APPENDIX – VI

IRRIGATION AND DRAINAGE

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1. Present Condition of Irrigation and Drainage

1.1 Present Conditions of Irrigation and Water Management

An extensive survey of the existing projects and command area within the Munyati River basin and out side was carried out. Two projects namely Ngondoma and Takavinga constructed within the Project area were seen intensively. These projects cover an area of 44 ha and 8 ha respectively. Two more projects namely Nyamaropa and Chibwe (Musikanvahnu) lying outside the project area and serving an area of around 500 ha and 703 ha were also intensively seen along with their command area. These projects mainly serve communal and settlement areas. Virtually, no concept in respect of conveyance, delivery, distribution of water or water management was observed.

(1) Gates have been provided at the off-take points of distributaries and Agritex staff is required to operate them as per schedule. But on account of shortage of staff it has not been possible for the Agritex staff to operate them. One of the supervisors mentioned that on one of his projects only two Water Bailiffs are available, as such it is not possible to attend the gate operations. The gates are being operated by the farmers at their will. Similarly, the gates provided at the openings of the distributaries (so called outlets), from where the watercourses take-off, are also operated by the farmers at their will.

(2) It is encouraging to note that water is taken by the farmers from the watercourses for irrigating their fields turn by turn. But the time period of the turns is not fixed. With the result, the farmers keep on applying water irrespective of their requirements. Too much over irrigation was observed particularly in the head reaches.

(3) On one of the projects (constructed with European assistance), measuring devices were found installed by using steel parshall flumes embedded in concrete. The farmers were not aware of these installations. A little training to the farmers would be necessary to appreciate these facilities.

(4) Water is taken from the distributaries into the watercourses by constructing outlets in the distributaries. Here no formal outlets / measuring devices are installed. Only rectangular openings are made where in the discharge drawn in the watercourses depended upon the level in the watercourses. Some farmers were using more number of siphon pipes to keep the water level in the watercourses low so as to facilitate withdrawal of more water from the distributaries.

(5) Most of the fields were not found properly developed. Application of water by the farmers at the field level was found to be discouraging. In most of the cases irrigation was being done by furrows method of irrigation. The lengths of the furrows were found to be too long compared to the stream size. On questioning, the farmers were not found aware of the relationship between

stream size, slope, length of irrigation run, and type of soil. Opportunity time of water absorption was found to be drastically varying, resulting in over irrigation at one location and under irrigation at the others. On discussing these situations with the farmers, it was good to note that they were found to be very receptive and interested in adopting the given practices.

(6) In all the communal area flow irrigation projects water supplies were found to be much more than the demands except for drought years. In summer season, water supplies are in abundance because of the prevailing rainy season. Farmers are cultivating only less water consuming crops such as maize. In winter season, when plenty of water is available in the reservoir, farmers don't effectively utilize the same by growing food crops such as wheat and oil seed crop like sunflower. Water, in this season in abundantly used for growing vegetables only. Utilization is very low.

(7) Night Storage Reservoirs have been constructed on all the projects. These are all small projects. But the Project like Lower Munyati, is required to be treated at a different level in planning, design, construction, operation and maintenance. There is a need to categorize the projects in small, medium and major projects. The potential dangers of constructing night storage reservoirs in respect of loss of water through seepage in the night reservoir area lying in the command, and health concerning diseases like malaria and bilharzia etc. need attention while dealing with the major projects.

The maladies as above are well appreciated by the top bosses of Agritex and scholars of University of Zimbabwe. These have also been reflected in performance assessment studies.

1.2 Irrigation Performance Assessment Studies

Many studies relating to irrigation performance assessment have been carried out in Zimbabwe. One of the latest studies relates to a collaborative program of irrigation research to assess smallholder irrigation performance in Zimbabwe. The study was initiated in 1989 involving the University of Zimbabwe, Agritex, and the International Food Policy Research Institute. The results of the study were presented at a workshop held in August 1993 and are contained in the Proceedings of the workshop published by the University of Zimbabwe in 1994.

One of the concerns of the study was Water Management as to 'how it is practiced in different schemes and how it can be improved'. On the subject of Water Supply and Distribution Effectiveness the Study has recorded:

> "The problem of adequacy of water supply seems chronic on Agritex and Community managed schemes. To further complicate the problem, the distribution of water within system appears inequitable. Tail-enders are often disadvantaged and current management systems appear unable to tackle this problem adequately. The question is, are there enforceable technical solutions

to the water inequity problem? It may also be that irrigation schemes, as with communal areas generally lack in firm institutional and organizational framework for a community based democratic system of allocating resources and adjudicating disputes….."

Mr. Emmanuel Manzungu has recorded in his case study – Contradictions in Standardization:

"In many smallholder irrigation schemes in Zimbabwe poor water use is cited as one common problem. Water is reported lost during conveyance, distribution and application in field. The causes of this problem are varied. Most of the losses are said to be at or below channel gate (Pearce and Armstrong, 1991). Inequitable distribution of water between blocks, between head and tail users along canals and differential water distribution at field level have been documented (Pazvakavambwa, 1984; Pearce and Armstrong, 1990; Donkor, 1991). Over irrigation has also been cited as another problem, particularly in gravity schemes (Makadho, 1993). These studies, in various ways have emphasized the need for solutions to be found to the water-management problem in smallholder irrigation."

Regarding crop choices it is mentioned that the Government started to interfere with irrigators' crops from about 1936. This continued or rather became excessive by 1974. But the situation is somewhat changed today. Bourdillon and Madzudzo (1994) reviewed the situation of six schemes, all built after independence. They found only one scheme, Shamrock, in which irrigators were to decide which crops to grow. This was also the most successful scheme of the sample. The authors (Emmanuel Manzungu and Pieter van der Zaag) clearly suggest that freedom of crop choice correlates positively with performance.

2. Formulation of Irrigation and Drainage Development Plan for Munyati River Basin

2.1 Proposed Irrigation Area and Irrigation System

2.1.1 Probability and Level of Certainty:

It is proposed to adopt 20 % risk level for irrigation development plan. This project, though including a little urban/industrial water supply, is a single purpose irrigation project and in such projects the management of water in short supply years is easy by establishing appropriate operation plans. More difficult problems arise in multipurpose projects, which cater for the needs of power or flood control in addition to irrigation. The multiple objectives of power or flood control restrict the releases of water as per their functional requirements.

For example, power needs may be small but sufficient water is required to be reserved in the reservoir for their regular releases round the year; flood control measures may warrant extra releases of water even when it is not required for irrigation in hope of subsequent excess inflows to moderate floods. These pre-requisites of multipurpose projects warrant lower risk factors. No such problems are encountered here in this single purpose project.

In the irrigation project, on the other hand, adoption of 20 % risk has the advantage to that of 10 % risk, because it would cover more large irrigation area. As far moisture stress conditions in high risk cases, net effect is very little. Though the manner in which water deficit affects the crop growth depends the crop species and crop growth requirements at a particular point, slight modifications in the cropping pattern and staggering of sowing dates of various crop-seed varieties, having different maturity duration time are sufficient to obviate this stress conditions.

The rainfall in the project area tapers off in March and project management will be able to evaluate with reasonable level of certainty, the supplies likely to be available. Operational rules will help in deciding allocations for winter crops, and carry over allocations for summer crops. The deficit year planning is much easier in case of single purpose projects, leaving only a little constraint with adoption of 20 % risk level.

2.1.2 Irrigation Area and Irrigation Method

(1) Irrigation Area

As observed earlier, the project economy is at best when the height of the dam is proposed as 72.70 m, enabling the available water resources to serve an irrigation area of 25000 ha. Master plan study indicates the division of area meant for irrigation under each category of consumers viz communal area & resettlement area; small scale commercial farms; and large scale commercial farms. The details are worked out as under:

The distribution of Irrigation Area

	Category	percentage	Irrigation area (ha)	
1	Communal & resettlement area	58.78	14685 say	14500
2	Small scale commercial farms	23.52	5880 say	6000
3	Large Scale Commercial Farms	17.70	4425 say	4500
	Total	100.00		25000

The areas relating to small and large scale commercial farms are located at the tail end of the canal system or are yet to be finalized. However, all the areas related to communal and resettlement, have been identified based on soil surveys and other specific considerations.

Soil surveys carried out for the project communal and resettlement area identified 23000 ha of area (gross) fit for irrigation. This area is scattered and wide spread. Accordingly to service the designated area, two main canals, one on the left side and other on right side, have been planned using 1/15000 orthophoto maps prepared in the Phase-I study.

From the planned canal route and the available working head it is broadly observed that: (i) 2770 ha of irrigable area, out of 23000 ha as that identified for communal and resettle area, is not found suitable because of their too far away and scattered locations. This leaves a balance area of 20230 ha, (ii) 9991 ha (gross area) can only be served through gravity irrigation and the remaining 10239 ha through pump irrigation.

From the available area, net irrigation area of 14500 ha has been selected for communal and resettlement area as detailed below.

Irrigable area

(Unit : ha)

Area identified	23,000
Area not suitable from service point of view	2,770
Balance area as available	20,230

Distribution of Irrigable area

(Unit : ha)

Area		Gross area	Net area as available(*)	Area selected for Irrigation		
				Left Main Canal (LMC)	Right Main Canal (RMC)	Total
Gravity Irrigation area		9,991	8,992	4,201	4,791	**8,992**
Pump Irrigation Area:						
Pump lift	<5m	2,603	2,343	1,277	1,065	2,343
	5m - 10m	2,106	1,895	683	634	1,895
	10m - 15m	1,516	1,364	-	588	1,270
	>15m	4,014	3,613	3,221		
Total under pump		10239	9215		2287	**5508**
Grand Total						14500

(*) Net area is estimated as 90% of gross area.

(2) Methods of Irrigation

(a) Gravity Irrigation

Selection of method for gravity irrigation mainly depends upon land slopes, type of soils, type of crops, depth of irrigation and water stream size. The soils of the irrigation area are mostly loamy and land slope is slight. The cropping pattern indicates maize, cotton, groundnut and vegetables in rainy season for which furrow method of irrigation is considered most suitable. In the dry season wheat crop has been proposed for which border method of irrigation is considered suitable. Under these conditions long / medium furrows and medium borders are generally preferred.

(b) Pump Lift Irrigation

In pump canal irrigation areas, water is proposed to be pumped in bulk from the main canal and conveyed to the respective high areas, in stages if so required to servc the higher areas. Irrigation area at each stage of pumping is proposed to be served by gravity methods of irrigation.

2.2 Irrigation Water Requirements

2.2.1 Crop Water Requirements

Crop water requirements have been worked out adopting the methodologies presented in FAO Irrigation and Drainage Paper No. 46, "Cropwat: A Computer Program for Irrigation Planning and Management", Paper No. 24 "Crop Water Requirements" and Paper No. 33, "Yield Response to Water."

2.2.2 Meteorological Data

Meteorological data has been collected from the Meteorological Office in Harare, as available for the Meteorological Stations of Kadoma and Gokwe , for the following years:

S.No.	Data	Period for Kadoma	Period for Gokwe
1	Daily rainfall	1952 –97	1964 – 97
2	Monthly and annual maximum Temperatures	1951 – 98	1963 – 98
3	Monthly and annual minimum Temperatures	1951 – 98	1963 – 98
4	Monthly and annual Wind Speed	1959 – 98	1963 – 98
5	Monthly and annual Cloud Amount	1959 – 98	1963 – 98
6	Monthly and annual Sunshine Hours	1951 – 98	1966 – 98
7	Monthly and annual Pan Evaporation	1962 – 98	1963 – 98
8	Monthly and annual Relative Humidity	Not Available	1983 – 98

For the purpose of computing irrigation water requirements the data for last 30 years has been utilized except for data of relative humidity, which is available for 5 years for the Gokwe Meteorological Station. The data of relative humidity is not available for the Kadoma Meteorological Station, as such the water requirements have been worked out taking the data of Gokwe station.

Kadoma Meteorological Station

S.No	Description		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annu
1	Average Rainfall	mm	0.3	1.2	8.3	35.0	90.8	164.4	184.7	128.0	86.7	27.7	6.8	1.5	735.4
	Air Temperature:														

2 Max.Mean of Daily	℃	24.0	26.7	30.4	32.0	30.7	29.0	28.6	28.4	28.9	28.1	26.4	24.1	28.1
3 Min. Mean of Daily	℃	8.5	10.3	13.8	16.8	17.6	17.8	17.7	17.3	16.3	14.5	11.4	8.8	14.2
4 Relative Humidity (esti)	%	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
5 Pan Evaporatn. Rate	mm	4.8	6.3	8.4	9.0	7.6	5.8	5.5	5.2	5.5	5.3	4.9	4.5	6.0
6 Av. Wind Speed	Km/hr	226.9	246.2	264.9	276.2	244.2	204.0	176.6	162.4	172.0	193.5	194.2	212.5	214.7
7 Sun shine	hours	9.4	10.0	9.9	9.1	7.5	6.6	7.2	7.3	8.3	8.9	9.2	9.2	8.5

Data for Relative Humidity for Kadoma Station is not available.

Gokwe Meteorological Station

S. No	Description		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annu
1	Average Rainfall	mm	0.2	0.8	3.3	27.6	86.5	163.5	181.8	161.9	80.5	36.2	6.2	1.1	749.5
	Air Temperature:														
2	Max.Mean of Daily	℃	22.6	25.3	29.0	30.2	29.4	27.6	27.3	27.1	27.6	26.8	25.0	22.8	26.7
3	Min. Mean of Daily	℃	8.9	11.4	15.2	17.6	18.0	17.6	17.7	17.4	17.0	15.1	12.0	9.3	14.8
4	Relative Humidity	%	48.5	41.4	37.0	41.6	51.7	68.5	74.0	72.1	67.3	59.3	53.4	50.5	55.2
5	Pan Evaporatn. Rate	mm	4.9	6.3	10.4	8.9	7.5	5.7	5.5	5.5	5.8	5.6	5.1	4.6	6.3
6	Av. Wind Speed	Km/hr	190.6	200.4	223.4	229.9	205.2	173.5	158.5	160.6	171.7	182.5	173.3	177.7	187.1
7	Sun shine	hours	9.6	10.2	10.0	9.4	8.0	6.8	7.1	7.4	8.0	8.9	9.3	9.4	8.7

2.2.3 Agronomical Data

Data on agronomical aspects of crops covering lengths of stages, crop coefficients, rooting depths, depletion level, and yield response factors for all the crops has been taken from Irrigation Manual, Second Edition, 1994 published by UNDP / FAO / AGRITEX Project ZIM/91/005.

Crop	Length Stage (days)					Crop Coeff.			Rooting Depth (m)		
	Growth Stage					Growth Stage			Growth Stage		
	Init	Deve	Mid	Late	Total	Init	Mid	Late	Init	Mid	Late
Cotton	30	50	55	45	180	0.4	1.15	0.65	0.3	1.4	1.4
Maize	25	35	25	65	150	0.44	1.12	0.6	0.3	0.75	0.75
Tomato	25	30	30	40	125	0.7	1.05	0.8	0.2	0.5	0.5
G nut	40	50	45	30	165	0.5	0.95	0.55	0.15	0.4	0.4
Wheat	15	20	42	25	102	0.55	1.1	0.65	0.25	0.75	0.75
	20	20	55	25	120						
Cabage	20	35	25	10	90	0.5	1.1	0.9	0.15	0.4	0.4

Crop	Depletion Level (fract.)					Yield response F (coeff.)				
	Growth Stage					Growth Stage				
	Init	Deve	Mid	Late	Total	Init	Deve	Mid	Late	Total
Cotton	0.6		0.6	0.9		0.4	0.4	0.5	0.4	0.85
Maize	0.5		0.5	0.5		0.4	1.5	0.5	0.2	1.25
Tomato	0.4		0.5	0.5		0.4	1.1	0.8	0.4	1.05
G nut	0.4		0.5	0.5		0.2	0.8	0.6	0.2	0.70
Wheat	0.5		0.5	0.5		1.0	1.0	1.0	1.0	1.0
Cabage	0.4		0.5	0.5		0.2	0.45	0.45	0.6	0.95

2.2.4 Crop Calendar And Cropping Pattern

The details of the cropping pattern and the crop calendar as proposed for the Project are given below.

Crop	Sowing dates	Harvesting dates	Percentage
Cotton	15-Oct to 15-Nov	15-Apr to 15-May	70
Maize	15-Oct to 15-Nov	15-Mar to 15-Apr	18
Tomato	15-Dec to 15-Jan	15-Apr to 15-May	7
Groundnut	1-Oct to 31-Oct	15-Mar to 30-Apr	5
Wheat	15-May to 30-Jun	15-Sept to 31-Oct	63
Cabbage	15-May to 31- May	15-Aug to 31-Aug	7

While computing the irrigation water requirements, the sowing dates have been suitably staggered during the sowing period

2.2.5 Net Irrigation Requirements

Initially Reference Crop Evapotranspiration (ETo) is worked using meteorological data of Gokwe Station, as complete data is available for this station. This is given below:

Month	Max Temp (°C)	Min Temp (°C)	Humid (%)	Wind Speed (km/day)	Sunshine (hours)	Sol.Radia (MJ/m2/ day)	ETo (mm/day)
January	27.3	17.7	74	159	7.1	21.7	4.6
February	27.1	17.4	72	161	7.4	21.8	4.6
March	27.6	17.0	67	172	8.0	21.3	4.7
April	26.8	15.1	59	183	8.9	20.3	4.5
May	25.0	12.0	53	173	9.3	18.4	3.9
June	22.8	9.3	51	178	9.4	17.2	3.5
July	22.6	8.9	49	191	9.6	18.0	3.7
August	25.3	11.4	41	200	10.2	21.0	4.6
Sept	29.0	15.2	37	223	10.0	23.3	5.9
October	30.2	17.6	42	230	9.4	24.3	6.5
Novem	29.4	18.0	52	205	8.0	22.9	5.9
Decem	27.6	17.6	69	174	6.8	21.2	4.8
Average/Total	26.7	14.8	56	187	8.7	21.0	1744 *

*: mm/year

- Meteorological Station : Gokwe, Altitude: 1282, Coordinates : 18.13 S.L. , 28.56 E.L.

Crop water requirements is calculated using the same program for the case in which effective rainfall is not considered. The effective rainfall for 30 years has been separately worked out from ten-day rainfall data as converted from the corresponding daily rainfall data (of 30 years). Net irrigation requirements are worked out by reducing effective rainfall from crop water requirements.

2.2.6 Diversion Irrigation Requirements at the Canal Head

Diversion irrigation requirement is worked out by applying 50 % of irrigation efficiency, which consists of conveyance efficiency, field canal efficiency, and field application efficiency to net irrigation water requirements. Average monthly diversion irrigation water requirements under proposed cropping pattern are shown below.

Monthly Diversion Irrigation Requirements

(Unit : MCM)

Category	Irrigation Area		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
For C.A. and R.A.	14,500	ha	8.0	13.2	21.8	15.1	4.5	18.6	30.9	32.7	17.6	5.5	5.7	5.4	178.8
For S.S.C.F.	6,000	ha	3.3	5.5	9.0	6.2	1.8	7.7	12.8	13.5	7.3	2.3	2.4	2.2	74.0
For L.S.C.F.	4,500	ha	2.5	4.1	6.8	4.7	1.4	5.8	9.6	10.1	5.5	1.7	1.8	1.7	55.5
Total	25,000	ha	13.9	22.8	37.7	26.0	7.7	32.0	53.3	56.3	30.3	9.5	9.9	9.3	308.7

C.A. : Communal Area, R.A. : Resettlement Area, L.S.C.F : Large Scale Commercial Farm,
S.S.C.F : Small Scale Commercial Farm

2.2.7 Unit Design Water Discharge

Unit design water discharge has been worked out on 10-day basis from diversion irrigation requirements, by applying planned cropping pattern and the meteorological data having been observed at Gokwe Station from 1968 to1997. The following table shows the top ten years of peak diversion requirements by decade in the 30 years of water requirements analysis. The sixth biggest year of peak diversion requirements has been selected as basic year out of 30 years , because 5-years return period is applied in determination of the unit design water discharge.

Peak Diversion Requirement

Order	Peak Diversion Requirements (m^3/sec/ha)	Peak Decade
1	1.25	Feb-3rd ,1991
2	1.25	Feb-3rd ,1983
3	1.21	Feb-3rd ,1968
4	1.15	Feb-3rd ,1990
5	1.14	Feb-3rd ,1970
6	1.12	Feb-3rd ,1971
7	1.05	Feb-3rd ,1992
8	1.05	Feb-3rd ,1994
9	1.03	Feb-3rd ,1996
10	1.03	Feb-3rd ,1985

According to the above table, the basic year should be 1971(peak decade : third decade in February) and peak diversion requirement at the time is 1.12 l/sec/ha.

The farmers are new to cultivation and their needs/aspiration may vary as per future time resulting in some change of cropping pattern at any subsequent stage. As such it is proposed to keep around 5% additional allowance. It is therefore proposed to adopt unit design water discharge as 1.2 l/sec/ha.

The details are given in the Tables 1 to 4.

