981. He concluded that the ground water table at the experimental watershed showed sinusoidal fluctuations in water level with an average amplitude of 3.37.

Khillare and Kulkarni (1980) studied effects of soil conservation practices on ground water in micro watershed of 118.1 ha located in Solapur district. Data on water level in 5 wells before and after provision of soil conservation structures indicated the rise in water table in all the 5 wells. 14.3, 13.2, 17.7, 17.9 and 10.10 percent increased the water levels in the 5 wells respectively.

Gavande *et al.* (1974) reported that, as a result of bunding and terracing, the well situated in the catchment area were found to have received more water. They found that water level had risen to a minimum of 1.2 m. In another project Himkhedi 2 in M.P., bunding and terracing resulted in the rise of water table by more than 1.2 m within a period of three years.

Ramrao and Gurmel Singh (1974) pointed out that no evaluation of soil conservation programme has so for been carried out comprehensively of any uniform pattern on all India basis. Present efforts was therefore made to carry out on a limited extent, the evaluation of soil conservation programme in Madhya Pradesh. As a result of bunding, the well situated in bunded catchment were found to have received more water. On the basis of water table of 9 wells for which the record was available, it was found that the water level has raised to a minimum of 1.2 m during this period. This improved in ground water resources resulted in digging more wells in bunded areas.

Sharma and Subba Rao (1973) studied the rainfall and groundwater recharge in Chandtompalen basin in Andhra Pradesh. They collected data regarding rainfall and water table fluctuation from 114 open wells for three years in the plain areas of the basin. The rise in water table was observed to be associated the monsoon and cyclonic rains. On an average there was a rise of 3 m in water table for the entire area during an year and that 1 mm of rainfall caused 3 mm of rise in water table.

2.3 Socio-economic impact of soil and water conservation structures:

Lavarale (2003) studied the socio-economic survey carried out in Kachighati watershed during year 2002-03 reported that implementation of watershed development programme in Kachighati watershed resulted in overall socio-economic development of the beneficiaries. The population of the illiterate people was found to be decreased from 254 to 110. The number of postgraduate and graduates increase from 10 to 15. In post development stage, crop productivity of cereals, pulses, oilseeds, cotton and vegetable were increased by 35, 20.19, 28.75, 31.86 and 20.0% in kharif season respectively over the pre development stage. In rabi season the crop productivity of cereals pulses and oilseeds were increased by 49, 20.96 and 42.38% respectively in the year 2002-03 over the predevelopment stage.

Rathod and Ingle (2002) studied the impact of watershed development programme on tribal of melghat in Maharashtra. From 300 tribal farmers information regarding change in agricultural production, productivity, cropping intensity, employment and annual income was collected by personal interview method. The comparative analysis revealed that average increase in agricultural production, productivity and cropping intensity of farmers under IWDP was found to be 60.13, 56.62 and 11.84 per cent respectively after the watershed development programme was launched.

Singh *et al.* (2001) studied the social features of the people in Doon valley watershed. The farmers of two groups of two villages were found less similar in age, educational level and land holdings. About three fourth of respondents belonged to marginal farm category. Two sets of the villages differed on one aspects. Farmers of less successfully villages did not fallow small family norms with the results most of the nuclear families with large size had been there.

Patel and Rajput (2001) conducted study on the participatory rural appraisal in Rithauri watershed. The analysis of information generated through PRA (Participatory Rural Appraisal) indicated water scarcity as the major problem of the village necessitating water harvesting runoff reduction and efficient utilization of water as the priorities for the overall development of the village.

Koppad *et al.* (2001) evaluated the performance of different soil and water conservation practices viz. mechanical measures, agronomical measures and alternate land use system in Vardha watershed. Productivity of different crops such as rice, pigeon pea and horse gram increased by 55, 124 and 21 per cent respectively due to different conservation practices over control. The results showed that there was considerable increase in agriculture production by adopting new technologies in the area. Further, alternate land use system such as teak based agro forestry and mango based agro horticulture system were successfully adopted by farmers. The farmers appreciated these introductions and are new extending these technologies to other areas of the watershed.

Badgi *et al.* (2001) studied the adoption level of soil and water conservation technologies by the farmers of sardar sarovar project catchment in Gujrat state. Results of the study revealed that all the respondents were of tribal origin and they were very poor and backward. Majority of them were dependent on agriculture. The average family size of the respondents was

10.7 members. Majority of them were illiterate and only 18 per cent could read and write. Soil and water conservation practices adopted by farmers were intercropping and summer ploughing, gully plugging. Overall adoption level of recommended soil and water conservation practices in area was 52.3 per cent. Finance and labour availability were the major constraints for adoption of soil and water conservation practices, social factor and lack of awareness also contributed to non adoption of soil and water conservation measures.

Gore *et al.* (2000) studied the impact of soil and water conservation structures on socio-economic status of farmers at Wagarwadi watershed for socio-economic survey, the information on the point like education status, area under cultivation and fallow land, cropping pattern change in water table depth, land use pattern before and after development of watershed was collected. The crop productivity increased from 29.5 to 67.67 per cent in post development stage over pre development. The net cultivated area was 138 ha in pre development stage, which was increased to 194 ha. in post development stage. After development of watershed the area under contour cultivation, bunded cultivation, orchards and forests has been increased. Number of open wells was also increased from 8 before development to 240 after development of watershed.

Dyani, B.L. *et al.* (1991) at Deharadun estimated that the average family income within watershed farm group is 44.5% higher than outside watershed farm group family. Agriculture income in both family groups is 51.5 and 49.8%

respectively. The contribution of the service personal in family income is 34% and 28% within and outside farm group respectively.

Shinde (1997) studied the socio-economic status of farmers in Ghodegaon watershed in Aurangabad district. The study revealed that the soil conservation measures viz. nala bunding increased the yield of wells. The watershed technology showed its positive impact of various sources of income. Due to availability of water the area and yield of cash crop was considerably increased. Increase in per capita income from Rs. 6767 to Rs. 13630 and reduction in migration of marginal cultivators and land less labour was also found.

Gaikwad and Ramesh Kumar (1997) carried out the project work at Nagpur district that the impact of soil and water conservation in a watershed on the agricultural productivity, natural resource use, food consumption and economic condition of the farmers. The land development activities considerable of the construction of earthen check dams, graded bunding, trench-cum-mound structures and stone pitching. Data was collected from the 20 participating watershed farmers and for comparison from 20 non-participatory farmers outside of the watershed during 1994-95.

MATERIAL AND METHODS

CHAPTER-III

MATERIAL AND METHODS

This chapter presents the general description of watershed and techniques adopted to collect the basic data for evaluation of soil and water conservation structures in Darakwadi watershed of Aurangabad district.

General :

Darakwadi village is situated in Aurangabad district of Marathwada region, 45 km from Aurangabad city and 13 km from the Karmad Railway station. It is located between 19° 36' 15" N latitude and 75° 48' 45" E longitude. The average annual rainfall of Aurangabad is 600 mm. South-West monsoon is the major source of rainfall. Most of the soils in this region are medium to deep black with some part of degraded land. Topography is flat to undulating. Population of the village is 688.

3.1.1 Darakwadi watershed in brief :

Darkwadi watershed has been developed by Non-Government Organization "Dilasa Janvikas Pratisthan" Aurangabad, with the support of United Nation Children Development Fund (UNIFCEF) Mumbai and Member of Legislative Council (MLC) Fund. Watershed development programme has been implemented during the year 2002-03 in Darakwadi. Total geographical area of Darakwadi watershed is 479 ha.

The objectives of watershed development programme are.

1) To strengthen water resources by various methods applicable according to suitable sites.
2) To strengthen community participation, specially participation by women.
3) To orient community regarding micro planning of water.
4) To conserve and improve the natural resources, economic upliftment of cultivators.

Total population of watershed is 688. Total number of families covered within target area are 135. Land holding wise classification of the families in the Darakwadi watershed are presented in Table 3.1

Table 3.1 Land holding wise classification of the families in Darakwadi watershed.

Sr. No.	Land holding category	Land holding (ha)	Families
1.	Marginal	0 to1	22
2.	Small	1to 2	63
3.	Medium	2 to 4	37
4.	Large farmers	Above 4	13

3.1.2 Project Implementing Agency (PIA) :

Dilasa is a voluntary Non-Government Organization engaged in socio-economic upliftment of rural people. Dilasa firmly believes that watershed development is the key of rural upliftment. The organization aims at improving the quality of rural life through regeneration and renewal of the degraded natural resources viz. land, water and biomass through integrated development programme during last 8 years. Dilasa developed more than 20000 ha of land under various watershed programmes with active community participation thereby combining the social and technical aspects to ensure holistic development.

3.2 Experimental site :

3.2.1 Location :

Darakwadi watershed is located about 40 km away from Aurangabad and 13 km from Karmad railway station, on Aurangabad-Jalna road in Aurangabad district, surrounded by Karhol on north, Kolghar on south, Kawadgaon on East, and Adgaon on West. Darakwadi watershed is situated at 524 m Average Mean Sea Level (AMSL). The main water course (nala) of the watershed starts from karhol side and it flows towards Kolghar side. The watershed is bounded by the karhol (north) and Adgaon(west) side hilly area.

The location map of Darakwadi watershed is presented in Fig. 3.1.

3.2.2 Area and Topography :

Total geographical area of Darakwadi watershed is 479 ha, with undulating topography. The general slope of cultivable land in the watershed ranges from 1 to 3 percent. However, at some locations maximum slope of 5.5 per cent is observed. In non-cultivated area at hilly and elevated degraded lands maximum slope of 15 to 24 per cent is observed. The toposheet of the Darakwadi watershed has been presented in Appendix-III.

