CONJUNCTIVE USE OF WATER RESOURCES IN DECCAN TRAP (INDIA)

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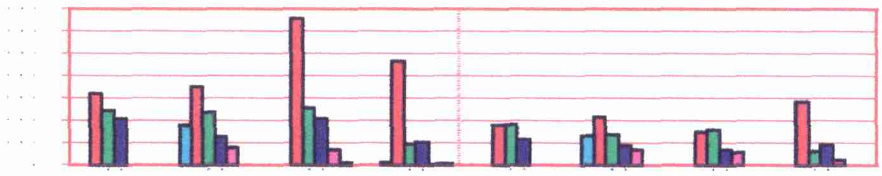

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CONJUNCTIVE USE OF WATER RESOURCES IN DECCAN TRAP (INDIA)

EXECUTIVE SUMMARY

BACKGROUND

The Deccan trap basalt covers an area of about 50000 sq kms in Central India and is spread over the states of Maharashtra, Madhya Pradesh, Gujarat and Karnataka. It encompasses different agroclimatic zones. Groundwater occurs in rocks in the secondary porosity namely in the weathered mantle. The Trap area has wide rainfall variations, ranging from severe floods in Western Maharashtra in the rainy season to frequent drought conditions in some districts from Central Maharashtra. A large area suffers due to deficiency of soil moisture and high potential evaporation rates. In many areas a large number of aquifers are inadequately saturated due to geomorphological characters and poor permeability of the strata. As a consequence, borewells and dugwells are of poor-yielding category. The rugged topography contributes to the large run-off from the streams. The result is inadequate water both for irrigation and drinking purposes. The conservation and utilisation of water resources are therefore crucial in meeting the irrigation and drinking water demands of the rural population.

It was against this background that a project was conceived for developing methodology for conjunctive use of surface water and ground water resources in the Deccan Trap.

THE PROJECT

The concept of undertaking a research study for development and use of water resources was perceived by BAIF during the implementation of rural development activities during 1989 - 1992.

BAIF Development Research Foundation, a non-government voluntary organisation, initiated it's Integrated Tribal Rehabilitation Programme six years ago in Akole Taluka of Ahmednagar District, which also incorporates an integrated watershed development project since 1993. The area is typical of the Western Ghats part of the Deccan Trap. BAIF identified a need for developing appropriate methodology to make maximum use of available water sources and to alleviate the scarcity problem to the extent possible. Accordingly, a project with the sponsorship of IDRC was launched in April 1992, to develop a systematic approach for optimum utilisation of surface as well as ground water resources.

The project has been undertaken jointly by BAIF Development Research Foundation, Pune, India, and the Department of Earth Sciences (formerly the Department of Geology), University of Windsor, Canada.

The project was initiated in three micro watersheds of three villages, viz. Manhere, Ambevangan and Titvi in Akole Taluka of Ahmednagar District, Maharashtra, India.

OBJECTIVES

To develop a methodology for the sustainable exploitation and utilisation of surface and groundwater resources through integration of geological, hydrogeological, and hydrological studies with the participation of the tribal and rural communities in the Deccan Trap area.

METHODOLOGY

The work was divided into three stages of Data Collection, Field and Laboratory Studies and Standardisation of Results. The data required to crystallise the project action was collected in the first year of project. Secondary data collection from available governmental records was supplemented by actual surveys in the area and covered demographic information, education levels, land holding pattern, livestock ownership, agricultural production and income assessment.

Remote Sensing technique was employed for obtaining reliable information on natural resources at different levels of detail in collaboration with Space Application Centre, Ahmedabad. This was supplemented with ground data collected during field studies and was used for geological, hydrogeological and hydrological studies planned under the Conjunctive Water Use Project.

During the second stage of the project, emphasis was given on Geological and Hydrological studies, with the help of direction interpreted from the secondary data and baseline data.

The study of geology included study of Soil Texture, Bed rock, Lineaments and Ground features having geological significance. Hydrological Studies were undertaken between November and December, 1993 and May 1995, by researchers from the University of Windsor and BAIF. Work was focused on determining water storage properties of the soils and the soil water availability in the study watersheds.

Subsequent data recording is continued by the BAIF team at the project site.

GEOLOGICAL FEATURES

The project area is in the middle of Thakurwadi formation of Kalsubai Sub-Group of Deccan basalt group. There are twenty well-defined members that can be grouped into lower, middle and upper divisions based on their physiographic and chemical signatures. The formation is characterised by a thick sequence of fine to coarse grained, aphyric to micro-phyric, amygdaloidal compound flows with picritic and related matic-phyric horizons at various stratigraphic levels. A giant plagioclase basalt (GPB) horizon forms the top of the Thakurwadi formation.

OUTCOME

Several tangible results have been observed. These include:

- Prevention of loss of top soil equivalent to a layer of 6-10 mm per year, as a result of conservation measures.
- 30% additional land has been brought under cultivation while 25% has yielded a second crop.
- Additional availability of 750 litres of drinking water per person during scarcity period.
- 20% households have acquired skills in water resource management.

IMPACT

As part of developing an approach to conjunctive water use in the Deccan Trap area, a wide range of measures has been identified, conceived and implemented on a pilot basis. The measures and techniques apply to both the surface and the subsurface circuits of water in the hydrologic cycle. These include use of indigenous knowledge, catchment treatment, artificial recharge, development of springs and wells, farm ponds, checkbunds, gabions and roof top water harvesting.

The overall impact of the field interventions is the increased water availability and increased awareness among the community in soil and water conservation techniques. Other benefits include an awareness about constructive use of scarce resources, local skills development, an awareness about conjunctive use of water and greater enthusiasm amongst the community. Furthermore, skills acquired by BAIF staff can and will be applied to other areas in India.

Significantly, new protocols have been developed and tested in the Deccan trap. Of these methodologies for recharging, conventional contour trenching and gully plugging are replicable in all situations. The protocols of gabion structure and ferrocement gabion can be used for soil and water conservation as a low cost technology in hilly areas. Roof top water harvesting systems are also very useful in areas of water scarcity.

RECOMMENDATIONS

Setting up of one meteorological station every 5km in the transition zone of the Deccan Trap to collect relevant data. Remote sensing interpretations should be made available to all agencies involved in the field.

Water storage tanks of ferrocement to be installed near the houses in areas with water scarcity, to filled up from nearby sources. Alternately rain water can be collected from the roofs of houses and filled in these tanks. This is a better alternative to community schemes of water supply. Instead of creating large water storage's, post monsoon flows should be arrested in nallas / gorges by a series of small checkdams. Gabion structure with ferrocement developed by BAIF is an effective low-cost alternative to conventional masonry or earthen checkdams.

Planning of watershed projects must involve local skills and knowledge. Community members must be trained well in advance in all activities identified under the project.

Replication studies should be undertaken in other areas of the country to implement methodologies developed in the present study and to develop suitable modifications as required. This will be useful for future watershed development programmes.

INFORMATION DISSEMINATION

Data generated during the experiment and results thereof have been shared with the project area to enable their implementation for improved agricultural practices. Successful findings have been compiled into booklets, manuals and handouts for widespread distribution to field and other personnel. Included are, a manual on Conjunctive Use of Water Resources in Deccan Trap Area, a booklet on Concept of Watershed, a Technical Awareness Brochure on Ferrocement Impervious Gabion and a booklet on Rooftop Water Harvesting.

Information gathered and results obtained have also been shared at various national level workshops and seminars.

END NOTE

BAIF and the University of Windsor wish to thank all those involved, directly and indirectly in making this project a success. Special thanks to IDRC, Canada, who made the study possible.

1: GENERAL INFORMATION

1.1 BACKGROUND

The Deccan trap basalt covers an area of about 50000 sq kms in Central India. It is spread over the states of Maharashtra, Madhya Pradesh, Gujarat and Karnataka (Refer map at **Annexure 1**). As it has a vast coverage lengthwise and widthwise, it encompasses different agroclimatic zones. These zones differ from each other in type of soil cover and its extent, total precipitation, percolation, evapo-transpiration and vegetation. Basaltic rocks are hard and compact and do not possess any primary granular porosity. However, secondary porosity is introduced in this rock formation due to weathering, jointing and fracturing. Groundwater occurs in these rocks in the secondary porosity namely in the weathered mantle. The joints and fissures in these rocks act as carriers of groundwater through their channels. The capacity of these rocks to hold and transmit water is limited and is largely controlled by the intensity of weathering and extent of joints and fractures available.

The Deccan Trap area has wide rainfall variations, ranging from severe floods in Western Maharashtra in the rainy season to frequent drought conditions in some districts from Central Maharashtra. A large area suffers due to deficiency of soil moisture and high potential evaporation rates. In many areas a large number of aquifers are inadequately saturated due to geomorphological characters and poor permeability of the strata. As a consequence, borewells and dugwells are of poor-yielding category.

The physiographic conditions in the Deccan Trap terrain are also very uneven with high gradients in some places. The rugged topography contributes to the large run-off from the streams. These conditions of rainfall uncertainties and land gradients lead to inadequate water both for irrigation and drinking purposes. The conservation and utilisation of water resources are therefore, crucial in meeting the irrigation and drinking water demands of the rural population. This assumes even greater significance during scarcity conditions.

It was against this background that a project was conceived for developing methodology for conjunctive use of surface water and ground water in the Deccan Trap.

1.2 INTRODUCTION

BAIF Development Research Foundation, a non-government voluntary organisation, has initiated its Integrated Tribal Rehabilitation Programme six years ago in Akole Taluka of Ahmednagar District. The programme includes horticulture, forestry, wasteland development and water resources development. An integrated watershed development project also has been in added since 1993.

The area is typical of the Western Ghats part of the Deccan Trap. It receives heavy rainfall during the monsoon and faces acute water scarcity in summer. BAIF identified a need for developing appropriate methodology to make maximum use of available water sources and to alleviate the scarcity problem to the maximum extent possible. Accordingly, a project with the sponsorship of IDRC was launched in April 1992, to develop a systematic approach for optimum utilisation of surface as well as ground water resources.

The project has been undertaken jointly by BAIF Development Research Foundation, Pune, India, and the Department of Earth Sciences (formerly the Department of Geology), University of Windsor, Canada.

1.2.1 PROJECT AREA

A LOCATION

The project was initiated in three micro watersheds of three villages, viz. Manhere, Ambevangan and Titvi in Akole Taluka of Ahmednagar District, Maharashtra, India. The project area is situated between longitudes 73°45' East and 73°55' East and latitudes 19°30' North and 19°40' North. The area lies in the Deccan Trap region and forms part of Western Ghats mountain range and is situated in the western part of Ahmednagar District bordering Nasik District. Nasik at 85 km is the nearest city from the project area. **Annexure 1.1** provides a map of the project area.

B TOPOGRAPHY AND DRAINAGE

The area is characterised by a rugged range of hills, forming the highest part of the Western Ghats. Kalsubai, the highest peak of the Western Ghats mountain range is only about 5 km away from the project area. The hills in the north of the project area near the villages of Manhere and Ambevangan are at an elevation of over 1000 meters above mean sea level. The general slope of the area is towards the south.

The system is part of the Godavari River drainage basin, with the Pravara river as the main drainage channel. The project area is well drained by numerous streams and their tributaries. which originate in the hills to the North, finally joining the Pravara to the South of the project area.

C RAINFALL AND CLIMATE

The project area lies in the tropical zone and receives all of its annual precipitation from the Southwest Monsoon. The rainy season normally starts in mid-June and ends by the beginning of October. July is the wettest month of the year, followed by August. There is a very high variation in the rainfall within the region, from about 2000 mm in the far west of the project area to 600 mm in the eastern part.

D GEOLOGY AND GROUND WATER

The area is covered by Deccan Trap basaltic rocks; amygdaloidal basalts form the bedrock. There is shallow soil cover overlying weathered and fractured rocks, resting on hard massive basalt. The basalts are nearly horizontal, separated by thin layers of ancient soil and volcanic ash (red bole). Numerous fractures, mainly trending NW - SE, exist in the area. **Annexure 1.2** gives geological location map of the area.

Groundwater occurs mainly in the superficial deposits, the weathered basalt and the fractured and jointed basalt. Principal water-bearing zones are shallow aquifers in the soil and weathered bedrock ranging from 3 to 5 m below the ground. **Annexure 3** gives well inventory of the area.

1.3 PROJECT OBJECTIVES

1.3.1 GENERAL OBJECTIVES

The overall objective of this collaborative project is to develop a methodology for the sustainable exploitation and utilisation of surface and groundwater resources through integration of geological, hydrogeological, and hydrological studies with the participation of the tribal and rural communities in the Deccan Trap area.

1.3.2 SPECIFIC OBJECTIVES

1. To collect essential baseline data.
2. To carry out geological, hydrological and hydrogeological studies of specific watershed areas with a view to locating and identifying the available resources.
3. To develop socially and economically acceptable methods for the exploitation and utilisation of available water resources.

1.4 SCOPE AND METHODOLOGY OF WORK

Secondary data of relevant parameters had been collected from all possible sources with a view to understand the area, the people and their priority needs. This was the first step before initiating actual experiments.

1.4.1 SCOPE

Three micro-watersheds were selected in three villages namely Manhere, Titvi and Ambevangan with an area of 300 ha., 81.79 ha. and 205 ha. respectively. These watersheds have been studied thoroughly for climate, topography and geohydrology. The major thrust was to study the relevance of all the factors with the development of the methodology for conjunctive use of water resources in the study area.

1.4.2 METHODOLOGY

The work was divided into three phases:

Phase I : Data Collection

- Collection of socio-economic baseline data.
- Establishment of meteorological stations and collection of meteorological data of nearby stations.
- Preparation of topographic and land capability maps
- Collection of remote sensing data
- Analysis of data.

Phase II : Field and Laboratory Studies

- Geological studies
- Study of bedrocks
- Study of lineaments
- Study of ground features having geological significance.
- Hydrological studies
- Application of relevant experimental measures.

Phase III : Result Standardisation

- Analysis and study of the data and experiments.
- Standardisation of designs of experimental measures.
- Study on utility of the ground features.
- Impact analysis.

2: DATA COLLECTION

Secondary data collection from available governmental records supplemented by actual surveys in the area was initiated in the first year of the project. Information available included climatic data from Meteorological Department, topographical maps from Surveyor General and soil survey maps and satellite imageries from Satellite Application Centre. Surveys were conducted for socio-economic factors, topography and preliminary information on geohydrology of the area. Details of data collected and analysed is given below.

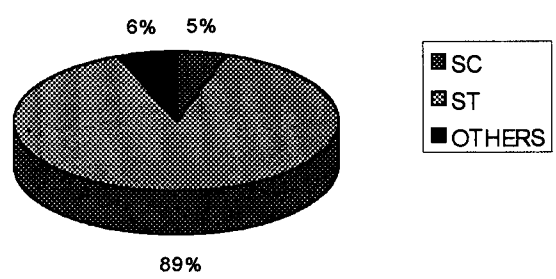
2.1 SOCIOECONOMIC BASELINE DATA

POPULATION DISTRIBUTION

The total population residing in the study area is 3239 (January 1993). Of these, 54.03% are males while 45.97 % are females.

The age distributions show that 15.07% belong to the under five age group, 23.56% belong to the five to fifteen age group while as many as 39.67% belong to the fifteen to forty age group. Since only 1.45% belong to the above sixty age group, it may be concluded that the population of this area is dominated by younger people.

FIG. 2.1: ETHNIC DISTRIBUTION

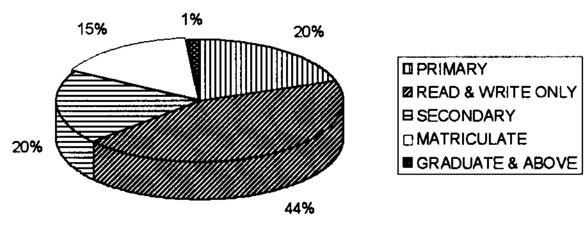


Of the total number of households in these villages, 89.34% are Scheduled Tribe households while 4.92% are Scheduled Caste households. These are the weakest sections of Indian society. Details of the demographic information are provided in **Figure 2.1**.

EDUCATIONAL LEVELS

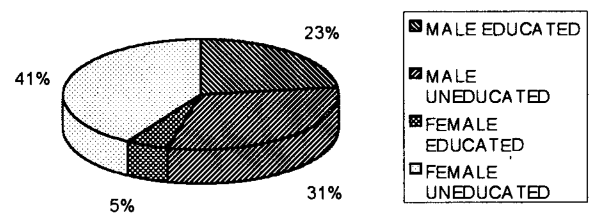
The literacy rate is 41.54% for males and much lower for females being only 11.62%. The overall literacy rate is 28.10%.

FIG. 2.2: EDUCATIONAL STATUS



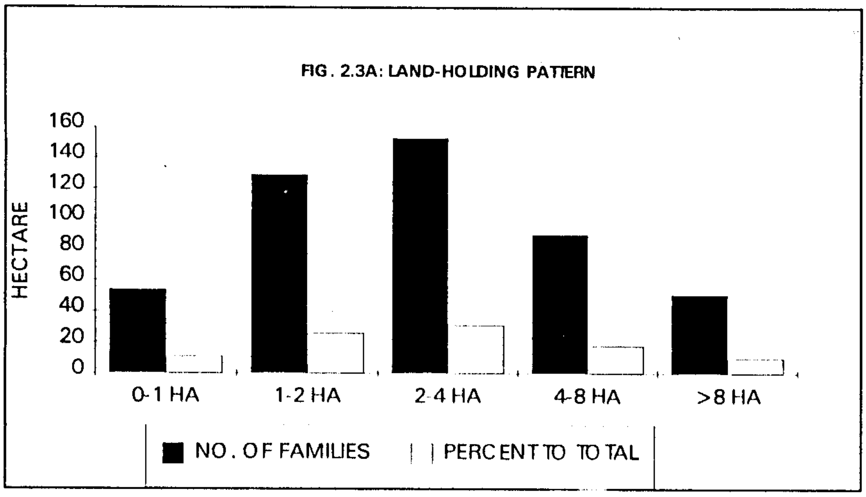
Of the literate males, 30.53% can only read and write 38.81% have studied upto the primary level and 15.33% upto the secondary level. As many as 13.84% are matriculates and 1.49% have studied upto the graduation level or above.

FIG. 2.2A: SEX-WISE EDUCATIONAL STATUS



In case of women literates, 31.79% can only read and write, while 58.38% have studied upto the primary level. No female has studied upto matriculate level and above.
The literacy rates are low in general, but extremely low for women. Details of the educational levels are provided in **Figure 2.2 & 2.2A.**

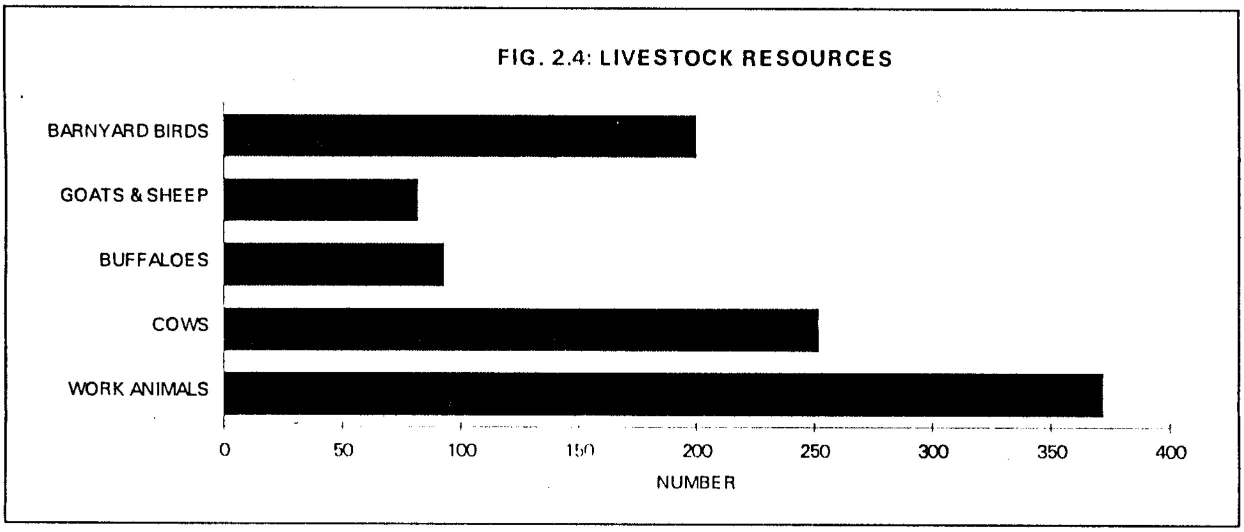
Of the 494 households covered in the area, only 3.44% are landless. The largest group holds between 2 to 4 hectares of land. Nearly 31% of the families fall in this category. 10.32% of the families held more than 8 hectares of land.



The average land held per household is 4.28 hectares. Details regarding the land-holding pattern are provided in **Figure 2.3 and 2.3A.**

LIVESTOCK OWNERSHIP

Animals owned by the inhabitants of this area include bullocks, cows, heifers; buffaloes (male and female), female goats, sheep, and hens. The average number of bullocks owned per household is 0.75. The average number of cows owned is 0.51. Very few sheep, male buffaloes and heifers are held by the residents of these villages. In general, the livestock resource is poor and is continuously decreasing. Details of livestock ownership are provided in **Figure 2.4.**



AGRICULTURE

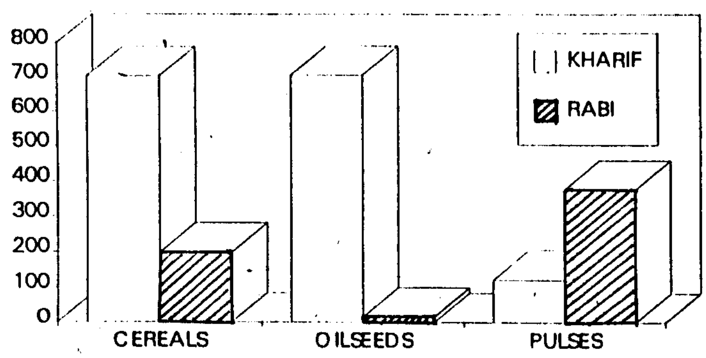
Both Kharif and Rabi farming are taken up by the farmers in this area with the Rabi crop directly related to the rainfall of the year and its distribution.

In the Kharif season, rice, ragi, 'varai', maize, groundnut, niger, sunflower, soyabean, horse gram, beans, black gram, pigeon-pea, cow-pea, gram, green gram, and local grass are cultivated.

In the rabi season, wheat, maize, pearl millet, rice, 'shalu', sorghum, 'aawali', groundnut, niger, sunflower, gram, horse gram, beans, lentil, black gram, cow-pea and pigeon-pea are cultivated.

The average production per hectare was 3899.17 kg for grass, 1196.05 kg for rice (Kharif), 1000 kg for maize (Kharif), 900 kg for green gram (Kharif) and 812.5 kg for cow-pea (Kharif). The average production per hectare was low for soyabean and sunflower being only 48.45kg and 61.22 kg respectively.

FIG. 2.5: AGRICULTURAL PRODUCTION



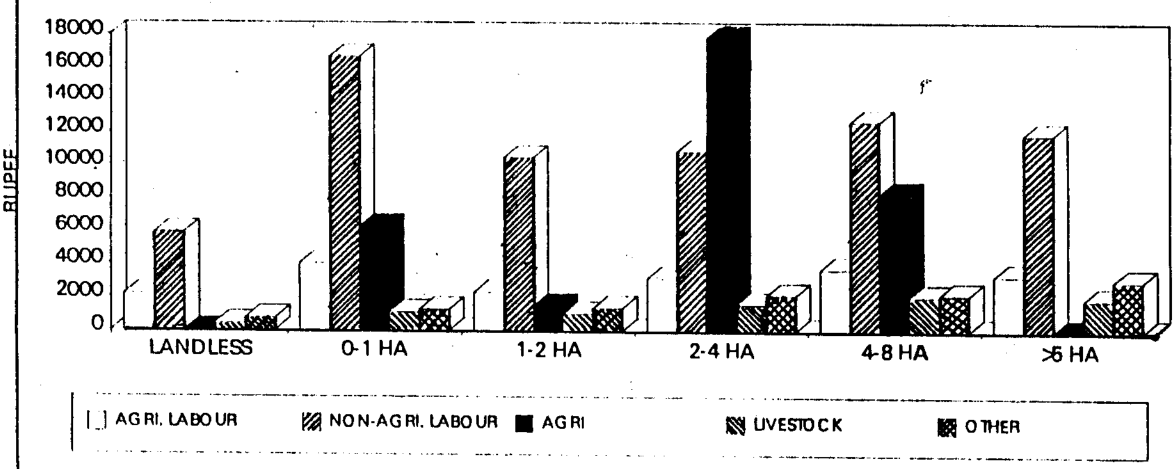
In the Rabi season, average production per hectare was 4000 kg for niger, 1466.67 kg for rice, 900 kg for green-gram and 726.30 kg for wheat. The average production was low for cow-pea, being only 150 kg per hectare.

The productivity per hectare is lower than the national average in case of all cereals and pulses and most oilseeds. Only in case of niger the production per hectare is on par with the national average.

In the Kharif season, the largest area is under rice, local grass, groundnut and ragi, while the smallest area cultivated in the Rabi season is under maize, pulses other than horse gram, pigeon-pea and soya-bean. In the Rabi season, wheat and gram are the main crops sown. Details regarding agricultural production are provided in **Figure 2.5.**

INCOME ASSESSMENT

FIG. 2.6: INCOME ASSESSMENT



The average household income for the project area for the year was extremely low, being only Rs.821.45. The various sources of income included agricultural labour, non agricultural labour, agriculture and livestock. The average annual income (Rs.2926.03) was the largest for the farmers owning more than 8 hectares of land. The annual household income was the lowest (Rs.465.77) amongst category of farmers owning between 2 to 4 hectares of land. Details regarding the various sources of income are provided in **Figure 2.6.**

2.2 METEOROLOGICAL DATA

The meteorological data of the study area is one of the most crucial inputs and was collected on following important climatic variables:

- Rainfall
- Temperature
- Humidity
- Wind
- Evaporation

There are four meteorological stations established by the Government of Maharashtra in the vicinity of the project area, located at village Waki, Randha, Bhandardara and Akole. Only the daily rainfall data is available at these stations.

METEOROLOGICAL STATIONS ESTABLISHED UNDER THE PROJECT

As the area is subject to very high climatic variations, it was necessary to establish meteorological stations in the watershed areas under study. Two meteorological stations have been established in two project villages viz. Manhere and Titvi. The details of equipment installed at the field stations are given in the following table.

TABLE 2.1 METEOROLOGICAL EQUIPMENT AT FIELD STATIONS

S. No.	Equipment	Description
1	Cup Counter Anemometer	Indicates the total run of wind past an observation point in Kms.
2	Rain gauge	Indicates rainfall.
3	Open Pan evaporimeter	Measures evaporation rate.
4	Minimum-Maximum Thermometer	Indicates daily maximum and minimum temperature
5	Wall thermometer	Indicates temperature
6	Stevenson's screen	Designed to shield all types of meteorological thermometers and hygrometers

2.3 TOPOGRAPHICAL AND GEOLOGICAL MAPPING

The toposheets of the area prepared by the Survey of India have been procured. But as these maps are at 1:50,000 scale with 20 m contour interval, they are useful only for general area planning. For detailed micro-level planning, topographical maps on smaller scale with 5 m contour interval are required. A detailed topographical survey has been carried out in the study area. The topographical maps at 1:4000 scale have been prepared with 5 m contour interval. The information on slope groups has been derived on the basis of the maps with Scale 1:50,000. A slope group map has been prepared with the help of GIS software, using three main slope groups as detailed below. An overlay of slope group map and contour map has been presented in **Annexure 5.** The details of areas under different slope groups is shown in **Table 2.2.**

TABLE 2.2 AREAS UNDER DIFFERENT SLOPE GROUPS.

Sr.No.	Slope Group (Ha.)	Area	% age To Total Area
1	0 to 10%	198.36	33.80
2	10 to 20	199.45	33.99
3	30 % And Above	188.98	32.21
Total		586.79	100.00

LAND CAPABILITY

The data about the Land Capability Classification of the watershed area has been procured from the Soil Survey Department of the Government of Maharashtra. The data is entered in a separate database and a Land Capability map has been drawn up using GIS software. The data has been analysed and the details are provided in **Table 2.3.**

TABLE 2.3 LAND CAPABILITY CLASSIFICATION

Sr.No.	Land Capability Class	% age To Total Area
1	I	-
2	II	32.36
3	III	5.11
4	IV	29.31
5	V	-
6	VI	26.02
7	VII	7.20
8	VIII	-
Total		100.00

As seen from the above table nearly 62% of the total watershed area falls under Land Capability Class IV and above. The main characteristics of areas under these classes are:

- Shallow soil depth
- Low permeability
- Steep slopes
- Low water holding capacity
- Heavy rate of erosion

The information on slope groups and land capability has a direct bearing on surface and ground water related aspects. This data had been useful for planning a detailed Geological and Geo-Hydrological study.

The existing geological maps prepared by the Geological Survey of India have been procured. The published geological data of the study area is being collected and compiled to have better understanding of the geology of the study area.

2.4 GEOHYDROLOGY OF AREA

Information about Dug wells, Borewells, Percolation tanks, Checkbunds in the three villages of Akole region has been collected. The details are as follows :

INVENTORY OF DUG WELLS

Information about existing dug wells in the project area has been collected through an intensive field survey. The information collected in the first year has been updated. See **Annexure 3.** Location map of wells is given in **Annexure 4.**

There are total 46 dug wells in the study watershed area. Most of the wells are shallow to medium depth wells. The average depth is 6.94 m, ranging from maximum 15.85 m to 2.43 m.

TABLE 2.4 DETAILS OF BOREWELLS IN AKOLE AREA

Village	Date	Dia in mm.	Depth in M	Casing M	Status Dry/P.Y.*/ Successful	No. of borewells / Successful borewells	Population 1981	Total Area in Hectares
Titvi	30.05.83	150	52.15	3.05	P.Y.	3/0	595	988
	02.05.83	150	73.65	6.10	Dry.			
	24.03.89	150	60.00	3.05	Dry			
Manhere	14.10.79	100	68.45	4.5	Dry	3/2	1106	768
	13.09.80	150	83.82	3.05	3375 LPH	(4/3)		
	08.09.90	150	60.00	-	597 LPH			
	22.10.91	150	61.00	3.05	P.Y.			
		(Hydrofractured)						
Ambevangan	11.10.79	100	60.96	3.05	P.Y.	5/3	568	693
	24.05.83	150	69.15	6.10	597 LPH			
	04.05.83	150	73.65	6.10	3380 LPH			
	12.05.84	150	76.00	3.05	Dry			
	07.03.90	150	61.00	3.05	597 LPH			

* P.Y. = Perennial Yield.

There is a very high variation of water levels in wells in different seasons. As most of the wells are located in the valley portion, the wells are full to their maximum capacity during monsoon. The water level drops in post-monsoon season and in summer most of the wells are dry.

BORE-WELLS

Data about borewells drilled by State Govt. in project villages is presented in **Table 2.4.** The details have been obtained from GSDA office at Ahmednagar.

As per GSDA records, there are in all 11 borewells in the three villages, of which only 4 borewells have encountered water. Their present condition is unclear as most of the handpumps installed are not in working condition.

2.5 REMOTE SENSING DATA

In the recent years Remote Sensing has emerged as a powerful technique for providing reliable information on natural resources at different levels of detail. BAIF Development Research Foundation, Pune and Space Application Centre, Ahmedabad have jointly taken up water resources development programme using satellite data for group of villages in Akole Taluka of Ahmednagar District.

The main objective of this collaborative effort had been to use remote sensing data to develop methodology for micro-level planning for sustainable development of natural resources in Akole tribal area.

The thematic maps on 1:25,000 scale have been prepared and integrated to suggest sites for water resources development and this information has been transferred on cadastral level maps (1:10,000) for three priority villages viz. Manhere, Ambewangan and Titvi selected for this study.

In addition to this, information was also obtained from the Maharashtra Remote Sensing Application Centre, Nagpur in the form of maps (1:50,000) for the Akole Taluka.

INFORMATION OBTAINED FROM SPACE APPLICATION CENTRE, AHMEDABAD

DATA USED

I. Satellite Imageries:

- IRS LISS II : 19th February 1990, 4th March 1989
- SPOT MLA : 7th November 1990, 9th May 1988
- SPOT PLA (B/W) : 12th November, 1988

II. Collateral data

Survey of India Toposheets (scale 1:50000) cadastral level village maps.

Steps involved while preparing maps:

1. Data procurement
2. Base map preparation
3. Preliminary interpretation of satellite Imagery
4. Field checks (Ground Truth)
5. Final interpretation
6. Final mapping

Survey of India (SOI) topographic maps on 1:50,000 scale and satellite data (IRS-1A LISS-II) FCC SPOT PLA black & white and SPOT MLA FCC, in the from of 9" transparency were procured.

Since information for the implementation programme is required at cadastral level (1:10,000), interpretation of satellite images at the largest scale possible, that is 1:25,000 has been considered optimum. A base map on 1:50,000 scale using SOI topographic map indicating longitude, latitude, major drainage network, roads, location of villages etc. was prepared. Diapositive (transparency) of this base map was made. Using a high magnification enlarger (HME), which enables magnification upto 45 times, diapositive of the base map of 1:50,000 scale was enlarged to 1:25,000 scale after which the base map was prepared.

The transparencies of satellite images were enlarged to 1:25,000 scale using the HME. Thematic information was transferred to the base map. On the basis of tone, texture, shape, size, pattern, association etc., various theme categories such as valley fills, linear features, various categories of wastelands and various forest densities were delineated. Interpreted overlays were superimposed over multidate images and additional information was also transferred on the overlays. Using this methodology, six base maps for Akole area were prepared. The list of maps is provided below. These base maps have been used for further studies taken up under the projects.

MAPS OBTAINED FROM SAC

A. Slope map (1:25000)

B. Hydrogeomorphological map (1:25000)

C. Forest density map (1:25000)

D. Sub watershed / Drainage map (1:25000)

E. Suggested sites for water resources development (1:25000)

F. Water resources and wasteland development sites for Manhere, Titvi and Ambewangan villages (1:25000)

CONTENTS OF BASE MAPS

A. Slope Derivation

The slope was derived from 20m contour interval. The data source for this purpose was 1:50,000 Survey of India topographical maps. The slope was derived on a grid (1cm x 1cm) basis. Each grid was 25 ha at 1:50,000 scale area. It was assumed that each grid would have a unique and representative slope value. Thus, two elevation points (maximum and minimum) were selected in each grid. It was assumed possible to derive the maximum possible slope in each grid and thereby to show the maximum possible limitation with respect to topography in the grid.

B. Hydrogeomorphology

The usefulness of satellite data is well established in mapping of fractured and weathered zones, which are usually the zones of localisation of groundwater in hard rocks and certain geomorphic features such as valley fills, alluvial pans etc. which often form good aquifers. Thus, remote sensing helps to narrow down the areas for the search of ground water for detailed ground-water recharge and rain water harvesting structures.

Using satellite images, hydrogeomorphological map of 1:25,000 scale depicting various hydrogeomorphologic units such as valley fills, lineaments and escarpments in the Deccan Plateau were prepared for Akole taluka, Ahmednagar district. It was found that typical aquifers having sufficient ground water are absent. The main solution to solve the water problem is to develop water resources by constructing rain water harvesting structures. Keeping this in view, a map showing suggested sites for water resource development was prepared.

C. Forest

The forest boundary was taken from the SOI topographical maps on 1:50,000 scale and was transferred to the base map. Density based classification was adopted to provide present condition of forest in mainly three categories; closed forest (>40% canopy cover), open forest (>10% to <40% canopy cover) and degraded forest (<10% canopy cover).

D. Sub-watershed boundary

Sub-watershed is a hydrological boundary suitable for any developmental action plan. Area under one sub-watershed is generally not influenced by the hydrological, soil and land parameters of the neighbouring watershed. Therefore, the development plan suggested for a watershed will be unique and independent of others. In the present study, upper and lower limits of the sub-watershed were assumed to be 2500ha and 1000ha respectively. For drawing the sub-watershed boundary, the drainage and elevation contour information were utilised from 1:50,000 SOI topomaps. In all, there are 14 sub-watersheds covering the area of Akole taluka. According to Watershed Atlas of India (AIS&LUS, 1990), the study area comes under Region 4, Basin E, Catchment 8, Sub- catchment and Watershed 8.

E. Sites for Water Resource Development

By integrating the available information, the sites for water resources development were suggested.

MAPS OBTAINED FROM MRSAC, NAGPUR

Maharashtra Remote Sensing Application Centre, Nagpur provided the following maps of Akole taluka (1:50,000 scale) so as to use this data for micro level planning.

A. Soil erosion status map

This map gives the information on physiographic units and slope, land use/land cover information, soils erosion extent (slight, moderate, severe, very severe)

Data used

1. IRS LISS II : 8th May 1989, 17th April 1989
2. AIS & LUS Organisation Report 508
3. Soil Survey Organisation (M.S.)
4. NBSS & LUP (waste land maps)
5. Forest maps

B. Hydrogeomorphological map

This gives information about Geomorphic unit; whether it is of fluvial origin (valley fills, ravines) or structural origin (highly / moderately/slightly dissected basaltic plateau, plateau top) e.g. dyke, lineament, fracture line valley, escarpment or butte. Also the map provides description of geomorphic unit and groundwater prospectus in the area.

Data used : IRS LISS II 28th December 1988

C. Surface water bodies / drainage & watershed

In this map, river basins, watersheds, subwatersheds microwatersheds and reservoirs are depicted.

Data used

1. Survey of India toposheet (1:50,000)

2. IRS LISS II: 23rd October 1988, 28th December 1988, April 1989

D. Land use / Land cover map

Classification of land use has been provided in this map, whether the land is agricultural land, forest land, or wasteland.

Data used:

1. IRS LISS II : 18th January 1989, 22nd October 1988, December 1988
   23rd October 1988

E. Transport Network and settlement location map

Information about roads, railways and settlements has been given.

DATA USED

1. SOI maps
2. Road map prepared by P.W.D. Ahmednagar

F. Slope map

Slope category of 0-1%, 1-3%, 3-5%, 5- 10%, 10-15%, 15-35% and more than 35% has been shown in the map.

Data used :

SOI toposheet :1,50,000)

USE OF REMOTE SENSING DATA

Remote sensing was supplemented with ground data collected during field studies. This data had been used for Geological, hydrogeological and hydrological studies planned under the Conjunctive Water Use Project.

3 FIELD AND LABORATORY STUDIES

During the second phase of the project, emphasis has been given on Geological and Hydrological studies, with the help of direction interpreted from the secondary data and baseline data.

3.1 GEOLOGICAL STUDIES

The study of geology included study of three major factors :

a. Soil Texture

b. Bed rock

c. Lineaments

d. Ground features having geological significance.

3.1.1 SOIL TEXTURE

The soil classification available with the GOI records show that the soils are sandy loams and silty loams. BAIF had tested ten samples collected in 1994 from the adjacent valley in Ambevangan village on the east side. Nine of these were silt loams while one was a sandy loam. To establish that silt loams are the dominant variety in the conjuctive study areas, twelve soil samples were analysed at the University of Windsor in June 1995. These were collected from various locations and depths in an attempt recognise any systematic differences that may exist in soil textures within the study areas. Nine of the samples were from nalla paddy fields and three from hillside terraces. **Annexure 15** shows the sample locations. **Annexure 12** provides details on precise location and classification. The samples were analysed using hydrometer method outlined by Sheldrick and Wang (1993). The coarse fractions were determined by wet sieving the samples through a #200 sieve (75μ) and oven drying the retained material.

3.1.2 STUDY OF BED ROCK

The rock samples collected from the project area were examined at UW (see photograph on previous page). A preliminary geological map, based on the work of Beane et al. (1986), Deshmukh and Sehgal (1988), and Khadri et al (1988), was overlain on the topographic survey sheet as a basis for further refinement in the fall of 1994, field season. The preliminary map is included in **Annexure 6**. It indicates that the samples of basalt collected from blast holes and hand-dug wells in and around the areas of detailed study are referable to the Thakurvadi Formation of the Kalsubai Subgroup, recognised across a wide area of the Deccan Trap region. During 1993-94, geochemical analysis of the basalt samples was carried out to facilitate correlation within the Thakurvadi Formation across the areas of detailed study. It became clear that an understanding of alteration processes, which have affected the lava pile must precede any attempt at geochemical correlation. Accordingly, the following paragraph on metasomatism and weathering modifications of basalts geo-chemistry have been prepared by S. Agarwal, an M.Sc. candidate at UW, working under the guidance of T.E. Smith. The corresponding diagrams are included in **Annexure 7.**

Beswick and Soucie (1978) devised a method that involves plotting the data in terms of oxide molecular proportion ratios in the form of log X/Z vs. log Y/Z, where X,Y, Z are the oxide molecular proportions of volcanic rock samples (e.g. SiO2, A1203 etc.) to identify the nature of chemical alteration during weathering and metasomatism. Such diagrams provide a unique solution for possible changes in X,Y and Z components, for a given suite of chemically altered samples. On a log X/Z vs. log Y/Z plot, 'X' metasomatism will displace an original composition parallel to the log X/Z axis, 'Y' metasomatism will displace it parallel to log Y/Z axis while 'Z' metasomatism will displace an original composition along a line with a constant slope. Generally speaking the greater the amount of X,Y,Z gained or lost, the greater will be the extent of displacement of a secondary composition from a primary one.

The suggestions of these authors were applied to the samples from project area that are all relatively fresh basalts with SiO2 content ranging from 48-50%. Their chemical composition is plotted on the Figures as provided in **Annexure** 7. On each plot the various suites fall along a single well defined trend, which extends from the area occupied from the basalts away from the origin into the rhyolitic field closest to the origin. A few samples (TCSM1-1, WAI-1, UP1-1, TPZ1-1) on **Figs. 7.1 to 7.3.** plot away from this well defined trend.

In **Figs. 7.1 to 7.5** which largely remains in the liquid phase during the early and middle stages of fractionation, is used as the denominator in the LMPR plots. The least fractionated parental liquids have the highest ratios and hence plot furthest from the origin on these diagrams. With progressive fractionation K2O increases in the liquid which results in progressive decrease in the rations, so that successive residual liquids plot closer to the origin.