2.3 Basic Plan of Irrigation Facilities

2.3.1 Concept of Water Management

As mentioned earlier, only small projects are being constructed and operated in Zimbabwe. The maximum size of the project in the communal and settlement areas has been found to be around 500 ha. These projects have mainly suffered from inequity in water distribution and sub-optimal / inefficient water utilization. These projects being small, some laxity developed in the implementation of basic requirements and principles concerning operation of the system and water management. One of the issues, which have attracted attention, is the absence of night irrigation and provision of night storage reservoir.

Night storage reservoirs are constructed at the head of the distribution system to store water during times when there is abstraction in the system from the water source, but water is not taken by the farmers for irrigation. This practice is being adopted in some schemes where farmers do not take water during the nighttime. In these small schemes, the flows in the main canal during the nighttime are being contained in these so called night reservoirs. During the daytime this stored water is utilized in irrigating a separate block of almost half the area. That means, in a way, one more reservoir has been constructed, of half the capacity at the head of the system. Normally, the farmers do not take water during the night-time. A few projects have, however, been identified where, during the scarcity period all the farmers took water in rotation round the clock in both day and night. For success of any irrigation project, it is necessary that awareness of water as a scarce resource be fostered. There is need to create artificial scarcity conditions to inculcate the habit of optimal and economic utilization of this resource.

This night storage reservoir concept cannot be adopted on bigger projects, because of higher discharge in the system requiring huge reservoirs and specific operational requirements and methodologies. The potential dangers of avoidable reservoirs in respect of loss of water through seepage and health need not be emphasized.

All the above issues and maladies as detailed earlier have been considered to develop a viable concept of water management. The concept would ensure:

- Well defined water allocation and distribution principles
- Efficient system design
- Equitable distribution of water
- Fixation of turn schedules at the secondary and tertiary levels
- Optimum utilization of water at the farm level
- Introduction of volumetric concept
- Control and monitoring mechanism
- Water accounting
- Simple and efficient procedures for operations and maintenance
- Training and adaptive research
- Preparation of manuals and guidelines, etc.

2.3.2 Water Allocation and Distribution Principles

Water allocation and distribution principles form the basis on which an irrigation project is planned, constructed and operated. The main theme revolves round the water availability, the corresponding demands, adjustments/compromise between availability and demand and its distribution amongst the farmers. The social obligations of benefiting as many farmers as possible, is also an important consideration. The existing systems suffer from inequity in water distribution, the tail-enders don't get their allocated share, over irrigation is generally observed. Water allocation and distribution in the project area is being proposed with due regard to equity. Disparities in the distribution of water between head reach and tail farms would be obviated by adoption of rotational water distribution system. Supply of water is proposed on need based and with volumetric concept.

2.3.3 Approach

The project is being planned for a risk period of 20 %. Under this 20 out of 100 years may have deficient water availability conditions. The way of water distribution will be divided into two cases; (a) when water resources are adequate, and (b) when water resources are deficient.

(1) Adequate Water Availability Condition

The approach to water management with adequate supplies is based on filling the soil root-zone reservoir to field capacity, allowing the crop to deplete the moisture to the defined value of wilting point, and then irrigating the soil to make up this deficit in the root-zone-plans. In short, the crops would be irrigated when the available soil moisture has reached a specified level. The concepts of field capacity and wilting point have proved satisfactory criteria for fixing the turn schedules of canal systems.

This approach is also based on co-relation of yield response to soil moisture deficits for crops after taking into account plant characteristics, growth stages and evapotranspiration losses. Here the turn schedules of water distribution will be fixed in such a manner that all the farmers get the required water allotted to them turn by turn during a rotational cycle of one week. In this case irrigation requirements as worked out by modified Penman Method would be matched with the water availability condition to ensure that the demands are fully met.

(2) Deficient Water Availability Condition

During the water deficient periods, when the supplies are not sufficient to meet full crop requirements over the entire project area, two options are available: (i) Reduce the irrigated area so that full crop water requirements are met on the newly planned limited area or (ii) meet the crop water requirements only partially on the project area in the most suited scientific method.

It is proposed to follow the alternative (ii). The policy of spreading water thinly over extensive area recognizes the fact that the crops will slightly suffer water deficit during the growth period.

In fact when at a particular stage, the supply of water is deficient and crop water requirements are not fully met, moisture stress conditions develop, in which case the water loss due to evapotranspiration exceeds the rate of water supply to plant. These conditions affect the crop growth adversely. The manner in which water deficit affects the crop growth depends upon the crop species and crop growth requirements at a particular point. Generally crops are more sensitive to water deficiency during emergence, flowering and early yield formations than they are during early vegetative and late growth periods. As such in these cases schedule would be fixed as per water requirements of crops during their sensitive/critical stages of growth. Slight modifications in the cropping pattern and staggering of sowing dates of various crops-seed varieties, having different maturity duration time are sufficient to obviate stress conditions.

2.3.4 System Design

A good network planning and operational criteria are essential to achieve equity and assured timely water supplies to all farmers. For every farmer to know well in advance his seasonal entitlement and when he will receive it, distribution system must have the following attributes:

- well designed network with an adequate number of control points, measurement and regulating structures to divide the available supply so that every channel receives and delivers its design flow;
- single operational plan based on realistic system efficiencies that ensures farmers receiving their allocations in time; and
- trained management force whose duty and functions are to accomplish these tasks.

(1) Structured System

The guiding principal in the structured system design is that a minimum amount of intervention will be needed for day to day operations and the structured layout fulfills this criterion. The structured system would be a sort of fully self-regulated / automated system at the primary and secondary level when sufficient water is available to meet the crop water requirements. The system would require a bit of regulation during short supplies. The distribution of water at tertiary level would be attended by the farmers.

Accordingly the networks have been planned in two stages. Firstly the main canal system has been designed to supply water to the whole of the command area, and then distribution net works are laid out within this area (through distributary or minor canals off-taking from the main canal) to deliver water to the respective distributary / minor blocks. Within distributary / minor blocks water is distributed through tertiary canals. In this system each distributary or minor taking-off from main canal, functions as an independent unit to deliver the required quantum of water to each sub-unit. The system either flows with full design discharge or kept fully closed.

As such the command area is proposed to be irrigated through a network of distributaries / minors. Outlets would be provided in the distributaries / minors to feed the respective sub units.

(2) Components of the Structured System

Each component of the structured system has hydraulic and networks flow considerations, which will be taken care through integrated planning methodology.

(a) Main canal / Branch canal – Primary system

Water from the outlet of the reservoir is led into the Main Canal, which would further bifurcate in Left Main Canal and Right Main Canal. The discharge in these canals would vary as per the requirements and as such these primary canals may or may not run full. Preferably, no direct irrigation is carried out from the main canals.

(b) Distributary / Minor channels - Secondary canals

A channel taking-off from the main canal is called a distributary or a minor depending upon their discharge. A minor may also take- off from a distributary. Outlets are fixed on the distributary / minor, which provide water to the watercourses (tertiary canals).

To facilitate the outlets to draw their authorized discharge, the distributaries / minors would always be run to their full capacities or alternatively kept closed. Similar will be the case for the running of distributaries and minors where in the FSL of the main canal at the off-take point of distributary / minor would be maintained at the designed level.

(c) Tertiary canals

Tertiary canals called as watercourses carry water from the outlets provided in the distributaries / minor canals to the fields.

In the main canal, principal concerns relate to sizing, spacing of control structures, locating escape structures, determining response time for gate operation to ensure safe filling and emptying periods, water losses, and establishing method of communicating information from downstream network to main canal operations. The secondary canal system concerns involve mainly maintaining designed Full Supply Levels (FSLs), estimating response time, and ensuring that control and regulating structures deliver the required flows with a high level of precision to the designated areas. The concerns in the tertiary area mainly relate to the alignment of tertiary canals taking into account the micro-topography of the sub areas and farmers fields.

With this in view, the entire system has been planned, to be operated as an integrated network.

(d) Cross Regulator and Head Regulator

A cross-regulator is provided at the head of the main canal, downstream of an off-taking distributary and is operated when necessary so as to head up water on its upstream side, thus to ensure the full supply in the distributary even during the periods of low flow in the main canal. The main functions of a cross regulator are:

- To effectively control the entire canal irrigation syste
- When the water level in the main canal is low, it helps in heading up water on upstream side to the required level so as to feed the off-taking distributary to its full capacity.
- It helps in absorbing fluctuations in the various sections of canal system.
- Cross regulator is often combined with the road bridge so as to carry the road which may cross the irrigation channel near the site of canal regulator. It is also usually combined with a fall if required.

A head regulator is provided at the head of the distributary / minor to close the same during 'OFF' periods. It also functions as a measuring device for water entering the distributary or minor.

(e) Outlets

Open flume outlets are being proposed for taking water from the distributaries / minors. They also function as measuring devices for the water entering the system. Open flume outlet is a weir type outlet with a constricted throat and an expanding flume on the downstream. Due to the constriction, a super critical velocity is ensured in the throat there by, allowing the formation of a hydraulic jump in the expanding flume. The formation of the hydraulic jump makes the outlet independent of the water level in the watercourse. The outlets would be un-gated, so that they start drawing water by themselves when the distributaries/minors are drawing water. Outlets on the distributaries/minors would be designed for the respective discharges required to serve their designated areas.

(f) Canal Escapes

An escape is a side channel constructed to remove surplus water from the main canal or distributary into a natural drain. The water in these channels may become surplus due to some mistake or difficulty in regulation at the head. Some times, due to excessive rainfall in the command area the farmers may not like to take water. In such cases, the canal supplies shall become surplus and this excess may have to be escaped to avoid overflowing. No doubt, in all such cases, the supplies shall be reduced or stopped from the head but the effect of this reduction is felt only after a certain time. Therefore, in order to avoid damage, some immediate action is required, and this is achieved by means of operating an escape.

(g) Measuring devices

Flow measurements in the irrigation channels are necessary for effective management of water. These measurements are carried out by constructing measuring devices. Variety of structures, devices and methods are available for this purpose

2.3.5 Design of Main Irrigation Canal

Considering the above mentioned design policy and economic aspect, main canal routes, irrigation diagram, canal type, typical canal cross-section and crossing structures are proposed as follows:

(1) Main Canal Routes and Irrigation Diagram

Irrigation water being impounded in Kudu Dam is conveyed to Left Main Canal through intake structure of the dam, and diverted to Right Main Canal at 6.4km from the beginning point. After diversion, Right Main Canal is designed to cross Munyati River by siphon. The length of Left Main Canal and Right Main Canal is 103.8 km and 74.1km, respectively, and total length becomes 177.9km.

Main canal routes are decided by using orthophoto map of sacle 1:15,000, which was prepared during the Phase I First Field Survey. The canal routes are decided to keep gravity irrigation areas as much as possible, considering the design headwater at the intake structure of the dam and hydraulic losses. The canal route and irrigation diagram are shown in Drawings.

(2) Canal Type

In this study, two types of canal lining were compared, one is trapezoidal concrete lining type and the other is rectangular reinforced concrete type. Since efficiency of irrigation water use, labor requirements and O&M cost and construction works are not so different between two canal types, the canal type was examined through financial aspect. Comparative study was carried out at the Phase-I stage using the unit price as of the expiration time of the Phase I Field Survey, June 1999. As shown in the following table, the trapezoidal concrete lining type became more profitable.

Trapezoidal Concrete Lining Type Canal

Work Item	Quantity	Unit Price	Amount
Clear &Grub	4,144,000 m^2	Z$ 8.0 /m^2	Z$33,152,000
Excavation	3,343,000 m^3	Z$ 73.5 /m^3	Z$245,711,000
Embankment	2,260,000 m^3	Z$ 89.0 /m^3	Z$201,140,000
Plain Concrete	128,230 m^3	Z$ 3,750.0 /m^3	Z$480,863,000
		Total	Z$960,866,000

Rectangular Reinforced Concrete Lining Type Canal

Work Item	Quantity	Unit Price	Amount
Clear &Grub	3,351,000 m^2	Z$ 8.0 /m^2	Z$26,808,000
Excavation	6,202,000 m^3	Z$ 73.5 /m^3	Z$455,847,000
Embankment	2,938,000 m^3	Z$ 89.0 /m^3	Z$261,482,000
Reinforced Concrete	836,690 m^3	Z$ 5,000.0 /m^3	Z$4,183,450,000
		Total	Z$4,927,587,000

Moreover, trapezoidal concrete lining type canals have been constructed in Zimbabwe since former Rhodesian period, e.g., Mutiriawe Canal (Constructed in 1960s, length: 56.0km) and Tokwane Canal (Constructed in 1992, Length: 14.0km, Design Discharge: 14.5m^3/sec).

Considering all the above, the trapezoidal concrete lining type was selected for most part of the main canal, and rectangular reinforced concrete type was adopted only for the steep slope area such as around the diversion structure from left main canal to right main canal.

(3) Typical Cross-section

The cross-section of main irrigation canal was designed based on the design discharge by using Manning formulation. The design discharge was derived from multiplication of irrigation area and unit design water discharge, and roughness coefficient (n=0.015) is adopted for Manning formulation. Gravel-paved O&M road with 4.0m width was planned to be constructed along the main canal. In relation with the ground surface elevation along the canal, two type canals, excavated canal and embanked canal, were considered. Typical cross-sections for the both types are shown in Drawings.

(4) River Crossing Structures

There exist many tributaries on the both banks of Munyati river. In case the main canal crosses a tributary, if topographical conditions are allowed, aqueduct is proposed considering decrease of the hydraulic loss and continuity of O&M road along the canal.

Major river crossing structures on the main canals are shown below.

Right Main Canal				Left Main Canal			
Crossing River	Crossing Distance (m)	Canal Design Discharge (m^3/sec)	Crossing Structure	Crossing River	Crossing Distance (m)	Canal Design Discharge (m^3/sec)	Crossing Structure
Munyati River	500	8.493	Siphon	Ngondoma River	150	24.600	Aqueduct
Ncherechere River	370	8.493	Aqueduct	Gwenya River	1,200	16.018	Siphon
Grisnake River	350	8.493	Aqueduct	Gwanika River	240	15.908	Aqueduct
Unknown	250	8.306	Aqueduct	Gwanika Tributary	120	15.908	Aqueduct
Chemveri River	150	7.774	Aqueduct	Mtanke River	200	15.908	Aqueduct
Renji River	800	2.838	Siphon	Msorowa Parukwe River	450	14.373	Aqueduct
				Msorowa Parkwe Tributary	120	14.373	Aqueduct
				Nyamachene River	550	14.373	Aqueduct
				Nyarpakwe Tributary-1	450	13.739	Aqueduct
				Nyarpakwe River	350	13.739	Aqueduct
				Nyarpakwe Tributary-2	130	12.927	Aqueduct
				Muzongwe River	350	10.650	Aqueduct
				Karaya River	350	10.650	Aqueduct
				Umuchini River	200	10.650	Aqueduct
				Mabiribiri River	700	10.650	Siphon

Further, if the canal crosses depression such as small river and stream other than the above tributaries, cross drain will be constructed to convey the water easily. If the canal crosses existing major road, box culvert will be constructed. Typical drawings of all the above structures are shown in Drawings.

2.4 Water Users Associations (WUAs)

2.4.1 Enactment for Water Resources Development and Distribution

Water resources development and distribution in Zimbabwe has been regulated through enactment of two new acts viz. (a) Zimbabwe National Water Authority (ZINWA) Act (Chapter 20:25) No.11/98 and (b) Water Act (Chapter 20:24) No.31/98. Some Salient Features of ZINWA Act and Water Act are given below.

(1) Zimbabwe National Water Authority (ZINWA) Act

The Zimbabwe National Water Authority Act (Chapter 20:25), No.11/98, as enacted by the President and the Parliament of Zimbabwe, provides for

- establishment of ZINWA and its functions,
- appointment and functions of a board of the Authority,
- raising of charges for the provision of water and other services by the Authority,
- funds of the Authority,
- imposition and collection of a water levy, etc.

As per the enactment, ZINWA has been established as a body corporate capable of suing and being sued in its own name and subject to this Act, of performing all acts that bodies corporate may by law perform.

The operations of the Authority shall be directed and controlled by a board consisting of :

(1) a chairman appointed by the Minister,
(2) the chief executive, and
(3) eight other members of whom

- four shall be appointed by the Minister; out of these four one shall be a member of the Public Service who is a water engineer appointed from among the water engineers employed by the Ministry for which the Minister is responsible; and the remainder, as well as chairman, shall be persons recognised for their ability and experience in the development and management of water resources, business or administration.
- four shall be appointed by the Minister from a list of not less than five persons nominated by the catchment councils established in terms of the Water Act.

Main functions of ZINWA are given below:

(1) to advise the Minister on the formulation of national policies and standards on
    - water resources planning, management and development,
    - water quality and pollution control and environmental protection,
    - hydrology and hydrogeology,
    - dam safety and borehole drilling, and
    - water pricing,

(2) assist and participate in or advise on any matter pertaining to the planning of the development, exploitation, protection and conservation of water resources,

(3) to exploit, conserve and manage the water resources with the object of
    - securing equitable accessibility and efficient allocation, distribution, use and development,
    - providing, in both the short and long term, adequate water on a cost effective basis;
    - taking appropriate measures to minimise the impacts of droughts, floods, or other hazards,

(4) promote an equitable, efficient and sustainable allocation and distribution of water resources,

(5) encourage and assist local authorities in the discharge of their functions with regard to the development and management of water resources in areas under their jurisdiction and in particular, the provision of potable water and the disposal of waste water,

(6) ensure that, catchment councils discharge their functions in accordance with the Water Act,

(7) encourage and assist catchment councils to plan and coordinate the development and management of water resources in areas under their jurisdiction,

(8) operate and maintain any water works owned or managed by the Authority and to sell any water therefrom, to dispose of waste water, to construct boreholes and to provide design and construction services,

(9) provide, at such fee as the Authority may determine, all forms of assistance, including technical assistance, personnel, advisory and training, information and other services to the Government, local authorities and catchment councils in connection with the exploitation, development, management and distribution of water resources,

(10) undertake research studies and develop a database on hydrological issues pertaining to or of interest to Zimbabwe and to publish the findings and any other data compiled by the Authority,

(11) conduct hydrological and geographical surveys and to produce plans, maps or other information necessary in the planning, development and exploitation of water resources and to publish any such surveys, plans, maps or other information,

(12) promote such mechanisms for the cooperative management of international water resources as the Minister may determine, and

(13) carry out any function that may be conferred or imposed on the Authority by or under this Act, the Water Act or any other enactment.

As per the Schedule (section 6), ZINWA has the power of authority, with the approval of the Minister, to construct, establish, acquire, maintain and operate dams, reservoirs, canals, distribution works, and hydro-electric power stations in any area on such terms and conditions as may be approved by the Ministers. For such purposes ZINWA may raise loans or borrow money. For efficient exercise of powers, ZINWA may purchase, take on lease or otherwise acquire and hold property and interests in or rights over land, rights to the use of water and any other rights, which may be necessary.

The funds of the Authority shall consist of:

(1) such moneys as may be payable to the Authority

- from moneys appropriated for the purpose by Act of Parliament,
- by any subsidiary company promoted, established or acquired by the Authority,
- from the funds allocated to the Authority for the purpose of meeting the expenditure incurred or to be incurred by the Authority in performing such functions, other than commercial functions, as the Minister may approve,

(2) any donations and grants made to the Authority,

(3) such moneys as loans or by way of other financial assistance,

(4) charges recovered as any fee or charges in respect of any services rendered by the Authority, and

(5) such other moneys or assets as may accrue to the Authority, whether in the course of its operations or otherwise.

As far water and other charges, ZINWA, with the approval of Minister and subject to the Water Act, may fix charges for

- the sale of raw or treated water from water works operated or controlled by the Authority
- the disposal of waste water
- the drilling of boreholes, and provision of consultancy services

The change or increase of any charge, shall have the approval of the Minister.

(2) The Water Act

The new Water Act (Chapter 20:24) No.31/98 as enacted by the President and the Parliament of Zimbabwe, inter-alia, provides for

- the development and utilisation of water resources of Zimbabwe;
- establishment, powers and procedures of catchment councils and sub-catchment councils;
- grant of permits for the use of water;
- control of the use of water when water is in short supply;
- acquisition of servitudes in respect of water;
- protection of environment and the prevention and control of water pollution; etc.

Subject to this Act, all water is vested in the President. No person shall be entitled to ownership of any water and no water shall be stored, abstracted, apportioned, controlled, diverted, used or in any way dealt with except in accordance with this Act. A permit issued in terms of this Act shall confer upon its holder a right to the use of this water in accordance with the permit.

For the purpose of this Act the functions of the Minister shall be

- to develop policies to guide the orderly and integrated planning of the optimum development, and utilization of water resources,

- to ensure the availability of water to all citizens for primary purposes and to meet the needs of aquatic and associated ecosystems particularly when there are competing demands of water,
- to ensure the equitable and efficient allocation of available water resources in national interest for the development of rural, urban, industrial, mining, and agricultural sectors and to encourage participation by consumers in all the referred sectors and catchment councils in the development, exploitation and distribution of water resources.

