BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR THE PARO VALLEY AGRICULTURAL DEVELOPMENT
IN
THE KINGDOM OF BHUTAN
(PHASE 2)

APRIL 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

BASIC DESIGN STUDY REPORT ON THE PROJECT FOR
THE PARO VALLEY AGRICULTURAL DEVELOPMENT IN THE KINGDOM OF BHUTAN (PHASE 2)
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PREFACE

In response to a request from the Government of the Kingdom of Bhutan, the Government of Japan has decided to conduct a Basic Design Study on the Project for the Paro Valley Agricultural Development and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Bhutan a Survey Team headed by Mr. Yasuhiko Yamamoto, Director, Planning Department, Hokuriku Agricultural Administration Office, Ministry of Agriculture, Forestry and Fisheries from November 7th to December 16th 1989.

The team exchanged views on the Project with the concerned officials of the Government of Bhutan and conducted a field survey. After the team returned to Japan, further studies were made. Then, a mission was sent to Bhutan in order to discuss a draft report and the present report was prepared.

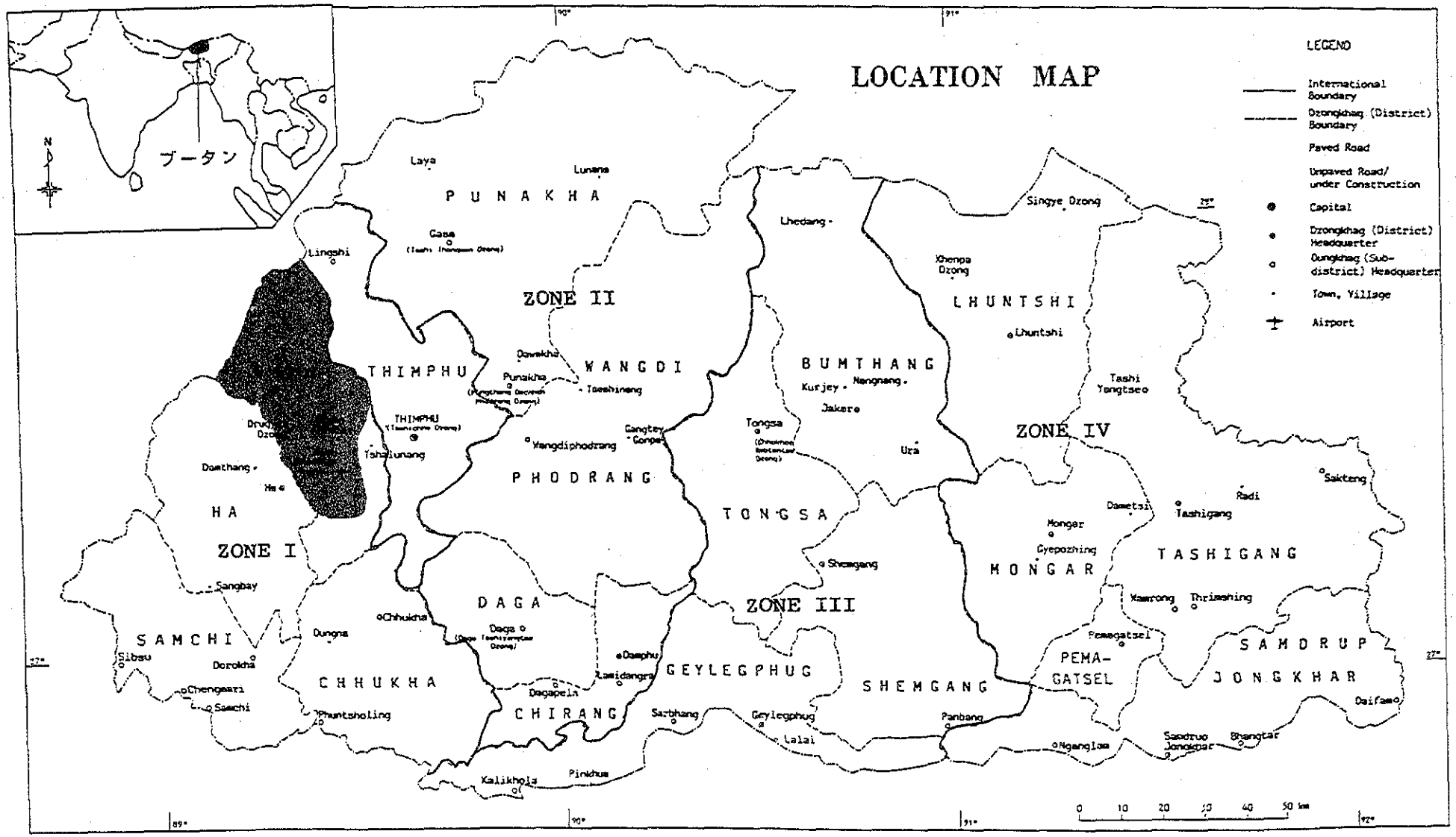
I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the concerned officials of the Government of the Kingdom of Bhutan for their close cooperation extended to the team.

April 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency


LOCATION MAP
ブータン
N
LEGEND
International Boundary
Dzongkhag (District) Boundary
Paved Road
Unpaved Road/ under Construction
Capital
Dzongkhag (District) Headquarter
Dungkhag (Sub-district) Headquarter
Town, Village
Airport
PUNAKHA
Laya
Lunana
Gasa
Lingshi
ZONE II
THIMPHU
WANGDI
Punakha
Tseshinang
Dawakha
THIMPHU
Yshalunang
Wangdiphodrang
Gangtey
Gompa
PHODRANG
Damthang
Ha
HA
ZONE I
Sangbay
SAMCHI
Sibsu
Dorokha
Chengsari
Sasehi
Dungna
Chhuikha
CHHUKHA
Phuntsholing
DAGA
Daga
Dagapela
CHIRANG
Daophu
Lamidangra
Sarbhang
GEYLEGPHUG
Geylegphug
Lalai
Kalikhola
Pinchua
Lhedang
BUMTHANG
Kurjey
Nangnang
Jakare
Tongsa
Ura
TONGSA
ZONE III
Shemgang
SHEMGANG
Panbang
Singye Dzong
LHUNTSHI
Khenpa Dzong
Lhuntshi
Tashi Yangtseo
ZONE IV
Saktang
Radi
Dametsi
Tashigang
TASHIGANG
Monger
Gyepozhing
MONGAR
Mamrong
Thrimshing
Pemagatsel
PEMA-GATSEL
SAMDRUP JONGKHAR
Daifam
Nganglam
Samdrup Jongkhar
Bhangtar
0 10 20 30 40 50 km

SUMMARY

Agriculture and livestock are the most important industrial sectors in Bhutan, accounting for 41.4 percent of its gross domestic product (GDP) and employing 87.2 percent of its labor force. Bhutan has a total land area of 46,500 sq. km, nearly all of which is characterized by the geographical features of the Himalayas Mountain. The country belongs to the monsoon climate zone. Farmland accounts for only 7.7 percent, 356,000 ha, of the total area, of which only about 30,000 ha are irrigated. The population and its growth rate were estimated at 1,343,600 and 2.4 percent, respectively, as of 1987, and because of its geographical features, coupled with its low agricultural productivity, Bhutan has not achieved self-sufficiency in food.

GNP per capita was US$ 150 in 1987. Thus Bhutan has been included among the least developed countries. However, being geographically isolated from others, it has maintained a traditional economic society centering on agriculture and forestry, and has avoided investing in modern industry. As a result, its international debt was only US$ 41 million in 1987, making its debt status considerably sounder than in other least developed countries.

Economic self-reliance is the principle goal of the 6th Development plan (1987-1992), and to realize it, each region has to be self-reliant. With this in mind, the Government of Bhutan selected five areas in the country as priority areas for agricultural development, and has planned and built agriculture-related facilities in each of them. The area where the Paro Valley Integrated Agricultural Development Project will be carried out is one of the five selected areas.

In response to a request made by the Government of Bhutan, the Regional Office for Asia and the Pacific (RAPA) of the Food and Agriculture Organization of the United Nations (FAO) carried out in 1987 a preliminary survey in Bhutan and prepared a developmental proposal for the four areas of the Paro Valley Basin in which it concluded that the Dotey Basin would be given top priority. On the basis of this proposal, the Government of Bhutan asked the Government of Japan for grant aid. Upon receiving this proposal, the latter decided to

implement a basic design survey, and the Japan International Cooperation Agency (JICA) dispatched a preliminary survey team to Bhutan from November through December 1988. On the basis of the results obtained by the team, a basic development policy for the project concerned was confirmed and project components calling for rehabilitation were agreed upon.

In accordance with the above confirmation and agreement, a decision was reached to dispatch a basic design study team to Bhutan. The survey would be carried out in two phases. In phase 1, the team would conduct a survey on the present status of agriculture in the whole Paro Valley area, prepare an outline of the consolidation plan in the form of a master plan, and carry out a basic design survey on construction machinery, plants and rehabilitation of existing farm road. In Phase 2, the team would prepare a basic design for each component based on the master plan established in Phase 1. According to this basic policy, JICA dispatched a Phase 1 basic design study team. As the study results, a master plan and its basic design were as described below.

(1) **MASTER PLAN**

IRRIGATION FACILITIES

- Rehabilitation of irrigation channels :

  Concrete lining : 5.0 km long (with concrete blocks and cast in place concrete)

  Consolidation of earth channel : 9.0 km long (including diversion)

  Replacement of steel flumes : 3.5 km long (Channel No.17)

- Construction of intake facilities:

  Concrete intakes : 4 sites (Channel Nos. 6, 13, 14, 19)

  Wooden mattress : 7 sites (Channel Nos. 1, 3, 4, 8, 11, 12, 15)

FARM ROADS

- Rehabilitation of existing road : Site 1, L= 3.7 km (3.0 m, gravel)

- Construction

  of new roads : Site 2, L= 6.8 km (3.0 m, gravel)
  Site 3, L= 9.5 km (- ditto -)
  Site 4, L= 1.75 km (- ditto -)
  Site 6, L= 1.8 km (- ditto -)
  Site 7, L= 3.2 km (- ditto -)

  Total L= 26.75 km

FARMLAND CONSOLIDATION

(at Changkha-Thang area, one site)

- Irrigation channel : Channel No.8
- Irrigation area : 28 ha
- Number of farmhouses : 30

RIVER PROTECTION WORKS

- New construction : Site 1, L= 3.7 km (Left bank), gabion
  L= 3.7 km (Right bank), gabion
  Site 2, L= 6.5 km, gabion
  Site 4, L= 1.75 km, gabion
  Site 5, L= 2.05 km, riverbed excavation
  Site 7, L= 3.0 km, gabion

  Total L= 20.7 km

(2) **BASIC DESIGN**

In the Phase 1 survey, the basic design was carried out on plants, construction equipments and rehabilitation of existing farm road. Its outline is as follows:

CONSTRUCTION EQUIPMENT (Stage 1.1)

Bulldozer (21 ton)	: 1
" (15 ton)	: 4
Bulldozer (3 ton)	: 1
Backhoe (0.6 cu.m)	: 3
" (0.20 cu.m)	: 1
" (0.04 cu.m)	: 2
Clamshell (0.6 cu.m)	: 1
Dump truck (11 ton)	: 8
Vibratory roller (10 ton)	: 1
Truck mixer (2.2 cu.m)	: 2
Mortar pump	: 1
Power trowel	: 1
Compressor (7.5 cu.m/min)	: 1
Jack hammer	: 2
Vibrator	: 2
Tamper	: 4
Wheel loader (0.34 cu.m)	: 1
Belt conveyer (7 m)	: 1
Supporting equipment	: 1 set

PLANTS

Crushing Plant (30 t/hr)	: 1 set
Bather plant (Forced mixing type)	: 1 set
Precast Concrete Plant	
Block manufacturing equipment	: 1 set
Steam curing equipment	: 1 set
Forklift	: 2
Diesel generator (45 KW)	: 1
Steel-bar cutter	: 1
Water treatment facility	: 1 set

REHABILITATION OF EXISTING FARM ROAD

Length	: 3.7 km
Width	: 3.0 m
Design speed	: 30 k.p.h
Pavement	: Crushed stone

CONSTRUCTION EQUIPMENT (Stage 1.3)

Bulldozer (21 ton)	: 1
" (15 ton)	: 1
Rakedozer (15 ton)	: 1
Backhoe (0.6 cu.m)	: 1
" (0.35 cu.m)	: 1
Dump truck (11 ton)	: 8
Vibratory roller (10 ton)	: 1

On the basis of the results obtained in Phase 1, a Phase 2 basic design study team was dispatched for 40 days, from 7 November through 16

December 1989. The team began its work by explaining to the Bhutan side the basic policy stipulated in the master plan as well as the results of its priority ranking and selection of the various components and carried out the Phase 2 survey after obtaining the approval of the Bhutan side for every aspect of the project. In this survey, measurements were taken in all sections and areas targeted for improvement in irrigation channels, farm roads, river protection and farmland consolidation, that is, those items selected as project components in the development master plan. In addition, agricultural and rural social survey was conducted as a part of the Phase 2 survey to ascertain the economic effect of the rehabilitation project concerned, the facilities maintenance plan and the formation of farmers' organizations.