For example, in **Figs. 7.1 to 7.3.** increases in the liquid phase resulting in decrease in ratios of log A1203/K2O,FM/K2O, and SiO2/K2O on the X axis. This shows that 'X' metasomatism has displaced primary composition parallel to log X/Z axis. On the other hand, K2O fractionation also decreases log CaO/K2O and log SiO2/K2O ratios along the 'Y' axis due to 'Y' metasomatism, that has displaced primary composition parallel to log Y/Z axis. Hence he rock samples plot toward the rhyolitic end. However, such liquids may also show progressive increase in SiO2 and CaO contents, but as observed on the plots, their CaO/K2O and SiO2/K2O ratios decreases. This is due to more rapid increase in K2O content in the liquid as compared to CaO and SiO2. Therefore the resultant vector direction of X and Y metasomatism is represented by the movement of samples towards the rhyolitic field. i.e. closer to the origin along a line of constant slope. This is due to 'Z' metasomatism or potash metasomatism.

In **Figs. 7.1 to 7.3** the samples TCSM I-1, WAI-I UPI-I show deviation from the linear trend. This suggests that a sudden decrease in CaO content or CaO mobility has dropped them down the linear trend. In **Figs. 7.5 to 7.7** where Na2O was taken as the ratio oxide, similar but less defined trends were obtained. This suggests that Na2O metasomatism is not as pronounced as that far K2O.

DECCAN TRAP ZEOLITES

The following information deal with zeolites found as vesicle infillings in the Deccan basalts, they were written by M. Macdonald, B.Sc. Candidate at UW, working under the supervision of W.H. Blackburn. The zeolites from the Deccan Trap Plateau in the Akole Taluka tribal area are products of post-volcanic hydrothermal solutions in dominantly theolitic basaltic volcanic rocks and these basalts have been microscopically examined and found to contain natrolite, stilbite, harmotome, scolecite, wairakite and heulandite. The natrolite and the stilbite are the most abundant zeolite species and the other species occur in minor amounts. Natrolite occurs as minute cavity lining crystals, as fibrous, radiating needles and also as anhedral to euhedral prismatic crystals. In the majority of samples, there appears to be a relationship between the presence of natrolite and the occurrence of green celadonite.

Stilbite is commonly found as sheaflike or radiating bundles of crystals which gives a subspherical shape and well formed platy crystal often shows cruciform penetration twinning and wavy extinction. Granular stilbite crystals have also been observed. In a large proportion of the stilbite samples, there is often an abundant amount of contaminating brownish clay minerals which may partially on completely hide the mineral's optical properties. Zonation of zeolites, as seen in hand samples, is the result of either an increase in grain size of the natrolite or stilbite crystals away from the cavity wall or of natrolite rimming stilbite crystals. Other zeolite minerals include acicular, radiating scolecite crystals, thin strands of harmotome enclosed in stilbite, and tabular heulandite crystals. Rhombs of calcite occur with an isotropic, rhombic, calcic-rich variety of analcime known as wairakite in a late-stage high temperature hydrothermal event.

It is suggested that further methods such as X Ray Diffraction and a scanning electron microscope be used to confirm the identification of these zeolites. It is known that the optical properties of zeolites of a species may vary significantly depending on the degree of hydration and that the optical properties among different species overlap. The zeolites during the making of the thin section may have undergone changes in temperature and moisture and this would have affected optical properties. Due to the limited number of zeolites identified, a relationship between the mineralogy and its form of occurrence (i.e. pipe-like bodies) does not seem evident.

3.1.3 STUDY OF LINEAMENTS

The usefulness of satellite data in mapping of fractured and weathered zones in hard rock areas is well established. During preliminary discussions with the University of Windsor team the idea of using such data for the project area was first raised. The satellite data provided by the Space Application Centre of the Department of Space, Government of India, has been used to identify the major lineaments in the project area.

A preliminary analysis of the lineaments identified using the remote sensing data has been done.The details of the analysis are provided in **Table 3.1**. A map showing the lineaments in the study area is enclosed as **Annexure 8**.

TABLE 3.1 ANALYSIS OF THE LINEAMENTS

Lineament Identification No.	Description
M-1	Not apparent in the field. Thick soil cover. May be representing a weak, fracture zone. Direction : NW-SE.
M-2	Marked E-W, on a fairly large plateau which supports a lot of vegetation. The lineament could actually represent a line of ridge and trees running in the east west directions. There is no direct evidence of either a fracture or a dyke.
M-3 M-4	These represent the crest of a ridge running N-S. The crest supports some vegetation. No evidence of major regional fracture or joint patterns.
M-5	No direct evidence of fracture or jointing in the rock. A part of it coincides with the NW-SE regional trend.
M-6	No surface expression due to the thickness of soil cover.
A-7	Not apparent in the fields to the north of the road leading to Ambevangan. However, the fracture system or fracture zone is very clear to the S-SE of Wadi and south of the causeway on the road to Ambevangan. At this location, the fracture zone is evident in the stream beds in the form of fractures trending N-NW - S-SE. The springs and seeps are aligned along this trend. The southern most portion of the lineament has not been marked on the lineament map but can be traced further downstream.
T-8	Titvi watershed - No evidence of a fracture or dyke. The lineament is practically parallel to the main drainage direction. The lineament seems to represent portions (in the higher reaches) of stream segments.

The best possible methods for augmenting the water resources using the information on lineaments were finalised and possible options were experimented.

3.1.4 STUDY OF GROUND FEATURES

During their various field visits, BAIF staff with the help of the local tribals, have identified various ground features which may be of significance from the point of influencing ground water movement and its utilisation. Some of these ground features have significance from the geological point of view. All these features are being studied to understand their potential for water resources development. A map indicating locations of these ground features is provided in **Annexure 9**. The initial observations are given in **Table 3.2.**

TABLE 3.2 GROUND FEATURES

Identification No.	Description
M - I	This is a fracture running NW-SE. The fracture zone shows large apertures and is evident in one of the seepages / springs which are tapped south of Manhere village.
A - II	A major fracture zone again trending NW-SE and cutting across the stream beds, is apparent. There are two master joints which trend NNW-SSE. A noteworthy feature of this fracture is the evidence of a spring aligned along it. Similarly the water table is shallow in wells along this fracture zone.
D - III	A very clear expression of the major fractures from within a fracture zone. The trend of the fracture zone is from NNW-SSE to NW-SE. For some distance, drainage is controlled by the fracture and the groundwater movement appears to be along this fracture zone in a south easterly direction with emergence as discharge into the stream through a large cavity in vesicular basalt (Spring development site of BAIF.)
P - IV	Pimparkane (NE of Pimparkane) Igneous intrusion aligned along major fracture running WNW-EES. Location of spring developed by BAIF along this lineament.
P - V	One major fracture running NW-SE with the width of the fracture being 8 to 12 inches. Can be traced in the stream bed. The fracture appears to traverse several small basaltic flow units.

GEOELECTRICAL SURVEY

Geoelectrical surveys have been carried out at the location of the lineaments and ground features to confirm their existence and to check their potential for water resource development. The surveys carried out at two such locations are described below.

RESISTIVITY SURVEY AT COMMUNITY WELL - MANHERE

This is a large diameter well by the side of Manhere - Ambevangan road close to a nalla crossing. This well has a stone masonry lining. However, it goes dry in the summer. Three vertical electrical soundings were conducted on 18.5.96 in the vicinity of this well, to ascertain presence of aquifer in the area and extension of observed fracture in the well.

The well exhibits the lithostratigraphic as shown in **Annexure 10.** All measurements were taken at the top of parapet wall standing 1.22 m above ground level.

Springs in the well are located in hard jointed basalt at a depth of about 9.75 m (32 ft) from the top. Some seepage was also observed along fracture zone trending along N40^{0}W - S40^{0}E which is reported to be 0.6m thick. Springs were mainly seen on NW side of the well. Although the spring seepages carry meagre amount of water, it appears that majority of villagers draw water from the same well.

VERTICAL ELECTRICAL SOUNDINGS

VES I (18.5.1996) was conducted aligned with existing fracture zone along N40^{0}W - S40^{0}E. AB/2, the depth of probe was 100 m BGL.

The resistivity curve obtained (**Plate 1, Annexure 10**) is of H type and indicates low resistivity zone at depth of 10m which almost coincides with the aquifer zone seen in the well formed by hand jointed basalt. However, deeper layers do not show any sign of low resistance, indicating absence of any deeper aquifer zone.

Thus, it can be inferred that deepening of well or taking in well bore will not be able to increase the yield of the well; however horizontal bores along the joints in N20^0 E and N40^{0}E directions would widen the channels and may result in better yield. Any surface recharge pond which may be planned should be located on the fracture alignments. (N40^{0}W).

VES II was conducted parallel to VES I, but not in alignments with the fracture zone observed in the well. This curve is of A type **(Plate 2, Annexure 10)** and does not show the presence of any low resistivity zone. AB/2, the depth of probe was 40 m BGL. This indicates that the aquifer zone at 10m depth selectively extends along fracture and is not really extensive.

VES III was conducted perpendicular to the directions of VES I and VES II to ascertain presence of any deeper aquifer, but even this resistivity curve is of H type **(Plate 3, Annexure 10)** and does not indicate presence of deeper aquifer. AB/2, the depth of probe was 100 m BGL.

RESISTIVITY SURVEY AT WELL ON MANHERE RIDGE:

This vertical electrical sounding (VES IV) was conducted on 18.5.96 across the slope and along the contour near well site located about 1 km NW of Manhere village on the western flank of a local ridge trending N-S and with a small plateau top at an elevation between 880 to 900 mts above MSL. The dug well is located about 60 mts. above the main nalla of Manhere and 30 mts. below the plateau top.

The source of water in this well is mainly seepage through joints in dyke. The dyke is 15 cm in thickness and trends along N40^{0}W - S40^{0}E.

The VES curve obtained is a four layer curve of KH - Type **(Plate 4, Annexure 10)** and it shows the third layer of low resistance, which probably matches with the downward extension of dyke as this VES was conducted exactly across the trend of the dyke. From the matching curve technique the thickness of this zone with dyke appears to be about 45 m. Thus, the low resistance may be due to contribution of jointed dyke and not due to presence of any deeper extensive aquifer zone.

No profiling could be carried out in this region due to steep ground slope and hence extension of dyke along the slope in the direction of Nalla could not be traced.

It appears that grouting of the dyke in downstream direction after deepening of the well may increase its yield. The deepening will expose larger inflow dyke-face from upslope direction and grouting on downslope side will prevent outflow from well in the down slope direction.

3.2 HYDROLOGICAL STUDIES

The work on hydrological studies was undertaken between November and December, 1993 and May 1995, by D.W. Steele in consultation with M.G. Sklash and F. Simpson. Work was focused on determining water storage properties of the soils and the soil water availability in the study watersheds. In all, 17 permeameter tests were conducted at various depths, 19 soil samples were collected, three monitoring wells were placed in areas of saturated soil and one tensiometer cluster (containing four tensiometers) was installed. Additionally, 23 water samples and 27 measurements of electrical conductivity were taken at wells and surface waters from both study areas. Subsequent data recording is continued by the BAIF team at the project site.

3.2.1 PERMEABILITY TESTS

Field-saturated hydraulic conductivities (K_{fs}) of the study area field soils were estimated using the constant-head well method outlined by Reynolds and Elrick (1986, 1987) and Elrick and Reynolds (1992). The measurements were made using a field permeameter constructed by technical support staff at the University of Windsor. The UW permeameter was designed to be used in an auger hole with a minimum diameter of 6.0 cm and a maximum depth of 5 m. The measurements performed during this field work session were completed in 9.0 cm diameter auger holes of various depths. K_{fs} calculations were based on $\alpha = 4$ and C value associated with Guelph loam.

STUDIES IN THE TITVI AREA

Permeameter tests were conducted in three separate fields. **Annexure 11** provides details on permeameter tests. A 1x1x1 m soil pit was excavated in the first test field (Titvi-1) from which 10 soil core samples were collected. Three additional soil samples were taken from the auger holes in the third field (Titvi-3) and were examined. **Annexure 12** provides the soil moisture, porosity and bulk density for all soil samples collected. Eleven water samples (30 ml) were collected and 13 measurements of electrical conductivity were taken. The details are provided in **Annexure 13**. Instantaneous rivulet discharge (2.25 L/s) was estimated on Dec. 8/93 approximately 100 m down-valley from the last paddy field in the study area. No monitoring wells or tensiometers were installed in the area.

STUDIES IN THE MANHERE/AMBEVANGAN AREA

Permeameter tests were conducted in four separate fields (**Annexure 11**). Six soil samples were collected from auger holes in the four fields. Ten water samples (30 ml) were collected and 14 measurements of electrical conductivity were taken (**Annexure 13**). Instantaneous rivulet discharge (7.99 L/s) was estimated on Dec.11/93 in the paddy field directly above the Kelly spring in Ambevangan. Three groundwater monitoring wells (Amb wl, Amb w2 & Man w1) were installed as deep as possible in pockets of saturated soil.

Several more sites were identified for well installation. A tensiometer cluster was installed in a representative paddy field (third above the Kelly spring) in the eastern nalla in Ambevangan. There are four tensiometers in the cluster at depths of 60, 90, 120 and 150 cm. Protective barriers have been arranged for the tensiometers and monitoring well sites. The tensiometer readings and readings of the water levels in the monitoring wells are being recorded regularly.

Three fields of Ambevangan had pockets of saturated soil and monitoring wells were installed in two of these fields. A monitoring well was installed in a saturated area of the nalla immediately west of the Manhere community well (at the road). Several more fields of Manhere appeared to be saturated but have not yet been investigated. It is planned to map the areas with saturated soil during the wet and dry seasons. These areas are worth detailed study because they may represent : (i) successful dugwell sites or (ii) if a well already exists, an opportunity to increase water availability by delaying / minimising subsurface losses with a subsurface barrier. Hanson and Nilsson (1986) state that simple water table monitoring can help identify the natural flow pattern which is necessary for site assessment.

In a few locations, rivulet waters were observed emerging from the bottom of paddy field bunds. At two such sites, test holes were augured in the paddy fields immediately above the emergence points but weathered rock terminated auguring before detection of the water table. This suggests that the weathered basalt has the capability of storing and releasing significant amounts of water. No measurements of the effective porosity or specific yield of the weathered materials in the study area were attempted but others (e.g. Deolankar 1980; Chandrashekhar et.al. 1976) have reported specific yields of weathered deccan basalts in the range of 2-7%. An approach for determining the transmissivity of this material would be to perform pump tests (e.g. Barker and Herbert 1989) with the existing dug wells that partially or wholly penetrate the weathered basalt. The hydraulic conductivity of the weathered basalts remains unknown because of the difficulty with hand auguring into the material. Deolankar and Kulkarni (1985) investigated the Deccan basalts of Maharashtra using pump tests from dugwells and reported permeabilities of 2 to 5 m/day for weathered amygdaloidal basalts and 0.1 to 1 m/day for jointed basalts. Limaye and Limaye (1985) state that the Deccan Traps have permeability which is related to the presence of vesicular flows, permeable flow junctions, intertrappean beds, red boles, etc., and the permeability of the near surface (< 100 m) basalts ranges between 1.2×10^{-8} m/s and 5.8×10^{-7} m/s (.001 to .05 m/day).

The majority of the hand-dug wells and blast holes in the study area penetrate the weathered basalts, but it seems that only a few produce water during the late summer months. It may be possible to increase the yields from some of these dug wells by the conversion to collector wells. Ball and Herbert (1992) converted 32 dug wells in Sri Lanka and found that the yields doubled on average.

The electrical conductivity of the tested waters (**Annexure 13**) reveal that there is little variation in the electrical conductance of bored well, dugwell and surface waters of the study areas. All samples fall into the range of 170-315 μS/cm and are in agreement with the values reported in association with the reconnaissance survey of May, 1992. No anomalies were observed.

3.2.2 SURFACE INFILTRATION RATE ESTIMATES

Estimates of surface infiltration rates complement the field permeameter data, which yield estimates of the average (vertical and horizontal) saturated hydraulic conductivities within the matrix. The surface tests are required to provide information on how fast one can expect ponded water to penetrate the various surfaces common in the study areas. **Annexure 14** gives details about the surface infiltration tests. **Annexure 15** shows the locations of the surface infiltration tests. Five locations were tested for infiltration capacities. Two were soil surfaces (one hillside and one paddy), two were at the weathered rock (murum) surface and the remaining site was carved into weathered basalt. All sides of the test holes were lined with plastic to minimize lateral water loss except the hole excavated into the weathered basalt. This would not completely prevent lateral movement of water so the resulting infiltration rates should be considered as maximum values. Water was added to each test hole before measurements began in order to saturate the matrix. The quantity of water added varied from about 1 L to 20 L. At the Man-chan-m site, observation holes were created at 20 cm and 60 cm below the test hole. Our infiltration tests indicated that the rates of movement though the unsaturated weathered rock were not uniform. The first water at the 20 cm level appeared four hours (1.4 x 10^{-5} m/s) after initial water addition, but was not evident at the deeper hole until approximately the 42 hour mark (4.0 x 10^{-6} m/s).

This weathered basalt variability was supported by another test nearby where infiltrating water travelled a distance of 90 cm in approximately six hours (4.2 x 10^{-5} m/s). Owing to the swelling properties of the soils and the fine material in the joints of the weathered rock and /or less permeable horizons at depth, the infiltration rates decreased with time.

3.2.3 RADON TESTS: APRIL/MAY 1995

Bedrock geology is the main control on radon distribution. Background radon levels in a basalt terrain are relatively low because basic igneous rocks are characteristically low in uranium content. It follows that basaltic-type rock aquifers are also low in radon. Michel (1990) reports radon levels in the range of 260 to 550 pCi/L for these aquifers in comparison to granitic-type rock aquifers which usually have radon levels greater than 8000 pCi/L. Additionally, soil gas radon levels vary from day to day and season to season because of environmental factors such as soil moisture, precipitation, barometric pressure, soil temperature, air temperature and wind (Asher-Bolinder et al., 1991).

Radon moves through permeable pathways and can often be detected hundreds of meters from the uranium source. Some ground water prospecting methodologies use radon as a natural tracer in areas with suspected fracture porosity.

It was feasible that some of the water sources available during the pre-monsoon season were supplied water by a deep-seated fracture or seepage and an anomously high radon concentration in soil gas above the site may confirm the existence of ground water with origins other than the basalt bedrock. Radon soil gas measurements were taken in the study area at locations where both suspected lineaments and possibly related water supplies existed. Sample transects were placed across suspected lineaments in order to check for unusual radon levels over the lineaments that might indicate deep groundwater sources associated with the structures. Four sites were monitored for radon soil gas concentrations. **Annexure 17** provides details about the sites and **Annexure 18** shows the locations. The soil gas levels were measured with a portable Rn200 Radon Detector equipped with a 150 V2 scintillation cell provided by Instruscience Ltd. The cell sensitivity was 0.5 CPM/pCi/L. An active sampling method was employed as a hand vacuum pump continuously drew soil gas through the cell for a seven-minute count period. One meter lengths of steel pipe with slotted bottoms and sealed tops were used to obtain soil gas samples from 75 cm below soil surface. The steel pipes were installed in hand augured holes.

3.2.4 METEOROLOGICAL DATA

Rainfall data of the stations surrounding the areas, available with meteorological department have been compiled to know the trend and to compare with the data of the stations established in the project area.

Time series of Annual Rainfall

The fragmentary project's records of annual rainfall in and near Akole Taluka from 1840 to the present day in general support the concept of a causative connection between drought and the climatic disturbance known as "El Nino".

El Nino - Southern Oscillation (ENSO) events are large-scale ocean-atmospheric interactions. The tendency for atmospheric surface pressure to be relatively low in the central and south Pacific, when it is relatively high across Australia, SE Asia and the India Ocean, and vice versa, is termed the Southern Oscillation. The low-pressure condition in the Pacific is accompanied by warming of surface waters in the central and eastern equatorial Pacific and is termed as El Nino. So-called "anti-ENSO" events involve cooling of surface waters in the eastern Pacific. ENSO events occur every two to ten years.

Climatic anomalies, associated with ENSO and anti-ENSO events, are termed teleconnections. ENSO events are associated with reduced rainfall in many parts of the eastern hemisphere. Weak monsoon rainfall in El Nino years frequently gave rise to drought conditions in India in the past two centuries. In general, this view is supported by the time series of annual rainfall from Akole Taluka.

In the past, an important clue about imminent ENSO conditions has been the development of a high-pressure system east of Tahiti, giving rise to strong southeastern trade winds and warming conditions in the western Pacific. However, this sequence of events is far from invariable and much research remains to be done on reliable forecasting mechanisms. Possibly an additional factor is subsea volcanism in the southwestern Pacific. **(Annexure 2)**

Selected References:

Philander, S.G., 1990. El Nino, La Nino and the Southern Oscillation. New York, Academic Press Inc., 293 pp.

Whetton, P., and Rutherford, I., 1994. Historical ENSO teleconnections in the eastern hemisphere. Climatic Change, v.28, pp 221-253.

The rainfall data collected from the two raingauge stations established in the project villages viz. Titvi and Manhere shows a considerable variation in the rainfall on a day-by-day basis at both locations, even during the wettest month. The details are provided in **Annexure 16.1 & 16.2 & 16.3**.

The annual rainfall data from the nearest existing rainfall stations has been collected and presented in tabulated form to compare with the rainfall of Manhere. Large variation is observed within these short distances. See **Table 3.3**.

TABLE 3.3 VARIATION OF RAINFALL

Station	Location from Manhere		Annual Rainfall in mm			
	Distance (km)	Direction	1992	1993	1994	1995
Bhandardara	5.00	S-W		2875	4214	1635.5
Manhere	0.00	-	1548.75	1985.81	2809	1447.73
Titvi	3.75	E	956.1	1294.11	874.3	927.5
Randha	3.25	S-SE		1500	2004	1127.75
Akole	23.00	S-SE			432	350.59

3.2.5 STAGE MEASUREMENTS (RUNOFF ANALYSIS)

The percentage of rainfall that leaves the study area watersheds as surface runoff is presumed to be very high owing to factors such as extreme precipitation intensities, shallow soils and high drainage densities and relief. Runoff/rainfall ratios for the study areas would be very useful as monitoring and assessment tools. For example, long-term examination of the ratios can help with assessing the effectiveness of catchment treatments. BAIF has commenced work on obtaining these ratios.

BAIF has installed a stage monitoring device, equipped with a data logger in a sub-basin of Manhere for the 1994 monsoon season. A check dam with a rectangular spillway was constructed at this site. The check dam is located at $19^0 35.42$N 73^0 47.00' E in the main nalla of Manhere.

The drainage area based upon the topographic divide was determined to be approximately 1.02 km2. BAIF's stage measurements at the check dam were converted into discharge estimates using the discharge formula for sharp-crested weirs found in Gregory and Walling (1973). The formula for a rectangular weir is as follows :

$$Q = 1.86\ BH^{1.5}$$

Where Q = Discharge in m3/s

H = Head of water in m

B = Width of weir crest in m.

The discharge data for a period of July 26th, 1994 to Sept. 4th, 1994 revealed that approximately 1.248 x 10^6 m3 water left the sub-basin over the spillway of the check dam. Based upon the catchment area of 1.02 km2, the above volume was converted to a water depth of 1.22 m. Unfortunately a runoff/rainfall ratio could not be calculated for the sub-basin. An equipment problem at the Manhere weather station resulted in a failure to obtain rainfall data for the entire period. There are no rainfall data available for the period of July 31st to Aug. 6th. The measured rainfall was 0.82 m. Obviously, even with heavy rains during the seven days of missing data, water outputs from the sub-basin appeared to be greater than or at least equal to precipitation inputs. Analysis for a shorter period of Aug. 7th to Sept. 4th yielded a runoff/rainfall ratio of 1.59. The limited data reveal the problems of examining only a small portion of the rainy season.

Surface outflow from the sub-basin appeared to be equal to or greater than inputs because of the lag time between water falling on the upper reaches of the drainage area and flowing over the check dam. The runoff / rainfall ratios need to be determined for the entire flow period and for drainage areas of different sizes.

One more masonry weir has been constructed at the outlet of Titvi micro-watershed to measure the stages for discharge calculations. Length of the structure is 11.0 m, height above GL is 1.25 m, d/s slope 0.5:1 and upstream vertical.

3.2.6 USE OF GEOGRAPHIC INFORMATION SYSTEM (GIS)

The planning for conjunctive use of water resources had been greatly facilitated by use of Geographical Information Systems. These enable overlaying of diverse spatial data and its referencing with tabular data. BAIF has made use of its in-house facility to develop application systems for comprehensive land and water use planning. This system have been an important output of the project and will be useful for conjunctive water use planning at various locations. The BIRC computer section is mapping and analysing the data for the entire study watershed covering the villages Manhere, Ambevangan and Titvi. Specific outputs of the GIS package are enclosed in this report in the form of maps.

The lineaments map was plotted on the cadastral map in the scale of 1:10,000. This map was prepared using remote sensing data. This map is further being updated by adding information on ground features. All the springs in the above mentioned villages have been mapped with the help of a global positioning system (GPS) which was brought to the project area by the UW team. All these data sets are being analysed and the outputs in the required format are given to the project team for future studies.

3.3 EXPERIMENTAL MEASURES FOR SOIL & WATER CONSERVATION

As part of developing an approach to conjunctive water use in the Deccan Trap area, a wide range of measures have been identified / conceived and implemented on a pilot basis. The measures and techniques apply to both the surface and the subsurface circuits of water in the hydrologic cycle. Details regarding the measures taken up for pilot introduction are given below.

3.3.1 USE OF INDIGENOUS KNOWLEDGE

As tribal people are in the area for generations together they have a storehouse of indepth knowledge about the area. This reservoir of indigenous knowledge has been used effectively; mainly for identifying spring sites and locating specific ground features. As most of these involve very small water flows they are almost impossible to locate by any grosser techniques which may be appropriate for scanning on larger scale. IK alongwith scientific techniques thus becomes a necessary combination for water use planning and action at the micro level. More details regarding Indigenous knowhow is in Chapter 6.

3.3.2 CATCHMENT TREATMENT

Various soil and water conservation measures like gully plugging, rill plugging, contour trenching, plantation of fruit and forestry trees, vegetative barriers using agave and vetiver grass have been taken up in the study watershed areas. It is expected that all these soil and water conservation measures will contribute to ground water recharge.

3.3.3 ARTIFICIAL RECHARGE

a Infiltration pits

In the Manhere valley 18 infiltration pits were dug in two paddy fields. The length and breadth of the pits was 1.5 m x 1.5 m. These pits were dug up to the bed rock and the depth varied from 2.0 m to 2.5 m. These pits were then filled with graded boulders. This was done to increase the infiltration of water into the subsurface zone. The influence of these pits on the recharge is being monitored.

b Infiltration trenches

From the saturated field permeability tests in the paddy fields of the project area, it is observed that the top soil layer of the fields is almost impervious. But the weathered basalts below the top soil (50 cm to 150 cm depth) are permeable. A spring (keli) near roadside in Ambevangan valley is developed and is a heavily used source of drinking water and was hence taken as a focus. Assuming the weathered basalt in the paddy field as a source aquifer of the spring, a continuous infiltration trench (filled with boulders and gravel) was dug at a distance of about 50 m on the upslope side of the spring. The length of trench was extended throughout the length of the field.

More trenches have been constructed in Manhere and Titvi area in 1996 to increase the water yields of the existing drinking water sources.

3.2.4 DEVELOPMENT OF SPRINGS AND WELLS

a. Springs

The spring sites were identified with the help of the local people. These springs are then deepened and cleaned for increased inflow and storage of water. One spring in the project area (kelicha bandh) has been developed by providing a pipe at the point of emergence and collecting water in a tank of 5000 litres capacity. Taps are provided to this tank which are used by the people to draw the drinking water. One more spring has been also developed in Ambevangan area for the same purpose.

b. Wells

The existing drinking water sources were deepened by blasting into the rocks. An old well, which was a main source of drinking water for Titvi village was defunct during the past 3 to 4 years, due to the deposition of silt into the well and falling of the steining into it. The silt has been taken out and steining also repaired. One more well at Ambevangan having similar situation has been also developed.

3.2.5 FARM PONDS

a. Small ponds with lining

Small farm ponds (size 3 x 1.5 x 1.5 meters) were dug on the hill slopes for storage of water for providing protective irrigation to the fruit plants. A plastic lining was used to prevent seepages.

b. Larger ponds

Farm ponds of sizes ranging from 10m x10m x1.5m to 20m x20m x2m have been constructed. These ponds are located on the hill slopes on the upslope side of the agriculture fields and the existing water sources / springs. The purpose is to increase the moisture levels of the fields and increase the water yields of existing sources. The total number of ponds in the study area is 19.

3.2.6 CHECKBUNDS

Three types of low cost checkbunds were constructed in the project area.

a. Checkbunds using sand bags

These are prepared using gunny bags filled with sand / silt and placing them across the nalla. About 14 such checkbunds were constructed under the project support. The stored water had been used for protective irrigation to the second crops.

b. Dry boulder checkbunds

These are prepared using loose boulders available in the nalla and arranging them systematically across the nalla to form a stone wall.

c. Gabion checkbunds

Traditional dry stone bunds can't withstand high velocity runoffs in places where streams have steep slopes. In such cases, gabions have been constructed. These are of two types for different situations:

i Gabions without impervious barrier

These have been constructed in the upper and middle reaches of the watershed and consist of dry boulder bund enclosed in GI wire chain link. A total of 25 structures have been constructed under the project.

ii Gabions with impervious barriers

As above but with an impervious barrier of earth / ferrocement which begins from the hard foundation strata and goes to the top of the structure. Two such structures have been constructed, one with earthen barrier and the other with ferrocement barrier.

The detailed models are provided in Chapter 5 under section 4 & 5.

3.2.7 MASONRY CHECKDAMS

Checkdam 1

A checkbund for harvesting runoff water has been constructed in village Manhere in May 1993. The site is in the middle reaches of the Manhere valley and was selected taking into account the topographic conditions, the catchment area, storage capacity and the preference of the local people. The checkbund has been constructed in a 'V' shape valley having exposed hard rock on both banks of the nalla. A foundation trench was dug across the nalla up to the bed rock. The maximum depth of the trench in the centre is 3 meters.

Considering the steep slopes on the banks, boreholes of 25 mm dia and 75 cm deep were drilled. Steel bars of 20 mm dia. were fixed in the boreholes in such a way that about 1 metre length was above the strata for keying the structure. Uncoursed rubble masonry in cement mortar (1:4) was constructed as an overflow section.

Checkdam 2

One more checkdam on the upstream side of the above checkdam has been constructed in March - April 1995. It is about 50 m upstream and is about 5.0 m higher than the earlier checkdam field level. This checkdam has been constructed on the exposed rock to use the natural head to operate micro irrigation systems in the fields on downstream side.

Checkdam 3

This is near the outlet of the Titvi micro-watershed, located in a deep valley. It has been constructed to store water for use by the villagers for drinking and for protective irrigation purposes.

3.2.8 ROOF TOP WATER HARVESTING

Water harvesting from the roofs of the houses has been introduced in the project area.

For storing this water, a storage tank made of ferrocement of 2500 litre capacity is prepared. The water is collected from the roofs by providing and fixing troughs made of galvanised sheets. A team of local youths is now trained to carry out the entire work of making ferrocement tanks and providing troughs. In three villages, the total number of systems installed is 26. The details are given in Chapter 5 under section 3.

3.2.9 WATER SOURCE THROUGH FRACTURE AT AMBEVANGAN

A permanent masonry checkdam was constructed in Ambevangan valley. During the excavation for the foundation of this checkdam, a fracture was observed. At this fracture site, excavation down to 3.5 m below the bed was carried out to get a firm base for the foundation

TABLE 3.3 SALIENT FEATURES OF CHECKDAMS

Description	Village		
	Manhere	Manhere	Titvi
Type of Structure	Masonry checkdam	Masonry checkdam	Masonry checkdam
Catchment area (ha) :			
.. Under cultivation	11.35	11.35	2333
.. Under pasture	6.11	6.11	2267
.. Under forest			341
Total area in hectare	17 46	17.46	4941
Highest Reduced Level (m)	1060	1065	1121
Lowest Reduced Level (m)	835	839	800
Elevation difference (m)	225	221	326
Total length of checkdam (m)	17.295	12.0	23.5
Overflow length (m)	12.95	10.0	21.5
Top width (m)	1.2	1.2	2.0
Height above GL (m)	2.0	2.5	3.5
Upstream slope	Vertical	Vertical	Vertical
Downstream slope			
.. Below GL	0.8H:1V	0.6H:1V	0.6H:1V
.. Above GL	0.6H:1V	0.6H:1V	0.6H:1V
Maximum foundation depth (m)	3.0	0.3	0.5
Downstream apron.			
.. Length (m)	2.5	Exposed hard rock	Exposed hard rock
.. Thickness (m)	0.5		
Free board (m)	1.0	--	--
Storage capacity (ha.m.)	0.2	0.2	0.81

but without success. Hence a masonry casing-cum-observation well was constructed from the top of the head-wall extension of checkdam down to 3.5 m depth. Surprisingly, when there was not a single drop of water in this part of the area at the end of the summer, the yield of water from this fracture was about 400-500 litres per day.

3.2.10 ARTIFICIAL AQUICLUDE

An experiment has been conducted in creating an artificial aquiclude. The purpose of the experiment is to arrest the flow of subsurface water by installation of an impermeable barrier (aquitard) in the subsurface strata. During the monsoon there is lot of surface water and subsurface flows. In the post monsoon period, although the surface run-off stops immediately after monsoon, the subsurface flow continues for some time. The idea is to arrest this flow and store the water below the ground. This stored water can then be tapped and made available to the local population mainly for drinking purposes during the water scarcity period.

The experiment was conducted in a small valley in Manhere village. The experimental site which was originally a small rivulet had been converted into small paddy fields by silt entrapment method. As this was done a long time ago (about 10-15 years), a thick soil layer (about 2 to 2.5 m) has been formed in the lower valley portion. In this narrow valley, below the soil layer is a thin layer of weathered basalt, below which lies compact basalt as the bed rock.

The experiment consisted of putting an impermeable barrier in the subsurface strata down to the bed rock. The experiment was initiated during the first year of the project.

During the first year i.e. in May 1992, a bamboo panel (max. height. of 2.44 m in centre, min. height. 0.5 m at sides) covered with a thick plastic sheet was used as an impermeable barrier. The bamboo panel was inserted in the trench and anchored to the bedrock with a cement wall of 30 cm height, all along the trench.

It was observed that though there was water immediately after monsoon, there was no water during the second inspection after 45 days. This was because the plastic barrier was damaged. The conclusion was that the water must have escaped from the damaged barrier.

As a corrective measure it was decided to construct a stone masonry wall as an impermeable barrier to ensure that there are no leakages. The trench was reopened and a masonry wall was constructed. The trench was filled with solt soil on both sides of the wall.

An observation chamber of 1 cu.m. volume was constructed upstream of the wall. An outlet from the bottom of the chamber to the downstream side of the wall was provided with a PVC pipe of 7cm diameter. This pipe crossed the cement wall at right angles just above the bedrock and ran almost horizontally underground for about 38 m until it emerged from the ground due to the downward gradient of the valley. The pipe outlet was capped and closed.

During the monsoon the observation chamber was full of water but when the surface flow stopped there was no water in the observation chamber.

4: OBSERVATIONS AND ANALYSIS OF INVESTIGATIONS

4.1 GEOLOGICAL SETTING, OPERATING CONDITIONS

Project area is in the middle of Thakurwadi formation of Kalsubai Sub-Group of Deccan basalt group (see **Annexure 1** for map.)

There are twenty well defined members which can be grouped into lower, middle and upper divisions based on their physiographic and chemical signatures. The formation is characterised by a thick sequence of fine to coarse grained, aphyric to micro-phyric, amygdaloidal, compound flows with picritic and related mafic-phyric horizons at various stratigraphic levels. A giant plagioclase basalt (GPB) horizon forms the top of the Thakurwadi formation.

(Study by S.F.R. Khadri, K.V. Subbarao, P.R. Hooper and J.N. Walsh.)

TABLE 4.1 GEOLOGICAL SETTING OF AREA

GROUP	SUB-GROUP	FORMATION	CODE	
D		Desur	D	
E		Panhala	Pa	
C	WAI	Mahabaleshwar	M	
C		Ambenali	A	
A		Poladpur	P	
N	LONAVALA	Bushe	B	
		Khandala	K	
		Bhimashankar	Bh	
B		Upper		ThU
A	KALSUBAI	Thakurwadi Middle	Th	ThL
S		Lower		ThL
A		Neral	N	
L		Igatpuri	I	
T		Jawhar	J	
BASEMENT			Bas	

4.2 GEOLOGY STUDIES

4.2.1 SOIL TEXTURE

The samples ranged between silt and loamy sand. The soils tend to be coarser at higher levels in the watershed and closer to the weathered rock. There are exceptions to this, as demonstrated by the two samples Amb-TENS (nalla paddy) and Amb-IP (hillside terrace). These two samples were separated by a vertical distance of 20-30 m, but are very similar in texture. Five of the samples were from the area upvalley from the developed roadside spring (kely spring) in Ambevangan. This spring is relied on heavily for potable water supply and it is desirable to increase the quantity of water available to this particular source. Typically, the source dries up in May. The weathered basalt below the soil cover is the suspected aquifer for the spring and therefore must be the focus for recharge. Buried infiltration pits (stone-filled) were placed in the paddy field immediately above the spring, but the usefulness of these structures is in doubt partly because of the silt loam covering the pits. All the samples collected in the area were silt loam or silt. The amount of recharge water moving through these soils to the weathered rock is minimal. Local landowners are against any structures that reduce paddy field area or interfere with their field work. If acceptable, narrow recharge trenches allowing direct movement of surface water to the weathered basalt may increase the water supply at this spring.

Three samples were selected down the main nalla of Manhere and they reveal a change of coarser to finer material in a downvalley direction. The soils of the valley head areas tend to be shallower, but appear to be more conductive than the paddy soils in valley bottoms. Unfortunately, in all likelihood, water entering the watershed at these higher locations flows back out to the surface a short distance downvalley above impermeable basalt flows.

It is interesting to note that the coarsest material found was extracted from the soil / weathered basalt interface (Titvi-3B). This was the only sample collected at the interface.

4.2.2 BEDROCK ANALYSIS

A STUDY OF BEDROCK

The plots based on oxide molecular proportion ratios suggest that there have been changes in the composition of the rocks, including increase in the K_2O content and a small increase in the Na_2O content. The plots also suggest that the SiO_2, FM and CaO contents (except for the four samples named above) were relatively unaffected by alteration.

B ZEOLITES OF KALSUBAI SUBGROUP

The following paragraph is abstracted from the thesis prepared by Michelle L. MacDonald under the supervision of Dr. W.H. Blackburn in the Department of Earth Sciences, University of Windsor.

"In the study area of Akole Taluka, Maharashtra State, India, gently dipping Deccan tholeiitic basalts in the Middle Thakurvadi of the Kalsubai Sub Group contain amygdules with complex mineralization. The pipe-like or spherical amygdules are filled with cavity-rimming celadonite, calcite, and five varieties of zeolites: heulandite, stilbite, epistilbite, mordenite, and scolecite, which were identified petrographically and by employing microprobe investigations. The zeolites are all calcium-rich and relatively low-temperature with heulandite, epistilbite, and scolecite being the abundant zeolites throughout the 200 m sequence. Mordenite and stilbite occur only rarely. The three most abundant zeolites occur throughout the stratigraphic sequence and since there are very few occurrences of the others, it cannot be said statistically that there is any stratigraphic zonation of the zeolites. Yet, zeolites are zoned within particular cavities throughout the sequence and this is due to the zonation in size of a zeolite within the cavity from finer grained at the rim to larger grained in the centre of the cavity. Mineralogical zonation also occurs within cavities as scolecite rims heulandite, and mordenite rims heulandite. This observation does not support the theory that the deposition of zeolites proceed along an increase of the Si/Al ratio and the enrichment of water molecules."

C GEOCHEMISTRY AND GEOHYDROLOGY OF KALSUBAI SUBGROUP

The bedrock in the project area is massive tholeiitic basalt of the Thakurvadi Formation. The petrography and geochemistry of the 47 samples collected mainly from hand-dug wells and blastholes were examined in order to determine their petrogenesis and to establish the geochemical stratigraphy of the Thakurvadi Formation.

Petrographically the rocks are porphyritic to microphyric and aphyric, fine-to medium grained massive basalts. They are commonly amygdaloidal filled with zeolites. Two suites were defined on the basis of phenocryst content: Suite No. 1 with olivine, plagioclase, clinopyroxene assemblages, and Suite No 2 with olivine, plagioclase, clinopyroxene and magnetite assemblages. Chemically the rocks are altered and show variation in composition, with increases in K_2O content and relatively small increases in Na_2O content. The SiO_2 / FM (FeO + MgO + MnO) and CaO (except in four samples) content were relatively less altered. The two petrographic suites were not found to be useful in interpreting the petrogenetic history. However, MgO-FeO diagrams and vector plots using the high field strength elements suggest that fractional crystallisation was the dominant influence in the petrogenetic history of these basalts.

An attempt has been made to establish a stratigraphic sequence for 40 rock samples within the middle Thakurvadi Formation. In order to achieve uniformity of approach with the previous investigations, the samples were arranged in the increasing order to their elevation, and were plotted against the trace element chemistry and petrographic features at intervals of 20-30 m.

The results of the present study indicate no physiographic breaks in the rock chemistry. Marker horizon(s) such as Giant Plagioclase Basalts (2-5 cm) are not present; hence no distinct boundary or intra-formational sub-divisions were recognised. This suggests that the study area probably belongs to flows that show petrographically two distinct suites, but shows an overlap in chemistry. Because lavas pinch out and dip, it is difficult to correlate the chemical types in the study area with that of the reference section.

A brief account of the geohydrologic significance of bedrock features, with considerations of lineaments in the Deccan Trap is also given. The maximum concentration of lineaments was found to be in range of $N150^0$-N1800 and $N120^0$ to $N150^0$. These lineaments were found to be predominantly zones of structural weakness along which there was formation of fractures. Some of the lineaments that occur in the study area are suggested as the possible sites of groundwater occurrence. It is suggested that groundwater in the study area may occur in association with

1 ground features with fractures trending NNW-SSE

2 valley fills with unconsolidated material coinciding with the lineaments and

3 vesicular and weathered portions of the basaltic flows.

The above study on the geochemistry and geohydrology of Deccan volcanic rocks was carried out by Shashank Agarwal as a part of his MSc degree under supervision of Dr.T.E. Smith and Dr.F. Simpson in the Department of Earth Sciences, University of Windsor.

D GROUND FEATURE STUDY (GEOELECTRICAL SURVEY RESULTS, 1996)

The attempt to employ geoelectric surveys, despite adverse topography, to test their utility in mapping subsurface extension of favourable water bearing features like the dykes and fractures have proved useful only to a limited extent.