The Water Act emphasis on the development through catchment councils. The Minister, after consultation with ZINWA, may declare any catchment area, group of catchment areas and any aquifer in the area concerned to be a river system. A river system shall be under the control of a catchment council. A catchment council shall be a body corporate capable of suing and being sued.

The Water Act specifies that for ensuring the optimum development and utilization of water resources of Zimbabwe, ZINWA and the catchment council concerned, shall prepare an outline water development plan for every river system. Such an outline, may indicate and specify, among other issues, availability of resources, potential sites and priorities in allocation and utilisation of water etc.

Main functions of the catchment councils include:

- in conjunction with the National Water Authority, prepare an outline plan for its river system in accordance with the Act.
- determine applications made and grant permits required in terms of Act.
- regulate and supervise the exercise of rights to, and use of, water in respect of the river system for which it is established, and
- to supervise the performance functions by sub-catchment councils, etc.

Main functions of subcatchments include:

- regulate and supervise the exercise of rights to water within the area for which it was established
- with the approval of the Minister, a subcatchment council may levy rates upon persons who holds permits with in the area for which the subcatchment council was established and may charge fee for any service rendered by it.

2.4.2 Catchment Council Boundaries

The Water Act emphasis on the development through catchment councils. A catchment describes the drainage area of a particular river system, which often encompasses parts of different administrative areas such as Rural District Councils and may be even parts of different nations (e.g. the Amanzamnyama in Metabele land, which becomes the Nata River in Bostswana).

As is known the Rural Districts Councils cover comparatively small area, and river water plans made on district basis may remain fragmented or overlap in some cases, thus obviating the overall utilization of resources on optimal and sustainable basis. It has, thus been decided to plan the water resources on catchment basis through River Catchment Councils.

Based on the above concept, it has been proposed to divide Zimbabwe into 7 (seven) Catchment Boundaries as detailed below:

CATCHMENT COUNCIL BOUNDARIES

S. No	Council Boundary	Sub-Catchment Councils/Tributaries
1	Sanyati	Sanyati, Mupfure, Lower Munyati, Upper Munyati, Nyaodza.
2	Manyame	Manyame, Angwa, Musengezi, Rukomichi.
3	Mazowe	Mazowe, Muruodzi, Ruya, Rwenya, Nyangombe, Shavanhowe, Nyadire, Gairezi, Pungwe
4	Save	Save, Odzi, Devure, Nyazvidzi, Nyanyadzi, Ruzavi, Macheke, Rusape, Rusitu, Honde, Musirizwi, Zonwe, Buzi
5	Runde	Runde, Chiredzi, Mutirikwe, Tokwe, Ngezi.
6	Mzingwane	Mzingwane, Limpopo, Shashi, Insiza, Ncema, Nyanguni, Tuli, Mwenezi.
7	Gwayi	Gwayi, Shangani, Nata, Bembazi, Gwabazabuya, Tegwani, Lukozi, Ruziruhwa, Deka, Matetsi.

The Lower Munyati Project is a sub-catchment project in Sanyati Catchment Boundary

2.4.3 Water Management in Council Boundaries

The Lower Munyati Sub-Catchment Council has already been planned and its water management aspects would be guided by the Water Act (Ch. 20:24) No.31/98. As far water allocation / distribution, the Act entrusts the Minister, as one of his functions, to ensure the equitable and efficient allocation of available water resources in the national interest for the development of the rural, urban, industrial, mining and agricultural sectors. In the performance of this function, participation by consumers in all sectors and catchment councils will be encouraged.

2.4.4 Organisational Work at Command Level

Though sub-catchment council for Lower Munyati is already planned, there will be need to start mobilising farmers participation in terms of organising Water Users Associations (WUA) at the outlet command level and proceed to higher levels. As per the basic concept organising work would start from the initial hydraulic unit i.e. outlet and extend to distributaries.

For a WUA to be established as a legal entity there has to be a law authorising its establishment. The legal framework for establishing them and facilitating them to operate may be derived through

- The enabling act
- Co-operative Societies Act, Societies/Associations Registration Act or any other Act as available facilitating their registration as a Society or Association
- The transfer agreement between the sub-catchment council and the WUA

(1) Structure of WUAs

The structure of WUAs will depend upon the available legal framework, however from the general management point of view, a WUA should not be too large to be non-cohesive and personal contacts lessened, nor too small to endanger its viability. The organization activities will be focused initially on each minor or each part distributary through outlet commands.

Depending upon the available legal framework, a three-tiered organisation is envisaged.

(a) Out let Committee:

This is the lowest level of organization constituted at the outlet level and is intended to remain informal. It is important to clarify as to why the outlet committee should be the lowest level of organization. The process of organizing has to be bottom-up and also from the general management point of view, WUA should not be too large to be non-cohesive, and personal contacts lessened. Nor it should be too small resulting in exceeding large number of associations becoming uneconomical from overhead costs point of view and also difficult to correlate their activities. As such it has been proposed to keep it informal.

All farmers, who take water from the outlet, shall be its members.

(b) Water Users' Association (WUA):

The formal working level would be a minor/part distributary. The CCA of one WUA shall not exceed 200 ha. The WUA would be registered to function as a legal body.

(c) Federation:

At the Project level, a federation of WUAs will be established that will have a formal but non-binding advisory role.

(2) Some Organisational Issues at the Command Level.

(a) Through WUAs, the farmers can enter into an agreement to provide certain agreed quantities of water in normal years. This point is immediately caught and understood by the farmers to ensure their water allocation and they would readily agree to form WUAs and take over the system.

(b) It may be necessary to give a legal status to the WUAs, as certain agreements (on volume, rates, payments etc.) have to be entered into. Such agreements may not be possible at the individual levels..

(c) Participation of farmers imposes heavy burden on farmers in terms of time, money and they have to make adjustments with others. This calls for tangible and visible incentives/benefits in-built in the system. The incentives to the Associations should be adequate to attract their interest in assuming greater management responsibility.

(d) The question arises who should take the initiative for organising the farmers- Agritex, farmers or NGOs. In Zimbabwe, where almost all the irrigation projects are investigated, planned, constructed and operated by Government agencies, the best choice for promoting farmers' participation would be a way that the Government agencies enunciate the process and widely disseminate it. The farmers under the present socio-economic system, on their own may not be able to form WUAs. The involvement of NGOs is the effective choice for assisting the Government agencies in organising the farmers. The NGOs can dialogue with the farmers in a friendly atmosphere and farmers would be well disposed towards NGOs. Some experiences suggest that Irrigation Community Organisers (ICOs) encadred by Government agencies are in a position to motivate the irrigators and form associations. The Agritex staff could also be trained and deployed for organisation work. In any case extensive motivational and promotional campaign will have to be organised in order to familiarise the farmers with objective of forming associations and turnover. This becomes important because building WUA at the grass root level is a difficult and long drawn process because of legal, technical and social complexities and differences in attitudes.

(e) The WUA should have a set of Bye-laws, spelling out broadly its objectives, functions, obligations, responsibilities, rights etc.

(f) For effective functioning of WUA and to provide confidence among individual farmers, it would be necessary to have a memorandum of understanding (MoU) between the WUA and the Irrigation Authority. The MoU shall provide the rights and responsibilities of both the parties.

(3) Implementation Process

It is proposed to start the activity of organising WUA even before the starting of construction of main canal.

(a) Training and Orientation of Staff

Training and orientation programme would be organised for all levels of staff. This would include 2 days appreciation work shop for Senior Irrigation Specialists and Senior Agricultural Extension Officers. For the junior staff the training duration may be kept 5 days or so.

(b) Participatory Rapid Appraisals

During this phase, the junior staff, under suitable guidance, will organise a series of meetings with the farmers in groups and explain the concept in a play-way manner giving them opportunity to open out freely to express their opinion. This will help in understanding their perception of the issue, requirements and aspirations.

(c) Organising WUA

The process of organising farmers will precede the construction activity. The logic for this is to involve the farmers right at the construction stage so that the spirit of ownership is inculcated enabling easy turn over. WUAs are to have the status of legal person, it would be imperative to define the obligations, duties, and responsibilities of both the project Office and farmers. As such the provisional Memorandum of Understanding (MoU) and Bye-laws drawn up jointly by the Project Office and farmer groups, will be discussed with the area farmers.

(d) Turn Over

During this period, the WUAs will learn how to manage the functioning of the system. Farmers will work closely with the project field staff to understand the detailed procedures etc.

After satisfaction the responsibility of operation and maintenance would be passed on to the WUAs. The staff would continue to guide the WUAs till such time the associations become self-sustaining.

2.5 Drainage Plan

2.5.1 Drainage System

Surface Drainage is removal of water from the surface of land. The water may be from excess precipitation, water applied in irrigation, or losses from conveyance channel etc. For maintenance of sustained production from irrigated agriculture, drainage of land is essential. The prime objective of drainage in the cropped lands is to develop and maintain soil zone in such a condition that moisture, air and soluble salts are in favorable balance for the plant growth. In irrigated agriculture drainage is necessary to achieve and maintain such a balance. Proper drainage results in better and increased production compared to that in a poorly drained area.

Surface drainage broadly comprises following categories:

(1) On-farm field drainage system - It consists of graded channels that collect excess water from fields.

(2) Link drains- These are intermediate collector drains which link various field drains and sub-main drains or main drains.

(3) Main drains - Main/sub-drains are principally excavated or natural drains, collecting water from link drains or directly from field drains.

The project area is new to irrigated agriculture and most natural soil surfaces including many cultivated fields are some what irregular consisting of randomly distributed elevated areas and depressions. It results in pondage of water in depressions and inefficient irrigation. Farmers, by themselves will be able to take care of these situations by reforming the land surface so as to provide continuous gentle slope to result in regulated water flow and adequate drainage.

2.5.2 Drainage Needs of Project Area.

Drainage requirements are determined on the basis of various factors such as physiography of the area, soils, rainfall, sub-soil water conditions of the area, and the types of crops grown. The elevation of the study area extends from 800 to1000 m. The right bank of the Munyati river has a gentle slope towards the Munyati river, and its tributaries which flow from the east to west are almost small except for the Sakungwe river. On the other hand, the left bank is characterized by the Mafungabusi Plateau and Chinwavaenzu Hills which lie between the elevation of 1000 m and 1200 m along the west boundary. In the left bank, there are many tributaries and form river bank terraces.

The command area has uniform slopes and is interspersed with small streams. These streams are presently draining the proposed command area. A network of natural drainage out falling into major streams is available. As such no surface drainage problem is expected. However, the command area on development of irrigation would require some link drains leading to natural streams.

2.5.3 Determination of Runoff from Rainfall

One of the best and complete methods for determination of direct runoff from the rainfall is Soil Conservation Service Method. This method is developed by United States Soil Conservation Services. It takes in to consideration the antecedent soil moisture conditions, soil characteristics, like infiltration and permeability, land use and cropping pattern etc.

In this method, the rainfall is converted to runoff by the following mathematical relation

$$Q = (P - Ia)^2 / (P - Ia + S)$$

Where

Q = the depth of actual runoff over the catchment in mm

P = the depth of rainfall in the catchment in mm

Ia = the initial abstraction in equivalent depth over the catchment in mm.

Initial abstraction, Ia is that portion of rainfall which is interceptedby foliage etc. in surface storage or that infiltrates into the ground surface. All these take place before runoff occurs.

S = the potential maximum retention of water by the soil and cover in equivalent depth over the watershed. The potential maximum retention – S is controlled by the rate of infiltration at the soil surface or (as in paddy) by the rate of transmission in the soil profile, or by the water storage capacity of the profile, which ever is limiting factor

Normally, drainage system is designed for runoff occurring from rainfall frequencies that occur on the average of once in every five years (20 % chance). However when increased drainage protection is required 10% chance is adopted. It is proposed to adopt a chance of 10 %. The depth of rainfall for the storm for which runoff is to be estimated is determined from the selected design frequency. Rainfall depths for 24 hours have been used for drainage design as per normal practice. The probable rainfall for the adopted chance of 10% has been found out using Plotting Method of determining frequency curve for annual series record of 24 hours rainfall intensities. Daily rainfall data for Gokwe station is available for the period from 1964 to 1998 and this data has been used to compile the year wise maximum 24 hours rainfall. Maximum 24 hour rainfall was found to be 98.8 mm on 10th February1996. This data has been used in the frequency curve analysis.

Initial Abstraction essentially consists of losses from interception, surface storage, and water which infiltrates prior to runoff. It is related to and is a part of the maximum retention (S). The relationship has been determined from the runoff potential of the soil with due regard to Antecedent Moisture Conditions (AMC). Knowing the values of depth of rainfall in the catchment, initial abstraction in equivalent depth, and the potential maximum retention, the depth of actual runoff over the catchment has been worked out using the given formulae. The value of the runoff called as drainage coefficient works out to 1.76 lps/ha. The link/main drains where ever required, would be suitably designed taking drainage coefficient of 1.76 lps / ha..

2.6 Plan of Operation and Maintenance

2.6.1 Scope

The Plan of Operation and Maintenance (POM) is the management plan of an irrigation and drainage system. It comprises permanent set of documents and instructions, work procedures and rules (including coordination with other disciplines), programs and schedules. It is a framework of broad guidelines. POM often requires updating during project implementation. It may have to be reviewed in the post-implementation period of the project in the light of advances in science and technology, management techniques (such as computerization, automation etc.) and the experiences gained during operation and maintenance of the system. The POM should have readily available complete information/statements for reference and guidance at every level in the project organization. The POM should specifically include:

(1) System Operations – Detailed operational policy, rules & regulations, operational plans, operational procedures, above and below outlets.

(2) System Maintenance – Identification of works, development of work plan, covering routine and special repairs.

(3) Personnel and water users – Relationship, rights and obligations, offenses and penalties, policies and procedures.

(4) Organization, Management and Responsibilities – Project policies, goals, and objectives, functional units their responsibilities and organizational structure.

(5) Financing – Development of budgetary cycle, funding sources, water rates and recoveries, etc.

2.6.2 System Operations

Water meant for irrigation is proposed to be distributed on the rotational system of water distribution by fixation of turn schedules at both the secondary and tertiary levels.

(1) Turn Schedule at Secondary Canals (TSS)

Water is introduced at the main canal system according to the fixed schedules. As water reaches the control points in the system, the gates in the main canal are operated in such a way so as to maintain the required FSL in the main canal to pass the required discharge in the respective distributaries/minors at their full supply levels.

Irrigation supplies are delivered to each of the distributary/minor ensuring its full supply for a normal rotational period of 7 days-nights (7x24= 168 hours, here after called as days). During the peak demand period, when crop water requirements are at peak, constant irrigation would be delivered continuously.

During non-peak period demand or when the supplies are short, the flows would be made intermittent, they would be either 'ON' or 'OFF'. The 'OFF' periods may last 7 or 14 days depending upon the situation. In such cases, adjustments in rotational time would be made so as to ensure running of secondary canals to their full capacities during the rotational cycle of 7 days.

(2) Turn Schedule at Tertiary Canals (TST)

Turn Schedule at Tertiary canals, called as 'TST', in an outlet command area may be defined as a system of equitable distribution of water in a rotational cycle of 7 day-nights (7x24 = 168 hours) by turns according to fixed schedule, specifying the day, time and duration of supply to each farmer in proportion to land holding sizes. Thus every farmer in the outlet command has fixed number of hours for which he is entitled to water in a weekly cycle of 7 days i.e. 168 hours.

Based on this concept, TST schedules will be prepared for all the outlets commands.

2.6.3 Plan of Maintenance

Maintenance refers to operations performed in preserving system and facilities in good or nearly original condition without increasing its capital cost. Maintenance may be normal or routine, emergency, or special repairs. Deferred maintenance is the accumulation of maintenance being accrued under the normal or routine maintenance program – which results due to shortage of funds and other reasons.

In the project the maintenance activities have been grouped according to the major elements of the system; they are : (a) dam and reservoir; (b) irrigation network; and (c) drainage network. They are described below:

(1) Dam and Reservoir

Main activities in a reservoir comprise:

(a) Controlling aquatic weeds,
(b) Removing large debris (e.g. tree trunks) floating in the water that may damage hydraulic structures.
(c) Monitoring the water quality: not only from silt content point of view but also from a biological standpoint in order to detect possible sources of pollution.
(d) Surveying the sediment deposition in the bottom of the reservoir.

These are periodic activities and do not require much time with the exception of aquatic weed control, which is not likely to be a severe problem. However, they are extremely important in order to detect promptly the need for corrective action.

The main maintenance activities for an irrigation dam are: lubrication of gates, anti-corrosion treatment, cleaning of debris, control of filters, and some other minor control required once or twice a year.

(2) Irrigation Network

Canal Lining: Canals in the system would be lined and as such should require little maintenance. When the concrete lined canal cracks, it would be attended immediately.

Erosion of banks: Canal banks often get eroded by heavy rainfall or wind, stock grazing or passage of animals, and transit of vehicles. This has been proposed to be repaired by mechanical means or manually.

3. Formulation of Development Plan of Nyarupakwe Pilot Irrigation Area

3.1 Present Conditions of Pilot Irrigation Area

There are no irrigation and drainage schemes in the Pilot Project Area. The pilot irrigation area is selected from the present cultivated land with rainfed condition and comprises around 37.5 ha of land of the village Magonyo and 22.5 ha from the village Hlamba. The area is horizontally bisected by a village road, leaving some area of both the villages on the north side of road and remaining on the south side. Village boundary bisects the area vertically. The intersection of the village boundary and the road has been taken as the reference point for the planning purposes.

Most of the farms are distinctly separated by rows of trees laid in the north-south direction (with reference to road), generally, in disorderly manner and the distance between two farms (intercepted with trees and intense bushes) is found to be around 10-20 metres. The land slopes of irrigation area vary from 1 in 230 to 1 in 250. On the north and south side of the pilot area lands are sloping with steep slopes up to 1 in 40 or even less. No drainage problem is observed.

Farmers, in the whole of the irrigation area are having rainfed cultivation. The crops mainly include cotton about 60%, the remaining area being covered with maize, groundnut, millet grains etc. Most of the farmers were found to be fully aware of the cropping practices. A bit of training will be sufficient to facilitate change from rainfed cultivation to irrigated one.

As far land formations, most of the area would need land grading except for some reaches that would require land leveling. The soils vary from sandy-loam to loam and as such land formation will not be difficult.

3.2 Irrigation and Drainage Development Plan

3.2.1 Irrigation Area

(1) Pilot Irrigation Area

The pilot irrigation area is selected among the existing rain-fed cultivated lands in two villages of Magonyo and Hlamba in due consideration of location for water resources, topography and soil, where were identified as the area suitable for irrigation during Phase I Study. This area is relatively easy to access due to farm roads running between this area and Gokwe town, which is passable by vehicles. A small dam is proposed on the Nyarupakwe River, which would service the proposed irrigation area.

The central portion of the identified cultivable area is moderately sloping with land slopes varying from 1 in 230 to 1 in 250. On the north and south side of the pilot area lands are sloping with steep slopes up to 1 in 40 and even less. As such, the central portion has been considered for irrigation development.

(2) Delineation of Pilot Irrigation Area Boundary

For carrying out survey on the incorporation of Social Dimensions into the Pilot Project, ITDG/JICA study team initiated discussions with the farmers of the identified area. This area covers part areas of the villages of Magonyo and Hlamba. Out of this, some area as mentioned above, have very steep slopes and could be excluded from the pilot study. The area fit for irrigation has been estimated at 88.10 ha.

Water available for irrigation is 0.74 MCM, which will be able to irrigate 60 ha, as such out of the available area of 88.10 ha as worked out above, a compact contiguous block covering net irrigation area of 60 ha has been selected. Net distribution of areas amongst two villages is as follows.

Mogonyo village	37.57	ha
Hlamba village	22.43	ha

Total area acquired would be around 72 ha to cover up other requirements of watercourses, laterals, drains and farm roads etc. The area may need some change/adjustments to accommodate some changes in water availability, or existence of local high/low patches or jungle/tree growth or homesteads etc.

3.2.2 Irrigation Water Requirements

While working out the irrigation water requirements for the feasibility study on the Lower Munyati Project, the meteorological data of Gokwe Meteorological Station was utilized. The same data is very much valid for the pilot project also. Further, the cropping pattern proposed for the irrigation area is same as adopted for the mentioned study. As such the unit irrigation water requirements worked out for the Muniyati Project has been adopted in this case also. The details are given in Section 2.2.

Based on the above procedure, average monthly diversion irrigation requirements as worked out for the irrigation area of 60 ha are given below.

Diversion Irrigation Requirements

(for 60ha)

Month	Irrigation Water Reqs. (million liters)
January	33.28
February	53.80
March	90.40
April	62.38
May	18.47
June	76.79
July	127.94
August	135.22
September	72.68
October	22.82
November	23.68
December	22.53
Total	739.99 or 0.74MC

The unit design water discharge is evaluated in 10-day basis from diversion irrigation requirement of 5-year return period, by applying planned cropping pattern and the meteorological data having been observed at Gokwe Station from 1968 to 1997.

