(2) Execution Agency

The responsible ministry of Zimbabwe for this Project is the Ministry of Lands, Agriculture and Water Development. The executing agencies of Zimbabwe are the Department of Agricultural Technical and Extension Services (AGRITEX) and the Department of Water Development (DWD) under this Ministry. The works to be executed by each agency have been divided at a particular structure point in the whole irrigation system: the so called "field edge". The field edge in this Project is an outlet gate of each farm pond.

AGRITEX is in charge of on-farm facilities, such as irrigation canals, drainage canals and farm roads, after the field edge.

DWD is in charge of main irrigation facilities, such as pump stations, head races and farm ponds, before the field edge.

(3) Works to be Executed

The works requested are the construction of the irrigation facilities for five (5) blocks for five (5) villages in the Nyakomba Ward.

1) Irrigation Facilities

• Pump Station	:	5 Places (Head 50~80 m, 4 Pump units per station, Generator 1 Unit)
• Head Race	:	Length 14.3~3.9 km / Each Block, pipe ø 200 ~ 700 mm)
• Farm Pond	:	12 Places, Water volume 110 ~ 1,260 m^3
• Irrigation Canal	:	38.4 km in total
• Drainage Canal	:	33.7 km in total
• Farm Road	:	7.9 km in total

2) Project Management Facilities

• Office building, Workshop, Multi-purpose hall, Staff quarter, etc. (60~360 m^2, 22 buildings in total)

1-3 Project and/or Program of Other Donors

International assistance to Zimbabwe has increased since the first half of 1980, mainly from International Organizations. However, the importance of bilateral assistance has gradually been increasing, and in these last few years, about 90% of foreign governments' assistance is occupied with bilateral assistance. This assistance is provided principally by western countries, especially by the member countries of DAC. The present status of assistance by the major donor countries and International Organizations are as follows.

(1) Bilateral Assistance

a) Germany

Germany has enthusiastically been giving assistance to Zimbabwe prior to her independence. The principal assistance is acceptance of students and technical cooperation. In the other fields, assistance of railway electrification, irrigation projects and improvement of telecommunication facilities is being executed.

b) Great Britain

Since Great Britain was the suzerain of Zimbabwe, it has been giving assistance prior to her independence. The first priority is given to the assistance of education and technical cooperation.

(2) Assistance of International Organizations

a) European Community (EC)

Within the framework of the Rome Agreement, the European Community has been giving broad assistance. Comprehensive assistance based on the Fourth Rome Agreement has concentrated on rural development since 1990.

b) World Bank Group

Multilateral assistance given to Zimbabwe by the International Development Association (IDA) gives priority to the improvement of infrastructures, such as transport and telecommunication, and to agricultural cooperation.

c) African Development Bank (AfDB)

The African Development Bank provides assistance for the rehabilitation on socio-industrial infrastructures, such as water supply facilities and electricity networks.

(3) Current Status of Japanese Assistance

Japanese assistance to Zimbabwe covers both financial and technical cooperation. The major assistance for the agricultural development of this sector during the last five years is as follows.

1) Grant Aid

<u>General Grant Aid</u>

- The Project for the Construction of Medium Size Dams in Masvingo Province (1989 ~ 1994)

<u>KR Food Grant Aid</u>

- Maize from the U. S. A. (1992 June)

<u>Grant Aid for Promotion of Food Production</u>

- Agricultural Machines (1991 April)
- Agricultural Machines (1991 July)
- Pesticide, Agricultural Machines (1992 June)
- Fertilizer, Pesticide, Agricultural Machines (1993 April)

2) Technical Cooperation

- The Feasibility Study on the Nyakomba Irrigation Development Project (1988 ~ 1990)

CHAPTER 2 OUTLINE OF THE PROJECT

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CHAPTER 2 Outline of the Project

2-1 Objectives of the Project

The objectives of the Project are to introduce irrigation facilities, aiming at stability of food self-sufficiency, the improvement of employment opportunity and improvement of living standards by means of the expansion of agricultural production in Communal Lands. The proposed site is the Nyakomba Ward belonging to the Saunyama Communal Land in the north-eastern part of the Nyanga District, the Manicaland Province, with a total area of about 5,300 ha and a population of about 4,700.

The facilities proposed to be implemented are one pump station, head races and one farm pond functioning as an outlet reservoir of water from the pump station, at each block: Block B and Block C. In the farms, concrete irrigation canals, earth drainage canals and farm roads are to be implemented.

The project management facilities i.e. project management building, workshop/garage, agricultural warehouse and fuel station are to be implemented. The project management building consists of a project office, dormitory for trainees and an assembly hall. The workshop/garage is for storing and repairing the agricultural machines procured for the maintenance of the Project. The agricultural warehouse is for storing of agricultural facilities and products.

2-2 Study and Examination on the Request

2-2-1 Basic Policy of the Project

In response to the request of implementation of the Nyakomba Irrigation Project by Japanese Grant Aid from the Government of Zimbabwe, the Japanese Government has decided to conduct a basic design study on this project.

To conduct the study and examination on the request, it was confirmed that the following basic policy of the Project should be taken into consideration.

<u>Basic Policy</u>

Concerning the Nyakomba Irrigation Development Project, it is assured that without irrigation farming by means of irrigation pumps, efficient development of this Communal Land will not be realized.

However, in consideration of insufficient experience of irrigation systems by pumps with such high pump heads and about 30 years for developing the adjacent and similar Nyamaropa Irrigation Scheme with a 440 ha of irrigation area, it is judged that development of the whole 680 ha of this Project is difficult when considering the total project cost as well.

In those conditions, it is judged that the implementation of a small area of one or two blocks, as the first step, shall be appropriate in this area. Consequently, the fore-mentioned is decided on as the basic policy.

2-2-2 Outcome from Study and Examination on the Request

The study made so far has proved that the implementation of the Project will considerably contribute to the improvement of living standards in the Nyakomba Ward, by means of an increase of income by the introduction of irrigation facilities, the improvement of employment opportunity, a stable food supply, and the reduction of the labour burden of women and children by a consistent water supply.

Similar projects are in progress around the adjacent areas, and operation and maintenance have been soundly carried out with the cooperation of AGRITEX. Consequently, concerning the practicability of the Project, there will not be any substantial problems on the implementation of the Project with the current organizations.

The execution capacity of Zimbabwe, which has been accumulating through long experience in similar irrigation projects in the country, is considered to be sufficient to execute the Project. Zimbabwe has already the idea on how to programme the recruitment and training of the staff required after the realization of the Project. In addition, the Zimbabwean side will secure the budget needed for the Project, and substantial problems on the implementation of the Project are not anticipated.

The positive effect and practicability of the Project and the execution capacity of the parties concerning of Zimbabwe have been confirmed appropriate from the outcome of the study made so far, and the positive effect of the Project conforms to the system of the Grant Aid of Japan. In consequence, concerning the implementation of the Project, it is judged to be appropriate with Japan's Grant Aid. Accordingly, on condition that the Grant Aid is provided, the outline of the Project is to be studied and the basic design is to be executed.

However, as to the contents of the Project, the appropriateness of the partial modification of the request has already been mentioned in the basic policy. Consequently, it is decided that the basic design will be carried out on Block B and Block C with a total farming area of 268 ha. The components shall be as follows.

Study blocks: Block B and Block C

Facilities to be implemented:

- Irrigation pump station in each block
- Head race and farm pond in each block
- Irrigation canals, drainage canals and farm roads in each block
- Project management facilities (project management building, workshop/garage, agricultural warehouse, fuel station)

2-3 Project Description

2-3-1 Execution Agency and Operational Structure

As to the organization and method of operation and management of the Project including facilities' maintenance after completion of the project facilities, the Zimbabwean side has been programmed as follows.

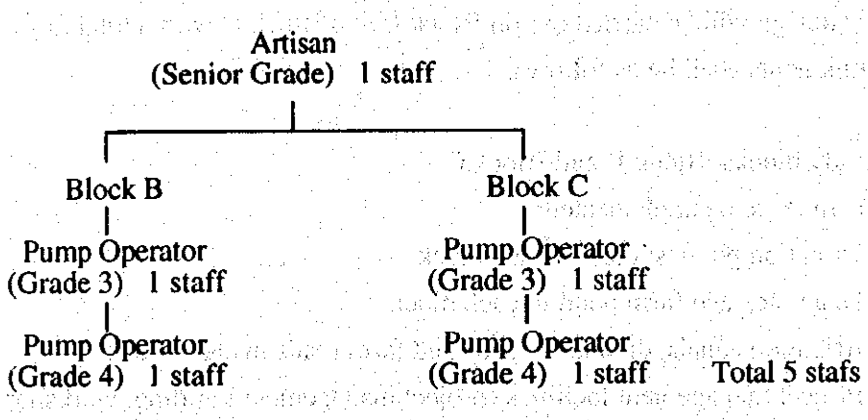
The Project is composed of main irrigation facilities, such as pump stations, head races and farm ponds, and on-farm facilities, such as irrigation canals, drainage canals and farm roads. Among these facilities, the main irrigation facilities are managed by DWD, and the on-farm facilities are managed by AGRITEX.