Outline of the facilities selected from the Phase 2 survey are as follows:

1) Irrigation Facilities (Total 28.55 km)

Irrigation channels to be rehabilitated within the scope of the projected are as follows:

Channel	Length in m	Command area in ha
No.1 Shaba Shengo	1,906.0*	10.11
No.3 Shaba Bara	2,240.0*	18.20
No.4 Dujey Dingkha	1,672.0*	28.20
No.6 Serekha	1,398.2*	32.00
No.8 Tshetey Yuwa	666.9*	19.60
No.11 Kempa Tangyul	1,912.0*	15.60
No.12 Gesse Chawa	1,623.0*	34.00
No.13 Sharimochu	1,230.0*	24.00
No.14 Gangyul	2,547.0*	21.60
No.15 Damjimayu	2,390.0*	42.80
No.17 Jangsa	5,234.0*	60.80
No.19 Chendo Chukha	2,990.7*	48.00
No.21 Bamdoley	1,904.0*	40.00
No.28 Rema Thangyul	837.0*	24.20

(Note): The mark (*) in the above table shows the total length of the existing channel; being different from the length to be rehabilitated under this project.

2) Farm Roads (Total 21.6 km)

The following routes are all scheduled to be constructed as new farm roads under this project:

	Route	Length in km	Benefited area in ha	No. of farmhouse
Site 2	Bamdoley = Jangsa	6.2	116	95
Site 3	Satsan Chorten = Tshongdu	8.6	310	174
Site 4	Nyemizam = Khangku	1.7	43	38
Site 6	Bondey = Gyebjana	1.7	50	20
Site 7	Chorten-Sarpa = Deankha	3.4	50	32

3) River Protection Works (Total 17.05 km)

	Route/Site	Distance in km
Site 1	Right bank of Dotey River	3.7*
Site 2	Bamdoley-Jangsa (Market Bridge)/ Left bank of Paro River	6.8*
Site 4	Nyemizam-Khangku	1.7*
Site 5	Right bank of Gyebjana Rongchu	2.05*
Site 7	Chorten-Sarpa-Deankha	3.4*

(Note): The mark (*) in the above table shows the total length of the river; being different from the length to be rehabilitated under this project.

4) Farmland Consolidation

Land readjustment, setting up of farm roads and installation of irrigation channels are to be consolidated on a farmland 18.50 ha in area in the Changkha-Thang.

The project implementation schedule is shown below.

Stage 1

1st Phase
- Procurement of Construction Equipment (First)
- Construction of Plants

2nd Phase
- Irrigation Facilities:
  No.17 Jangsa (L=5,234m*), No.12 Gesse Chawa (L=1,623m*),
  No.11 Kempa Tangyul (L=1,912m*), and No.15 Damjimayu (L=2,390m*)
- Farm Road and River Protection:
  Site 1 Left bank of Dotey River (L=3.7km)
- River Protection:
  Site 1 Right bank of Dotey River (L=3.7km*)

3rd Phase
- Irrigation Facilities:
  No.21 Bamdoley (L=1,904m*), No.19 Chendo Chukha (L=2,991m*),
  and No.28 Rema Thangyul (L=837m*)
- Farm Road and River Protection:
  Site 2 Bamdoley-Jangsa (Market Bridge)/
  Left bank of Paro River (L=6.2km)
- River Protection:
  Site 2 Bamdoley-Jangsa (Market Bridge)/
  Left bank of Paro River (L=6.2km*)
- Procurement of Construction Equipment (Second)

Stage 2

1st Phase
- Irrigation Facilities:
  No.13 Sharimochu (L=1,230m*), No.14 Gangyul (L=2,547m*),
  No.1 Shaba Shengo (L=1,906m*), and No.8 Tshetey Yuwa (L=667m*)
- Farm Road:
  Site 3 Satsan Chorten-Tshongdu (L=8.6km), and
  Site 4 Nyemizam-Khangku (L=1.7km)
- River Protection:
  Site 4 Nyemizam-Khangku (L=1.7km*)
- Farmland Consolidation: Approximately 50%, Upstream side

2nd Phase
- Irrigation Facilities:
  No.3 Shaba Bara (L=2,240m*), No.4 Dujey Dingkha (L=1,672m*), and
  No.6 Serekha (L=1,398m*)
- Farm Road:
  Site 6 Bondey-Gyebjana (L=1.7km), and
  Site 7 Chorten-Sarpa-Deankha (L=3.4km)
- River Protection:
  Site 5 Right bank of Gyebjana Rongchu (L=2.05km*), and
  Site 7 Chorten-Sarpa-Deankha (L=3.4km*)
- Farmland Consolidation: Approximately 50%, Downstream side

(Note): The mark (*) in the above table shows the total length of

the route; being different from the length to be rehabilitated under this project.

The Department of Agriculture, the subcoordinate organization of the Ministry of Agriculture, will be responsible for implementing this project. The operators for the equipment whose procurement was already planned on in the Phase 1 survey are under training at AMC. The plant manager and the operator are about to undergo training in Japan. Furthermore, those operators are scheduled to be trained also on the job during the construction stage.

In carrying out the construction under this project, the Japanese side will use without compensation the equipment procured under this project and bear the cost of repair, fuel and labor. The Bhutan side will supply the project site without compensation and secure the personnel necessary to execute the land substitution and construction work on the farmland consolidation site. Construction work of the 2nd Phase in the Stage 1 will take 11 months, while other phases take each 12 months. In the case of construction of irrigation channels and farmland consolidation, the actual working period is scheduled to e each 8 months, since during the rainy season or cultivating period, construction work will be halted.

Agricultural mechanization will be promoted through construction of farm road, but the local farmers regard highly the importance of livestock. This is because cow's milk is an important source of nourishment, and farmyard manure is the main type of fertilizer used in the Paro Valley. The farmers in this area intend to maintain their present mixed system of agriculture and livestock without significantly reducing number of animals despite future agricultural mechanization.

This project should result in increase of paddy and cash crop production. The increase is expected as follows:

Paddy	902 M.T. (Metric ton)
Potato	2,815 M.T.
Apple	3,490 M.T.

The total increase of these three products is equivalent to around

¥ 370.9 million when converted into this year's farm gate prices, or ¥ 192,200 per household. According to the above increase of farmer's income, agricultural mechanization will be promoted and agriculture productivity will be increased as well as leveling up of the farmers' living standard. By the introduction of power tillers and transplanters, rice plantation cost per ha will be decreased by Nu. 6,732 (¥ 57,902). As a farmer's land area is 0.8 ha on the average, he will save about Nu. 5,380. It is not economical that each farmer owns a power tiller which costs Nu. 30,000 (¥ 258,030) and a transplanter more expensive than a power tiller. It is advisable that machinery owners work for others with contracts in a way currently practiced. Consolidation of agricultural infrastructure and promotion of agricultural mechanization will result in increase of agriculture productivity; and further greatly contribute to progress of the National Development plan, as a model of a self sufficient area. Therefore, it is judged appropriate to implement this project by using the Japanese grant aid.

LIST OF ABBREVIATIONS

FAO : Food and Agriculture Organization of the United Nations

RAPA : Regional Office for Asia and the Pacific

UNDP : United Nations Development Programme

IFAD : International Fund for Agricultural Development

BRTF : Indian Border Road Task Force

NUDC : National Urban Development Corporation

FCB : Food Corporation of Bhutan

PWD : Public Works Department

STCB : State Corporation of Bhutan

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ANNEX

Chapter 1. INTRODUCTION

Economic self-reliance is the principal goal of the 6th Development Plan (1987-1992), and to realize it, each region has to be self-reliant. With this in mind, the Government of Bhutan selected five areas in the country as priority areas for agricultural development, and has planned and built agriculture-related facilities in each of them. The area where the Paro Valley Integrated Agricultural Development Project will be carried out is one of the five selected areas.

In response to a request made by the Government of Bhutan, the Regional Office for Asia and the Pacific (RAPA) of the Food and Agriculture Organization (FAO) carried out in 1987 a preliminary survey in Bhutan and prepared a development proposal for the four areas of the Paro Valley Basin in which it concluded that the Dotey Basin would be given top priority. On the basis of this proposal, the Government of Bhutan asked the Government of Japan for grant aid. Upon receiving this proposal, the latter decided to implement a basic design survey, and the Japan International Cooperation Agency (JICA) dispatched a preliminary survey team to Bhutan from November through December 1988. On the basis of the results obtained by the team, a basic development policy -- to rehabilitate the existing infrastructures effectively, considering present situation, in order to eliminate the hindrance and to raise farm work productivity -- for the project concerned was confirmed and project components calling for rehabilitation were agreed upon.

In accordance with the above confirmation and agreement, a decision was reached to dispatch a basic design study team to Bhutan. The survey would be carried out in two phases. In Phase 1, the team would conduct a survey on the present status of agriculture in the whole Paro Valley area, prepare an outline of the consolidation plan in the form of a master plan, and carry out a basic design survey on construction machinery, plants and rehabilitation of existing farm road. In Phase 2, the team would prepare a basic design for each component based on the master plan established in Phase 1. According to this basic policy, JICA dispatched a Phase 1 basic design study team headed by

Mr. Yasuhiko Yamamoto, Director of Planning Division, Hokuriku Agricultural Administration Office of MAFF, for 29 days, from 29 March trough 26 April 1989. After returning, the team attended to its domestic duties and brought Phase 1 to its conclusion.

On the basis of the results obtained in Phase 1, a Phase 2 basic design study team headed by the same Mr. Yasuhiko Yamamoto was dispatched to Bhutan for 40 days, from 7 November through 16 December 1989. The team began its work by explaining to the Bhutan side the basic policy stipulated in the master plan as well as the results of its priority ranking and selection of the various components and carried out the Phase 2 survey after obtaining the approval of the Bhutan side for every aspect of the project. In this survey, measurements were taken in all sections and areas targeted for improvement in irrigation facilities, farm roads, river protection and farmland consolidation, that is, those items selected as project components in the development master plan. In addition, an agricultural and rural social survey was conducted as part of the Phase 2 survey to ascertain the economic effects of the rehabilitation project concerned, the facilities maintenance plan and the formation of farmers' organizations. This report presents the results of the Phase 2 study.

The list of the survey team members, the survey schedule, the list of participants, the minutes of discussions and the data collected are given in the Annex.

Chapter 2. BACKGROUND OF THE PROJECT

2.1 Outline of Bhutan

Agriculture and livestock are the most important industrial sectors in Bhutan, accounting for 41.4 percent of its gross domestic product (GDP) and employing 87.2 percent of its labour force. Bhutan has a total land area of 46,500 sq. km, nearly all of which is characterized by the geographical features of the Himalayas Mountains. The country belongs to the monsoon climate zone. Farmland accounts for only 7.7 percent, 356,000 ha, of the total area, of which only about 30,000 ha are irrigated. The population and its growth rate were estimated at 1,343,600 and annually 2.4 percent respectively, as of 1987, and because of its geographical features, coupled with its low agricultural productivity, Bhutan has not achieved self-sufficiency in food.