The results of this evaluation are as follows:

Basic year	:	1971 (peak-third decade in February)
Unit Design Water Discharge	:	1.2 litres / sec / ha

3.2.3 Main Conveyance System - From Dam to Irrigation Area

Water from the dam outlet to the head of the irrigation area could be carried through either by the open/covered canal system or pipeline or a combination of both, suitably aligned depending upon the terrain as encountered and other specific requirements.

(1) Main Canal Alignment

While proposing the canal alignment, consideration has been given to the following aspects:

(a) The irrigation area is only 60 ha and the section of the open canal if adopted would be very small. The section being small, even if a little more length becomes necessary to avoid huge drainage crossings or low level areas, it should be preferred. The balanced section in respect of cut-fill would be ideal where ever possible, with due regard to the command area. The incremental cost of the additional length would be much less than the additional incremental cost on the specialized structures.

(b) Heavy structures for such a small size canal should be avoided as far as possible, because such structures require higher technology and sophistication, which is not easily available locally. Simple structures that could be constructed with local know-how should be preferred.

(c) Although an open channel is cheaper per metre length than a pipeline, the latter could be selected when the topography of the land is highly uneven or undulating, which would make the construction of an open canal either very expensive or even impossible/unworkable.

(d) It is a pilot irrigation area situated in the remote location and it would be desirable to avoid high filling sections, so as to avoid drainage problem enroute.

(e) The system is to be maintained by the farmers, who are new to irrigated agriculture and maintenance of related structures, as such the system should be sturdy without any complications.

With the above considerations two sets of alignment plans have been marked on the contour plan one with open canal and other with the pipeline. These alignments could be used individually or in combination depending upon field investigations and other specific requirements.

(2) Field Investigations

Two sets of alignments as marked on the contour plan, one for the pipeline and the other for the canal system were investigated in field.

(a) Methodology adopted for investigation

The field investigations were carried out in such a manner that the coordination of each turning point (TP) on canal alignment was grasped from 1/5,000 map prior to field investigation, and the location of TP was pointed out in the field by GPS (Grovel Positioning System). The canal alignment between two TPs was indicated by GPS using its navigation system. Cross-check of the TP location was also performed by taking distance and orientation between TP and road intersections or major buildings in the site.

(b) Investigation Details

The portion of land along alignment from RD 0 to 770 m was found to be uneven and undulating interspersed with small valleys and local depressions / mounds. In addition, the alignment crosses two valleys, one at around RD 320 m and the other at around RD 435 m. First valley is very deep (about 4m), with a width of about 15 m. The second valley meanders and is very wide (about 40 m at top) with bank slopes gently rising high.

Field investigations show that laying of open canal will be very difficult in the first 770 m, and as such laying of pipeline is desirable from RD 0-770 m. In the remaining portion, which is gently sloping, open/covered rectangular/trapezoidal canal or pipeline could be adopted as per functioning requirements and cost considerations.

While looking at the portion of open canal alignment, it is observed that the alignment for passing from Murandu Village (co-ordinates 8000175, 725460 - about 125 m southwest of Murandu school) to Magonyo Village(co-ordinates 8000975, 725565 - about 380 m away in the southwest from the Magonyo village chief's house), takes the shape of two sides of a triangle (or a truncated cone) rather than joining straight, there by taking longer route.

In an effort to reduce the length of the truncated triangular route as proposed, the area was surveyed intensively looking for various alternative options. In between the two points as mentioned above (between near Murandu school and near Magonyo chief's house), the alignment has to cross a major stream. The stream has a long catchment and is also joined upstream by another stream having its own catchment and it carries a substantial discharge. The stream meanders repeatedly and the area is manifested with dense bushes and some trees.

In the straight length between the two mentioned points, the stream has large meandering width with low bed levels. As we go upstream to cross the stream the bank slopes become gentle, rising slowly taking a long distance to gain the required matching height. Crossing the stream at immediate upstream locations would call for structures requiring higher technologies and sophistication that is not easily available locally. Maintenance would need added attention. The filling length of the canal would also lead to obstruction in drainage of the area.

Keeping in view the site conditions (as detailed above) between the two points as referred above (between near Murandu school and near Magonyo chief's house), two sets of alignments have been marked, one shortest as feasible for canal and other for pipeline, and included in the overall alignments as proposed.

(c) Alignment Options

In the first 770 m length, because of difficult terrain laying of canal is not feasible and only pipeline should be laid. In the remaining length either canal or pipeline could be laid. The following alignment options are available:

(i) Pipeline in full length of 4678 m
(ii) Pipeline in first 770 m and open/covered canal in the remaining 4883 m, total length being 5653 m

These are shown in Fig. 1.

(3) System Designs

This being a small scheme, the water conveyance system could be designed either for delivering water for 12 hours during the day-time, there by avoiding night irrigation or alternatively for delivering continuous supplies i.e. day & night - for 24 hours.

(4) Comparative Study

Based on the above options of canal alignment and system designs, the following alternatives have been studied.

Alternative-I : System Design for only day-time irrigation (for 12 hours)

Alternative I - (a) : With night storage reservoir

Alternative I - (b) : With pipeline from dam to irrigation area.

Alternative I - (c) : With pipeline and open canal from dam to irrigation area

Alternative-II : System design for continuous irrigation (24 hours)

Table 5 shows the summary of 3 alternatives excluding Alternative I - (a) and the following are detailed explanation for the above alternatives.

(a) Alternative I - (a) : Night storage reservoir

In Zimbabwe, sometimes, on small projects, night reservoirs are constructed at the head of the distribution system to store water during times when there is abstraction in the system from the water source, but water is not taken by the farmers for irrigation. This practice is being adopted in some schemes where farmers do not take water during the night-time. In these small schemes, the flows in the main canal during the night-time are contained in these so called night reservoirs. During the day-time this stored water is utilized for irrigating a separate section of irrigation area.

The Night reservoirs result in loss of water through seepage and a potential health danger in respect of diseases like malaria and bilharzia and as such, it is not advisable to promote them. But incidentally, in this pilot project, no head is available enabling constructing any night reservoir for storing water coming in the main canal during the night-time for its utilization during the day time.

(b) Alternative I - (b) : System design for day-time irrigation with pipeline from dam outlet to irrigation Area

Optimum alignment for the pipeline from dam outlet to the pilot irrigation area has already been marked with due field investigations. The total length of pipeline required is 4678 m. The discharge required to serve the 60 ha irrigation area for continuous day-night (24 hours) supplies as worked out earlier is 72 lps. In case the same area is required to be irrigated in 12 hours, instead of 24 hours per day, the discharge required would be double i.e. 144 lps. The length of the pipeline is 4678 m. The pipe diameter as required to carry the discharge from the dam outlet to the head of the pilot area works out to 0.7m. The flow velocity in the pipe works out to only 0.37 m/sec. The design details are given in Table 6.

It is proposed to use Class 6 Fibre-cement Pressure Pipes manufactured from Chrysotile Asbestos fibre and Portland Cement as per SAZS No. 113:1987. The Class 6 pipes are manufactured for a working pressure of 30 m head with a test pressure of 60 m head and the length of each pipe as available is 4 m. The diameter of the pipe proposed to be used is 699 mm of internal diameter, 742 mm of external diameter and mass per pipe of four meters is 493.12 kg.

The approximate cost of supply, carriage and laying of pipeline with joints and bends etc. is estimated at Z$ 35 million.

(c) Alternative I - (c) : System design for day-time irrigation with pipeline and open canal from dam outlet to irrigation area

The optimum alignment as investigated earlier for the pipeline of 770 m combined with the open canal of 4883 m is considered. The design is given in Table 7.

For flow discharge of 144 lps, the diameter of the pipe required works out to 0.7 m. In this length it is proposed to adopt the same pipes as proposed in (b) above for pipeline from dam outlet to irrigation area.

For the subsequent open canal length of 4883 m, a trapezoidal section is proposed, since the discharge is sufficiently high. The section works out to 0.5 x 0.55 m with side slope 0.5:1. The velocity works out to 0.53 m/sec which is slightly less than 0.6 m/sec but could be accepted (health considerations - bilharzia).

The cost of this alternative is estimated at Z$10 million.

(d) Alternative II - (a) : System design for continuous irrigation with pipeline and open channel from dam outlet to irrigation area

Ithis alternative water will be supplied continuously day and night, all the 24 hours in weekly rotations.

The pipeline with the length of 770 m has been designed for a head discharge of 72 lps. The pipe diameter works out to 0.5 m and velocity of flow as 0.37 m/sec. It is proposed to use Class 6 Fibre-cement Pressure Pipes manufactured from Chrysotile Asbestos fibre and Portland Cement as per SAZS No. 113:1987. The Class 6 pipes are manufactured for a working pressure of 30 m head with a test pressure of 60 m head and the length of each pipe as available is 4 m. The diameter of the pipe proposed to be used is 552 mm of internal diameter, 587 mm external diameter and mass per pipe of four meters is 323.70 kg.

Open canal length is 4883 m and the discharge at its off-take is taken as 72 lps. The discharge being small it is proposed to adopt a rectangular section. The size of the canal with slope of 1 in 1800 works out to 0.5 m x 0.5 m with water flow velocity of 0.43 m/sec. The design is given in Table 8.

The velocity of water in the main canal works out to 0.43 m/sec. This velocity, being low, has been examined in relation to the transmission of 'bilharzia' (schistosomiasis) disease. Bilharzia is transmitted via water borne vector - aquatic snail. The snails live on aquatic weeds, usually in water with a depth of less than 1m. The snail's activity is inhibited in water velocities exceeding 0.6 m/sec and they are susceptible to desiccation. To avoid such incidents it is proposed to cover the open canal with pre-cast concrete slabs (covers).

The pipeline would be working under various reservoir levels and despite control at head, it may some times carry excess discharge. A balancing tower would be required at the junction of the pipe end and inlet to open canal with suitable flow controls both at the entrance and exit from the tower. A parshall flume would be required at a small distance downstream of balancing tower to facilitate measurement of flow of water in the open canal. From safety considerations, and to cover up contingencies, an escape at FSL of the canal would be necessary at its off-take to avoid any over flow in the canal system.

The cost of the pipeline for initial length of 770m and open canal with covers for the length from 770m to 5653m is estimated at Z$ 11 million.

(e) Adoptability of Alternatives

For day-time irrigation, three cases have been discussed viz. night storage reservoir, pipeline for the whole length from dam outlet to the pilot area; and combination of pipeline and open canal.

The first case Alternative I - (a) is not recommended in consideration of loss of water, health danger and insufficient head between dam and irrigation area.

The second case Alternative I - (b) is very costly and investment will not commensurate with the benefits. There are problems in the availability of the bends, sluice valves and air relief valves of 0.7 m diameter. Use of reducers is restricted due to head limitations. Even for minor maintenance heavy machinery will be required. Normally, unless other wise required for some specialized considerations, pipelines are found to be feasible where available head is more and flow through it passes at a high velocity. Here both the water head and the velocity of flow are very low.

The third case Alternative I - (c), shows the lowest cost among 4 alternatives. But this alternative design has some operational considerations which result in the loss of water leading to the reduction of irrigation area.

(i) Water Losses in Alternative I-(c)-Day-time Irrigation

The operational considerations, which lead to water losses, mainly relate to the water allocation and distribution policies, water application time and water losses that occur before the starting time of irrigation and that after the closing time of irrigation.

Water allocation and distribution policies: Adopting equity principles as detailed earlier, the allocations to the individual farms will be made in proportion to the area of the individual farm declared for irrigation and the distribution based on the 'rotational system of water distribution' by fixation of both the turn and the time period of water application in weekly rotations, keeping the flow constant. The primary requirement here is ensuring a constant flow and allocating time to each farm in proportion to its individual allocated area. Volumetric concept is followed using time base and constant water supply in each weekly rotation.

Water Application: In this alternative, farmers will apply water for 12 hours during the daytime only. During the remaining 12 hours farmers will not take water and as such the supplies will be closed. As per the operational criteria, full supply in terms of designed discharge with the designed depth should be available in the main canal at its tail end in the daytime period of 12 hours so that the farmers are able to take full discharge during their allotted time

(ii) Water losses before the Start of Irrigation

When the canal system is switched 'ON' from the 'OFF' position, water starts flowing in the canal from its regulation point. The flow then advances in the main canal and initially it just touches the tail end of the main canal (start of irrigation area) and then continues further beyond this tail end with gradual rise in depth of water at this tail end. Before the start of irrigation by the farmers in the morning (at the time fixed for the starting irrigation), the main canal must attain the designed full supply depth at its tail end. The amount of water crossed over the tail end from touching to till attaining full depth at the start of irrigation time is not used by the farmers and becomes the losses before the start of irrigation. The time taken by water to travel from the regulation point (dam outlet) to

(1) first touching the tail end, and
(2) then for attaining the full supply level at tail end i.e. head of the pilot irrigation area,

would need estimation for the assessment of losses.

When the dam outlet regulation gate is opened, the wave front moves in the inclined bed of canal whose profile is unchanged as the canal section remains fixed and the source of supply is constant. This can be considered as a special case of uniformly progressive flow, known specifically as a roll wave. The shape of this roll wave is similar to that seen in case of failure of a dam. Taking the equation representing the required profile of the roll wave obtained at the failure of a dam, the volume of water passed at the tail end till the full water depth is attained at the tail is worked out. The adopted equation is:

$$x = \frac{y_n}{So} [z + \ln (1-z)]$$

Where $z = y / yn$, x is the horizontal distance and y is depth.

Choosing the tip of the wave-front, where $x = 0$ and $y = 0$ as the origin, the length of the wave profile from the wave front to the section of designed depth (0.39m), works out to around 1890 m. In this length of 1890 m from the location of designed depth to the tip the wave takes the smooth round shape looks typical/similar to say, a log curve. (Table 9).

The volume of water in this profile from the tip to just attaining full depth works out to about 405 cum, which is equivalent to 0.78 hours of full running of canal.

Distance of the pilot irrigation area from the dam outlet = 5653 m

Cross-sectional area of main canal = 0.271 sq.m

Flow rate (Q) = 0.144 cum/sec

Time required for filling the

main canal = 0.271 * 5653 / 0.144 / 3600 = 2.96 hrs

Volume of water lost

at the start of irrigation = 405 cum

Equivalent time of full running for the loss of water = 0.78 hrs or 45 mts

Total time required for attaining full depth at the tail end of the main canal.

= 2.96 + 0.78 = 3.74hrs

or 3 hrs 45 mts

In case the regulation is carried out from the dam outlet, water will take about 3hrs:45mts to attain the full supply level in the main canal at its tail end or at the head of irrigation area. Further, it would be necessary to allow some response time for the gate operation (pipe diameter is 0.7 m) and also to avoid damages in the pipe resulting due to water hammer, and open canal from back pressures, etc. on sudden opening / closing of the gate. This would depend upon the gate opening / closing mechanism and the type of soil supporting lining. This can only be precisely determined on the basis of analytical / experimental data. In case 15 minutes are assumed for this purpose, the operation of gate will have to be started about 4 hours before the starting of irrigation.

(iii) Water losses after closing time of irrigation period

As per the operational criteria, full supply in terms of designed discharge with the designed depth should continue till the close of irrigation time so that the last farmer in any day is able to draw his authorized discharge till his closing time of the day. Therefore the main canal will have to continue running with full discharge at its tail end till the closing time of irrigation. Thereafter the farmers will not draw water but the main canal flow will continue with the residual water after the regulation gate is closed at the dam outlet.

When ever a small change in flow occurs, two infinitesimal dynamic waves are created by this disturbance, one moving upstream and other downstream. On summation the discrete changes merge into a continuous variation of depth and flow rate. On closure of the outlet gate and the simultaneous formation of two waves, one moving in the upstream and the other in the downstream, the momentum of water which could maintain the full depth at the tail end gets reduced. However, to have the benefit of regression time, the operation of closing of the gate should be started before the ending time of irrigation taking care that the reduction of flow at the regulation point does not affect the flow depth at the tail end during the irrigation time period. Under the mentioned constrain the benefit of regression could be taken as 20 %. This means, for 20 % of the filling time (20% of 2.96 hrs = 35 mts), full depth at the tail end would remain in tact after the closure of the regulation gate, and thereafter it will start decreasing and residual water will continue flowing after the end of irrigation time till the full canal length is vacated. The closing of the regulation gate could be done 30 minutes before the closing time of irrigation.

Though the authorized depth will be maintained at the tail end during the irrigation period, but the residual water will continue flowing after the end of irrigation time for about 4 hours or even more with lesser depth.

Volume of full length of main canal = 0.271 * 5653 = 1531.96 cum

Equivalent time = 0.271 * 5653 / 0.144 / 3600
= 2.96 hrs

Taking the benefit of regression as 20 %, the canal could be closed half an hour before the closure time. Thus the equivalent water loss could be taken as 2 hrs and 30mts..

(iv) Total water loss

The equivalent loss of water in terms of time is 45 minutes before the start of irrigation and that of 2 hrs and 30 mts after the close of irrigation time. The total loss works out to 3hrs.15mts in any day with total working time of 12 hours. The loss works out to about 25 %. As such the 12 hours of irrigation supply time would result in the reduction of irrigation to the tune of

25 %.

The pilot irrigation area is located at a distance of 5653 m from the dam outlet or 4883 m from the off-take of the main canal. When the regulation is carried out from the dam outlet (assuming the pipeline as empty), water will take about 3 hours and 45 minutes to attain the full supply level in the main canal at its tail end or at the head of irrigation area. Further, it would be necessary to allow some response time for the gate operation (pipe diameter is 0.7 m) and also to avoid damages in the pipe resulting due to water hammer, and open canal from back pressures, etc. on sudden opening / closing of the gate. This would depend upon the gate opening / closing mechanism and the type of soil supporting lining. This can only be precisely determined on the basis of analytical / experimental data. In case half an hour time is assumed for this purpose, the operation of gate will have to be started about 4 hours before the starting of irrigation by the farmers.

Similarly, for the closing time, the operation of closing of the gate should be started just before the ending time of irrigation so that the reduction of flow at the regulation point does not affect the flow depth at the tail end during the irrigation time period. The period of advance closure of gate has been assessed as 30 minutes.

In case, to save this loss of water, the opening of the gate is delayed or the closing operation of gate is started earlier, it will not be possible to retain the flow depth in the full irrigation period and consequently the concerned farmers will not be able to draw their authorized share of water. Under these conditions of varying flows, it will not be possible for the farmers to stick to their allotted time.

This alternative results in huge water losses (to the extent of 25 %) and the regulation is also difficult requiring intensive care and monitoring. The alternative is not considered suitable for adoption.

In the fourth case Alternative II - (a), the cost is almost same as of Alternative I - (c) but no loss of water is expected. In this alternative water will be supplied continuously in weekly rotations. It implies that during the seven days of 'ON' period, the system would be working round the clock i.e. day and night, all the 24 hours or 168 (7x24) hours in a week and each and every farmer would get water in turns (turn by turn) for its allocated time once in this period of one week. In this process irrigation will be carried out by the farmers during inconvenient night-time also. Irrigation time will be suitably rotated after every crop season so as to distribute the inconvenient time periods equitably.

Comparative study of the above alternatives shows that the continuous irrigation as per Alternative II - (a) is most appropriate and as such it is proposed to design the system for continuous day-night irrigation.

(5) Discussions with the Farmers

The irrigation area is located in the villages of Magonyo and Hlamba. The main canal passes through the Murandu village in addition to these two villages. The farmers of these villages were contacted in-groups and also individually at various times. The features and the functioning of the irrigation system (as detailed above) were explained to them, including the necessity of irrigation during inconvenient night-time, to ascertain their views. The farmers understood the limitations in the functioning of the system and agreed to taking water during their turn, including all the inconvenient times.

3.2.4 Tertiary Canal Network

(1) Designs

(a) Available Data

Using the aerial photographs and orthophotomaps, which were prepared during the Phase-I Field work, JICA Study team prepared map of pilot area at scale 1:5000 with index contour interval of 2m and intermediate contour of 1 m interval. For planning the main canal from the dam outlet to the start of the pilot area these maps have been utilized.

At tertiary level, water would be applied to fields and the objective would be to attain highest order of water application efficiency. This would depend upon the status of the existing terrain at the field. The primary requirement is proper land preparation for uniform distribution of water over whole of the field area. This requirement would call for a closer contour interval and in between spot levels for:

- assessing the extent of undulations and trends in land slopes;
- identifying the locations of the highest commands area zones for working out the required FSL at downstream of the distributor and alignment and shape of the fields.

Generally, a contour interval of 15 cm for lands up to 1 % slope and 25 cm for lands above 1% slope is considered appropriate. The available intermediate 1m contour interval indicates a slope of 0.4% (1:250), as such intensive topographical survey of the pilot area would be necessary. The field surveys would also help in the modifications in the alignment of the proposed canals taking off from the distributors to the respective sections if required. However, presently the tertiary network planning has been carried out with the available maps with 1 m intermediate contour interval.

(b) Field Surveys / Present condition of the Farms

The pilot area comprises around 37.57 ha of net irrigated land of the village Magonyo and that of 22.43 ha from the village Hlamba. The area is horizontally bisected by a village road, leaving some area of both the villages on the north side of road and remaining on the south side. Village boundary bisects the area vertically.