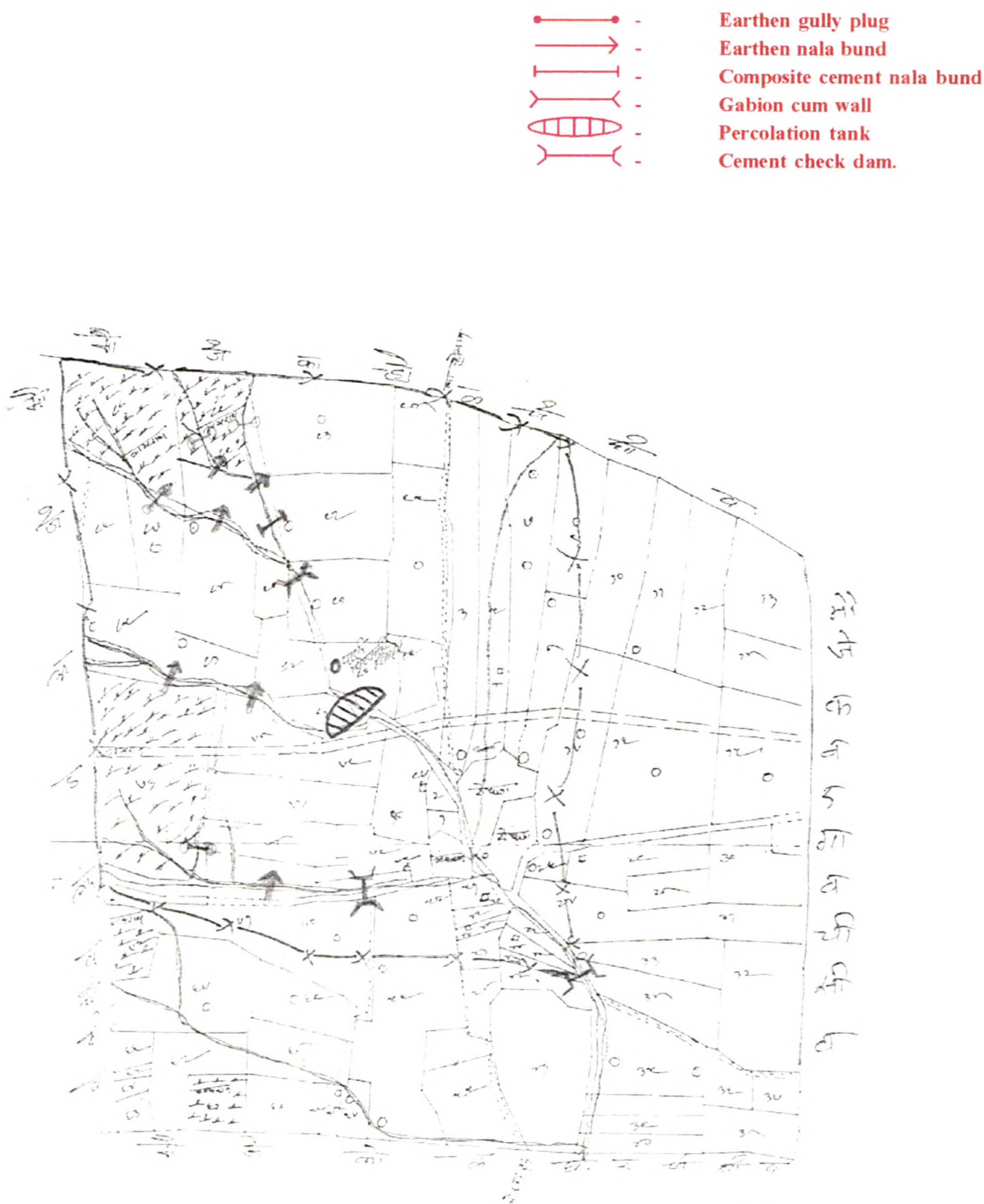


Fig. 3.1 Map of Darakwadi Watershed

3.2.3 Vegetation :

Sparse vegetation cover in the farm of local tree species like Mango, Custard apple, Ber, Neem, Babul, Tamarind, Sandal was found in the watershed area, before the implementation of watershed development programme.

3.2.4 Hydrology :

Darakwadi watershed receives on an average 600 mm rainfall annually. South West monsoon is the chief source of rainfall, receiving about 90% annual rainfall, ground water through wells is chief source of irrigation and drinking water potential. Owing to infiltration characteristics of the black soil land use and drainage net work infiltration to the ground water was limited. This caused the situation where, the demand of drinking and irrigation water, was not satisfying before implementation of development programme. Sufficient number of open wells existing in the watershed were used for monitoring ground water table.

3.2.5 Climate :

Darakwadi watershed falls under semi-arid tropic having highest temperature 45°C during the month of May while the lowest of 14°C during December. The average annual rainfall is 600 mm. Rainfall is uneven, erratic and varies from year to year. About 90% of rainfall is receives during the month of June to October.

3.2.6 Soil and land use classification :

The most of the soil type in the Darakwadi watershed ranges from light to heavy. The heavy deep soils are mostly clay in texture. The soils are well drained and of moderate slope.

The pH of the soil of Darakwadi watershed ranges between 6.9 to 8.1. The organic carbon content of watershed ranges between 0.5-0.72 %. As per the report of soil survey conducted by DILASA, the details about land use, soil type, hydrological data & fertility of soil is given in the Table 3.2.

Table 3.2 : Soil type, hydrological and fertility status of the Darakwai watershed.

Sr. No.	Particulars	Cultivable land (ha)	Non cultivable land (ha)
1.	**Soil class**		
	a) Class-II	5.10	23.78
	b) Class-III	369.58	--
	c) Class-IV	27.96	24.32
	d) Class-VI	--	28.26
	Total	**402.64**	**76.36**
2.	**Texture of soil**		
	a) Clay loam	178.60	--
	b) Loam	63.68	--
	c) Sandy clay loam	83.44	--
	d) Sandy loam	53.86	28.05
	e) Rocky	23.06	48.31
	Total	**402.64**	**76.36**
3.	**Depth of soil**		
	a) Marginal	--	76.36
	b) Medium	264.92	
	c) Deep	137.72	
	Total	**402.64**	**76.36**
4.	**Permeability (mm/hr)**	Moderate	Low
5.	**Drainability**	Well drained	Well drained
6.	**Fertility**	Moderate	Poor

Table 3.3 : Physico-chemical properties of soil of Darakwadi watershed.

Sr. No.	Particulars	Range of soil types shallow to medium deep
1.	Area (ha)	479
2.	Course sand %	29.27 to 9.25
3.	Fine sand %	24.57 to 17.36
4.	Silt %	22.29 to 26.85
5.	Clay %	20.60 to 44.66
6.	$CaCo_3$	7.5 to 6.23
7.	PH	6.9 to 8.1
8.	Organic carbon %	0.50 to 0.72
9.	Bulk density gm/cc	1.45 to 1.06
10.	Field capacity %	20.80 to 36.50
11.	P.W.P.%	12.30 to 18.40

3.2.6 Cropping pattern :

Cropping pattern and cropping system are mainly influenced by rainfall pattern. The cropping pattern followed before development of watershed during kharif and rabi season is as below :

Kharif : Sorghum, pearl millet, pigeon pea, green gram, black gram, Cotton, Sunflower, Groundnut, Maize.

Rabi : Sorghum, Wheat, Gram, Sunflower.

3.3 Soil and water conservation treatments detail :

According to the potential available in the Darakwadi watershed, the development components proposed regarding soil and water conservation were presented in Table 3.4. Implementation of soil and water conservation treatments were initiated in 2002 and completed in April 2003. The area treated by different activities is 479 ha.

Table 3.4 : Soil and water conservation structures in Darakwadi watershed.

Sr. No.	Particulars	No. of structures constructed / area
1.	Earthen gully plug	6
2.	Earthen nala bund	6
3.	Composite cement nala bund	1
4.	Gabion cum wall	1
5.	Cement check dam	2
6.	Percolation tank	1
7.	Continuous contour trenching	42 ha

For the present evaluation study all the structure listed in Table 3.4 were considered.

3.3.1 Earthen gully plug :

In Darakwadi watershed six earthen gully plugs have been constructed across the gully to conserve soil and water. The structures were proposed in Darakwadi watershed using following criteria.

1) Sites at upper reaches of catchment.
2) In the gullies just formed or branches of main nalas.
3) Length of the gully on upstream of the structure should not be more than 100 m.

Earthen gully plug stops further deepening of gullies, retains sediments and runoff. It reduces runoff velocity and sedimentation from that area. It stops erosion and increase the recharge of water at upper reaches. It also reduces the degree of slope of the gully bed by constructing a series of gully plugs at regular interval, across the width, in the gully. Total six earthen gully plugs are constructed across gullies in Darakwadi watershed and selected for their evaluation study. Table 3.5 presents the storage capacity and catchment area of each earthen gully plug.

Table 3.5 : Storage capacity and catchment area of earthen gully plugs in Darakwadi watershed.

Sr. No.	Particulars	Storage capacity m^3	Catchment area (ha)
1.	EGP-1	75.26	5.31
2.	EGP-2	112.07	9.65
3.	EGP-3	91.58	7.04
4.	EGP-4	171.23	11.17
5.	EGP-5	96.45	8.23
6.	EGP-6	198.42	12.14

3.3.2 Earthen nala bund :

In Darakwadi watershed earthen nala bunds are constructed across a nala to hold up water for a period and let it gradually percolate to raise the surrounding ground water level . All six earthen nala bunds were proposed in Darakwadi watershed using following criteria.

1) Narrow valley for least amount of earth fill.
2) Nala bed slope not more than 3%
3) Nala width more than 5 m and less than 15 m.
4) Sufficient clayey soil for the core wall should be available near by.

5) One of the banks should have suitable strata and area for the spillway.

6) The structure should not lead to water spreads into the near by agricultural fields.

7) Foundation strata should be capable of bearing the load of the structure.

Earthen nala bunds involves construction of the bund of suitable size across the nala for intercepting the runoff coming from catchment area and to create a temporary water storage for few days. Earthen nala bund reduces the soil erosion and provides a means of ground water recharge. Six earthen nala bunds, constructed in Darakwadi watershed, were selected for evaluation study.

Storage capacity and catchment area of earthen nala bunds are presented in Table 3.6.

Table 3.6 : Storage capacity and catchment area of earthen nala bunds in Darakwadi watershed.

Sr. No.	Particulars	Storage capacity m^3	Catchment area (ha)
1.	ENB-1	1144.06	34.60
2.	ENB-2	1497.60	69.29
3.	ENB-3	2850.81	70.58
4.	ENB-4	1950.37	75.37
5.	ENB-5	2898.41	84.77
6.	ENB-6	4284.72	91.09

3.3.3 Composite cement nala bund :

Composite cement nala bund was constructed where cement nala bund was not possible to construct due to slope, catchment area and cost of construction. Composite cement nala bund consists of vertical hollow cement wall constructed across the width of the nala. Hollow cement wall was constructed of stones, cement and sand. The wall was plastered with the cement from inside and outside and filled with black cotton soil. Its functions are similar to cement nala bund. However its cost of construction is comparatively low.

Storage capacity and catchment area of composite cement nala bund is presented in Table 3.7

Table 3.7 : Storage capacity and catchment area of composite cement nala bund in Darakwadi watershed.

Sr. No.	Particular	Storage capacity m^3	Catchment area (ha)
1.	CCNB-1	3970.21	103.55

Photograph of composite cement nala bund is shown in Plate No.1.

3.3.4 Gabion cum wall :

The demand regarding water storage structures increased rapidly during execution of watershed. Considering this fact gabion cum wall type structure is really a special tool to convince the people regarding erosion control and water storage.

Gabion cum wall is constructed across the nala, it is combined form of gabion structure and cement plug. In gabion cum wall, a vertical wall on upstream side as incase of cement plug and gabion wall on downstream side, both form single wall. It is very interesting structure as it looks like small cement nala bund at one side and gabion at other side. It is

Plate No. 1 Composite cement nala bund

Plate No. 2. Gabion cum wall.

used to control soil erosion and to impound huge quantity of water with in nala portion. Only one gabion cum wall was constructed in Darakwadi watershed and selected for evaluation study. Photograph of gabion cum wall is shown in Plate No.2.

Storage capacity and catchment area of gabion cum wall is given in Table 3.8.

Table 3.8 : Storage capacity and catchment area of Gabion cum wall in Darakwadi watershed.

Sr. No.	Particular	Storage capacity m^3	Catchment area (m^2)
1.	GCW-1	540.79	129.38

3.3.5 Cement check dam :

In Darakwadi watershed cement check dam is constructed to control the soil erosion and improve the water table. This is low weir without a canal taking off from it, but providing facility for lift irrigation and firming up by means of percolation under the wells in the surrounding area. It is generally provided on small streams or nalas having continuous flow, particularly during rabi season.

Site selection :

1) The streams have a straight reach on both sides.
2) Nala bed slope should not more than 3%.
3) Nala width should be less than 30 m.
4) Nala should have stable banks on either sides.

5) The rock level below the bed level should not be more than half the height of the structure above ground level.

6) The structure should not in any way lead to water spreads into nearby agricultural fields.

In Darakwadi watershed, two cement check dams have been constructed and were selected for evaluation study.

Photograph of cement check dam is shown in Plate No.3. Storage capacity and catchment area of cement check dams are given in Table 3.9.

Table 3.9 : Storage capacity and catchment area of cement check dam in Darakwadi watershed.

Sr. No.	Particulars	Storage capacity m^3	Catchment area (ha)
1.	CCD-1	4607.50	97.03
2.	CCD-2	8098.75	454.21

3.3.6 Percolation tank :

In Darakwadi watershed percolation tank was constructed to conserve the water for irrigation purpose and to increase the ground water potential. It also controls the soil erosion from the upstream side. The side slope of percolation tank embankment is 2.5 :1 in the upstream side and 2:1 in down stream side. The top of the percolation tank embankment is 2 m wide and is used as road. To dispose of excess water from percolation tank, spillway was constructed. For evaluation study percolation tank is selected. Photograph of percolation

Plate No. 3. Cement check dam.