As the result of the study on the organization and the personnel together with DWD and AGRITEX, the following organization is considered appropriate.

(1) Department of Water Development (DWD)

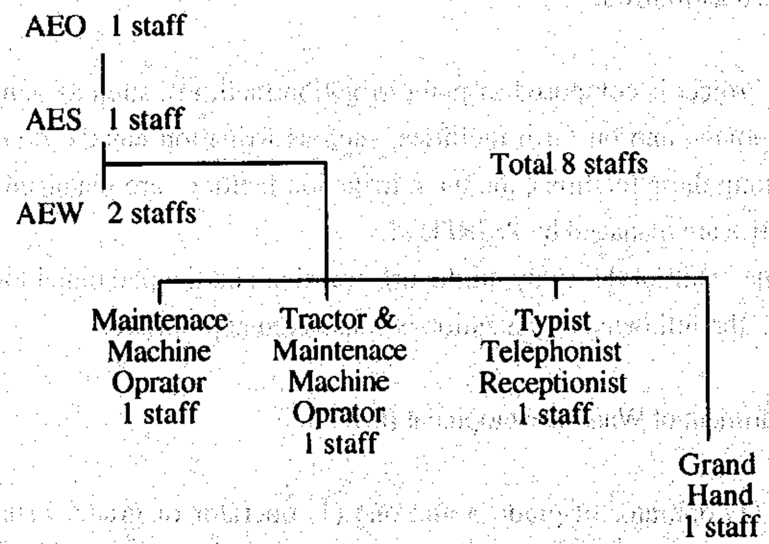
One (1) operator of grade 3 and one (1) operator of grade 4 shall be stationed at the respective pump stations for the proposed Block B and Block C. As a superintendent of the two pump stations, a personnel of senior grade is to be stationed.

The pumps are operated by electricity and the assignment of an electric engineer was considered. However, since the engineer is stationed at the workshop in Mutare, the capital of the province, its office is to deal with emergencies.



(2) Department of Agricultural Technical and Extension Services (AGRITEX)

As to the assignment of the personnel of AGRITEX to Block B and Block C, twelve (12) staffs are stationed as shown in the following organization chart; one (1) agricultural extension officer, one (1) agricultural extension supervisor, two (2) agricultural extension workers, two (2) machine operators, one (1) typist and one (1) grand hand.
These staffs are in charge of water management in the farms and operation and maintenance of the field facilities, stationed at the project management building.



2-3-2 Plan of Operation (Activity)

The following is considered to be the contents of operation and maintenance of the Project carried out by DWD and AGRITEX.

(1) Department of Water Development (DWD)

- Daily operation (Electric power supply, Valves, Pumps)
- Record of operation time, Inspection record of machine conditions
- Supply and inspection of articles of consumption, e.g. lubricant, for pumps and motors
- Cleaning, safety check and maintenance of pump houses and intakes
- Maintenance of head races and farm ponds
- etc.

(2) Department of Agricultural Technical and Extension Services (AGRITEX)

- Routine works (Operation and maintenance of valves and division gates)
- Water management at the division works
- Inspection and maintenance of agricultural machines
- Inspection and maintenance of irrigation canals, drainage canals and farm roads
- Record of management and maintenance
- etc.

2-3-3 Location and Condition of Project Site

(1) Natural Conditions

1) Climate

According to Köppen's climatic classification, Zimbabwe is located in the tropical savannah climatic zone (AW). In this climate zone, there exists one rainy season, but the timing of the beginning of the rainy season and the annual precipitation vary to a great extent. Monthly precipitation is considerably irregular, which affects the yield of agricultural crops. The Project area is located along the border with Mozambique in the eastern side of the eastern mountainous zone. The altitude ranges from 800 m to 850 m, with an annual average temperature of 23.3 °C, and an annual average rainfall of 903 mm. As the major climate characteristics, the temperature and precipitation are shown in the table below.

Table 2.1 Temperature and Rainfall Data at the Site

Monthly

	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
Ave.Max.	29.8	29.9	29.6	28.9	27.5	25.5	24.7	27.1	30.0	30.9	30.0	29.2	28.6
Ave.Min.	21.4	21.2	20.1	18.3	15.8	14.1	13.9	14.7	16.5	19.0	20.0	20.4	18.0
(°C)													Annual
Rainfall (mm)	216.0	226.4	119.2	33.6	6.1	1.4	1.9	0.9	4.3	25.9	82.0	185.2	902.9

Yearly

	82	83	84	85	86	87	88	89	90	91	92	93	Annual
Rainfall (mm)	723	475	750	1,568	928	561	1,083	1,128	852	450	380	969	903

2) Hydrology

The Gairezi River, which is the water resource of the Project, flows down into the project area from Mt. Inyangani, the highest peak in the eastern mountainous range of the eastern end of the central highland. After flowing down to the north-north-east through the steep mountainous zone, the river joins the Zambezi river in Mozambique.

In accordance with opinion of the local people, it is confirmed that the water level of the Gairezi River has not lowered remarkably in the dry season since the Feasibility Study. The discharge of the Gairezi River is confirmed to be sufficient as water resources for irrigation water in the Project area.

3) Topography

The Titowa mountainous region lies in the east of the Nyakomba Ward, and from the east to the west the Mazumba mountain chain ranges. The flat farm land extends along the Gairezi river at the foot of these mountains. The elevation of the Ward ranges from 800 m, at the riverside of the Gairezi, to 1,350 m, on the top of the Mountains. Most of the farm lands extend in the comparatively flat land from El. 800 to El. 850.

The Gairezi River runs from the south to the north in the eastern part of the Project area, and the small tributaries flow down into the Gairezi river from the mountainous region, with the runoff of the project area.

Almost all the tributaries dry up in the dry season, and a considerably strong gully erosion caused by the irregular flow are found in many places.

4) Geology and Soil

The soil around the Project area is composed of the metamorphic granites of the pre-Cambrian, their residuals and the basalts. The basement is the Unkondo geological layer, specific to Zimbabwe. This layer is composed of uneven deposits of the said rocks. The flat land used for the farm land consists of the alluvial soil and the surface deposits of the Gairezi River.
The soil is of the kaolinite type, and is composed generally of clay, subject to bleaching from a medium to a high degree. The color of the soil varies from a deep red brown to a dull red brown. The composition of the soil is clay with fine sand or clay.

5) Ground Conditions

The proposed sites of the pump stations and the farm ponds where the ground condition shall be studied, in the Block B and Block C, were explored by boring, and the formation and its bearing capacity were confirmed.

The formation of the proposed pump stations is composed of the black river deposits, mixed with gravel and cobbles in both Block B and Block C. The rocks are exposed along the river. However, the rocks are not discovered up to 7 m below the surface of the proposed sites of the pump station by boring. Since the soft layer of having a N-value less than 4 exists in the layer 5 m below the surface of the proposed site of the pump station in Block B, the foundation work is to be examined.
At the proposed sites of the farm ponds, located at the foot of the mountains, the rocks and the cobbles are mixed in the soil. The ground, however, is strong enough for the proposed structure.

(2) Social Infrastructure

The social infrastructures in the Nyakomba Ward are as follows:

1) Road

The asphalt pavement on the National Road No. 264 (Nyanga-Ruwangwe: 80 km) and the District Road No. 266 (13 km) from Resina Coeli (44 km from Nyanga) to the center of Nyamaropa, that was under construction when the Feasibility Study was conducted in 1989/1990, was completed. Consequently, the access road up to the Nyakomba Ward has drastically been improved.

The road connecting the Nyamaropa village with the Nyakomba village is the District Road No. 269 paved with gravel. The road surface has been maintained in good condition by regular repair. It is about 13 km to the center of Nyakomba village and about 11 km to the proposed site of the project management facilities.

2) Electricity

Electrification has not been completed yet in the Nyakomba Ward. It is confirmed that the reinforcement work of electricity (33 kv-132 kv) between Mutare and Nyanga is in progress to be completed by August 1996. It is also confirmed that the extension work of the power line between Nyanga and Nyakomba is to be executed by the budget of the AGRITEX at the same period.
Accordingly, the electrification in the Project area will have been completed by the completion of the construction of pump stations.

3) Water Supply

In the Project area, a sanitary water system is not available. The water from the Gairezi River, which will be the water resources for the Project, is used by the inhabitants living around there. In addition, under the well drilling project that has been carried out by the assistance of Denmark, several wells with hand operating pump have been completed in the Nyakomba area, and are used for potable water, etc.