Rainfed cultivation is going on in whole of the area and as such, the area stands divided into various farms of different sizes. Most of the farms are distinctly separated by rows of trees laid, generally, in disorderly manner. The distance between two farms (intercepted with trees) is found to be around 10-20 metres.

(c) Field Water Application Practices

In the existing irrigation projects, the fields are irrigated from the watercourses by using siphon pipes. Siphon pipes are usually made of plastic or rubber hose. Siphons are easy to install and to remove without disturbing the canal bank. They are portable and the total water supply into the field varies according to the number of siphons used at a time.

To use a siphon pipe it must first be filled with water to takeout the air and then laid over the canal bank while having a hand placed over the end of the pipe in order to avoid having air entered in the pipe.

The discharge through the siphon pipe depends upon its diameter, the length and the difference in water level between the water level in the watercourse and the water level in the field or the center of the pipe if it is not submerged in water in the field.

The size of siphon pipes, as being adopted by the farmers is 50 mm which delivers a discharge of around 2 lps under working head varying from 15 to 18 cm.

(d) Size of the Tertiary Section and Discharge

From the watercourses the fields are irrigated through siphon pipes. The size of siphon pipes as being adopted is 50mm diameter which delivers a discharge of 2 lps. The size of the tertiary network and the discharge of the corresponding watercourse would depend upon the capacity of the farmers to manage maximum number of siphon pipes at a time to siphon off and apply all the flow-water running in the watercourse.

During visits to the some of the existing irrigation projects and discussions with the farmers, they (farmers) mentioned that they have been able to use 25 siphon pipes of 50 mm diameter at a time. However, on close examination it was observed that the farmers, including women farmers were comfortably using 10-15 pipes of 50 mm diameter, there by indicating the discharge range of 20-30 lps. With these considerations the tertiary networks have been planned.

The pilot irrigation area covers a part area of village Magonyo and a part of village Hlamba. The net irrigation area relating to the Magonyo village is 37.57 ha and it is proposed to irrigate it with two sets of tertiary sections with separate watercourses and their corresponding tertiary networks. The net irrigation area relating to Hlamba village is 22.43 ha and will be irrigated through one separate watercourse with its tertiary network.

As such, as water reaches the pilot area, the flow is distributed in three parts viz.(i) for the Section-A covering whole of the area of Magonyo village north of the dividing road, and a part of Magonyo village south of the dividing road; (ii) for the Section-B covering remaining portion of Magonyo village south of the dividing road and (iii) for the Hlamba village. Proportional distributors are proposed to be provided at desired locations.

Pilot net irrigation area = 60 ha.
This has been divided in following sections: Farm numbers/areas are tentative.
Area of Magonyo village = 37.57 ha.
Magonyo Section-A: M-5(part)=4.65, M-6=4.83, M-4(part)=1.5,
M-10=9.13, Total=20.11 ha

Magonyo Section-B: M-7=4.08, M-13=2.9, M-8=3.58, M-14=2.6,
M-9=2.8, M-16(part)=1.5, Total=17.46 ha

Area of Hlamba village = 22.43 ha
(H-1=5.35, H-5=2.3, H-4(part)=6.0,
H-2(part)=5.0
H-6(part)=3.78, Total=22.43 ha

Village	Area in ha	Discharge in lps
Magonyo	Section-A, 20.11	21.7
	Section-B, 17.46	18.9
Hlamba	22.43	24.2

Discharge coeff. at tertiary canal head = 1.2 - 10% loss = 1.08 lps/ha
Discharge at tertiary head = 60 x 1.08 = 64.8 lps

(e) Design of tertiary canal section

The discharges of tertiary sections are given below:

Magonyo	Section A	21.7 lps
	Section B	18.9 lps

Hlamba	24.2 lps

The discharge in the tertiary canals serving the above sections is very low, as such only minimum workable section will be sufficient. A trapezoidal section with minimum bed width of 30 cm and depth of 40 cm is proposed with the side slope of 0.5(horizontal) : 1 (vertical). Trapezoidal section will facilitate easy application of water by the farmers through siphon pipes.

(f) Layout of Tertiary Canals

Field layout should permit proper conveyance of irrigation water from the source to each corner of every farm efficiently so that the crops grown should not suffer due to water stagnation or the scarcity of water. The objective is to ensure that the opportunity time of water absorption is same throughout the plot area.

Each field layout depends on local situation. Generally it is governed by the topography and possible lengths of furrows or borders.

(i) On flat lands, the fields can be laid in a rectangular fashion and the tertiary canal can irrigate on both sides.
(ii) On slightly sloping lands, the fields are laid perpendicular to the contour lines. Here the tertiary canals get water from the main watercourse and run almost parallel to the contour lines. The distance between the tertiary canals depends upon the allowable length of furrows or borders, which run down the natural slope.
(iii) On moderately sloping lands, the furrows or borders could run under an angle from the tertiary canal as against perpendicular mentioned in (ii) above. This is called as 'herring-bone layout' with tertiary canal supplying water to graded fields on both sides; and direction of fields on one side of canal differing from that on the other side thus forming herring-bone pattern.
(iv) On heavily sloping lands the benches are constructed across the slope on which the graded fields are laid.

For precise layout, as already mentioned, contours at 15-25 cm intervals are required. The available data shows contours with 1m intermediate interval, which are almost parallel to each other. The land is slightly sloping (case (b) above). As such, tentatively the tertiary canals may be proposed parallel to the contours and the fields may be proposed perpendicular to the tertiary canals. The distance between the two tertiary canals would depend upon the lengths of the furrows and borders.

The soils of the irrigation area comprise sandy loam to loam and the land slope is slight. For irrigation farmers use 50 mm diameter siphon pipes each giving a discharge of 2 lps. The cropping pattern indicates maize, cotton, groundnut and vegetables in the rainy season for which furrow method of irrigation is considered as most suitable. In the dry season wheat crop has been proposed for which border method of irrigation is considered suitable. Under such conditions long/medium furrows and medium borders are preferred.

Presently, most of the farms are distinctly separated by rows of trees laid in the north- south direction with intense bushes, generally in disorderly manner. This may restrict the realignment of field boundaries. If need be, the fields in between the rows of trees can be aligned at an angle rather than straight lengths. The net irrigation area covers 60 ha which will be distributed amongst the farmers. The process of the distribution of land is being discussed among the farmers. After the distribution of land is finalized by the farmers, field layouts would then be decided in consultation with them (farmers).

With the available data tentative alignment of main watercourses and laterals have been marked along with the farm drains and farm roads. These are shown in Fig.2.

(2) System Operations

(a) Operational Requirements / constraints

The pilot irrigation area, comprising in a compact block, is serviced through a main canal taking off from the dam outlet and leading to the head of the irrigation area. On reaching the irrigation area the flow is suitably diverted from the main canal to respective tertiary sections through the provision of suitably located proportional distributors.

The discharge of this, so called, main canal is very low (72 lps) and serves the pilot area directly after its off-take from the dam outlet. This main canal cannot be treated, in real terms, as primary or secondary canal. It, in fact, works as a feeder tertiary canal requiring regulation, at the dam outlet and/or at the end of the pipe line, as per schedules fixed on the basis of irrigation requirements in the pilot area.

(b) Operations Criteria

The system has been designed to cater for irrigation water requirements during peak periods of demand. During this period of peak demand (multiples of 7 days), the main canal and correspondingly all the three tertiary sections will draw water continuously to their full-authorized discharges, ensuring water to each and every farmer once every week. These are called as weekly 'ON' periods.

During non-peak period of demand, or when the supplies are short, the flows in respective channels would be made intermittent, they would be either 'ON' or 'OFF'. For regulation in non-peak / short supply periods, the gates provided at the distributors will be suitably operated. The 'OFF' periods may last 7 or 14 days depending upon the situations. The intervals are kept in seven day multiples so as to maintain weekly turn schedules amongst the farmers. This implies that during the seven days of 'ON' period, the distributors would deliver the authorized discharge to its tertiary sections.

The quantum of supplies in the system will be regulated at the dam outlet / off-take of the main canal.

(c) Operations Procedure for the Main Canal

As already mentioned, the irrigation area covers a part area of village Magonyo and a part of village Hlamba. The net irrigation area relating to the Magonyo village is 37.57 ha and it is proposed to irrigate it with two sets of tertiary sections with separate watercourses and their corresponding tertiary networks. The net irrigation area relating to Hlamba village is 22.43 ha and will be irrigated through one separate watercourse with its tertiary network.

As such, as water reaches the pilot area, the flow is distributed in three parts viz.(i) for the Section-A covering whole of the area of Magonyo village north of the dividing road, and a part of Magonyo village south of the dividing road; (ii) for the Section-B covering remaining portion of Magonyo village south of the dividing road and (iii) for the Hlamba village. Proportional distributors are proposed to be provided at desired locations.

Village	Area in ha	Discharge in lps
Magonyo	Section-A, 20.11	21.7
	Section-B, 17.46	18.9
Hlamba	22.43	24.2

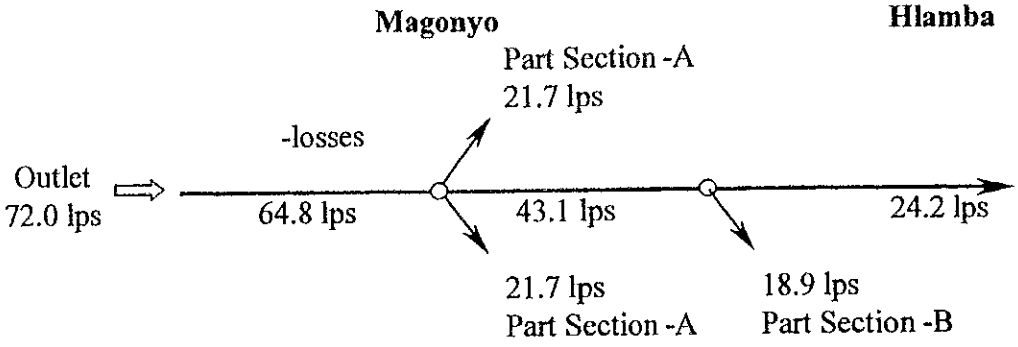
Discharge coeff. at main canal head = 1.2 lps/ha

Discharge coeff. at tertiary canal head = 1.2 -10% loss = 1.08 lps/ha

Discharge at tertiary head = 60 x 1.08 = 64.8 lps

Accordingly, during the peak periods (multiple of 7days) a discharge of 72 lps will be released at the dam outlet using regulation controls at dam outlet / offtake of canal. Taking into account the seepage losses a discharge of 64.8 lps will be reaching the head of the pilot area.

As 64.8 lps of water reaches the pilot area, a flow of 21.7 lps would be diverted for its utilisation in the Magonyo-Section A and the remaining 43.1 lps would continue running in the main canal. Further on arrival of main canal water at the start of the Magonyo-Section B, a discharge of 18.9 lps would be diverted from the main canal for its utilisation in the Magonyo-Section B and the remaining discharge of 24.2 lps would be led to Hlamba village.



At the diversion / off-take points of canals for Magonyo-Section A and Magonyo-Section B from the main canal, suitably designed proportional distributors would be provided to divide the water between the main canal and the concerned service area. The proportional distributor will also function as a regulation structure. To facilitate regulation, gates have been proposed at each of the openings of the distributors and the main canal at distributor locations.

During non-peak period of demand, or when the supplies are short, the flows in the respective sections would be made intermittent in rotation. They would either be 'ON' or 'OFF'. For regulation in non-peak / short supply periods, the gates provided at the distributor locations will be suitably operated. The 'OFF' periods may last 7 or 14 days depending upon the situation.

When the main canal is switched 'ON' from the 'OFF' position, water starts flowing in the main canal from its regulation point and it takes some time for the main canal to attain the full supply levels up to its tail end (start of irrigation area). In the seven-day 'ON' and 'OFF' interval cycle, this filling time is in addition to seven days and so it is required to be duly accounted for. In this case for seven days of 'ON' period, the main canal will be opened four hours before the start of the 'ON' period.

Based on the above criteria a turn schedule program for the main canal would be prepared in accordance with the irrigation water requirements.

(d) Operation Procedure for the Tertiary Sections

For the distribution of water amongst the farmers in each of the tertiary sections, suitable schedules called as 'Turn Schedule at Tertiary' would be prepared.

Turn Schedule at Tertiary canals, called as 'TST', of any tertiary section may be defined as a system of equitable distribution of water in a rotational cycle of 7 day-nights (7x24 = 168 hours) by turns according to fixed schedule, specifying the day, time and duration of supply to each farmer in proportion to land holding sizes. Thus every farmer in his tertiary section has fixed number of hours for which he is entitled

to water in a weekly cycle of 7 days i.e. 168 hours.

Based on this concept, TST schedules will be prepared separately for the three tertiary sections.

3.2.5 Drainage Plan

(1) Drainage needs of the Irrigation Area

The irrigation area is only 60 ha and comprises sloping and well drained lands. The land slopes vary from 1 in 230 to 1 in 250. On the north and south side of the pilot area lands are sloping with steep slopes up to 1 in 40 or even less. The area may be categorized as well drained area. However, suitable provision for drainage has been made.

(2) Determination of Runoff from Rainfall

A unit runoff factor of 1.76 lps / ha has already been worked out for the design of drainage system for the Project. (Section 2.5- Drainage Plan). It is proposed to adopt the same for the drainage design of the pilot area.

(3) Drainage Design

At the end of the furrows, a drain has been proposed which would lead excess water to the side un-irrigated areas, which are located at lower levels. Where the field drain touches the cultivated area, a link/collector drains have been proposed to lead water to the main/natural stream.

The area to be drained is very small as such a minimum section with each of bed width and depth of 0.5m with side slope of 1.5 (horizontal) : 1 (vertical) is proposed to be adopted. The same minimum section will also be sufficient for the collector/link drains.

Farm drains have also been marked on the Fig. 2.

3.2.6 Farm Roads

The irrigation area is bisected by a wide earth road. This road has been proposed for rehabilitation and further development to the concerned sectors. With in the irrigation area a provision for the farm roads has been made as a comprehensive plan along with irrigation channels and drainage.

The farm roads have been aligned along the watercourses to facilitate the operation and maintenance of watercourses and also for carriage of agricultural inputs and outputs from the fields.

These are shown in Fig. 2.

3.3 Discussions with the Farmers of Irrigation Area

The irrigation area is located in the villages of Magonyo and Hlamba. The main canal passes through the Murandu village in addition to these two villages. The farmers of these villages were contacted in-groups and also individually at various times. The features and the functioning of the irrigation system were explained to them to ascertain their views.

(1) Economic Use of Water

For the supply of water, a dam has been proposed and water from the dam will be carried to the irrigation area located at a distance of about 6 km through a canal system. The canal system would serve each and every farm. The question arises whether the farmers recognize the efforts being put in to bring water and use the same economically in the most optimal manner.

The farmers mentioned that they are not new to the process of cultivation. They are already having rainfed cultivation in whole of their fields. The rainfed crops being cultivated by the farmers include: cotton, maize, groundnut, sunflower, and millets etc. They very well understand the loss done to the crops on account of delay or untimely rains. They are, as they mentioned, fully seized of the importance and the precious value of water. They will be merely shifting from rainfed agriculture to the irrigated agriculture. They assured to use the water most economically and in the most optimal manner to derive maximum benefits from this facility. They would however, need suitable guidance in irrigated agriculture.

The investment risk, as far water utilisation is concerned is absolutely zero.

(2) Equity in water distribution

Water allocation and distribution in the irrigation area is being proposed with due regard to equity. Disparities in the distribution of water between head reach and tail farms will be obviated by adoption of equity considerations and rotational water distribution. Water allocations to the individual farms will be made in proportion to the area of the individual farm declared for irrigation. Water will be distributed on the rotational system of water distribution by fixation of turn schedules ensuring water deliveries to each and every farm turn by turn. Supply of water is proposed on crop-need based and with volumetric concept using time base and constant supply in each weekly rotation.

The question arises whether the farmers agree to the given equity principles and are willing to take their allocated share turn by turn.

Some of the farmers mentioned that in the existing projects, the concerned farmers are already taking water turn by turn and as such they are somewhat aware of this.

The farmers appreciated the need of discipline in taking water and assured to take water in the allocated turn on the principles of equity and rotational distribution of water.

(3) Inconvenient time in water application

Water would be released in the canal system from the outlet of the dam and would travel in the canal for about 6 km till it reaches the pilot area. This condition would become severe in case of the Muyati Project which has to ultimately serve 25000 ha of the command area and the tail of the irrigation system is miles and miles away.

Once the dam outlet is opened it will not be possible to close it for regulation purposes since it is far away from the pilot area and the effect of closing will not be immediate but would take plenty of time to affect the irrigation area. Farmers were explained the underlying principles of water allocation and distribution policies, requiring a constant flow in terms of discharge and depth during the time allocated to farmers to enable them to draw their authorized share of water. They were also explained as to how the day time irrigation for 12 hours results in water loss leading to reduction of irrigation area to the extent of 25 %.

Further it is not desirable to open/close the outlet suddenly from technical considerations. Even in emergency the outlet is opened/closed slowly to avoid damaging effects.

As such, the farmers were informed that the system would be working round the clock i.e. day and night, all the 24 hours or 168 (24x7) hours in a week. Weekly rotation is proposed i.e. every farmer would get water, in turns (turn by turn), for its allocated time once a week.

During the water application period each farmer (during his turn) will have to continue watering operation in some inconvenient hours of night or early day, depending upon the allocated time and the time of start of the turn. This will happen once a week only as the rotational period has been kept as one week. In terms of justice, with respect to time fixed in the weekly water distribution schedules prepared for water application, the starting time of water application will be shifted by 8 hours at the start of each crop season or as decided by the Water Users Association.

The farmers understood the limitations in the functioning of the system and agreed to taking water during their turn, including all the inconvenient times.

(4) Construction Facilities

Taking-off from the dam outlet, the water conveyance pipe line / canal crosses through the villages of Murandu, and Mogonyo till it reaches the irrigation area covering part area of Mogonyo village and part area of Hlamba village. In the irrigation area, a network of tertiary canals would be required to supply water to each farm. Some land would be required for laying the pipeline/canal, tertiary canals, its allied structures and other facilities such as roads, drains etc. Farmers offered to cooperate and provide all the possible assistance.