Plate No. 4. Percolation tank.

tank is shown in Plate No.4. Storage capacity and catchment area of the percolation tank is given in Table 3.10.

Table 3.10 : Storage capacity and catchment area of percolation tank in Darakwadi watershed.

Sr. No.	Particular	Storage capacity m^3	Catchment area (ha)
1.	Percolation tank	522000.36	238.05

3.3.7 Continuous contour trenching :

In Darakwadi watershed continuous contour trenching was constructed in 42 ha area having slope range from 4-15% to control runoff and soil erosion. Continuous contour trenching involves construction of small trench along the contour line, continuous contour trenching was adopted as a soil conservation structure in the uncultivated land. It reduces the speed of water coming from top of hill, soil erosion and stop the water in trench and allow to infiltrate into soil. Small trenches are constructed having section of $60x30cm^2$. The distance between two trenches is 10 m.

Selection of site :

1) Soil class VI and V are adopted for this purpose.

2) The minimum depth of soil should be 7.5 cm.

Cross section of the continuous contour trench is shown in Fig. 3.2.

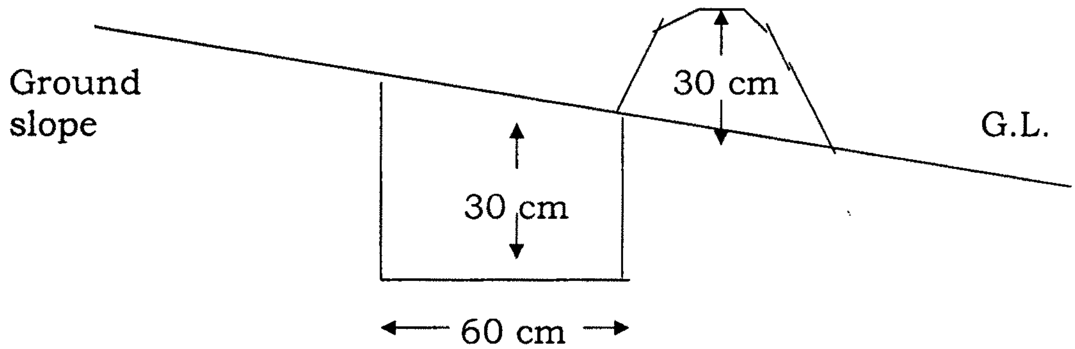


Fig 3.2. Cross section of continuous contour trench.

3.4 Methodology :

3.4.1 Measurement of silt deposition :

The data on silt deposition i.e. depth of silt deposited in storage area, area of silt deposited were collected. For this, small pits were made in impounding area of the structure upto a depth of original ground surface at different locations and average depth of silt deposited was determined. Area of silt deposited is measured by dividing it into regular triangles and rectangle. Volume of silt deposited at each structure was determined by multiplying the area of silt deposition and depth of silt deposited. Weight of silt deposited was calculated by multiplying the volume of silt by bulk density of the silt. The bulk density of silt was found as 1.25 gm/cc. The measurement of silt deposition at cement check dam is shown in Plate No.5.

Plate No. 5. Measurement of silt deposition at cement check dam.

Plate No. 6. Measurement of dimensions of earthen nala bund.

3.4.2 Measurement of dimensions of structures :

In this evaluation study, various soil and water conservation structures like earthen gully plug, earthen nala bund, composite cement nala bund, gabion cum wall, cement check dam, percolation tank, and continuous contour trenching were studied.

The existing dimensions of the structures i.e. top width, bottom width, height and cross section area were be recorded and compared with the designed dimensions for determining the percent reduction in different dimensions of structures collected from Dilasa Janvikas Prathsthan, Aurangabad. The measurement of dimensions at earthen nala bund is shown in Plate No.6.

3.4.3 Measurement of water table depth :

In watershed area 12 wells were selected to determine the effect of various water harvesting structures on ground water recharge. Three wells in influencing area of each structure like earthen nala bund, composite cement nala bund, percolation tank and cement check dam were selected. The data on the water table depth in the wells is monitored monthly from the month of June 2004 till May-2005. The measurement of water level in the well is shown in Plate No.7.

3.4.4 Socio-economic study :

The socio-economic study was carried out in Darakwadi watershed to assess the impact of watershed development programme on village peoples and farming system. The data pertaining to socio-economic condition of the farmers were collected. Information was collected from farmers by personal

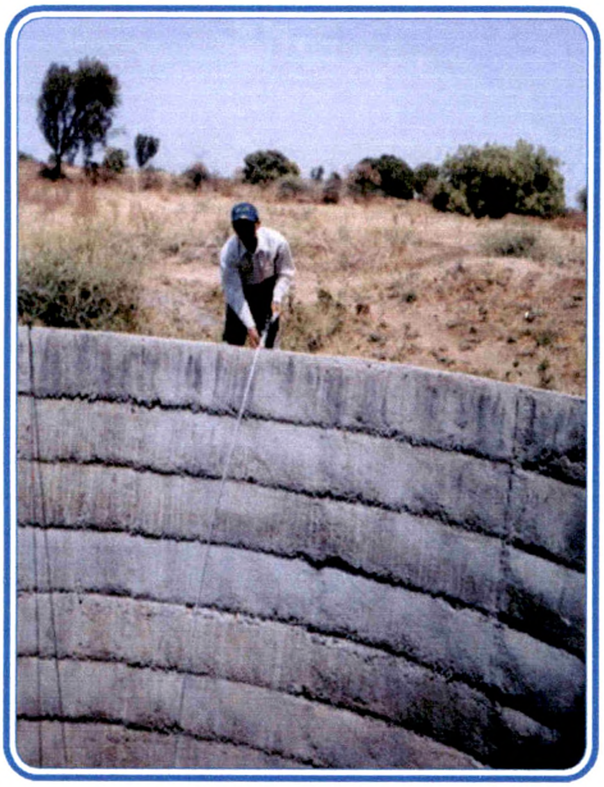


Plate No. 7. Measurement of water level in the well.

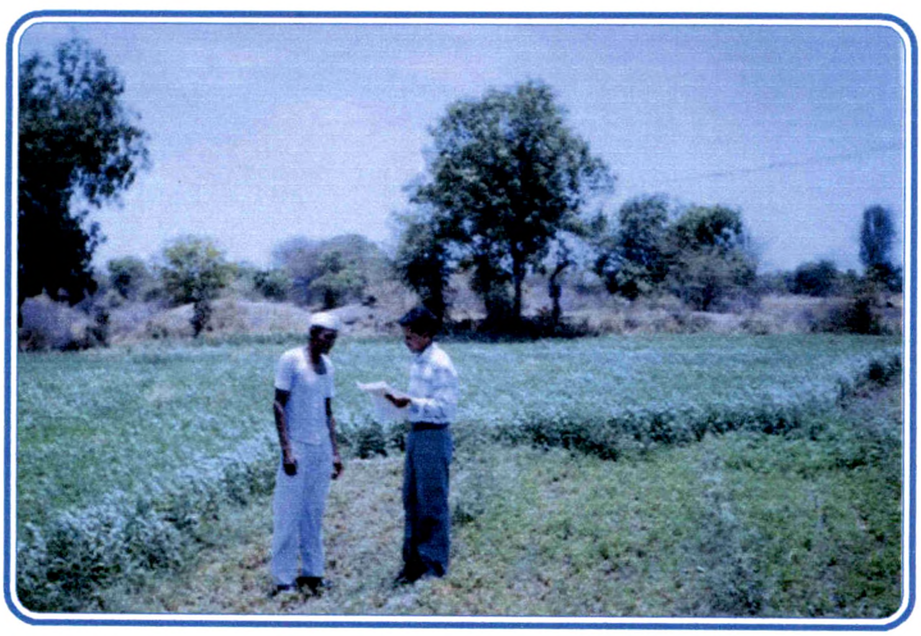


Plate No. 8. Discussion with farmer on socio-economic aspects.

interview method on various aspects. At the time of interview, the major points covered were educational status, small scale business, live stock, farm mechanization and land use and cropping pattern. The data collected from farmers was compared with pre development data provided by Dilasa Janvikas Pratishthan Aurangabad. Plate No. 8 shows the photograph of discussion with farmer on socio-economic aspects.

RESULTS AND DISCUSSION

CHAPTER-IV

RESULTS AND DISCUSSION

Performance evaluation study on various soil and water conservation structures in Darakwadi watershed was carried during the year 2004-05. The watershed is located in Aurangabad district of Maharashtra state. Under this study soil and water conservation structures namely, earthen gully plug, earthen nala bund, composite cement nala bund, gabion cum wall, cement check dam, percolation tank, continuous contour trenches were evaluated. Silt deposited in impounding area of structure was determined by measuring depth of silt deposited and the area of silt deposition. The designed dimensions of the structures were compared with the existing dimensions of the structures. Twelve wells were selected from down streamside of the structures to study the effect of water harvesting structure on ground water recharge. Socio economic survey was conducted to study the impact of watershed development programme with the parameters such as small scale business, live stock, farm mechanization and land use and cropping pattern. Results of this study have been discussed under the following sub heads.

4.1 Silt deposition in various soil and water conservation structures in Darakwadi watershed.

4.2 Comparison of design and existing dimensions of the soil and water conservation structures.

4.3 Effect of water harvesting structures on ground water recharge.

4.4 Socio-economic impact of soil and water conservation structures.

4.1 Silt deposition in various soil and water conservation structures:

Silt deposition in various soil and water conservation structures namely, earthen gully plug, earthen nala bund, composite cement nala bund, gabion cum wall, cement check dam, percolation tank and continuous contour trenches was measured.

4.1.1 Earthen gully plug :

The data on silt deposition in earthen gully plug are presented in Table 4.1

Table 4.1 : Silt deposition in earthen gully plug.

EGP No.	Catchment area (ha)	Storage capacity (m^3)	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Wt. of silt deposition (tonnes)	Erosion rate (t/ha/yr)	Current storage capacity (m^3)	Percent reduction in storage capacity
1.	5	75.26	0.19	13.20	2.50	3.12	0.312	72.76	3.32
2.	9	112.07	0.24	18.38	4.41	5.51	0.306	107.66	3.93
3.	7	91.58	0.23	14.87	3.42	4.27	0.305	88.16	3.73
4.	11	171.23	0.29	19.72	5.71	7.13	0.324	165.52	3.33
5.	8	96.45	0.23	15.26	3.50	4.37	0.273	92.95	3.62
6.	12	198.42	0.25	20.91	6.69	8.36	0.348	191.73	3.37
	Total silt deposition in earthen gully plug					**32.76**			**3.55**

From Table 4.1, it is revealed that average depth of silt deposition at each earthen gully plug ranged between 0.19 to 0.29 m. Area of silt deposited in impounding area of the structure range between 13.20 to 20.91 m^2, whereas total silt deposited in all the six earthen gully plug was found to be 32.76 tonnes during the period of two years after the construction of structures.

From the catchment area of each earthen gully plugs namely 1,2,3,4,5 and 6 the average annual soil loss was found to be 0.32, 0.306, 0.305, 0.324, 0.273 and 0.348 tonnes/ha/yr respectively, which is in the permissible limit of soil erosion.

Percent reduction in storage capacity of all the earthen gully plugs range between 3.32 to 3.93. Annual soil loss from the catchment area of every earthen gully plugs is observed to be minimum because provision of erosion control measures such as barriers of stone, grass, agricultural waste etc. at the outlet of fields.

4.1.2. Earthen nala bund :

The data on silt deposition in earthen nala bund are presented in Table 4.2

Table 4.2 : Silt deposition in earthen nala bund.