In 1987, GNP per capita was US$ 150, lower than the US$ 160 GNP per capita in Bangladesh. Thus Bhutan is included among the least developed countries. However, being geographically isolated from others, it has maintained a traditional economic society centering on agriculture and forestry, and has avoided investing in modern industry. As a result, its international debt was only US$ 41 million in 1987, making its debt status considerably sounder than in other least developed countries.

Bhutan is divided into 18 Dzongkhangs, which are categorized into four Zonal Administrations (ZA) in the framework of the 6th Development Plan.

They are:

- Zone I (Western Zone) : Ha, Paro, Chukha and Samchi
- Zone II (Western-Central Zone) : Punakha, Wangdiphodrang, Chirang, and Daga
- Zone III (Eastern-Central Zone) : Bumthang, Tongsa, Shemgang and Geylegphug
- Zone IV (Eastern Zone) : Lhuntshi, Mongar, Tashigang, Pemagatsel and Samdrupjongkhar

Thimpu is an independent metropolitan zone, excluded from the above zones.

The objectives of ZA are as follows:

1) To strengthen decentralization and local autonomy.
2) To strengthen mutual cooperation of the Dzongkhangs in ZA and to promote development cooperation in each zone.
3) To strengthen implementation capability of projects and programmes transferred to the zone.
4) To coordinate ZA to promote development capability of each Dzongkhang.
5) To promote various development projects for local inhabitants by cooperating with the agencies concerned.

The Paro Prefecture, the project area, is in Zone I, the administrative capital of which is established in Chukha. Activities in Zones I and II commenced on 1st January 1989, and those in Zone III on 1st July 1989. Activities in Zone IV are under preparation.

2.2 General Condition of Agriculture in Bhutan

(1) Land Use and Form of Land Ownership

The total area of agricultural land in Bhutan is estimated at 356,000 ha, 65,000 ha of which is cultivated land with land slope less than 30%, and 176,000 ha terraced farmland with land slopes of more than 30%. The remaining 115,000 ha is for shifting cultivation.

According to the results of the 1988 agricultural survey conducted in nine Dzongkhangs in Thimpu and Zones I and II, the total area of farmland was 60,130 ha, 15,400 ha of which was for paddy fields, 25,100 ha for upland fields, 11,130 ha for shifting cultivation, 980 ha for kitchen gardens and 7,500 ha for orchards.

The number of holders by size of holding in the above survey area is shown below:

Size of holding in ha	Number of holders	Percentage
0.01-0.49	2,330	8.3
0.50-0.99	4,410	15.8
1.00-1.49	4,830	17.3
1.50-1.99	3,310	11.8
2.00-2.99	5,260	18.8
3.00-4.99	4,380	15.7
above 5.00	2,960	10.6
Land holders	27,480	98.3
All holders	27,960	100.0

The total number of the holders was 27,960 in the survey area, and the average size of holding was 2.15 ha. The number of holders with less than 1.0 ha of each farmland amounted to 24.1%, that with less than 2.0 ha 53.2% and that with less than 3.0 ha 72.0%. Landless holders in nine Dzongkhangs numbered 480, less than 2% of the total number of farmers.

(2) Agricultural Products

Rice, maize, wheat, barley, buckwheat and millet are the main grain in Bhutan. The total cropped land area for the grain was 124,100 ha in 1984. Crops, land areas and products, including beans and potatoes in 1984 are compared below with those in 1981.

Crops		Cropped land area in '000 ha		Products in '000 M.T.	
		1981	1984	1981	1094
Grain	Rice	28.0	30.6	57.4	65.0
	Wheat/Barley	12.0	14.4	13.3	16.0
	Maize	56.8	58.5	80.7	87.3
	Buckwheat/Millet	15.5	20.6	12.3	16.8
Others	Pulse	4.0	3.0	2.4	2.6
	Mustard	2.9	5.0	1.9	3.5
	Potatoes	3.7	4.2	24.9	32.6
	Chilies/Vegetables	3.1	1.7	12.2	5.3
	Oranges	6.2	7.8	25.6	30.7
	Apples	1.5	1.6	3.3	3.5
	Cardamoms	5.9	8.8	2.8	3.0

The above table shows that only chilies production is on the decline.

(3) Cash Crops

In the past, Bhutan exported its agricultural products only to India, but Bangladesh has emerged in recent years as a new market, thus significantly altering its exporting pattern. Apple and orange exports to Bangladesh, commenced in 1982; other products such as green peas and tomatoes have been exported on a trial basis since 1988. According to the State Trading Corporation of Bhutan, 2,000 tons of apples and 8,000-10,000 tons of oranges are now exported to Bangladesh annually, accounting for 70-80% of Bhutan's total exports.

By exporting agricultural products to Bangladesh, Bhutan can obtain hard currencies such as US dollar, Japanese yen, Sterling pounds, Germany mark, French franc, Swiss franc, Singapore dollar, Hongkong dollar and Australian dollar. Thus the Government of Bhutan has encouraged exports to Bangladesh by granting 30% subsidy to the selling price of all Bangladesh-bound exports. Bangladesh in turn-exports them to Middle East oil producing countries. For this reason, Bhutan packs its exports in wood (although recently this is being replaced by corrugated cardboard). To export to India, products have to be classified into three categories, but because of the absolute shortage of supply, this classification procedure has not been adopted for exports to the Bangladesh market.

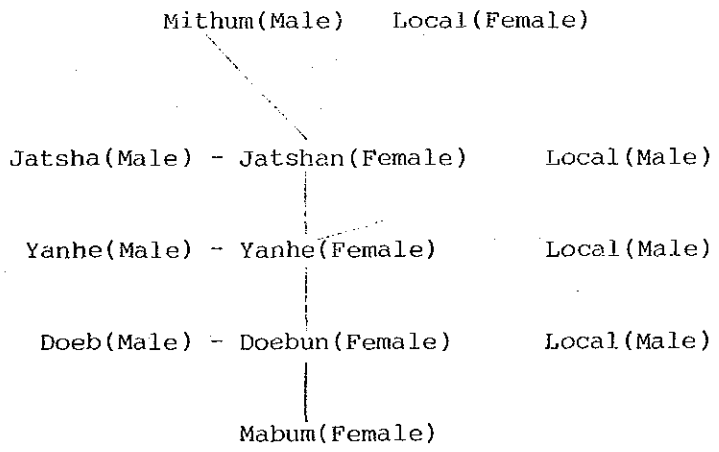
At present, there are four traders in Paro Dzongkhang dealing in apple exports. In comparatively large orchards with a land area slightly more than an acre, products are purchased through competitive bidding among the four traders. The traders are responsible for harvesting, packing, transporting and paying reparation for damaged apple trees. Thus, exports to Bangladesh are welcomed by farmers as well as the Government. The dealing price of apples is about Nu. 6.00/kg at the orchards, and the exporting price to Bangladesh is about US$ 689/ton (approximately Nu. 11.53 per kg). This transaction is carried out through the good office of STCB. The Bangladesh dealer pays STCB the price in US$ and the latter adds 30 percent to the amount it receives and pays the traders the sum in the local currency.

(4) Livestock

Yaks are raised in the mountainous area more than 3,000 m above sea level, while buffalo and goat are raised in the southern areas near the Indian border. Cattle are raised throughout the country. The breakdown of livestock in 1988: cattle 401,446, yak 40,065, buffaloes 5,467, sheep 39,235, goat 48,055, horses/donkey 27,083, pigs 73,287 and poultry 229,944.

Yaks are raised for their milk or for breeding, but not as domestic beasts of burden.

Cattle are important domestic beasts of burden in Bhutan, where mechanization has lagged behind, and cow milk is an important source of nourishment for its people. The Mithum cattle, a native to Assam, India, are high in milk fat, but owing to their violent temper they are not suitable as domestic beasts of burden, and hence have traditionally been crossbred with local cattle. Chromosome of ordinary cattle is 2n=60 in number, while that of the Mithum cattle is 2n=58. A crossbred male is hence not capable of propagating. Thus traditionally the Mithum cattle have been crossbred in the following manner:



A crossbred has a specific name according to its generation. Its humps and horns come in different size and shapes.

Horses are raised for transportation services and not used for farming work at all. Yak, pigs and poultry are raised for food.

2.3 General Condition of Related Plans

2.3.1 National Development Plan

The Government of Bhutan, with assistance of the Indian Government, the United Nations and other international aid agencies, has planned and executed five Five-Year Development Plans so far (1961-66, 1966-71, 1971-76, 1976-81 and 1987-92) and one Six-Year Development Plan (1981-87). Through these plans, educational and medical facilities have been enlarged, and 2,000 km of new roads have been constructed. The sixth Development Plan is now in progress.

Sectorial and yearly allocation of expenditures of the Development Plans is given in Table 2.1. Comparing the expenditures with those of the first Development Plan, the total expenditure increased to 1.9 times in the second Development Plan, 4.4 times in the third, 10.3 times in the fourth and 43.4 times in the fifth. Further, in the sixth Development Plan it reached 88.7 times that of the first. The following nine items are established as the goals of the 6th development Plan:

(1) Improve the administrative capability of the central government
(2) Defend, maintain and promote national identity
(3) Mobilize domestic resources
(4) Raise income of the rural sector
(5) Improve the housing conditions in the rural sector and promote relocation
(6) Integrate and improve development services
(7) Develop human resources
(8) Encourage people to participate in their country's development
(9) Promote national "self-reliance"

TABLE 2.1 OUTLAYS OF DEVELPMENT PLANS

unit : Nu.in millioms

Sector	First Plan 1961-66	Second Plan 1966-71	Third Plan 1971-76	Fourth Plan 1976-81	Fifth Plan 1981-87	Sixth Plan 1987-92
Agriculture	1.9	21.6	58.3	259.0	419.4	822.1
Food Corporation of Bhutan	-	-	-	-	135.5	106.5
Animal Husbandry	1.5	5.8	24.2	61.5	162.4	331.0
Forestry	3.2	6.9	28.4	110.3	229.9	418.2
Power	1.5	9.1	30.1	50.5	340.5	1,247.9
Trade and Industries	1.1	1.0	25.2	175.0	323.3	1,276.1
Geological Survey	-	-	-	-	-	-
Public Works Department	62.9	70.5	84.6	128.3	787.5	887.2
Road Transport/Aviation	7.5	12.0	9.5	-	26.3	48.8
Post & Telegraph	0.5	5.9	11.4	16.9	65.8	68.1
Telecommunication	-	-	14.8	37.3	33.7	133.8
Tourism	-	-	14.1	12.5	29.1	-
Druk Air	-	-	-	-	-	391.0
Education	9.4	35.7	90.0	134.6	519.1	778.8
Health	3.1	16.7	38.1	54.6	237.5	399.1
Information and Broadcasting	0.1	1.4	4.0	11.0	36.1	95.9
Urban Development	-	-	-	-	187.3	248.7
General Government	-	-	-	-	1,114.9	1,973.8
Dzongkhags	-	-	-	-	-	238.5
Other	14.4	15.6	42.5	54.7	-	-
TOTAL OUTLAY	107.2	202.2	475.2	1,106.2	4,648.3	9,500.9

Source : Planning commission

2.3.2 Agricultural Development Plan

(1) Agricultural Sector

The target and policy of the agricultural sector in the sixth Development Plan are outlined below:

1) Target

a) Increasing self-sufficiency in staple foods.

b) Increasing farmers' income through diversification of cash crops.

c) Improving productivity of land and labor.

2) Basic Policy of Agricultural Development

a) Development of Prior Areas

First, fundamental agricultural facilities will be consolidated in areas where high productivity is expected. After that, agricultural development projects will be implemented. As a result of the study, the following five areas were selected as higher priority projects.