4) Communication

The telephone line works are in progress in the Nyakomba Ward, and will become available in the near future. The post office is not placed yet.

5) Business Center (B. C.)

The Business Center, center of the Nyakomba Ward, is located in the northern side of Block C, and several shops, hotels, restaurants and flour mill are centralized. It also serves as relay points of the buses and plays a role as the business center of the area.

(3) Environment

The environment to be affected by the realization of the Project will be as follows.

1) Occurrence of Malaria Mosquitoes

It is feared that an occurrence of Malaria mosquitoes will erupt after the construction of farm ponds that form pools. However, water in the farm ponds does not stay still and is drained off in a short time. Therefore, the possibility of occurrence of Malaria mosquitoes will hardly erupt. In the case of its occurrence, the question will be settled by referring to the examples of the other irrigation areas.

2) Environmental Pollution

The noise caused by operation of pumps would not pose any substantial problem, because of the introduction of electric pumps and remote distance to the houses.

3) Change of Ecological System

By the introduction of irrigation, it becomes possible to cultivate crops in the dry season. It is feared that disease and the insects will cause damage to the crops. The question will be settled by referring to the examples of the other irrigation areas.

4) Resettlement of Inhabitants

There may be residential areas to be included in the proposed site of the farm pond to be installed in the upper part of the proposed irrigation area. In this case, it will become necessary to move the houses. However, the land itself belongs to the State, and only the right to use the land is allowed to the inhabitants. It has been confirmed in Zimbabwe that there exists no substantial problem of the resettlement of the inhabitants.

In accordance with the above-mentioned, it is not considered that any big environmental problems will erupt in this Project.

2-3-4 Outline of Facilities and Equipment

Outline of Facilities and Equipment to be provided by the Project are as follows.

Irrigation Pump Station (Block B)

Sub-structure	Type:	Reinforced Concrete Structure
Pumps	Bore Diameter:	ø 250 mm
	Type:	Horizontal, Double Suction
	Discharge:	6.14 m^3/min
	Unit:	3 units
	Total Head:	73.87 m
	Motor Power:	132 kw

Irrigation Pump Station (Block C)

Sub-structure	Type:	Reinforced Concrete Structure
Pumps	Bore Diameter:	ø 250 mm
	Type:	Horizontal, Double Suction
	Discharge:	6.73 m^3/min
	Unit:	3 units
	Total Head:	81.40 m
	Motor Power:	150 kw

Irrigation Facilities, Drainage Canals and Farm Roads (Block B)

Head Races	Ductile Cast Iron Pipe:	ø 500 mm, L = 1,656 m
	PVC Pipe	ø 500 mm, L = 769 m
	PVC Pipe	ø 400 mm, L = 523 m
	PVC Pipe	ø 300 mm, L = 746 m
Farm Ponds	Capacity:	560 m^3
	Type:	T-type Reinforced Concrete Retaining Wall
Irrigation Canals	Type:	Reinforced Concrete
	Length:	12,035 m
	Bottom Width:	0.20 ~ 0.35 m
	Appurtenant Works:	Division Works, Drop, etc.
Drainage Canals	Type:	Earth Canal
	Length:	14,163 m
	Bottom Width:	0.50 m
	Appurtenant Works:	Confluence Works, Ground Sill, etc.

Farm Roads	Type:	Gravel Pavement	
	Length:	Trunk Farm Road	150 m
		Secondary Farm Roads	3,915 m
	Width:	Trunk Farm Road	3 m
		Secondary Farm Roads	5 m
	Appurtenant Works: Road Bridge		

Irrigation Facilities, Drainage Canals and Farm Roads (Block C)

Head Races	Ductile Cast Iron Pipe:		ø 500 mm, L = 1,941 m
	PVC Pipe		ø 450 mm, L = 891 m
	PVC Pipe		ø 300 mm, L = 930 m
Farm Ponds	Capacity:	620 m^3	
	Type:	T-type Reinforced Concrete Retaining Wall	
Irrigation Canals	Type:	Reinforced Concrete	
	Length:	14,998 m	
	Bottom Width:	0.20 ~ 0.35 m	
	Appurtenant Works: Division Works, Drop, etc.		
Drainage Canals	Type:	Earth Canal	
	Length:	16,336 m	
	Bottom Width:	0.50 m	
	Appurtenant Works: Confluence Works, Ground Sill, etc.		
Farm Roads	Type:	Gravel Pavement	
	Length:	Trunk Farm Road	160 m
		Secondary Farm Roads	4,096 m
	Width:	Trunk Farm Road	3 m
		Secondary Farm Roads	5 m

Project Management Facilities

Project Management Building:	603 m^2
	Reinforced Concrete Pillar, Brick Structure Wall
	Wooden Truss Rafter Roof
Workshop/Garage:	272 m^2
	Reinforced Concrete Pillar, Brick Structure Wall
	Steel Frame Truss Angle Roof
Agricultural Warehouse:	162 m^2
	Reinforced Concrete Pillar, Brick Structure Wall
	Steel Frame Truss Angle Roof

Fuel Station: 52 m^2

Reinforced Concrete Pillar, Brick Structure Wall

Wooden Truss Rafter Roof

Equipment

Agricultural Machines: 1 unit each

Tractor: 4WD, 75 HP

Attachments: Rotary Harrow, Disc Plow, Ridger, Trailer

Field Maintenance Machine:

Motor grader: B = 2.80 m 1 unit

Other Equipment:

Pickup: 500 kg 1 unit

Truck: 6 ton 1 unit

Motorcycle: 90 cc 1 unit

Equipment for the Workshop 1 set

2-3-5 Operation and Maintenance Plan

(1) Budget

The following is the budget which would be needed for the operation and maintenance of the Project after the completion of project facilities.

Table 2-3-5 Annual Cost of the Operation and Maintenance

Benefited Area	Annual Cost of the Operation and Maintenance		(Z$)
(ha)	L/C	Total	Cost per ha
268	563,134	563,134	2,101

* Renewal cost of the equipment is excluded.

In Zimbabwe, the annual burden of the farmers in the irrigated areas for the irrigation facilities is uniformly 145 Z$/ha/year regardless of types of irrigation. Once the farmers pay this amount, the whole operation and maintenance of the facilities are carried out by DWD and AGRITEX. However, this payment does not cover the actual operation and maintenance cost. Consequently, it means that the Government makes up for the shortage of the cost as a subsidy. In accordance with the Structure Adjustment Programme, such a subsidy shall be decreased. Therefore, this system will have to be reconsidered and the farmers will have to be able to afford the operation and maintenance cost by themselves for each project.

Concerning the Project, as mentioned above, the annual operation and maintenance cost is estimated at 2.101 Z$/ha/year, and 1,956 Z$/ha/year would be shortage involved and shall be paid as a subsidy by the Government.

(2) Training Programme

After the completion of project facilities, the system and method (quality and quantity) of the operation and maintenance will be needed. To create a good system and method, skilled personnel of the Execution Agencies are required. Therefore, the training of the personnel is very important to achieve the Project successfully.

AGRITEX

AGRITEX has training program for the operation and maintenance on the Nyakomba Irrigation Project (1995 - 1998) shown below;

1) Marketing

- Contents: Marketing Study
- Period: 1985

2) Study Tour

- Contents: Study tour for 60 farmers in Block B and C on Aug/Sep, 1996
  Study tour for 60 farmers in Block A, D and E on Aug/Sep, 1997
  Study tour for 60 farmers in all Blocks on Aug/Sep, 1998
- Tour Place: Irrigation project areas including the Midlands and the Mashonaland East Provinces

3) Farmers Training

- Contents: Subject on agronomy, irrigation, horticulture, livestock and records and etc.
- Period: 1996~1997

4) Staff Training

- Contents: 1995 - Informal diagnostic survey
  1996 - Irrigation and Crops
  1997 - Supervision and Marketing

The rough estimate for the above-mentioned program is shown below;

Item	Cost
• Marketing	Z$ 78,000
• Study Tour	10,500
• Farmer Training	50,000
• Staff Training	28,000
Total	Z$166,500

DWD

DWD has a pump operator training course which aims to provide competence in the following:

1) Water Treatment Plan: Operating principles of settlement tanks, coagulation basics, slow sand filters, rapid gravity sand filters and pressure filters.

2) Water Quality Study: Supplying correct chemical dosages and maintain quality control.

3) Pumps and Pump Operation: Different types of pumps and their duties. Basic maintenance and servicing.

4) Prime Movers: Petrol engines, diesel engines and electric motors.

5) Pipes and Water Mains: Different engines and electric motors.

6) Meter: Reading, servicing and new connections.

7) Water Hygiene: Bacteriological examination, chemical standards.

8) Water Law: Water act, water supply rules and water pollution control regulations.

9) Record keeping and compilation of monthly operation charts.

10) Safety precautions, cleanliness of buildings and upkeep of surroundings.