EGP No.	Catchment area (ha)	Storage capacity (m^3)	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Wt. of silt deposition (tonnes)	Erosion rate (t/ha/yr)	Current storage capacity (m^3)	Percent reduction in storage capacity
1.	34.60	1144.06	0.24	385.19	92.44	115.55	1.66	1051.62	8.07
2.	69.29	1497.60	0.27	576.07	155.53	194.41	1.40	1342.07	10.38
3.	70.58	2850.81	0.25	675.54	168.11	211.10	1.49	2681.19	5.92
4.	75.17	1950.37	0.23	873.67	200.94	251.18	1.67	1749.43	10.30
5.	84.77	2898.41	0.24	824.17	197.80	247.25	1.45	2700.61	6.82
6.	91.09	4284.72	0.26	838.39	217.98	272.47	1.49	4066.74	5.08
	Total silt deposition in earthen nala bund					**1291.96**			**7.76**

From the Table 4.2 it is revealed that average depth of silt deposited at each earthen nala bunds ranged between 0.23 to 0.27 m. Area of silt deposited in impounding area of structures ranged between 385.19 to 873.67 m^2. Where as the total silt deposited in the impounding area is found to be 1291.96 tonnes during the period of two years after construction.

From the catchment area of each structure i.e. ENB-1, 2,3,4,5 and 6, the average annual soil loss is found to be 1.66, 1.40, 1.49, 1.67, 1.45 and 1.49 tonnes/ha/yr respectively. Which is in the permissible limit.

Due to silt deposition in the impounding area storage capacity of structures is reduced. Percent reduction in storage capacity of ENB-1, 2, 3,4, 5 and 6 is found to be 8.07, 10.38, 5.92, 10.30, 6.82 and 5.08 respectively, over the period of two years after construction. Soil loss estimated from the earthen nala bund is in permissible limit but is more as compared to that of catchment area of earthen gully plug. This is because of lack of bunding works and protection of individual fields.

4.1.3. Permanent structures :

The data on silt deposition at composite cement nala bund, gabion cum wall and cement check dam are presented in Table 4.3

Table 4.3 : Silt deposition at permanent structures.

Structures	Catchment area (ha)	Storage capacity (m^3)	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Wt. of silt deposition (tonnes)	Erosion rate (t/ha/yr)	Current storage capacity (m^3)	Percent reduction in storage capacity
CCNB	103.55	3970.21	0.40	763.24	305.29	381.62	1.84	3664.92	7.68
GCW	129.20	540.79	0.27	228.03	61.56	76.95	0.297	479.23	11.38
CCD-1	97.03	4607.50	0.34	817.11	277.81	347.27	1.78	4329.69	6.02
CCD-2	454.21	8098.75	0.41	1074.27	440.45	550.56	0.606	7658.30	5.43
	Total silt deposition at permanent structures.					**1356.4**			**7.62**

Table 4.4 : Silt deposition at percolation tank.

Structures	Catchment area (ha)	Storage capacity (m^3)	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Wt. of silt deposition (tonnes)	Erosion rate (t/ha/yr)	Current storage capacity (m^3)	Percent reduction in storage capacity
P.T.	238.05	522000.36	0.43	2432.63	1046.03	1307.53	1.83	520954.33	0.20

From the Table 4.3, it is seen that average depth of silt deposited at CCNB, GCW, CCD-1 and CCD-2 is found to be 0.40, 0.27, 0.34 and 0.41m respectively and area of silt deposited is found to be 763.24, 228.03, 817.11 and 1974.27 m^2 respectively in impounding area of structures. Total silt deposited at all the structures is found to be 1356.4 tonnes during the period of two years.

From the catchment area of CCNB, GCW, CCD-1 and CCD-2 the average annual soil loss is found to be 1.84, 0.297, 1.78 and 0.606 tonnes/ha/yr respectively and which is in the permissible limit.

Storage capacity of the CCNB, GCW, CCD-1 and CCD-2 is reduced by 7.68%, 11.38%, 6.02% and 5.43% respectively, compared with design storage capacity.

The higher rates of soil erosion from the catchement areas of these structures may be due to lack of sufficient erosion control measures, such as mechanical bunds, protection at the outlet and comparatively higher slope range of the fields.

4.1.4 Percolation tank :

The data on silt deposition in percolation tank are presented in Table 4.4.

From the Table 4.4, it can be seen that average depth of silt deposited in percolation tank is found to be 0.43 m. Area of silt deposited in percolation tank is found to be 2432.63 m^2. Total silt deposited in impounding area of percolation tank is found to be 1307.53 tonnes. The average annual soil loss from catchment area of percolation tank is found to be 1.83-tonnes/ha/yr. Storage capacity of percolation tank is reduce by 0.20% over the period of three years.

4.1.5 Continuous contour trenches :

The data on site deposition in continuous contour trenches are presented in Table 4.5.

Table 4.5 : Silt deposition in continuous contour trenches.

CCT No.	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Wt. Of silt deposition (tonnes)
1	0.12	381.25	45.75	57.18
2	0.15	432.17	64.82	81.03
3	0.13	373.49	48.55	60.68
4	0.17	294.29	56.02	62.53
5	0.14	361.28	50.57	63.22
6	0.13	329.90	42.88	53.60
7	0.14	409.16	57.28	71.60
8	0.15	323.37	48.50	60.63
9	0.12	359.31	43.11	53.89
10	0.13	341.61	44.40	55.51
Total silt deposition in continuous contour trenches				**619.87**

From the Table 4.5, it reveals that average depth of silt deposited and area of silt deposited in continuous contour trenches range between 0.12 to 0.17 m and 294.29 to 432.17 m^2 respectively. Total 619.87 tonnes of silt has been arrested in the trenches over the period of two years after construction in the continuous contour trenches.

4.2 Comparison of designed and existing dimensions of the soil and water conservation structures:

Six earthen gully plug, six earthen nala bund, two cement check dam, composite cement nala bund, gabion cum wall, percolation tank and continuous control trenches were selected for comparing their designed and existing dimensions. Data on designed dimensions of these structures were collected from DILASA. Existing dimensions of the structures such as top width, bottom width and height of structures were measured. Present cross sectional area of each structure was calculated and compared with the designed cross sectional area and percent reduction in cross sectional area has been determined.

4.2.1 Earthen gully plug :

The data on designed and existing dimensions of the earthen gully plugs are presented in Table 4.6.

Table 4.6 : Designed and existing dimensions of earthen gully plugs.

EGP NO.	Designed dimensions (2002-2003)				Existing dimensions (2004-2005)				Percent reduction in C/s area
	TW (m)	BW (m)	H (m)	Area (m^2)	TW (m)	BW (m)	H (m)	Area (m^2)	
1	0.50	3.30	1.20	2.28	0.67	3.55	0.91	1.92	15.78
2.	0.50	3.70	1.06	2.22	0.73	3.91	0.82	1.90	14.41
3.	0.60	3.30	1.26	2.45	0.78	3.65	0.88	1.94	20.81
4.	0.60	4.55	1.50	3.86	0.81	4.86	1.13	3.20	17.09
5.	0.60	3.50	1.10	2.25	0.75	3.98	0.80	1.89	16.00
6.	0.60	4.55	1.50	3.86	0.76	5.10	1.25	3.66	5.46
							Average		**14.92**

The above table shows the percent reduction in cross sectional area of earthen gully plug. Comparison of designed and existing dimensions indicates that top width is increased, bottom width is increased and height is decreased. It is due to the compaction of earthen gully plugs after the construction.

From the data on designed and existing cross sectional area of earthen gully plug, it is revealed that reduction in cross sectional area of earthen gully plugs is found to be range between 5.46 to 20.81 per cent. On an average reduction in cross sectional area is found to be 14.92 per cent as compared to designed cross sections.

4.2.2 Earthen nala bund :

The data on designed and existing dimensions of the earthen nala bund are presented in Table 4.7.

Table 4.7 : Designed and existing dimensions of earthen nala bunds.

ENB NO.	Designed dimensions (2002-2003)				Existing dimensions (2004-2005)				Percent reduction in C/s area
	TW (m)	BW (m)	H (m)	Area (m^2)	TW (m)	BW (m)	H (m)	Area (m^2)	
1	0.60	5.80	2.60	8.32	0.95	6.18	2.07	7.37	11.41
2.	0.60	5.20	2.30	6.67	0.86	5.79	1.98	6.58	1.34
3.	0.60	6.20	2.80	9.52	0.93	6.66	2.44	9.25	2.83
4.	0.60	6.60	3.00	10.8	0.83	7.03	2.62	10.29	4.72
5.	0.60	6.60	3.00	10.8	0.96	6.97	2.64	10.46	3.14
6.	0.60	6.20	2.80	9.52	0.97	6.74	2.26	8.70	8.61
								Average	**5.34**

The it reveals from Table 4.7 that, top and bottom width increased and height of earthen nala bund decreased during the period of two years after construction.

From the data on designed and existing cross sectional area in table 4.7, it is revealed that reduction in cross sectional area range between 1.34 to 11.41 per cent. On an average reduction in cross sectional area is found to be 5.34 per cent as compared to designed cross sections.

4.2.3 Permanent structures :

The data on designed and existing dimensions of permanent structures namely composite cement nala bund, gabion cum wall and cement check dam are presented in Table 4.8.

Table 4.8 : Designed and existing dimensions of permanent structures.

Struc-tures	Designed dimensions				Existing dimensions				Percent reduction in C/s area
	TW (m)	BW (m)	H (m)	Area (m^2)	TW (m)	BW (m)	H (m)	Area (m^2)	
CCNB	2.40	2.40	1.60	3.84	2.40	2.40	1.60	3.84	00
GCW	0.60	2.6	1.5	2.40	0.60	2.6	1.5	2.4	00
CCD-1	0.90	1.65	2.5	3.18	0.90	1.65	2.5	3.18	00
CCD-2	0.90	1.85	2.75	3.78	0.90	1.85	2.75	3.78	00
								Average	**00**

From the Table 4.8, it is revealed that designed dimensions of the permanent structures i.e. CCNB, GCW. CCD-1 and CCD-2 taken under study were not changed as the structures were constructed with cement, sand and stone. All the designed dimensions such as top width bottom width and height of structures are found to be unchanged at the time of measurements over the period of two years after their construction.

4.2.4 Percolation tank :

The data on designed and existing dimensions of the percolation tank are presented in Table 4.9.

Table 4.9 : Designed and existing dimensions of percolation tank.

Stru-cture	Designed dimensions (2002-2003)				Existing dimensions (2004-2005)				Percent reduction in C/s area
	TW (m)	BW (m)	H (m)	Area (m^2)	TW (m)	BW (m)	H (m)	Area (m^2)	
Per-colation tank	2.0	22	7.5	9.0	2.66	23.60	6.52	85.60	4.88

The designed and existing dimensions and percent reduction in C/S area of percolation tank are presented in Table 4.9. From the Table 4.9 it reveals that top width increased from 2.0 m to 2.66 m, bottom width increased from 22 m to 23.60 m and height of percolation tank is decreased from 7.5 m to 6.52 m respectively.

The reduction in C/S area of percolation tank is found to be 4.88% during the period of three years after their construction.

4.2.5 Continuous contour trenches :

The data on designed and existing dimensions of the continuous contour trenches are presented in Table 4.10.

Table 4.10 : Designed and existing dimensions of continuous contour trenches.