Chirang Hill Irrigation Project

- Components : Improvement of the existing irrigation facilities; soil conservation and improvement of management in the river basin; and strengthening of the supporting services for promotion of crop diversification.
- Area : Four districts of Chirang Dzongkhang
  River basin : 4,400 ha
  Farmland area : 2,800 ha
  Irrigated area: 1,310 ha
- Project cost : US$ 4.35 million
- Assisting organization : ADB

Tashigang-Mongar Area Development Project

- Components : Rehabilitation and improvement of irrigation facilities

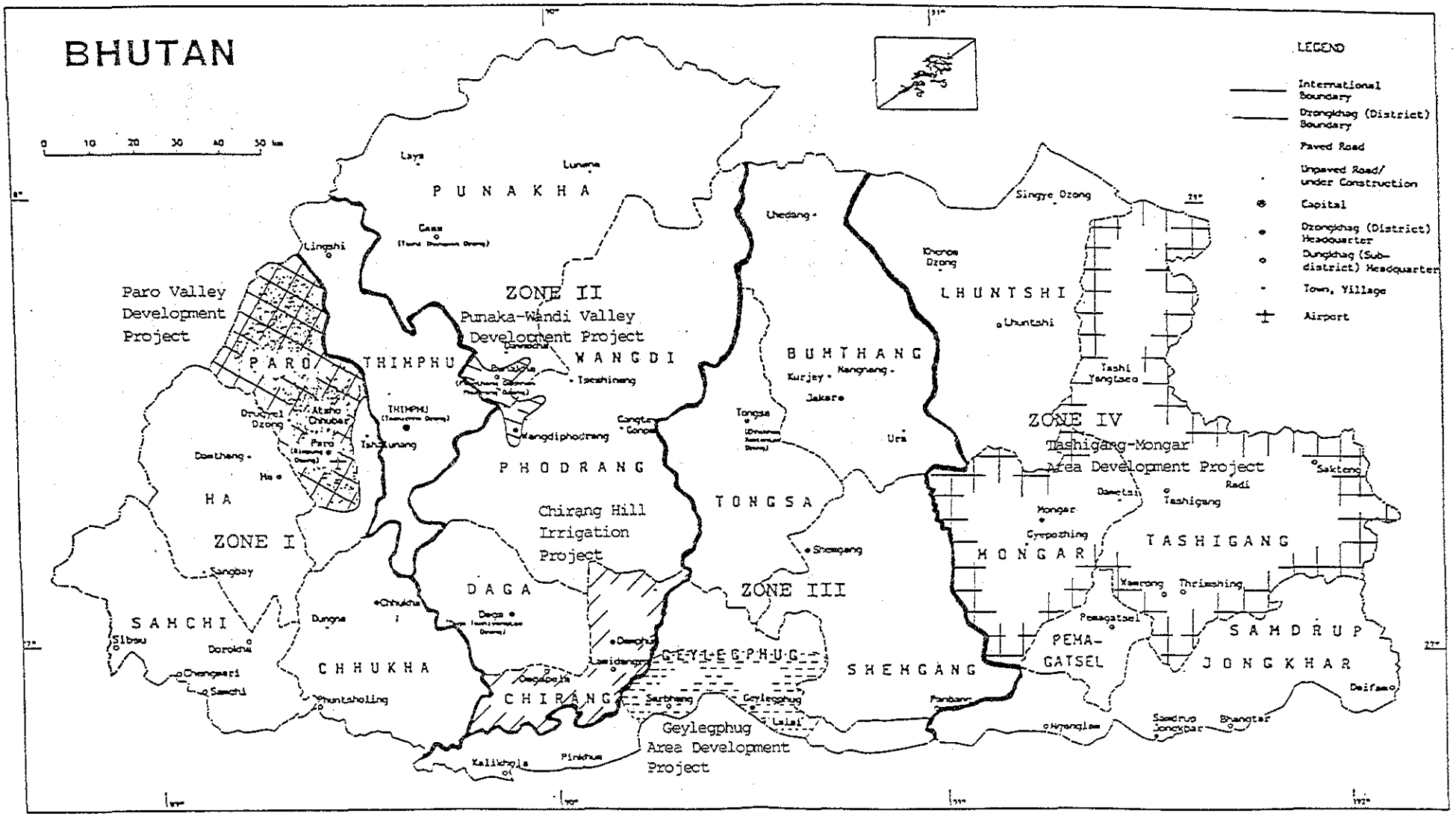


Fig. 2.1 LOCATION MAP OF HIGHER PRIORITY PROJECT SITES

in four areas; construction of farm roads with total distance of 34 km in three areas; and strengthening of various agricultural supporting services.

- Area : Tashigang and Mongar Dzongkhang
- Project cost : US$ 6.667 million
- Assisting organizations : UNDP, IFAD

Punakha-Wangdi Valley Development Project

- Components : Rehabilitation and improvement of irrigation facilities; strengthening of various agricultural supporting services; and soil conservation and environmental protection through the execution of pilot projects for strengthening community forests.
- Area : 9 Gewogs in Punakha Dzongkhang, 8 Gewogs in Wangdi Dzongkhang and 2 Gewogs in Thimpu Dzongkhang.
- Project cost : US$ 3.74 million
- Assisting organizations : IFAD, UNDP

Paro Valley Development Project

The project under consideration.

Geylegphug Area Development Project

- Components : Irrigation development and rehabilitation; soil and land resource assessment; land terracing and soil conservation; green manuring and compost sheds; agricultural extension services; manpower development; agricultural development; Bhur farm development; horticulture development; technical assistance; adaptive research; intensification of food grain and oilseed production; improvement of cattle through cross breeding; improvement of buffaloes; piggery development; poultry development; development and feed and fodder; livestock extension.
- Area : 7 Gewogs in Geylegphug Dzongkhang.
- Project Cost : Nu. 51.570 million
- Assisting organization : Government of India

b) General Agricultural Development Project

Various agricultural support services will be strengthened.

c) Strengthening General Agricultural Support Services

Supporting services will be provided and strengthened along the following lines:

i) Technical support for irrigation and land development through design supervision, etc.
ii) Agricultural research.
iii) Plant protection service.
iv) Supply of agricultural equipment, seeds and plants, fertilizer, tools and agricultural machinery.
v) Agricultural credit for farmers.
vi) Post-harvest support services.
vii) Agricultural extension and training services.

(2) Livestock Sector

The target and policy of the livestock sector in the sixth Development Plan are outlined below:

1) Target

a) Realization of self-sufficiency in the livestock sector.
b) Increase of household income in agricultural areas.
c) Nation wide support services for farmers by supplying farmyard manure and power force of draft animal.

2) Basic Livestock Development Policy

The main programme is composed of the following three components:

a) Intensive Livestock Development Programme

Among the country, 35 Gewogs will be selected national wide to implement development projects centering on dairy. Further, fisheries development projects will be implemented in 5 Gewogs.

High Altitude Area Development Project

Area : 4 Gewogs in Bumthang, 2 Gewogs in Lhuntshi and 4 Gewogs in Wangdiphodrang.

Objective : To improve livestock productivity through effective utilization of resources; and to realize self-sufficiency in main livestock products such as milk, butter and cheese.

Components : Artificial insemination, supply of bull, vaccination, farmers' credit, and construction of a dairy factory in Bumthang.

Project cost : Nu. 39.3 million

Assisting organization : The Government of Switzerland

Highland Livestock Development Project

Area : 3 Gewogs in Mongar, 1 Gewog in Lhuntshi, 2 Gewogs in Tashigang, 1 Gewog in Samdrupjongkhar, 7 Gewogs in Pemagatsel, 10 Gewogs in Chhukha, and 1 Gewog in Samchi.

Objective : To improve livestock productivity; to increase farmers' income to improve marketing systems for domestic use of livestock products; and to conserve environmental conditions through proper management of grazing lands.

Components : Artificial insemination; supply of bull; vaccination; construction of veterinary service centres, farmer's credit; and construction of a Dairy factory with a 700 ltr/hour capacity in Phuntsholing.

Project cost : Nu. 83.3 million

Assisting organizations : ADB, The Government of Norway

Integrated Fishery Development Project

Area : 2 Gewogs in Geylegphug and 3 Gewogs in Samdrupjongkhar.

Components : Fish farming in ponds with a total area of 108 ha;

technical training of fish farming for 300-400 farmers; and supply of 1,090,000 young fishes, 9,396 young pigs and 71,438 ducklings.

Project cost : Nu. 11.482 million

Assisting organization : Unknown

b) Dzongkhang General Livestock Development Programme

This will be implemented in the 156 Gewogs which are not involved in the Intensive Livestock Development Programme.

Components : Artificial insemination; supply of bull; vaccination; construction of veterinary service centres; farmers' credit etc.

Project cost : Nu. 51.042 million

c) Central Management Scheme

This aims to manage and control machinery, equipment and materials necessary for development at the central administrative agencies in order to ensure effective utilization.

Project cost : Nu. 114.775 million

2.4 Outline of the Request

The Paro Valley has played a leading role in the Kingdom of Bhutan as one of its most advanced agricultural regions. The establishment of a modern centre for agricultural development in the Paro Valley area the aim of the 6th National Development Plan, is extremely important for Bhutan and will contribute significantly to making the country self-sufficient in food supply.

Modernization of agriculture is said to be attained by activating the regional economy principally through agricultural mechanization and consolidation and improvement of the infrastructure. Although in Paro

agricultural mechanization has already started through the implementation of Japanese grant aid projects such as AMC, there is an urgent need for further improvement and consolidation of the infrastructure, for example, rehabilitation of irrigation channels, rehabilitation and improvement of farm roads, promotion of river protection works for conservation of farmland subjects for modernizing agriculture in the Paro Valley area. The Government of Japan is requested to hammer out a strategy for achieving these objects.

The Government of Bhutan, meanwhile, asked for a study of an agricultural development plan for the Paro Valley area, one of the prior areas involved in the Agricultural Development Projects. In response to this request, FAO(RAPA) carried out a preliminary survey during the period of September and October 1987. On the basis of this survey, FAO prepared a report in which the Paro Valley is divided into four areas and the Dotey River Basin is given the top priority .

On the basis of this report, the Government of Bhutan asked the Government of Japan for grant aid. The Government of Japan responded by dispatching a preliminary survey mission to Bhutan from November through December 1988. The mission confirmed the following basic items.

1) If the Dotey Basin is the only area selected for an intensive agricultural development project as suggested by FAO's preliminary survey, the investment cost per farm family may become so high as to prevent the Government of Bhutan from promoting infrastractural consolidation for development projects in other areas, and agricultural production system and social system may be altered drastically. Hence, it is advisable to rehabilitate the existing infrastructure effectively and to make a infrastructure consolidation plan for the whole Paro Valley Basin.

2) It is appropriate to take up components of irrigation facilities, farm roads, river protection works and farmland consolidation in the development master plan, and it is necessary to study the development needs for each component by district. In addition, a basic design survey should be carried out on the supply of

construction machinery and the construction of concrete plants, necessary for project implementation and maintenance.

3) It is appropriate to incorporate farmland consolidation into the project as a pilot scheme.

In accordance with these basic items, a decision was made on the Japanese side to conduct a basic design survey in two stages: Phase 1 and Phase 2. Prior to dispatching the basic design study team for Phase 1, the Government of Bhutan submitted a detailed appraisal, which is shown below.

i) Irrigation Channels

Gewog	No. of Channel	Canal Length in km	Command Area in ha
Tsento	4	9.92	191.20
Lango	4	11.12	447.37
Shaba	4	8.36	186.23
Wangchang	3	4.926	225.96
Dotey	2	4.86	111.74
Luni	3	7.11	186.45
Shari/Hore	7	18.09	446.14
Total	27	64.386	1,795.09

ii) Farm Roads : 64.78 km

iii) River Protection Works : 39.3 km

iv) Farmland Consolidation : (a) Chanktang 28.3 ha
: (b) Dob Damji 30.4 km

v) Equipment

- Construction Machinery

(a) Bulldozer (200 HP, 15 tons)	2 units
(b) Bulldozer (100 HP)	2 units
(c) Pay-loader (120-130 HP)	4 units
(d) Backhoe (60 HP)	2 units
(e) Backhoe (39 HP)	2 units
(f) Backhoe (20-25 HP)	5 units
(g) Belt conveyer	10 units
(h) Dump truck (2 cu.m)	8 units
(i) Vibratory roller (8-10 tons)	2 units
(j) Carrier truck (2.5-5 tons)	10 units
(k) Tamper (4 HP)	5 units
(l) Power trowel	5 units

- Supporting Equipment 1 set

vi) Plant : (a) Crushing plant
(b) Precast concrete plant

vii) Others : Supply of spare parts,
Costs for transportation, installation and training.