The vertical electrical soundings located close to and coinciding with the alignment of a dyke (Manhere, Ridge well) has confirmed presence of water bearing strata and extension of this dyke at depth. The thin dyke encountered in Manhere ridge well (VES IV 18.5.96) seems to be extending down to 47m depth and is likely to be water bearing. At Manhere community well site, the indication of water bearing strata in VES I (18.5.96) at a point on the fracture alignment down to 10 m depth but not in other soundings, though located close by (VES II, VES III 18.5.96), also indicates that water bearing fracture is extending upto a limited depth of 10 m. only along the indicated alignment.

These findings have helped in proposing possible remedies for augmenting yields of the above wells as discussed earlier.

The conclusion'of earlier reconnaissance survey regarding absence of water bearing strata below the water table zone is generally confirmed, except in case of Manhere Ridge well. The Vertical Electrical soundings at Manhere Community well site and Devgaon nala have confirmed that below the shallow water bearing strata, the basalts are hard consolidated and non-water bearing.

4.3 HYDROLOGICAL STUDIES

4.3.1 PERMEABILITY TESTS

The hydraulic conductivities (Kfs) expected for soil types of the area range between 10^{-8} and 10^{-6} m/s. Field permeameter tests for both 1993 and 1995 fall within this range. **Annexure 11** give details about the 1995 field permeameter tests. **Annexure 15** shows the locations of the 1993 and 1995 permeameter tests.

Four of the tests were at terraced hillside areas, three at non-terraced hillside locations and two in weathered basalt (murum). Hand augering was difficult in two shallow holes which were excavated using sharpened metal bars and probes. Overall, the hydraulic conductivities were greater for the 1995 tests compared to the results of 1993. The four terraced hillside conductivities were in the 10^{-6} m/s range, the fastest of all the conductivities measured (1993 included). This is interesting because the soil texture of samples taken at the terraced hillsides were not different from the other soils tested. Both the hillside samples were silt loams. The weathered basalt tests suggest that the weathered rocks are not as conductive as the terraced hillside soils, but are more conductive than the soils of the paddy fields in the main nallas. Heterogeneity of the weathered basalts, related to the extent of weathering, will modify this relationship from place to place.

DISCUSSIONS ON PERMEABILITY TEST RESULTS

The results shown in **Annexure 11** reveal that the soils in the main nalla paddy fields of the study areas are of very low permeability (10^{-8} m/s). The soil texture is very fine (silt/clay) and the soils become mouldable when moist. Surface cracking (up to 1 cm wide) is evident as the fields dry out. Soil texture remains fairly uniform with depth down to the weathered rock interface. Soils of higher permeability (10^{-6} m/s) appear to exist in upland areas but there is not yet sufficient information to determine the extent to which these conditions prevail. The soil porosity ranges from 39-53 (% soil vol.), but the sample with the lowest porosity (39 %) represents the soil weathered rock interface. This data indicates that the soils of the study area are capable of storing significant amounts of water but are of low permeability because of their very fine texture. A low specific yield (e.g. 1-2%) is suspected for these soils and this is not favourable for the subsurface storage of water. Hanson and Nilsson (1986) state that the storage media should contain significant amounts of sands and / or gravels and should be underlain by low permeability material. These researchers point out that it is possible to use an aquifer of low permeability but additional collection systems (e.g. slotted pipes normal to the subsurface dam) are required to increase water availability. This is assuming that natural subsurface flow is responsible for the loss of groundwater at the site in question.

Saturated soil conditions were not common. No saturated soils were found in Titvi and only a few saturated pockets were observed in the Manhere/Ambevangan study area. The majority of dugwells and blast holes were full of water but in most cases the adjacent soils were not saturated. With a few exceptions, the soils in the main nallas are of such low permeability that rivulet water simply flows across the top of the unsaturated fields with very little infiltration. Water retained in surface depressions on some of the field is lost by evaporation.

4.3.2 SURFACE INFILTRATION RATES

Generally, all the infiltration rates were in the lower 10^{-5} m/s range. The slowest of the surface tests (Man-hill-s) was still approximately double the fastest permeameter result and these measurements were taken in close proximity. This suggests that the near surface layers are more conductive and/or the vertical hydraulic conductivity is greater than the horizontal hydraulic conductivity. The presence of macropores (e.g. root channels) naturally will increase the rate of near surface water movement. Overall, the data indicates that surface water will move quickly into the near surface zone, but then soon reaches more compact or less permeable layers. Under these conditions, the upper permeable horizons may become saturated and cause partial area overland flow even though the matrix below is unsaturated. This in turn implies that the soils of the study area watershed may never reach full saturation during the monsoon season and that shallow groundwater recharge only occurs at isolated locations.

4.3.3 RADON TESTS FOR DEEP GROUND WATER IDENTIFICATION

All soil gas radon levels were in the range of 309 to 838 pCi/L (11 to 31 Bq/L). No anomolous radon levels were discovered. Radon concentrations over the suspected lineaments were similar to concentrations measured on either side. Soils in the study area are fine textured (silt loams) and of low permeability and thus a hindrance to the movement of soil gas. The sampling points in such an environment may have to be very close to the radon source (e.g. water in a fracture belt - defined as a lineament) in order to identify the anomaly. In this study, there is evidence of short term variation in radon levels indicated at the radon-2 site. At the same sampling location (pipe), the radon concentration on May 15th was half that measured on April 30th. This short-term variation at the same sampling location was greater than any measured difference between sampling locations along the same transect. The data collected does not eliminate the sites for source of groundwater originating from basement rocks. This is in agreement with the environmental isotope data from water samples collected on two occasions by the University of Windsor team.

4.3.4 METEOROLOGICAL DATA

The calculations of runoff are based on the meteorological parameters viz. rainfall, evaporation and stage measurement data. The rainfall and evaporation data from automatic meteorological station at Manhere and the rainfall data of Titvi is enclosed in **Annexure 19.** Annual rainfall data for 1992, 1993, 1994 and 1995 is also enclosed.

Annual rainfall data of Ahmednagar (Lat $19^0$05N, Long. $74^0$55'E) Akole (Lat $19^0$33'N - $74^0$01'E) and Nasik (Lat 20^0N, Long. $73^0$47E) obtained from Indian Meteorological Department (IMD) is presented in graphical forms in **Annexure 2** and demonstrates the high degree of variability from year to year which characterises the rainfall in the northern part of Maharashtra.

4.3.5 STAGE MEASUREMENTS (RUNOFF ANALYSIS IN MANHERE), 1994

Surface outflow from the sub-basin appeared to be equal to or greater than inputs because of the lag time between water falling on the upper reaches of the drainage area and flowing over the check dam. The runoff / rainfall ratios need to be determined for the entire flow period and for drainage areas of different sizes.

4.3.6 GROUND WATER EVIDENCE MONITORING

The general observation of locals as well as BAIF officers is that the ground water retention period is directly proportional to the rainfall. This is particularly true if sufficient rainfall occurs in the later part of the monsoon. The ground water gets over in the months of March - April itself if it does not rain during September - October.

The rainfall data of the Manhere station (installed in the area) shows that there was only 12 mm rainfall in the month of October, 1995 as against 150 mm in the same month in 1994. Further the total rainfall during 1995 was only 1448 mm as against 280 mm in 1994.

Inspite of the poor rainfall it is observed that the seepage evidences and water levels are almost same for both 1994 and 1995. This has occurred due to the water recharging measures in the area of watershed. See **Annexure 3**.

In the last week of month of may 1996 the wells and springs in the study area were visited and the seepage evidence, water levels and yields were observed. This exercise was also conducted in the same period in 1995.

4.4 EXPERIMENTAL MEASURES FOR SOIL & WATER CONSERVATION

Experimental measures for soil and water conservation were taken up in second and third year of the project. Their performance has been observed during all the seasons in the third year. Appropriate designs have been standardised based on their performance and utility.

4.4.1 IN-SITU SOIL AND MOISTURE CONSERVATION (CATCHMENT TREATMENT)

The study area has been treated on watershed basis. Starting from the upland part and progressing downslope towards the outlet of microwatershed, various in-situ soil and moisture conservation measures were applied. The whole catchment has been treated with gully plugging, contour trenching, terrace bund improvements, pasture development and plantation of fruit and forestry trees. Observations of the measures implemented during first and second years showed that as a result of the contour trenching, pasture growth as well as plantation growth was enhanced and soil erosion reduced. Gully plugs restricted further deepening of gullies and also served as sediment traps. The terrace bund improvements with proper outlet systems have improved the moisture status of the soils and in the course of time the fertility of the soils will also increase.

4.4.2 DEVELOPMENT OF SPRINGS AND WELLS

The springs from where the people were using water for drinking have been developed. Earlier the water was being shared with cattle from the same source with consequent lack of hygiene. Secondly people had to wait for long time to fill their pots.

Hygiene is now improved due to the provision of closed tanks with water filter at inlet and provision of separate troughs for cattle. During the night the seepage water gets collected in the tanks. This gives more time for women who now get water on tap. It also helps reduce wastage of water improves water hygiene.

Additional water has been made available for irrigation and drinking needs due to development of wells.

4.4.3 FARM PONDS

Farm ponds have been dug on the upstream side of the agricultural fields and water sources. The ponds excavated during second year have given very impressive and encouraging results. A direct benefit is that farmers have grown vegetables for home consumption by using water stored in the ponds. Secondly due to the water recharge from the upslope sides of the agricultural fields, the moisture level in the fields downslope was maintained and even dry spells have not affected the crop yields of these fields. Instead, crop yields were higher than normal. Thirdly, some of the farmers have been able to grow second crops due to the increased moisture holding period of fields.

As a result of this, in the last year (1995-96) all farmers were eager to take up ponds in their fields, an idea which was earlier very difficult to introduce.

4.4.4 CHECKBUNDS

Three types of low-cost checkbunds were constructed in the project area.

a. **Checkbunds using sand bags**

By constructing these checkbunds the post monsoon flows are arrested and second crop can be grown. The habit of constructing these checkbunds has been developed in the community to grow second crop / cash crop.

b. **Dry boulder checkbunds**

Dry boulder checkbunds were found useful for soil conservation in the small streams where the velocity of runoff is less and nalla slope is less. The silt is arrested due to these structures as a result of which there is very little silting in the permanent masonry structures downstream. The risk of damage to the permanent structure is minimal due to the reduced velocity of runoff.

c. **Gabion checkbunds**

Results and Observations of two types of gabion structures are explained below.

i **Gabion without impervious barrier**

Structures have been constructed in the upper reaches of the catchment. The main purpose has been to tap the silt of the runoffs. It has been observed that the silt is well arrested in the storage area of gabions and the exit water containing very little silt. Post-monsoon flows also have almost negligible silt due to the intervention by these gabions.

These structures are suitable where the dry boulder checkdam doesn't withstand high velocity of runoff. It has also been observed that gabion with side slope of 1:1 section as planned earlier is not necessary and can be reduced. Structures with side slopes of 0.5:1 on both upstream and downstream faces withstand and bear the thrust of water adequately.

Hence structure with self stability (i.e. the section required for self stability) is sufficient. It has been also experienced that structure with height upto 2.5m can be constructed.

Such a structure serves the following purposes:

a Stops the soil erosion.

b Arrests the silt of the runoffs.

c Accelerates the ground water recharging.

ii Gabion with impervious barrier

In the Manhere main channel, one of the gabion structure has been constructed with an impervious barrier of black cotton (BC) soil. This barrier starts from 3.0 m below the bed level in the COT and is up to the 2 m level i.e. the top level of the gabion structure. This was constructed during second year of the project. The new structure has since become a solid mass, due to silt trapped in the gaps within the stones, the growth of weeds in the trapped silt and the impervious wall of black cotton soil. It was also observed that due to the impervious barrier down to 3.0 m below ground level, water of the storage area percolates very deeply into the ground and recharges the area. Other structures with impervious barrier of ferrocement have been constructed, one in Manhere and one in Ambevangan. The observation have shown the same effect like one with BC soil barrier. The structure having hard foundation strata stores the water like permanent masonry checkdams. More details are provided under analysis and modelling in section 5.4.

4.4.5 GRAVITY FLOW SYSTEMS (MASONRY CHECKDAMS)

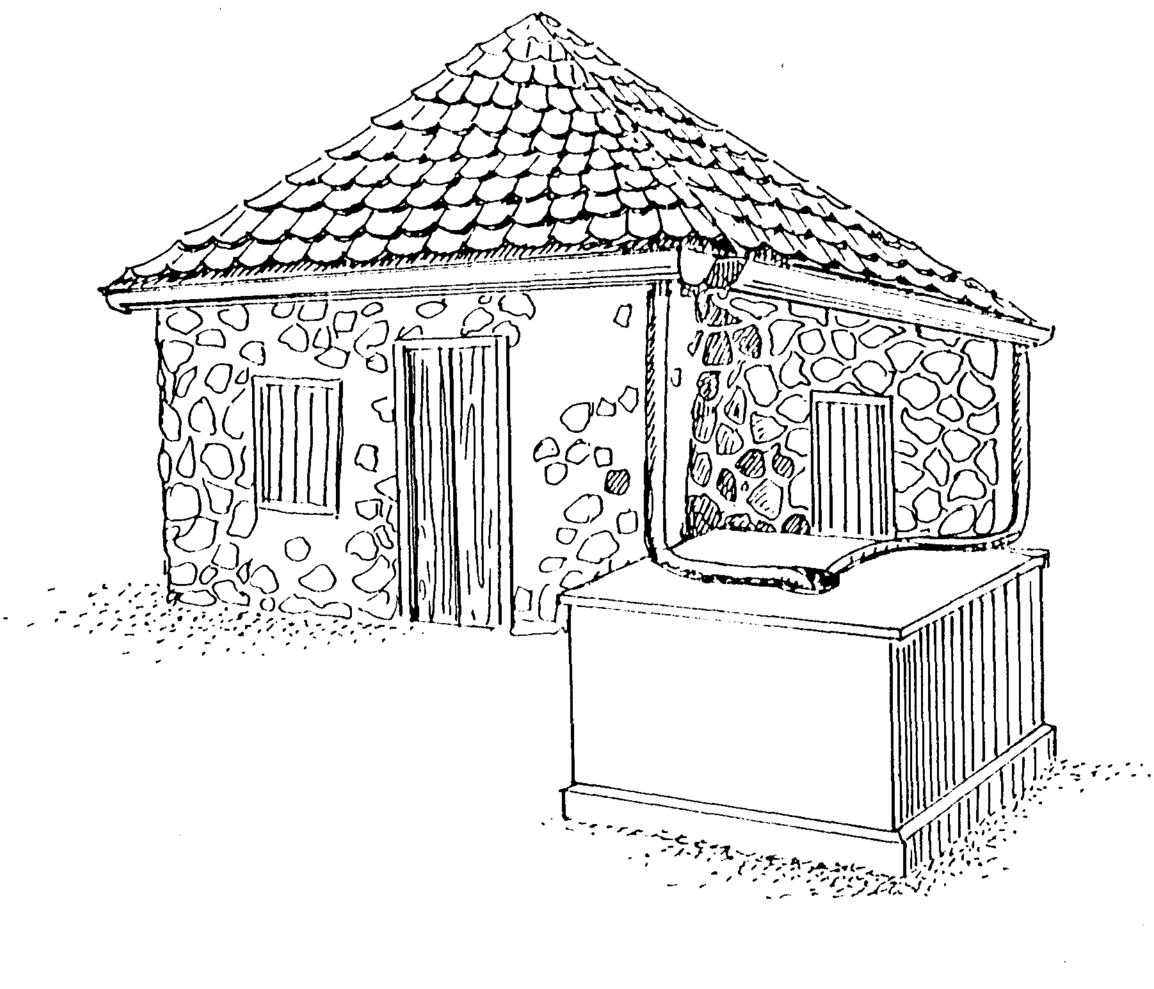
A micro-irrigation system was introduced to cultivate one acre of wheat crop just downstream of the masonry checkdam, constructed during the second year. A micro version of sprinklers called fanjets, which require much less operating head than sprinklers was used in irrigation of the second crop on a pilot basis.

In the same valley a masonry checkdam was constructed in the second year where it was found that by creating surface storage just upstream of it, the natural head was adequate to operate drip irrigation in the fields downstream. Hence, a permanent masonry structure was constructed at this site which has about 5.0 m natural head above the agricultural fields downstream of it. This head will be used to operate a dripper system through poritex strip newly introduced in the market and which requires a head of only 1 m for operation.

Micro-sprinklers were also introduced to irrigate the nursery and a wheat crop.

4.4.6 ROOF-TOP WATER HARVESTING

The systems installed in the project area are serving the purpose of drinking water in all the seasons. The technology has been well appreciated by the community. The details of the system are elaborated in section 5.3 under analysis and modelling.



4.4.7 WATER SOURCE THROUGH FRACTURE AT AMBEVANGAN

Regular observations were made to note the yield of the fracture exposed in the foundation of checkdam at Ambevangan which was later protected by a observation well. Due to contour trenching on the upslope side of the fracture, recharge of water has increased the yield of the source. Despite absence of late rains in 1995, this source provided drinking water for the hamlet of Topewadi of Ambevangan till the next monsoon.

4.4.8 ARTIFICIAL AQUICLUDE

A subsurface barrier was constructed in a small valley at Manhere during the second year of the project. A perforated pipe laid in the storage basin provided a piped outlet downslope for observation. The plastic sheet used as a barrier initially was replaced with a stone structure. Observations through this experiment showed that water can be stored in the storage area of the UGB and can be taken out by a piped outlet. The storage was very small in amount and the period of water retention was not much more than the period of surface flow.

5 ANALYSIS AND MODELLING

Models have been standardised based on analysis and field tests carried out on soil-and-water conservation-and-utilisation measures and suitable survey methodologies.

5.1 FIELD LEVEL RAINFALL MEASUREMENT AND ANALYSIS

The rainfall information for the project area is one of the most crucial design inputs in the planning and designing process. This is because rainfall shows extreme variability not only from day to day during the season but also from hour to hour. As a result averages are often meaningless. Designs of water harvesting structures have to be based on actual peak intensities during storms. Dimensions of infiltration measures such as trenches also depend on the rainfall distribution in order to maximise arrest of run-off and hence infiltration.

Often, in a country like India, secondary rainfall data from rain gauge stations is available. Such data can be used for gross estimations but is subject to the following limitations :

- The data is generally available as daily totals which does not give an idea of occurrence of storms. The peak intensities can therefore be calculated only as an average.
- In transition zones where the rainfall pattern changes very sharply, the existing rain gauge stations may not give even a reasonable idea about the actual rainfall pattern at site. There may thus be an under / over estimation of peak hourly rainfall as well as total rainfall.
- Estimation of peak hourly intensities on the lower side would lead to under-designing of water storage structures and under- estimation of catchment area treatment measures as well as under- utilisation of run-off water either for storage or for infiltration. On the other hand estimation of the peak intensities on the higher side would lead to over designing of structures and a more-than-necessary catchment area treatment. This in turn will unnecessarily push up costs.

In view of the above factors it is worthwhile to go in for on-site rainfall measurement in the following stages:

- As the first step a simple manual rain gauge should be installed.
- It is recommended that an automatic rain gauge with / without data logger be installed in case of transition zones and if the daily rainfall pattern is known or observed to be considerably different than the nearest rain-gauge station data.

A simple manual rain gauge can be easily installed in an open area and the accumulated rainfall measured regularly once a day. **Enclosure 1** provides the specifications of the equipment and site preparation for installation. An automatic rain-gauge with a data-logging arrangement enables continuous monitoring of the rainfall and easy retrieval of the stored data using a lap-top. Typical specifications for such a unit are provided in **Enclosure 2.**

The data collected needs to be properly analysed and used as a design input in the watershed development plan. As one proceeds from the gross (monthly rainfall data) to the detailed (hourly rainfall data), the variations start becoming more and more sharp. **Enclosure 3, 4 and 5** provides the rainfall pattern in the village Manhere taluka Akole of Ahmednagar district, for the year 1994, as monthly, daily and hourly rainfall information. **Enclosure 5** also shows the storm events for 15/08/94 of Manhere raingauge station. **Enclosure 6** provides the rainfall during the same year for two rain gauge stations at Manhere and Bhandardara locations. Rainfall data needs to be analysed in respect of various parameters. **Enclosure 7A & B** provides daily rainfall data of Bhandardara and Manhere stations. **Enclosure 7C** gives the following:

- Total and average rainfall.
- Number of rainy days.
- Number of storms events.
- Peak intensities.
- Run-off estimation.
- Implications for water storage structure design.
- Implications for area treatment.

Enclosure 8 gives the design of graded bunds for Manhere watershed area using the peak intensity of Manhere raingauge station with recurrence interval of 2 years.

ENCLOSURE 1

SPECIFICATION FOR MANUAL RAINFALL MEASUREMENT

Specifications as per IS 4986 - 1983

All forms of precipitation shall be measured on the basis of vertical depth of water or water equivalent which will accumulate on a level surface if the precipitation accumulates without loss. The measurement of precipitation, therefore, presumes that the observations made at a point is representative of certain area around the point to which the measurements refer to. Before analysing the rainfall data from raingauges within a catchment, the condition of the raingauge, its maintenance, period of data and control exercised on the quality of data collected should be examined. The raingauge conforming to IS:5225-1969 shall be used for that purpose.

In the formulation of this standard due weightage has been given to International co-ordinator among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in India.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Exposure of raingauge

- The amount of precipitation collected by a raingauge depends on its exposure and the points given below shall be specially taken into consideration in selecting a suitable site.
- The gauge shall be placed on level ground not upon a slope or terrace and never on a wall or roof.
- On no account the raingauge shall be placed on a slope such that the ground falls away steeply on the side of the prevailing wind.
- The distance between the raingauages and the nearest object should be generally be four times the height of the object, but shall never be less than twice the height of the object.
- Great care shall be taken at mountain and coast stations that the gauges are not unduly exposed to the sweep of the wind. A belt of trees or a wall on the side of the prevailing wind at a distance, preferably four times its own height but exceeding at least twice its height, shall form an efficient shelter.
- In the hills where it is difficult to find a level space, the site for the gauge be shall chosen with a minimum level area of 6 x 6 m, where it is best shielded from high winds and where the wind does not cause eddies. However, the instrument under no circumstances should be installed on unstable or their close proximity.

Installation of raingauge

The raingauge shall be fixed on a masonry or concrete foundation 600 x 600 x 600 mm sunk into the ground. It may also be fixed using steel structurals or wooden planks as shown in **Fig. 1**.

Into this foundation, the base of the gauge shall be cemented so that the rim of the gauge is exactly 300 mm above ground level. This height is necessary to prevent more than a negligible amount of water splashing into the gauge. If the height exceeds 300 mm the amount of rain collected decreases owing to wind eddies set up by the gauge.

Anything which varies the effective area of the collector changes the amount of rain collected. Hence the top of the gauge shall be kept perfectly level and true to shape.

In flood-prone areas the level of the raingauge should be kept 300 mm above the maximum flood line.

After the installation of the raingauge, a plan or sketch showing various objects with their heights and their distances from the raingauge should be prepared and kept in record.

Protection of raingauge

The raingauge shall be protected from being damaged (particularly by stray cattle) by erecting a fence around it as in **Fig. 2**. This may be made of any suitable material. The fence shall be such that the top of the fence is not higher than half the distance of the fence from the gauge.

The raingauge shall be kept locked and periodically got painted to prevent its surface from corroding or deteriorating.

Measurement of rainfall

1. To measure the rainfall, the water in the bottle shall be poured into the glass measuring cylinder (IS:4849-1968) which shall be placed on a level surface. Care shall be taken to avoid spilling any of the collected water. The eye shall then be brought into horizontal line with bottom of the curved surface of the water (meniscus) and its reading shall be taken. If the bottom surface of the water rests between two divisions, the rainfall shall be estimated to the nearest 0.1 mm.

2. If there is more water in the bottle than the measuring glass can hold, the glass shall be filled nearly up to the top gradation mark and the reading noted shall be written down. This water shall then be thrown away and the above process repeated till all the water collected has been individually measured and written down. The total rainfall shall be the sum of all these measurements.

3. The rain water in the gauge shall be measured every day at 08.30 h Indian Standard time (IST) and the raingauge shall be examined every day at that hour even when in the observer's opinion no rain has fallen.

4. The observer at each station shall maintain a written record of the rainfall measured at 08.30 in Indian Standard time each day. The amount of rainfall measured shall be entered against the date of measurement irrespective of the fact whether the rainfall was received on the date of measurement or on the previous date.

5. Raingauge of appropriate capacity as specified in IS:5225-1969 shall be used to ensure the measurement of extremes of rainfall in the event of the observer being unable to take observations repeatedly on the day of such heavy rainfall.

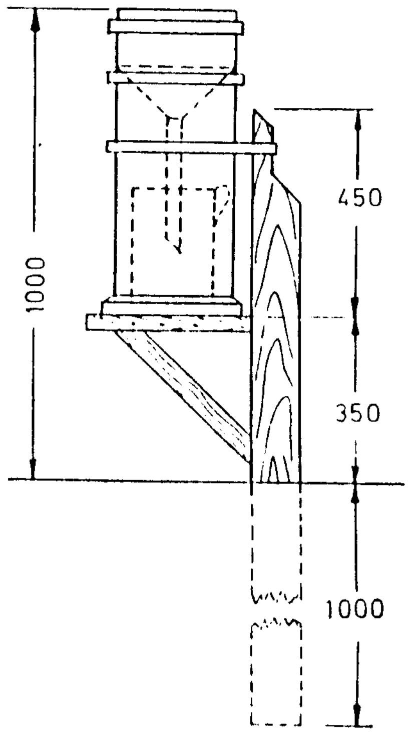
6. If it is raining at the time of observation, all operations shall be completed as quickly as possible to avoid errors. If rainfall is heavy at the time of observation, a spare bottle shall be placed immediately after the bottle inside the receiver is taken out for measurement of rainfall in order that no record is missed during the interval. The bottle shall then be replaced quickly and the rainfall collected in spare bottle shall be poured into the bottle inside the receiver.

7. If owing to neglect of the directions given at 5,6, the bottle has overflowed, the overflow receiver shall be taken up, and its contents measured and added to those of the bottle. If there is water in the overflow receiver when the bottle is not full, the bottle shall be examined for leaks.
8. In order to avoid damage to the rim of the collector, the following procedure shall be adopted while handling the raingauge:
   - The collector shall be removed gently and held in one hand.
   - The receiver shall be taken out with the other hand.
   - The collector shall be replaced.
   - After measurement of the rainfall, the collector shall be again removed and held in one hand and the receiver should be resorted to its position in the raingauge with the other hand.
   - The collector should be replaced in its prescribed position for locking.
9. Proper instructions and training should be given to an observer before being given charge of a raingauge station.

Types Of Rain Measures (Ref. IS 4849:1992)

The rain measures shall be of the following types :

- Type 1 - 20 mm capacity rain measure suitable for use with precipitation gauges having collectors of 200 cm^2 area;
- Type 2 - 10 mm capacity rain measure suitable for use with precipitation gauges having collectors of 200 cm^2 area;
- Type 3 - 20 mm capacity rain measure suitable for use with precipitation gauges having collectors of 100 cm^2 area;
- Type 4 - 10 mm capacity rain measure for 325 cm^2 recording gauge; and
- Type 5 - 25 mm capacity rain measure for 130 cm^2 recording rain gauge.



All dimensions in millimetres.

FIG. 1 INSTALLATION OF RAINGAUGE USING WOODEN PLANKS

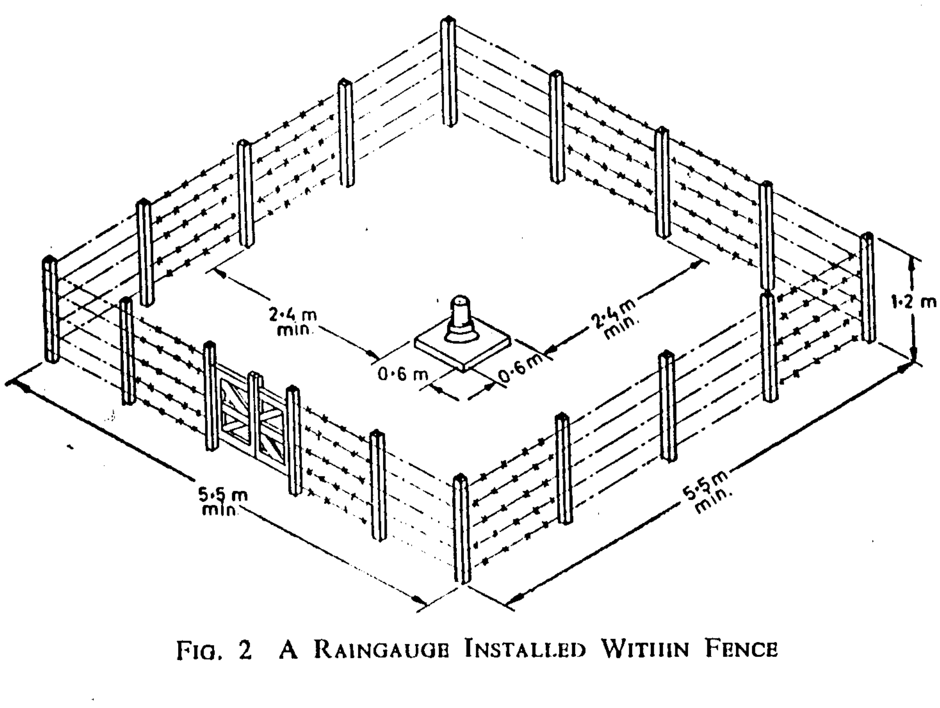


FIG. 2 A RAINGAUGE INSTALLED WITHIN FENCE

ENCLOSURE 2

SPECIFICATIONS OF AUTOMATIC RAINGAUGE STATION

RAINFALL SENSOR MODEL (DTR 8104)

Raingauge	Tipping bucket Raingauge.
Sensing	Magnet and Reed Switch
Resolution	0.5 mm
Accuracy	1 mm
Rim Diameter	203 mm
Collecting Area	325 mm
Material	Raingauge shell made of FRP.
	Bucket & Mounting assembly of Brass & Stainless steel.
Capacity	Unlimited
Sensitivity	0.5 mm (Rainfall per pulse)

PRINCIPLE OF OPERATION

This instrument produces an electric pulse every time it receives a predetermined quantity of rainfall(16.5 cc of water for 0.2 mm of rain).

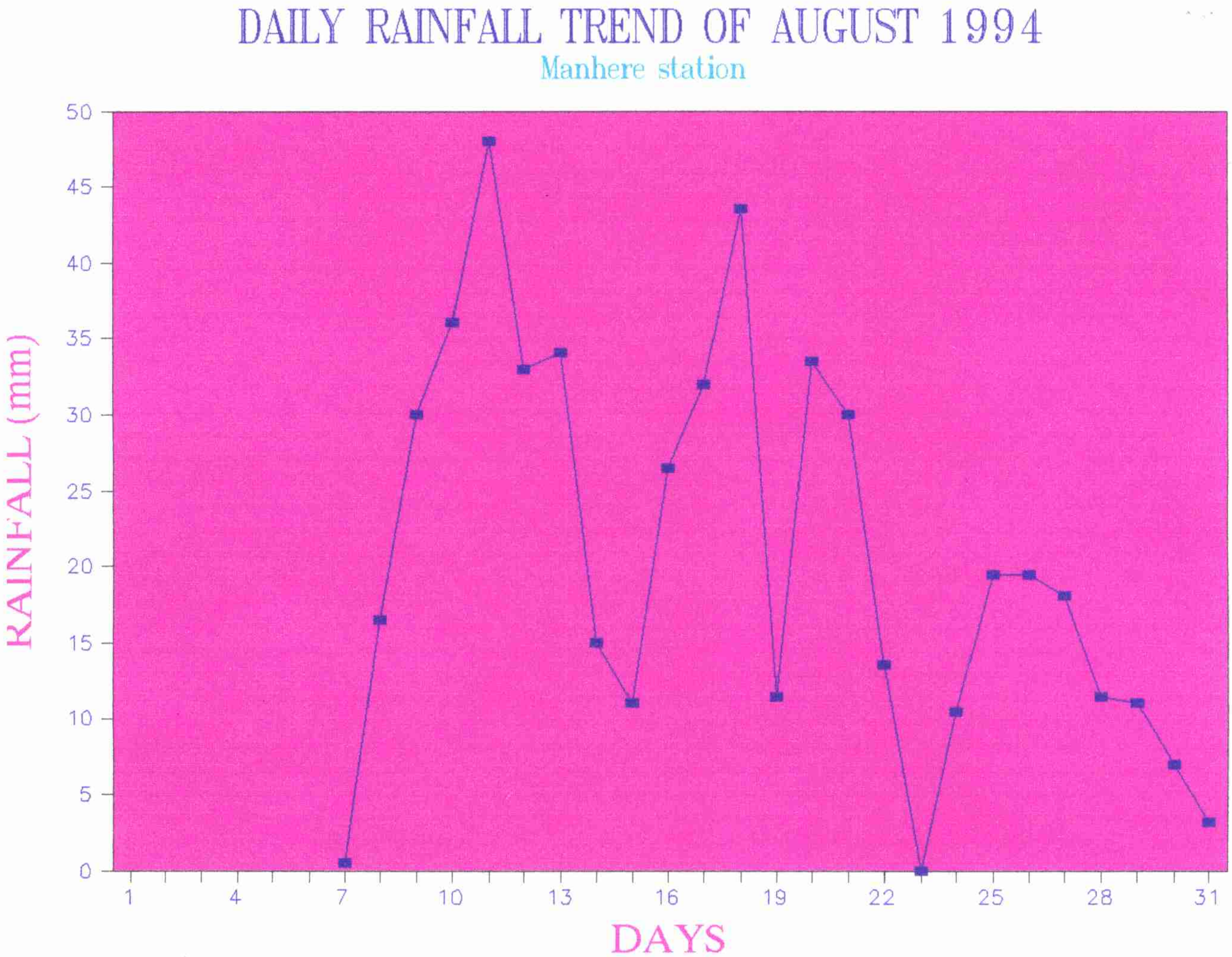
The body and the funnel are made of FRP (Fibre glass Reinforced Plastic) while the rim is made of Gun metal. All parts having contact with water are made of SS.

The mechanism consists of a tipping bucket pivoted at its centre. Rain water is collected in the upper half. When this is full, the mechanism tilts and discharges the collected water, allowing the other half of the bucket to start filling. Alternate filling and discharging continue so long as rain is falling and at each tilt a magnet momentarily closes the contact of a reed switch, generating a pulse.

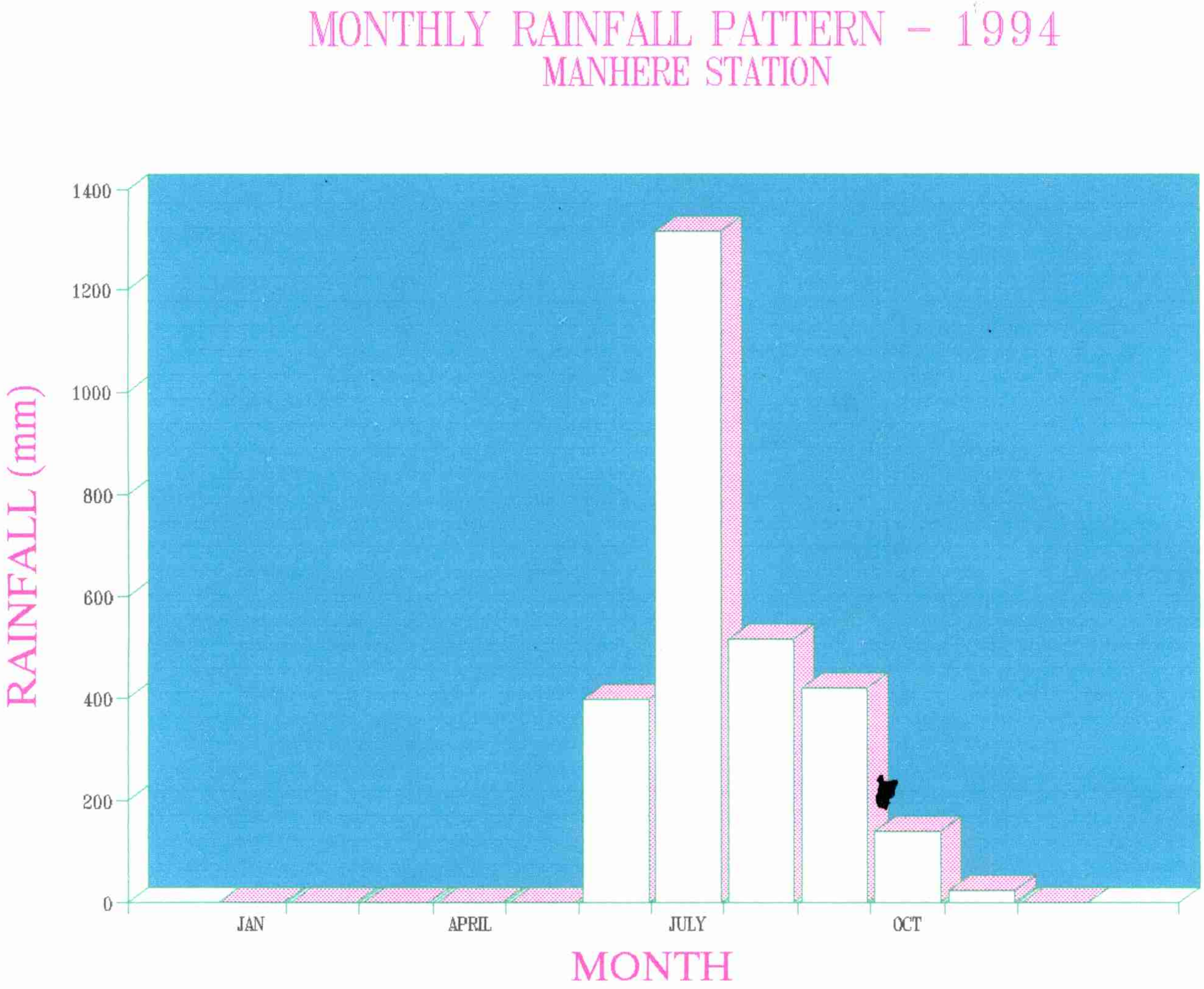
CALIBRATION OF RAINFALL SENSOR

For testing the rainfall sensor pour 324 cc of water at a slow rate into the rain collector. The displayed reading should increase by 10.0 +/- count. To recalibrate the instrument remove the top cover (refer fig. below.) The sensor consists of tilting bucket, a feed funnel 'A', setting screws C1 and C2. While calibrating, each side has to be calibrated separately. To calibrate the C2 side tilt the bucket to rest on C1 screw. Measured quantities of water (6.5 cc corresponds to 0.2 mm of rainfall) is poured through the funnel at slow rate. The screw C1 is adjusted so that the bucket tilts at exactly 16.2 cc. The bucket on C1 side is set similarly using the C2 screw.