CCT No.	Designed dimensions				Existing dimensions				Percent reduction in C/s area
	TW (m)	BW (m)	H (m)	Area (m^2)	TW (m)	BW (m)	H (m)	Area (m^2)	
1	0.75	0.60	0.38	0.25	0.82	0.57	0.26	0.18	28.00
2.	0.75	0.60	0.33	0.22	0.83	0.57	0.18	0.12	45.45
3.	0.80	0.58	0.33	0.22	0.86	0.51	0.20	0.13	45.45
4.	0.81	0.60	0.35	0.24	0.86	0.5	0.18	0.12	50.00
5.	0.85	0.62	0.35	0.23	0.89	0.58	0.21	0.15	34.78
6.	0.85	0.63	0.30	0.22	0.88	0.58	0.17	0.12	45.45
7.	0.85	0.60	0.34	0.24	0.90	0.58	0.20	0.14	41.66
8.	0.80	0.62	0.36	0.25	0.83	0.56	0.21	0.14	44.00
9.	0.80	0.60	0.30	0.21	0.84	0.57	0.18	0.12	42.85
10.	0.80	0.60	0.32	0.22	0.84	0.56	0.19	0.13	40.90
							Average		**41.85**

The Table 4.10 shows the percent reduction in cross sectional area of continuous contour trenches. Comparison of designed top width and existing top width indicates that top width increased, bottom width and height of CCT reduced during the period after construction. Increase in top width of CCT's might be due to inflow of water from upstream side, reduction in bottom width and height may be due to siltation.

From comparison of designed and existing cross sectional area of the continuous contour trenches, it is reveals that reduction in cross sectional area of continuous contour trenches range between 28.00 to 50.00 percent. On an average reduction in the cross sectional area of continuous contour trenches is found to be 41.85 per cent.

The observation of Continuous contour trenches constructed in watershed, reveals that vegetation of good density is found to be developed due to conservation of moisture by trenches.

4.3 Effect of water harvesting structures on ground water recharge:

To study the effect of water harvesting structures on ground water recharge 12 open wells located in the influencing area of the structures on downstream side were selected. Out of 12 wells, 3 wells were located at downstream side of earthen nala bund, 3 wells at downstream side of composite cement nala bund, 3 wells at down stream side of percolation tank and 3 wells at downstream side of cement check dam.

Water level in the wells was measured monthly by using measuring tape with respect to reference point. These water levels were compared with pre development levels.

4.3.1 Effect of earthen nala bund:

The data on water level fluctuations in the well on downstream side of earthen nala bund are presented in Table 4.11 and depicted in Fig. 4.1

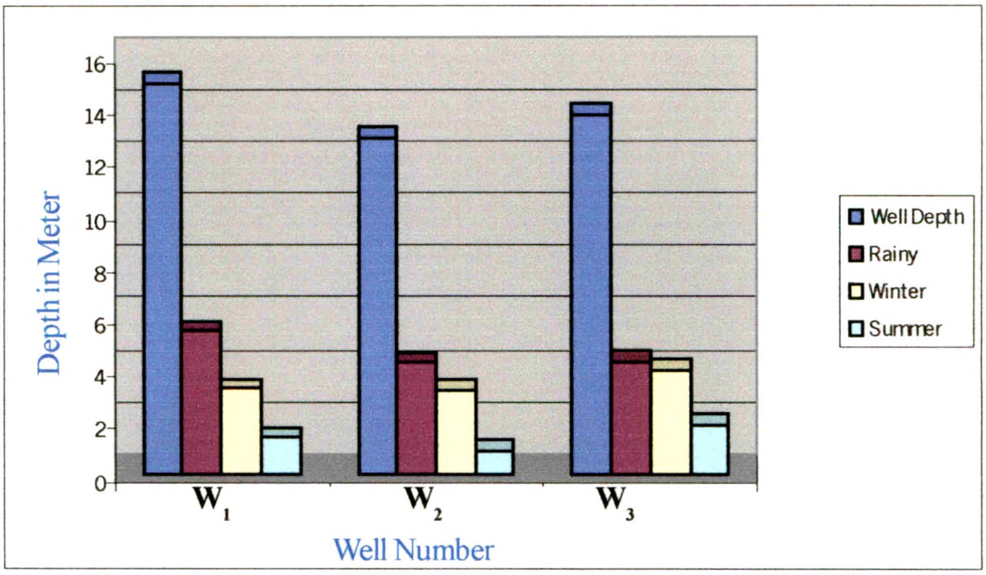
Table 4.11 : Water level fluctuation in the wells on downstream side of earthen nala bund.

Sr. No.	Month	Water level depth in the wells (m)						Increase in water table (m) (2004-2005)		
		Pre development 2002-2003			Post development 2004-2005					
		W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
1.	June	1.73	0.69	1.49	2.92	1.80	2.64	1.19	1.11	1.15
2.	July	4.21	2.6	1.83	6.69	3.69	5.03	2.48	1.09	3.20
3.	Aug.	5.92	4.33	3.58	7.76	5.92	7.52	1.84	1.59	2.94
4.	Sept.	6.32	4.99	6.03	10.66	9.65	10.30	4.34	4.66	4.27
5.	Oct.	5.21	4.88	5.70	10.55	8.74	9.86	5.34	3.86	4.16
6.	Nov.	4.21	4.60	5.10	9.86	7.89	9.02	5.65	3.29	3.92
7.	Dec.	3.86	3.76	4.32	8.14	7.12	7.51	4.28	3.36	3.19
8.	Jan.	2.66	2.43	3.40	6.51	5.53	6.48	3.85	3.10	3.08
9.	Feb.	2.12	1.84	2.91	5.32	4.38	5.71	3.2	2.54	2.80
10.	March	1.72	1.48	2.42	4.12	3.80	4.68	2.4	2.32	2.26
11.	April	1.03	1.11	1.83	3.16	3.13	3.97	2.13	2.02	2.14
12.	May	0.91	00	1.54	2.72	1.92	2.81	1.81	1.92	1.27

From the Table 4.11 and Fig. 4.1 it reveals that before the development of Darakwadi watershed in the year 2002-03, water level depth in the wells was too much below in all the three wells W_1, W_2 and W_3. Water level depth in the wells ranges between 0.91-6.32 m, 0.0-4.99m and 1.49-6.03 m respectively.

After the development of watershed maximum water is harvested by earthen nala bunds and it helps to increase the water table. In the year 2004-2005 in all the wells W_1, W_2 and W_3, water level depth ranged between 2.72-10.66m, 1.80-9.65 m and 2.64-10.30m respectively.

Pre Development



Post Development

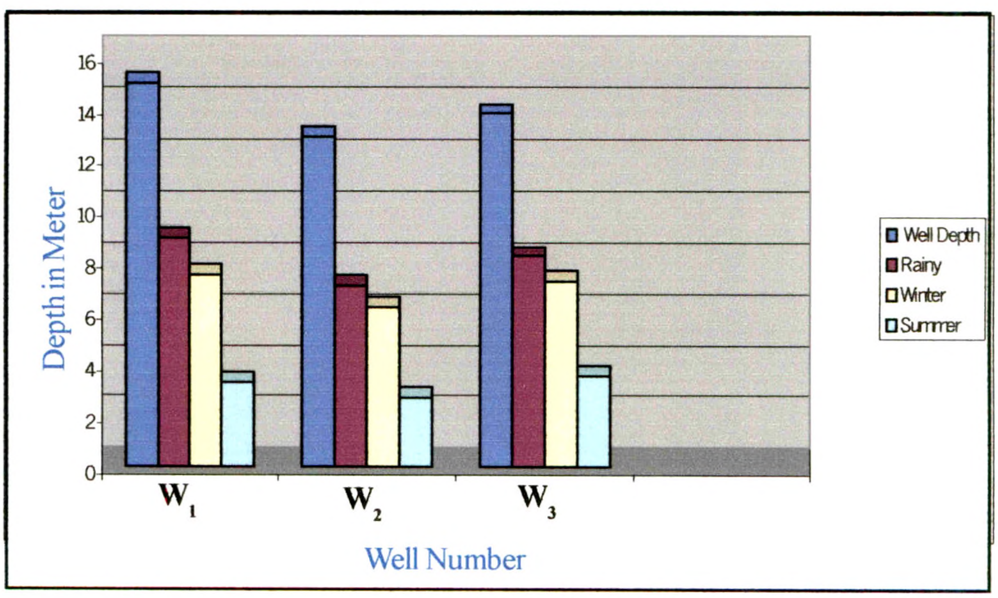


Fig. 4.1 : Seasonal average water level fluctuation in the wells downstream side of the earthen nala bund.

There is increase in water table in all the wells W_1, W_2 and W_3 after watershed development and the increase in water level ranged between 1.19-5.65 m, 1.09-4.66 m and 1.15 - 4.27 m respectively, from June to May as compared to water levels before development.

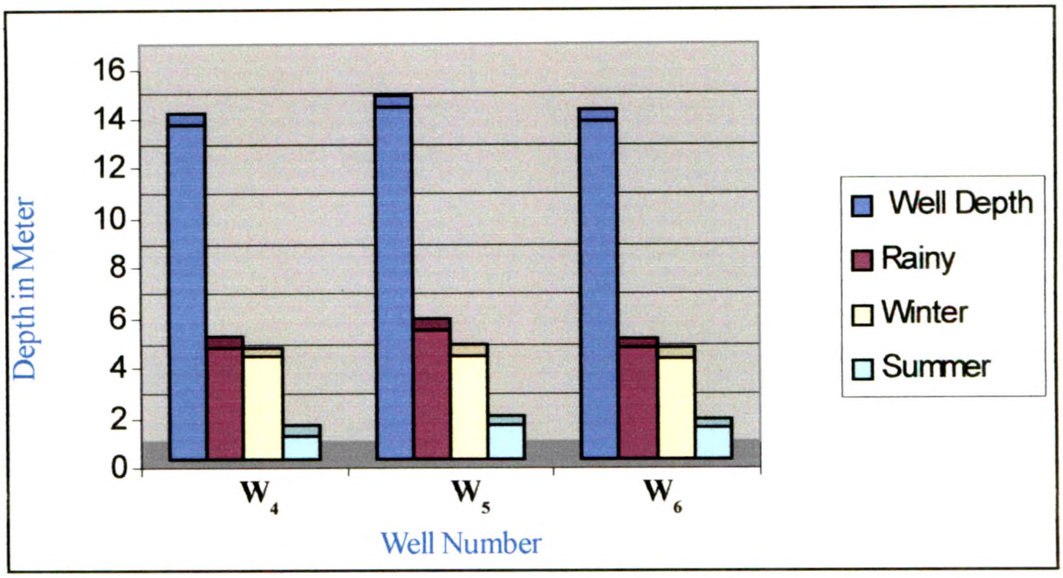
4.3.2 Effect of composite cement nala bund:

The data on water level fluctuations in the wells on downstream side of composite cement nala bund are presented in Table 4.12 and depicted in Fig.4.2.

Table 4.12 : Water level fluctuation in the wells on downstream side of composite cement nala bund.