TABLES

Table 1 Rainfall at Gokwe Meteorological Station

Unit: mm

Year	Jan 1	Jan 2	Jan 3	Feb 1	Feb 2	Feb 3	Mar 1	Mar 2	Mar 3	Apr 1	Apr 2	Apr 3	May 1	May 2	May 3	Jun 1	Jun 2	Jun 3
66	11.5	46.5	86.7	101.5	168.9	49.6	21.6	4.1	1.3	32.0	0.3	0.0	0.3	1.5	0.0	0.8	1.8	0.0
67	83.0	56.7	44.8	94.9	38.9	12.1	2.9	37.0	13.9	62.7	24.1	3.6	53.1	0.0	0.0	0.5	0.0	0.0
68	2.6	46.5	61.2	56.9	81.0	2.5	6.9	28.2	3.0	16.3	10.7	0.0	0.0	0.0	20.6	0.0	0.0	0.0
69	73.2	5.3	119.7	35.6	39.6	80.6	63.0	99.3	22.6	17.0	6.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0
70	0.5	11.2	4.9	42.4	10.2	5.3	0.0	0.0	0.0	20.8	83.3	19.8	0.0	0.0	0.0	0.0	0.0	0.3
71	109.4	82.2	72.4	32.5	42.8	6.0	16.7	1.0	0.0	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	77.3	60.9	147.8	100.6	1.4	41.9	18.2	4.0	31.7	39.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	79.6	11.6	29.9	6.3	62.3	67.9	14.8	0.0	0.0	0.6	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
74	70.8	75.3	99.3	66.7	116.3	47.9	78.0	50.7	4.3	15.5	0.2	0.3	7.3	3.2	0.0	0.0	0.0	0.0
75	24.8	83.8	131.5	54.2	136.2	11.9	32.3	0.0	1.8	7.2	23.6	0.7	0.0	0.0	0.0	0.5	0.0	0.0
76	75.9	137.3	48.1	34.1	47.8	40.5	32.2	114.1	105.4	43.6	6.6	0.0	1.8	0.0	0.0	0.0	0.0	0.0
77	3.0	48.6	80.1	134.6	94.6	73.4	83.2	52.4	51.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	45.5	50.8	118.4	37.1	92.0	103.8	47.7	45.3	12.8	2.1	64.2	8.5	0.0	0.0	27.1	0.4	0.0	0.0
79	24.7	55.3	61.0	0.0	41.1	40.6	31.2	42.1	17.3	0.0	0.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0
80	20.2	0.8	26.0	1.3	44.3	61.2	90.6	0.0	4.1	0.5	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	32.6	93.9	152.2	160.1	164.0	81.4	47.3	20.3	2.6	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
82	109.1	25.6	21.9	4.4	56.0	14.7	0.3	0.0	0.5	0.0	24.0	20.2	0.0	0.0	0.0	0.0	0.0	0.0
83	6.0	99.4	77.8	107.7	51.7	0.3	28.2	0.0	4.1	2.9	0.6	32.4	7.7	0.0	0.0	0.0	0.0	0.0
84	67.6	6.8	41.0	80.0	46.1	30.8	32.9	7.8	58.1	47.6	0.0	8.2	1.4	0.0	0.0	0.0	0.0	0.0
85	80.1	37.8	131.8	200.6	14.5	9.8	48.3	10.4	3.9	30.0	0.0	0.0	1.0	6.0	0.0	0.0	0.0	0.0
86	49.9	20.9	67.9	24.7	26.0	50.0	5.3	7.5	65.3	0.2	108.8	61.5	0.0	0.0	0.0	0.0	0.0	0.0
87	5.0	107.1	44.3	51.4	24.8	12.4	6.0	20.1	22.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
88	10.8	35.6	97.4	29.2	114.7	61.5	70.1	99.2	0.2	2.8	0.0	30.1	0.0	0.8	0.0	0.0	0.0	32.1
89	80.4	9.8	116.4	76.0	73.2	81.8	17.0	2.3	40.2	4.3	0.0	8.3	3.4	0.0	0.0	0.0	0.0	0.0
90	98.2	27.4	157.0	100.6	74.5	4.7	29.1	25.5	21.5	27.3	5.1	29.5	0.0	4.6	0.0	0.0	0.0	0.0
91	129.5	8.5	27.8	40.5	33.7	0.0	3.6	50.4	60.6	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0
92	43.7	16.7	45.6	0.0	5.8	8.5	17.2	44.8	76.0	0.0	6.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
93	53.9	0.8	26.6	118.1	12.8	25.2	40.1	26.6	36.3	29.9	24.1	13.0	0.0	0.0	0.0	0.0	0.0	0.0
94	23.1	127.4	38.9	104.2	33.4	8.8	0.0	1.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
95	2.0	66.9	1.5	20.9	0.0	19.5	0.1	6.2	45.1	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0
96	76.7	104.7	151.8	146.5	95.5	9.7	31.2	2.4	0.8	1.2	0.0	0.0	0.0	41.7	12.0	0.0	0.0	0.0
97	35.5	114.4	204.1	58.5	126.7	22.4	67.9	70.3	12.0	82.1	4.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
AVERAGE	50.1	52.4	79.2	66.3	61.6	34.0	30.7	27.3	22.5	16.0	12.6	7.6	2.4	1.9	1.9	0.1	0.1	1.0

Year	Jul 1	Jul 2	Jul 3	Aug 1	Aug 2	Aug 3	Sep 1	Sep 2	Sep 3	Oct 1	Oct 2	Oct 3	Nov 1	Nov 2	Nov 3	Dec 1	Dec 2	Dec 3	AVERAGE	TOTAL (mm)
66	0.0	0.0	0.0	0.0	0.3	7.4	0.0	0.0	0.0	0.0	0.0	0.0	22.4	8.7	3.6	51.5	140.4	32.3	22.1	795.0
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.5	30.4	11.4	26.9	28.7	27.2	15.2	32.4	19.5	703.2
68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	25.4	93.8	85.3	5.6	96.3	17.9	644.1
69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	24.4	3.9	50.1	29.9	0.0	22.1	159.1	84.4	151.1	30.2	1088.6
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	1.0	5.6	41.4	147.1	0.5	26.5	107.5	14.8	531.1
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	5.0	0.0	43.8	115.0	23.0	6.3	32.4	23.7	17.9	645.2
72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.9	0.7	0.0	16.7	0.0	7.2	4.5	40.2	25.4	17.2	620.3
73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	9.8	0.0	2.2	37.7	62.4	55.7	100.0	61.1	163.6	21.5	774.5
74	2.9	0.0	0.0	0.0	2.0	9.6	2.4	0.0	0.0	0.3	0.0	17.7	20.8	28.8	77.9	134.6	171.1	49.2	32.0	1153.1
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.8	0.3	0.0	51.8	67.6	46.8	36.1	20.3	731.9
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	13.6	4.8	12.5	18.1	0.4	8.0	35.0	4.7	69.9	23.8	857.2
77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	0.0	0.0	0.0	8.5	0.8	155.7	22.4	107.3	203.8	31.8	1144.2
78	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	41.0	0.3	100.8	10.6	2.5	44.6	181.0	5.3	29.1	1046.4
79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.0	36.3	28.8	12.2	59.4	253.9	50.3	37.1	23.2	833.9
80	0.0	0.0	0.0	1.0	0.0	0.0	3.1	0.0	0.0	0.0	22.1	13.5	15.4	22.0	80.7	6.6	83.5	137.9	17.9	645.0
81	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.9	2.8	6.8	6.8	20.8	87.3	7.2	2.0	19.4	25.3	909.1
82	0.1	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	68.7	5.5	4.9	37.3	19.6	52.9	7.0	21.4	13.8	495.2
83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2	0.6	3.0	24.3	30.7	69.9	19.5	36.7	17.6	632.7
84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4	5.7	2.1	31.1	9.9	39.8	114.3	37.4	53.5	20.4	733.5
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	24.4	0.0	0.2	18.0	91.0	84.2	22.2	799.0
86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	1.0	29.3	46.6	21.0	0.0	10.1	148.0	7.0	30.8	21.8	784.7
87	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	9.3	3.0	14.8	0.0	51.2	0.0	61.8	37.1	105.0	30.6	16.9	607.7
88	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.9	13.0	3.4	0.0	43.3	24.3	10.8	6.9	20.7	745.7
89	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	2.5	0.4	23.7	27.4	15.0	15.5	50.2	3.0	26.3	18.9	680.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	9.8	0.7	0.0	7.0	33.3	36.5	12.1	32.7	20.5	737.8
91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.0	41.7	10.7	0.0	34.9	14.2	26.0	1.1	129.9	17.2	618.0
92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	6.6	25.6	8.8	19.8	100.4	64.3	13.8	497.4
93	2.4	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	36.2	33.6	97.7	56.7	17.3	44.2	19.3	696.0
94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.9	6.0	8.3	0.0	19.9	1.8	29.4	58.5	13.9	501.6
95	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5	0.0	39.2	112.8	107.3	29.7	16.9	13.8	497.3
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.3	0.0	0.0	8.5	4.4	65.6	97.9	17.0	45.6	29.7	26.2	944.7
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.6	0.0	0.2	4.6	21.0	0.0	0.0	0.0	6.8	0.8	10.5	24.8	891.0
AVERAGE	0.2	0.0	0.0	0.2	0.1	0.5	0.3	1.6	1.5	2.7	13.4	11.5	18.4	20.9	47.2	56.0	49.1	58.4	20.8	749.5

Table 2 Usable Effective Rainfall

Unit: m^3

Month / 10 Days

Year	Jan 1	Jan 2	Jan 3	Feb 1	Feb 2	Feb 3	Mar 1	Mar 2	Mar 3	Apr 1	Apr 2	Apr 3	May 1	May 2	May 3	Jun 1	Jun 2	Jun 3
66	87.9	320.3	381.1	398.1	411.9	332.7	163.6	24.6	7.8	228.3	1.8	0.0	1.7	8.7	0.0	4.6	10.4	0.0
67	333.8	355.3	306.5	398.1	271.3	91.5	17.4	256.8	108.6	337.6	175.0	21.6	41.8	0.0	0.0	2.9	0.0	0.0
68	15.6	320.3	381.1	380.2	411.9	15.0	50.8	203.2	18.0	119.5	82.9	0.0	0.0	0.0	112.5	0.0	0.0	0.0
69	333.8	40.6	381.1	251.2	274.8	432.9	444.0	425.9	168.4	129.3	45.7	0.0	1.7	0.0	0.0	0.0	0.0	0.0
70	3.0	86.1	38.0	295.5	80.1	40.6	0.0	0.0	0.0	151.3	249.1	129.0	0.0	0.0	0.0	0.0	0.0	1.7
71	333.8	355.3	381.1	231.5	297.3	45.1	127.9	6.0	0.0	170.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	333.8	355.3	381.1	398.1	8.4	293.2	136.6	24.0	227.6	272.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	333.8	88.5	219.0	47.0	409.1	432.9	112.8	0.0	0.0	3.6	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
74	333.8	355.3	381.1	398.1	411.9	325.9	444.0	343.4	34.2	115.8	1.2	1.8	41.8	18.0	0.0	0.0	0.0	0.0
75	179.0	355.3	381.1	367.8	411.9	90.3	230.5	0.0	10.8	52.7	172.6	4.2	0.0	0.0	0.0	2.9	0.0	0.0
76	333.8	355.3	326.7	245.2	325.5	279.3	230.0	425.9	383.6	300.2	48.9	0.0	10.4	0.0	0.0	0.0	0.0	0.0
77	18.0	328.7	381.1	398.1	411.9	432.9	444.0	351.9	344.9	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
78	309.8	343.9	381.1	257.2	411.9	432.9	325.1	308.8	103.6	12.6	249.1	69.7	0.0	0.0	112.5	2.3	0.0	0.0
79	178.5	355.3	381.1	0.0	282.3	279.8	225.2	294.1	131.4	0.0	0.6	9.0	0.0	0.0	0.0	0.0	0.0	0.0
80	148.2	4.8	191.8	7.8	304.2	404.7	444.0	0.0	24.6	3.0	79.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	231.9	355.3	381.1	398.1	411.9	432.9	323.5	148.8	15.6	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0
82	333.8	189.7	165.1	34.8	376.1	112.3	1.8	0.0	3.0	0.0	174.5	129.0	0.0	0.0	0.0	0.0	0.0	0.0
83	45.1	355.3	381.1	398.1	348.4	1.8	203.2	0.0	24.6	17.4	3.6	129.0	41.8	0.0	0.0	0.0	0.0	0.0
84	333.8	50.2	281.8	398.1	318.7	223.3	233.4	56.6	383.6	323.7	0.0	59.1	8.1	0.0	0.0	0.0	0.0	0.0
85	333.8	265.8	381.1	398.1	111.4	77.7	327.5	81.3	23.4	218.7	0.0	0.0	5.8	18.0	0.0	0.0	0.0	0.0
86	333.8	160.3	381.1	178.5	191.8	339.9	40.6	54.7	383.6	1.2	249.1	129.0	0.0	0.0	0.0	0.0	0.0	0.0
87	38.7	355.3	304.2	346.9	179.0	93.3	45.1	147.6	168.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
88	83.7	251.2	381.1	215.6	411.9	405.9	444.0	425.9	1.2	16.8	0.0	129.0	0.0	4.6	0.0	0.0	0.0	215.7
89	333.8	77.7	381.1	398.1	411.9	432.9	129.7	13.8	277.8	34.2	0.0	59.8	19.7	0.0	0.0	0.0	0.0	0.0
90	333.8	199.1	381.1	398.1	411.9	36.7	207.8	189.2	163.3	198.0	39.3	129.0	0.0	18.0	0.0	0.0	0.0	0.0
91	333.8	69.9	201.2	279.3	243.6	0.0	21.6	341.9	383.6	0.0	0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0
92	301.5	127.9	310.2	0.0	43.8	69.9	138.8	306.5	383.6	0.0	45.1	3.6	0.0	0.0	0.0	0.0	0.0	0.0
93	333.8	4.8	194.9	398.1	103.6	187.6	277.3	194.9	254.0	218.2	175.0	104.3	0.0	0.0	0.0	0.0	0.0	0.0
94	161.2	355.3	271.3	398.1	242.4	71.7	0.0	9.0	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0
95	12.0	355.3	9.0	160.3	0.0	144.2	0.6	46.3	307.9	0.0	0.0	34.2	0.0	0.0	0.0	0.0	0.0	0.0
96	333.8	355.3	381.1	398.1	411.9	77.1	225.2	14.4	4.8	7.2	0.0	0.0	0.0	18.0	86.8	0.0	0.0	0.0
97	250.8	355.3	381.1	393.9	411.9	167.5	444.0	425.9	90.9	337.6	34.8	1.2	0.6	0.0	0.0	0.0	0.0	0.0
AVERAGE	231.4	247.0	314.4	289.6	292.3	212.6	201.6	160.1	138.5	102.6	57.2	36.1	5.4	3.2	9.7	0.4	0.3	6.8

Year	Jul 1	Jul 2	Jul 3	Aug 1	Aug 2	Aug 3	Sep 1	Sep 2	Sep 3	Oct 1	Oct 2	Oct 3	Nov 1	Nov 2	Nov 3	Dec 1	Dec 2	Dec 3	AVERAGE	Total (MCM)
66	0.0	0.0	0.0	0.0	1.8	54.0	0.0	0.0	0.0	0.0	0.0	0.0	165.8	80.4	23.8	217.1	240.9	231.3	94.4	3,398.7
67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	9.9	123.8	95.0	185.8	197.4	198.6	114.8	231.6	107.9	3,883.9
68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	185.8	197.4	217.1	42.5	290.2	84.8	3,052.6
69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	88.0	25.7	123.8	165.8	0.0	184.1	217.1	240.9	290.2	118.7	4,273.6
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.5	6.6	47.6	185.8	197.4	3.0	195.0	290.2	56.1	2,018.4
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.5	43.0	0.0	165.8	185.8	189.4	47.0	231.8	174.3	85.3	3,072.6
72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	5.9	4.6	0.0	143.7	0.0	59.7	35.5	240.9	189.3	86.7	3,120.2
73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.0	86.9	0.0	14.5	165.8	185.8	197.4	217.1	240.9	290.2	86.6	3,116.1
74	16.8	0.0	0.0	0.0	12.0	76.4	15.8	0.0	0.0	2.0	0.0	123.8	165.8	185.8	197.4	217.1	240.9	290.2	131.9	4,750.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.8	2.0	0.0	197.4	217.1	240.9	254.0	91.5	3,294.1
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.5	88.0	41.5	109.0	152.1	2.6	65.8	217.1	36.7	290.2	119.1	4,286.5
77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	136.7	0.0	0.0	0.0	79.3	5.3	197.4	168.1	240.9	290.2	117.9	4,242.9
78	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.8	97.2	2.0	165.8	90.6	16.5	217.1	240.9	40.6	117.2	4,220.1
79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.2	123.8	165.8	99.3	197.4	217.1	240.9	258.0	98.2	3,536.7
80	0.0	0.0	0.0	6.0	6.0	0.0	20.5	0.0	0.0	0.0	97.2	115.4	127.0	183.6	197.4	48.9	240.9	290.2	81.7	2,939.9
81	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	5.9	18.5	56.7	56.7	168.3	197.4	52.7	12.0	144.0	94.9	3,415.6
82	0.6	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0	0.0	97.2	46.8	42.2	185.8	161.1	217.1	51.5	163.3	69.2	2,492.8
83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.2	4.0	19.8	185.8	197.4	217.1	144.6	256.4	85.3	3,071.5
84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.0	48.3	13.9	165.8	86.9	197.4	217.1	240.9	290.2	111.6	4,018.9
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.2	165.8	0.0	1.3	135.9	240.9	290.2	87.1	3,134.7
86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	6.6	97.2	123.8	165.8	0.0	87.9	217.1	51.5	224.1	95.5	3,436.5
87	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	83.6	19.8	97.2	0.0	165.8	0.0	197.4	217.1	240.9	223.1	81.4	2,931.0
88	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.2	112.2	22.4	0.0	197.4	177.2	83.9	50.8	103.6	3,731.1
89	0.0	0.0	0.0	17.4	0.0	0.0	0.0	0.0	0.0	16.5	2.6	123.8	165.8	124.4	127.6	217.1	18.0	194.0	99.4	3,577.6
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	86.9	4.6	0.0	58.2	197.4	217.1	91.7	233.2	100.0	3,598.9
91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	19.8	97.2	91.8	0.0	185.8	119.3	192.4	6.6	290.2	80.3	2,889.1
92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.2	55.2	185.8	80.9	146.3	240.9	290.2	77.2	2,780.4
93	13.9	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	165.8	185.8	197.4	217.1	131.8	290.2	101.4	3,651.5
94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.2	50.6	68.1	0.0	162.9	10.8	217.4	290.2	67.1	2,414.8
95	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.8	0.0	185.8	197.4	217.1	218.8	129.5	59.7	2,150.5
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	8.6	0.0	0.0	79.9	38.4	185.8	197.4	130.1	240.9	218.8	94.9	3,416.7
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	225.0	0.0	1.3	40.0	123.8	0.0	0.0	0.0	50.2	4.8	82.1	106.2	3,821.9
AVERAGE	1.4	0.0	0.0	1.0	0.4	4.2	1.7	7.4	10.7	17.0	41.0	60.8	97.0	103.6	151.0	165.8	164.6	230.0	93.5	3,366.9

Table 3 Crop Water Requirement for Lower Munyati Agricultural Development Project

STATEMENT - 1

Culturable Command Area: 25,000 ha

Unit: mm

S. No. Crops/Season	Date of Sowing		Total Net Irr. Req.	Crops% in CCA	Jan			Feb			Mar			Apr			May			Jun		
					1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
SUMMER CROPS																						
1 Cotton 10/15	10	15	619.3	30	37.5	38.4	40.2	41.9	43.7	46.5	46.9	44.5	41.3	37.5	16.7							
2 Cotton 10/25	10	25	627.2	30	33.7	37.2	40.2	41.9	43.7	46.5	49.3	49.6	46.5	43.0	39.0	16.7						
3 Cotton 11/05	11	5	638.7	20	28.7	33.4	38.9	41.9	43.7	46.5	49.3	52.1	51.8	48.5	44.7	39.0	16.7					
4 Maize 10/15	10	15	469.3	8	37.8	36.1	34.9	33.5	31.9	30.7	29.1	13.6										
5 Maize 10/25	10	25	466.7	5	37.8	37.4	37.7	36.5	35.0	34.0	32.6	30.8	14.2									
6 Maize 11/05	11	5	469.8	5	36.1	37.4	39.1	39.4	38.0	37.2	36.0	34.4	32.2	14.8								
7 Tomato 12/15	12	15	456.2	3	23.6	25.3	30.6	36.2	39.9	42.5	45.0	46.1	45.2	44.1	42.6							
8 Tomato 12/25	12	25	473.6	2	23.6	23.4	26.5	31.9	37.7	42.5	45.0	47.6	48.2	47.1	45.8	42.6						
9 Tomato 01/05	1	5	490.8	2	11.8	23.4	24.5	27.7	33.3	40.1	45.0	47.6	49.7	50.2	49.1	45.8	42.6					
10 Groundnuts 10/1	10	1	487.3	2	32.0	31.7	33.2	34.6	34.8	33.0	29.3	12.5										
11 Groundnuts 10/10	10	10	483.9	1.5	30.5	31.7	33.2	34.6	36.1	37.1	35.0	31.0	13.0									
12 Groundnuts 10/20	10	20	483.9	1.5	27.5	30.2	33.2	34.6	36.1	38.4	39.3	37.0	32.3	13.6								
13																						
14																						
15																						
16																						
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26																						
27																						
28																						
29																						
30																						
WINTER CROPS																						
31 Wheat-120 05/20	5	20	578.5	15															27.8	27.4	33.7	47.3
32 Wheat-120 06/05	6	5	594.2	15																13.7	27.0	30.4
33 Wheat-120 06/20	6	20	608.6	10																		27.0
34 Wheat-102 05/15	5	15	483.4	10														14.1	27.8	34.2	47.2	54.0
35 Wheat-102 05/20	5	20	503.2	7															27.8	30.8	40.4	50.7
36 Wheat-102 05/25	5	25	491.5	6															13.9	27.4	33.7	47.3
37																						
VEGETABLES																						
40 Cabbage 05/15	5	15	380.7	3														12.9	25.3	27.0	32.9	41.4
41 Cabbage 05/20	5	20	383.8	2															25.3	24.9	28.7	37.2
42 Cabbage 05/25	5	25	386.8	2															12.7	24.9	26.6	33.0
43																						
44																						
45																						
46																						
47																						
48																						
49																						
50																						
51																						
52																						
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60																						
GRAND TOTAL				170	33.4	35.5	38.1	39.8	41.2	43.3	44.4	42.6	38.4	33.8	24.9	12.9	4.2	1.8	11.2	15.2	20.8	28.8
GRAND TOTAL					100	100	100	100	100	100	100	100	90	84	77	44	22	13	45	60	60	70