In settling of the master plan for Phase 1, a basic policy was adopted calling for maximum use and improvement of the existing agriultural infrastructure so that farm work can be made more efficient. Priority ranking was established in each component on the basis of urgency and importance, and component combinations were considered. With regard to irrigation facilities, farm roads and river protection, a comprehensive plan was made for improving and consolidating the whole Paro Valley area. And with regard to farmland consolidation, a plan was adopted to build a pilot farm in the region. The outline of the master plan is presented below.

IRRIGATION CHANNELS

Rehabilitation
- Concrete lining : 5.0 km long (with concrete blocks and job-site concrete)
- Consolidation of earth channel : 9.0 km long (including diversion)
- Replacement of steel flumes : 3.5 km long (Channel No.17)

Construction of Intake Facilities
- Concrete intakes : 3 sites (Channel Nos. 13, 14, 19)
- Wooden mattress : 6 sites (Channel Nos. 3, 4, 8, 11, 12, 15)

FARM ROADS
- Rehabilitation of existing road : Site 1, L= 3.7 km (3.0 m, gravel)
- Construction of new road : Site 2, L= 6.8 km (" ")
" Site 3, L= 9.5 km (" ")
" Site 4, L= 1.75 km (" ")
" Site 6, L= 1.8 km (" ")
" Site 7, L= 3.2 km (" ")

Total L= 26.75 km

FARMLAND CONSOLIDATION

(at Changkha-Thang area, one site)

- Irrigation channel : Channel No.8
- Irrigation area : 28 ha
- Number of farm houses : 33

RIVER REVETMENTS

- New construction : Site 1, L= 3.7 km (Left bank), gabion
  " ", L= 3.7 km (Right bank), gabion
  Site 2, L= 6.5 km, gabion
  Site 4, L= 1.75 km, gabion
  Site 5, L= 2.05 km, riverbed excavation
  Site 7, L= 3.0 km, gabion

  Total L= 20.7 km

The project covers a wide area totaling 3,000 ha of narrow lands along rivers and involves a large amount of construction work. There is also a basic policy that the project be executed with the help of a labor force of farmers thereby to be benefited in the area. Considering the above, it is important for the project implementation that to strictly keep the labor force, and the construction machinery is used effectively. Under the above provision, it is recommended that the project be implemented in two stages: Stage 1 for areas located upstream of the River Paro, including the River Dotey; and Stage 2 for the areas downstream. The implementation period will be 36 months for the Stage 1, and 24 months for the Stage 2.

In the Phase 1 survey, the basic design was carried out on plants, construction machinery and rehabilitation of existing farm roads, and specifications were proposed on their scales as well as kinds and equipment. Its outline is as follows:

Stage 1.1

CONSTRUCTION MACHINERY

Bulldozer (21 ton)	: 1
" (15 ton)	: 4
" (3 ton)	: 1
Backhoe (0.6 m3)	: 3
" (0.20 m3)	: 1
" (0.04 m3)	: 2
Clamshell (0.6 m3)	: 1
Dump truck (11 ton)	: 8
Vibrating roller (10 ton)	: 2
Truck mixer (2.2 m3)	: 2
Mortar pump	: 1
Power trowel	: 1
Compressor (7.5 m3/min)	: 1
Jack hammer	: 2
Vibrator	: 2
Tamper	: 4
Tractor shovel (0.34 m3)	: 1
Belt conveyer (7 m)	: 1
Supporting equipment	: 1 set

PLANTS

Crushing Plant (30 t/hr)	: 1 set
Batcher Plant (Forced mixing type)	: 1 set
Pre-Cast Concrete Plant	
Block manufacturing equipment	: 1 set
Steam curing equipment	: 1 set
Forklift	: 2
Diesel generator (45 kw)	: 1
Steel-bar cutter	: 1
Water treatment facility	: 1 set

Stage 1.2

REHABILITATION OF EXISTING FARM ROAD

Length	: 3.7 m
Width	: 3.0 m
Design speed	: 30 km/hr
Pavement	: Crushed stone

Stage 1.3

CONSTRUCTION MACHINERY

Bulldozer (21 ton)	: 1
" (15 ton)	: 1
Rakedozer (15 ton)	: 1
Backhoe (0.6 m3)	: 1
" (0.35 m3)	: 1
Dump truck (11 ton)	: 8
Vibrating roller (10 ton)	: 1

Chapter 3. OUTLINE OF THE PROJECT AREA

3.1 Location and Socio-Economic Conditions of the Area

The project area is an agriculture land located in Paro Dzongkhang, western zone of the Kingdom of Bhutan. It is located in north latitude 27°20'-27°35' and east longitude 89°15'-89°30', and situated along the Paro River and its tributary, the Dotey River. The project area covers eight gewogs - Tsento, Lango, Dotey, Shari, Hore, Wangchang, Luni and Shaba - as shown in Fig. 3.1. Population as of 1987 by gewog is shown below:

Gewog	Population	Number of Households
Tsento	1,768	282
Lango	1,845	320
Dotey	767	134
Shari	1,361	213
Hore	786	185
Wangchang	1,785	345
Luni	1,287	197
Shaba	1,569	185
Total	11,168	1,930

Since Dalai Lama's escape from Tibet in 1959, refugees from Tibet have settled in the Paro area. They are scattered in various gewogs and given farmland. Dalai Lama has recently called on the Tibetan public to emigrate to India, but the Government of Bhutan, for its part, has a policy to accept refugees from Tibet in Bhutan if they wish to do so.

In the Paro district, Indian labours constitute a larger foreign population than do the Tibetans. Among other thing, they engage in operation and maintenance of national highways and in airport expansion work, they live in barracks and form their own community. Twenty-three percent of all government employees in Bhutan are foreigners and most of them are Indians.

Agriculture and forestry are the main industries in Paro, and exports of cash crops and timber are thriving. There is an international airport in Paro - the only one in Bhutan - and there are many tourist attractions such as the Togtshshang Monastery, called the Tiger's Nest, and the Drugyal Dzong Museum. A festival held in spring every year in

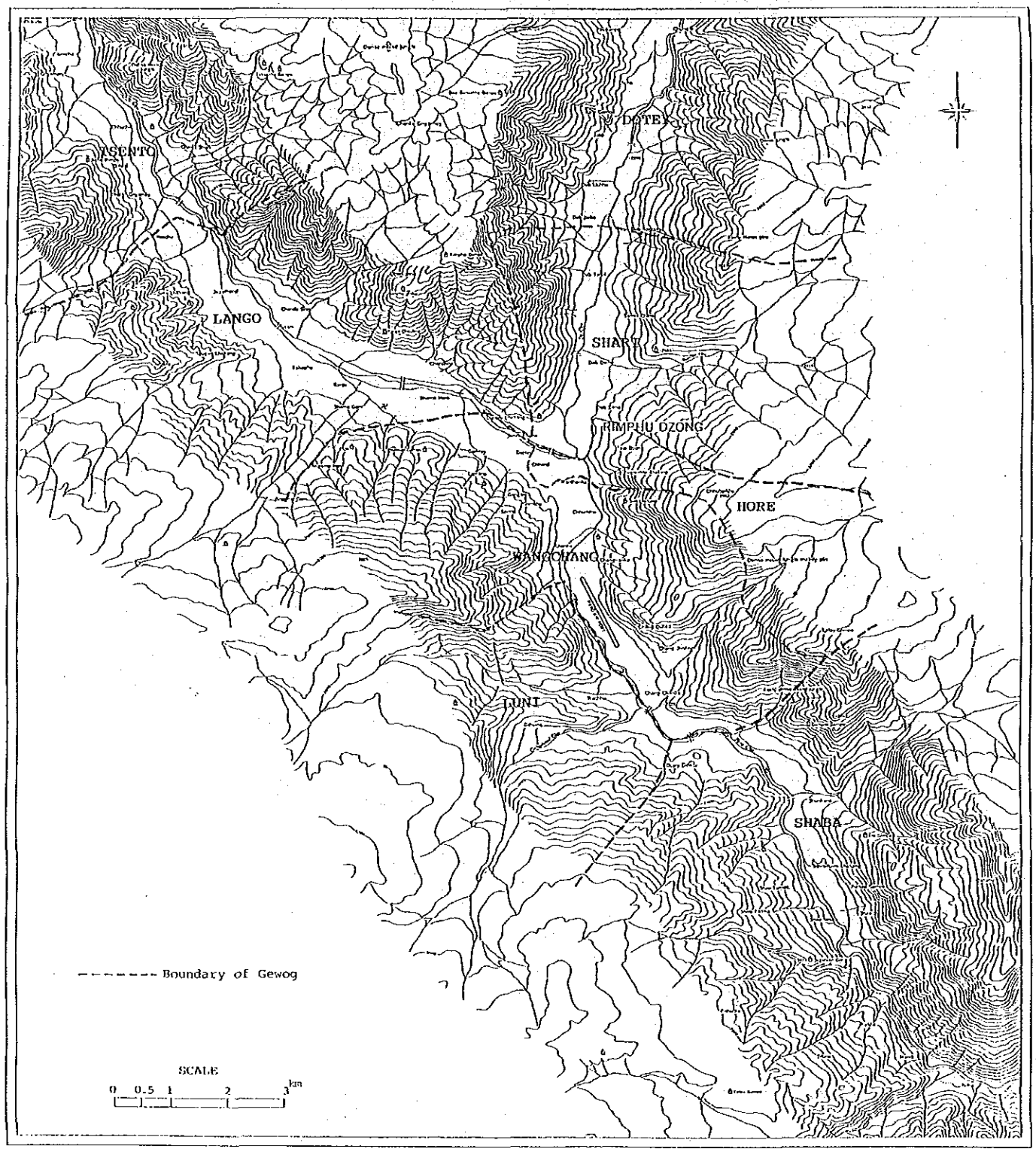


Fig. 3.1 BOUNDARY OF GEWOG

Paro is well known through the country. Although Bhutan's tourism was launched in 1974, because of the Government's policy of limiting the number of foreign tourists, only about 2,500 tourists visit Bhutan annually, even today.

In Paro, there is an old shopping centre in the vicinity where the two rivers, Paro and Dotey, join and another near the Bondey Bridge. Also, an open market is held every Sunday at the edge of the old shopping centre. Vegetables and meat used to be sold on that day only, but recently the shopping area near the Bondey Bridge supplies vegetables everyday.

3.2 Natural Conditions

3.2.1 Climate

Paro Dzongkhang belongs to the monsoon climate zone with a rainy season (June to September) and a dry season (December to February). The annual precipitation is 500-1,000 mm. In Paro Dzongkhang, meteorological observations are made at Bitekha, near the border with Ha Dzongkhang, at the Bondey Farm and at Dotey. The records for Bitekha and the Bondey Farm, which are relatively complete, are given in Table 3.1.

3.2.2 Geology

Geology in and around the project area is composed of gneisses from the Precambrian age and covered with overburden consisting of fan deposits, talus deposits and riverbed deposits of the Pleistocene age to the Recent Quarternary age.

Gneisses are of two types: a melanocratic banded gneiss containing a large amount of biotite (garnet bearing) and a leucocratic gneiss consisting mainly of quartz and feldspar.