Sr. No.	Month	Water level depth in the wells (m)						Increase in water table (m) (2004-2005)		
		Pre development 2002-2003			Post development 2004-2005					
		W_4	W_5	W_6	W_4	W_5	W_6	W_4	W_5	W_6
1.	June	0.90	1.39	0.70	2.33	3.52	2.70	1.43	2.13	2.00
2.	July	2.3	2.31	1.90	4.4	5.39	5.79	2.1	3.08	3.89
3.	Aug.	4.14	5.00	4.04	6.43	8.15	7.88	2.29	3.15	3.84
4.	Sept.	6.1	7.00	6.13	9.17	10.63	10.60	3.07	3.63	4.47
5.	Oct.	5.69	6.80	6.00	8.73	10.4	10.20	3.04	3.60	4.20
6.	Nov.	5.33	5.5	5.40	8.31	9.70	8.70	2.77	4.20	3.30
7.	Dec.	4.62	4.83	4.30	7.5	8.30	7.80	2.88	3.47	3.50
8.	Jan.	3.69	3.59	3.74	6.23	6.60	7.12	2.54	3.01	3.38
9.	Feb.	2.89	2.92	3.03	5.32	5.91	5.92	2.43	2.99	2.89
10.	March	1.69	2.24	1.91	4.00	4.23	4.68	2.31	1.99	2.77
11.	April	0.89	1.3	1.52	3.12	2.59	3.30	2.23	1.29	1.78
12.	May	0.50	0.80	1.00	2.10	1.97	2.63	1.60	1.17	1.63

Pre Development



Post Development

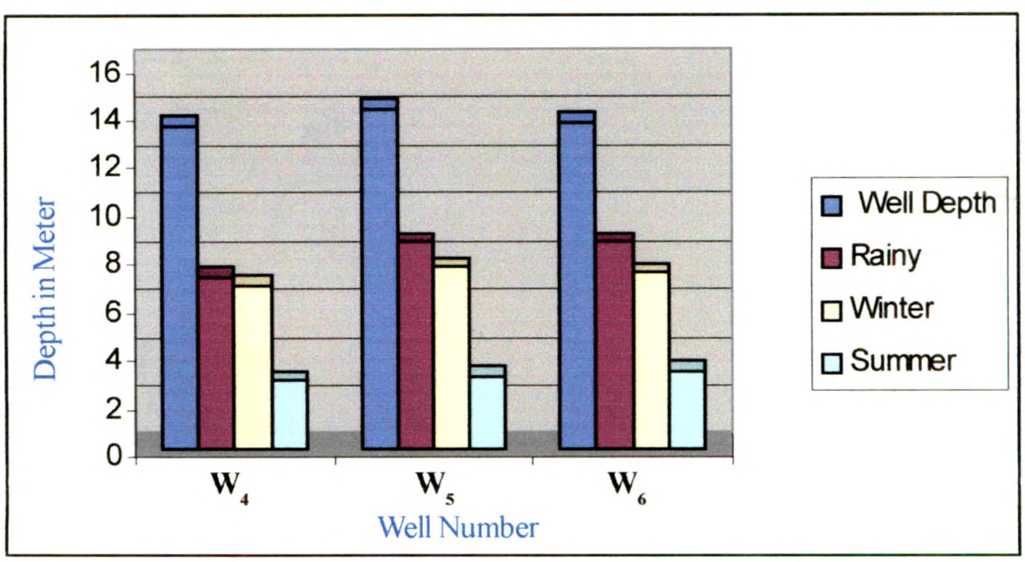


Fig. 4.2 : Seasonal average water level fluctuation in the wells downstream side of the composite cement nala bund.

From the Table 4.12 and Fig 4.2, it reveals that in pre development of Darakwadi watershed in 2002-03, water level depth in all the three wells W_4, W_5 and W_6 downstream side of composite cement nala bund is range between 0.50-6.10 m, 0.80-7.0 m and 0.70-6.13 m respectively from June to May.

In post development period (2004-05), water level depth in all the three wells W_4, W_5 and W_6 downstream side of composite cement nala bund range between 2.10-9.17m, 1.97-10.63m and 2.63-10.60 m respectively, from June to May.

Increase in water table in 2004-05 in all the three wells W_4, W_5 and W_6 range between 1.43-3.07 m, 1.17-4.20 m, and 1.63-4.47 m respectively as compared to pre development.

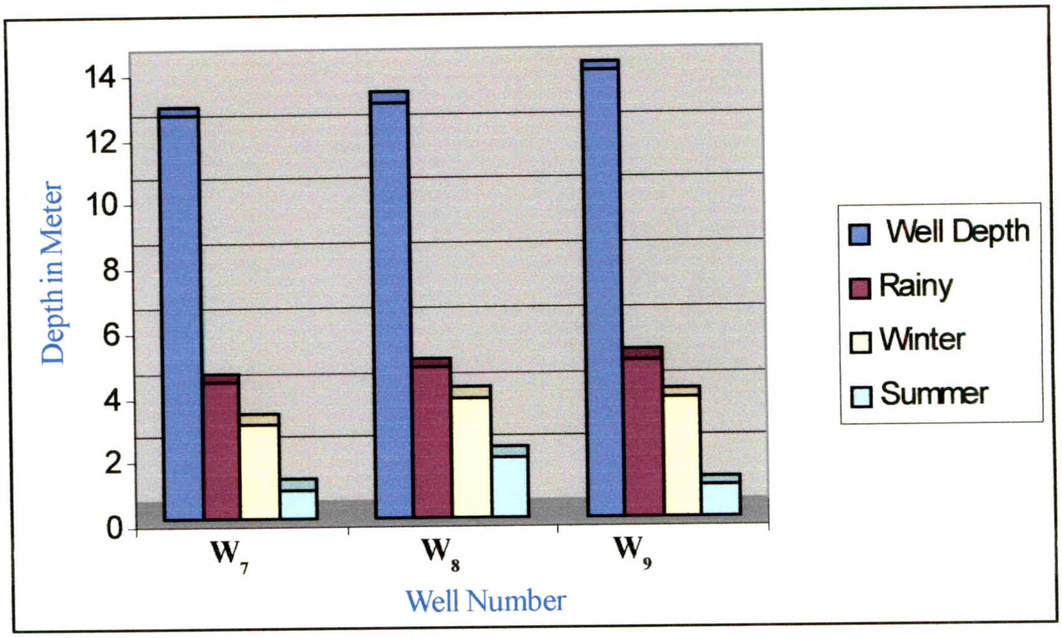
4.3.3 Effect of percolation tank:

The data on water level fluctuations in the wells on downstream side of percolation tank are presented in Table 4.13 and depicted in Fig.4.3.

Table 4.13 : Water level fluctuation in the wells on downstream side of percolation tank.

Sr. No.	Month	Water level depth in the wells (m)						Increase in water table (m) (2004-2005)		
		Pre development 2002-2003			Post development 2004-2005					
		W_7	W_8	W_9	W_7	W_8	W_9	W_7	W_8	W_9
1.	June	1.3	1.82	0.80	2.40	3.19	2.1	1.10	1.37	1.30
2.	July	2.33	2.90	2.60	4.27	4.80	3.68	1.94	1.90	1.08
3.	Aug.	4.21	4.02	4.56	5.89	6.79	6.5	1.68	2.77	1.94
4.	Sept.	5.40	6.75	6.52	9.42	9.92	9.60	4.02	3.17	3.08
5.	Oct.	4.92	5.09	5.89	9.09	9.69	9.50	4.17	4.60	3.61
6.	Nov.	4.30	4.78	5.39	8.89	9.12	8.80	4.59	4.34	3.41
7.	Dec.	3.13	3.92	3.96	7.71	7.26	7.39	4.58	3.34	3.43
8.	Jan.	2.66	3.29	3.19	5.93	5.68	6.29	3.27	2.39	3.10
9.	Feb.	1.82	3.00	2.25	4.69	4.63	5.07	2.87	1.63	2.82
10.	March	1.36	2.43	1.58	3.59	3.57	3.98	2.23	1.14	2.40
11.	April	0.62	1.92	0.86	2.61	3.01	2.60	1.99	1.09	1.74
12.	May	0.42	1.46	0.74	2.02	2.52	2.02	1.60	1.06	1.28

Pre Development



Post Development

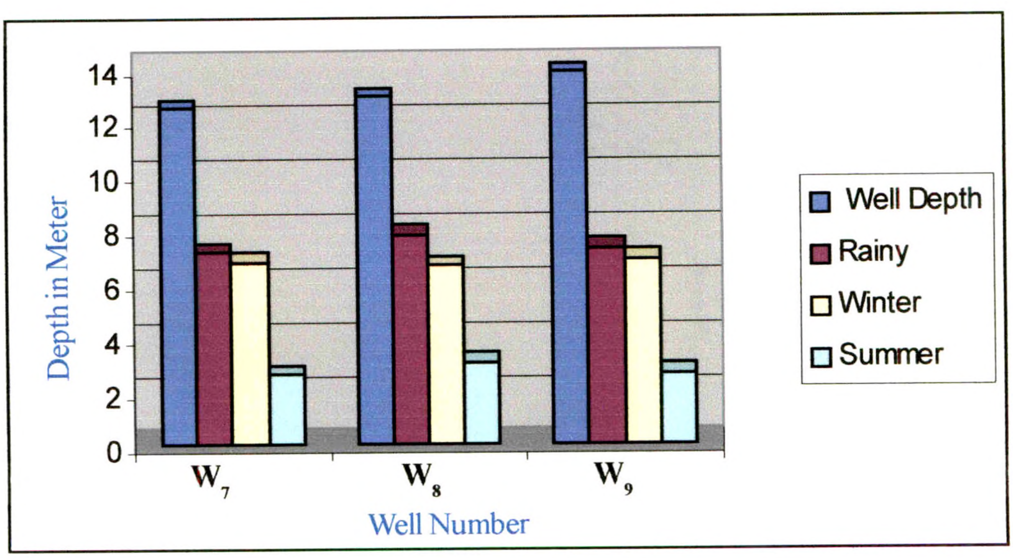


Fig. 4.3 : Seasonal average water level fluctuation in the wells downstream side of the percolation tank.

From the Table 4.13 and Fig 4.3, it reveals that in pre development of Darakwadi watershed in all the three wells W_7, W_8 and W_9, downstream side of the percolation tank, water level depth in the wells ranged between 0.42-5.40 m, 1.46-6.75 m and 0.74-6.52 m respectively from June to May.

In post development period (2004-2005), water level depth in all the three wells W_7, W_8 and W_9, downstream side of percolation tank ranged between 2.02-9.42 m, 2.52-9.92 m and 2.02-9.60 m respectively. Increase in water table in all the three wells W_7, W_8 and W_9, downstream side of percolation tank range between 1.10-4.59 m, 1.06-4.60 m and 1.08-3.61 m respectively, as compared to pre development water levels.

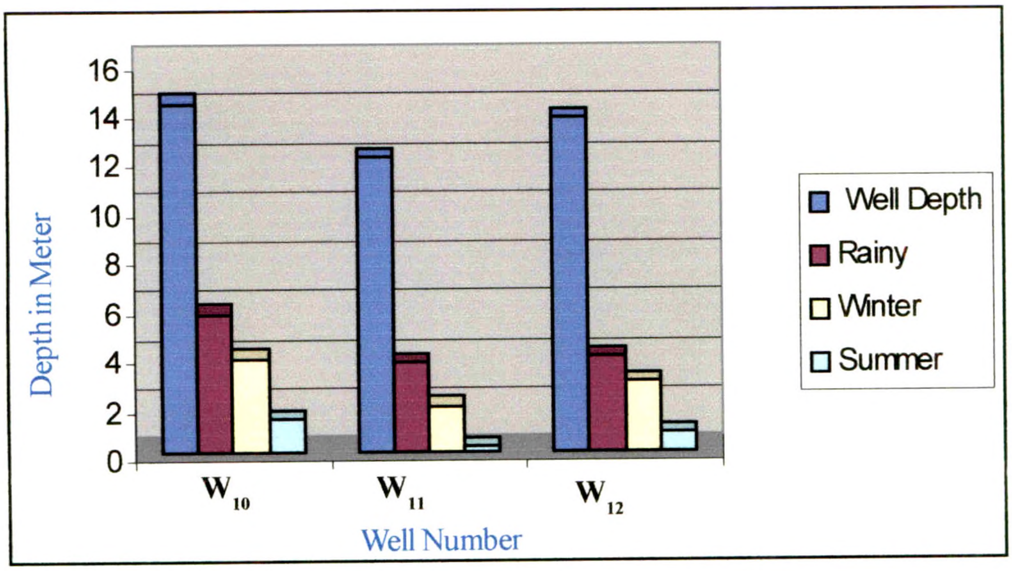
4.3.4 Effect of cement check dam:

The data on water level fluctuations in the wells on downstream side of cement check dam are presented in Table 4.14 and depicted in Fig.4.4.

Table 4.14 : Water level fluctuation in the wells on downstream side of cement check dam.