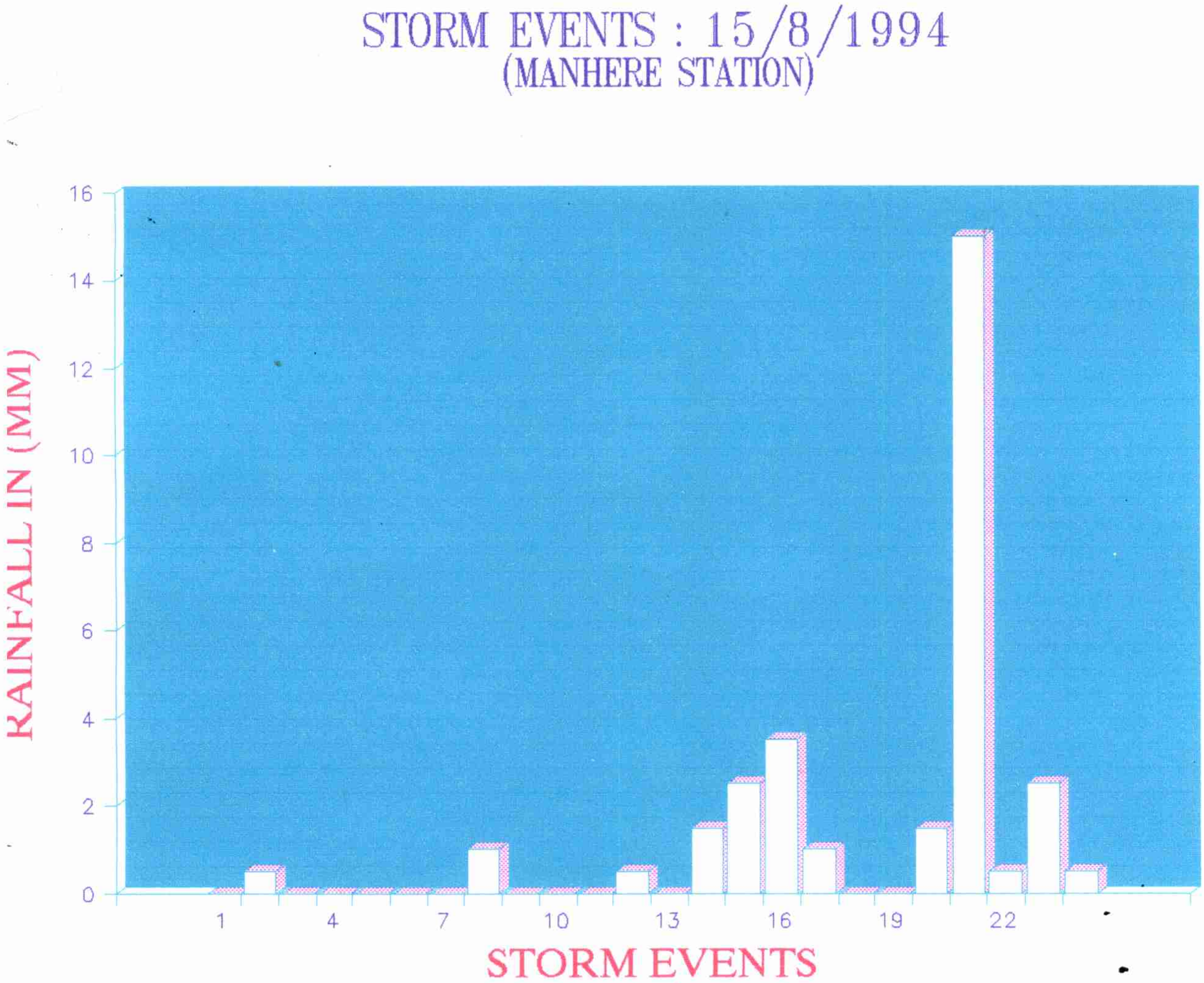
ENCLOSURE 3


DAILY RAINFALL TREND OF AUGUST 1994
Manhere station
RAINFALL (mm)
50
45
40
35
30
25
20
15
10
5
0
1
4
7
10
13
16
19
22
25
28
31
DAYS

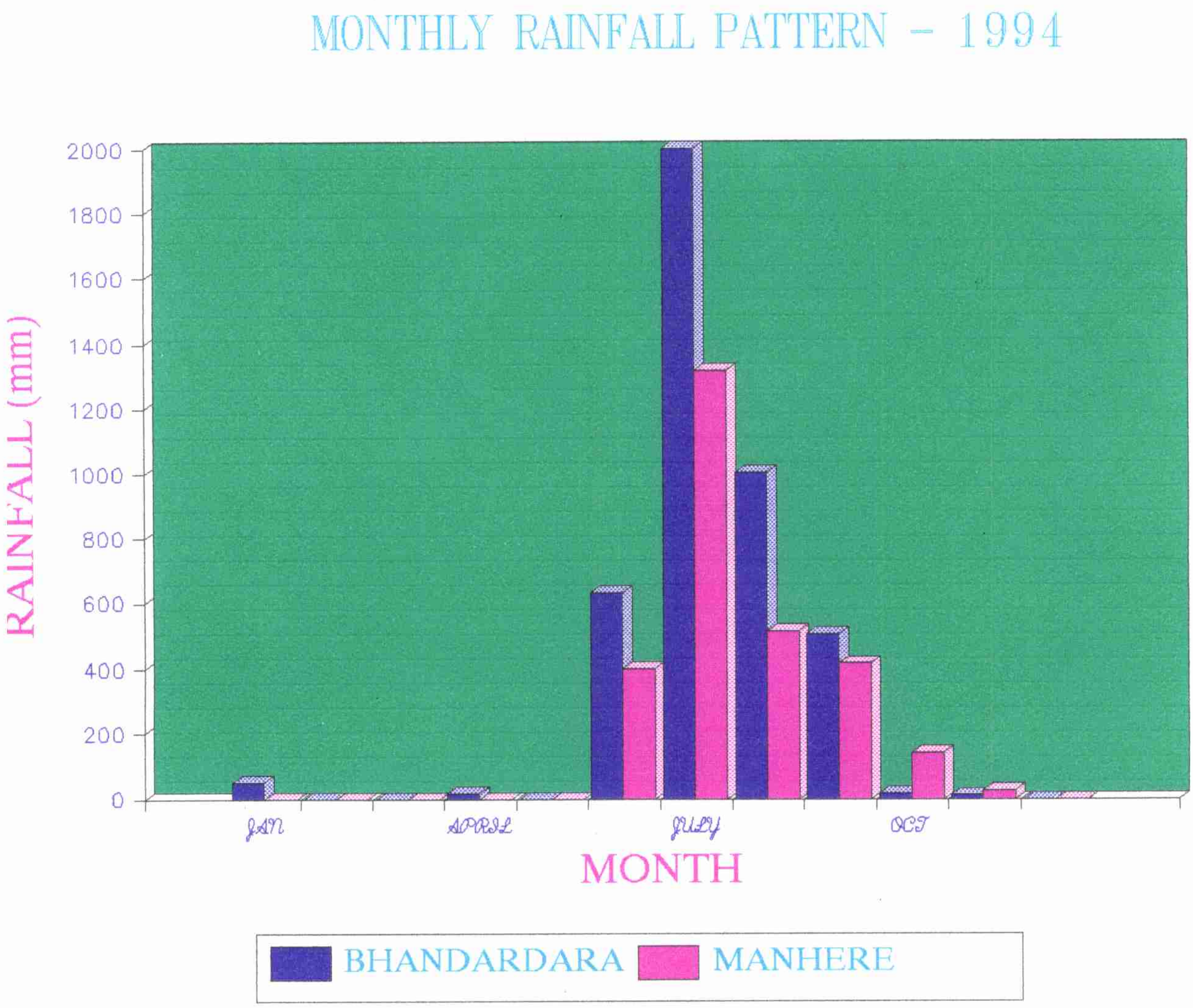
ENCLOSURE 4


MONTHLY RAINFALL PATTERN - 1994
MANHERE STATION
RAINFALL (mm)
1400
1200
1000
800
600
400
200
0
JAN
APRIL
JULY
OCT
MONTH

ENCLOSURE 5


STORM EVENTS : 15/8/1994
(MANHERE STATION)
RAINFALL IN (MM)
16
14
12
10
8
6
4
2
0
1
4
7
10
13
16
19
22
STORM EVENTS

ENCLOSURE 6


MONTHLY RAINFALL PATTERN - 1994
RAINFALL (mm)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
JAN
APRIL
JULY
OCT
MONTH
BHANDARDARA
MANHERE

ENCLOSURE 7A

Daily Rainfall of Bhandardara Station (1994) in mm

Date	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1						2	62	15	6.5			
2							8.5	83	70			
3							13	73.5	105			
4							6	13.5	10			
5						8	14.5	3.5	24			
6						8.5	11	2	72			
7							30.5	2	52			
8							46	22	81.5			
9							24	31	31.5			
10				10.5		25	47	14.5	28		12	
11							80	44	10			
12	50						74	37.5	1.5	4.5		
13				3		13.5	137	26.5				
14						15	214.5	11.5				
15						22.5	154	13.5				
16						114.5	75.5	13		9		
17						57.5	56.5	26	1.5			
18						20	81.5	52.5	6.5	2		
19						45	78	12.5	1			
20						0.5	145.5	48	3.5			
21							123.5	16.5				
22						5	75	12				
23						38	68.5	1.5				
24						67	85	10.5				
25						12	40.5	43.5				
26						21	60	43				
27						33.5	36.5	135.5				
28						20	40	96.5				
29						93.5	45	18				
30						10.5	40.5	47.5				
31							23.5	31				
Total	50	0	0	13.5	0	632.5	1997	1001	504.5	15.5	12	0

Total Annual Rainfall = 4225.5 mm

ENCLOSURE 7B

Daily Rainfall of Manhere Station (1994) in mm

Date	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1									4.25			
2									9.5			
3									11.35	11.2		
4									72.5			
5									39.45		10.5	
6						10.5			92.4		1	
7						0.5		0.5	28			
8								16.5	64.4			
9								30	45.25			
10						32.5		36	30			
11							74.5	48		24.53		
12							108.5	33		24.13		
13						3.6	81.5	34	0.8	12.35		
14						9	74.5	15	6.25			
15						16	108.5	11	0.8		12	
16						65	81.5	26.5	7.25			
17						24.5	46.5	32				
18						17.5	74.5	43.5	5.4	20		
19						40.5	35	11.5		13.3		
20						0.5	51	33.5		4.1		
21							120.5	30		14		
22							62.5	13.5				
23							73.5					
24							63	10.5		16.3		
25							48	19.5				
26						21	71.5	19.5				
27						33.5	23.5	18				
28						20	43	11.5				
29						93.5	73.5	11				
30						10.5		7				
31								3.2				
Total	0	0	0	0	0	398.7	1315	514.7	417.6	139.9	23.5	0

Total Annual Rainfall = 2809.37 mm

ENCLOSURE 7C

RAINFALL ANALYSIS OF MANHERE AND BHANDARDARA STATIONS FOR 1994 (IN MM)

Sr. No.	Description	Rainguage Station	
		Bhandardara	Manhere
1	Total rainfall	4225.5	1665
2	No. of rainy days	106	95
3	Average daily rainfall		
	a. All days basis	11.577	7.6969
	b. Rainy days basis	39.863	29.572
4	Peak intensities		
	a. All days basis	0.48	0.3207
	b. Rainy days basis	1.66	1.2322
5	Peak hourly rainfall mm/hr		15
6	Storm events (15.8.94)		
	a. Numbers		5
	b. Average spacing in hours		3.4

ENCLOSURE 8

DESIGN OF GRADED BUNDS

Design criteria	based on concept of stable channel.
Soil type	light soils with shallow depths.
Maximum length of terrace	150 m
Average slope S	5%

Minimum cross section of bund for shallow soils and bunds with vegetative protection 0.3 sqm.

Rainfall intensity

2 years recurrence interval 46.5mm/hr.

(Automatic raingauge station in project area)

a Vertical interval V.I. = (S/a + b) x 0.3

where a = constant with value = 3.0; b = constant with average value of 2.0

So, VI = (5/3 + 2) X 0.3 = 1.1 m

b Average width of terrace W = VI/S x 100 = 1.1/5 x 100 = 22 m

c Inter terrace area A = 150 x 22 = 3300 m^2 = 0.33 ha.

Runoff coefficient (for the area) C = 0.27

Longitudinal gradient = 0.5%

Rainfall Intensity, I = 46.5 mm/hr.

Peak Discharge Q = CIA/360 = (0.27 x 46.5 x 0.33)/100 = 0.0115 cumec.

Assuming a watersheet flowing along bund with 0.10 m depth, the flow area becomes :

c/s of flow = 1/2 (2.002+0.1) = 0.1051 m^2

The wetted perimeter for this section is 0.141+2 = 2.141 m

Hydraulic radius R = A/P = 0.105/2.141 = 0.049

According to Mannings formula, V= $(R^{2/3} S^{1/2})/n$ = $\{(0.049)^{2/3} \times (0.005)^{1/2}\}/ 0.05$

= 0.189 m/sec.

Velocity is safe

Q = AV = 0.1051x0.189 = 0.01988, say = 0.0199m3/sec.

Hence adopt bund with following dimensions

Top width	= 0.3 m
Side slopes	= 1:1
Height of bund	= 0.4 m
Base width	= 1.1 m
VI	= 1.1 m

Note : From the isohytal map the hourly rainfall intensity for the project area is 90 mm/hr (for 10 year recurrence interval). This shows that the intensity from isohytal maps is twice the actual. The comparison is with 2 years against 10 years. Despite this, there is a big difference. Hence the design of bunds or any other storage structure will be over-designed by isohytal map intensity.

5.2 FIELD SATURATED HYDRAULIC CONDUCTIVITY

5.2.1 INTRODUCTION

The rate of flow of liquid into a porous medium containing entrapped air is known as field saturated hydraulic conductivity. It is denoted by K_{fs}.

Depending on the amount of entrapped air, K_{fs} can be as much as 50 percent below the only saturated (i.e. no entrapped air) hydraulic conductivity K_s.,

Hydraulic conductivity primarily depends on the wetness of soil and texture of soil and also on the viscosity of the liquid.

5.2.2 RELEVANCE

K_{fs} is used to determine the infiltration rate of water into soil. Rate of infiltration is the prime factor while designing infiltration measures for soil and water conservation. Hence a realistic value of K_{fs} alongwith rainfall intensity is crucial to the correct design of soil and water conservation measures like contour trenching, contour bunding and infiltration trenching.

The relationship between infiltration rates and soil texture has been developed and is available in various books and papers. But this secondary data may lead to over-design if the rates are less than the actual values and would lead to under-design if the conductivity rates are more than the actual. Hence in-situ hydraulic conductivity values are essential for appropriate and economical designs. See **Enclosure 9** for design of contour trenches using field saturated hydraulic conductivity.

Hydraulic conductivity values are also used to determine appropriate technology for ground water recharge. For example, if the water storage capacity of soil is good but its hydraulic conductivity is poor, the soil is unsuitable for construction of underground storage structures.

5.2.3 MEASUREMENT

A number of field methods have been developed for in-situ measurement of hydraulic conductivity. Detailed descriptions of many of these can be found in established monographs and manuals. However many of them are not cost effective due to large equipment, personnel, time and liquid requirements. A recently developed technique, the Guelph Permeameter (GP) method is capable of simultaneous in situ measurement of K_{fs}. The method uses simple inexpensive and easily portable equipment, requires only one operator and produces results within relatively short periods of time and with low liquid use.

Measurement technique

The GP method measures the steady-state liquid recharge Q (m^3/s), necessary to maintain a constant depth of water H(m), in an uncased cylindrical well of radius a(m), finished above the water table. K_{fs} is then calculated from Q, H and a using Laplace analysis.

The GP apparatus operates on the Mariotte siphon principle. The air inlet tube maintains sufficient vacuum above the liquid in the permeameter such that liquid flows out of the permeameter at the rate required to keep liquid level in the well at the same height as the base of the air-inlet tube. With this system, the recharge from the well is obtained by simply measuring the rate of fall of the liquid in the permeameter. The flow rate out of the permeameter (and therefore out of the well and into the soil) generally declines to steady value (i.e. the Q value) within a short period of time, usually within 5 to 60 minutes.

Apparatus

There are two basic GP designs: one for high conductivity porous media, "Model 1." (**Fig. 1**) and one for low conductivity porous media, "Model 2" (**Fig. 2**). Approximate dimensions of various components of the two models are given in Table 1.

TABLE 5.1 APPROXIMATE DIMENSIONS IN CMS. OF VARIOUS COMPONENTS OF THE GUELPH PERMEAMETER.

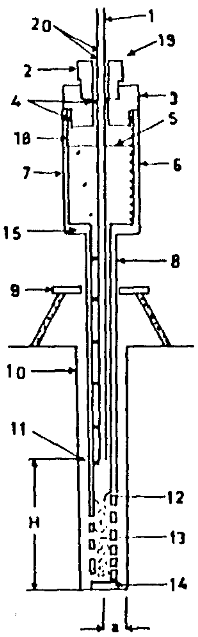
	Model 1			Model 2		
	Inside dia.	Wall thickness	Length	Inside dia.	Wall thickness	Length
Air-inlet tube	0.64	0.16	180-190	0.32	0.32	185
Reservoir tube	5.72-10.80	0.32	40 - 70	-	-	-
Outlet tube					0.32	175
Side tube	-	-	-	0.32	0.16	175

The GP apparatus is essentially an "In-hole" Mariotte bottle constructed of concentric, transparent plastic tubes. The inner "air-inlet tube" provides the air supply to the permeameter and the outer tube(s) provide(s) the liquid outlet (the "outlet tube) into the well. The air-inlet tube is inserted through the other tube(s) via a sliding airtight O-ring seal in an airtight, removable cap on the top of the reservoir. The sliding seal allows convenient change of the H-level through adjustment of the height of the air-inlet tube. The removable cap provides the means for filling the reservoir tube with liquid. Liquid flows out of the outlet tube through a funnel-shaped port located immediately above the permeameter tip. The permeameter tip is a perforated section of outlet tube filled with fine gravel. The gravel reduces the turbulence of liquid flow out of the permeameter during the initial filling to the H-level.

The two permeameter designs (i.e. Models 1 and 2) reflect the necessity to satisfy two main criteria. The volume of the reservoirs must be large enough so that Q is obtained before they run dry. The reservoir diameters must be such that the rate of fall of the liquid surface allows an accurate calculation for Q.

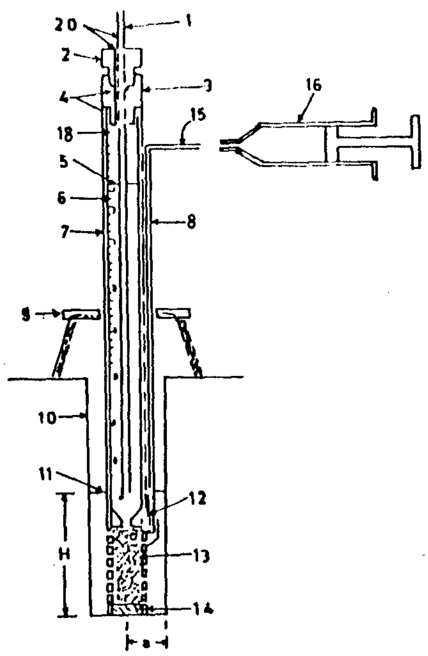
The Model 1 permeameter satisfies these criteria by using a removable reservoir tube (Fig. 1), which allows reservoir dimensions to be matched to porous medium conductivity. In general, longer and larger diameter reservoirs are required for higher conductivity materials.

In the Model 2 permeameter, the diameter criterion requires that the reservoir diameter be about the same as that of the outlet tube. The two are therefore simplified into one uniform tube (Fig. 2). The reservoir volume criterion is satisfied in the Model 2 permeameter using the "Side-tube" and a large syringe. Since the reservoir diameter must be small, the volume of the reservoir is also small. A significant proportion of the total liquid storage in the Model 2 permeameter can therefore be used up in the initial filling of the well to the H-level, with the



1. Air-inlet tube (threaded at base)
2. Threaded collar
3. Removable cap
4. Sliding air-tight seals
5. Liquid surface in reservoir
6. Measuring scale
7. Reservoir tube
8. Outlet tube
9. Tripod assembly
10. Well
11. Steady liquid leve in well
12. Outlet port (threaded)
13. Permeameter tip
14. Rubber stopper
15. Threaded coupling
18. Pressure transducer (optional)
19. Release valve
20. Calibration lines

FIGURE 1 SCHEMATIC OF THE GUELPH PERMEAMETER
MODEL 1 (NOT TO SCALE)



1. Air-inlet tube (threaded at base)
2. Threaded collar
3. Removable cap
4. Sliding air-tight seals
5. Liquid surface in reservoir
6. Measuring scale
7. Combined Reservoir and outlet tube
8. Flexible side-tube
9. Tripod assembly
10. Well
11. Steady liquid leve in well
12. Outlet port (threaded)
13. Permeameter tip
14. Rubber stopper
15. Clamp
18. Pressure transducer (optional)
20. Calibration lines

FIGURE 2 SCHEMATIC OF THE GUELPH PERMEAMETER
MODEL 2 (NOT TO SCALE)

result that the permeameter may run dry before Q is obtained. This is remedied by prefilling the well via the side tube with the syringe, which therefore makes the full storage volume of the reservoir available for measuring Q. The syringe is easily calibrated to fill the well to the desired H-level.

An aluminium tripod assembly is used to hold the permeameter steady and upright in shallow wells. It is generally not required, however, for wells deeper than about half the length of the outlet tube. The tripod has detachable legs for easy transport.

Permeameters of the dimensions given in Table I are designed for operation in uncased wells ranging in radii from about 0.02 m to 0.05 m. For depths less than 1 to 2m, the wells are easily dug with a manual soil auger or probe. If a screw type soil auger is used it is recommended that the central point be ground off in order to give a flat-bottom well (as assumed in theory). If a soil probe is used it is recommended that the normal cutting tip, which is bevelled on its outer surface, be replaced by a tip bevelled on its inner surface. This modification produces a straighter more uniform well and minimises compaction of the wall during probe insertion.

In porous media containing a significant amount of clay, both the auger and the probe tend to smear the walls of the well as it is being dug. (A smear layer generally appears as a smooth or polished surface when the well is inspected with a flashlight.) There is also a tendency for silting up of the well in porous media high in silt and clay. Since all the water must flow through the wall and base of the well, any partial sealing of these surfaces by smearing or siltation generally results in an unrepresentatively low WQ value (and correspondingly unrepresentative K_{fs} ** $_{m}$).

Smear layer can usually be removed using a small, spiked wheel mounted on a handle **(Fig. 3)**. When the wheel runs up and down the well wall several times the smear layer is broken up and plucked off by the sharpened, paddy-shaped spikes. Siltation of the well is due primarily to dislodgement of silt and clay from the well wall during the initial filling, and its subsequent "plating out" back onto the wall during the course of the measurement. This can usually be minimised by slow initial filling of the well. (Slow initial filling also serves to minimise entrapment of air in the porous medium). In porous media particularly susceptible to siltation (primarily soils with high silt content), addition of flocculent to the permeameter liquid may advisable.

Model 1 and 2 permeameters of the dimensions given in Table 1 have a practical measurement range for K_{fs} of about 10^{-6} to 10^{-4} ms^{-1} and about 10^{-8} to 10^{-6} ms^{-1} respectively. The rate of fall of the liquid surface in the reservoir becomes too slow for accurate manual calculation of Q (using the measuring scale and a stopwatch) at K_{fs} values below the lower limits of these ranges. The lower limit is extended somewhat, however, if the pressure transducer - data logger system is used (see Procedure section.) The upper limits can be extended somewhat by decreasing the resistance to flow in the permeameter tip and by increasing the radial dimensions of the outlet, reservoir and air-inlet tubes. Keeping the H-levels as small as possible also helps.

The maximum depth at which measurements can be made is governed by the length of the outlet tube. This depth is about 1 m for the permeameters presented here, but it can be readily extended to the practical limit of Mariotte bottle operation. This can be extended about 8 m by simply increasing the length of the outlet and air-inlet tubes. For depths greater

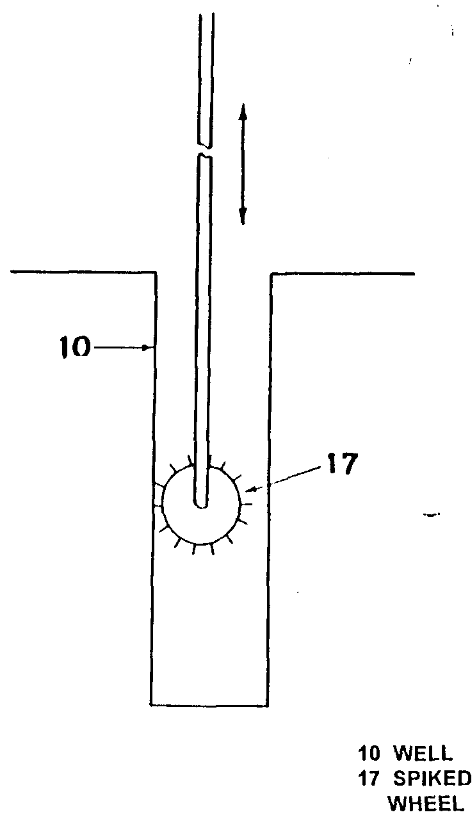


FIGURE - 3 APPARATUS FOR SMEAR LAYER REMOVAL
(NOT TO SCALE)

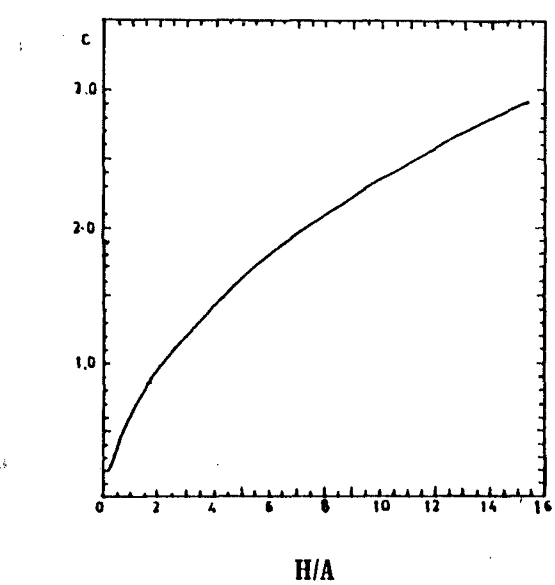


FIGURE - 4C VS. H/A RELATIONSHIP

than 8 m the GP Theory and calculations can still be applied, but different apparatus is required to maintain H and to measure Q (such as the float valve storage tank system commonly used in the shallow well pump-in method - Bureau of Reclamation 1978).

Procedure

The following is a detailed, step by step procedure for obtaining K_{fs} measurements using the GP method.

1. Using a soil auger or probe, excavate a cylindrical well (10) (numbers in brackets refer to the corresponding number in Figs. 1,2 and 3) to the desired depth in the material to be tested. The completed well should be inspected (a flashlight is good enough) for irregular geometry and smearing. If the well has highly irregular geometry, a new well should be dug. A smear layer, if present, should be removed using the spiked wheel (17) **(Fig. 3)** or by other means.
2. Stand the GP in the well (10) and secure with the tripod (9) if needed.
3. Slide the air-inlet tube (1) down to the base of the permeameter and screw the end firmly (by hand only) into the outlet port (12). This prevents flow out of the permeameter during filling.
4. Remove the cap (3) from the reservoir tube (7) and slide it to the top of the air-inlet tube (1). The Seal (4) between the cap and air-inlet tube will hold the cap above the reservoir and thereby provide an opening for filling the permeameter with the liquid (i.e. water, leachate, etc.) Fill the permeameter with liquid to within about 0.03m of the top of the reservoir tube.
5. Slide the cap (30) down into place on the reservoir tube (7) with the seal between the cap and the air-inlet tube (1) which is controlled by the threaded collar (2) and loose enough for easy manipulation. Release compressed air between the liquid surface in the reservoir (5) and the cap by momentarily depressing the release valve (19). (The Model 2 permeameter does not require the release valve function).
6. Tighten the threaded collar (2) sufficiently to ensure an air-tight but sliding seal between the cap (3) and the air-inlet tube (1).

7a. Model 1 (Fig.1) : Unscrew the air-inlet tube (1) from the outlet port (12) and raise the air inlet tube to establish and maintain the desired height of liquid (H) in the well (11). The air-inlet tube should be unscrewed and raised slowly out of the outlet port in order to prevent a sudden rush of liquid, which can erode the well (10), stir silt and clay into suspension, and cause excessive air entrapment. The desired H level is obtained by aligning the appropriate calibration line on the air-inlet tube (20) with the top of the threaded collar (2).

7b. Model 2 (Fig. 2) : Using the syringe (19) fill the well (10) to the desired depth (H) via the side tube (8). The well should be filled slowly for the same reasons as given above for the Model 1 permeameter.

Clamp the side tube (15), remove the syringe (16), slowly unscrew the air-inlet tube (1) from the outlet port (12), and slowly raise the air-inlet tube to the desired H-level.

8. Tighten the threaded collar (2) sufficiently to hold the air-inlet tube (1) in position and to ensure an air-tight seal. After a short period of time, air bubbles will start to rise in the permeameter. This indicates that the permeameter has started. For the Model 2

permeameter, the time between raising the air-inlet tube and the first appearance of bubbles can be minimised by using the syringe (16) to withdraw liquid from the well (via the side tube (8) until bubbles appear.

9. Monitor the rate of fall (R) of the liquid surface (5) in the permeameter by recording the liquid level using the measuring scale (6) at regular time intervals. This is conveniently accomplished using a stopwatch and the data sheets given in Tables 2 and 3. (An optional pressure transducer (18) data logger system can be used in place of manual recording.)

10. When R becomes effectively constant (R_1), the air-inlet tube (1) is slowly raised to establish a new H-level (H_2) in the well (10). It is recommended that the tube always be raised to obtain H_2 rather than lowered. Lowering the air-inlet tube will cause partial drainage in part of the flow field adjacent to the well, which may in turn, introduce hysteresis effects.

11. Monitor the new rate of fall (R_2) of the liquid surface (5) until a new constant value is obtained (R_2) . Depending on soil conditions and whether the "Simultaneous equations" approach or the "least squares" approach is used to solve for K_{fs} (see Table 3) one or two (or more) additional R values may be obtained following the sequence in step 10.

12 Calculate the steady flow rates. Q1, Q2 ... corresponding to R_1, R_2... respectively. using the relationships given in Tables 2 and 3.

13. Calculate K_{fs} (Laplace analysis) and O^1m (Gardner analysis) using the equations given in Table 2. The C values used in the calculation of B and T are obtained from Figure 4. The relationships in Table 2 are derived in Reynolds and Reynolds et al. (1983)

14. Calculate Kfs, (Richards analysis) using either the "Simultaneous equations" approach or the "least squares" approach, as described in Table 3. The simultaneous equations approach uses two successively ponded H-levels in one well and their corresponding Q values (i.e. Q1 and Q2). The least squares approach uses two or more H-levels and the corresponding Q values. Explanation of the various equations and constants in Table 3 can be found in Reynolds and Elrick (1985). The C values are obtained from **Fig 4**.

15. The permeameter is stopped by pushing the air-inlet tube (1) down (this may require a slight loosening of the threaded collar (2) and screwing it into the outlet port (12). If there is enough liquid remaining in the permeameter, it can now be simply moved to the next well and the measurement procedure initiated at step 6. Otherwise, the permeameter should be refilled before installation in the next well. If re-filling is required, removal of the cap (3) is facilitated by first depressing the release valve (19) to release the vacuum above the liquid surface (5).

TABLE 5.2 DATA SHEET AND CALCULATIONS FOR RICHARDS K_{FS} ANALYSIS

Site	:	Date	:
Station No.	:	Depth of well	:
Permeameter	:	Permeameter Model	:
H_1 =	a =	H_2 =	a =

Cumulative Time, t (min)	Reading L (cm)	Rate, R L/T	Cumulative Time, t (min)	Reading L (cm)	Rate, R L/T
$\overline{R_1}$ = (L / T constant value) / Time Interval = $Q_1 = A * \overline{R_1}$			$\overline{R_2} = Q_2 = A * \overline{R_2}$		

Simultaneous Equation Approach

$K_{fs} = G_2Q_2 - G_1Q_1$

where

$G_2 = (H_1C_2) / \Pi[2H_1H_2(H_2-H_1)+a^2(H_1C_2-H_2C_1)]$

$G_1 = G_2(H_2C_1) / H_1C_2$

Least Square Approach

$$K_{fs} = \frac{\sum_{i=1}^{n} Hi^2 \sum_{i=1}^{n} C_iQ_i\left(\frac{Ciai^2}{2} + H_i^2\right) - \sum_{i=1}^{n} H_iC_iQ_i \sum_{i=1}^{n} H_i\left(\frac{Ciai^2}{2}\ H_i^2\right)}{2\Pi\left\{\sum_{i=1}^{n} H_i^2 \sum_{i=1}^{n}\left(\frac{C_ia_i^2}{2} + H_i^2\right)^2 - \left[\sum_{i=1}^{n} H_i\left(\frac{C_ia_i^2}{2} + H_i^2\right)\right]^2\right\}}$$

where n = number of H levels

Notations:

a	Well radius
C	Proportionality parameter dependent (primarily) on the H/a ratio
$C_{1,2}$	C parameters corresponding to H1/a, H2/a, etc.
H	Depth of liquid (constant) in the well
$H_{1,2}$	Specified liquid depths in the well
Q	Steady state liquid recharge necessory to maintain H in the well

$Q_{1,2}$ Steady state liquid recharges corresponding to H1,2 etc.

R Rate of fall of the liquid surface in the reservoir tube of the GP

R Steady-state R

$R_{1,2}$ Steady state R corresponding to H1.2 and Q1,2etc.

GP Guelph Permeameter

Assessment of Results

Heterogeneity in the porous medium can result in unrealistic calculations of K_{fs}. When a significant heterogeneity, such as large macroscope or a layer of boundary is encountered between two H levels, the calculations based on those H levels may yield a negative K_{fs} value. Both positive as well as unrealistic negative value shall be discarded when this occurs. If the heterogeneity consists of a continuous layer boundary, the H levels should be altered such that it does not fall between them, otherwise every measurement based on those two H-levels could produce negative K_{fs}. If the heterogeneities are extreme and random it is recommended that the H_2-level be as close to the H_1-level as sensitivity will allow, in order that both H-levels sample as nearly as possible the same volume of porous medium. A persistent problem of negative values can often be minimised by successively ponding three or more H-levels instead of just two, and using the least square solution. This approach tends to average out the variation between the H-levels, producing a weighted mean K_{fs}.

A further check is provided by the Laplace analysis. If only "ball Park" of K value is required, the simpler and less labour intensive K'_{fs} calculation can sometimes be substituted for the Kfs calculations. It requires only one H-level. See table 3.

TABLE 5.3 DATA SHEET AND CALCULATIONS FOR THE LAPLACE K'_{FS} ANALYSIS

Station No. : Soil texture :

Depth of well : Water Temperature :

Permeameter : Permeameter Model :

Cumulative Time,T (min)	Reading L cm	Rate, R L/T

$$K'_{fs} = BQ \text{ where } Q = \frac{AR}{C}$$

$$B = \frac{\quad}{2\,\Pi\, H^2(1+C/2(a/H)^2)}$$

ENCLOSURE 9

Field Saturated Permeability at village Ambevangan in Akole Taluka of Ahmednagar District, Maharashtra, India. Raingauge station in the watershed project area itself.

Example showing implication of K values on design of contour trenching

a. Design with secondary data:

Daily rainfall intensity : 4.65 cm/hr

(two year cycle)

Soil type : Silt Loam

Infiltration rate : 5.5 cm/hr

(Rate for silt loam secondary data)

Area : 1 hectare

Total volume of water due to the one hour rainfall falling in one hectare of land

V_1 = 1(ha)X4.65(cm/hr)

= 4.64 ha.cm

= 4.64/100 ha.m

V_1 = 464 cum

Total volume of water infiltrated into ground due the one hour infiltration in one hectare of land

V_2 = 1(ha)X 5.5(cm/hr)

= 5.5 ha.cm

= 5.5/100 ha.m

V_2 = 550 cum

Net volume of water to be stored in one hectare area

V = V_1 - V_2 (Neglecting the evaporation losses)

= 85.0 cum

This implies that there is total infiltration of rainwater into the ground and no need of providing trenches.

b. Design with actual Field Saturated Permeability:

Rainfall intensity : 4.65 cm/hr

(two year cycle)

Soil type : Silt Loam

Infiltration rate : 1.37 cm/hr

Area : 1 hectare

Total volume of water due to the one hour rainfall falling in one hectare of land

V_1 = 1(ha)X4.65 (cm/hr)

= 4.65 ha.cm

= 4.65/100 ha.m

V_1 = 465 cum

Total volume of water infiltrated into ground due to the one hour infiltration in one hectare of land

V_2 = 1(ha)X 1.37 (cm/hr)

= 1.37 ha.cm

= 1.37/100 ha.m

V_2 = 137 cum

Net volume of water to be stored in one hectare area

V = V_1 - V_2 (Neglecting the evaporation losses)

= 328 cum

Considering the dimensions of trenches as below

Top width = 1.2m

Bottom width = 0.6m

Side slopes = 1H:0.5V

Depth = 0.6m

Cross sectional area of trench = 1/2(1.2+0.6)x0.6

= 0.54 sq.m

Storage capacity of trench per metre length

= 0.54x1.0

v = 0.54 cum/m

Length per ha = V/v = 328/ 0.54

= 607.4 m

5.3 ROOF TOP WATER HARVESTING TECHNIQUE

The priority need identified by the community residing in the study area was water for drinking. Although the area receives high rains (1500 mm) in the monsoon, the scarcity of water starts in March and continues till next monsoon. The typical feature of the area is the pattern of scattered population as many farmers stay in their farms. Due to this peculiarity, many hamlets do not receive the water supplied by Zilha Panchayat during the scarcity period so they have to walk long distances to fetch the water.

With a view to tackle the problem of drinking water, a localised water harvesting system for individual households was thought of. The idea was well received and accepted by the people which led to the introduction of roof top water harvesting system. People appreciated the cost-benefit, the life of the construction and use of simple techniques. Another significant reason could be the traditional practice in the area of collecting roof top water with a hollow bamboo in empty barrels of kerosene. This was however limited to a few households and the water thus collected was used for other than drinking purposes during the monsoon. Based on domestic consumption during the scarcity period, a 2500 litres tank appeared sufficient (and affordable) to meet the needs of one family.

The traditional method of fetching water from the source (with metal vessels on the head) was estimated to take about 3 to 5 hours daily to fulfil the needs of a family of five. Efforts have been made to reduce that time and energy expended solely by womenfolk.

Estimate of water requirement

Daily requirement per capita	15 litre (Drinking, cooking, etc.)
Average family size	= 6 members
Daily requirement per family	= 6 x 15 = 90 litre.
Total requirement per month per family	= 90 x 30 = 2700 litre.

An affordable unit of 2500 litres was thus decided.

The volume of tank	= 2.5 cum .
The surface area of roof	= 6 x 3 = 18 sqm
The rainfall required to fill up the tank	= 2.5 cum / 18 sqm
	= 0.1388 m = 138.88 mm

Say = 140 mm

Compensating for losses, 150 mm rainfall is required. The rainfall data indicates that the area receives this much rainfall in the month of October which is the last month of rainy season.

The total number of roof top water harvesting systems installed in the study area under the present project is 19.

Contribution from families in the cost of installation is about 30 %.

Surprisingly, the systems proved to be useful in all the seasons. Benefits observed and narrated by the people are as below:

Rainy season

In this season, the water stored was used for washing, for cattle, for bathing and even for drinking. Kitchen gardens were also maintained by using this water as protective irrigation in the dry spells.

Since the area is hilly and wells are located in the valleys it is difficult for women in hamlets to fetch water from such wells during heavy rains. Hence the stored water is being used extensively for various purposes. The water is covered and then used for drinking purpose.

Winter season

The water was used for drinking, kitchen garden, washing and for other purposes. Generally, post-monsoon rains are active till late October and the tanks can be refilled by the end of November, as most of the families did. The stored water was then used for almost a month thereafter. Subsequently, the family refills the tank by water from nearby sources.

Summer season

During the summer, water is not available in the village (Gavthan) as well as in the hamlets. Provision of water through tankers was not available to the families in the hamlets. Usually, these families had to fetch water from 2 to 3 kms every day. Now the tanks are filled by water brought from available sources by bullock carts and is used during this period.

Community perception

Although the tanks were promoted for the storage of drinking water, the community perception is different. They felt that since pure and fresh water is essential to maintain good health, stored water cannot be used for drinking. Although this was the initial reaction, since the families have to anyway depend on the tanks for drinking water during the scarcity periods, they gradually accepted tank water as potable. The stored water proved to be useful during village gatherings, marriages and other community activities. The first impression of a woman from one of the beneficiary families was encouraging as she confirmed that the new systems were useful for womenfolk in saving time and energy which can be put to good use elsewhere. During scarcity period the entire family is busy fetching water since early morning. This is avoidable effort as they also need to reach work sites for earning their daily bread.

The systems have been installed by involving the local trained youths. They were at BAIF's training centre, Vansda. Repairs and maintenance will also be handled by them. Fortunately, the entire family had contributed their labour during the installation / construction of the tanks. This resulted in an on-the-job training to the family members in the techniques of repairs and maintenance. Hence it is hoped that the systems will be maintained properly in future.

5.4 GABION STRUCTURE

5.4.1 INTRODUCTION

For conservation of soil in water, stone bunds are generally constructed in series in the nallas of upper and middle reaches of the catchment area. The purpose is to reduce the velocity of flow which leads to the settlement of silt in the nalla beds. However simple stone bunds do not withstand high run-off velocities created by high rainfall intensities and sloping lands and get washed away with flood. In such cases gabion structures are effective.

In gabion structure, the whole stone bund is bound in chainlink. Due to this it becomes a single heavy gravity unit and withstands thrust of water. With time and after 3 to 4 rainy seasons, silt gets trapped in to the voids of the stone masonry wall and vegetation grows on it, thus forming a solid mass which can store water.

5.4.2 METHODOLOGY OF CONSTRUCTION

- Clean the site where structure is to be constructed.
- Excavate the gully bed upto a minimum depth of 0.3 meters.
- Lay down the galvanised chainlink of size 6" x 6" and 10 swg along the section of the proposed checkdam. Quality of chainlink plays an important role on durability and strength of gabion.
- Construct a stone bund with locally available stone.
- Structure should go 0.3 to 0.6 meters into the stable portion of gully sides to prevent end cutting.
- Bind the structure with GI wire of 20 gauge.

- The sides are raised to provide sufficient water way in between to discharge the maximum runoff from the catchment and to avoid side scouring.
- On the downstream side of gabion an apron is provided if the bed is not hard enough to withstand water hammering from the bund. This prevents scouring of the. The thickness of apron packing should not be less than 0.45 meter and gully sides above the apron have to be protected with stone pitching to a height of at least 0.2 meter above the anticipated maximum water level. This work in turn prevents sides scours being formed by the falling water.

5.4.3 ADVANTAGES OF GABION

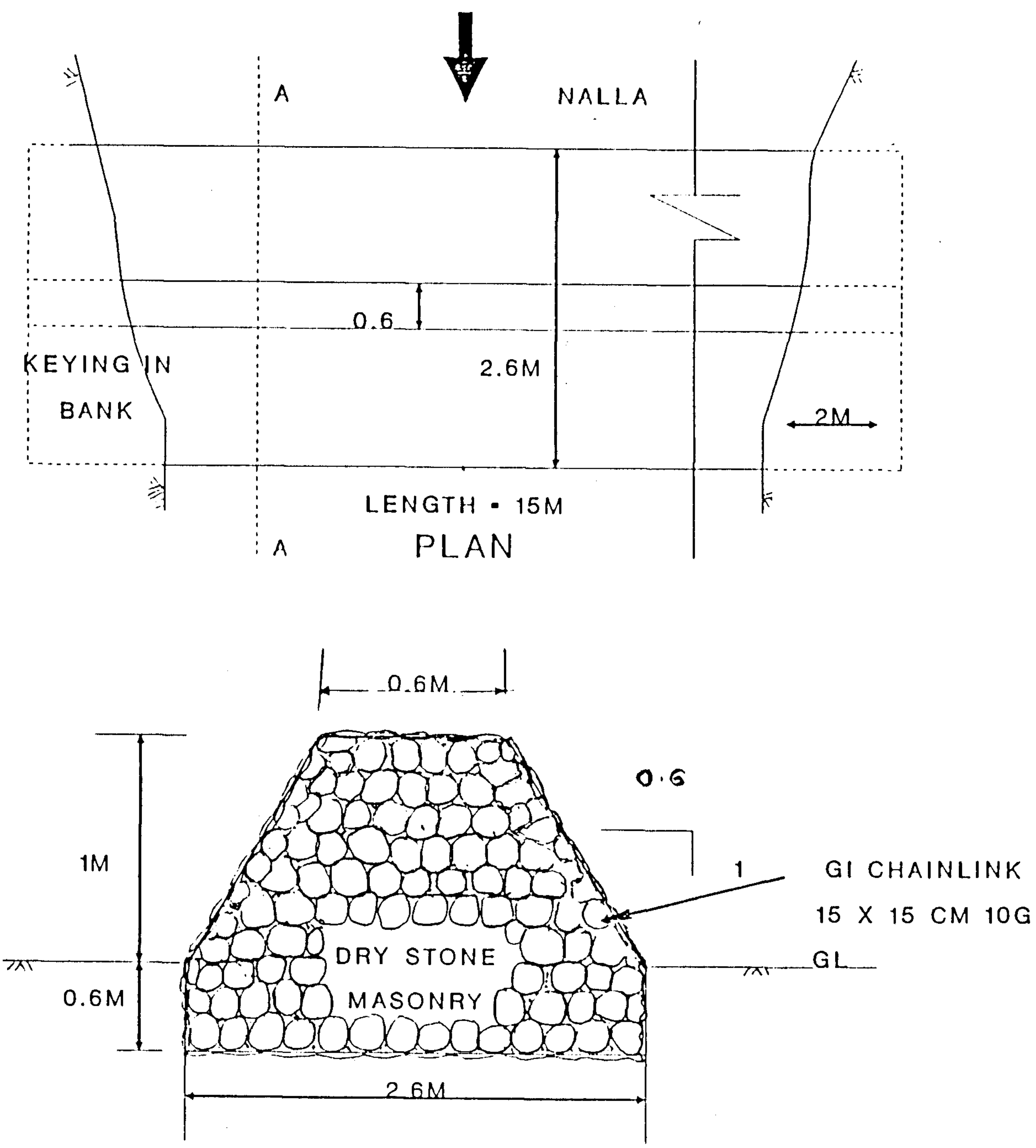
1. Flexibility - In uneven, sinking foundations gabions can bend without breaking, whenever there is some unequal settlement on the foundation. These structures do not collapse like rigid structures.
2. Permeability - Gabion structures are highly permeable and act as self draining units. Seepage or baseflow is easily drained off and structures are thus safe against hydrostatic pressure.
3. Stability - A gabion is a heavy gravity unit, able to withstand water thrust.
4. Economy - With little additional cost of chainlink structure this achieves stability comparable to permanent masonry structure.