S. No. Crops/Season	Jul			Aug			Sep			Oct			Nov			Dec		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
SUMMER CROPS																		
1 Cotton 10/15											11.5	21.4	19.9	20.1	23.2	26.3	28.4	33.4
2 Cotton 10/25												10.7	19.9	18.4	18.4	20.7	23.4	28.4
3 Cotton 11/05													10.0	18.4	16.9	16.5	18.4	23.4
4 Maize 10/15											12.7	23.6	21.9	24.7	30.8	34.8	35.8	37.4
5 Maize 10/25												11.8	21.9	20.2	22.6	27.5	30.9	35.8
6 Maize 11/05													11.0	20.2	18.5	20.2	24.4	30.9
7 Tomato 12/15																	11.7	23.4
8 Tomato 12/25																		11.7
9 Tomato 01/05																		
10 Groundnuts 10/1										29.2	28.7	26.8	24.9	25.1	26.8	27.3	27.2	30.2
11 Groundnuts 10/10											28.7	26.8	24.9	23.0	23.0	23.9	24.2	27.2
12 Groundnuts 10/20												26.8	24.9	23.0	21.1	20.5	21.2	24.2
WINTER CROPS																		
31 Wheat-120 05/20	54.2	54.3	56.4	58.4	60.5	59.9	53.9	44.7										
32 Wheat-120 06/05	40.6	50.9	56.4	58.4	60.5	62.5	64.5	61.0	49.3	19.0								
33 Wheat-120 06/20	27.1	34.0	49.3	58.4	60.5	62.5	64.5	66.4	62.7	53.7	42.5							
34 Wheat-102 05/15	54.2	54.3	56.4	54.6	47.6	39.0												
35 Wheat-102 05/20	54.2	54.3	56.4	57.0	52.6	44.1	34.9											
36 Wheat-102 05/25	54.2	54.3	56.4	58.4	56.5	49.2	40.2											
VEGETABLES																		
40 Cabbage 05/15	50.0	54.3	56.4	55.8	24.8													
41 Cabbage 05/20	45.7	52.2	56.4	58.4	55.0													
42 Cabbage 05/25	41.5	50.1	56.4	58.4	57.7	25.6												
GRAND TOTAL	32.6	35.3	38.8	40.3	39.0	35.1	29.1	22.5	13.7	8.8	9.7	12.4	16.6	18.6	19.7	21.7	24.1	29.0
GRAND TOTAL	70	70	70	70	70	65	53	40	25	27	52	68	93	93	93	93	96	98

Table 4 Diversion Water Requirement

Unit: MCM

Year	Jan 1	Jan 2	Jan 3	Feb 1	Feb 2	Feb 3	Mar 1	Mar 2	Mar 3	Apr 1	Apr 2	Apr 3	May 1	May 2	May 3	Jun 1	Jun 2	Jun 3
66	12.29	1.75	0.00	0.00	0.00	5.01	14.02	20.07	18.79	5.47	12.37	6.45	2.00	0.46	5.62	7.36	9.86	14.39
67	0.00	0.00	3.72	0.00	7.03	17.07	21.33	8.46	13.75	0.00	3.70	5.37	0.00	0.90	5.62	7.45	10.38	14.39
68	15.91	1.75	0.00	0.89	0.00	23.50	19.66	11.14	18.28	10.91	8.31	6.45	2.09	0.90	0.00	7.60	10.38	14.39
69	0.00	15.73	0.00	7.35	6.85	0.00	0.00	0.00	10.76	10.42	10.17	6.45	2.00	0.90	5.62	7.60	10.38	14.39
70	16.54	13.46	17.15	5.13	16.59	19.61	22.20	21.30	19.18	9.32	0.00	0.00	2.09	0.90	5.62	7.60	10.38	14.31
71	0.00	0.00	0.00	8.33	5.73	19.39	15.80	21.00	19.18	8.37	12.46	6.45	2.09	0.90	5.62	7.60	10.38	14.39
72	0.00	0.00	0.00	0.00	20.17	7.86	15.37	20.10	7.80	3.24	12.37	6.45	2.09	0.90	5.62	7.60	10.38	14.39
73	0.00	13.34	8.11	17.56	0.14	0.00	16.56	21.30	19.18	16.70	12.46	6.00	2.09	0.90	5.62	7.60	10.38	14.39
74	0.00	0.00	0.00	0.00	0.00	5.35	0.00	4.13	17.47	11.09	12.40	6.36	0.00	0.00	5.62	7.60	10.38	14.39
75	7.74	0.00	0.00	1.52	0.00	17.13	10.67	21.30	18.64	14.24	3.82	6.24	2.09	0.90	5.62	7.45	10.38	14.39
76	0.00	0.00	2.72	7.65	4.32	8.64	10.70	0.00	0.00	1.87	10.01	6.45	1.57	0.90	5.62	7.60	10.38	14.39
77	15.79	1.33	0.00	0.00	0.00	0.00	0.00	3.70	1.94	16.19	12.46	6.45	2.09	0.90	5.62	7.60	10.38	14.39
78	1.20	0.57	0.00	7.05	0.00	0.00	5.94	5.85	14.00	16.25	0.00	2.97	2.09	0.90	0.00	7.48	10.38	14.39
79	7.76	0.00	0.00	19.91	6.48	7.65	10.94	6.59	12.61	16.88	12.43	6.00	2.09	0.90	5.62	7.60	10.38	14.39
80	9.28	17.52	9.47	19.52	5.38	1.58	0.00	21.30	17.95	16.73	8.46	6.45	2.09	0.90	5.62	7.60	10.38	14.39
81	5.09	0.00	0.00	0.00	0.00	0.00	6.02	13.86	18.40	16.88	12.46	6.33	2.09	0.90	5.62	7.60	10.38	14.39
82	0.00	8.28	10.80	18.17	1.79	16.03	22.11	21.30	19.03	16.88	3.73	0.00	2.09	0.90	5.62	7.60	10.38	14.39
83	14.43	0.00	0.00	0.00	3.18	21.55	12.04	21.30	17.95	16.01	12.28	0.00	0.00	0.90	5.62	7.60	10.38	14.39
84	0.00	15.25	4.96	0.00	4.66	11.79	10.53	18.47	0.00	0.69	12.46	3.49	1.69	0.90	5.62	7.60	10.38	14.39
85	0.00	4.47	0.00	0.00	15.02	17.76	5.82	17.23	18.01	5.95	12.46	6.45	1.80	0.00	5.62	7.60	10.38	14.39
86	0.00	9.75	0.00	10.98	11.00	4.65	20.17	18.56	0.00	16.92	0.00	0.00	2.09	0.90	5.62	7.60	10.38	14.39
87	14.75	0.00	3.84	2.56	11.65	16.98	15.95	13.91	10.74	16.88	12.46	6.45	2.09	0.90	5.62	7.60	10.38	14.39
88	12.50	5.20	0.00	9.13	0.00	1.51	0.00	0.00	19.12	16.04	12.46	0.00	2.09	0.67	5.62	7.60	10.38	3.61
89	0.00	13.98	0.00	0.00	0.00	0.00	15.72	20.61	5.29	15.17	12.46	3.46	1.11	0.90	5.62	7.60	10.38	14.39
90	0.00	7.81	0.00	0.00	0.00	19.81	11.81	11.83	11.02	6.98	10.49	0.00	2.09	0.00	5.62	7.60	10.38	14.39
91	0.00	14.27	9.00	5.94	8.41	21.64	21.12	4.20	0.00	16.88	12.46	6.45	2.09	0.43	5.62	7.60	10.38	14.39
92	1.61	11.37	3.54	19.91	18.40	20.42	15.66	5.97	0.00	16.88	10.20	6.27	2.09	0.90	5.62	7.60	10.38	14.39
93	0.00	17.52	9.31	0.00	15.42	12.26	8.33	11.55	6.48	5.97	3.70	1.23	2.09	0.90	5.62	7.60	10.38	14.39
94	8.63	0.00	5.49	0.00	8.47	18.06	22.20	20.85	19.18	16.88	12.46	6.45	2.09	0.46	5.62	7.60	10.38	14.39
95	16.09	0.60	18.61	11.89	20.59	14.43	22.17	18.98	3.79	16.88	12.46	4.74	2.09	0.90	5.62	7.60	10.38	14.39
96	0.00	0.00	0.00	0.00	0.00	20.01	10.94	20.58	18.94	16.52	12.46	6.45	2.09	0.00	1.28	7.60	10.38	14.39
97	4.15	0.00	0.00	0.21	0.00	13.27	0.00	0.00	14.64	0.00	10.71	6.39	2.09	0.90	5.62	7.60	10.38	14.39
AVERAGE	5.12	5.41	3.34	5.43	5.98	11.34	12.12	13.29	12.25	11.75	9.60	4.65	1.82	0.74	5.14	7.58	10.37	14.05

Year	Jul 1	Jul 2	Jul 3	Aug 1	Aug 2	Aug 3	Sep 1	Sep 2	Sep 3	Oct 1	Oct 2	Oct 3	Nov 1	Nov 2	Nov 3	Dec 1	Dec 2	Dec 3	AVERAGE	TOTAL (MCM)
66	16.32	17.67	19.39	20.16	19.42	14.24	13.19	11.25	6.83	4.40	4.86	6.19	0.00	5.27	8.68	0.00	0.00	2.94	8.52	306.73
67	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	3.97	4.36	0.00	3.54	0.00	0.00	0.92	6.30	2.92	7.85	282.48
68	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	4.86	5.76	8.29	0.00	0.00	0.00	9.92	0.00	9.07	326.65
69	16.32	17.67	19.39	20.16	19.51	16.95	13.19	10.82	6.83	0.00	3.57	0.00	0.00	9.29	0.66	0.00	0.00	0.00	7.31	262.99
70	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	3.93	5.86	5.91	0.00	0.00	10.71	2.29	0.00	10.44	375.76
71	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	0.03	2.71	6.19	0.00	0.00	0.40	8.51	0.45	5.79	8.97	323.05
72	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.44	4.11	4.63	6.19	1.11	9.29	6.88	9.08	0.00	5.05	8.93	321.54
73	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	3.73	0.06	4.86	5.46	0.00	0.00	0.00	0.00	0.00	0.00	8.91	320.87
74	15.48	17.67	19.39	20.16	18.91	13.13	12.40	11.25	6.83	4.30	4.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.64	239.17
75	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	4.86	0.00	8.19	9.29	0.00	0.00	0.00	1.81	8.67	311.97
76	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	5.91	0.00	2.78	0.74	0.69	9.16	6.58	0.00	10.21	0.00	7.31	263.31
77	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	0.00	4.40	4.86	6.19	4.32	9.03	0.00	2.45	0.00	0.00	7.35	264.53
78	15.86	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	3.41	0.00	6.09	0.00	4.76	9.04	0.00	0.00	12.48	7.38	265.67
79	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	0.00	0.00	0.00	4.33	0.00	0.00	0.00	1.61	8.33	299.84
80	16.32	17.67	19.39	19.86	19.51	16.95	12.17	11.25	6.83	4.40	0.00	0.42	1.94	0.11	0.00	8.41	0.00	0.00	9.16	329.86
81	16.32	17.67	19.39	20.16	19.51	16.95	13.09	11.25	6.83	4.11	3.93	3.36	5.46	0.88	0.00	8.22	11.44	7.31	8.50	305.89
82	16.29	17.67	19.39	20.16	19.51	16.95	12.83	11.25	6.83	4.40	0.00	3.85	6.18	0.00	1.81	0.00	9.47	6.35	9.78	352.04
83	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	0.00	5.99	7.30	0.00	0.00	0.00	4.81	1.69	8.97	323.10
84	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	0.00	2.44	5.50	0.00	4.95	0.00	0.00	0.00	0.00	7.70	277.06
85	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	4.86	3.28	0.00	9.29	9.80	4.06	0.00	0.00	8.89	319.94
86	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	5.88	4.07	0.00	0.00	0.00	9.29	5.47	0.00	9.47	3.30	8.47	304.85
87	16.32	17.67	19.39	20.16	19.51	16.95	12.83	11.25	2.65	3.41	0.00	6.19	0.00	9.29	0.00	0.00	0.00	3.35	9.17	330.13
88	16.15	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	0.00	0.58	7.17	9.29	0.00	2.00	7.85	11.97	8.06	290.28
89	16.32	17.67	19.39	19.29	19.51	16.95	13.19	11.25	6.83	3.58	4.73	0.00	0.00	3.07	3.49	0.00	11.14	4.81	8.27	297.80
90	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.60	4.40	0.51	5.96	8.29	6.38	0.00	0.00	7.46	2.85	8.24	296.73
91	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.75	6.73	3.41	0.00	1.60	8.29	0.00	3.90	1.34	11.71	0.00	9.23	332.22
92	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	4.86	3.28	5.53	0.00	5.82	3.54	0.00	0.00	9.44	339.93
93	15.62	17.67	19.39	20.16	19.51	16.80	13.19	11.25	6.83	4.40	4.66	6.19	0.00	0.00	0.00	0.00	5.45	0.00	8.17	294.10
94	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.25	6.83	4.40	0.00	3.66	4.89	9.29	1.72	10.32	1.17	0.00	9.89	355.94
95	16.32	17.67	19.39	19.74	19.51	16.95	13.19	11.25	6.83	4.40	4.86	0.00	8.29	0.00	0.00	0.00	1.10	8.03	10.25	369.15
96	16.32	17.67	19.39	20.16	19.51	16.95	13.19	11.08	6.40	4.40	4.86	2.19	6.37	0.00	0.00	4.35	0.00	3.57	8.56	308.06
97	16.32	17.67	19.39	20.16	19.51	16.95	13.19	0.00	6.83	4.34	2.86	0.00	8.29	9.29	9.87	8.35	11.80	10.41	7.93	285.58
AVERAGE	16.25	17.67	19.39	20.11	19.49	16.74	13.11	10.88	6.30	3.55	2.81	3.15	3.44	4.11	2.32	2.57	3.81	3.01	8.57	308.66

Table 5 Conveyance System - Design Alternatives

Alternative	Design Option	Length of Pipe (m)	Length of Open canal (m)	Discharge (litres/sec)	Velocity in Pipe (m/sec)	Velocity in open canal (m/sec)	Dia of pipe (m)	Section of canal (m)	Cost in Z$ million
Alternative - I System Design for day-time irrigation (for 12 hours)									
I - (b)	Pipelie only	4,678	-	144	0.37	-	0.7	-	35
I - (a)	Pipeline and open canal	770	4,883	144	0.37	0.53	0.7	Trapezoidal 0.5 x	10
Alternative - II System Design for Continuous Irrigation (day & night - 24 hours)									
II - (a)	Pipeline and canal with	770	4,883	72	0.37	0.43	0.5	Rectangular 0.5 x	11

Feasibility Considerations:

(i) Pipe (12 hours supply)
- Very costly and investments will not commensurate with the benefits
- Bends, sluice valves and air relief valves are not available and will have to be imported/order made
- Heavy machinery will be required for even minor repairs
- Pipes are feasible only where head is more and flow passes at high velocity. Here both the head and the velocity of flow are very low

(ii) Pipe and Open canal (12 hours supply)
- Every morning the flow will have to be started about 3-4 hours before the start of irrigation time to fill the empty canals
- Flow of water after the ending time of irrigation will not be used by the farmers and the irrigation area will get reduced

(iii) Pipe and covered canal (24 hours supply)
- Flow will be continuous for 24 hours and farmers will have to take water in the inconvenient times also.

Table 6 Conveyance System with Pipeline for Day-time (12 hours) Water Supply

Discharge	0.144 Cumec	Velocity= 4 * Q / 3.1416*d^2
Dia.of Pip(	0.7	(assuming loss in bends etc 15%)
R	0.175	Friction Loss = 1.15 x f·L/D·V2/2g
C	140	$(f = 133.7/(C^{1.85}xD^{0.167}xV^{0.148}))$
Total Enag	893.2	$V = 0.849C \cdot R^{0.63} \cdot I^{0.54}$
		StaticEnergy EL = Water El - Cumulative Friction loss
	(centre)*	Velocity head = v^2 / 2g
		=893.5 - 0.3(loss from Intake to Off-take)

(*)-Theoretical to be finalised on the drawing

Particulars	R.D.	NSL	Trench level (*)	Velocity	Friction Loss	Static head(EL)	Velocity Head	Total Energy EL
Off-take	0	893.5	892	0.374	0.000	893.19	0.01	893.20
	268	894	892.5	0.374	0.103	893.09	0.01	893.10
	285	892	890.5	0.374	0.007	893.08	0.01	893.09
	460	892	890.5	0.374	0.068	893.02	0.01	893.02
	475	894	892.5	0.374	0.006	893.01	0.01	893.02
	578	892	890.5	0.374	0.040	892.97	0.01	892.98
TP-1	735	891	889.5	0.374	0.061	892.91	0.01	892.92
	840	892	890.5	0.374	0.041	892.87	0.01	892.88
TP-2	990	892	890.5	0.374	0.058	892.81	0.01	892.82
TP-3	1170	892	890.5	0.374	0.070	892.74	0.01	892.75
TP-4	1295	892	890.5	0.374	0.048	892.69	0.01	892.70
	1310	894	892.5	0.374	0.006	892.69	0.01	892.69
	1480	894	892.5	0.374	0.066	892.62	0.01	892.63
	1630	894	892.5	0.374	0.058	892.56	0.01	892.57
	1870	894	892.5	0.374	0.093	892.47	0.01	892.48
	2045	893	891.5	0.374	0.068	892.40	0.01	892.41
TP-5	2100	892.5	891	0.374	0.021	892.38	0.01	892.39
	2140	892	890.5	0.374	0.015	892.37	0.01	892.37
	2200	891	889.5	0.374	0.023	892.34	0.01	892.35
	2240	890	888.5	0.374	0.015	892.33	0.01	892.33
	2360	889	887.5	0.374	0.046	892.28	0.01	892.29
TP-6	2475	889	887.5	0.374	0.044	892.24	0.01	892.24
TP-7	2665	889	887.5	0.374	0.073	892.16	0.01	892.17
	2760		-1.5	0.374	0.037	892.13	0.01	892.13
	2785	889	887.5	0.374	0.010	892.12	0.01	892.12
	2943	890	888.5	0.374	0.061	892.06	0.01	892.06
TP-8	3073	890.8	889.3	0.374	0.050	892.01	0.01	892.01
TP-9	3273	891	889.5	0.374	0.077	891.93	0.01	891.94
	3463	890	888.5	0.374	0.073	891.86	0.01	891.86
	3568	890	888.5	0.374	0.041	891.81	0.01	891.82
	3748	890	888.5	0.374	0.070	891.75	0.01	891.75
	3818	890	888.5	0.374	0.027	891.72	0.01	891.73
TP-10	4078	889.7	888.2	0.374	0.100	891.62	0.01	891.63
	4518	889	887.5	0.374	0.170	891.45	0.01	891.46
PD	4678	888.3	886.8	0.374	0.062	891.39	0.01	891.39

Table 7 Conveyance System with Pipeline and Canal for Day-time (12 hours) Water Supply

Discharge	0.072	Cumec	Velocity= 4 * Q / 3.1416*d^2
Dia.of Pip(	0.5		(assuming loss in bends etc 15%)
R	0.125		Friction Loss = 1.15 x f·L/D·V2/2g
C	140		($f = 133.7/(C^{1.85}xD^{0.167}xV^{0.148})$)
Total Enag	893.2		$V = 0.849C \cdot R^{0.63} \cdot I^{0.54}$
			StaticEnergy EL = Water El - Cumulative Friction loss
		(centre)*	Velocity head = v^2 / 2g
			=893.5 - 0.3(loss from Intake to Off-take)

(*)-Theoretical to be finalised on the drawing

Particulars	R.D.	NSL	Trench level(*)	Velocity	Friction Loss	Static head (EL)	Velocity Head	Total EnergyEL	Remarks
Off-take	0.0	893.5	892	0.367	0.000	893.19	0.01	893.20	
	25.0	894	892.5	0.367	0.015	893.18	0.01	893.19	
	275.0	894	892.5	0.367	0.145	893.03	0.01	893.04	
	295.0	892	890.5	0.367	0.012	893.02	0.01	893.03	
	320.0	892	890.5	0.367	0.015	893.01	0.01	893.01	Valley
	360.0	892	890.5	0.367	0.023	892.98	0.01	892.99	
	375.0	892	890.5	0.367	0.009	892.98	0.01	892.98	
	417.0	894	892.5	0.367	0.024	892.95	0.01	892.96	
	435.0	892	890.5	0.367	0.010	892.94	0.01	892.95	Valley
	470.0	892	890.5	0.367	0.020	892.92	0.01	892.93	
	485.0	894	892.5	0.367	0.009	892.91	0.01	892.92	
	515.0	895	893.5	0.367	0.017	892.89	0.01	892.90	
	575.0	894	892.5	0.367	0.035	892.86	0.01	892.87	
	625.0	892	890.5	0.367	0.029	892.83	0.01	892.84	
	770.0	892	890.5	0.367	0.084	892.75	0.01	892.75	
					0.447				