The course is divided into two weeks at the classroom level and two weeks at the workshop level to make up the basic induction course, followed by two years of inservice training. This later period is to be reinforced by "on-the-job" training session and self study period.

(3) Design Life of Irrigation Facilities

Recommended design lives of the different elements of a pumping station.

Element	Design Life
Pumps and mechanical equipment	15 years
Electrical equipment	15 years
Internal piping	15 years
Structures	30 years

2-4 Technical Cooperation

Aiming at the efficient development and promotion of the Project after its commencement, both Governments shall consider the system of technical cooperation.

The Zimbabwean side has been strongly interested in technical cooperation. Dispatching experts (long term and short term), making good use of the Japan Overseas Cooperation Volunteers (JOCV) and training of the personnel of the Zimbabwean side in Japan are considerable as technical cooperation.

Irrigation, water management, marketing, agronomy, horticulture, livestock, etc. are considerable as target fields for cooperation, and the Zimbabwean side will make further studies and decide a particular fields.

CHAPTER 3 BASIC DESIGN

[illegible]

Chapter 3 Basic Design

3-1 Design Policy

(1) Pump Facility

a) Location of Pump Station

Pump stations will be installed along the Gairezi River. The Gairezi River bank is covered with grass, and the river's course is relatively stabilized. The location of pump stations will be decided in consideration of selecting places with sufficient depth and relatively fast flow in order to avoid sedimentation and intrusion of contamination into the intake canal.

b) Water Intake Level

The width of the Gairezi River is narrow (approximately 20 - 30 m), and the difference between water levels in the dry season and the rainy season is approximately 10 m at the maximum. Fluctuation of the water level will be carefully considered in deciding on the selection of pumps, method of installation and height of pump location.

c) Operation and Maintenance of Pump Facilities

As the difference in water levels between intake and output is considerable, it is necessary to use a high water-head pump with more than 70 m as total head. At present, pumps made in Europe and South Africa are normally used for irrigation pumps in similar scale projects in Zimbabwe, as the pumps made in Zimbabwe have limited capacity. It is therefore necessary to make a sufficient study regarding selection of pumps from among the pumps made in Zimbabwe, Europe, South Africa and Japan.

Electric motors will be used, as electrification at the site will be completed. Pump operation will be conducted by the simple ON-OFF switch system that is usually used in Zimbabwe. In order to make pump operation simple, water will be pumped up to the firm pond that is placed at the highest point of the block, and will be supplied to the main division works by gravity. Water management between the pumps and the firm pond will be carried out by a water level gauge installed at the pond and the control board equipped with a buzzer and light.

Operating hours per day will be twelve (12) hours in compliance with the local farmers' working hours.

(2) Irrigation, Drainage and Farm Roads

When facilities are designed, the designs will reflect the proper level of technology and cost complying with local conditions regarding execution skill, materials and financial resources in order to attain easy construction and easy operation and maintenance in future, while satisfying modern technical standards.

Concerning the structural design of the facilities, the results of the field surveys conducted at the Nyamaropa and Masvingo projects and the Irrigation Manual issued by AGRITEX will be referred to.

Concerning design standards, a specific set of standards has not been available in Zimbabwe. The design standards adopted are JIS (Japanese Industrial Standard) or an equivalent.

When pipelines are installed along a district road they will be buried outside the road area, and when they are installed within the project area, they will be principally buried under the road.
Types of pipe will be determined by the internal pressure and external pressure (e.g., earth pressure, dynamic load, etc.). There are many areas of rocky soil along the proposed alignments, so durability and construction features will also be considered.

In order to carry out water management smoothly and efficiently, a stable supply of irrigation water will be realized. To secure stable irrigation, farm ponds combining the role of discharge chamber will be constructed. The capacity of the ponds will be determined in accordance with the allowed shut-down interval of the pumps.

Irrigation canals and drainage canals will be aligned with an interval of 100 meters or less, in consideration of the 100-meter oblong length of the fields established by the F/S report, except in special sections.

The cross section of the irrigation canals will be sufficient to irrigate the target farming area. As the water is delivered to farms by the siphon method, the water level will be set 20 to 30 cm higher than the field level. Reinforced concrete trapezoidal canals as normally employed by AGRITEX will be adopted as irrigation canals in order to prevent seepage and to make operation and maintenance easy.

Division works, drops, and other appurtenant facilities are to be set up where necessary along the irrigation canals, and the present conditions of local facilities will be taken into consideration in drawing up the design. The ends of the irrigation canals are connected to drainage canals or streams in order to drain off excess and residual water, and chutes will be placed at these connection points.

The drainage canals will be, in principle, aligned in low lands that are used, under present conditions, as natural drainage. The drainage canals will be made of earth.
Confluent facilities, ground sills, and other appurtenant facilities will be set up where necessary along the drainage canals. The ends of drainage canals will be joined to streams or to the Gairezi River, and chutes will be placed at these connection points.

Trunk farm roads designed for use by big trucks will link major district roads with the pump stations, and will be used to deliver machinery. Farms will be provided with secondary farm roads for use in farming activities and canal inspections.
The farm roads will be embanked, and the trunk farm roads will be 5 m wide while the secondary farm roads will be 3 m wide. Embankments will be either 30 or 40 cm high. In principle, the secondary farm roads will be constructed on relatively high land, and the necessity of locating appurtenant facilities at points where the roads intersect with the canals will be studied.

(3) Building Facility Planning

The location and scale of planned buildings will be determined in accordance with the current situation of the site, conditions of the surrounding area, usage of the buildings, and the numerical value indicated in Chapter 2 - 3 - 1 "Execution Agency and Operation Structure". Moreover, determination of the specifications, required size and number of rooms for the respective buildings, should reflect the results of analyses of the following conditions.

1) Natural Conditions

The project area has its lowest average temperature of 14 °C in June and July, and its highest temperature of 30.9 °C in October. In August and September, humidity is low at around 45 percent, the air is dry, and the difference between daytime and nighttime temperatures is relatively large.

The average annual precipitation amounts to 900 mm, and most of that is concentrated in the rainy season, from November to March. During this season, it is not uncommon to have thunder claps that are peculiar to mountainous regions. Moreover, the wind comes mostly from the south, from the mountainous region of Mozambique all year round.

Under these natural conditions, it is desirable, in the design of the buildings, to include means of waterproofing, wind protection, thermal insulation, etc. Accordingly, it is essential to examine the introduction of waterproof sheets, heat reserving materials, double ceilings, rooms provided with appropriate cubic space and openings, waterproof finished materials and so on.

2) Site Conditions

The site in the project area adjoins the Gairezi River basin (the border with Mozambique at a distance of approximately 120 m). The site inclines toward the south from the northeastern side of the boundary. The site is currently used as farmland. As the bearing capacity of the soil offers no constraints, it is proposed to adopt a direct foundation.

However, the project site contains many stones and rocks, and the land formation of the surrounding area is complicated. This calls for examination of the conditions from several perspectives before carrying out the construction.

3) Construction Conditions

Zimbabwe has the following regulations and laws regarding building construction.

The Building Construction Act
Rules on Urban Planning
The Labour Standards Act

In addition, local self-governing bodies have their own rules set by local assemblies. In respect to the construction of government facilities, it is required to comply with the ranking system of the Ministry of Public Construction and National Housing (MOPCNH). Moreover, the Manicaland office of MOPCNH in Mutare has particular regulations on building construction. In this project, however, the construction of buildings is carried out with the approval of AGRITEX and DWD.

4) Technical Level of Local Contractors

Architects and builders have profound knowledge and technical skills with full awareness of local climate and soil conditions as well as local contractors and their technical levels.

Technical levels of the contractors in Zimbabwe are relatively high, judging from the existing buildings.

The local contractors maintain construction machines such as truck cranes, bulldozers, generators, compacting machines and concrete mixers. This machinery is considered to be sufficient for execution of the work in this project.

Moreover, taking account of the technical levels of contractors as well as the scale, usage, and specification of buildings, it seems appropriate to design the buildings based on a brick structure, which is common in Zimbabwe.

As for construction materials, aggregate, cement, and concrete are popular in the country, and there are no serious shortages. In particular, aggregate, brick, and timber are accessible materials produced domestically in Zimbabwe.

5) Construction Period

The construction period will be determined in consideration of the fact that the project building site is located along the district road (it provides easy access to the site even during the rainy season) and factors such as the scale of the planned buildings, the usage and specifications of the buildings, the number of houses, the planned sites of the pump stations and the construction cost of each building.

6) Others

Along with the conditions mentioned above, in the design of the project buildings , it is aimed to minimize the project cost borne by Zimbabwe. Therefore, construction materials and machinery that are accessible in the country must be used as much as possible. Moreover, it is proposed to design facilities that will not require high maintenance and repair costs, considering the current situation of insufficient working funds. Furthermore, not only the cost but also the quality of materials is an essential factor to be regarded.