5.4.4 TYPE DESIGN

Specifications :

Nalla bed width	15.0 m
Length of structure	19.0 m
(2 m keying on either sides)	
Top width	0.6 m
Side slopes u/s & d/s	0.6 : 1
G.I. Chainlink : Size	15cm x 15 cm
Wire dia	3-4 mm
Height above G.L.	1.0 m
Depth of foundation	0.6 m

GABIAN BANDHARA



SECTION A-A

NOT TO SCALE

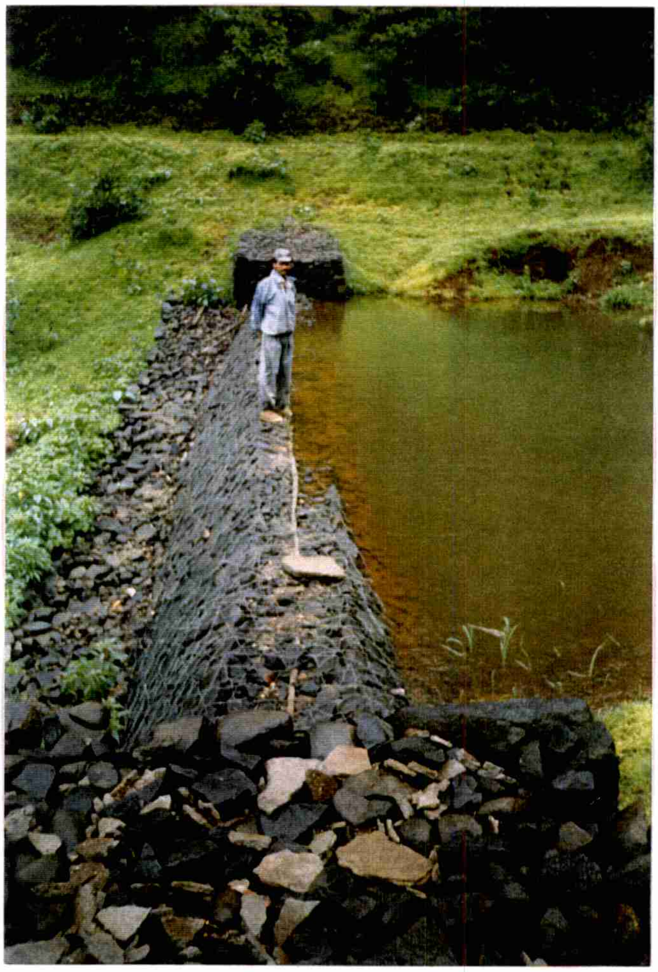
5.5 GABION STRUCTURE WITH FERROCEMENT IMPERVIOUS BARRIER

5.5.1 INTRODUCTION

Based on it's field experience, BAIF has modified the gabion to incorporate an impervious ferrocement barrier thereby improving its water retaining ability.

This structure is similar to the gabion structure, except it has a ferrocement impervious wall at the centre of structure which goes below ground level upto the hard strata. Due to this impervious wall, the structure stores water if the foundation strata is impervious. If the strata of storage area is pervious then the structure acts as a percolation tank and hence it increases the ground water table.

5.5.2 CONSTRUCTION



Material list

- Locally available stone.
- Galvanised Iron (GI) chainlink.
- Cement, sand and aggregates for concrete.
- Cement, sand, 6mm dia. mild steel bars and chicken mesh (15mm x 15mm, 218 gauge) for ferrocement.
- Water proofing powder.

Methodology

- First clean the site.
- Excavate the foundation trench upto the hard strata.
- Lay down concrete of 1:3:6 proportion, 15 cm. thick for ferrocement foundation.
- Construct the ferrocement wall at the centre of

foundation trench up to 7.5 cm below ground level. Fill the upstream and downstream sides of ferrocement with sand about 15 cm thick and the remaining trench by available soil. The sandy layers have a dual function. They:

- protect the ferrocement from swelling action of surrounding soil.
- allow the water sprinkled on top for curing of the ferrocement to percolate to the bottom.
- Next provide 7.5 cm thick concrete of 1:2:4 proportion on the ferrocement wall. Place G.I. chainlink of size 15 cm x 15 cm and 3 to 4 mm dia GI wires on it. Lay the remaining 7.5 cm thick concrete above the earlier layer so that the chainlink gets fully embedded in the concrete. As this chainlink is used to bind dry stone masonry, it should be of good quality to ensure durability and strength of the gabion.
- Construct a ferrocement wall above this concrete upto the full supply level of the structure.
- Construct a stone bund keeping the ferrocement wall at the centre.
- The whole structure including ferrocement core wall should go upto 30 to 60 cms into the stable portion of gully side to prevent end cuttings.
- Raise the end portions of the structure to the level equal to the flood depth plus free board to prevent scouring of the nalla banks.
- On downstream side of the structure, provide 2-2.5m width rubble soling along the full length. This helps to prevent soil erosion downside of the structure.

TYPICAL STRUCTURE

(Constructed at Ambevangan village of Akole Taluka, Ahmednagar District in May 1995.)

Nalla bed width		16.0 m
Length of structure (including 7 m keying)		23.0 m
Top width		0.6 m
Side slopes		1:1
G.I. Chainlink:	Size	15 cm x 15 cm
	Wire dia.	3-4 mm
Height of structure above bed level (Max.)		2.4 m
Depth of foundation:	Average	1.5 m
	Max.	2.7 m
Core wall:	a. Bed concrete	1:3:6
	b. Concrete at ground level in which chainlink is embedded	1:2:4
Ferrocement wall:	Thickness	25 mm
	Chickenmesh size	12.5mm x 12.5mm

Wire dia.	1mm
Mortar	Cement : Sand = 1:2.5

5.5.3 ADVANTAGES

This structures has all the advantages of gabion as detailed above *plus* the additional advantage of the stored water.

5.5.4 TYPE DESIGN

Structure constructed in Ambevangan village of Akole Taluka, Ahmednagar District in May 1995, with the following details:.

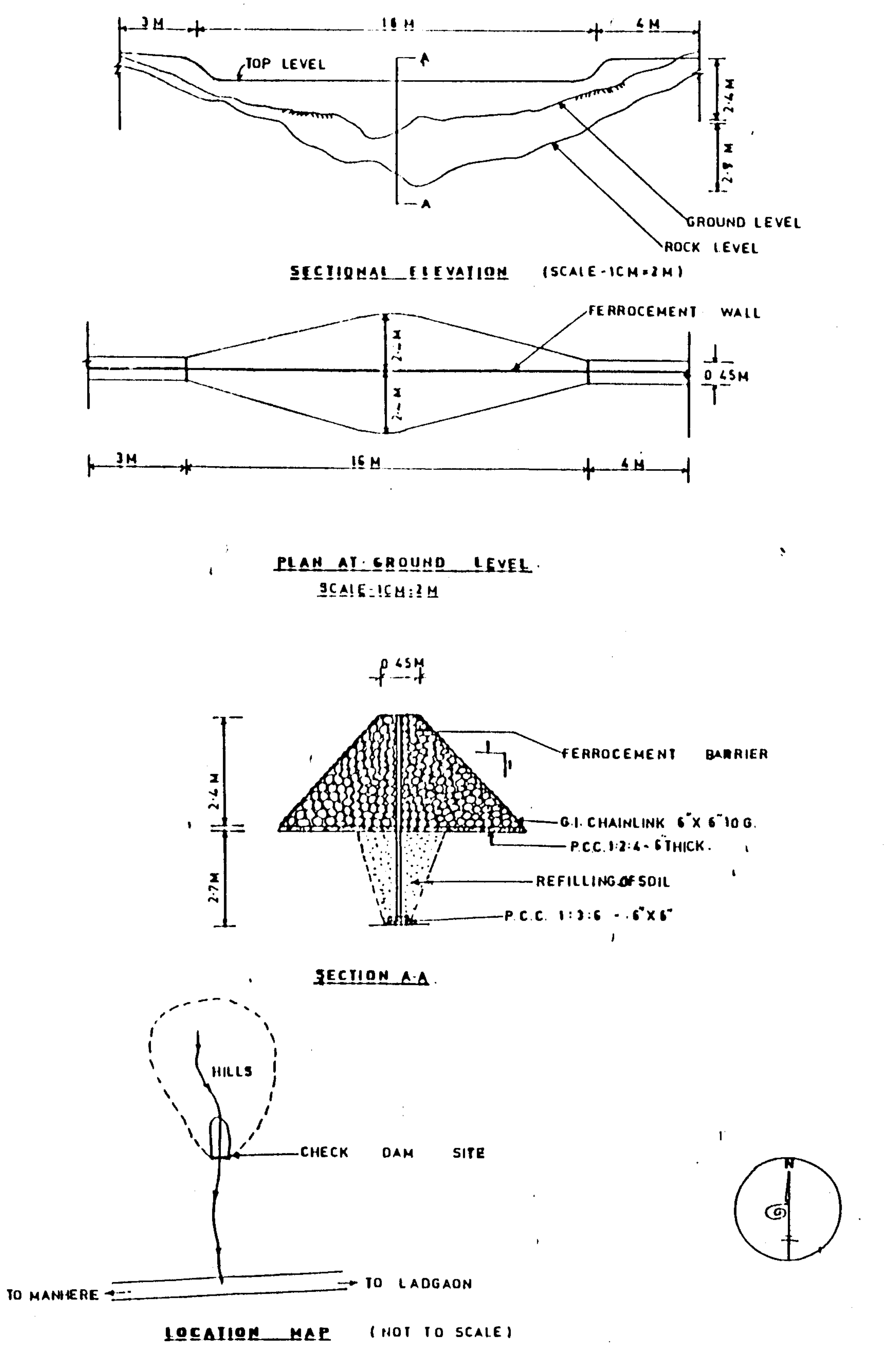
Specifications

Nalla bed width	16.0 m
Length of structure	23.0 m
(7 m keying and due to head wall extensions)	
Top width	0.6 m
Side slopes	1:1
G.I. Chainlink :	
Size	15cm x 15 cm
Wire dia	3-4 mm
Height of structure above bed level	2.4 m(Max.)
Depth of foundation	1.0 m
Average	1.5 m
Max.	2.7 m
Core wall	
a. Bed concrete	1:3:6
b. Concrete at bed level in which chainlink is embedded	1:2:4
c. Wall	25 mm thick ferrocement

EXPENDITURE STATEMENT

(Structure constructed at Ambevangan Village Tal. Akole, Dist. - Ahmednagar in 1995)

SR. NO.	ITEM	QUANTITY	UNIT	RATE PER UNIT	AMOUNT
1	Survey, site cleaning etc.	Lump sum	-	-	200.00
2	Excavation for foundation and disposing the stuff as directed.	26	Cum	18	468.00
3	PCC 1:3:6 for bed concrete	2.0	Cum	1295	2590.00
4	PCC 1:2:4 at nalla bed level	1.8	Cum	1733	3119.40
5	Ferrocement impervious wall with supports	48	Sqm	218	10464.00
6	Filling sand on either side of ferrocement wall (7.5 cm thick) & filling soil in the gaps on either side	15.25	Cum	30	457.50
7	Constructing dry rubble masonry for gabion	41.91	Cum	85	3562.35
8	Providing and binding the chainlink to masonry wall	180	Sqm	33	5940.00
9	Providing & constructing the apron on d/s side of gabion	6.37	Cum	55	350.35
	TOTAL				**27151.60**



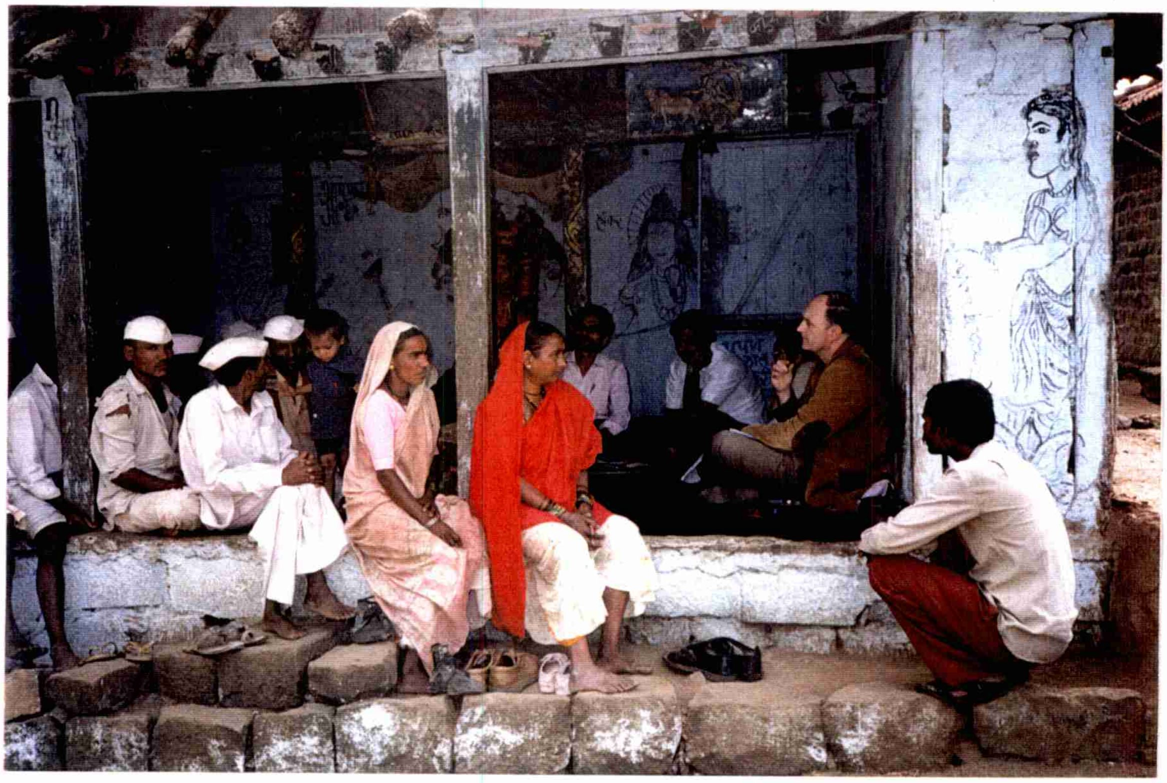
GABION CHECK DAM WITH IMERVIOUS FERROCEMENT
AT - AMBEVANGAN TAL - AKOLE. DIST - AHMEDNAGAR.

6: SOCIAL CONSIDERATIONS

6.1 INDIGENOUS KNOWLEDGE

6.1.1 HISTORY OF TRADITIONAL PRACTICES IN AGRICULTURE

The present tribal population moved into the project area about 150 years ago, after defeating the original inhabitants who were displaced. At that time, the area was surrounded by thick forest, whose produce was their main source of food. Before independence, the forest was cut down and burnt to produce charcoal by traders. Their main source of survival thus became scarce. Hence they started cultivating crops. Initially, the main water streams were arrested by stone bunds. Land on the banks of streams was very fertile and suitable for cultivation of paddy. This was mainly due to the deposition of biological waste such as tree leaves and sticks. This compost is known as 'MARWA 'in the local language. Subsidiary streams were also developed. However as they lacked constant supply of water, low yielding variety of paddy. was grown.



6.1.2 TYPE OF LAND

Land near the main stream is known as 'Garvi Jamin' where high yielding and long duration paddy is grown. Land around subsidiary streams (off-shoots is called as 'Halwi Jamin' where less yielding, short duration paddy is grown.

Land between main streams and off-shoots was composed of 'murum', i.e. hard rock due to constant soil erosion . This was developed by terrace bunding, locally known as 'Taali'. These Taalis were found suitable for legumes and oilseeds such as khurasni (Niger / Guizotia abyssinica), kulith (Horse gram / Dolichos biflorus L.) and ground-nut (Arachis hypogaea L.). 'Taalis yielded good output even with minimum efforts.

6.1.3 LAND USE PATTERN

Local land classification has the following categories: land for habitation, cultivation, grazing and waste land. Land used for cultivation mainly consists of following type of soils shown in Table 6.1. The land use pattern, soil type and seasons show interlinking.

TABLE 6.1 FARMERS CLASSIFICATION OF LAND AND CROP PATTERN

TYPE OF SOIL	KHARIF	RABI	SUMMER
Silt deposits (in main stream)	Paddy, Beans	Wheat, Bengal gram	
Brow Soil (near off-shoots)	Paddy, Vegetables	Oils Seeds, Millets	
Newly terraced land	Millets, Legumes	Oil seeds	
Bunds in area	Legumes	Oil seeds	
Rock / Hard murum	Cultivation not possible		

6.1.4 CULTIVATION PRACTICES

Earlier, soil erosion was arrested through bunds and land was used to produce sufficient grains for existing human population. However, the demand on available land was increased over the years with increase in the population. By use of manure and F.Y.M., fertility status of the soil was improved. 'Gomutra' (cow's urine) was discovered to be a useful insecticide. It was also considered sacred. It was experienced that the sprinkling of Gomutra generally restored sickly plants and creepers which were believed polluted by human or non-human intervention. This practise was replicated for other plant life including crops.

Similarly, Taag (Jute / corchorus capsularis L.) was grown on terraces and used in-situ as green manure by a process known as 'Shidwa' involves cutting mature jute which is then buried in-situ. While vermi-compost as a technique was not known, there was an awareness of the significance of worms in agriculture and their cultivation in the field was practised. Use of cow dung with Marwa gave good yields.

Crop rotation was followed to maintain quality of soil and to obtain increased agricultural production. The sequence was Legumes (Kulith) followed by lower millets (Nachni, Sawa), oil seeds(Khurasni) and finger millets (varai). It was known that biological wastes of these crops (leaves + sticks) helps in the growth of each subsequent crop. Shifting cultivation method was used, where one plot is used for cultivation while another is allowed for grazing. This ensured good quality fertiliser with the accumulation of cow-dung.

The tribals could recount eight varieties of paddy crops. Crops were categorised by quality, weight, taste, and yield. Each variety was cultivated in different fields and was recycled by preserving them in the form of seeds.

Paddy varieties grown here are purely local and hence do not have English synonyms. They are: 'Kalbhat', 'Takya', 'Jirwel', 'Kulpi', 'Varangal', 'Zini', 'Ambemohor' and 'Dhawlu'. Each one has derived its name from its properties. For example, "Kalbhat" means the one which is dark in colour, "Kala" being the work for black.

Paddy nurseries are grown on level platforms and then transplanted on different types of land depending on the variety. Before sowing, seedbeds are prepared by burning dry leaves and twigs. The prepared beds are used only after first monsoon showers.

The local varieties of rice, pulses, and oil seeds are main crops in the area. The cropping pattern follows a definite order. The monsoon is the time when maximum agriculture planting and production takes place. Winter crops are possible only when the monsoons are good. Summer crops are not possible.

6.1.5 PREDICTIONS ABOUT RAINFALL

There are some changes which take place in nature and which have observed for years. These are used as indicators for rainfall prediction. and are listed below:

- If mango and Jambhul fruits ripen and fall down early in summer (early May) then early rain is predicted
- If 'Sarda' (chameleons), change to red from the usual brown and black colour, rain is expected within 10 to 15 days thereafter.
- Mating period of Kiwa and Kumbha, the local birds starts 20 to 30 days before the beginning of rainfall.
- If ants are seen carrying their eggs to other places, rains are likely to commence within 8 days.

6.1.6 IDENTIFICATION OF GROUND WATER

- Vegetation on the ground appearing green in the month of April, ("Chaitra in local language") is an indication of under-ground water.
- It is believed that the "Umbar" tree grows above and near a water source. The roots of the tree moves in the direction of water source beneath it.
- The "Paier" tree grows on hard rock just above a water source.
- If two hills are situated on a line running east to west, there are good chances of an under water source in between them.
- There is another traditional technique of identifying underground source of water: If vegetation remains green even in summer there is a good possibility of underground water. To confirm, new earthen pots filled with water are placed at the four corners of the suspected area. The chances of underground water are good if the level of water in the pots is unchanged by next morning. This is because dry land absorbs water faster compared to land with source of water beneath it..

- A mute or blind person can identify sources of underground water. It is believed that their disability is compensated by a sixth sense Apparently, this is true in 70 to 80 % of cases which has encouraged its practice.

6.2 SOCIAL CONSTRAINTS IN THE WORK OF IMPLEMENTATION

Tribals living in remote areas get rare opportunities to interact with other people. Their sporadic external contacts have left them with an impression that all outsiders are exploiters. Hence they are hesitant to develop any relationship with strangers. Similarly, their interaction with other officers has left the feeling that outsiders are superior and natives are hardly worth anything. Our first experience with tribals was not any different. They were very shy and suspicious of our intentions. Fortunately, close interaction with them combined with intimate communication helped in paving the way for establishing a working relationship.

Like most of their brethren, they think of short term gains. So during the initial stages of the project they visualised measures like well deepening, construction of tanks and lift irrigation schemes. But the long term goal of the project was to find the methodology for optimum use of the surface and ground water resources. Hence there was a challenge to make them understand the significance of the long term objective and to help develop foresight.

Some constraints while implementing experimental measures are illustrated here. The farmers were very reluctant and hesitant to undertake work in their fields as they were apprehensive of the possibility of loosing their property to outsiders. Secondly, construction of farm ponds would lessen their area of cultivation and grazing. It was clear that unless they were convinced of the genuineness of efforts, their participation would not be assured.

The tribals are also known for their home-grown practices in agriculture which are adequate to satisfy needs in the short-tern. For instance, cultivation on field bunds has been the usual practice to get maximum available land under crops. This leads to heavy soil erosion of bunds and ultimately the whole terrace gets washed out. The practice of flood irrigation was employed due to lack of awareness of alternatives. Free grazing is practised with no restriction on the movement of cattle. This hampers the growth of young plants and existing grasses.

Since then, micro irrigation systems have been demonstrated in the area to make them aware of the optimal use of scare water resources.

7: OUTCOME, IMPACT AND RECOMMENDATIONS

7.1 METHODOLOGY FOR DATA COLLECTION, ANALYSIS AND PLANNING

The methodologies adopted during the project implementations for various studies are given below.

7.1.1 PROJECT INITIATION

The concept of undertaking a research study for development and use of water resources was perceived by BAIF during the implementation of Wadi project between 1989 and 1992. After finalisation of the programme, initiation started with Participatory Rural Appraisal methodology to convey ideas amongst the community and to study their response. Meetings with the villagers in all three proposed villages was the first step of project. Those meetings and PRA/RRA methodologies helped strengthen relations with the community and to introduce teams from the University of Windsor and BAIF, Pune.

The information generated through RRA has helped in formulating an entire strategy for planning and implementation of the proposed project theme. The transact walks in the study area included walks of project teams in all parts of the selected micro watershed. Some ground features like exposed fractures in rocks, caves and dykes observed in the area gave the direction for the proposed study. As a result of this, it was decided to study satellite imageries for developing potential ground features.

7.1.2 BASELINE DATA COLLECTION

The data required to crystallise the project concept was collected in the first year of the project. This included demographic information, education levels, land holding pattern, livestock ownership, agricultural production and income assessment.

A questionnaire in local language was prepared to cover all these aspects. All households residing in the project villages completed their respective information formats. Survey was conducted by BAIF field officers who had established a good rapport with villagers. The information was then analysed to obtain results in specific form which are summarised in this report in the form of charts and graphs. Specific studies to meet the priority needs of the people were drawn up based on this information.

7.2.3 METEOROLOGICAL DATA

The Indian Meteorological Department (IMD) has established raingauge stations at various places all over the country. State Irrigation Department has also established stations on their irrigation project sites. Annual rainfall recorded (from 1960 to 1991) at Bhandardara, Akole, Waki and Randha (Bk.) stations was procured from IMD. The distance of these stations varies from 3km to 30km from the project area. The data collected was then analysed to understand the variability of rainfall from area to area and probability distribution of annual rainfall at each station. Rainfall intensity and annual rainfall data was used to plan soil and water conservation measures. Additional meteorological stations were established in 1992 at two of the project villages viz. Titvi and Manhere. Automatic recording system has been used to generate data since 1993. Designs of water conservation measures were then standardised based on intensity of rainfall obtained from the Manhere raingauge station.

From data collected at Manhere, Titvi stations and other stations shows that the variation in annual average rainfall is as much as 500mm to 1000mm within a distance of 3 to 7 kms. The designs of catchment area treatments like contour trenching, contour bunding and drainage line treatments like gabions and masonry checkdams is based on the peak intensity of rainfall. The published isohytal maps of IMD show that the project area falls under an intensity zone of 90 mm/hr. for a ten year cycle. However for a two year cycle at Manhere station the intensity is only 46.5 mm/hr. The designs based on this intensity are almost half that of iso-hytel intensity. This realistic information was next used for standardising the designs of modules which were tested in the area.

7.1.4 GEOHYDROLOGICAL STUDIES

In the first phase (1992) all the springs, open wells, bore wells and percolation tanks of the study area and the surrounding 11 villages were surveyed. Information regarding water table in monsoon, summer and winter, the profile of the wells and their yields was also obtained. A similar survey was repeated in 1995 and 1996 in the month of May to the see the impact of water resources development measures applied in the study area. Each location and elevation was determined using the Navpro 5000 (GPS) and a pretel altimeter. Later, in the implementation phase, detailed studies were carried out to determine the nature of rock, its water-holding capacity and availability of deep ground water (fossil water). For this purpose, the soil gas levels were measured with a portable Rn 200 Radon Director equipped with a 150V2 scintillation cell and potential sources of water like fractures /dykes were studied.

These analyses of observations helped to define guidelines to plan specific treatment measures for developing water sources. This led to intensive water recharge measures such as contour trenching, farm ponds, gabions with impervious ferrocement barrier, roof top water harvesting systems and development of existing potential water sources.

7.1.5 STUDY OF SOIL PROPERTIES

Various soil parameters were studied with a view to understand the nature of soil for planning studies. Two types of tests were carried out.

1. Laboratory testing which included the soil texture, porosity, bulk density, water content, electric conductivity and nutrient status.

2. Field testing included permeability tests and infiltration rates at different locations covering different types of soils. Soil profiles were also studied to understand the depth of top soil, nature of subsurface strata and its percolating and yielding properties.

The study results indicated poor yielding capacity of top soil layer in the main drainage channels / paddy fields and poor availability of water reservoir capacity of subsurface soils in the paddy areas. Based on this information, treatments such as infiltration of water by breaking the top soil layer, water recharge ponds and farm ponds were evolved and implemented. For testing soils in the field, advanced equipments like `Guelph Permeameter" and Tensiometers were used for obtaining saturated field permeability and recording field moisture levels respectively.

7.1.6 USE OF REMOTE SENSING / SATELLITE IMAGERIES

BAIF and Space Application Centre, Ahmedabad jointly studied the satellite imageries of the project area. The imageries were integrated with topomaps and cadastral level maps. The steps involved were data procurement, base map preparation, preliminary interpretations of imageries, field checks, final inter-pretations and final mapping. The outputs were slope map, hydro-geomorphological map, forest density map, sub watershed / drainage map, suggested sites for water resources development, water resources and wasteland development sites for Manhere, Titvi and Ambevangan villages. Satellite imageries in the form of lineaments were studied, their interpretation on the ground was observed and plans to utilise those were finalised.

7.1.7 USE OF GIS

Geographic information system was very useful during initial phases of the project. It was used to translate tabular data available on the maps so as to specify its location. Diverse data procured in various maps was next overlaid to get a specific utility map. For example, lineament features were overlaid on the village level cadastral maps and drainage maps to locate and check ground features. All water sources i.e. springs and wells of the area were mapped with the help of GPS (Global Positioning System) by locating the latitude and longitude of the point. Updating of the information was carried out continuously for ready reference.

7.1.8 USE GEOLOGICAL / GROUND FEATURES

Two types of features have been studied. One is the lineament received from Satellite Application Centre in the form of a map. The other covers the visible ground features like exposed fractures and dykes known to BAIF field staff and villagers. The cadastral maps with lineaments overlaid on them were taken to the field and all such sites were observed to see the interpretation of these lines. Most of the lineaments were ridges and some were thick soil covers. Recharge methods were decided after clear understanding of these features. The ground features which were known to the villagers were studied with a view to utilise them as a source for water resource development. Geo-electrical method was used to find out the horizontal and vertical extents of the exposed fractures and dykes. Treatments to augment the water sources have been recommended after the study. One fracture was excavated in Ambevangan village at a spot upto 3m depth and an observation well has been constructed at this spot where water is now available throughout the year. The upstream side of this fracture has been treated intensively by trenching, gully plugging and construction of a farm pond.

7.2 PILOT TESTING OF EXPERIMENTAL SOIL & WATER CONSERVATION AND UTILISATION MEASURES

The following interventions for conservation, development and utilisation of water resources have been tested on pilot basis and standardised.

Appropriate use of traditional measures:

1. Gully plugging / stone bunding
2. Contour trenching / bunding
3. Recharge pits / ponds
4. Farm ponds
5. Well development & spring development
6. Masonry checkdam
7. Use of micro-irrigation techniques for efficient water utilisation
8. Creation of vegetation cover in catchment area

Innovative measures:

1. Gabion structure
2. Gabion structure with ferrocement barrier
3. Artificial recharge and utilisation of water from fracture
4. Roof top water harvesting
5. Infiltration trenches / breaking top soil layer
6. Spring development
7. Underground barrier

7.3 STANDARDISATION OF PROTOCOLS FOR DATA COLLECTION / FIELD MEASURES

Protocols for various experiment measures / field interventions have been developed. The literature for these activities has been published in the following forms:-

1. Field saturated hydraulic conductivity module
2. Ground water table logging module
3. Field level rainfall measurement module
4. Roof top water harvesting - Technical Awareness Brochure
5. Ferrocement gabion - Technology Awareness Brochure

7.4 IMPACT OF PILOT ACTIVITIES

The overall impact of field interventions is the increased water availability and increased awareness amongst the community in soil and water conservation techniques. Specific impact of measures applied through the study on pilot basis and after the extension of activities covering 4 villages under watershed development programme since 1993-94 are given below.

7.4.1 SOIL CONSERVATION

The area has been treated on watershed basis. Upper reaches which are mostly wastelands having slopes more than 30% have been treated with contour trenching plantations, grass development and plugging of small gullies. An area of 1000 ha has been treated with contour trenching. The estimated soil loss in this area before treatment was about 75-150 tonnes /ha per year. Due to the intervention (trenching), rainwater does not flow as a surface runoff and hence loss of soil is prevented. An annual soil loss of about 75000 - 150000 tonnes from an area of 1000 ha area has been prevented. In the gullies of upper and middle reaches, 6550 gully plugs, 75 dry stone bunds and 75 gabions have been constructed so far. Visual observations on depth of soil arrested by these measures indicates that about 8000 tonnes, 11000 tonnes and 13000 tonnes of fertile soil has been conserved behind these structures. The total annual soil loss prevented due to above mentioned interventions is equivalent to a top soil layer of 6mm to 10mm thick spread over the entire area.

7.4.2 WATER RECHARGING

Water recharge has been accelerated due to water arresting trenches (contour trenching) in the 1000 ha area. Annual average water recharging and forming as a sub-surface flow is in the region of 10-19 million cubic meters (based on 4 years annual average rainfall at Titvi and Manhere villages). Apart from this measurable recharge, gully plugging, stone bunds, gabions, recharge pits and ponds are augmenting ground water flows. The ultimate effect of this has been increased moisture in downstream fields which has enabled about 75 ha. of land to produce second crop during winter and about 300 ha additional land (which was a wasteland) to be brought under cultivation during the rainy season.

7.4.3 INCREASED WATER AVAILABILITY

Surface water storage structures, subsurface source developments and roof water harvesting systems have increased water availability and promoted easy accessibility for drinking and agricultural usages for all the 494 households of the project area. Twenty six households (5%) are getting water at their doorsteps through roof top water harvesting systems. Most of the households residing in the hamlets (which is about 10-20% of total households) are now getting year round safe drinking water as a result of development of 6 natural springs. About 73 thousand cum water is now been stored in 14 permanent masonry checkdams and 3 ferrocement gabions. This water is being used for drinking by the households residing in the hamlets and, in the dry periods, by cattle as well. With normal rains about 75 ha land has been brought under assured second crop due to increased soil moisture and surface water storage. The outcome is that water availability has been increased by about 750 litres per day per capita in the scarcity period.

7.4.4 INDIRECT BENEFITS

Awareness generated in the constructive use of scare resources was demonstrated by development of kitchen gardens fed by waste water. This has helped in maintaining sanitation around the houses. Such nutrition-rich food was made available to about 200 families with the help of kitchen gardens. Produce is available for about 8-10 months during the year. This activity is now inculcated amongst the villagers who have started developing kitchen gardens on their own.

7.4.5. SKILLS DEVELOPMENT

Local youth have acquired skills in all the water and soil-conservation related activities during the implementation phase of the project. About 25 youths have been trained in ferrocement technology and masonry constructions, 10-15 persons per village in the technology of erecting gabions and about 8-10 women and men technicians per village in the soil conservation activities of contour trenching, bunding etc. Nursery and grafting techniques have been also acquired by 4-5 youths per village. Techniques of installing roof top water harvesting systems, carrying out repairs to handpumps, construction of checkdams, soil and moisture conservation measures, etc., have been assimilated in many members of the villages.

As the programme was implemented by involvement of the villagers, they got an opportunity to apply rudimentary managerial skills and to develop their leadership qualities.

7.4.6. AWARENESS ABOUT CONJUNCTIVE USE OF WATER

Earlier, the degraded resources, lack of income generation opportunities and lack of other infrastructure development had spelt a gloomy picture in the minds of the youth. A more sustainable and encouraging impact of the study is seen in the increased level of motivation within the community. From their reactions it is apparent that they have realised the need and benefit of protecting their environment. Tribals who are the main beneficiaries of nature are sometimes not fully aware about environmental protection methods. Since various new techniques were introduced at different times and at different locations in the area, the dissemination of this knowledge has been spread widely and is not concentrated within any particular group. This has helped many people in developing their capacity to learn and acquire new skills in developing water resources.

Such demonstrations and experiments are giving greater exposure of modern technology to the community as well as knowledge of developing an eco-friendly environments in their villages. A positive attitude towards learning new things is noticed, particularly amongst the younger generation.

7.4.7. COMMUNITY ATTITUDE

In last two years, the area has received only 75 to 80 % rains within a narrow span of two months. As a result, the production of food grains was lower by about 30-40%. However, area under cultivation has increased by 20% thereby decreasing the food scarcity. This has also given an opportunity of producing surplus for sale.

Introduction of new skills and knowledge has stimulated the process of rejuvenating the fading enthusiasm.

7.5 ORGANISATIONAL STRENGTHENING

BAIF Development Research Foundation is working in five states of India. The major programmes are land based with water resources development as a core component of all these activities. The considerable technical know-how acquired during the above project will have positive implications in all other programmes undertaken by BAIF.

Specifically, skills acquired by BAIF staff in survey methodologies for developing water resources can be applied to any nature of area. Secondly techniques for water conservation experimented with and developed in the Deccan trap area will be tested and developed for other areas and agro-climatic conditions in the country as well. These will include ravines, drought-prone areas and deep soil areas through BAIF's ongoing programmes.

7.6 DEVELOPMENT OF REPLICABLE APPROACH

The protocols have been developed and tested in the Deccan trap. Of these protocols, methodologies for recharging, conventional contour trenching and gully plugging are replicable in all situations. Protocols of gabion structure and ferrocement gabion can be used for soil and water conservation as low cost technologies in hilly areas. Roof top water harvesting systems are very useful in areas of water scarcity. These systems are particularly useful in areas where the villages receive drinking water from brought from external sources by tankers.

Literature prepared on these technologies will be distributed amongst NGOs and government organisations involved in the field of water management. Training sessions and workshops will be held at national level to share technologies and methodologies developed during this study.

7.7 RECOMMENDATIONS

7.7.1 POLICY

- Western Ghats form a large part of the Deccan Trap. This region has tremendous variation in climatic conditions even within distances of 1-2 kms. Planning of water resources development programme on watershed basis needs factual climatic data. This is possible only with the establishment of a network of meteorological stations.

  In the transition zone of the western ghats, one station at every 5km distance is necessary to collect realistic data. The proposed **range is from the ridge to the existing meteorological stations of IMD towards eastern side.**

- Remote sensing interpretations like lineament maps, drainage maps, information about existing groundwater reservoirs and nature of subsurface strata is very useful for facilitating micro-level planning of water resource development. **These interpretations should be made available to the agencies involved in this field.**

- Use of **Geographic Information System (GIS) should be promoted to all agencies working in development of water resources.** GIS is also useful to analyse and update field information which can be mapped to a high degree of perfection.

7.7.2 TECHNOLOGY

- Water storage tanks must be installed near houses in areas with water scarcity in summer. These tanks can be filled up by water brought by groups of households or by a hamlet. Alternately, rain water can be collected from the roofs of houses and stored during rainy season for use in scarcity period. **Ferrocement is a low cost technology for constructing water tanks for roof top water harvesting system.**

  Domestic water availability and **storage facility for individual households or small groups of families (upto 5) is a manageable unit in scarcity areas.** Systems like roof top water harvesting will be the better alternative to community schemes of water supply. Since these schemes are also suitable for remote pockets, they **should promoted at such locations.**

- In high rainfall areas, the post monsoon flows exist for 3-4 months. Instead of creating large water storages on lands, these **flows should be arrested in the nallas / gorges by a series of small checkdams.**

- **Gabion structure with ferrocement is a good low-cost alternative to conventional masonry or earthen checkdams.**

7.7.4 INDIGENOUS TECHNICAL KNOW-HOW

- For projects on watershed development, **local skills and know-how must be taken into account at the** planning stage itself.

- Involvement of local community members with appropriate skills will ensure quality in works such as construction of checkdam, ferrocement works, bunding, trenching etc. Hence **local community members should be trained well in advance in all such activities identified** under the project.

7.7.5 RESEARCH

Methodology of conjunctive water use is widely applicable in the Deccan Trap area. Some modifications would be necessary, however, to use it in other areas. **Studies should be undertaken in other areas to implement methodologies developed in the present study with suitable modifications if any.** This will be useful for future watershed development programmes in various regions of the country.

8: TRAINING AND WORKSHOPS

8.1 DISSEMINATION MEASURES

Two type of dissemination have been adopted:

8.1.1 DOCUMENTATION

Data generated during the experiment and results thereof have been shared with the project area to enable their implementation for improved agricultural practices. Successful findings have been compiled into booklets, manuals and handouts for widespread distribution to field and other personnel, and include:

- Manual on Conjunctive Use of Water Resources in Deccan Trap Area.
- Booklet on Concept of Watershed and on Rooftop Water Harvesting.
- Technical Awareness Brochures on Ferrocement Impervious Gabion.

8.1.2 SHARING OF INFORMATION

Information gathered and results obtained have been shared at various national level workshops and seminars, as detailed in table given below.

TABLE 8.1 WORKSHOPS AND SEMINARS

Attended by	Subject	Conducted by
B.K. Kakade & S.C. Kanekar	Seminar on remote sensing application	National Remote Sensing Agency, Hyderabad
B.K. Kakade	AFPRO National workshop on Participatory watershed management. Paper presented on - Capacity building on participatory watershed management.	AFPRO, New Delhi August 1995
B.K. Kakade	"Wasteland development through Farm forest" National workshop on experiences sharing - Paper presented on 'Peoples participation in Watershed development.	IFFCO, Udaipur March 1996
BAIF officers and representatives of other NGOs	Seminar on Geology & Environment	BAIF, Pune, February, 1996

8.2 TRAINING

Training, both formal and informal, has been a continuous activity right from the beginning of the project. Formal training in the relevant subjects to the project staff was useful in implementation of the programme. It also helped initiate innovative ideas in water resource development.

TABLE 8.2 FORMAL TRAINING

Attended by	Subject	Conducted by
A. Long Duration (International)		
B.K. Kakade	Ferrocement Technology (1993)	AIT, Bangkok, Thailand
B.D. Pakhare	Post graduate course in exploration, exploitation & management of groundwater resources (1995)	Hebru University of Jerusalem Faculty of Agriculture, Rehort, Israel
B. Short Duratiion (National level)		
Hydrogeologist	Ground water exploration	National Geographic Research Institute (NGRI), Hyderabad.
S.C. Kanekar	Interpretation of satellite imageries and use of remote sensing data	Satellite Application Centre, Ahmedabad.
Field officer (1)	Natural resource management with participation of local community	Centre for science & environment (CSE)
Field officers (2)	Data analysis & survey of watershed development	Yusuf Meherally Centre, Mumbai
B.K. Kakade	1. PRA/RRA Watershed development 2. Micro-irrigation	MANAGE, Hyderabad MCCI, Pune
Field officers (3)	Nursery raising	Central Research Station, Urulikanchan.
Field officer (1)	Ferrocement technology	Auroville,

In anticipation of future requirements, local youths from the community were trained in various soil and water conservation activities, in the first year itself. This was useful during implementation of the experimental measures. There are now 3-4 trained teams in each watershed development activity who have the requisite expertise. Areas covered under this kind of training are given in the following table.

TABLE 8.3 INFORMAL (ON-THE-JOB) TRAINING

Attended by	Subject	Conducted by
BAIF field implementation staff	a. Testing of soil permeability with the field permeameter b. Water table mapping. c. Testing radon levels in soil gas. d. Testing surface infiltration rates.	CWU project team
Local community	Soil and water conservation techniques especially - Gabion structures - Checkdams - Farm ponds - Meteorological data collection.	BAIF
Village youths	Masonry and ferrocement	CRS, Urulikanchan & BAIF Vansda campus.
Local community members	Watershed Management	Agricultural University (AU)

8.3 SEMINAR ON GEOLOGY AND ENVIRONMENT

Rationale

Why Geology and the Environment ? The answer lies in the fact that the geological processes responsible for the evolution of the Earth

- gave rise to many of the natural resources used by humans;
- continue to control the arrangement of materials at the planet's surface, where humans carry out their life activities;
- are susceptible to change as a result of human interference in ways that are harmful to humans.