The weathered zone is found near the surface. It can be divided into two zones: (1) a highly weathered zone where rocks are brown in color and some of the rocks have changed into clay; and (2) a slightly

TABLE 3.1 METEOROLOGICAL DATA

	BITEKHA				BONDEY FARM			
	Aver. Min.Temp. in °C	Aver. Max.Temp. in °C	Aver. Humid. in %	Rain-fall in mm	Aver. Min.Temp. in °C	Aver. Max.Temp. in °C	Aver. Humid. in %	Rain-fall in mm
1988								
Jan	?	10.5	73	0	-2.0	16.6	67	0
Feb	?	11.5	69	9.0	-0.4	17.6	76	13.6
Mar	4.2	12.4	59	43.0	-	-	-	30.0
Apr	5.6	15.9	69	31.6	-	-	-	24.7
May	9.8	18.4	75	68.8	11.1	24.0	66	36.4
Jun	12.3	20.1	78	99.8	13.8	26.4	68	137.8
Jul	13.8	19.4	89	233.7	16.6	24.7	79	117.4
Aug	13.8	19.4	89	160.0	-	-	-	181.6
Sep	12.5	19.1	98.4	127.0	-	-	-	128.2
Oct	7.4	18.3	83.2	9.0	-	-	-	128.2
Nov	?	15.4	73.7	6.0	1.3	19.4	64	11.5
Dec	?	12.5	63.8	2.0	-0.1	16.9	73	16.2
1989								
Jan	0.7	10.6	55.5	4.0	?	?	?	?
Feb	0.0	11.6	73.3	9.0	-	-	-	110.0
Mar	4.2	12.5	50.5	43.0	3.4	18.6	-	48.5
Apr	5.3	15.4	71.3	36.2	5.6	20.9	-	50.2
May	9.9	17.7	79.0	148.8	11.4	23.5	-	175.2
Jun	14.0	20.8	89.2	239.6	-	-	-	190.6
Jul	13.9	20.6	90.5	245.3	-	-	-	168.0
Aug	14.0	19.7	91.0	85.7	-	-	-	98.2
Sep	12.6	18.6	88.9	209.0	-	-	-	95.4
Oct	8.8	15.7	82.4	0	-	-	-	10.4
Nov					-	-	-	0

weathered zone where joints are open and weathering is in progress. The weak weathered zone is around two to three meters thick.

Fan deposits are formed at places where tributaries flow into the main stream. They are rich in rounded gravel of gneiss.

Talus deposits are found at the sloping foot of mountains but are not distributed widely. They consist of silt and subangular gravels derived from the highly weathered zone of gneiss.

Riverbed deposits are distributed on riverbeds and consist mainly of cobble to boulder size rounded gravels. In addition to gneisses, the lithology of the main gravels consists of metamorphic rocks derived from the Precambrian series such as crystalline schist, marble and quartzite.

3.2.3 Rivers

The Paro River and its tributary, the Dotey River, are the main rivers in the project area. Both have rapid streams with longitudinal riverbed gradients of 1.5-2.0%, and their tractive force is so strong that their riverbeds have changed with every flood. As a result of the incessant heavy rainfall that occurred in May 1989, the Paro River overflowed at Lango Area, but no such flooding was triggered by a similar rainfall the following month, June 1989. This was because the river course had already been changed by the flood in the May rainfall. The river discharge records from 2 February 1987 through the end of October 1989 at the bridge in front of the Paro Dzongkhang are shown in Annex 5. The records of both the minimum and maximum discharge during the above recording period were 4.25 cu.m/sec in January 1988 and 169.12 cu.m/sec in July 1987, respectively.

3.2.4 Natural Environment

Of the 213,000 ha of land making up Paro Dzongkhang, 171,900 ha (80.7%) is forest land. The latter is maintained relatively well, but after deforestation, the affected areas have not been replanted. The policy taken instead has been one of merely waiting for the natural recovery

of trees, while the areas are fenced in order to protect against intrusion of animals. Most of the trees are pines, cypresses and oaks. There are some walnuts and rhododendrons, but few bamboo grasses. Willows are planted along riversides.

The area belongs to the monsoon climate zone with rainy and dry seasons. Expected annual precipitation is 500-1,000 mm. Surface water is abundant, and there are inhabitants near mountain summits. Yak are grazed in high mountain land with an elevation of more than 3,000 m, and in the lower lands, cattle are grazed in the mountains in summer. As a result, coliforms from their excretion sometimes causes contamination. Mainly farmyard manure is used as fertilizer. Chemical fertilizers have been used only slightly, and their influence on the environment is believed to be minimal. Currently, pesticides are supplied to farmers free of charge through EC assistance, but in an interview survey, it was found that farmers did not always understand what quantity of chemicals they should use. Thus it will be necessary to further spread the proper use of chemicals. The results of the water quality analysis carried out during the Phase 2 survey period are shown in Table 3.2. Since this was a period where there was seasonal changes and farm work was limited, the water quality was better during this period than during the Phase 1 survey period. In fact, the water at the time was good enough for domestic use.

Only nationwide data are mentioned below; data on animals and plants limited to the Paro area are not available.

There are reportedly about 5,000 kinds of plants in Bhutan. Ten to 15 of these are native species, of which five are almost extinct. As for mammals, birds and reptiles, 12 species, three species and one species, respectively, are nearly extinct. Regarding butterflies, there are 22-30 species, two of which are nearly extinct.

TABLE 3.2a WATER QUALITY FIELD TEST

Site of Sampling	A approx.100m downstream from Dzongkhag Bridge	B approx.50m upstream from Paro Market Bridge	C approx.100m upstream from Shari Ramna Bridge	D approx.100m upstream from Shaba Suspension Bridge
Date of Sampling	3 Dec. '89	3 Dec.'89	3 Dec. '89	3 Dec. '89
Time of Sampling	9:10	9:05	8:50	9:35
Weather	fine	fine	fine	fine
Air Temperature in °C	8.0	8.0	8.0	9.0
Water Temperature in °C	3.0	3.0	3.0	4.5
Turbidity in degreee	< 1	< 1	< 1	< 1
Colour in degree	< 2	< 2	< 2	< 2
pH	8.5	9.0	8.5	8.5
NO_3 - N in ppm	< 0.23	< 0.23	< 0.23	< 0.23
NH_4 - N in ppm	< 0.4	< 0.4	< 0.4	< 0.4
Cr^{+6} in ppm	< 0.05	< 0.05	< 0.05	< 0.05
Total Fe in ppm	< 0.2	< 0.2	< 0.2	< 0.2
Cu in ppm	< 0.5	< 0.5	< 0.5	< 0.5
Zn in ppm	0	0	0	0.3
Cl in ppm	0.7	0.1	0.3	0.2
NO_2 in ppm	< 0.02	< 0.02	< 0.02	< 0.02
Total Hardness in ppm	115	110	55	105
Chemical Oxygen Demand in ppm	3	7	5	5
Total Coliform in pieces/ml	0	0	0	0
Bacteria in pieces/ml	0	0	0	0

TABLE 3.2b WATER QUALITY LABORATORY TEST

Site of Sampling		A	B	C	D	Analytical Mehthod
Date of Sampling		13 Dec	13 Dec	13 Dec	13 Dec	
Time of Sampling		10:26	10:10	10:00	10:35	
Weather		fine	fine	fine	fine	
Air Temperature	in°C	10.0	10.0	10.0	10.5	
Water Temperature	in°C	2.5	2.5	2.5	3.0	
pH		7.7	7.8	7.6	7.8	Glass electrode
EC	in S/cm	126	131	75	132	EC meter
Cl	in ppm	0.5	0.5	0.5	0.5	$AgNO_3$ tritration
Na	in ppm	2.0	1.8	2.2	2.0	Flame photometry
K	in ppm	0.8	0.7	0.7	1.0	Flame photometry
Ca	in ppm	18.5	19.9	9.6	18.9	Atomic absorption
Mg	in ppm	3.5	2.7	1.1	2.9	Atomic absorption
Cu	in ppm	<0.005	<0.005	<0.005	<0.005	Atomic absorption
Zn	in ppm	0.01	0.03	0.02	0.02	Atomic absorption
Polychorinated Biphenyl	in ppm	<0.0005	<0.0005	<0.0005	<0.0005	Gas chromatography

3.3 Social Environment

(1) Roads

Road networks in Bhutan are inadequate. The first vehicle road in Bhutan was completed in 1962, at the time of the Indo-Chinese War. Since then, main roads have been constructed and maintained by the Indian Government (BRTF). In the project area, the only bridges passable by vehicles are Paro Market Bridge, Shari Ramna Bridge and Bondey Bridge. The Dzong Bridge is a traditional wooden bridge; the others are suspension bridges with wire ropes passable by people and livestock only. Roads can be classified into highways, feeder roads and farm roads. Road networks in the project area are shown in Fig. 3.2. As the figure shows, since farm roads are inadequate and absolutely lacking in some areas, transportation of agricultural products and agricultural inputs as well as agricultural mechanization has lagged behind and in many areas still has to dependent on human power and livestock force.

A traffic volume survey was carried out at two points -- Taju in the central part of the project area and Shaba in the down-stream part -- on December 6 (Wed) 1989, from 06:00 to 20:00. Although many trucks loaded with timber run on the other road linking Bondey with Ha, this road was not surveyed. This is because the latter is not important from the viewpoint of farm road planning, that is, trucks will not be using the farm roads even in the future. The survey results are given in Table 3.3. In the Paro area, about 8 cabs using 4-WD jeeps are in business. Farm roads are presumed to be used by cabs, tractors and power tiller.

Vehicles in Bhutan are not registered according to Dzongkhang; vehicles in five Dzongkhangs - Thimpu, Paro, Punakha, Wangdiphodrang and Ha - are registered in Thimpu. The number of registered vehicles is listed in Table 3.4. The record for the year 1989 is as of the end of September.