3-2 Study and Examination on Design Criteria

(1) Pump Facility

a) Criteria and Standards of Specifications

The following criteria and standards will be applied for design of the pump facility.

- Japanese Industrial Standard (JIS)
- Zimbabwe Standard
- South African Standards (SABS)
- British Standard (BS)
- Deutsche Industrie Norman (DIN)

b) Conditions for Scale of Pump

- Design Discharge

The monthly water requirements and the peak water requirements as shown in the following data will be used for calculating the design discharge. In calculating the water requirements, the cropping pattern, unit water requirement, area to be irrigated and irrigation efficiency as well as the requirement of water for daily living are taken into consideration.

Monthly Water Requirements

Unit: 1,000 m^3

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.
Block B	164.6	57.0	124.7	131.8	95.4	135.7
Block C	180.0	62.3	136.4	144.1	104.3	148.4

Month	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Block B	211.1	202.4	104.2	88.5	195.3	183.5
Block C	230.9	221.2	114.0	96.8	213.4	200.8

Water Requirements

Block	Peak Water Requirements	Water for Daily Living
B	259 lit/sec	2.1 lit/sec
C	284 lit/sec	2.3 lit/sec

• Design Suction Level

Design intake level will be set at 1/2 of the depth of the river in the dry season. Design discharge level will be set at the maximum water level of the farm pond.

Block	Design Suction Level	Design Discharge Water Level
B	EL 801.6	EL 861.5
C	EL 801.4	EL 863.5

(2) Irrigation, Drainage and Farm Roads

1) Soil Conditions

The topography of the project area is primarily rocky and mountainous, so it will be taken into account that a certain degree of excavation will be necessary to remove rocks.

2) Transportation Conditions

Materials produced in Zimbabwe will be brought in from Mutare and from the capital city of Harare. The roads between both of these cities and Nyamaropa are paved with asphalt, but a gravel road connects Nyamaropa to the project area. This presents no problems, however, as this is a district road used by large trucks.

Because Zimbabwe is an inland country with no harbor, ports in the adjoining Republic of Mozambique or the Republic of South Africa are proposed as points to unload imported material. Due to political instability in Mozambique, however, land routs there are often closed. Therefore, the imported materials will be unloaded at the Port of Durban in South Africa, and brought into Zimbabwe by truck.

3) Irrigation System

Irrigation water will be drawn from the Gairezi River by pumps, then pumped through pipelines to farm ponds constructed at elevated sites within the project area. Open concrete irrigation canals will carry the water from these farm ponds to the farms.

To simplify operation of the overall system, each farm pond will serve one block, and main division works will be constructed in each small block within the block. The water will flow by gravity through pipelines from the farm ponds to the main division works. After the main division works, the water will flow through open canals.

4) Design Conditions

The conditions for basic design of the irrigation facilities, i.e., the water allowance and the rate of runoff, are as follows.

[Water Allowance]

The water allowance is calculated by the irrigation interval determined based on the available soil moisture and effective soil layer, taking into account the effective rainfall and crop evapotranspiration.

Crop evapotranspiration is determined using the Modified Penman's Method that is uniformly used in Zimbabwe,

$$ETc = ETo \times Kc$$

Where:

ETc: Crop evapotranspiration (mm)
ETo: Standard evapotranspiration (mm)
Kc: Crop coefficient

The monthly average of ETo is calculated using the ETo map widely used for irrigation planning in Zimbabwe.

The individual Kc is adopted from the Irrigation Drainage Technical Manual No. 24, issued by FAO.

The water allowance calculated by the crop evapotranspiration includes 80 % of rainfall probability. The probable rainfall is calculated using the monthly rainfall records of conditions observed at the Nyamaropa irrigation office.

The peak water requirements calculated occur in July and August. The water allowance at peak comes to;

$q = 2.35$ l/s/ha.

[Rate of Runoff]

The rate of runoff is calculated so that two hours of rainfall in a hilly catchment area will be drained from the irrigated area in four hours. The calculation method is as follows.

$$Rt = R_{24}\ (t/24)k$$

Where:

- Rt: Rainfall at the time of concentration for t hour (mm)
- R_{24}: Rainfall per day at ten-year probability (mm)
- k: 1/2

Rainfall per day is calculated at 123.2 mm, and Rt is 35.6 mm for two hours and 50.3 mm for 4 hours. Using Rt the rate of runoff (q) is calculated as follows.

$$q = 10 \times Rt \times f/3{,}600 \times t$$

Where:

q: Rate of runoff (m^3/s/ha)

f: Runoff coefficient

- Farm: 0.52 (0.45 - 0.62)
- Hilly area: 0.82 (0.72 - 0.92)

The runoff coefficient (f) is 0.52 on a farm and 0.82 on a hilly area.
On the basis of this, qt was calculated as follows.

$q_2 = 0.0405$ m^3/s/ha (hilly area)

$q_4 = 0.0182$ m^3/s/ha (farm)

3-3 Basic Plan

3-3-1 Agricultural Plan

(1) Present State of Agriculture

Agriculture in the Nyakomba Ward is now limited to a single crop in the rainy season.

The following table shows the yields in the six villages of the Ward during the past five years.

Table 3.1 Crop Yield in Nyakomba Ward (ton/ha)

Crop	1989/90	1990/91	1991/92	1992/93	1993/94	Cultivated Area in 1993/94
Maize (White)	1.980	1.620	Nil	2.250	0.180	425 ha
Cotton	1.000	1.200	Nil	1.200	0.180	650
Tobacco	0.950	1.350	Nil	0.900	0.100	15
Groundnuts	0.640	0.640	Nil	0.720	0.040	8
Sunflower	1.100	1.100	Nil	1.375	0.165	20
Rapoko (Millet)	1.080	0.720	Nil	1.440	0.045	5
Rainfall (mm)	1,147	492	245	969	557	(Ave. 860)

(Source: AGRITEX)

Table 3.2 Crop Yield in Nyamaropa Project (ton/ha)

Crop	1989/90	1990/91	1991/92	1992/93	1993/94
Maize (White)	5.600	3.000	0.500	0.500 *1	4.000
Cotton	2.700	2.500	0.600	2.400	1.600
Tobacco	2.600	2.600	1.500	1.360	1.500
Wheat	2.300	3.000	4.200	4.500	4.0~5.0 *2
Winter beans	1.800	2.000	-	1.500	1.500
Summer beans	1.200	1.500	-	1.500	-*3

*1: Streak virus, *2: Anticipated, *3: Before season (Source: AGRITEX)

For reference, yield data for the irrigated part of neighboring Nyamaropa is also presented.

The 1991/92 year was a drought year throughout Zimbabwe, and no crops were harvested in Nyakomba then. Lower yields were seen even in the irrigated area. Yields in Nyakomba were also low in the relatively dry 1993/94.

(2) Crops Introduced

The current principal crops in the Nyakomba Ward are white maize, the staple food, and cotton, and tobacco, while sunflowers and peanuts are cultivated on small fields, as well.

Tobacco continues to be a very profitable crop, but, as cultivation will be reduced in future, studies have been conducted to find substitute crops.

Potential possibilities are maize, wheat, beans and vegetables. Based on studies of replant failures and cropping seasons, a combination of maize + vegetables (potatoes and tomatoes) is selected. Cropping patterns are shown in Figure 3.1.

Table 3.3 shows crop revenues and expenditures for this cropping pattern.