It follows that we must have a knowledge of these processes and the ways in which they are inter-related, if we are to:

- efficiently explore for and develop a wide variety of natural resources;
- minimise risk to human lives and property from natural hazards;
- greatly reduce the impact of human activities on the environment.

Planning on ways of getting the maximum benefit from water, soil and accumulations of mineral resources is very much a matter for trained specialists. So too are the predictions and, sometimes, control of geological hazards whether natural or induced by industrial activity.

But it is the "non-specialists" making up the greater part of society who, to a large extent, control the land-use patterns affecting the environment by investing in private industry, purchasing products in the market place, and electing government policy-makers into office. Clearly, it is to the advantage of society that such control be exerted in an educated manner. We all stand to benefit as more and more people become aware of how geological processes influence their daily lives.

Objectives

To enable participants appreciate the role of earth processes.

Programme

Module 1

- Environmental Processes
- Earth Process
- Water

Module 2

- Human Interaction with the Environment
- Sanitary Landfills
- Medical Geology
- Land Use Planning

Faculty

The programme was conducted by Professor Frank Simpson, Department Of Geology, University Of Windsor, Windsor, Ontario, Canada - N9B 3P4. Prof. Simpson is an experienced geologist having world wide experience in geology and environment topics.

Duration and venue

The programme was held for one day on February 26, 1996 from 9.30 a.m. to 4.00 p.m. at Hotel Raviraj, Bhandarkar Institute Road, Pune - 411 004.

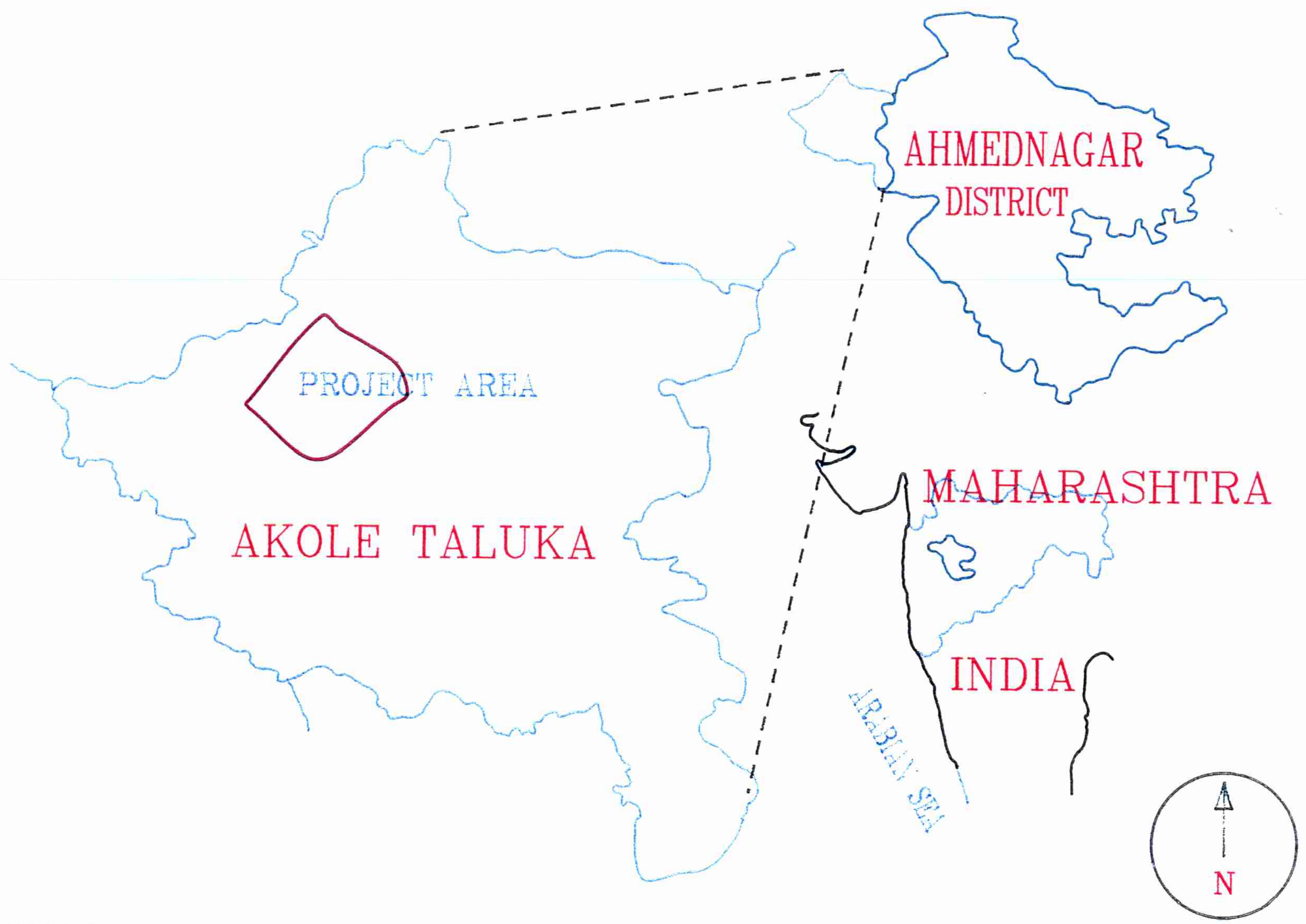
Participants

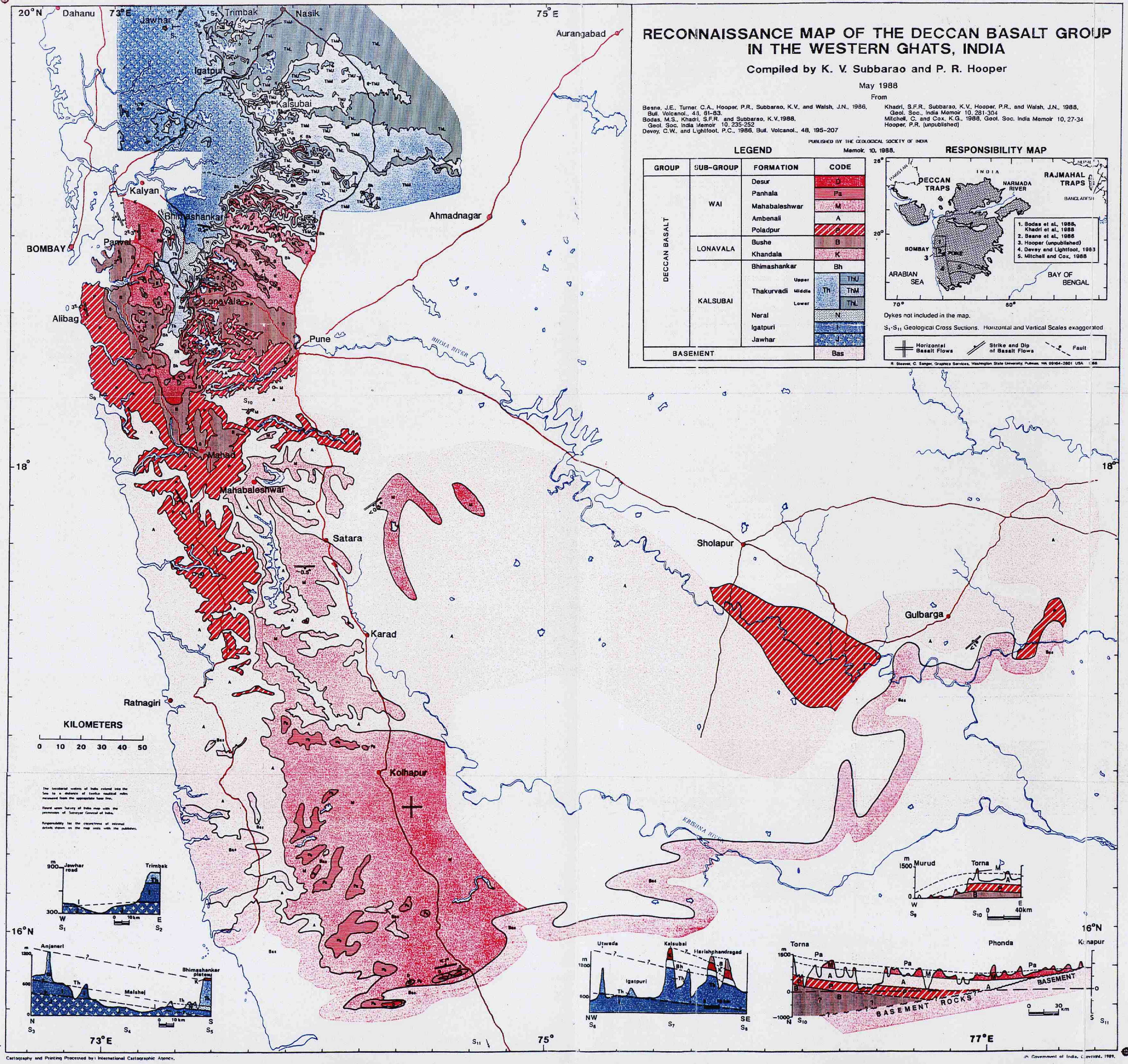
The programme was designed for development workers from NGOs, who are not geologists and are involved in field implementation of watershed or water resources development activities. Twenty four participants from BAIF, other NGOs and government departments attended the programme.

ANNEXURE 1

LOCATION MAP

PROJECT AREA : AKOLE TALUKA, MAHARASHTRA, INDIA



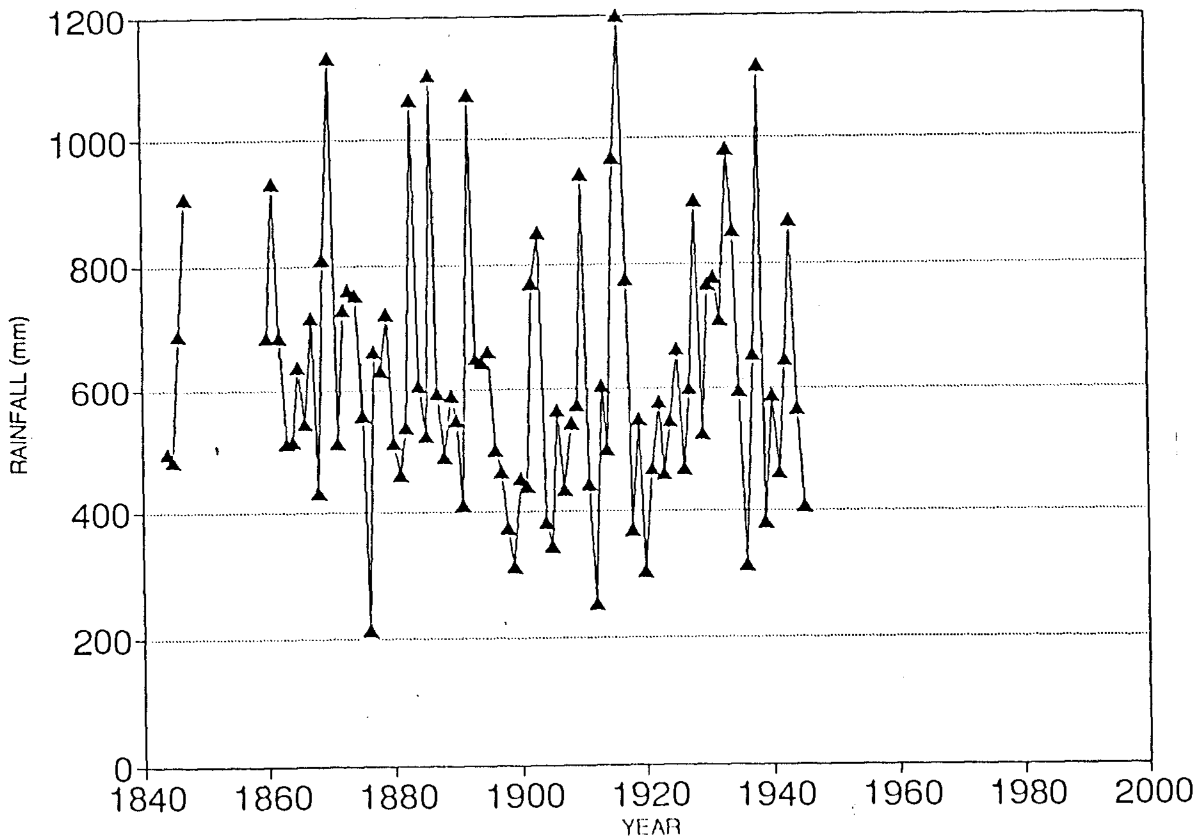


Cartography and Printing Processed by: International Cartographic Agency.

TIME SERIES OF RAINFALL

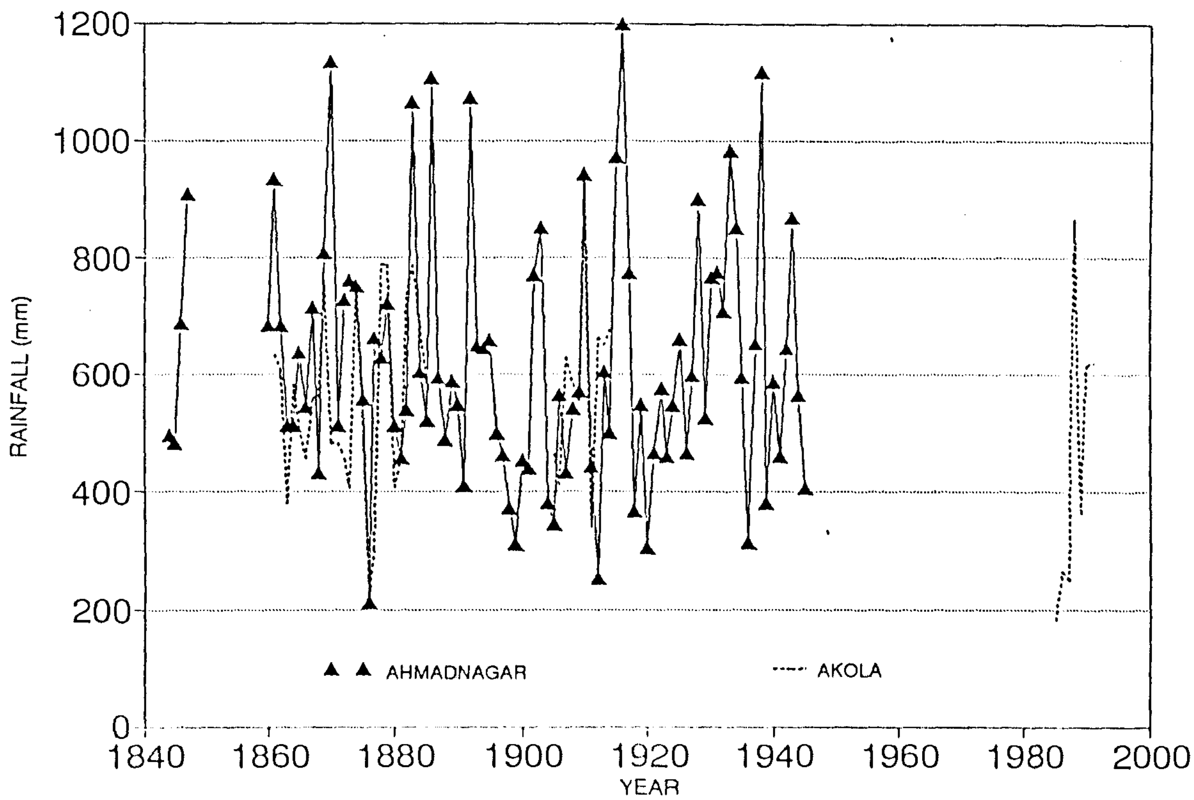
(Surrounding stations)

ANNUAL RAINFALL FOR AHMADNAGAR

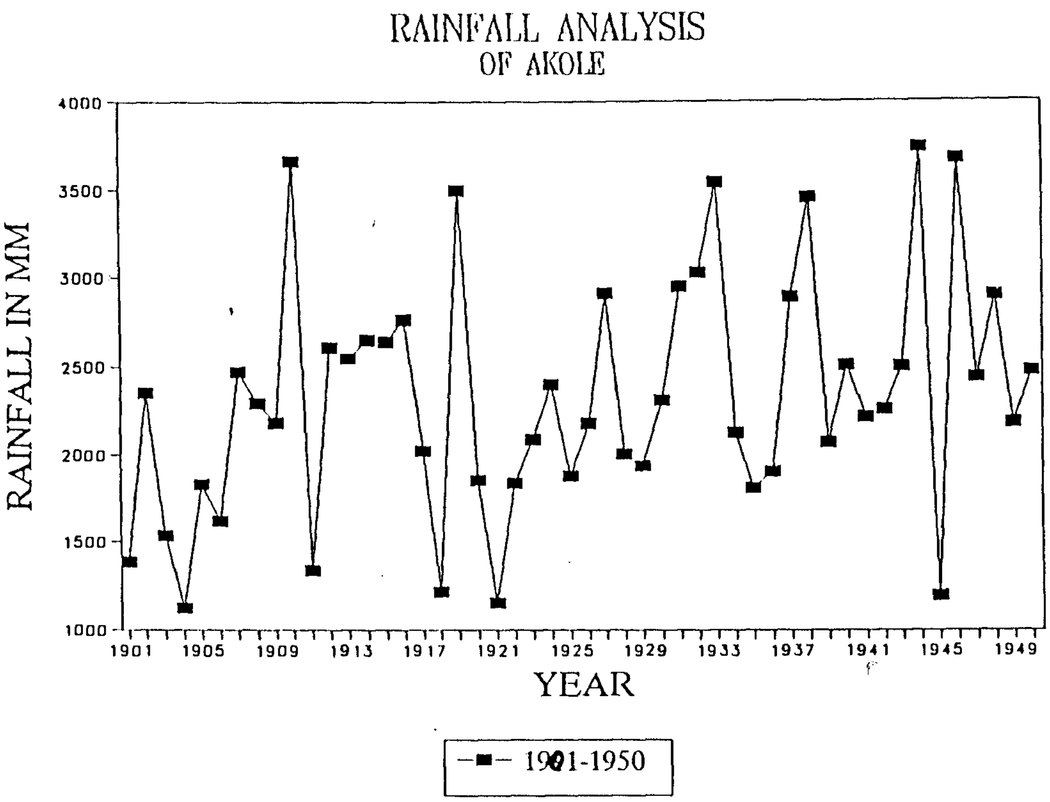


Credits: Blanford, 1886; McAlpin, 1983.

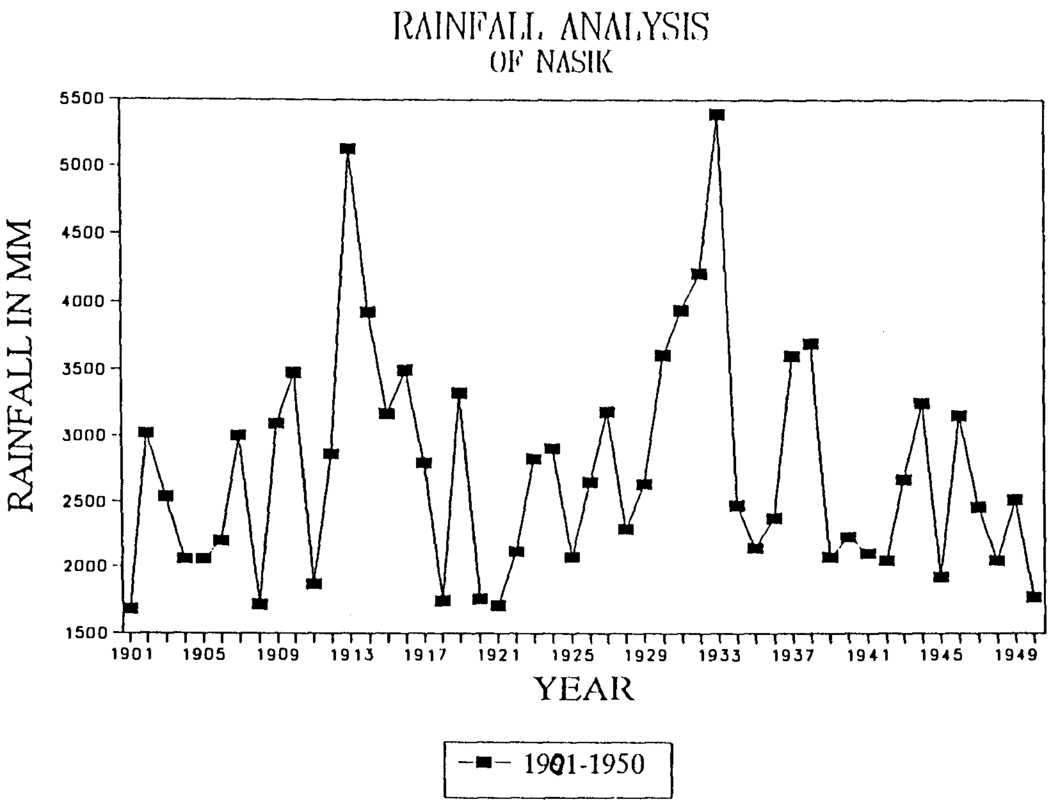
ANNUAL RAINFALL
AHMADNAGAR AND AKOLA



Credits: Blanford, 1886; Fletcher, 1988; Hey, 1916; McAlpin, 1983;
BAIF Development Research Foundation and University of Windsor, 1993.



RAINFALL ANALYSIS
OF AKOLE
RAINFALL IN MM
4000
3500
3000
2500
2000
1500
1000
1901
1905
1909
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
YEAR
1901-1950



RAINFALL ANALYSIS
OF NASIK
RAINFALL IN MM
5500
5000
4500
4000
3500
3000
2500
2000
1500
1901
1905
1909
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
YEAR
1901-1950

ANNEXURE 3

WELL INVENTORY

ANNEXURE 3

WATER RESOURCES IN AKOLE TALUKA

Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
MW1 Manhere Maruti Bhau Gabhale	Private excavation to the basalt in the main nalla. This is the northern most water source in the study area. 19°35.70N73°46.95E and 826m.	Yes-locals estimated a 30 cm overnite recovery. Seepage at 824 m.	15 cm overnight recovery. Seepage level at 824m.
MW2 Manhere Lalu Rama Zambade	Private, lined, large diameter dug well in the far eastern nalla : 19°35.65N73°47.24E and 830m.	Unknown-water level at 823 m.	Unknown water level at 823m.
MW3 Manhere Vijay Tukaram Zambade	Private blast hole in the far eastern nalla. 19°35.58N73°47.16E and 819m.	Yes - very small amount. Seepage at 815 m.	100 cm water depth
MW4 Manhere Dattu Rama Zambade	Private blast hole in the far eastern nalla and just west of a local hut: 19°35.56N73°47.13E and 814m.	Yes - very small amount. Seepage at 810 m.	
MW5 Manhere Chandar Laxman Zambade	Private blast hole at the nalla junction. Lining for the top 1.5m and a flow contact visible : 19°35.36N73°47.03E and 786m.	Unknown-but water level decreased slowly during the pre-monsoon season. Water level at 782-83 m.	
MW6 Manhere Poona Chima Zambade	Private dug well into basalt on the eastern hillside. Exhibiting a dyke (N35 W) approx. 15cm in width. Well is lined near the surface: 19°35.31N73°47.13E and 840m.	Yes-inflow evident through the dyke on the downslope side. Possibly return flow of spilled surface water. Water level at 835 m.	60 cm water depth
MW7 Manhere Sakharam Chima Zambade	Private, lined well into basalt in the main nalla: 19°35.23N73°46.98E and 780m.	Unknown-but water level decreased slowly during the pre-monsoon season. Water level at 774 m.	

Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
MW16 Manhere	Small (2m diameter),community well just south of the village: 19°34.65N73°47.47N and 761m.	Yes-inflow evident at a horizontal contact.Seepage at 758 m.	
MW17 Manhere Tukaram Bhau Gabhale	Large,private,lined well on the western edge of the main nalla:19°34.38N73°47.17E and 745m.	Unknown -water level at 739 m	15 cm water depth.
MW18 Manhere Tukaram Bhau Gabhale	Large,private,lined well on the northeastern edge of the main nalla. Vertical weak zone suggested by extended lining on opposite sides of the well. Hydro lines pass directly over this well. 19°34.19N73°47.36E and 731m.	Unknown-locals claimed yes. Water level at 722-23 m.	
MW19 Manhere Ravaji Gopal Gabhale	Small private blast hole on the northeastern hillside of the main nalla. This blast hole is just south of a dirt road that crosses the main nalla : 19°34.12N73°47.63E and 721m.	Yes-water level appeared to fluctuate from day to day. Water level at 719 m.	2.5 m of water depth.
AW1 Ambevangan Tulsa Dhondu Khetade	Private excavation at a relatively deep soil and murum pocket in the main nalla : 19°35.79N73°47.85E and 789m.	Yes-locals estimated a 50 to 60 cm.overnite recovery. Seepage at 782-83 m.	
AW2 Ambevangan Ganpat Laxman Dhande	Private blast hole at the base of the western slope of the western nalla:19°35.44N73°47.74E and 760m.	Unknown - water level at 755 m	
AW3 Ambevangan Keli Spring	Roadside community spring (kely spring) in the main nalla : 19°35.79N73°47.85E and 789m.	Yes - very small amount. Seepage at 749 m.	No seepage.
TW1 Titvi Public Well	Small, lined, community well in the lowest paddy field of the nalla: 19°34.42N73°49.42E and 706m.	Unknown-water level at 703 m.	30 cm water depth.

Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
MW8 Manhere Ramchandra Budha Zambade	Private blast hole on the eastern edge of the main nalla. Vertical zone of weathered rock is visible in the side of the hole: 19°34.99N73°47.13E and 771m.	Yes-locals estimated a slight overnite recovery. Water level at 767 m.	Slight overnight recovery.
MW9 Manhere Sampat Govinda Zambade	Two private blast holes on the eastern edge of the main nalla. Flor contact visible: 19°34.98N73°47.18E and 772m.	Yes-inflow evident at the flow contact in both holes. Locals estimated a 50 cm overnite recovery/ Seepage at 771 m.	
MW10 Manhere Ravaji Gopal Gabhale	Small excavation on the western edge of the main nalla. Appears to be at a flow contact:. 19°34.98N73°47.02E and 772m.	Yes-locals estimated a 20 cm overnite recovery.Seepage at 771 m.	
MW11 Manhere Maruti Dagadu Gabhale	Private,large diameter blast hole in the main nalla. Vertical zone of weathered rock is visible in the hole on bearing (N45 W) : 19°34.88N73°47.12E and 764m.	Yes - locals estimated a 4 m recovery within a week. Water level at 760 m.	30 cm water depth.
MW12 Manhere Bhiva Kisan Gabhale	Private,relatively deep, lined well in the main nalla: 19°34.82N73°47.13E and 761m.	Yes - locals estimated a 30 cm overnite recovery. Seepage at 754 M	15 cm water depth
MW13 Manhere Public Well	Large, roadside, community well just east of the village Gram Panchayat well: 19°34.87N73°47.62N and 773m.	Yes-locals estimated a 20 cm overnite recovery. Water level at 765 m.	15 cm overnight recovery.
MW14 Manhere Public well	Small, community well southeast of the Gram Panchayat well: 19°34.83N73°47.62N and 772m.	Unknown - water table at 768 m.	30 cm overnight recovery.
MW15 Manhere Mahadu Gopala Ghorpade	Private blast hole downvalley from the two community wells: (MW 13&14) 19°34.75N73°47.67N and 767m.	Unknown - water table at 766 m.	30 cm overnight recovery.

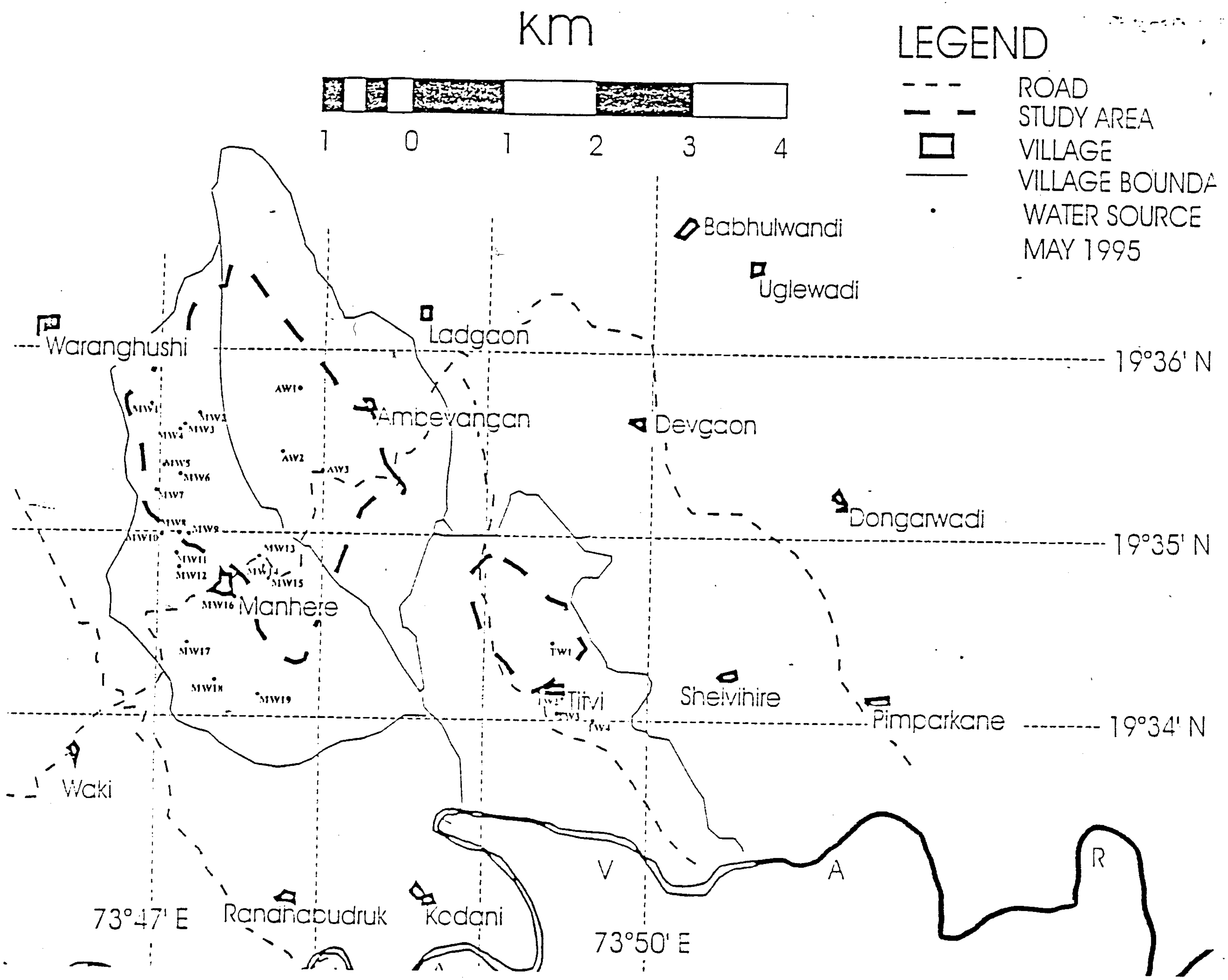
Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
TW2 Titvi Public Well	Deep, community well in the southeast corner of the village. Near surface portion is lined. 19^{0}34.13N73^{0}49.44E and 744m.	Yes-locals estimated a 40 L overnite recovery.Seepage from a vertical joint at 741 m.	
TW3 Titvi Harishandra Shankar Mundhe	Private blast hole south of the village. 19^{0}34.04N73^{0}49.46E and 732m.	Unknown-owner claimed that horizontal seepage occurred at 726m. Water level at 728m.	2.75 m water depth.
TW4 Titvi Public Well	Square, community well southeast of the village. An Umber tree is growing out of the inside of the well lining : 19^{0}34.00N73^{0}49.67E and 706m.	Yes-locals estimated a 100 Litre overnite recovery. Seepage at 696m.	30 cm water depth.

ANNEXURE 4

LOATION MAP

OF

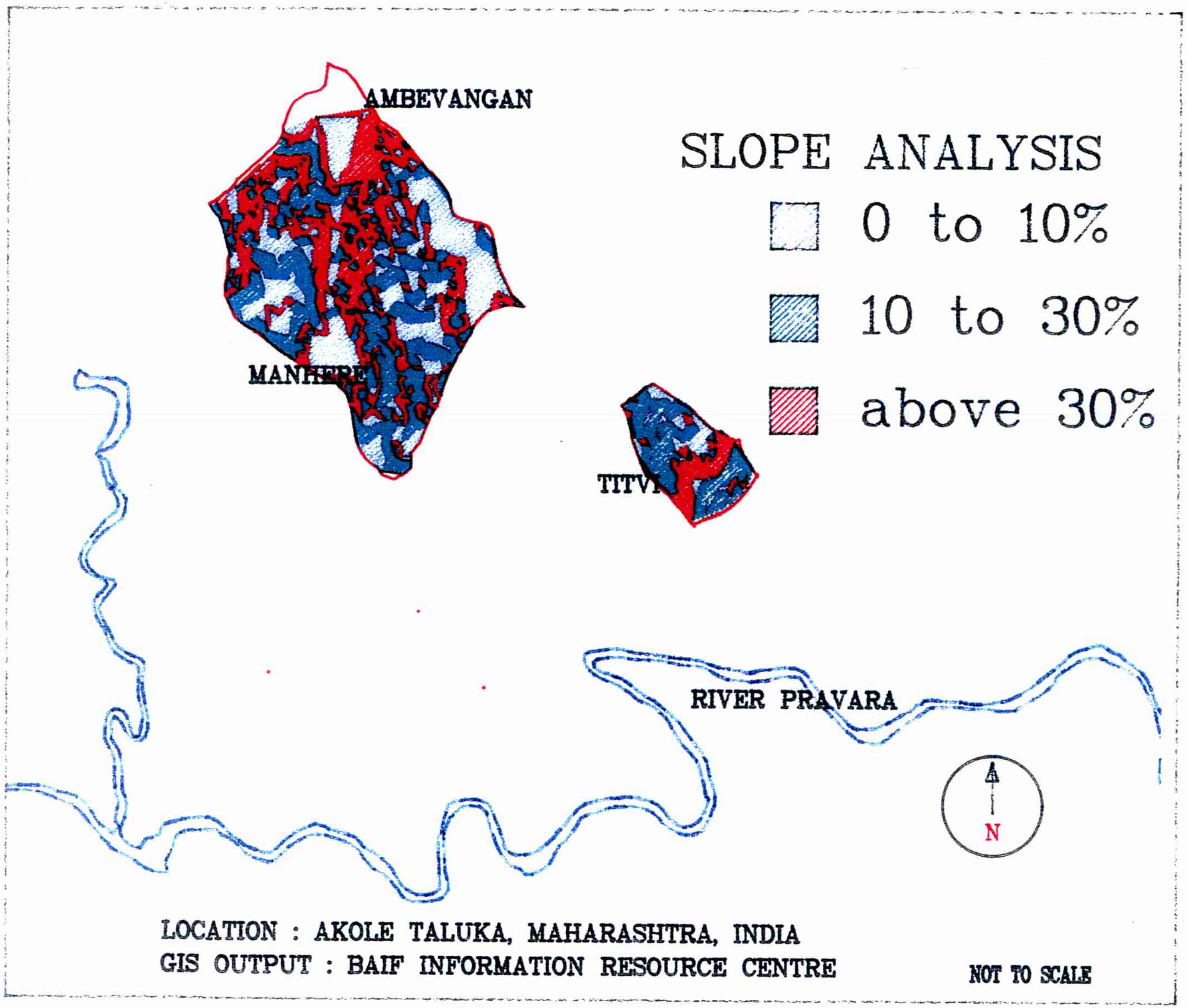
WELL INVENTORY SITES



Km
1 0 1 2 3 4
LEGEND
ROAD
STUDY AREA
VILLAGE
VILLAGE BOUNDA
WATER SOURCE
MAY 1995
Babhulwandi
Uglewadi
Waranghushi
Ladgaon
Ambevangan
Devgaon
Dongarwadi
Manhere
Tirvi
Shelvihire
Pimparkane
Waki
Ranahabudruk
Kodani
19°36' N
19°35' N
19°34' N
73°47' E
73°50' E
V
A
R

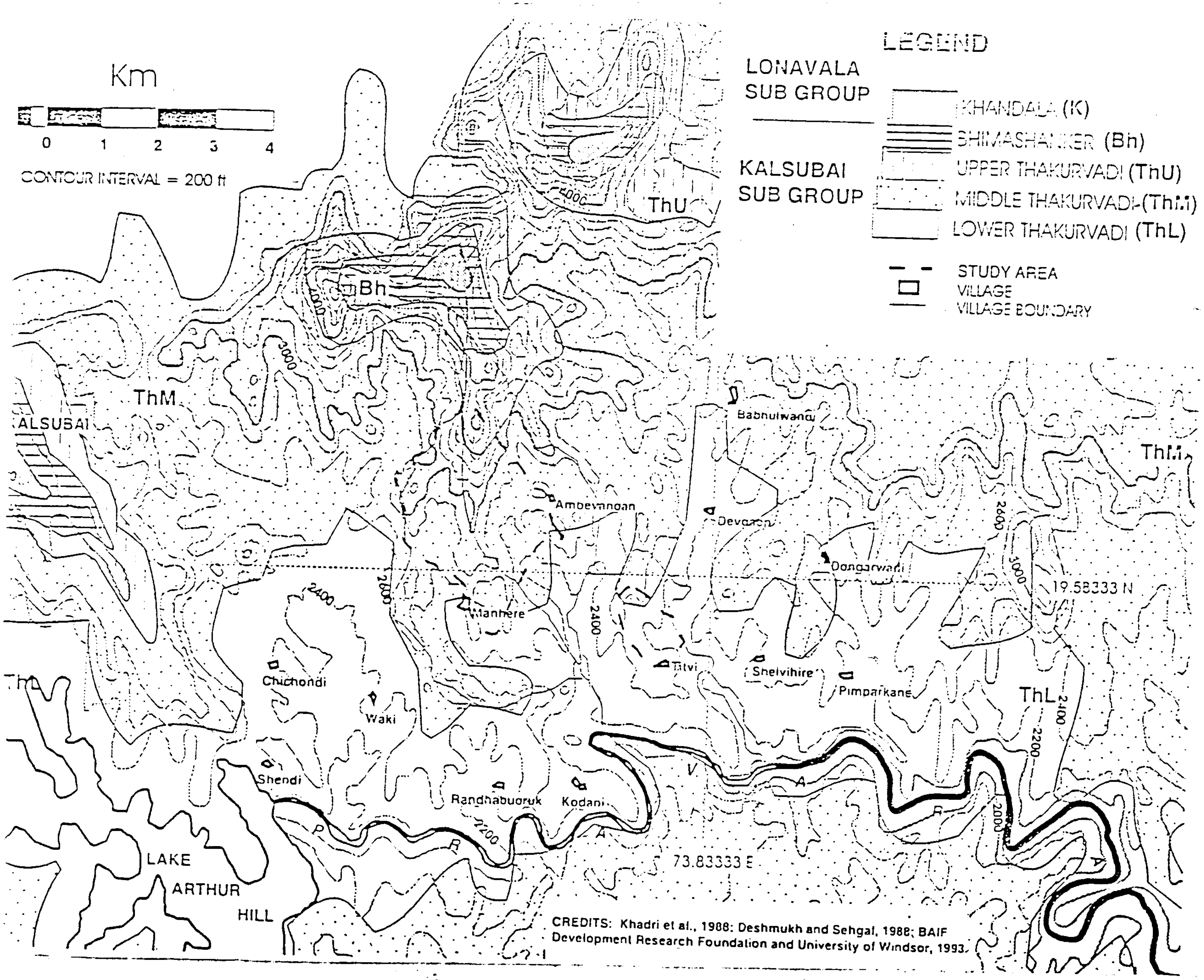
ANNEXURE 5

SLOPE GROUP MAP


AMBEVANGAN
MANHERE
TITVI
RIVER PRAVARA
N
SLOPE ANALYSIS
0 to 10%
10 to 30%
above 30%
LOCATION : AKOLE TALUKA, MAHARASHTRA, INDIA
GIS OUTPUT : BAIF INFORMATION RESOURCE CENTRE
NOT TO SCALE

ANNEXURE 6

PRELIMINARY GEOLOGICAL MAP


Km
0 1 2 3 4
CONTOUR INTERVAL = 200 ft
LEGEND
LONAVALA SUB GROUP
KHANDALA (K)
BHIMASHANKER (Bh)
KALSUBAI SUB GROUP
UPPER THAKURVADI (ThU)
MIDDLE THAKURVADI (ThM)
LOWER THAKURVADI (ThL)
STUDY AREA
VILLAGE
VILLAGE BOUNDARY
Bh
ThU
ThM
ThL
KALSUBAI
Babnulwandi
Ambevangan
Devgaon
Dongarwadi
19.58333 N
Manhere
Titvi
Shelvihire
Pimparkane
Chichondi
Waki
Shendi
Randhabuoruk
Kodani
73.83333 E
LAKE
ARTHUR
HILL
2000
2200
2400
2600
3000
4000
CREDITS: Khadri et al., 1988; Deshmukh and Sehgal, 1988; BAIF Development Research Foundation and University of Windsor, 1993.