Sr. No.	Month	Water level depth in the wells (m)						Increase in water table (m) (2004-2005)		
		Pre development 2002-2003			Post development 2004-2005					
		W_{10}	W_{11}	W_{12}	W_{10}	W_{11}	W_{12}	W_{10}	W_{11}	W_{12}
1.	June	1.5	0.9	1.6	2.9	2.1	3.3	1.4	1.20	1.70
2.	July	3.7	1.80	2.5	5.15	3.23	4.4	1.45	1.43	1.90
3.	Aug.	5.4	3.9	3.34	7.00	5.9	5.6	1.6	2.00	2.26
4.	Sept.	7.1	4.8	5.3	9.10	7.8	9.1	2.0	3.00	3.80
5.	Oct.	6.71	4.2	4.5	8.70	7.5	8.5	1.99	3.30	4.00
6.	Nov.	5.39	3.5	3.8	7.36	6.39	7.75	1.97	2.89	3.95
7.	Dec.	4.61	2.12	3.33	6.49	4.66	6.12	1.88	2.54	2.79
8.	Jan.	3.08	1.3	2.59	4.9	3.16	4.45	1.82	1.86	1.86
9.	Feb.	2.36	0.8	1.79	4.4	3.10	3.70	2.04	2.30	1.91
10.	March	1.94	0.20	1.40	3.98	2.29	3.20	2.04	2.09	1.80
11.	April	1.3	0.0	0.30	3.6	1.90	2.62	2.30	1.90	2.32
12.	May	0.81	0.0	0.0	2.9	1.20	2.03	2.09	1.20	2.03

Pre Development



Post Development

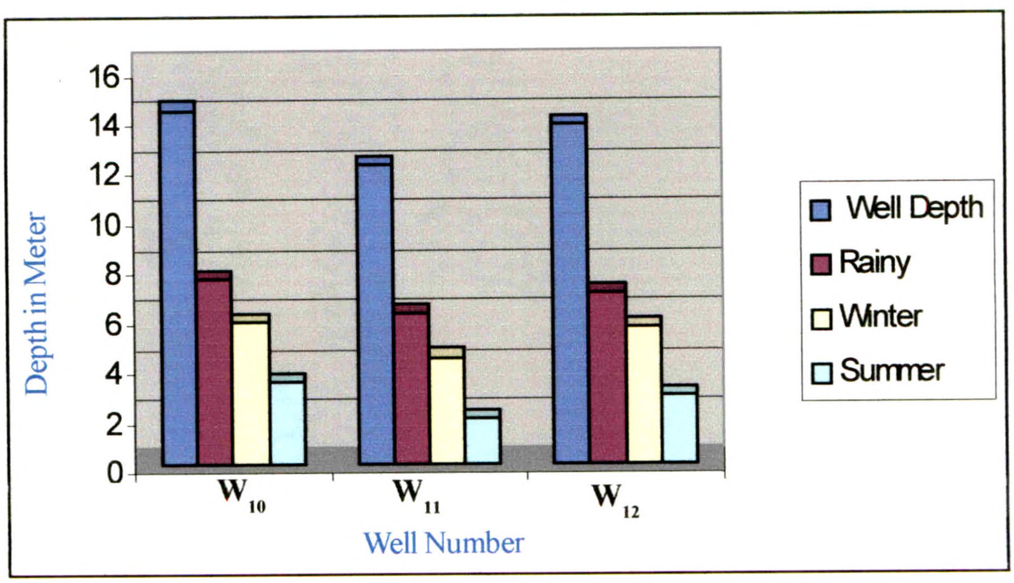


Fig. 4.4 : Seasonal average water level fluctuation in the wells downstream side of the cement check dam.

From the Table 4.14 and Fig 4.4, it reveals that in pre development in all the wells W_{10}, W_{11} and W_{12} downstream side of cement check dam, water level depth in all the wells W_{10},W_{11},W_{12} range between 0.81-7.1 m, 0.0-4.80 m and 0.0-5.30m respectively from June to May.

In post development in all the three wells W_{10}, W_{11} and W_{12} downstream side of the cement check dam, water level depth in the wells ranged between 2.9-9.10 m, 1.20-7.80 m and 2.03-9.1 m respectively from June to May.

Increase in the water table in all the three wells W_{10}, W_{11} and W_{12} ranged between 1.40-2.30 m, 1.20-3.30 m and 1.70-4.00 m respectively as compared to the pre development water levels.

4.4 Socio-economic impact of soil and water conservation structures:

Socio-economic study of Ben fisheries of soil and water conservation structures in the watershed was carried out to assess the impact of these structures on farming community with respect to small scale business, live stock, farm mechanization and land use and cropping pattern. The information related to above aspects was collected by conducting socio-economic survey. In this data is collected by conducting personal interview of the farmers. Information on socio economic status of Darakwadi watershed area during pre and post development stages of watershed development programme was collected. The collected information is tabulated for analysis.

4.4.1 Small scale business :

The data on small-scale business establishment in Darakwadi watershed in pre and post development are presented in Table 4.15.

Table 4.15: Effect of Darakwadi watershed development programme on small-scale business establishment.

Sr. No.	Name of the Business	Pre development (No./unit) 2002-03	Post development (No/unit) 2004-05
1.	Kirana shops	1	3
2.	Dairy	--	1
3.	Poultry	-	2
4.	Vermiculture	2	9
5.	Sericulture	2	5
6.	Three wheelers	--	2

Table 4.15 indicates the small scale business establishment in pre and post development of watershed.

In post development of watershed, Kirana shops increased from 1 to 3, vermiculture unit from 2 to 9 and sericulture unit from 2 to 5.

In addition to this one dairy and two poultry units have been developed. For goods transport two three wheelers have been purchased after the development of watershed. This is because of resource and capital increase due to watershed development.

4.4.2 Live stock population :

The data on live stock population in pre and post development of watershed are presented in Table 4.16.

Table 4.16: Live stock population in pre and post development of watershed.

Sr. No.	Particular	Pre development 2002-03	Post development 2004-05	Percent increase in livestock
.	Bullock	220	240	9.0
2.	Local cow bread	80	110	37.5
3.	Cross breed cows	8	39	387.0
4.	Buffalos	18	45	150.0
5.	Goats	115	80	--

From Table 4.16,it reveals that there is increase in live stock population with in the range of 9.0 to 387.0 % with respect to pre development live stock population. There is increase of 9.0 % in bullock population where as maximum increase of 387.0 % is in cross breed cow population. The tremendous increase in milch animal population is due to increase in fodder resources due to soil and water conservation activities.

4.4.3 Farm mechanization :

The data on farm mechanization in watershed are presented in Table 4.17.

Table 4.17: Farm mechanization in Darakwadi watershed

Sr. No.	Particular	Pre development 2002-03	Post development 2004-05
1.	Tractor	1	3
2.	Power tiller	--	1
3.	Tractor operated implement i.e. plough, cultivator etc.	2	11
4.	Electric motor pump	19	53
5.	Drip set	3	8
6.	Sprinkler set	3	7
7.	Spray pump	38	64
8.	Thresher	1	4

From the Table 4.17, it is seen that number of tractor increased from 1 to 3, power tiller from none to 1, tractor operated implement from 2 to 11, electric motor pumps from 19 to 53 in post development (2004-05).

Similarly drip sets and sprinkler sets increased from 3 to 8 and 3 to 7 respectively in post development.

Similarly insecticides and pesticides spray pumps and thresher increased from 38 to 64 and 1 to 4 respectively.

4.4.4 Land use pattern :

The data on land use pattern in Darakwadi watershed are presented in Table 4.18.

Table 4.18: Land use pattern in Darakwadi watershed.

Sr. No.	Land use	Pre development 2002-03		Post development	
		Area (ha)	Percent of total area	Area (ha)	Percent of total area
1.	Area under Cultivation	372.59	77.78	402.24	83.97
2.	Area under Pasture and Forest	38.18	7.97	45.28	9.46
3.	Area under Fallow land	68.23	14.25	--	--
4.	Area under constru-ction like ENB, CNB road, etc	--	--	31.48	6.57
		479	**100.00**	**479**	**100.00**

From the Table 4.18, it is seen that area under cultivation, area under pasture and forest is increased from 77.78 to 83.97, 7.97 to 9.46 percent respectively. Also it is seen that in post development, area under fallow land is brought under cultivation. Area under constructions like ENB, CCD, percolation tank etc is increased to 6.47 per cent in post development of watershed.

4.4.5 Cropping pattern :

The data on cropping pattern in Darakwadi watershed are presented in Table 4.19.

Table 4.19 : Cropping pattern in Darakwadi watershed.

Sr. No.	Crop	Pre development Area (ha)			Post development Area (ha)			Per cent increase or decrease in area		
		Kharif	Rabi	Summer	Kharif	Rabi	Summer	Kharif	Rabi	Summer
1.	Cereals	132.61	141.58	--	114.23	122.00	--	-13.86	-13.92	--
2.	Pulses	45.12	18.25	--	52.05	23.80	--	15.35	30.40	--
3.	Oil seeds	39.08	19.87	--	44.10	22.24	60.00	12.84	11.92	60.00
4.	Cotton	106.17	106.17	--	110.20	110.20	--	3.795	11.92	--
5.	Vegetables	28.38	36.29	20.36	35.28	42.00	48.00	24.31	15.73	135.75
6.	Fodder	11.20	15.24	28.72	18.38	25.00	70.00	64.10	64.04	143.73
7.	Mulberry	2.00	2.00	2.00	10.00	10.00	10.00	400	64.04	143.73
8.	Citrus	8.00	8.00	8.00	18.00	18.00	18.00	125	64.04	143.73
	Total	372.56	347.4	59.08	402.24	373.84	206.00	7.96	7.43	248.67
		372.59			402.24					

From the Table 4.19, it is seen that area under cereals in kharif and rabi season is found to be decreased from 132.61 to 114.23 ha and 141.58 to 122.00 ha respectively in post development. Area under pulses, oilseeds and vegetable in kharif and rabi season is found to be increased from 45.12 to 52.05 ha, 39.08 to 44.10 ha, 28.38 to 35.28 ha and 18.25 to 23.80 ha, 19.87 to 22.24 ha, 36.29 to 42.00 ha respectively in post development.

Area under cotton is found to be increased from 106.17 to 110.20 ha in post development. Area under fodder is found to be increased in kharif, rabi and summer from 11.20 to18.38 ha, 15.24 to 25.00 ha and 28.72 to 70.00 ha respectively in post development, this is because of increase in population of cows and buffalos.

Area under mulberry is increased from 2 to 10 ha in post development. Area under citrus is found to be increased from 8 to 18 ha in post development.

SUMMARY AND CONCLUSIONS

CHAPTER-V

SUMMARY AND CONCLUSIONS

The evaluation study of soil and water conservation structures in Darakwadi watershed was carried out during 2004-05. Darakwadi watershed is located in Aurangabad district of Maharashtra State. The project was implemented by DILASA, NGO, Aurangabad during the year 2002-03.

Soil and water conservation structure namely earthen gully plug, earthen nala bund, composite cement nala bund, cement check dam, percolation tank and continuous contour trenches were selected for their evaluation. Silt deposited at upstream side of structures was determined by measuring the depth of silt deposited and area of silt deposited. The designed dimensions of structures were compared with existing dimensions of structures. Twelve open wells from downstream side of structures were selected to study the effect of water harvesting structures on ground water recharge. Personal interview was conducted to study the impact of soil and water conservation structures on socio-economic aspects.

Based on the results of the study, following conclusions are drawn.

1) Silt deposition, average reduction in storage capacity and cross sectional area of earthen gully plugs, under study is found to be 32.76 tonnes, 3.55 % and 14.925 % respectively in post development.

2) Silt deposition, average reduction in storage capacity and cross sectional area of earthen nala bunds is found to be 1291.96 tonnes, 7.76% and 5.34% respectively. Average increase in water level in the wells downstream side of earthen nala bund is found to be 2.90 m in post development period.