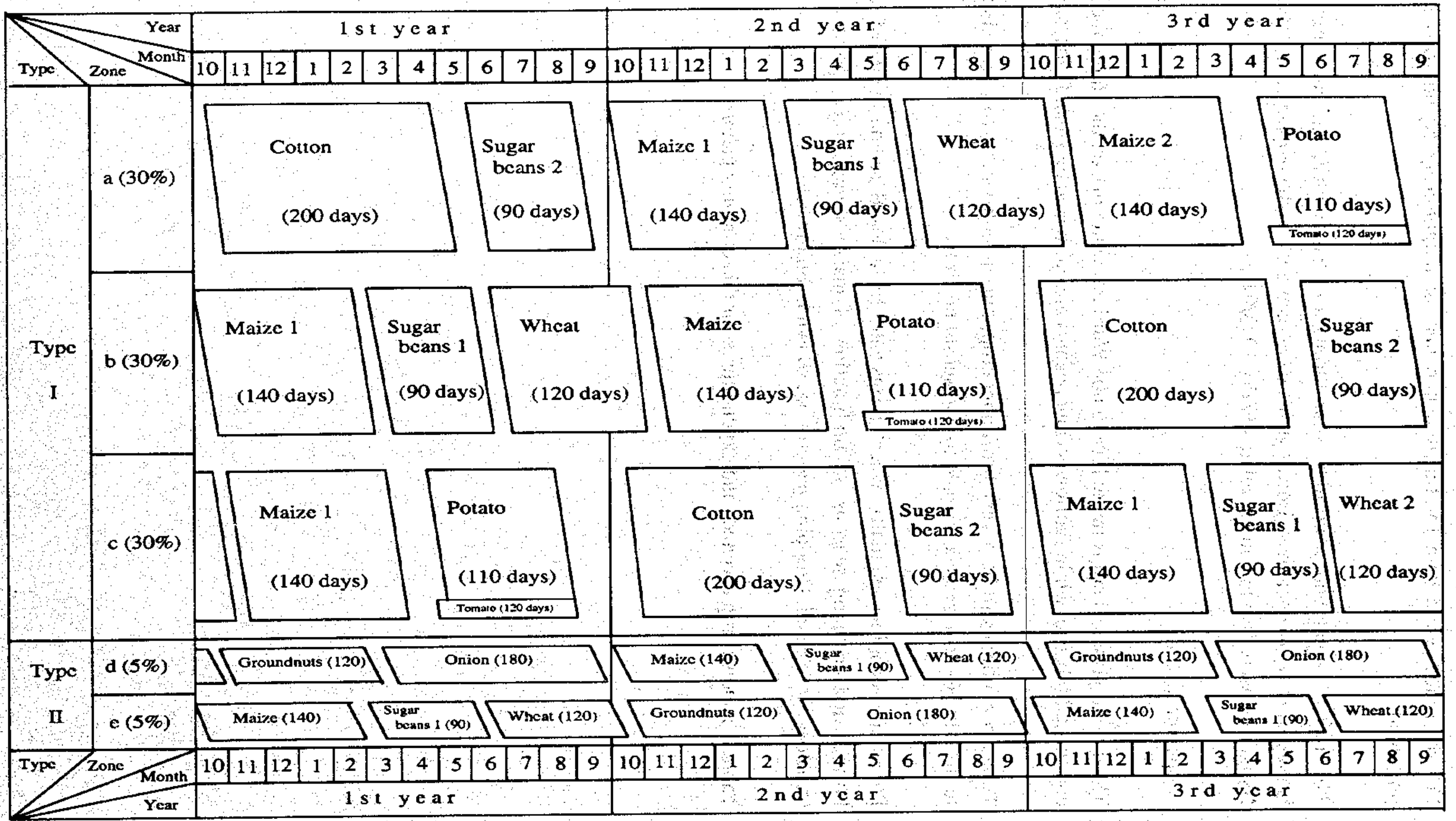


Fig. 3.1 Proposed Cropping Patterns

Table 3.3 Crop Revenue and Expenditures

Crop - Potato

Area - 1 hectare Expected yield - 30 tons Price - $ 1,000/ton

Input details	Quantity	Price/Unit	Z$
Seed	60 x 50 kg bags	Z$ 150/50 kg	9,000.00
Compound S	30 x 50 kg bags	Z$ 101/50 kg	3,030.00
Ammonium nitrate	3 x 50 kg bags	Z$ 80/50 kg	240.00
Rogor/dimethoate	1 litre	Z$ 54/litre	54.00
Dithene M45	2 kg	Z$ 72/kg	142.00
Packing material	300 x 100 kg packs	Z$ 3/pack	900.00
Transport to market	300 packs	Z$ 8/pack	2,400.00
Labour (planting)	-	-	
Total costs	-	-	15,766.00

Source: AGRITEX, 1994

Gross income - Z$ 30 000.00
Total costs - Z$ 15 766.00
Gross margin - Z$ 14 234.00

Crop - Tomato

Area - 1 hectare   Expected yield - 25 tons   Price - $ 3,000/ton

Input details	Quantity	Price/Unit	Z$
Seed	150 grams	Z$ 1/gram	150.00
Compound S	30.1 bags x 50 kg	Z$ 101/50 kg	3,040.10
Ammonium nitrate	6 bags x 50 kg	Z$ 80/50 kg	480.00
EDB	20 litres	Z$ 10/4 litre	50.00
Rogor/dimethoate	1 litre	Z$ 54/litre	54.00
Orithene	1 kg	Z$ 160/kg	160.00
Dithene M45	1 kg	Z$ 72/kg	72.00
Packing material	1000 x 30 kg cases	Z$6/bag	6,000.00
Transport to market	1,000 cases	Z$ 8/case	8,000.00
Labour (transplanting)	-	-	500.00
Total costs	-	-	18,506.10

Source: AGRITEX, 1994

Gross income - Z$ 75 000.00

Total costs - Z$ 18 506.10

Gross margin - Z$ 56 493.90

Crop - Onion

Area - 1 hectare   Expected yield - 30 tons   Price - $ 2,000/ton

Input details	Quantity	Price/Unit	Z$
Seed	3 kg	Z$ 500/kg	1,500.00
Compound S	20.3 bags x 50 kg	Z$ 101/50 kg	2,050.30
Ammonium nitrate	4 bags x 50 kg	Z$ 80/50 kg	320.00
Rogor	1 litre	Z$ 59/litre	59.00
Carbaryl	1 kg	Z$ 90/kg	90.00
Dithene M45	250 grams	Z$ 72/kg	18.00
Packing material	600 x 50 kg bags	Z$3/bag	1,800.00
Transport to market	600 bags	Z$ 8/bag	4,800.00
Labour (transplanting)	-	-	500.00
Total costs	-	-	11,137.30

Source: AGRITEX, 1994

Gross income - Z$ 60 000.00
Total costs - Z$ 11 137.30
Gross margin - Z$ 48 862.70

F/S			B/D		
Crop	/ha	/ha	Crop	/ha*	/ha
Tobacco	Z$ 15,888	Z$ 15,888	Maize (White)	Z$ 3,136	Z$ 3,136
Wheat	5,040	5,040	Potato	14,234	12,811
			Tomato	56,493	5,643
Total	-	Z$ 20,928	Total	-	Z$ 21,590

(3) Plan for a Farmers Association

The following farmers associations have been formed in the Nyakomba Ward.

1) Zimbabwe Farmers Union (ZFU)

About 10 % of the farmers in the Nyakomba Ward join the ZFU. The ZFU issues membership cards to the farmers for a fee of ten dollars as an organization to represent farmers in the Communal Land. In principle, members are able to enjoy conveniences such as making priority purchases of agricultural materials at the neighboring stores.

2) Product-Specific Groups

There are a cotton group, a tobacco group and so on. Their members are provided with information about crop diseases and marketing.

3) Agricultural Finance Cooperation (AFC)

Each year, about 100 farmers in the Nyakomba Ward use its services. A farmer who receives financing from the AFC can purchase agricultural materials by check. After he sells his yields, the AFC recovers the money by withdrawing it from his account. All crops are eligible, but the farmer must be a full-time farmer and his cultivation plans have to be approved by the AFC. The average amount loaned in the Nyakomba Ward is Z$1,400 year/person, at an interest rate of 22 %/year (for short loans of 18 months).

4) Cotton Marketing Board (CMB)

The CMB provides interest-free loans to cotton farmers who request them. The farmers form groups and participate meetings, and repay the loans through their accounts after the yielding.

There is the by-law of AGRITEX, and it prescribes that after the irrigation agriculture begins, a farmers union must be organized to meet the anticipated need for project management involving all the farmers. It will be organized using the above-mentioned organizations, and is shown in Fig. 3.2.