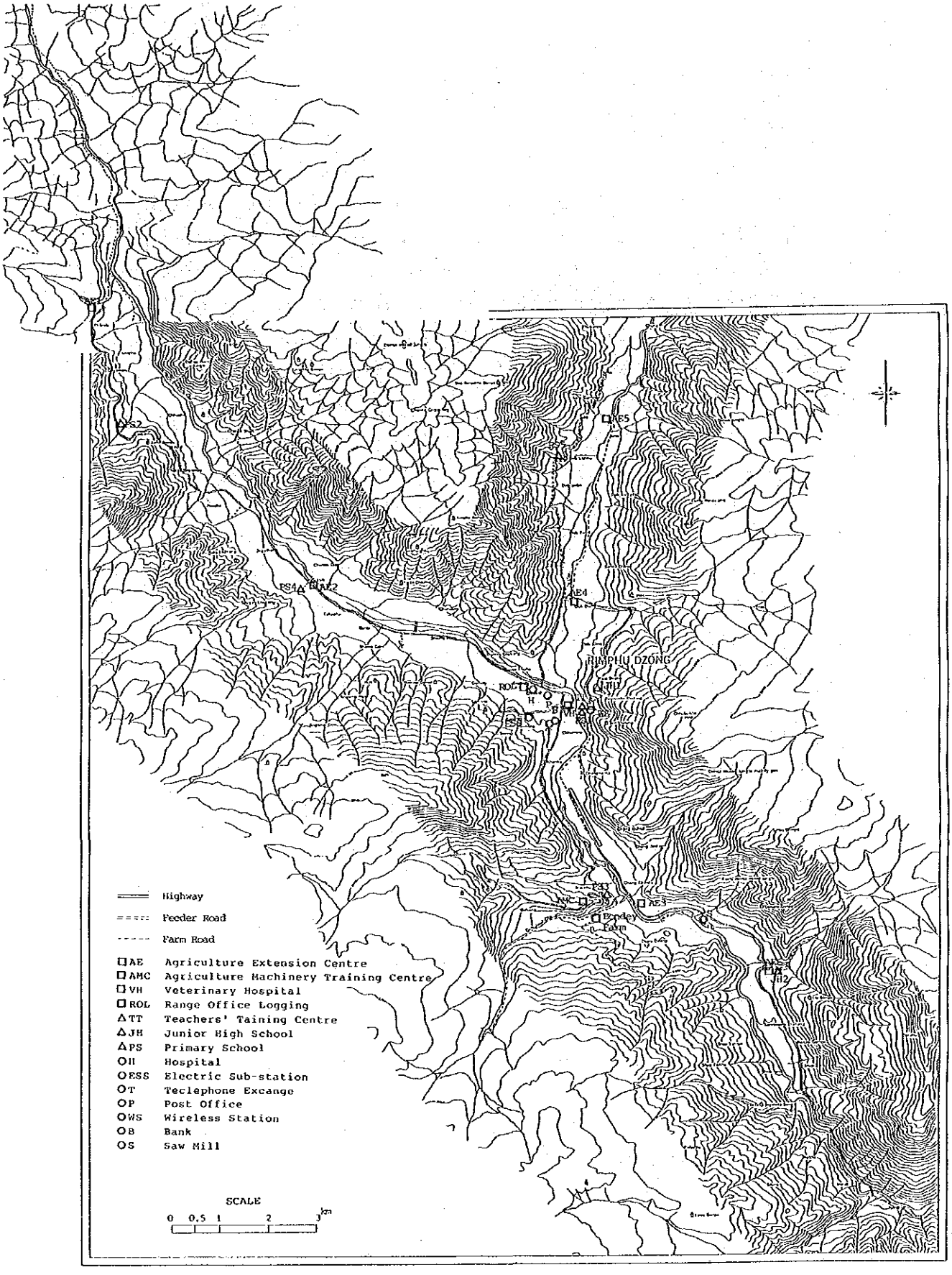


Fig. 3.2 EXISTING INFRASTRUCTURES

TABLE 3.3 TRANSPORT SURVEY

Date : 6th December, 1989

Time	CARS		BUSES		TRUCKS		POWER TILLER & TRACTORS		MOTOR CYCLE & SCOOTER		BICYCLE	
	TAJU	SHABA	TAJU	SHABA	TAJU	SHABA	TAJU	SHABA	TAJU	SHABA	TAJU	SHABA
6:00	0	7	0	0	2	0	0	0	0	0	0	0
7:00	9	11	0	0	4	0	0	0	2	0	0	1
8:00	18	16	0	0	4	7	0	0	8	0	1	1
9:00	27	13	2	1	8	8	2	0	6	1	3	2
10:00	19	15	0	0	8	10	0	0	10	4	1	1
11:00	13	6	1	1	8	9	0	0	10	4	0	0
12:00	5	16	0	0	1	9	1	1	11	5	0	3
13:00	16	11	0	0	1	7	1	0	10	3	0	0
14:00	12	13	1	0	1	6	0	0	9	2	0	0
15:00	20	21	0	2	4	11	1	0	8	2	1	1
16:00	9	10	1	1	1	13	0	0	9	1	5	1
17:00	9	15	0	0	3	13	0	0	6	4	2	1
18:00	5	8	0	0	2	4	0	0	6	0	5	1
19:00	4	7	0	0	0	1	0	0	2	0	0	1
20:00												
TOTAL	166	171	5	5	47	98	5	1	97	26	18	13

TABLE 3.4 NUMBER OF VEHICLES REGISTERED UNDER WESTERN REGION : THIMPHU, PARO, PUNAKA, WANDIPHODRAG AND HA

Year	CARS GOVERNMENT		CARS PRIVATE		BUSES		BULL-	TRUCKS			TAXIS	POWER TILLER/ TRACTOR		MOTOR CYCLE & SCOOTER GOVERNMENT		MOTOR CYCLE & SCOOTER PRIVATE		DIPLOMATIC				
	Car	Jeep	Car	Jeep	BGTS	Private	DOZER	Govt.	Private	Public		Govt.	Private	M/C	Scooter	M/C	Scooter	Car	Jeep	Scoot.	M/C	BUS
1985	61	78	12	11	2			5	7	11	25			18	1	6	101	13		4	1	
1986	62	96	16	10	2	1		7	3	2	23			18	1	3	135	8				
1987	26	63	7	20	5			2	9	21	39			1	2	7	158	4	1		2	
1988	98	17	15	31	2		2	11	4	19	25	10	70	45	16	52	280	1	3	1		1
1989*	95	32	23	11	5		7	17	5	2	31	7	42	15	8	18	114	5	2		2	
Total	342	286	73	83	16	1	9	42	28	55	143	17	112	97	28	86	788	31	6	5	5	1

* Data up to 30 September, 1989.

Source : Motor Vehicle Division, Revenue and Customs Department, Ministry of Finance.

(2) River Protection Works

The Paro Valley was damaged by floods in 1968 and 1973. According to an interview survey, the damage caused by deposits from small streams was severer than that cause by the Paro main stream. The area damaged by rivers is given below.

River	Damaged Area in ha
Paro	99.9
Dotey	12
Shari Rongchu	200
Gebiolumi Chu	80.0
Woochu	20.2
Mapepu Chu	8
Tom Chena	2
Others	22.8

Due to a shortage of construction machinery, about a half of the areas extensively damaged have not yet been restored to their original state; some former paddy fields remain as wasteland, while some others have been partly converted to orchards. Even today, in some damaged areas, accumulated sand is still left in the cultivated land.

Some river revetments have been constructed along the national highway and the Paro Airport, both of which are maintained by BRTF. But integrated river training works have not yet been executed. The Government of Bhutan normally provides gabion materials and guides farmers to build gabion, except for concrete revetment constructed in the Shaba area. The riverbeds were once expanded as a part of a foreign aid project in the section between the Paro Market Bridge made of reinforced concrete and the confluence of the Paro River with the Dotey River. Since then, no main river training works with foreign aid have been implemented.

(3) Public Facilities

The airport now being expanded is operated and managed by the Indian Government. As for public electricity, construction of a transmission line is under progress in Tsento Gewog, thus strengthening the effort toward complete electrification of the Paro area. The Bondey Farm plays a central role in agricultural development; nearby is the

agricultural machinery workshop, the food processing unit, the tissue culture laboratory, the agricultural machinery training center (AMC) and the seed production/processing packing center. In the Paro area there are six agriculture extension centres which supply farmers with agricultural materials.

Locations of the main public facilities are shown in Fig. 3.2.

3.4 Agriculture in the Project Area

(1) Land Use

Since there was a great discrepancy between the data on the farmland area submitted by the agency during the course of the field study in Phases 1 and 2 on the one hand and the actual land area on the other, the land register written in Dzongkha language was first translated into English and rearranged to determine the actual land area. The area of land use for each gewog is given in Table 3.5. The farmland area of Hore Gewog includes areas other than the project area, and the Hore Gewog's farmland area within the project area is estimated at 9.607 ha of wet land, 11.119 ha of dry land and 1.748 ha of kitchen gardens. The land use is shown in Fig. 3.3. The conversion of dry land to orchards has been accelerated over the past several years. Although the conversion of wet land to orchards is banned because of the need to protect grain products, the conversion of dry land is permitted and various protections are provided if the soil is considered suitable, for example, low-interest financing from farmers' credit and spraying insecticides free of charge.

(2) Agricultural Production

The report on agricultural production is being prepared in accordance with the Bhutanese fiscal year, June through May. When the survey team visited the project area , the data on paddy production for the summer of 1989 had not yet been arranged, and paddies were piled in farmers' garden, although some of them were being thrashed. The annual farming area as of May 1989 is presented in Table 3.6. The yields actually-

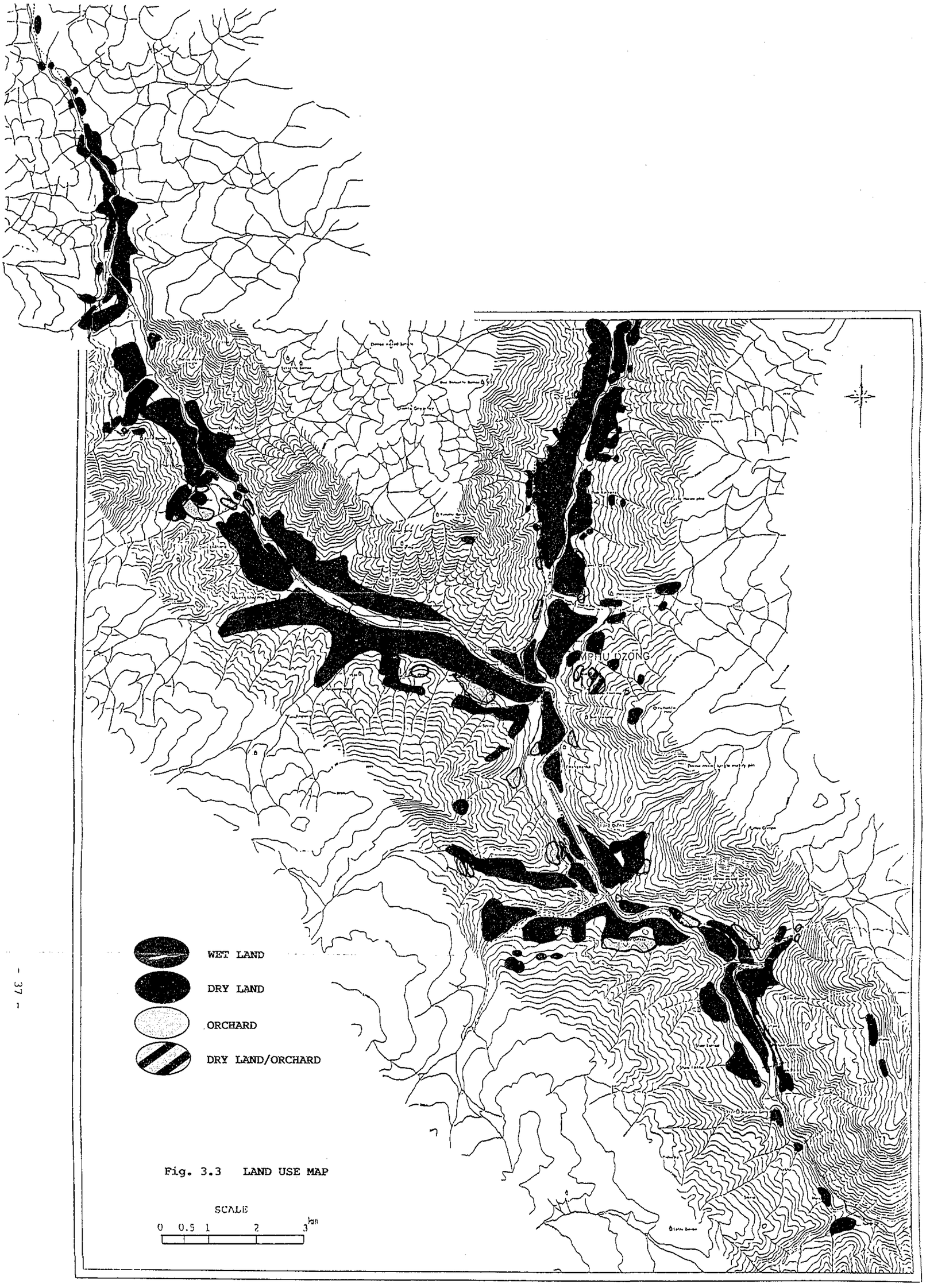


Fig. 3.3 LAND USE MAP

measured is given in Table 3.7. The table shows the results of a sampled survey carried out at five to six places in each gewog. Yields differ significantly in their productivity by gewog; in some cases, more than three times. The production in the project area are shown in Table 3.8. The pilot farmland on the Bondey Farm recorded during the above mentioned period paddy yield of 4.102 ton/ha in 1988 and of 4.646 ton/ha in 1989. The results of the agriculture survey by interviews are presented in Annex 6. The survey was conducted in Tsento, Wangchang, and Shaba, selecting from each district hamlets with about 10 households and located upstream, downstream and at sites in between, as well as in the proposed farmland consolidation area. Such small hamlets were selected because 10 is about the right number of households to interview and grasp the form of each community. The proposed farmland consolidation area was selected to examine the attitudes of farmers in an area targeted for development. The sample consisted of 40 households in total, 10 in each site. Paddy was cropped by all the farmers. Wheat, chili, radish/turnips and potatoes, in that order were harvested by more than 75% of the farmers. The average yield of paddy, wheat and potatoes was 2.99 t/ha, 0.99 t/ha and 6.55 t/ha, respectively.

Rates of fertilizer use for main crops in the survey sites are shown below. The main fertilizer used was farmyard manure; Suphala, a chemical fertilizer, was used mainly for potatoes.

Crops	Number of households cropping	Rate of fertilizer use (%)		
		Manure	Suphala	Urea
Paddy	40	100	28	15
Wheat	38	74	11	3
Potato	32	88	50	9
Apple	16	94	38	13
Radish/Turnip	33	67	24	12
Pulse	19	58	11	0
Cabbage	18	72	33	11
Chili	33	76	27	18

An insecticide was used for apples (19%), a herbicide for paddy (8%) - both at very low rates of use. The agricultural input derived from the Agriculture Extension Centres is recorded in Annex 7. Currently, pesticides are supplied free of charge through EC assistance.