Particulars/ strs	R.D. metres	Inbetween distance (on map 1:5000) (1cm=50m	Ground level (NSL)mts	Head Loss in structures/ working head	Length of main canal	S-slope	Loss of head through slope	Proposed FSL u/s	Proposed FSL d/s
Off-take	770.0	0.30	892.0	0.10	15	0.0005556	0.0083333	892.50	892.40
P.Flume	785.0	6.20	892.0	0.20	310	0.0005556	0.1722222	892.39	892.19
TP-1	1095.0	1.70	892.0		85	0.0005556	0.0472222	892.02	892.02
TP-2	1180.0	2.40	892.0		120	0.0005556	0.0666667	891.97	891.97
TP-3	1300.0	5.80	892.0		290	0.0005556	0.1611111	891.91	891.91
Xing-1	1590.0	4.50	893.8	0.05	225	0.0005556	0.125	891.74	891.69
Xing-2	1815.0	6.80	894.0	0.05	340	0.0005556	0.1888889	891.57	891.52
TP-4	2155.0	4.00	892.3		200	0.0005556	0.1111111	891.33	891.33
Xing-3	2355.0	6.60	890.8	0.05	330	0.0005556	0.1833333	891.22	891.17
TP-5	2685.0	1.60	890.3		80	0.0005556	0.0444444	890.99	890.99
Xing-4	2765.0	4.30	890.5	0.05	215	0.0005556	0.1194444	890.94	890.89
Xing-5	2980.0	0.46	891.3	0.05	23	0.0005556	0.0127778	890.77	890.72
TP-6	3003.0	0.80	890.6		40	0.0005556	0.0222222	890.71	890.71
Drg.Xg-1	3043.0	3.50	889.0		175	0.0005556	0.0972222	890.69	890.69
TP-7	3218.0	2.30	890.0		115	0.0005556	0.0638889	890.59	890.59
Drg.Xg-2	3333.0	1.80	889.0		90	0.0005556	0.05	890.53	890.53
Xing-6	3423.0	6.00	890.0	0.05	300	0.0005556	0.1666667	890.48	890.43
TP-8	3723.0	2.50	890.5		125	0.0005556	0.0694444	890.26	890.26
Xing-7	3848.0	4.20	890.5	0.05	210	0.0005556	0.1166667	890.19	890.14
TP-9	4058.0	4.30	890.3		215	0.0005556	0.1194444	890.02	890.02
TP-10&X8	4273.0	10.70	890.0	0.05	535	0.0005556	0.2972222	889.90	889.85
Xing-9	4808.0	10.80	889.8	0.05	540	0.0005556	0.3	889.56	889.51
Xing-10	5348.0	3.90	889.1	0.05	195	0.0005556	0.1083333	889.21	889.16
TP-11	5543.0	2.20	888.5		110	0.0005556	0.0611111	889.05	889.05
PD	5653.0		888.0	0.20		0.0005556	0	888.99	888.79
				1.00			2.7127778		

Table 8 Conveyance System with Pipeline and Canal for Day-Night(24 hours) Water Supply

Discharge	0.072	Cumec	Velocity= 4 * Q / 3.1416*d^2
Dia.of Pipe	0.5		(assuming loss in bends etc 15%)
R	0.125		Friction Loss = 1.15 x f·L/D·V2/2g
C	130		$(f = 133.7/(C^{1.85} x D^{0.167} x V^{0.148}))$
Total Enag	893.2		$V = 0.849C \cdot R^{0.63} \cdot I^{0.54}$
Min.W.El	893.5		StaticEnergy EL = Water El - Cumulative Friction loss
		(centre)*	Velocity head = v^2 / 2g
			=893.5 - 0.3(loss from Intake to Off-take)

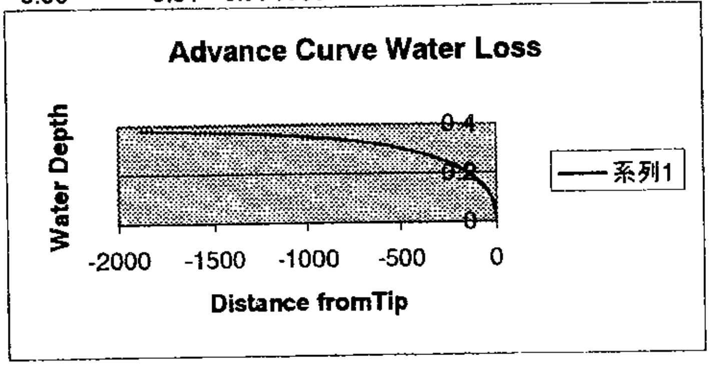
(*)-Theoretical to be finalised on the drawing

Particulars	R.D.	NSL	Trench level(*)	Velocity	Friction Loss	Static head (EL)	Velocity Head	Total Energy EL	Remarks
Off-take	0.0	893.5	892	0.367	0.000	893.19	0.007	893.20	
	25.0	894	892.5	0.367	0.010	893.18	0.007	893.19	
	275.0	894	892.5	0.367	0.097	893.09	0.007	893.09	
	295.0	892	890.5	0.367	0.008	893.08	0.007	893.09	
	320.0	892	890.5	0.367	0.010	893.07	0.007	893.08	Valley
	360.0	892	890.5	0.367	0.016	893.05	0.007	893.06	
	375.0	892	890.5	0.367	0.006	893.05	0.007	893.05	
	417.0	894	892.5	0.367	0.016	893.03	0.007	893.04	
	435.0	892	890.5	0.367	0.007	893.02	0.007	893.03	Valley
	470.0	892	890.5	0.367	0.014	893.01	0.007	893.02	
	485.0	894	892.5	0.367	0.006	893.01	0.007	893.01	
	515.0	895	893.5	0.367	0.012	892.99	0.007	893.00	
	575.0	894	892.5	0.367	0.023	892.97	0.007	892.98	
	625.0	892	890.5	0.367	0.019	892.95	0.007	892.96	
	770.0	892	890.5	0.367	0.056	892.89	0.007	892.90	
				Total Loss	**0.299**				
Particulars/ strs	R.D.	Inbetween distance (on map 1:5000) (1cm=50m	Ground level (NSL)mts	Head Loss in structures/ working head	Length of main canal	S-slope	Loss of head through slope	Proposed FSL u/s	Proposed FSL d/s
Off-take	770.0	0.30	892.0	0.10	15	0.0007	0.0111	892.89	892.79
P.Flume	785.0	6.20	892.0	0.20	310	0.0007	0.2299	892.78	892.58
TP-1	1095.0	1.70	892.0		85	0.0007	0.0630	892.35	892.35
TP-2	1180.0	2.40	892.0		120	0.0007	0.0890	892.29	892.29
TP-3	1300.0	5.80	892.0		290	0.0007	0.2151	892.20	892.20
Xing-1	1590.0	4.50	893.8		225	0.0007	0.1669	891.99	891.99
Xing-2	1815.0	6.80	894.0		340	0.0007	0.2522	891.82	891.82
TP-4	2155.0	4.00	892.3		200	0.0007	0.1483	891.57	891.57
Xing-3	2355.0	6.60	890.8		330	0.0007	0.2447	891.42	891.42
TP-5	2685.0	1.60	890.3		80	0.0007	0.0593	891.17	891.17
Xing-4	2765.0	4.30	890.5		215	0.0007	0.1595	891.11	891.11
Xing-5	2980.0	0.46	891.3		23	0.0007	0.0171	890.96	890.96
TP-6	3003.0	0.80	890.6		40	0.0007	0.0297	890.94	890.94
Drg.Xg-1	3043.0	3.50	889.0		175	0.0007	0.1298	890.91	890.91
TP-7	3218.0	2.30	890.0		115	0.0007	0.0853	890.78	890.78
Drg.Xg-2	3333.0	1.80	· 889.0		90	0.0007	0.0667	890.69	890.69
Xing-6	3423.0	6.00	890.0		300	0.0007	0.2225	890.63	890.63
TP-8	3723.0	2.50	890.5		125	0.0007	0.0927	890.40	890.40
Xing-7	3848.0	4.20	890.5		210	0.0007	0.1557	890.31	890.31
TP-9	4058.0	4.30	890.3		215	0.0007	0.1595	890.16	890.16
TP-10&X8	4273.0	10.70	890.0		535	0.0007	0.3968	890.00	890.00
Xing-9	4808.0	10.80	889.8		540	0.0007	0.4005	889.60	889.60
Xing-10	5348.0	3.90	889.1		195	0.0007	0.1446	889.20	889.20
TP-11	5543.0	2.20	888.5		110	0.0007	0.0816	889.05	889.05
PD	5653.0		888.0	0.20		0.0007	0.0000	888.97	888.77
				0.50			3.6216		

Table 9 Water Losses at Start of Irrigation

x = yn/So [z + ln (1 - z)] where z = y/yn, So = slope(1/18000)
ln is natural log

yn	y	#VALUE!	#VALUE!	s0		LongArea	X-area	Volume
0.39	0.38	0.025641	-3.66356	0.000556	-1887.82	-175.721	0.2622	-120.814
0.39	0.37	0.051282	-2.97041	0.000556	-1419.23	-97.3223	0.25345	-66.4258
0.39	0.36	0.076923	-2.56495	0.000556	-1152.59	-65.3032	0.2448	-44.2453
0.39	0.35	0.102564	-2.27727	0.000556	-968.642	-47.8331	0.23625	-32.1695
0.39	0.34	0.128205	-2.05412	0.000556	-829.995	-36.8466	0.2278	-24.5965
0.39	0.33	0.153846	-1.8718	0.000556	-720.005	-29.3195	0.21945	-19.4253
0.39	0.32	0.179487	-1.71765	0.000556	-629.791	-23.8578	0.2112	-15.6874
0.39	0.31	0.205128	-1.58412	0.000556	-554.052	-19.7285	0.20305	-12.8737
0.39	0.3	0.230769	-1.46634	0.000556	-489.369	-16.5091	0.195	-10.6903
0.39	0.29	0.25641	-1.36098	0.000556	-433.406	-13.9387	0.18705	-8.95623
0.39	0.28	0.282051	-1.26567	0.000556	-384.498	-11.8475	0.1792	-7.55335
0.39	0.27	0.307692	-1.17865	0.000556	-341.416	-10.1203	0.17145	-6.4016
0.39	0.26	0.333333	-1.09861	0.000556	-303.226	-8.67607	0.1638	-5.44466
0.39	0.25	0.358974	-1.0245	0.000556	-269.202	-7.45608	0.15625	-4.64179
0.39	0.24	0.384615	-0.95551	0.000556	-238.769	-6.41692	0.1488	-3.96279
0.39	0.23	0.410256	-0.89097	0.000556	-211.463	-5.52566	0.14145	-3.38477
0.39	0.22	0.435897	-0.83035	0.000556	-186.905	-4.75692	0.1342	-2.89011
0.39	0.21	0.461538	-0.77319	0.000556	-164.779	-4.09081	0.12705	-2.46496
0.39	0.2	0.487179	-0.71912	0.000556	-144.824	-3.51154	0.12	-2.09837
0.39	0.19	0.512821	-0.66783	0.000556	-126.816	-3.00638	0.11305	-1.78148
0.39	0.18	0.538462	-0.61904	0.000556	-110.566	-2.56498	0.1062	-1.50711
0.39	0.17	0.564103	-0.57252	0.000556	-95.9085	-2.17885	0.09945	-1.26934
0.39	0.16	0.589744	-0.52807	0.000556	-82.7033	-1.84091	0.0928	-1.06327
0.39	0.15	0.615385	-0.48551	0.000556	-70.8265	-1.54527	0.08625	-0.8848
0.39	0.14	0.641026	-0.44469	0.000556	-60.1694	-1.28695	0.0798	-0.73046
0.39	0.13	0.666667	-0.40547	0.000556	-50.6365	-1.06171	0.07345	-0.59732
0.39	0.12	0.692308	-0.36772	0.000556	-42.1428	-0.86596	0.0672	-0.48287
0.39	0.11	0.717949	-0.33136	0.000556	-34.6127	-0.69658	0.06105	-0.38494
0.39	0.1	0.74359	-0.29627	0.000556	-27.9786	-0.55089	0.055	-0.30169
0.39	0.09	0.769231	-0.26236	0.000556	-22.1797	-0.42657	0.04905	-0.23148
0.39	0.08	0.794872	-0.22957	0.000556	-17.1613	-0.32157	0.0432	-0.1729
0.39	0.07	0.820513	-0.19783	0.000556	-12.8737	-0.23411	0.03745	-0.12471
0.39	0.06	0.846154	-0.16705	0.000556	-9.27197	-0.16262	0.0318	-0.08582
0.39	0.05	0.871795	-0.1372	0.000556	-6.31519	-0.10572	0.02625	-0.05527
0.39	0.04	0.897436	-0.10821	0.000556	-3.96594	-0.06216	0.0208	-0.03219
0.39	0.03	0.923077	-0.08004	0.000556	-2.18998	-0.03085	0.01545	-0.01583
0.39	0.02	0.948718	-0.05264	0.000556	-0.9559	-0.01082	0.0102	-0.0055
0.39	0.01	0.974359	-0.02598	0.000556	-0.23479	-0.00117	0.00505	-0.00059
						-605.736		-404.454



FIGURES

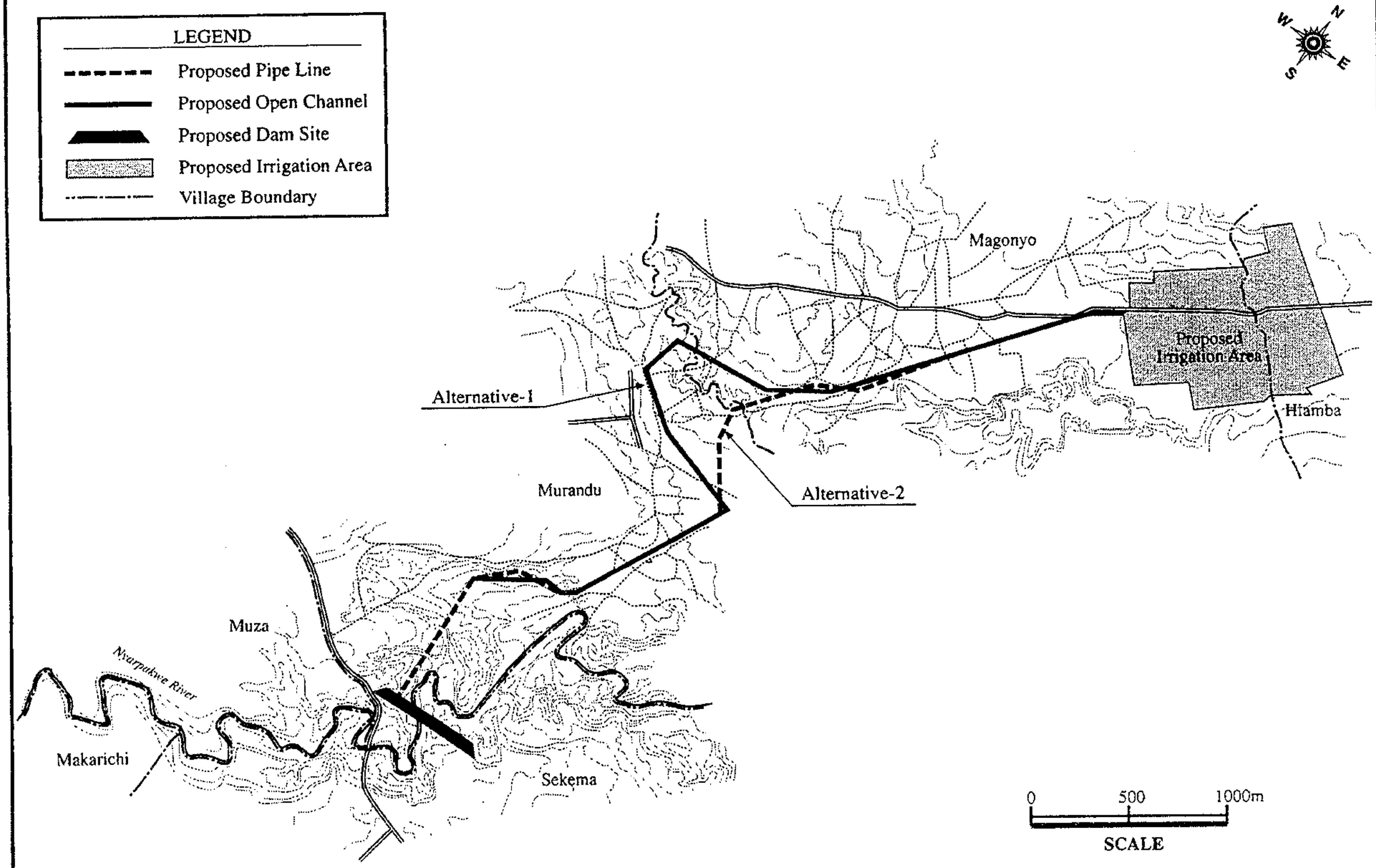


Fig. 1 Alignment of Conveyance System - Pilot Irrigation Area

NET IRRIGATION AREA

VILLAGE	AREA IN HECTARES	DISCHARGE IN L/S
Magonyo (M)	Section A = 20,11 Section B = 17,46	21,7 18,9
Hlamba (H)	22,43	24,2

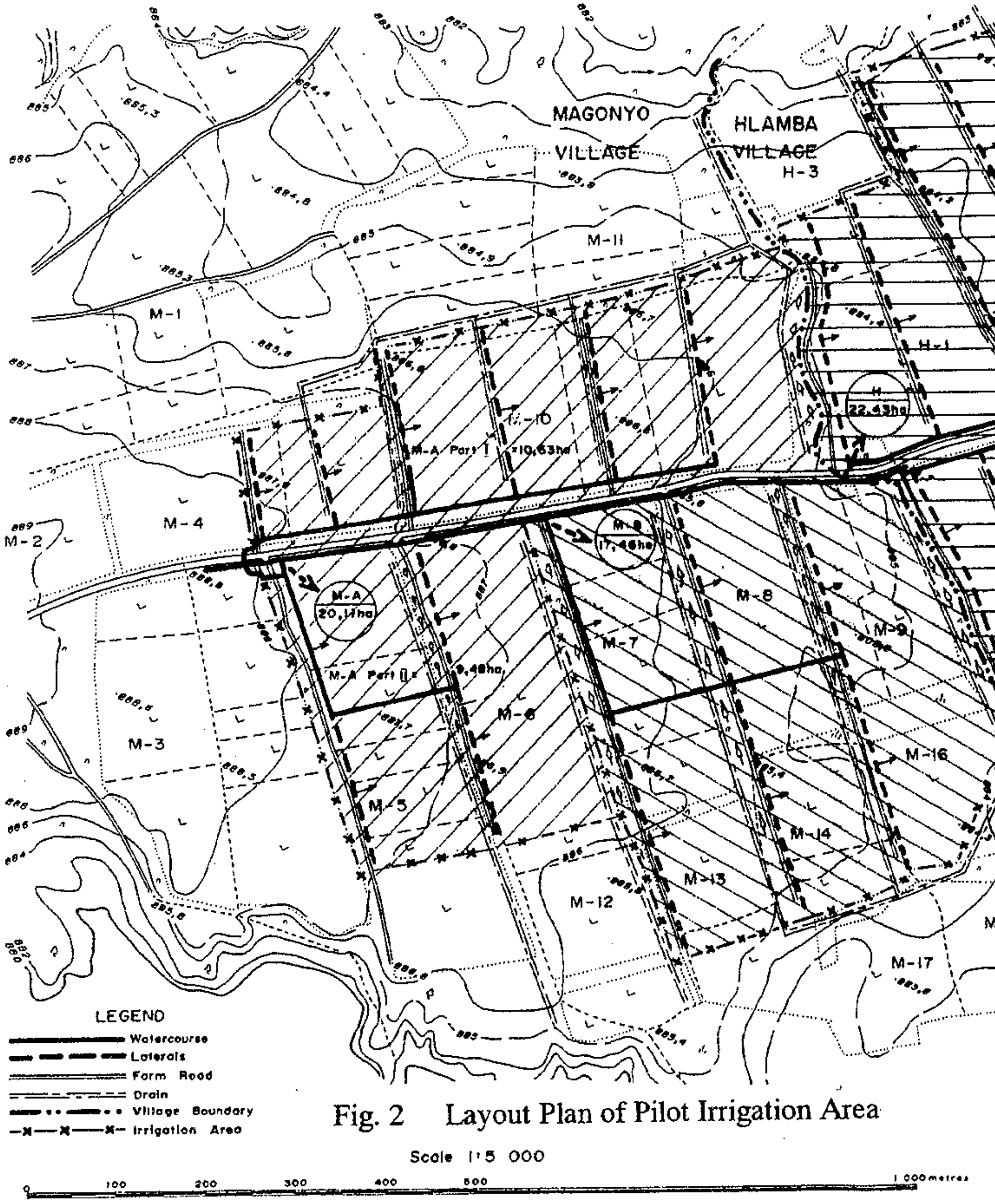
IDENTIFIED AREA

MAGONYO VILLAGE

	Hectares
M-1	6,38
M-2	2,10
M-3	8,40
M-4	4,25
M-5	6,70
M-6	4,83
M-7	4,08
M-8	3,58
M-9	2,80
M-10	9,13
M-11	6,93
M-12	2,15
M-13	2,90
M-14	2,60
M-15	2,00
M-16	2,35
M-17	2,60
Total	73,78

HLAMBA VILLAGE

	Hectares
H-1	5,35
H-2	10,50
H-3	3,08
H-4	7,75
H-5	2,30
H-6	6,35
H-7	5,15
H-8	6,43
Total	46,91



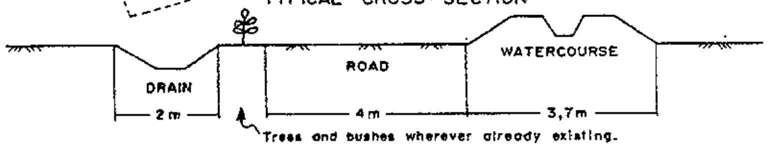


Fig. 2 Layout Plan of Pilot Irrigation Area