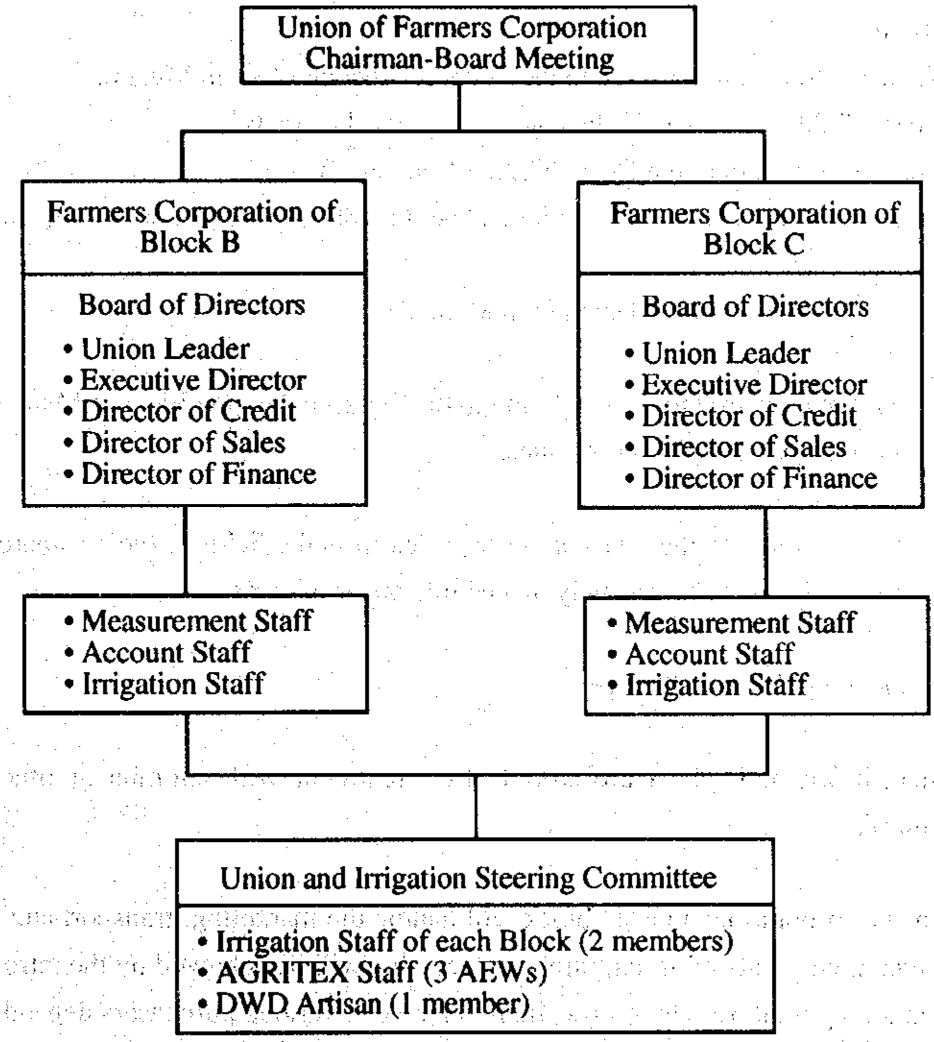


Fig. 3.2 Organization of Farmers Union of the Nyakomba Irrigation Project

(4) Distribution and Marketing Plans

Current purchasers of the agricultural products of the Nyakomba Ward and current methods of transportation and storage are as follows.

1) Purchasers of Agricultural Products

The following bodies purchase the agricultural products of the Nyakomba Ward.

- Maize: Surpluses are sold either to the GMB (Grain Marketing Board) or at local markets.

- Cotton: Sold and delivered to the Nyamaropa branch of the CMB (Cotton Marketing Board).
- Tobacco: Sold and delivered to the Tobacco Auction Floor in Mutare.
- Beans: Sold either to individual agents or at local markets.
- Sunflowers: Sold to the GMB (Grain Marketing Board).
- Tomatoes and other vegetables: Sold either to individual agents or at local markets.

2) Agricultural Product Transportation Methods

Products are delivered to the GMB and to the Tobacco Auction Floor in Mutare by trucks rented from local transport companies.

Products delivered to the CMB are transported from the fields to the Nyamaropa branch or to residential areas by privately owned tractors or ox-carts.

3) Agricultural Product Storage

Maize, beans and wheat are stored after treatment with shumba or other suitable chemicals.

Farmers' corporations in each block will handle the marketing, transport and storage of the increased yields of agricultural products that will be achieved by the introduction of irrigation agriculture. Up to now, there have been various purchasers depending on the products. After the Farmers Union is organized, however, it will oversee the planting, harvesting, shipping, transportation and marketing of all products. This will provide efficient agricultural management in the region.

3-3-2 Pump Facilities

a) Location of Pump Station

Locations of pump stations will be selected based on the aforementioned conditions and design policy, which is shown in the layout plan.

b) Total Head

The total head of the pumps will be calculated based on the local conditions, adding actual head and pipe loss, and the following formula will be used.

$$H = Ha + Hl = Ha + hl + V^{2/2g}$$

$$hl = f \times L/D \times V^{2/2g}$$

$$f = 134/C^{1.85} \times 1/(D^{1/6} \times V^{0.15})$$

Hazen & Williams formula

H: Total head (m)
Ha: Actual head (m)
Hl: Total head loss (m)
hl: Pipe loss (m)
L: Pipe length (m)
D: Pipe bore (m)
V: Velocity (m/s)
g: Acceleration of gravity (m/s^2)
f: Coefficient
C: Coefficient depending on the pipe (C=130)

Block	Actual Head	Total Head
B	60.2 m	73.87 m
C	62.4 m	81.40 m

c) Number and Bore of Pumps

The number of pumps to be installed will be decided in consideration of the following:

- Multiple pumps will be installed to deal with emergency breakdowns.

- The number and bore of pumps will be decided to facilitate efficient operation complying with fluctuations of water requirements. A combination of different pump bores will be considered. In consideration of simple operation and maintenance, however, all the pumps will have the same bore.

- The capacity of a single pump will be not less than minimum monthly water requirements.

- It will be a prime consideration that installation, construction and operation & maintenance will be economical. Large bore pumps will not be chosen, since that size of pump is not wide-spread in Zimbabwe.

Monthly Discharge

Monthly discharge will be calculated from the monthly water requirements, taking into consideration operation days, operation hours and irrigation efficiency with water for daily living , and the results are shown below.

Unit: m^3/min

Block B	Jan.	Feb.	Mar.	Apr.	May	Jun.
Monthly Water Requirements	8.676	3.326	6.573	7.179	5.028	7.391
Water for Daily Living	0.126	0.126	0.126	0.126	0.126	0.126
Total	8.802	3.452	6.699	7.0305	5.154	7.517

Block B	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Water Requirements	11.127	10.668	5.675	4.665	10.637	9.672
Water for Daily Living	0.126	0.126	0.126	0.126	0.126	0.126
Total	11.253	10.794	5.801	4.791	10.763	9.798

Unit: m^3/min

Block C	Jan.	Feb.	Mar.	Apr.	May	Jun.
Monthly Water Requirements	9.488	3.636	7.190	7.849	5.498	8.083
Water for Daily Living	0.138	0.138	0.138	0.138	0.138	0.138
Total	9.626	3.774	7.328	7.987	5.636	8.221

Block C	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly Water Requirements	12.171	11.659	6.209	5.102	11.623	10.584
Water for Daily Living	0.138	0.138	0.138	0.138	0.138	0.138
Total	12.309	11.797	6.347	5.240	11.761	10.722

Design Discharge

The design discharge will be calculated from the peak water requirements with the irrigation efficiency (85%), and shown below:

Block	Peak Water Requirements (lit/sec)	Water for Daily Living (lit/sec)	Design Total Discharge (m^3/min)	Unit Discharge (m^3/min)
B	256	2.1	18.408	6.14
C	284	2.3	20.447	6.73

Type of Combination

Taking into consideration the monthly water requirements and design total discharge mentioned above, the following types of combinations will be considered.

Block B

Type	350 mm 1 unit 250 mm 1 unit	300 mm 2 units	300 mm 1 unit 200 mm 2 units	250 mm 3 units
Civil & Buildings	Relatively smaller.	Relatively smaller.	Relatively larger.	Relatively larger.
Adaptability to Water Requirements	Forced to operate at limited capacity.	Difficult to adapt to the monthly minimum water requirements	Sufficiently adaptable to the water requirements.	Sufficiently adaptable to the water requirements.
Operation and Maintenance	Relatively easy, but various spare parts are needed	Relatively easy.	Various spare parts are needed. More careful attention to spare parts is needed	Few spare parts. Very easy O & M
Evaluation	△	△	○	◎

Block C

Type	350 mm 1 unit 250 mm 1 unit	300 mm 2 units	300 mm 1 unit 200 mm 2 units	250 mm 3 units
Civil & Buildings	Relatively smaller.	Relatively smaller.	Relatively larger.	Relatively larger.
Adaptability to Water Requirements	Forced to operate at limited capacity.	Difficult to adapt to the monthly minimum water requirements	Sufficiently adaptable to the water requirements.	Sufficiently adaptable to the water requirements.
Operation and Maintenance	Relatively easy, but various spare parts are needed	Relatively easy.	Various spare parts are needed. More careful attention to spare parts is needed	Few spare parts. Very easy O & M
Evaluation	△	△	○	◎

Pump bore is chosen from the followings, based on the "Design Standard for Pumps". Volute pumps may have the characteristic where a higher head pump has less bore.

Standard Bore (mm)	Hertzian Wave (Hz)	Discharge (m^3/min)	Average Discharge (m^3/min)
200	50	3.00 - 5.00	4.00
250	50	5.00 - 8.00	6.50
300	50	8.00 - 12.00	10.00
350	50	12.00 - 18.00	16.00

As shown in the above comparison, it is considered that the "250 mm 3 units" type of combination (marked with ◎) is the most suitable one.

d) Type of Pump

- Type of Installation

Generally, there are two types of pump installation, namely the suction type and the forcing type. In this Project, water will be pumped up from the river and the water level will be approximately 10 m lower than the pump station. If the forcing type were to be adopted, construction costs would be higher than with the other type due to the huge amount of excavation necessary for obtaining the space for building and pump installation. The suction type will be adopted in this Project taking into consideration the proper height for avoiding cavitation.