3) Silt deposition and average reduction in storage capacity of permanent structures (composite cement nala bund, gabion cum wall and cement check dams) is found to be 1356.4 tonnes and 7.62 % respectively. Cross sectional area of permanent structures is found to be unchanged. Average increase in water level in the wells downstream side of composite cement nala bund and cement check dam-1 is found to be 2.77 m and 2.18 m respectively in post development period.

4) Silt deposition, average reduction in storage capacity and cross sectional area of percolation tank is found to be 1307.53 tonnes, 0.2% and 4.88% respectively. Average increase in water level in the wells downstream side of percolation tank is found to be 2.55 m in post development period.

5) Silt deposition and average reduction in cross sectional area in continuous contour trenches is found to be 619.87 tonnes and 41.85 % respectively in post development period.

6) Increase in area under cultivation and pasture and forest is found to be 6.19 % and 1.49 % respectively in post development period.

7) Increase in area under cultivation during Kharif, Rabi and summer season is found to be 7.96 %, 7.43 % and 248.67 % respectively during post development period.

LITERATURE CITED

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Anonymous, (1987). Agresco report C.R.S., P.K.V., Akola Research report of work done by the Vidarbha soil conservation and demonstration scheme.

Bainade, S.S. (1997). Ground water table fluctuation and yield of wells in watershed. Research report on farm watershed research under N.W.D.P.R.A., M.A.U., Parbhani 1996-97 pp. 15-20.

Bedgi, G.L., Sharma, J.S. and Kumar, V. (2001). Adoption of soil and water conservation technologies by the farmers of sardar sarovar project catchment in Gujarat State. Indian Journal of Soil. Cons. 29(1) : 65-68.

Bhardwaj, S.P. (1984). Bunding and strip cropping for erosion control in agriculture lands of Doon Valley. Indian J. of Soil conservation, 22(3) : 15-19.

Dhurva Narayana, V.V. (1987). Mechanical measures for soil and water conservation. Indian Journal of Soil conservation, 15(3): 1-7.

Dyani, B.L. (1991). Impact of watershed management technology on farm income. Indian Journal of Soil. Cons. 22(3) : 71-77.

Gavande, C. P., B. S. Gill and K. S. K. Rao (1974). An assessment of soil conservation programmes. Madhya Pradesh soil conservation Digest 2 (2) : 54-58.

Gaikwad, S.T. and Ramesh kumar, S.C. (1997). Impact of soil and water conservation programme on farming community. National conference on soil and water conservation for sustainable farming system, 39-40.

Gaur, and Lal, M. (2001). Ground water recharge estimates of a small watershed. Indian Journal of Soil conservation 29(2) : 126-132.

Goel, A.K.and Singh,H. B. (1996). Imact of soil conservation measures on ground water availability. 24(1):19-24.

Gore, K.P., M.S. Pendke, Gurunatharao V. and Dhur R.L. (1998). Artificial recharge through water harvesting structures. An assessment of Wagarwadi watershed. Artificial recharge in India at NGRI, Hyderabad.

Gore, K.P., Pendke, M.S. and Jallawar, D.N. (2000). Impact assessment of soil and water conservation structures in wagarwadi watershed Karnataka Journal of Agric. Sci. 13(3) : 676-681

Grewal, S. S., Singh, B. and Bhushan, B.(2002). Evaluation of erotion control structures in treated watershed by structural and functional efficiency criteria. Indian Journal of soil cons. 30(3):214-225.

Jallawar, D.N. (1993). Evaluation of cement nala plug. Unpublished M.Tech. thesis submitted to P.G. PKV, Akola.

Kale, S.R. (1990). Effect of soil conservation practices on soil erosion and runoff Indian Journal of Soil conservation, 15(2) : 72-76.

Kale, S.R., Salvi, V.G. and Varade, P.V. (1993). Runoff and soil loss as affected by different soil conservation measures under elusine caracana (Ragi) in lataritic soils, West konkan region (Maharashtra). India, Indian Journal of Soil conservation 21(2) : 11-15.

Kamannavar, H.K. Singh, A. and Shah, K.A. (1977). Evaluation of contour and peripheral bunds for their stability in Ravines. Soil conservation Digest 5(2) : 23-28.

Khillare, R.M. and Kulkarni, S.D. (1980). Effect of soil conservation practices on ground water in Agril. Watershed, Sasur. Proceeding of seminar on modern technique of rain water harvesting and artificial recharge. Indian Journal of soil conservation. 26 (4) : 135-140.

Koppad, A. G., Manjappa, K. and Chandrasekharaiah, A. M. (2001).Impact of different conservation measures on rehabilization of degraded lands and agricultural productivity. Indian Journal of soil cons. 29(2):148-151.

Kumar, M and Warsi, A.S. (1998). Role of soil and water conservation measures on crop yield and ground water recharge in a Yamuna Ravine watershed – A field experience Indian Journal of Soil conservation. 26 (3) : 264-268.

Lavarale, M.S. (2003). Evaluation of soil and water conservation structures in Kachighati watershed. Unpublished M.Tech. thesis submitted to MAU, Parbhani.

Malikarjunappa and Maurya, N.L. (1988). Effect of nala bunding on ground water recharge, Indian Journal of Soil and water conservation, 16(1) : pp. 41-45.

Nambiar, K.T. and Meena, K.C. (1992). Evaluation of contour bunds and cement plugs. Annual report on soil and water conservation, Central Research and Training Institute Dehradun, 148.

Narayan Pethkar, A.B., V.V.S. Gurunatha rao and K. Mallick (1993). Evaluation of regional transmissivity pattern in Adila basin, a nested squares finite difference model. Journal of Geological society of India, 41(1): 21-32.

Padmanabhan, M.V. and B. Hanumanthappa (1989). Monitoring and evaluation of soil and water conservation practices at chevella watershed. Annual report of central research institute for dry land agriculture, Hyderabad : 58-59.

Patil, P.P. and G.B. Bangal (1987). Effects of soil conservation practices on soil erosion and runoff. Indian Journal of Soil conservation 15(2) : 72-73.

Patil, R.G. (1990). A study of water table fluctuations based on observation wells. Thesis submitted to Division of Agric. Engg. New Delhi.

Patel, N. and Rajput, T.B.S. (2001). Participatory rural appraisal in watershed management. A case study. Indian Journal of Soil. Cons. 29(2) : 152-157.

Pawade, M.N. (1981). Optimum utilization of water resources in Agricultural watersheds unpublished Ph.D. thesis submitted to the faculty of Post Graduate Institute, Indian Agriculture Institute, New Delhi. 178-187.

Pendke, M.S. (1997). Stability and performance studies of soil and water conservation structures. Research report on farm watershed research under N.W.D.P.R.A. M.A.U.,Parbhani 1996-97.PP 21-30.

Rana, R.S. and Goyal, N.L. (1994). Rainfall runoff, soil as relationship for submountaining zone of Himachal Pradesh. Indian Journal of Soil conservation, 23(2) : 168-170.

Rana, R.S. (1998). Evaluation of engineering and vegetative measures for dully control in KANDI region of Himachal Pradesh Indian Journal of Soil conservation 26 (3) : 219-225.

Ramrao, M.S.V. and Gurmel Singh (1974). Soil conservation in India, I.C.A.R., New Delhi 312.

Ram Babu (1976). Economic evaluation of water storage structures. Indian Journal of Soil conservation 15(3) : 145-151.

Rathod, M.K. and Ingle, P.O. (2002). Impact of watershed development programmes on tribals of Melghat in Maharashtra. Indian Journal of soil. cons. 30(3) : 268-272.

Reddy and M.L. Khybri (1991). Estimation of ground water recharge in semi-arid watershed. Indian Journal of Dry land Agric. Res. And Dev. 6(1,2) : 37-45.

Satapathy K.K. (1997). Performance of water harvesting ponds in hills. Journal of Indian water resource society 13 (1,2) : 110-115.

Sharma, V.V.J. and Subbarao, C.C. (1973). Rainfall and ground water recharge in Chandrampalem basin, Indian. Proceedings International symposium on development of ground water resources, Madras (1).

Shende, P.P. (1992). Evaluation of soil and water conservation structure in selected watersheds of Akola District unpublished M.Tech. thesis submitted to PDKV, Akola.

Shinde, B.B. (1997). Socio-economic benchmark survey of Ghodgaon watershed. Research reports on farm watershed research under N.W.D.P.R.A., M.A.U., Parbhani 1996-97 pp. 7-20.

Singh A. (1984). Management of saline shallow water table through open well. Agric. Engg. ISAE, 21(4) : 71-78.

Singh, A. (1979). Selection of structure for soil and water conservation. Soil conservation Digest 2(2) : 42-48.

Singh, L., Shinde, B.P. and Rao, D.O. M. (2001). Social features of the villagers in Doon valley watershed project. Indian Journal of Soil cons. 29(2) : 169-172.

Suraj Bhan and Tripathi, R.V. (1988). Effect of nitrogen application and moisture conservation practices on soil moisture plant canopy. Splash erosion and yield of jowar. Indian Journal of Soil conservation, 21(3) : 31-38.

Taley and Kohale (1990). Water balance study in an agricultural watershed for evaluating in ground water potential during least rainfall year PKVA. Res. J. 14(2): 148-154.

APPENDICES

APPENDIX - I

Details of the selected wells under study.

Sr. No.	Location of well survey	Year of construction	Diameter	Depth of well below GLM.
W_1	92	1990	7.0	14.93
W_2	90	1989	6.8	12.80
W_3	93	1993	5.2	13.70
W_4	91	1992	6.9	13.50
W_5	90	1990	7.3	14.20
W_6	82	1985	6.2	13.60
W_7	79	1987	5.8	12.50
W_8	80	1986	6.6	12.90
W_9	87	1985	6.9	13.80
W_{10}	41	1989	7.0	14.30
W_{11}	39	1996	6.9	12.10
W_{12}	40	1997	6.8	13.70

APPENDIX-II

Seasonal average water level fluctuation of the wells downstream side of the earthen nala bund.

Well No.	Seasonal average water levels (m)						Increase in water table (m)
	Pre development			Post development			
	Rainy	Winter	Summer	Rainy	Winter	Summer	
W_1	5.41	3.21	1.34	8.91	7.45	3.23	3.20
W_2	4.20	3.15	0.82	7.00	6.23	2.66	2.57
W_3	4.28	3.93	1.82	8.17	7.18	3.52	2.94
						Average	2.90

Seasonal average water level fluctuation of the wells downstream side of the composite cement nala bund.

Well No.	Seasonal average water levels (m)						Increase in water table (m)
	Pre development			Post development			
	Rainy	Winter	Summer	Rainy	Winter	Summer	
W_4	4.55	4.13	0.99	7.18	6.84	2.88	2.39
W_5	5.27	4.21	1.43	8.64	7.62	3.07	2.80
W_6	4.51	4.11	1.28	8.61	7.38	3.32	3.13
						Average	2.77

Seasonal average water level fluctuation of the wells downstream side of the percolation tank.

Well No.	Seasonal average water levels (m)						Increase in water table (m)
	Pre development			Post development			
	Rainy	Winter	Summer	Rainy	Winter	Summer	
W_7	4.21	2.97	0.92	7.16	6.80	2.65	2.83
W_8	4.69	3.74	1.90	7.80	6.67	3.07	2.40
W_9	4.89	3.69	0.99	7.32	6.88	2.67	2.43
						Average	2.55

Seasonal average water level fluctuation of the wells downstream side of the cement check dam.

Well No.	Seasonal average water levels (m)						Increase in water table (m)
	Pre development			Post development			
	Rainy	Winter	Summer	Rainy	Winter	Summer	
W_{10}	5.72	3.86	1.38	7.48	5.78	3.34	1.88
W_{11}	3.67	1.93	0.27	6.10	4.32	1.87	2.14
W_{12}	3.91	2.87	0.82	6.90	5.50	2.78	2.52
						Average	2.18

APPENDIX-III