ANNEXURE 7

METASOMATISM AND
WEATHERING MODIFICATIONS
OF
BASALTS GEO-CHEMISTRY

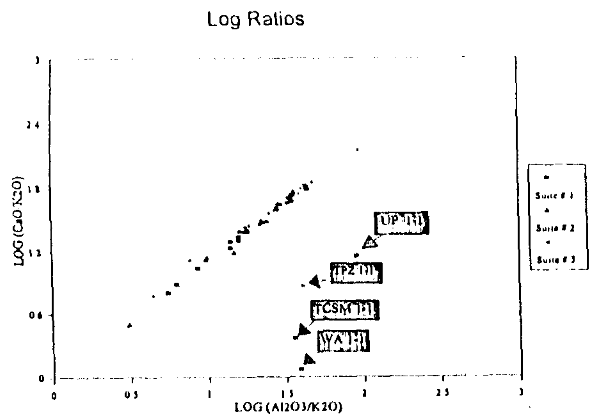


Figure 7.1

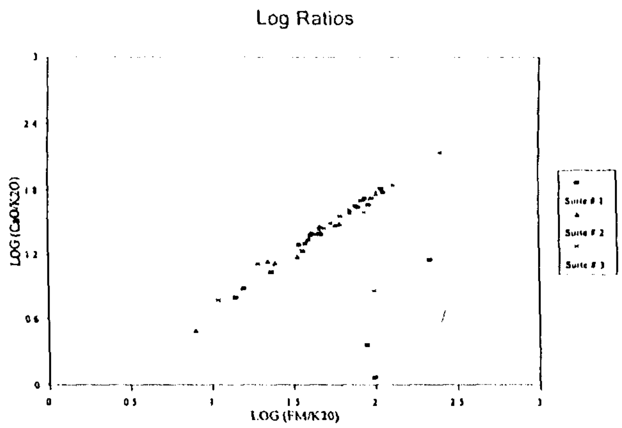


Figure 7.2

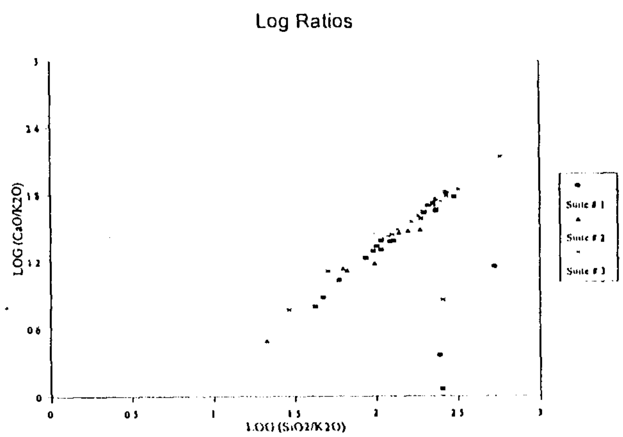


Figure 7.3

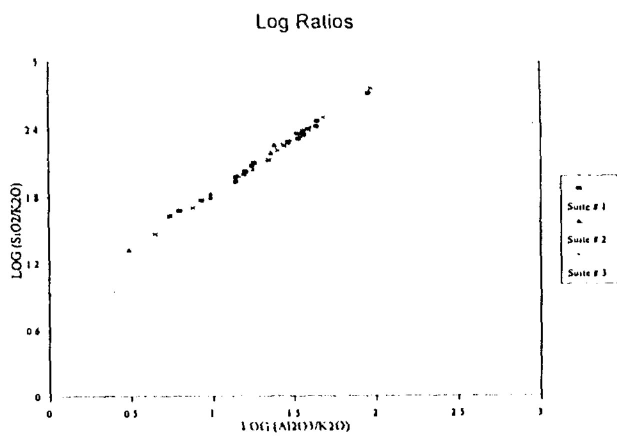


Figure 7.4

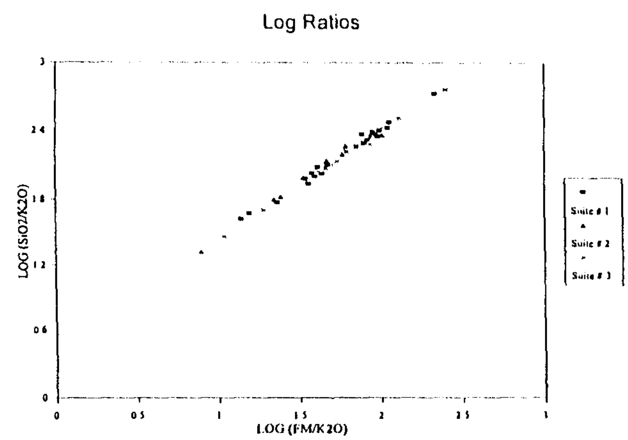


Figure 7.5

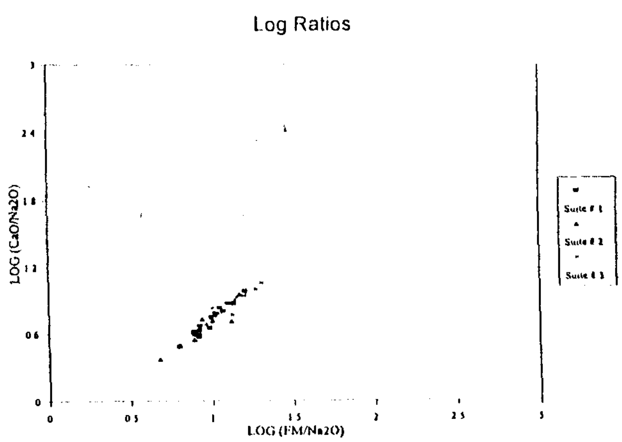


Figure 7.6

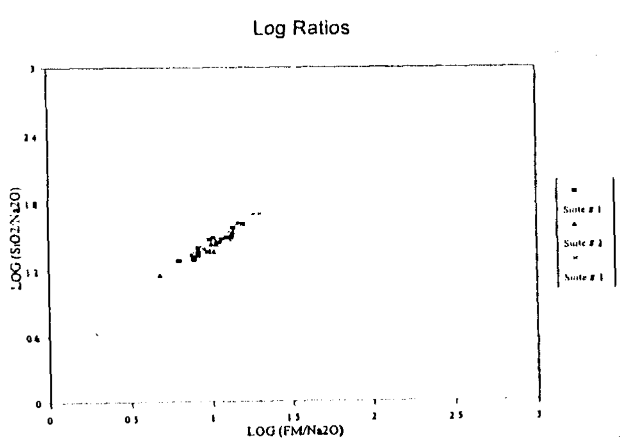
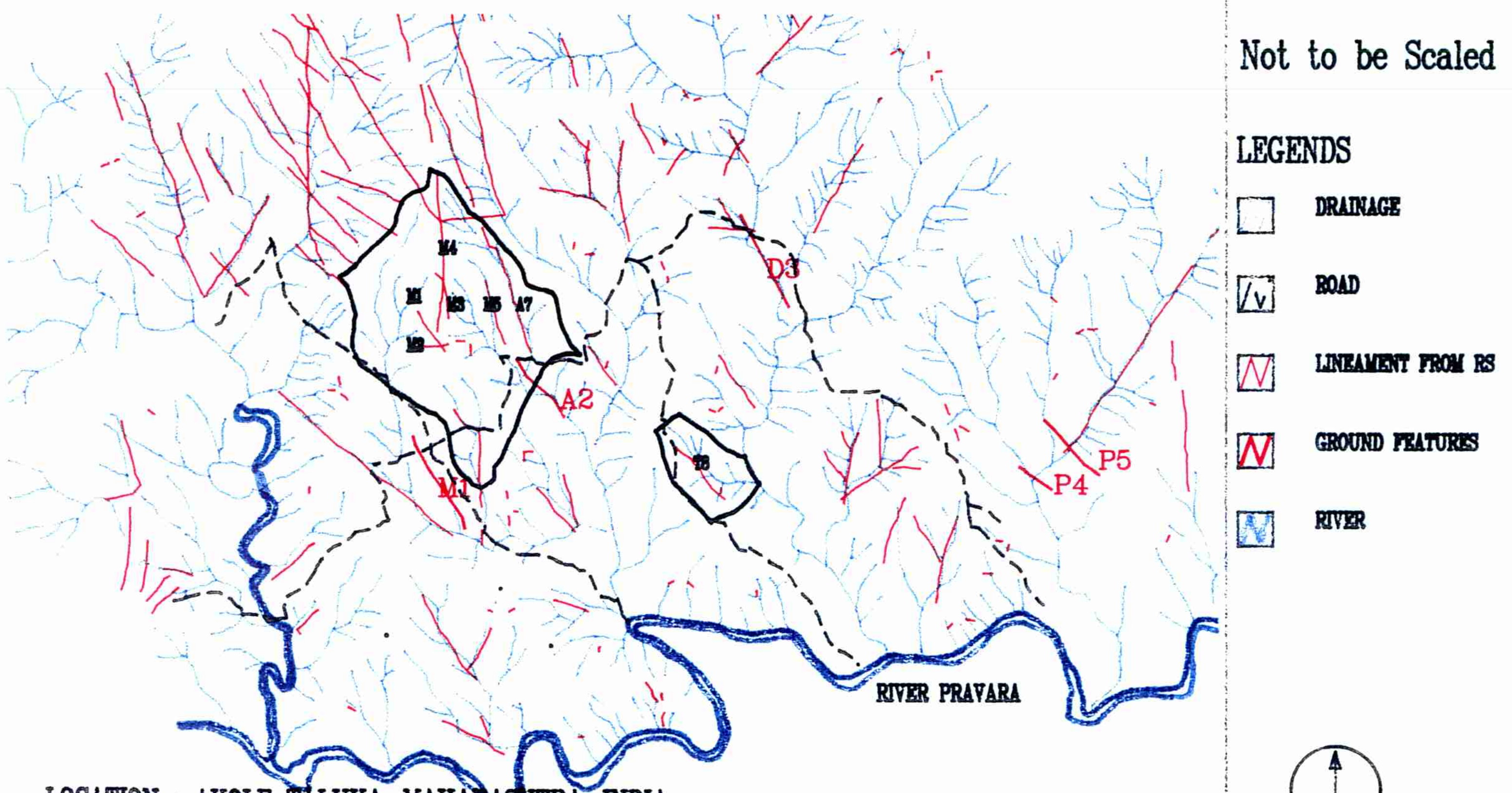


Figure 7.7

ANNEXURE 8

LINEAMENT MAP

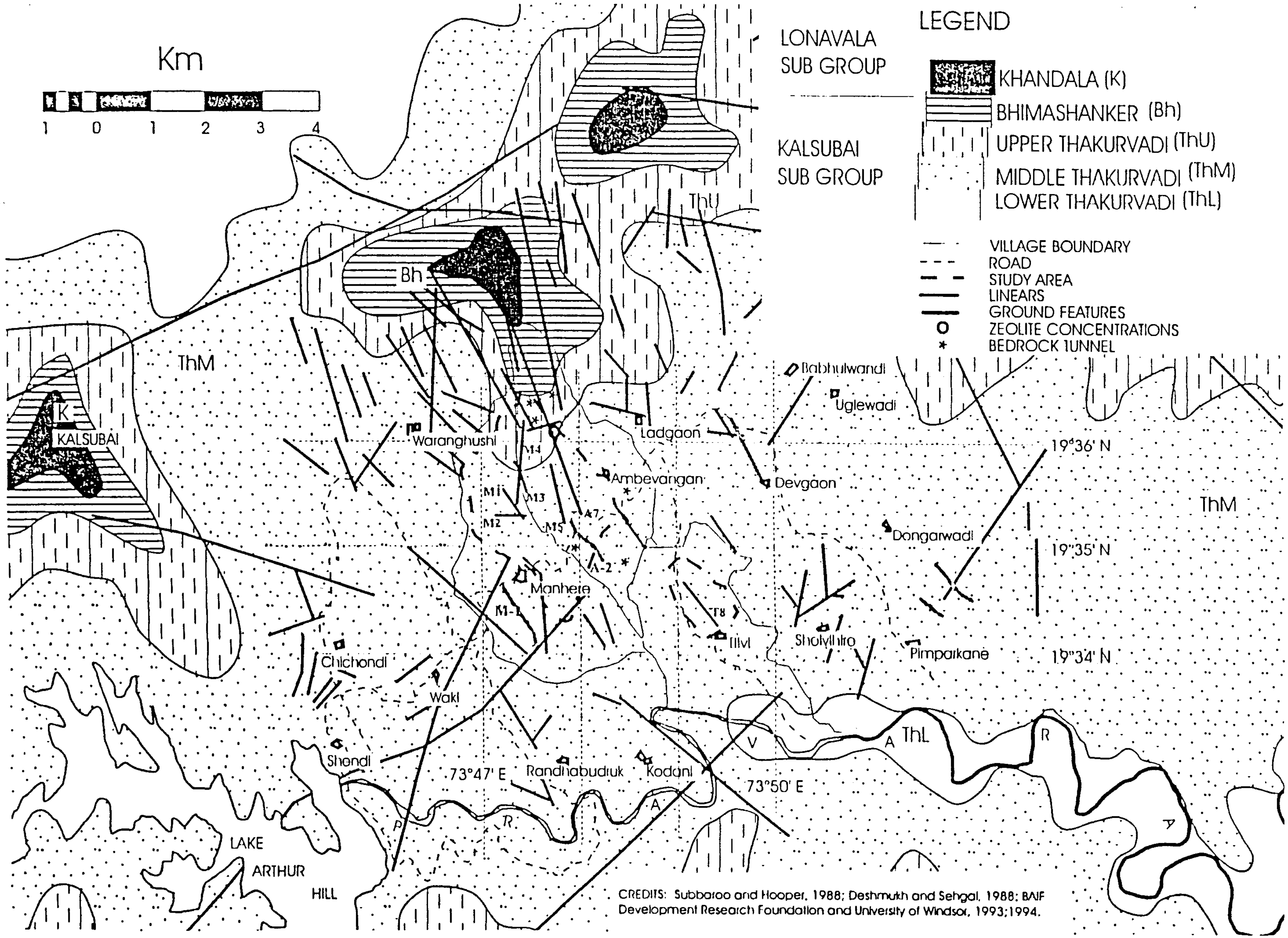
LINEAMENTS AND OTHER GROUND FEATURES



LOCATION : AKOLE TALUKA, MAHARASHTRA, INDIA

GIS OUTPUT : BAIF INFORMATION RESOURCE CENTRE

GROUND FEATURES MAP

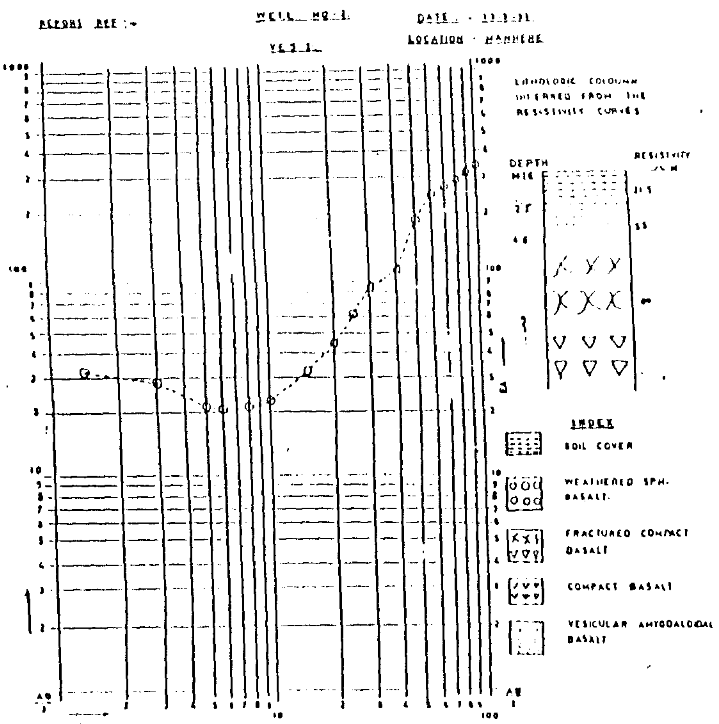


Km
1 0 1 2 3 4
LEGEND
LONAVALA SUB GROUP
KALSUBAI SUB GROUP
KHANDALA (K)
BHIMASHANKER (Bh)
UPPER THAKURVADI (ThU)
MIDDLE THAKURVADI (ThM)
LOWER THAKURVADI (ThL)
VILLAGE BOUNDARY
ROAD
STUDY AREA
LINEARS
GROUND FEATURES
ZEOLITE CONCENTRATIONS
BEDROCK TUNNEL
Bh
ThU
ThM
ThL
K
KALSUBAI
Babhulwandi
Uglewadi
Ladgaon
Waranghushi
Ambevangan
Devgaon
Dongarwadi
Manhere
Chichondi
Waki
Shendi
Tirvi
Sholyihiro
Pimparkane
Randhabudruk
Kodani
19°36' N
19°35' N
19°34' N
73°47' E
73°50' E
LAKE
ARTHUR
HILL
CREDITS: Subbarao and Hooper, 1988; Deshmukh and Sehgal, 1988; BAIF Development Research Foundation and University of Windsor, 1993;1994.

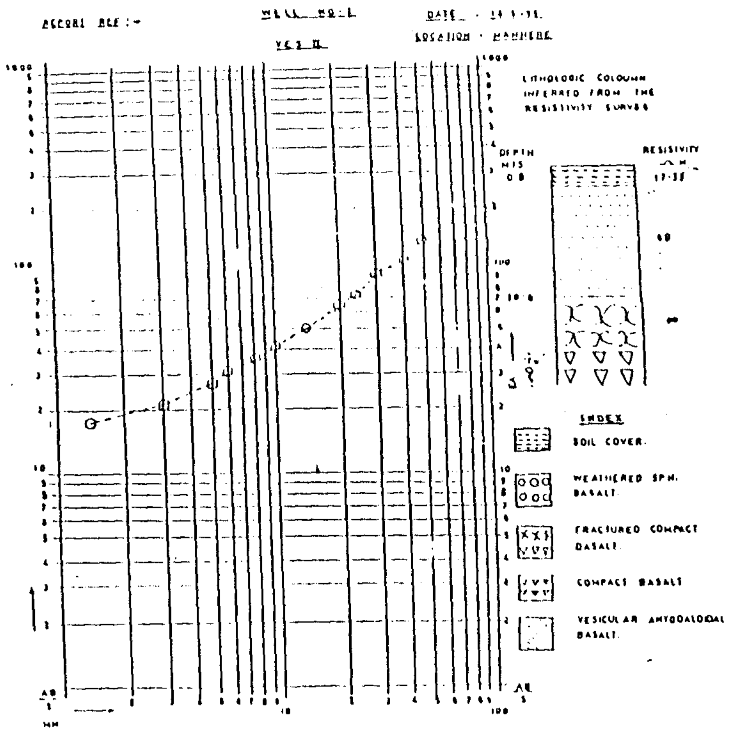
ANNEXURE 10

LITHOSTRATIGRAPHIC OF

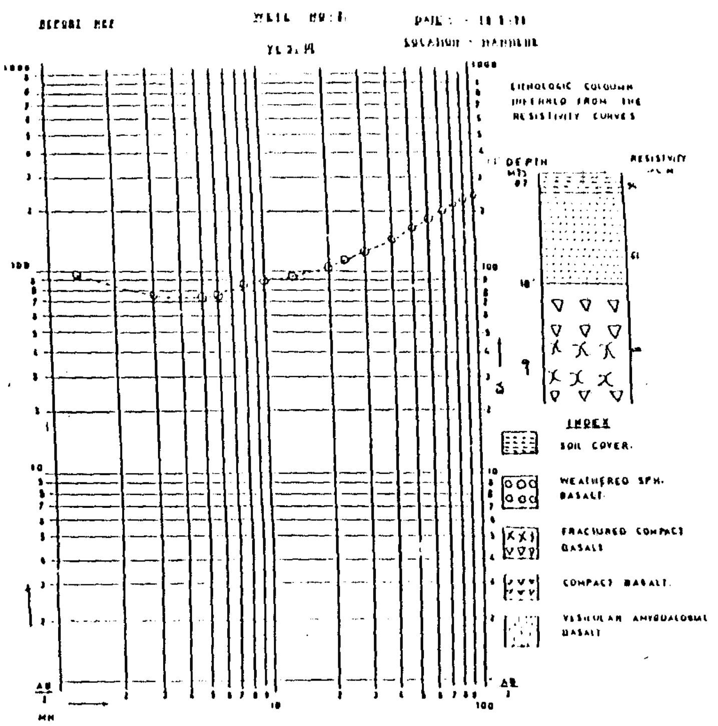
MANHERE WELLS AND VES



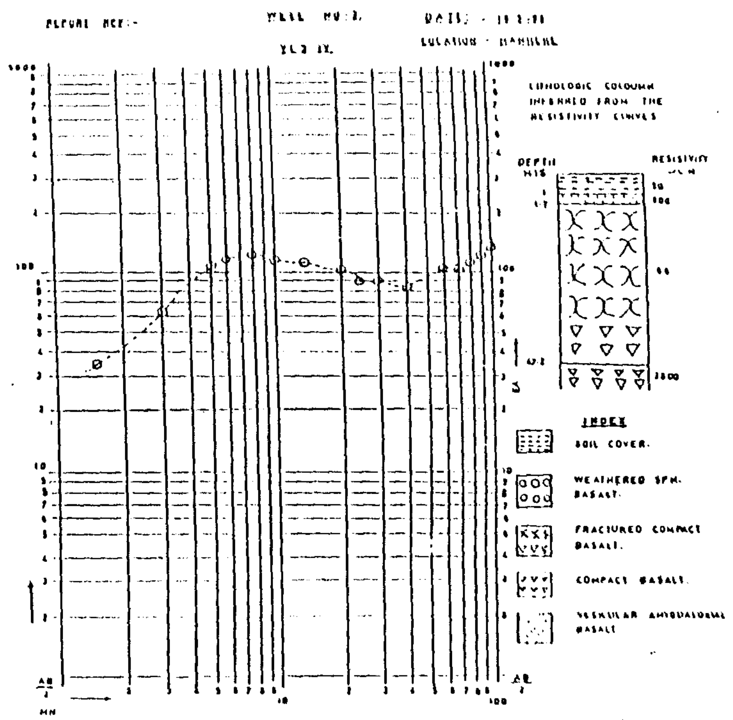
VERTICAL ELECTRICAL SOUNDING
FIELD CURVE



VERTICAL ELECTRICAL SOUNDING
FIELD CURVE

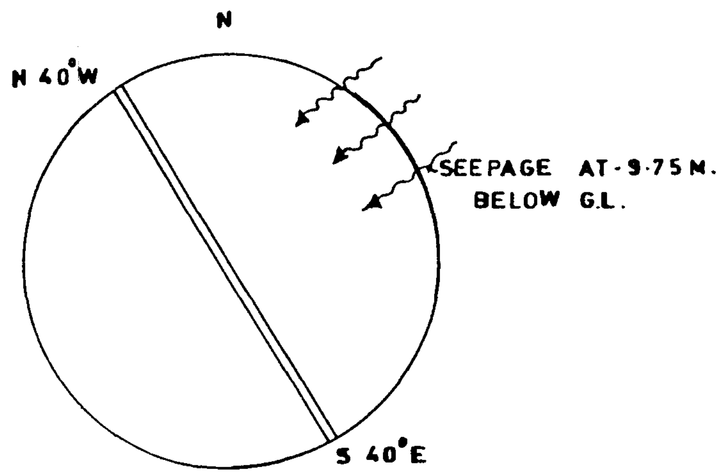


VERTICAL ELECTRICAL SOUNDING
FIELD CURVE

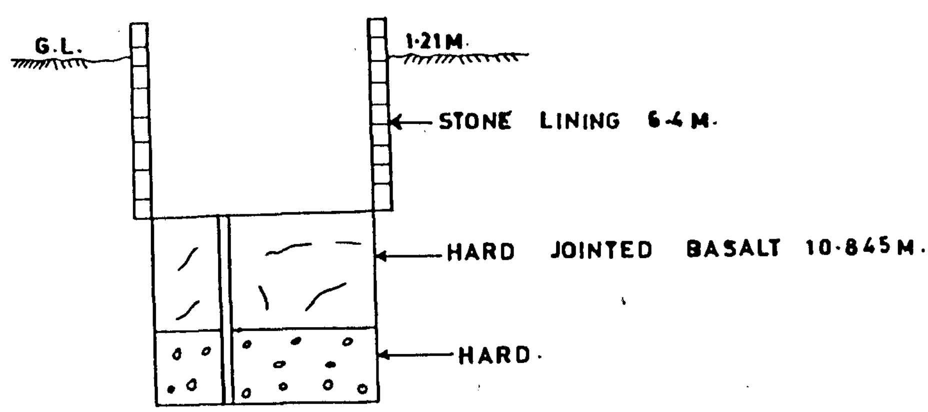


VERTICAL ELECTRICAL SOUNDING
FIELD CURVE

COMMUNITY WELL AT - MANHERE



PLAN



SECTION

ANNEXURE 11

PERMEAMETER TESTS

ANNEXURE 11 - A

FIELD PERMEAMETER TESTS FOR 1993

Test site	Land owner	Description	Depth (m)	Kfs (m/s)
Amb-1a	Devram Yeshy Dhandhe	Paddy field in the eastern nalla of the Ambevengan study area situated immediately above the highest well (spring) in the nalla.	0.38	9.7×10^{-8} SEA
Amb-1b	Devram Yeshu Dhandhe		1.05	1.1×10^{-7} SEA
Amb-1c	Devram Yeshu Dhandhe		2.04	9.6×10^{-8}
Amb-d	Devram Yeshu Dhandhe		2.24	1.7×10^{-7}
Amb-2a	Lalu Rama Bhojane	Paddy field in the middle nalla of the Ambevengan study area located 2 fields upstream of the junction of the western nalla.	0.4	6.1×10^{-3}
Amb-2b	Lalu Rama Bhojane		0.85	7.6×10^{-8}
Amb-4a	Tukarama S. Khatade		0.35	7.5×10^{-8}
Man-1a	Kisan Ghabhade	Paddy field immediately above the subsurface barrier in the Manhere study area.	0.35	1.4×10^{-7}
Man-1b	Kisan Ghabhade		0.85	1.9×10^{-6}
Man-c	Kisan Ghabhade		1.0	2.3×10^{-6} SEA
Titvi-1a	Kalu Bhaga Mundhe	Paddy field in the main nalla of the Titvi study area. The field immediately down vally of the highest well in the nalla. (Test hole in the western half.)	0.75	2.3×10^{-8}
Titvi-1b	Sakharam Bhaga Mundhe	(Test hole in the eastern half.)	0.75	1.6×10^{-8}
Titvi-1c	Kalu Bhaga Mundhe		1.4 #	1.3×10^{-7}
Titvi-2	Kalu Gaunga Mundhe	Paddy field on the western hill side of the Titvi study area.	0.75	3.8×10^{-7} SEA
Titvi-3a	Ramchandra N. Mundhe	Lowest paddy field in the Titvi study area.	0.35	2.0×10^{-8}
Titvi-3b	Ramchandra N. Mundhe		1.0	2.0×10^{-7} SEA
Titvi-3c	Ramchandra N. Mundhe		1.55 #	4.3×10^{-8}

#-test hole with rock bottom SEA-simultaneous equations approach

ANEXURE 11 - B

TABLE 3 FIELD PERMEAMETER TESTS FOR 1995

Test site	Description and Location	Depth (m)	K_{fs} (m/s)
Amb-sp	Soil pocket in the eastern nalla of the Ambevangan study area situated adjacent a deep (6m) spring in an earth hole: 19o15.79'N 71 17.85'E	0.55	9.2×10^{-7}
Amb-Spb	Paddy field immediately south of the above mentioned earth hole.	0.53	1.3×10^{-6} SEA
Amb-hill1 * Amb-1p	Infiltration pit on the western hillside of the kelly spring nalla. Three paddy fields north of the road: 19°35.39'N 73°47.99'E	0.23	3.5×10^{-6} SEA
Amb-hill2	Infiltration on the western hillside of the kelly spring nalla. Next terraced level above the previous lacation.	0.23	3.8×10^{-6}
Man-hill1 * Man-DW	Terraced ledge on the eastern hillside of the main nalla directly above the dyke well: 19°35.31'N 73°47.13'E	0.26	7.0×10^{-6}
Man-hill2	Same as above	0.32	4.9×10^{-6}
Man-mur 1	Weatherd basalt in the main nalla of Manhere. One paddy field east of a large diameter balst hole.	0.2	2.4×10^{-6} SEA#
Man-mur2	Weathered basalt on western edge of the main nalla in Manhere. 19°34.98'N 73°47.02'E	0.2	2.9×10^{-6} SEA#
Man-chan 1	Soil cover on the eastern hillside of the main nalla in Manhere and south of the village. 19°34.40'N 73°47.18'E	0.26	8.7×10^{-7} SEA
Man-chan2	Same as above	0.53	1.4×10^{-6} SEA#
Man-chan3	Same as above	0.2	1.4×10^{-6}

#- test hole in or on weathered basalt (murum)

SEA - simultaneous equitations approach

* soil sample analyzed

ANNEXURE 12

SOIL MOISTURE, POROSITY, BULK DENSITY AND TEXTURE

ANNEXURE 12 A

Soil parameters

Sample	Depth (m)	Field moisture (% soil vol.)	Porosity (% soil vol.)	Bulk Density (g/cm3)
Titvi-1:t1-.2	0.2	35.9	44.3	1.26
Titvi-1:t1-.4	0.4	41.8	44.3	1.34
Titvi-1:t1-.6	0.6	38.1	46.1	1.22
Titvi-1:t1-.8	0.8	47.7	50.1	1.24
Titvi-1:t1-.1.0	1.0	43.1	47.6	1.28
Titvi-11:t2-.2	0.2	48.1	50.3	1.32
Titvi-1:t2-.6	0.4	46.5	48.2	1.63
Titvi-1:t2-.8	0.6	43.5	48.1	1.27
Titvi-1:t2-.1.0	0.8	41.7	50.8	1.17
Titvi-3	1.0	45.2	47.0	1.37
Titvi-3	0.35-0.4	37.6	47.8	1.16
Titvi-3	1.0-1.05	47.8	52.6	1.34
Titvti-3	1.5-1.55	23.2	39.2	1.52
Amb-1	0.35-0.4	44.4	52.6	1.42
Amb-1	1.0-1.05	40.9	48.9	1.38
Amb-2	0.35-0.4			
Amb-4	1.4-1.45			
Man-1	0.8-0.85			
man-1	0.95-1.0			

Note : Titvi-1 core samples were collected horizontally from two walls of a soil pit.

ANNEXURE 12 B

Sample	Description and Location	Collection date	Depth (m)	Fine Gravel and sand %	Silt %	Clay %	Texture
Amb-P1	Paddy field: second above the kelly spring	1995	0.2	37	61	2	Silt loam
Amb-KS	Paddy field: immediately above the kelly spirng: 19.35.39'N 73 47.99'E	1995	0.2	36	63	1	Silt loam
Amb-4	Paddy field: third above kelly spring 19 35.39'N 73 47.99'E	1993	1.4	13	86	1	Silt
Amb-TENS	Paddy field:third above the kelly spring	1995	0.4	44	55	1	Silt loam
Amb-IP	Infiltration pit on the western hillside of the kelly spring nalla West of Amb-4's location	1995	0.3	43	55	2	Silt loam
Man-FW	Paddy field:Main nalla of Manhere near a large diameter blast hole:19 34.88'N 73.47.12'E	1995	0.2	21	76	3	Silt loam
Man-1B	Field immediately above the subsurface dam : 19 35.31'N 73 46.95'E	1993	0.8	62	37	1	Sandy loam
Man-DW	Terraced ledge on the eastern hillside of the main nalla directly : 19 35.31'N73 47.13'E	1995	0.2	34	65	1	Silt loam
Man-G	Storage area behind the gablon structure in uppr reaches of the main nalla: 19 35.91'N 73 46.95'E	1995	0.2	69	30	1	Sandy loam

ANNEXURE 13

ELECTRICAL CONDUCTIVITY

ANNEXURE 13

ELECTRICAL CONDUCTIVITY MEASUREMENTS FOR 1993.

Village	Site Description	Conductivity (μ/cm)
Titvi	Community dugwell located in the lowest paddy field (Titvi-3) of the study area.	260 *
Titvi	Rivulet water flowing across the lowest paddy field (Titvi-3) of the study area.	270 *
Titvi	Rivulet water emerging from the bottom of the stone bund below the lowest paddy field (Titvi-3) of the study area.	250 *
Titvi	Rivulet water of the main nalla immediately upstream of the Devgaon junction.	225 *
Titvi	Privte blast hole on the south side of the main nalla 6 fields upstream from the community well. (owned by Nana Q. Mundhe)	240 *
Titvi	Private dugwell located in the main nalla. This well is the highest in the main nalla. (owned by Kalu Bhaga Mundhe)	240 *
Titvi	Private blast hole on the north-eastern ridge. Water drainage is easterly towards Devgaon nalla. (owned by Sakharam B. Mundhe)	190 * 210 * (inflow)
Titvi	Private dugwell on the north-eastern ridge. The well is located at the top of a step east facing gully (onwed by Kisan B. Mundhe)	220 *
Titvi	Community dugwell on the north-eastern ridge	190 *
Titvi Titvi	Private dugwell in a small valley on the western side of the main nalla (6 paddy fields away). (Owned by Jamana S. Mundhe) Private dugwell (shallow pit) on the western side of the main nalla. (owned by Jamana S. Mundhe)	210 * 200 *
Titvi	Community well on the hilltop adjacent to the village.	170 *
Ambevangan	Rivulet water flowering across the paddy field immediately above the kelly spring (road)	310 *
Ambevangan	Private well (developed spring) in the main eastern nalla. Located 16 paddy fields upstream of the kelly spring. (owned by Ganpat L. Dhandhe)	300 * 290 & 315 (inflows)
Ambevangan	Rivulet water flowering across a paddy field (Amb-2) in the middle nalla located two fields above the junction of the western nallas.	270
Ambevangan	Rivulet water from the western nalla immediately above the junction with the middle nalla.	280 *
Ambevangan	Private dugwell in the paddy field of the western nalla located immediately upstream of the junction with the middle nalla. (owned by Shivrama S. Ghadhe)	240 *
Ambevangan	Private spring on the western ridge close to the village boundary. (owned by Maruti G. Gabhale)	240 *
Manhere	Private dugwell in the main nalla near the end of the dirt road.	270 *

	(owned by Maruti G. Gabhale)	
Village	**Site Description**	**Conductivity (μ/cm)**
Manhere	Private dugwell in the far eastern nalla at the area with four wells. This well is located in a deep soil pocket on the western side of the field (owned by Budha D. Zambade)	270 *
Manhere	Private dugwell in the far eastern nalla at the area with four wells. This well is located in the middle of the four wells. (owned by Sakharam C. Zambade)	270 *
Manhere	Rivulet water junction in the main nalla to the west of the village.	170 * & 260 (West & east)
Manhere	Community bored well in the main nalla (above the road) to the west of the village.	240 *
Manhere	Private blast hole to the west of the village directoly north of the ceremoial house on the road's edge.	290 *

* - Water sample collected.

ANNEXURE 14

SURFACE INFILTRATION TESTS

(1995)

ANNEXURE 14

Surface Infiltration Tests for 1995

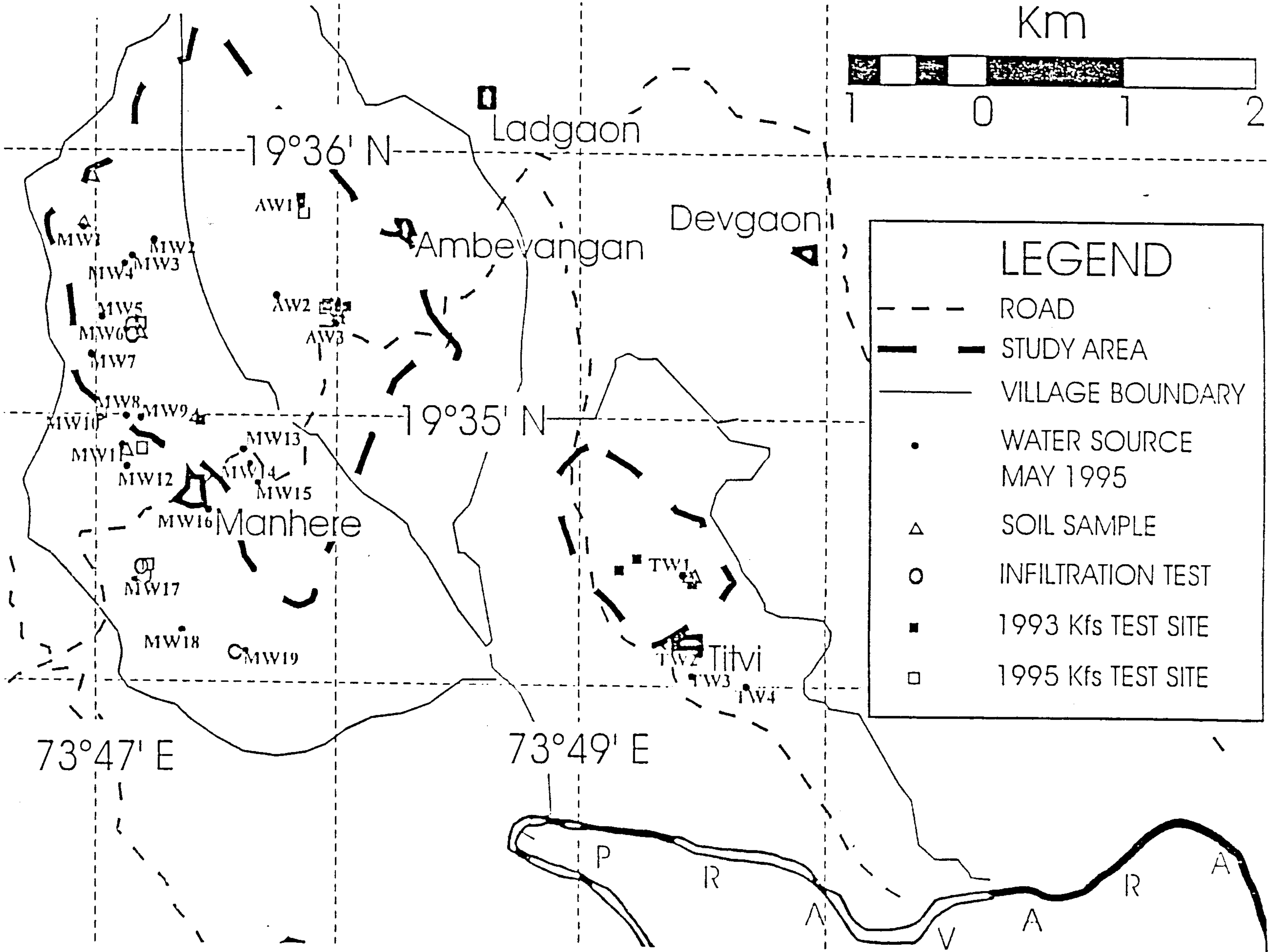
Test site	Description and location	Size	Infiltration Rate (m/s)
Man-paddy (Soil surface)	Paddy field south of village in the main nalla: 19°34.12'N 73°47.63'E	Lined 20x20 cm	Test#1:1.7x10^{-5} Test#2:1.48x10^{-5}
Man-hill-s (soil)	Terraced hillside on the eastern slopes of the main nalla and adjacent the dyke well: 19°35.31'N 73°47.13'E	Lined 20x20 cm	Test#1:2.19x10^{-5} Test#2:1.4x10^{-5} Test#3:1.1x10^{-5}
Man-hill-m (murum surface)	See above.	Lined 21x21 cm	Test#1:7.57x10^{-6} Test#2:3.78x10^{-5} Test#3:2.7x10^{-5}
Man-chan-wb (weathered basalt)	Spillway channel in the main nalla of Manhere and south of the village: 19°34.40'N 73°47.18'E	15x25 cm	Test#1:3.33x10^{-5} Test#2:2.56x10^{-5} Test#3:1.75x10^{-5} Test#4:1.45x10^{-5} Test#5:1.45x10^{-5}
Man-chan-m (murum surface)	See above	Lined 30x30 cm	Test#7.69x10^{-6}