Even though such a height will be maintained for the installation of pumps, the structure for pumps should be water-tight because the pump installation locations will be lower than the high water level of the Gairezi River in the rainy season.

- Type of Pump

The following pumps are possibilities for the selection of pump type based on the aforementioned bore, discharge and total head:

(a) Horizontal, Double Suction Volute Pump
(b) Vertical, Suction Volute Pump
(c) Horizontal, Suction Volute Pump

Table 3.4 Comparison of Pump Types

Item	(a) Horizontal, Double Suction	(b) Vertical, Suction	(c) Horizontal, Suction
Suction Performance	Good suction performance. Characteristic curve is round.	Less than (a). Characteristic curve is round.	Less than (a). Characteristic curve is round.
Maintenance	Easy as pumps and motors are installed horizontally	Very difficult as motors are installed above pumps, so need to move motors	Easy as pumps and motors are installed horizontally
Installation	Easy as pumps and motors are installed horizontally and as one body	Very difficult as motors are installed above pumps	Easy as pumps and motors are installed horizontally and as one body
Civil & Building	Need wider space than (2), unit load is smaller than (2)	Less space than (1), unit load is bigger than (2)	Need wider space than (2), unit load is smaller than (2)
Evaluation	◎	△	○

As shown in the above comparison, it is considered that horizontal double suction volute pumps are the most suitable ones, and they are adopted for this Project. It is necessary to install the pumps in a high position in order to avoid submersion of the pump facilities.

- Pump Revolution

Taking into consideration that, in the case where a higher suction head is applied, construction costs will be lower, and the discharge will be 6.14 m^3/min and 6.73 m^3/min for Block B and C respectively, the suitable pump revolution will be 4P-1450 rpm for horizontal double suction pumps in accordance with the "Design Standard for Pumps".

- Total Head

According to the aforementioned selection, the design total head with some margin head will be determined as follows.

Item	Block B	Block C
Actual Head	60.2 m	62.4 m
Screen Loss	(0.3 m)	(0.3 m)
Pump Loss	1.97 m	2.37 m
Suction	(0.52 m)	(0.63 m)
Discharge	(1.45 m)	(1.74 m)
Velocity Loss	0.13 m	0.15 m
Pipe Loss	11.58 m	16.31 m
Total Head	73.87 m	81.23 m
Design Total Head	74.0 m	81.5 m

e) Pump Installation Height

If the pumps are installed in a high position, harmful cavitation may occur. The pump installation height will be three meters (3 m) above the low water level. Detailed calculation data are shown in the following formula and table.

$$Z = NPSH(av) - NPSH(rq) = Pa - Pv - Ha - Hl - NPSH(rq)$$

Z:	Margin head (approximately 1 m) (m)
NPSH(av):	Available Net Positive Suction Head (m)
NPSH(rq):	Required Net Positive Suction Head (m)
Pa:	Atmospheric pressure (10.33 m at sea level) (m)
Pv:	Saturated vapor pressure (m)
Ha:	Actual suction head (m)
Hl:	Head loss at suction portion (m)

Item	Block B	Block C
Pa Atmospheric Pressure	9.39 m	9.39 m
Pv Saturated Vapor Pressure	0.57 m	0.57 m
Hl Suction Loss	1.28 m	1.44 m
Npsh(Rq) Required Net Positive Suction Head	2.72 m	2.81 m
Z Margin Head	1.00 m	1.00 m
Ha Actual Suction Head	3.82 m	3.57 m
Design Suction Head	3.0 m	3.0 m

f) Required Power

All pump stations will be supplied with sufficient electricity. Electric motors are selected as prime movers. Required power will be calculated by the following formula:

$$L = \frac{K \times Q \times H \times r}{n/100}$$

$$P = L \times (1 + A) \times nt$$

L: Shaft power (kw)
K: Constant figure (K = 0.163 at kW unit)
r: Specific weight of liquid (r = 1.0 at water)
n: Pump efficiency (%)
Q: Discharge (m^3/min)
H: Total head (m)
P: Required power (kW)
A: Margin (A = 0.1 at motor)
nt: Transmitting efficiency (nt = 1.0 at coupling)

Item	Block B	Block C
Q	6.14 m^3/min	6.73 m^3/min
H	74.0 m	81.5 m
n	68.0 %	68.0 %
L	108.9 kw	131.5 kw
P	119.8 kw	144.7 kw
Design Required Power	132 kw	150 kw

The following pump efficiency is used based on the "Design Standard for Pumps".

Bore (mm)	Volute	High Head Pump Vertical, Mixed Flow
200	65%	-
250	68%	-
300	71%	69%
350	74%	71%

g) Pump Arrangement and Plane Plan

There are a straight type, a two-line type, a face-to-face type and an inclined type for pump arrangement. The straight type will be selected in this Project, although the straight type requires a wider installation space than the others, because this type of pump arrangement is usually applied in Zimbabwe, and it is easy to operate and maintain with great safety. Pump installation space will require more than 1.1 m for the suction portion, 2.2 m for the discharge portion and 1.0 m for the space between pumps according to the "Design Standard for Pumps".

h) Valves

- Suction Side

Since the valve in the suction portion is only used for the repair and maintenance of the pump, a reliable, high-performance valve will be required. Therefore, a manual sluice valve will be applied considering the economical operation and reliability of these facilities. A foot valve will be used in order to fill up the suction pipe with water in order to start the pump easily.

- Discharge Side

The discharge valve and check valve in the discharge portion are operated automatically, therefore reliable valves with high performance will be necessary. An electrical butterfly valve and a check valve will be applied so as to be operated easily and to obtain relatively lower cost of materials.

i) Supplementary Facilities

- Sealing Water Facility

A quantity of sealing water will be required with a minimum of 30 litres for the operation of three pumps. Clean water is necessary for the sealing water, so river water will not be used. Water from a deep well, that will be used for cleaning the machine and building as well as for daily use water will be supplied for the sealing water. The required pressure for sealing will be approximately 10 m. Water pressure will be obtained by installing a water tank with a height of about 10 m on the top of the building. The water level of the river is high in the rainy season, therefore the building should be constructed high enough in order to avoid the intrusion of river water.

- Counter-measure for Water Hammer

Flywheels are applied in order to prevent the condition known as water hammer that may possibly occur at the time of power stoppages due to high pump heads.

j) Electric Facility

For these proposed pump stations, the power source to be used will be by the public 33 or 11 kV electric line . As the design capacity of the motors will be low in these pump stations, 380 V will be used for the power which will be supplied by the Zimbabwe side.

k) Pump Facility and Equipment Plan

Block B

Description	Specification	Quantity
-1. Main Pump	Horizontal, Double Suction Pump 6.14 m^3/min w/132 kW motor and coupling water-proof, squirrel cage 50 Hz, 380 V, 3-phase, 1450 rpm	3 sets
-2. Valves	Foot valve, 300 mm dia. Sluice valve, 300 mm dia. Electrical butterfly valve, 250 mm dia. Check valve, 250 mm dia.	3 units 3 units 3 units 3 units
-3. Pipes Around Pumps	Suction (1) Suction (2) Discharge (1) Discharge (2)	2 sets 2 sets 3 sets 1 set
-4. Water Supply System	Submersible pump, 3.7 kW Reservoir Pipeline for sealing water system Pipeline for cleaning	1 set 1 set 1 set 1 set
-5. Electric Facility	Transformer secondary board Control board Auxiliary board	1 unit 3 units 1 unit
-6. Overhead Crane	Manual, 3 ton capacity	1 unit
-7. Bar Screen	2000 mm x 2000 mm	1 unit

Block C

Description	Specification	Quantity
-1. Main Pump	Horizontal, Double Suction Pump 6.73 m^3/min w/150 kW motor and coupling water-proof, squirrel cage 50 Hz, 380 V, 3-phase, 1450 rpm	3 sets
-2. Valves	Foot valve, 300 mm dia. Sluice valve, 300 mm dia. Electrical butterfly valve, 250 mm dia. Check valve, 250 mm dia.	3 units 3 units 3 units 3 units
-3. Pipes Around Pumps	Suction (1) Suction (2) Discharge (1) Discharge (2)	2 sets 2 sets 3 sets 1 set
-4. Water Supply System	Submersible pump, 3.7 kW Reservoir Pipeline for sealing water system Pipeline for cleaning	1 set 1 set 1 set 1 set
-5. Electric Facility	Transformer secondary board Control board Auxiliary board	1 unit 3 units 1 unit
-6. Overhead Crane	Manual, 3 ton capacity	1 unit
-7. Bar Screen	2000 mm x 2000 mm	1 unit