ANNEXURE 15

LOCATIONS

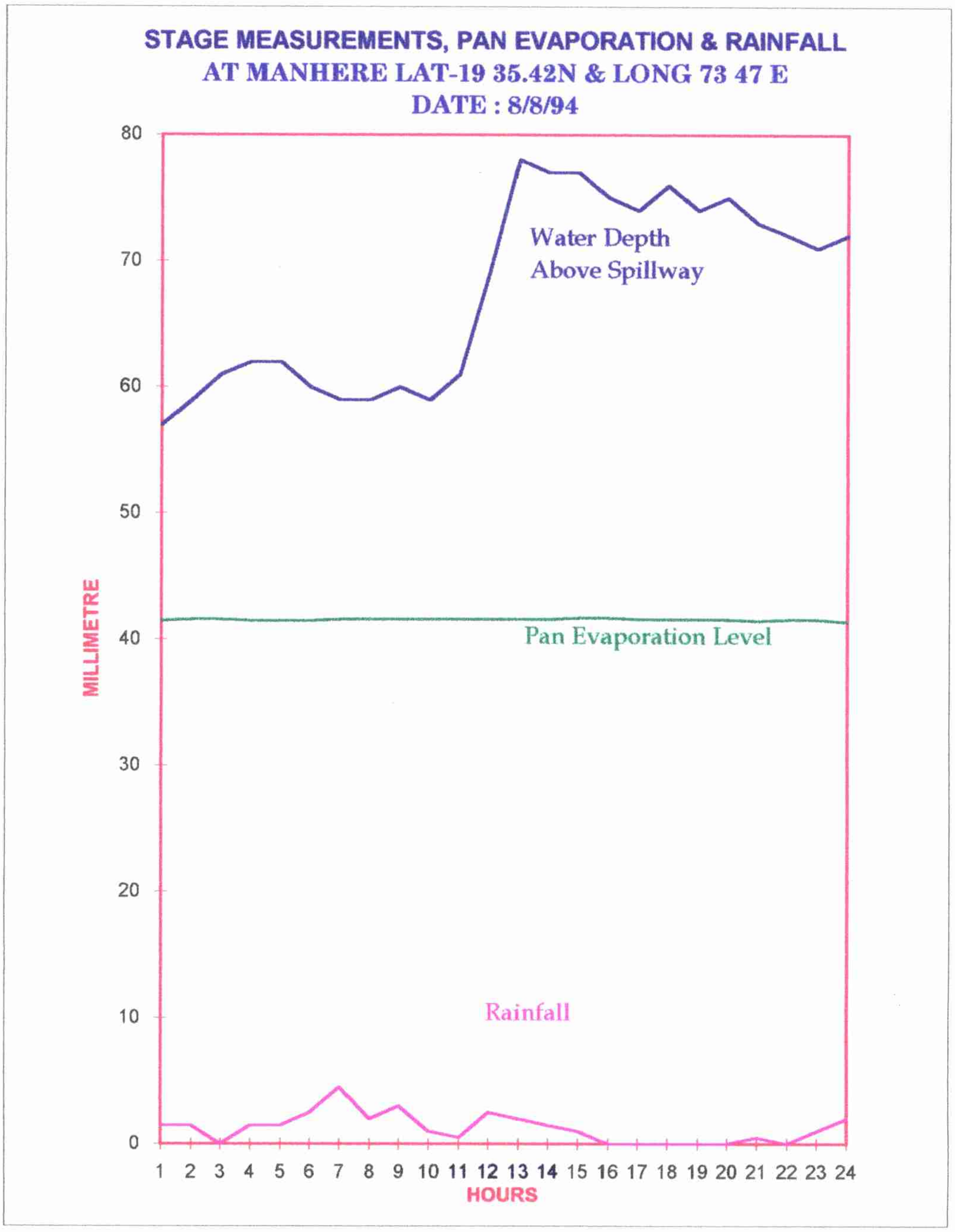
OF

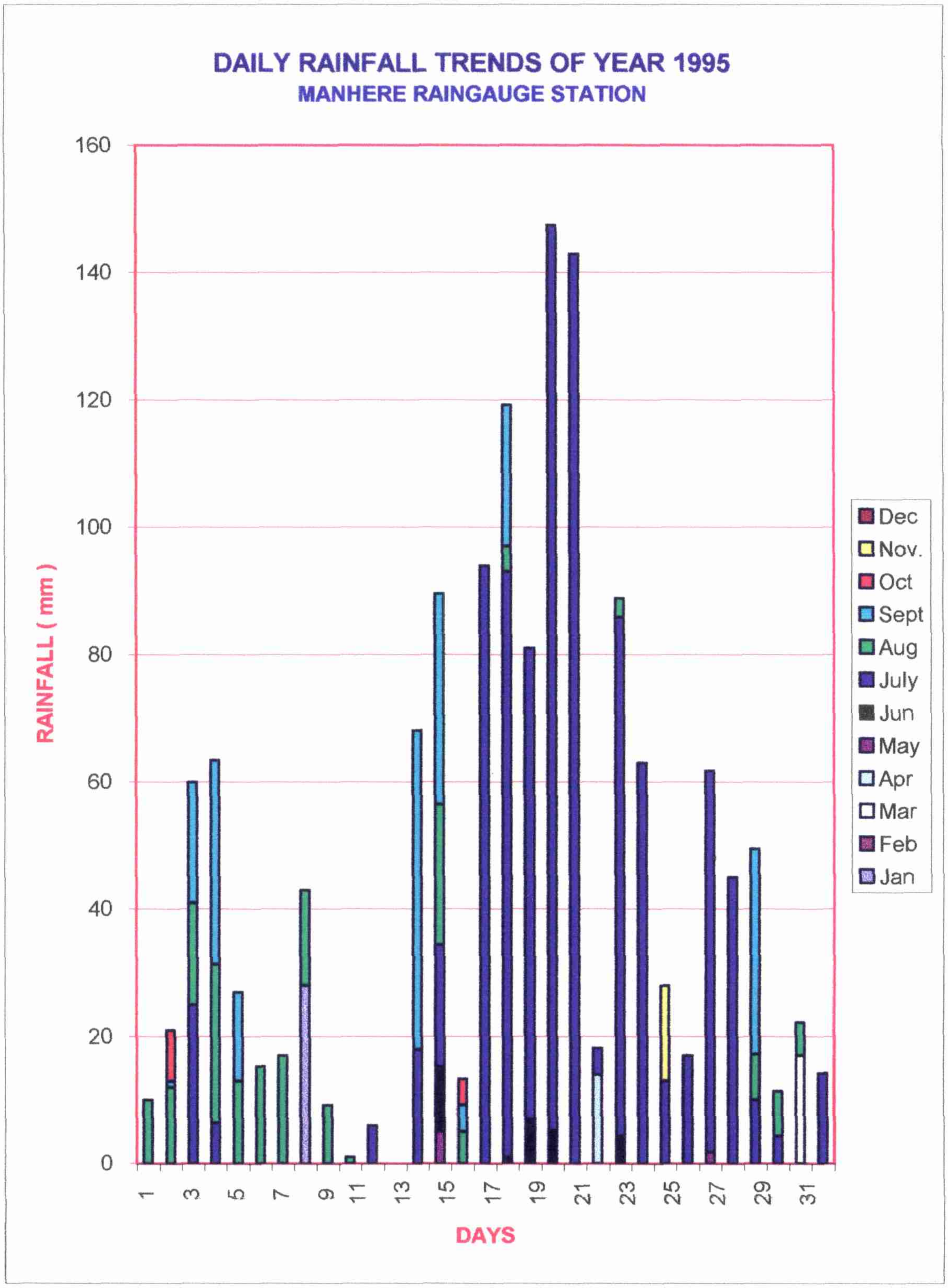
SURFACE INFILTRATION TESTS

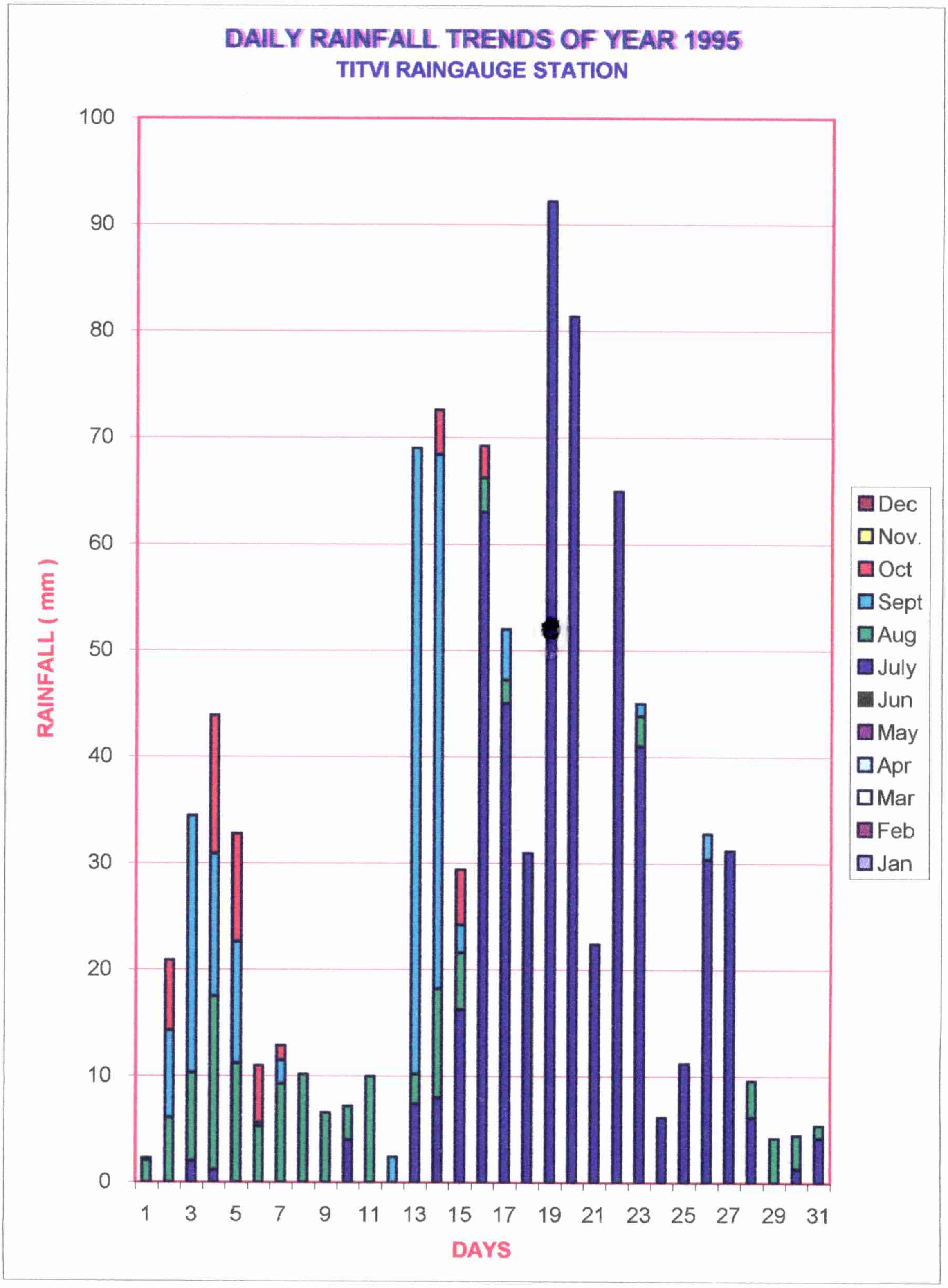

Km
1 0 1 2
LEGEND
ROAD
STUDY AREA
VILLAGE BOUNDARY
WATER SOURCE
MAY 1995
SOIL SAMPLE
INFILTRATION TEST
1993 Kfs TEST SITE
1995 Kfs TEST SITE
19°36' N
19°35' N
73°47' E
73°49' E
Ladgaon
Ambevangan
Devgaon
Manhere
Titvi
AW1
AW2
AW3
MW1
MW2
MW3
MW4
MW5
MW6
MW7
MW8
MW9
MW10
MW11
MW12
MW13
MW14
MW15
MW16
MW17
MW18
MW19
TW1
TW2
TW3
TW4
P R A V A R A

ANNEXURE 16

RAINFALL CHARACTERISTICS OF MANHERE AND TITVI AREAS


STAGE MEASUREMENTS, PAN EVAPORATION & RAINFALL
AT MANHERE LAT-19 35.42N & LONG 73 47 E
DATE : 8/8/94
80
70
60
50
40
30
20
10
0
MILLIMETRE
Water Depth
Above Spillway
Pan Evaporation Level
Rainfall
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
HOURS


DAILY RAINFALL TRENDS OF YEAR 1995
MANHERE RAINGAUGE STATION
RAINFALL (mm)
DAYS
0
20
40
60
80
100
120
140
160
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Dec
Nov.
Oct
Sept
Aug
July
Jun
May
Apr
Mar
Feb
Jan



DAILY RAINFALL TRENDS OF YEAR 1995
TITVI RAINGAUGE STATION
RAINFALL (mm)
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
DAYS
Dec
Nov.
Oct
Sept
Aug
July
Jun
May
Apr
Mar
Feb
Jan

ANNEXURE 17

RADON TESTS (1995)

ANNEXURE 17

Radon in Soil Gas of Akole Taluka: May 1995

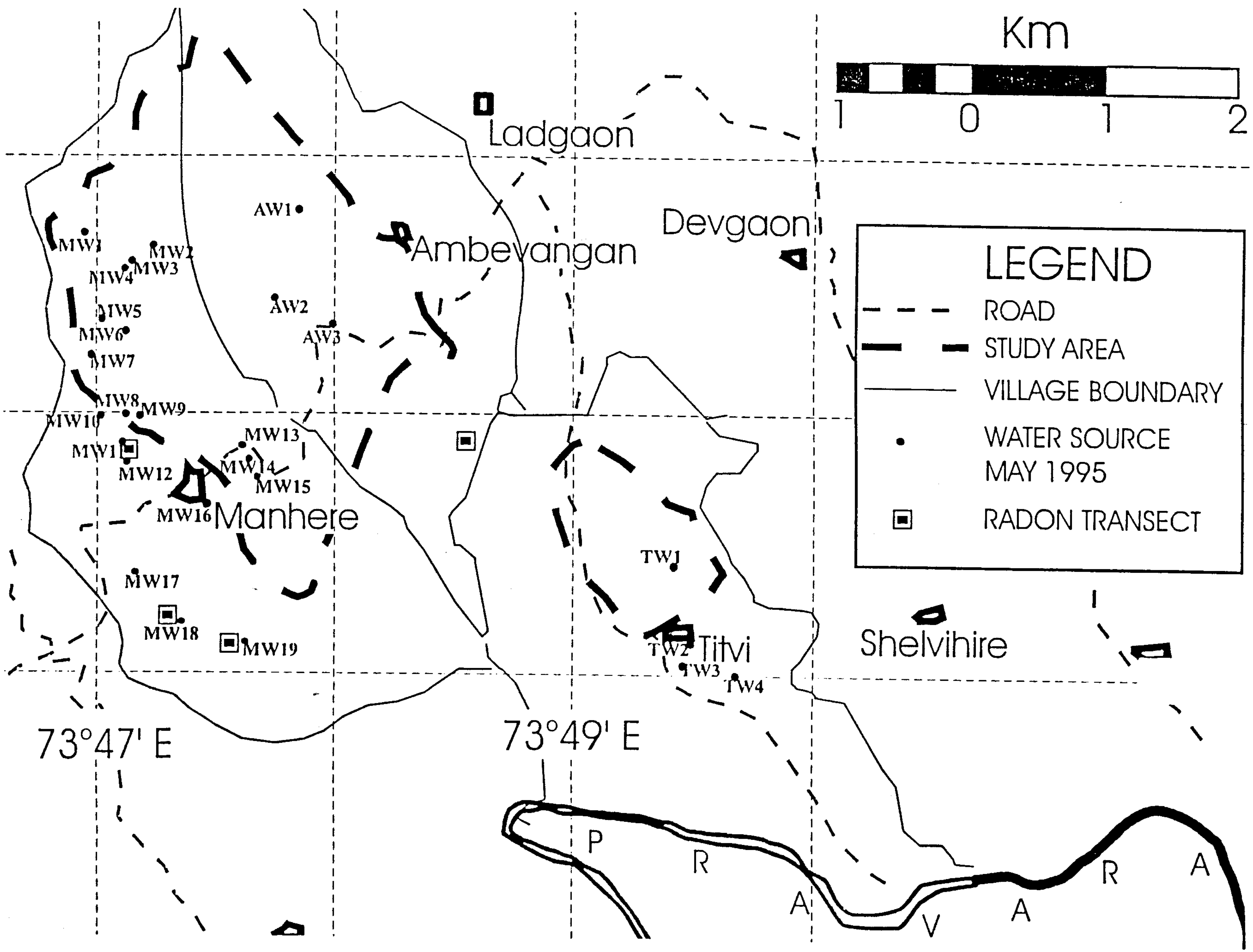
Test site	Description and Location	Sample Pipes	Radon level ($_p$Ci/L)
Radon-1 Manhere (May 3)	Paddy field south of the main nalla. Site of surface infiltration test Man-paddy and water source MW19. 19°34.12'N73°47.63'E and 719 m.	5 spaced at 10 m	Pipe#1:579 (east) weathered bedrock Pipe#2:538 Pipe#3:544 Pipe#4:671 Pipe#5:603 (West)
Radon-2 Manhere (April 30) (*=May 15)	Paddy field south of the village in the main nalla. Site of water source MW18. 19°34.19'N 73°47.36'E and 730m.	5 spaced at 5 m	West hillside 582* Pipe#1:838 (east) 414* (on linear) Pipe#2:629 Pipe#3:657 Pipe#4:528 Pipe#5:560 (West)
Raddon-3 Manhere (May 5)	Paddy field northwest of the village in the main nalla. Ground feature (N45°W) evident at the water source. 19°34.88'N 73°47.12'E and 764m.	3 spaced at 10 m and one on the ground feature to the southeast.	Pipe#1:422 (north) Pipe#2:465 (on linear) Pipe#3:561 (south) Pipe#4:330 (linear to SE) weathered bed rock
Radon-4 Titvi (May 8)	Step-sided valley northwest of the village. 19°34.925'N 73°48.54'E and 712-730 m.	3 spaced at 50 m	Pipe#1:369 (north) hilltop Pipe#2:309 valley (on linear) weathered bedrock Pipe#3:533 (south) hilltop

ANNEXURE 18

LOCATION MAPS

OF

RADON TESTS

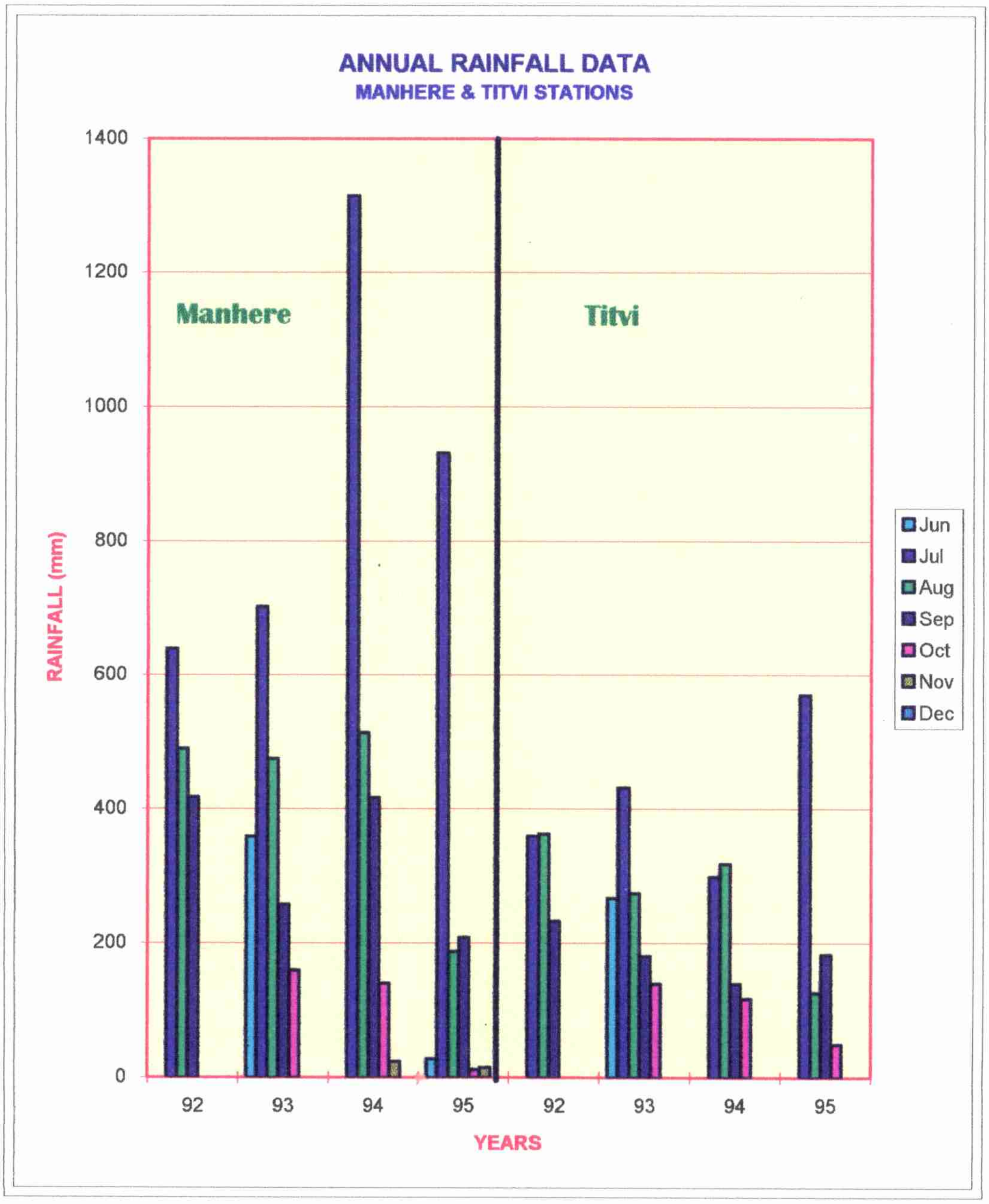

Km
1 0 1 2
LEGEND
ROAD
STUDY AREA
VILLAGE BOUNDARY
WATER SOURCE
MAY 1995
RADON TRANSECT
Ladgaon
Devgaon
Ambevangan
Manhere
Titvi
Shelvihire
AW1
AW2
AW3
MW1
MW2
MW3
MW4
MW5
MW6
MW7
MW8
MW9
MW10
MW11
MW12
MW13
MW14
MW15
MW16
MW17
MW18
MW19
TW1
TW2
TW3
TW4
73°47' E
73°49' E
P R A V A R A

ANNEXURE 19

ANNUAL RAINFALL

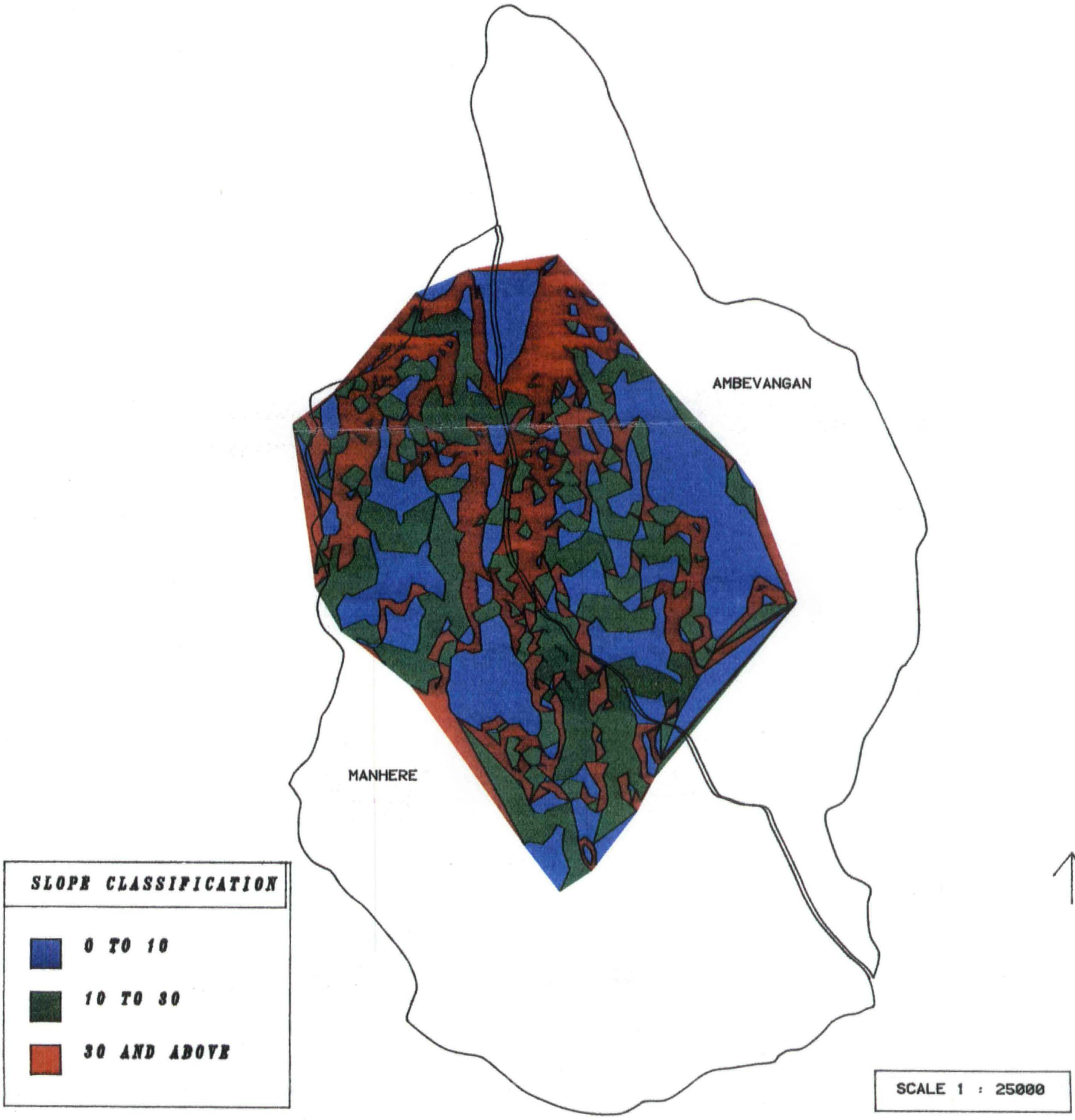
AT

MANHERE AND TITVI STATIONS


ANNUAL RAINFALL DATA
MANHERE & TITVI STATIONS
RAINFALL (mm)
1400
1200
1000
800
600
400
200
0
Manhere
Titvi
92
93
94
95
92
93
94
95
YEARS
Jun
Jul
Aug
Sep
Oct
Nov
Dec

PROJECT : CONJUNCTIVE USE OF WATER RESOURCES, AKOLE TALUKA

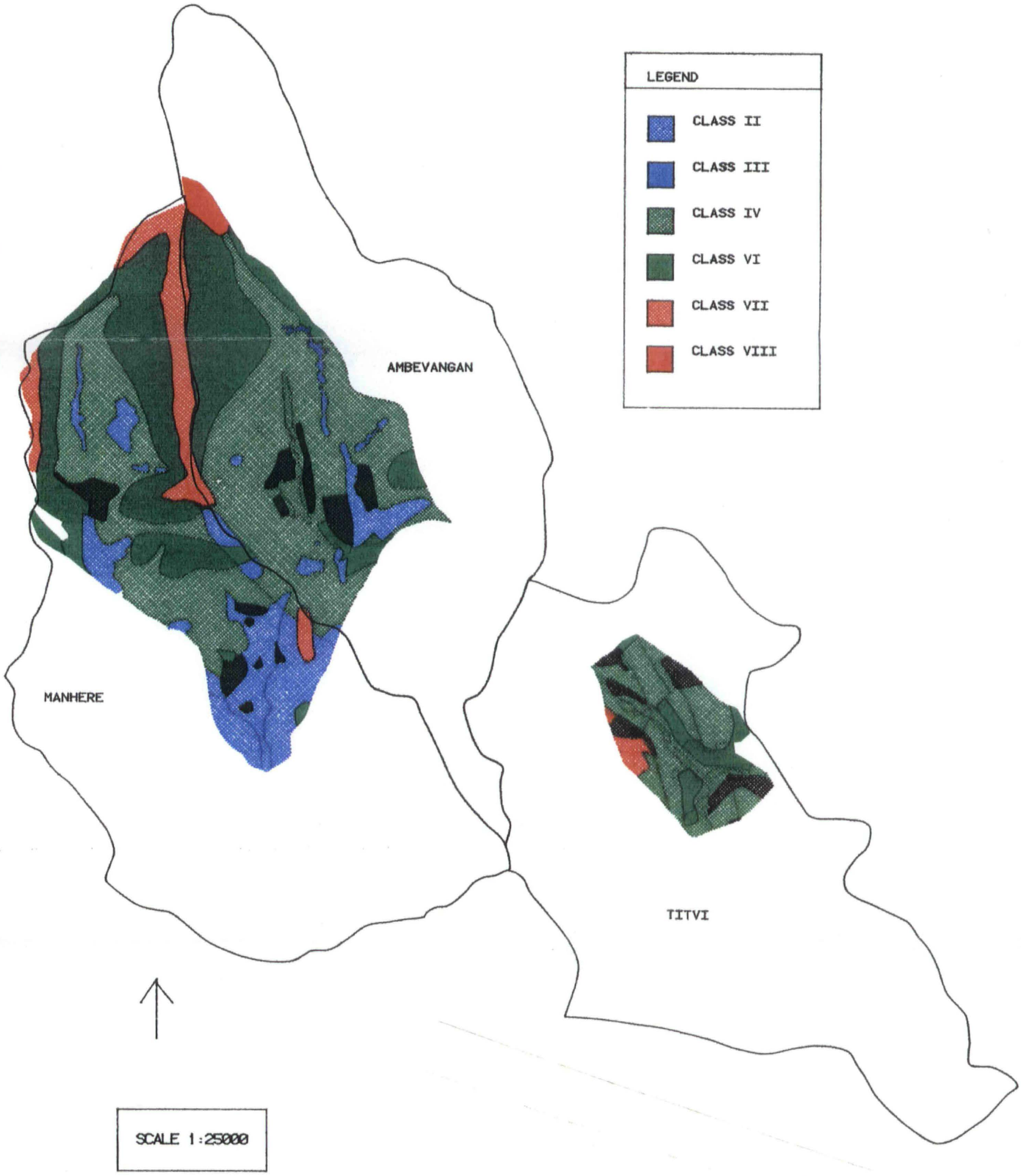
SLOPE CLASSIFICATION OF SELECTED WATERSHED AREA



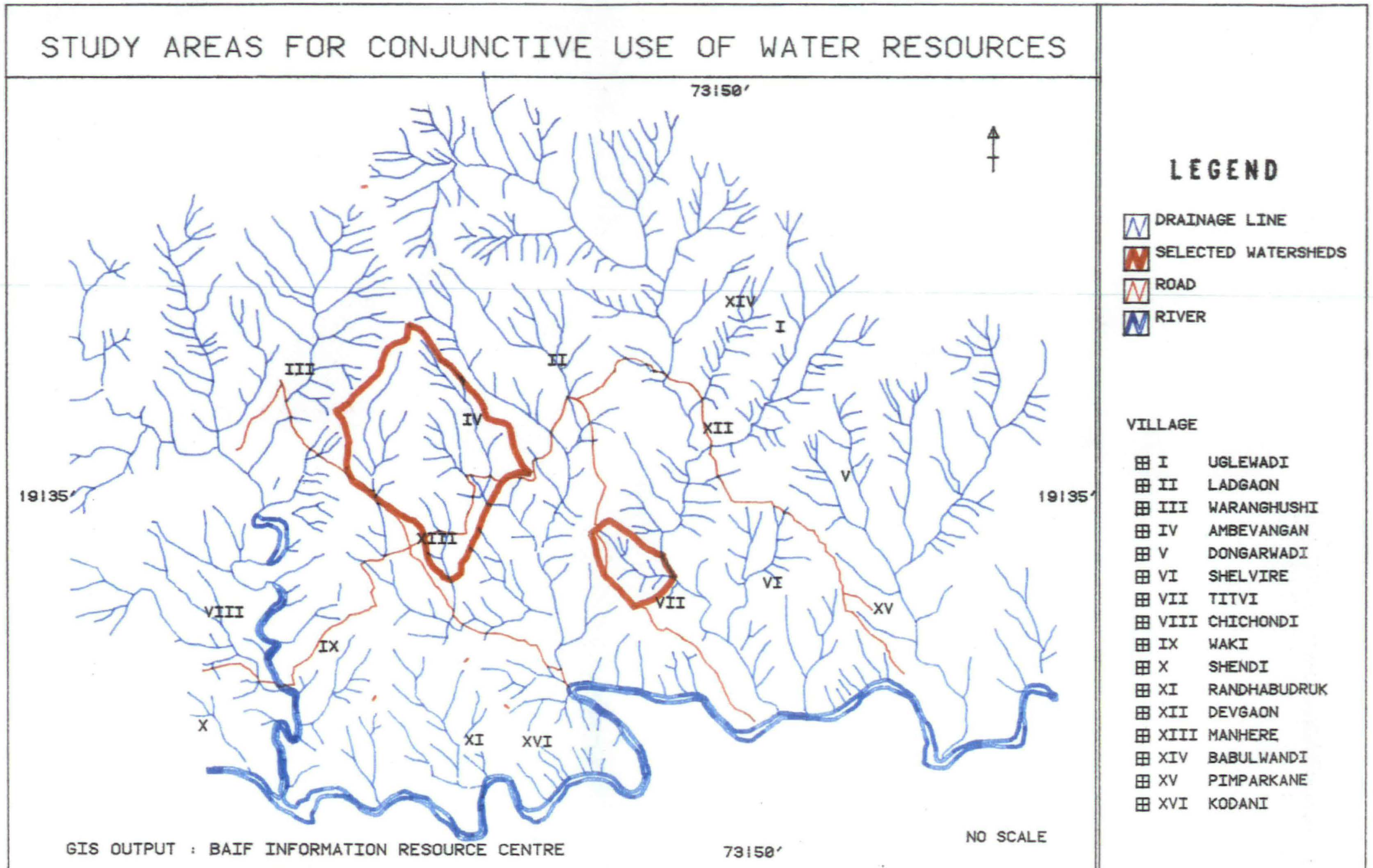
GIS OUTPUT : BAIF INFORMATION RESOURCE CENTRE

PROJECT : CONJUNCTIVE USE OF WATER RESOURCES, AKOLE TALUKA

LAND CAPABILITY CLASSIFICATION



GIS OUTPUT : BAIF INFORMATION RESOURCE CENTRE



MAP SHOWING THE DRAINAGE PATTERN OF AKOLE TALUKA AND THE STUDY AREAS MARKED FOR CONJUNCTIVE USE OF WATER RESOURCES.

ANNEXURE 10

DRAINAGE LINEAMENTS & SAMPLE STATIONS

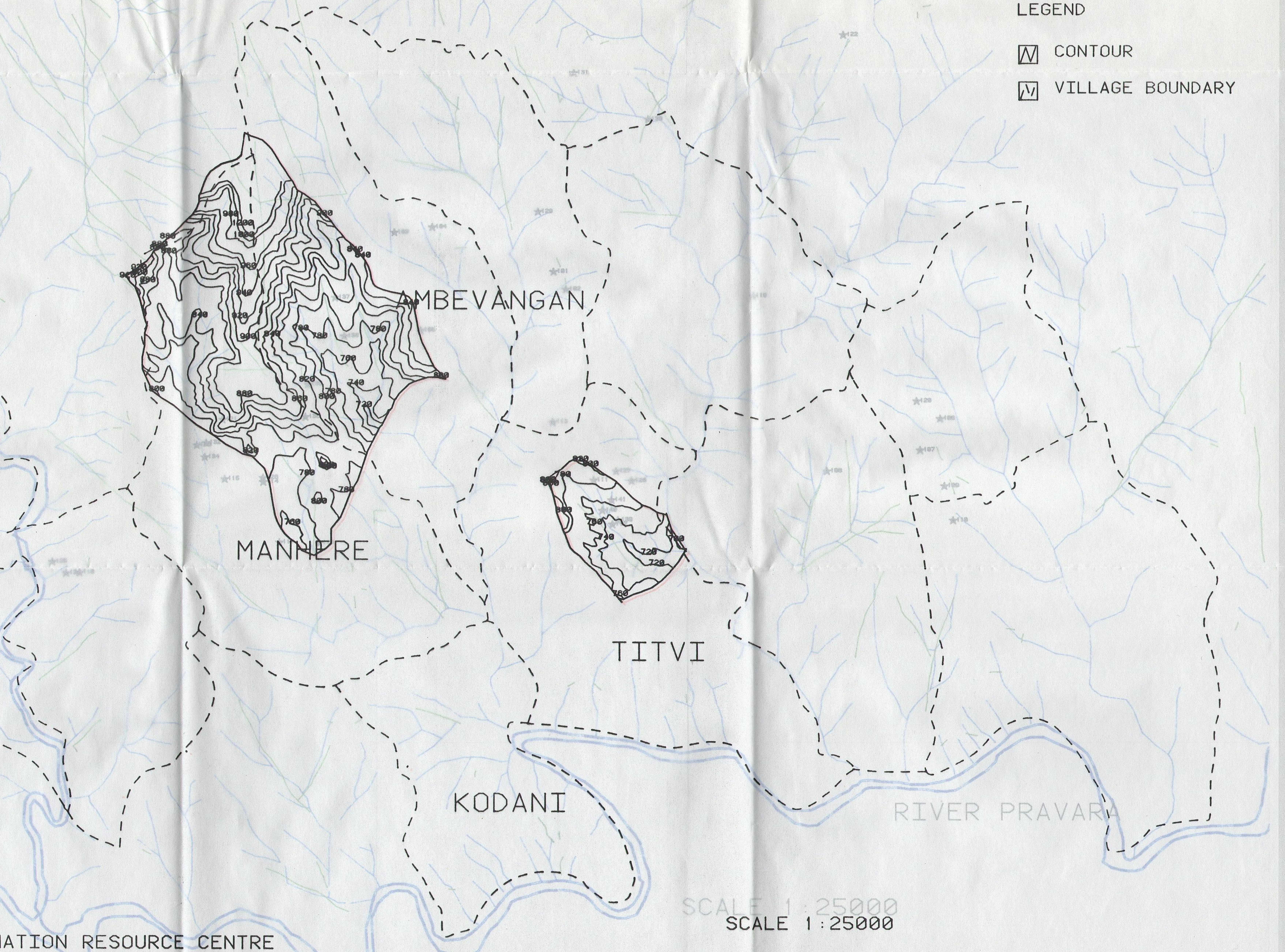
CONJUNCTIVE USE OF WATER RESOURCES, AKOLE TALUKA MAHARASHTRA, INDIA

TOPOGRAPHY

SAMPLE STATIONS

101	73.816167	19.591167	LPBAD1-1
102	73.817167	19.589667	LRNB1-1
103	73.802333	19.594833	AKKD1-1
104	73.805667	19.595167	ALDK1-1
105	73.804333	19.586667	ABKB1-1
106	73.849500	19.578167	PCT1-1
107	73.847667	19.575667	PS1-1
108	73.839500	19.574167	PK1-1
109	73.849667	19.572667	PKS1-1
110	73.850333	19.569833	PTV1-1
111	73.819000	19.574000	TKGM1-1
112	73.820500	19.570333	TGNM1-1
113	73.815667	19.578833	TCSM1-1
114	73.790167	19.574667	MMD2-1
115	73.786833	19.575000	MCN1-1
116	73.794833	19.569500	ML1-1
117	73.791333	19.569667	MK1-1
118	73.773667	19.567667	WA1-1
119	73.833500	19.588667	DPK1-1
120	73.847500	19.579667	PC1-1
121	73.786833	19.579833	MMC3-2
122	73.842167	19.610000	U1-1
123	73.840833	19.614500	UF1-1
124	73.772500	19.567667	WMM1-1
125	73.771333	19.568667	WK1-1
126	73.790167	19.575000	MMD1-1
127	73.821000	19.574667	TP-1
128	73.822333	19.573833	TP2-1
129	73.815000	19.596167	TPB-1
130	73.824833	19.603500	DT-1
131	73.818500	19.607500	DP-1
132	73.785333	19.578000	MMC-1-1
133	73.784500	19.577833	MMC-2-1
134	73.785167	19.576833	MMC-3-1
135	73.794333	19.582500	MSSB-1-4
136	73.794000	19.579833	MGG-1-2
137	73.797000	19.589500	AN-1
138	73.797667	19.586333	AKB-1
139	73.821000	19.570667	TCN-1
140	73.819667	19.571500	TCN-2
141	73.820500	19.572333	TCN-3

END



SCALE 1:25000

SCALE 1:25000

GIS OUTPUT : BAIF INFORMATION RESOURCE CENTRE

LOCATION : AKOLE TALUKA, MAHARASHTRA, INDIA GIS OUTPUT : BAIF INFORMATION RESOURCE CENTRE

15983 283

ANNEXURE 7

LEGEND I

VILLAGE BOUNDRY	
WS. BOUNDARY	
ROAD PATH	
RIVER NALLA	
T.B.M.	
WELL	
TEMPLE	
HUT	
5 M CONTOUR	700 — 700
SURVEY NO. BOUNDARY	80

BAIF DEVELOPMENT RESEARCH FOUNDATION

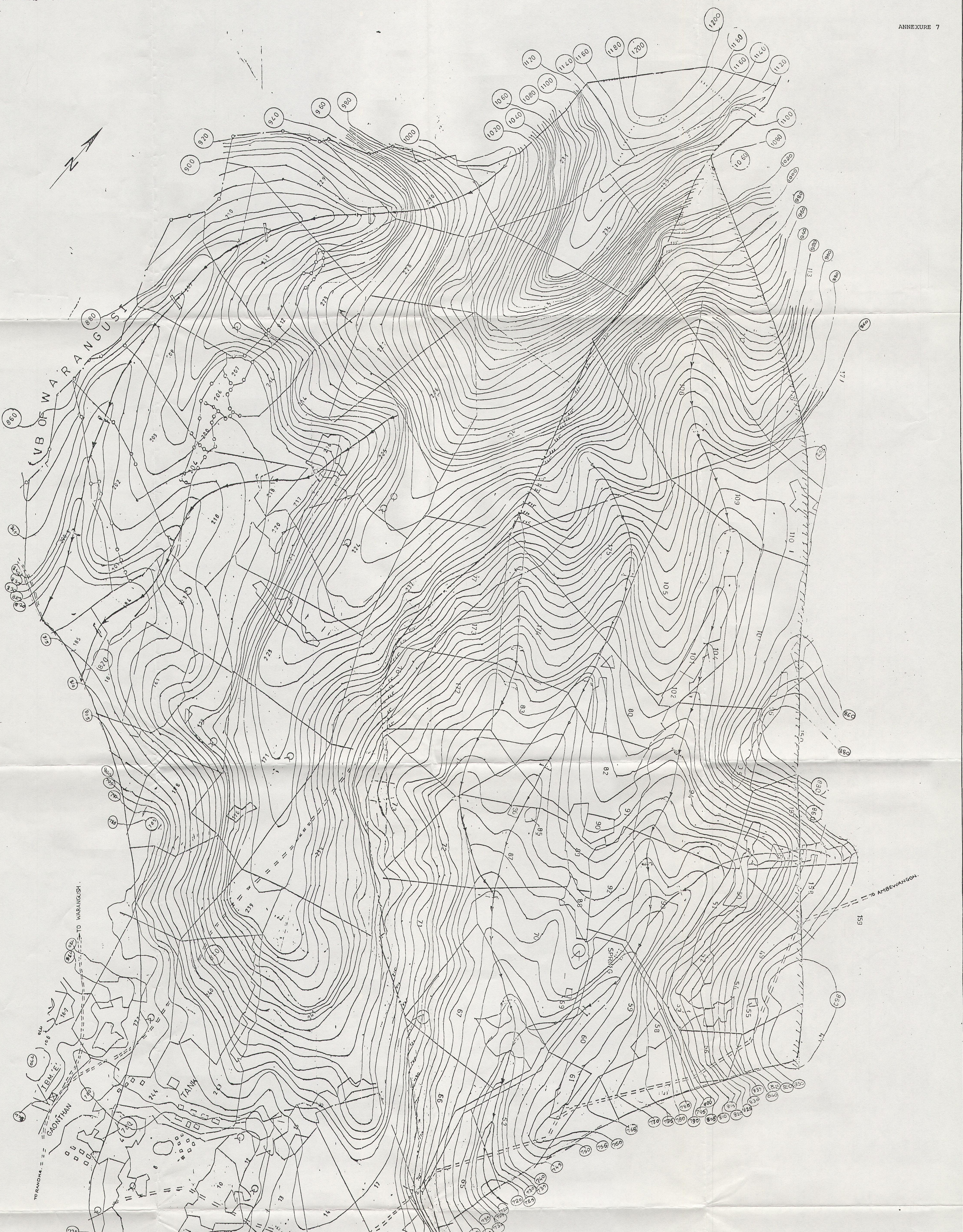
'KAMDHENU', S.B.MARG, PUNE - 16.

SUBJECT - CONTOUR MAP SHOWING WS BOUNDARY & SURVEY NO

VILLAGE - TITVI

DRAWING NO 18/93	SCALE - 1 : 4000
A.K.BHOSALE (J.P.C.O.)	D.N.JOSHI (CHIEF ENGINEER)

ANNEXURE 7



LEGEND I

VILLAGE BOUNDRY	
W.S. BOUNDARY	
ROAD PATH	
RIVER NALLA	
T.B.M.	
WELL	
TEMPLE	
HUT	
5 M CONTOUR	
SURVEY NO BOUNDARY	90

BAIF DEVELOPMENT RESEARCH FOUNDATION
'KAMDHENU', S.B.MARG, PUNE - 16.

SUBJECT - CONTOUR MAP SHOWING WATERSHED BOUNDARY & SURVEY NO.
VILLAGE - MANHERE & AMBEVNGON.

DRAWING NO : 18/93	SCALE - 1 : 4000
A.K.BHOSALE (J.P.C.O.)	D.N.JOSHI (CHIEF ENGINEER)