(3) Agriculture Labor Force

The labor force required for per ha of paddy production was surveyed through interviews. The results are given below:

Place	Land Preparation	Transplanting	Weeding	Harvesting
Tsento	23.9	33.1	110.7	26.9
Wangchang	15.2 (3.6)	46.2	67.6	19.8
Proposed area	18.5 (5.1)	46.5	72.2	28.0
Shaba	17.6	39.8	116.4	23.3
Average	18.8	41.1	91.8	24.5

Unit: Man-Days; the figures in parentheses are for power tiller use.

The labor force is supplied either through mutual aid or by hiring workers for pay. In the case of mutual aid, breakfast, lunch and tea are generally served. In the case of workers hired for pay, in addition to the above meals, Nu.30 per day is usually paid. In 1989, the Government submitted a notification that the daily wage should be set at Nu.25. But in Paro, it is apparently ignored. Seasonal workers from remote villages are frequently included among paid workers. Generally, in this case, the daily wage is Nu.30 and 4 meals together with accommodation are provided. The seasonal workers are mainly from Ha Dzongkhang.

The labor force input by crop is shown in Annex 8. Areas of cultivated land and wet land in the sampled survey sites are given below:

unit : No. of holders

Item	Area in ha 0.01 -0.49	0.50 -0.99	1.00 -1.49	1.50 -1.99	2.00 -2.99	3.00 -4.99	5.00 & above	Total
Cultivating land holders	2	10	10	8	6	1	3	40
Wet land holders	17	10	9	2	0	2	0	40

Most of the cultivated land of farmers is 1.0 ha or more in area, but in the case of wet land, most farmers have less than 1.0 ha of land. This is presumably the result of each farmer having cultivated inclined land. Consequently, as demonstrated by the measurements taken in the

TABLE 3.5 GEWOG WISE LAND USE

Unit : ha

Gewog	Wet Land	Dry Land	Kitchen Garden	Tsheriland	Pangshing	Orchard
Tsento	188.122	453.564	15.678	38.040	8.915	45.260
Lango	334.812	205.565	22.618	0.028	21.850	58.433
Wangchang	250.692	163.675	16.673	1.141	85.459	73.306
Hore	38.490	133.654	14.812	-	2.655	30.542
Dotey	167.637	213.367	12.122	-	14.605	4.468
Shari	207.871	160.360	16.799	1.886	29.652	66.087
Luni	204.318	212.193	19.243	0.563	23.877	34.646
Shaba	169.923	243.260	25.508	-	29.826	48.062
Total	1,561.865	1,790.638	143.453	41.658	216.839	360.804

Source : Paro Dzongkhag

TABLE 3.6 AREA UNDER DIFFERENT CROPS, 1989

Unit : ha

Crop	Tsento	Lango	Dotey	Shari	Luni	Wang-chang	Shaba	Horey	Total
Paddy	188.12	334.81	167.64	207.87	204.32	250.69	169.92	38.49	1561.86
Maize	-	-	-	-	-	-	-	4.05	4.05
Wheat	250.91	104.41	32.76	38.55	91.60	106.84	64.35	28.33	717.75
Barley	3.24	2.43	-	-	5.85	4.45	-	12.14	28.11
Buck Wheat	3.64	4.05	-	-	6.90	-	-	6.48	21.07
Millet	4.05	8.10	9.23	0.30	3.60	2.25	-	3.64	31.17
Peas	4.45	4.45	47.14	0.30	9.40	4.05	3.64	4.05	77.48
Beans	2.43	10.12	-	-	4.95	6.10	-	-	23.60
Potato	216.11	97.94	184.54	88.34	130.00	187.78	93.70	36.42	1034.83
Turnip	4.05	30.35	-	0.44	1.65	2.00	0.73	1.21	40.43
Radish	6.07	10.12	-	0.30	10.50	8.10	1.70	2.83	39.62
Chilli	14.16	10.12	1.15	1.48	5.90	6.10	6.10	4.05	49.06
Cabbage	4.05	-	-	0.89	7.65	8.10	3.15	-	23.84
Total	701.28	616.90	442.46	338.47	482.32	586.46	343.30	141.69	3652.88

Source : Paro Dzongkhag

TABLE 3.7 CROP WISE AVERAGE YIELD

Unit : M.T./ha

Gewog	Paddy	Maize	Wheat	Barley	Buck Wheat	Millet	Soya Beans
Tsento	1.98	-	0.44	0.47	0.64	0.32	-
Lango	2.22	-	0.42	0.44	0.79	0.35	-
Wangchang	4.94	-	1.24	1.48	-	0.79	1.98
Hore	4.20	2.97	0.49	0.74	0.49	0.49	-
Dotey	4.45	-	0.40	-	-	0.32	-
Shari	7.71	-	0.64	-	-	0.52	-
Luni	3.95	-	1.48	1.36	0.99	1.11	-
Shaba	4.94	-	0.40	-	-	-	-
Doga	3.34	3.71	0.57	0.62	0.79	0.49	-
Naja	1.48	0.37	1.73	1.24	0.99	0.74	-

Gewog	B/gram	Peas	Beans	Potato	Turnip	Radish	Chilli
Tsento	-	3.95	3.71	14.83	15.32	14.83	6.18
Lango	-	2.69	2.55	14.83	7.59	8.65	8.90
Wangchang	0.25	3.71	1.98	12.36	12.36	13.84	2.47
Hore	-	4.94	-	9.88	18.53	18.53	5.93
Dotey	-	2.47	-	12.85	-	-	2.47
Shari	-	11.86	-	9.88	12.36	13.59	4.94
Luni	-	4.45	1.85	16.06	21.62	13.84	4.69
Shaba	-	2.97	-	10.38	15.07	14.83	2.47
Doga	-	4.45	-	7.91	12.36	11.86	4.45
Naja	-	1.24	-	12.85	11.12	11.12	3.21

Gewog	Other Vegetables	Cabbage	Mustard
Tsento	14.83	7.41	-
Lango	8.65	-	-
Wangchang	13.84	12.36	-
Hore	18.53	-	-
Dotey	-	-	-
Shari	13.59	9.88	-
Luni	13.83	2.97	-
Shaba	14.83	13.59	-
Doga	11.86	11.86	0.74
Naja	11.12	9.88	0.99

TABLE 3.8 PRODUCTION

Unit : M.T.

Gewog	Paddy	Maize	Wheat	Barley	Buck Wheat	Millet	Peas
Tsento	370.60	-	88.32	1.49	2.32	1.29	17.57
Lango	743.28	-	35.08	1.06	3.19	2.75	11.97
Wangchang	1,238.41	-	65.705	4.45	-	1.66	14.98
Hore	161.65	12.00	9.716	8.98	3.17	1.71	20.00
Dotey	744.30	-	7.622	-	-	2.95	116.43
Shari	1,600.60	-	14.802	-	-	0.115	3.55
Luni	807.05	-	67.78	5.85	6.76	3.99	41.73
Shaba	839.41	-	15.054	-	-	-	10.77
Total	6,505.30	12.00	304.119	21.83	15.34	14.50	237.00

	Beans	Potato	Turnip	Chilli	Cabbage	Radish
Tsento	8.99	3,202.75	25.11	87.36	30.01	89.95
Lango	25.70	1,451.47	230.05	89.96	-	87.43
Wangchang	12.01	2,319.08	24.70	15.07	100.03	112.02
Hore	-	359.82	22.42	24.01	-	52.43
Dotey	-	2,369.49	-	2.89	-	-
Shari	-	872.79	5.43	7.31	8.79	4.07
Luni	9.15	2,087.80	35.67	27.67	22.64	145.21
Shaba	-	971.66	11.00	15.07	42.80	25.19
Total	55.58	13,634.86	354.38	269.29	209.36	516.30

Source : Paro Dzongkhag

farmland consolidation districts, owned land is scattered and effective labor force input is prevented.

(4) Livestock

Yaks are grazed in mountains 3,000 m or higher in altitude, and are moved to the low land in winter. They are raised as livestock for making dairy products, usually not for farming. Only oxen are used as draft animal, and they are used in pair plowing work. Horses are kept for transportation purposes. Pigs are bred in considerable number by each farmer, since one or two pigs per farmhouse is butchered and consumed every year. The livestock population in Paro Dzongkhang are given in Table 3.9. The condition of livestock in the sampled survey sites is dealt with in Annex 6.

Cattle are raised in two manners: by grazing them in mountains from June to October; and by keeping them in cattle sheds or on farmland. About half the wheat is not harvested; instead it is fed to the cattle. Silage training is carried out in the winter season, and it was confirmed during the survey that the said training was being undertaken at three farmhouses in Shari Gewog. Milk production is usually 1.0 ltr/head/day or less, most of which is consumed domestically.

The sampled survey revealed that employment of agricultural machinery reduced the number of oxen required in some cases. However, since the main fertilizer used was farmyard manure produced by cattle and the total number of cattle to be bred could not be changed - some oxen were replaced with almost the same number of cows. Thus, it is believed that, although the role of cattle as domestic beasts of burden will become less important in the Paro Valley area, which is stressing its role as a supplier of livestock products and a source of farmyard manure, the current system of farming and livestock feeding will not be significantly changed by agricultural mechanization.

The major livestock diseases that have broken out in the Paro Dzongkhang are listed below. The data are those collected at veterinary hospitals from November 1988 to December 1990.

Disease	Species	No. of animal affected
1) Foot and mouth disease	Cattle	16
2) - ditto -	Pig	5
3) Hemorrhagic septicemia	Pig	3
4) Black quarter	Cattle	2
5) Swine fever	Pig	21
6) Rabies	-	Nil
7) Anthra	-	Nil
8) Ranikhet	Poultry	Nil

Data source: The Veterinary Hospital, Paro

Cases of foot and mouth disease (1) and swine fever (5) have been reported widely. Thus there is certainly still much room for improvement.

(5) Agricultural Machinery

Table 3.10 shows the state of private-ownership of agricultural machinery in Paro Dzongkhang as of 15 November 1989. During the six months after the Phase 1 survey, the number of tractors increased by two units and cultivators by 24 units. These machines are equipped with accessories for cultivation, soil crushing and trailing, but not with planting and harvesting for paddy. Thus in paddy farming, labor force input for plant preparation is reduced by 24-28%, but no such change is observed for other works.

In many cases, tractor and power tiller owners work for others on a contract basis for Nu.240 and three meals a day. They will work anywhere, provided it is in Paro Dzongkhang - even if it is far from their farmland. Those who own rice mill undertake process on a contract basis generally for five percent of paddy volume.

TABLE 3.9a LIVESTOCK POPULATION FOR THE YEAR 1988 - 89

Gewog	Yak		Cattle						Horse				Mules	
			Local		Jersey Cross Breed		Mithun Cross Breed		Local		Improved			
	Male	Female	Male	Female	Male	Female	Jatsha (Male)	Jatsham (Female)	Male	Female	Male	Female	Male	Female
Wangchang	182	119	281	409	14	33	6	9	29	46	4	6	1	-
Shari	117	242	328	382	87	149	15	12	44	76	3	1	7	9
Dotey	239	91	322	275	17	17	1	-	33	77	5	1	5	3
Lango	302	827	483	574	2	8	28	10	37	42	79	2	10	2
Tsento	523	1,157	476	376	1	1	-	-	79	58	-	-	18	15
Luni	24	30	252	218	15	42	6	15	10	32	-	-	-	2
Shaba	20	184	145	255	11	11	4	-	11	16	-	-	1	-
Dogar	-	-	644	1,700	4	42	27	30	40	20	-	-	-	-
Naja	21	30	388	548	2	5	38	26	100	29	1	-	-	-
Hore	30	40	100	160	6	13	13	8	10	20	-	1	1	-
TOTAL	1,242	2,720	3,419	4,897	159	321	148	118	393	416	92	11	42	31

Source : District Animal Husbandary Office, Paro

TABLE 3.9b LIVESTOCK POPULATION FOR THE YEAR 1988 - 89

Gewog	Donkey		Sheep		Pig		Poultry		Dog	
	Male	Female	Local	Improved	Local	Improved	Local	Improved	Male	Female
Wangchang	-	-	1	-	128	694	236	244	73	56
Shari	-	1	45	-	99	61	204	253	101	77
Dotey	1	-	-	-	328	60	164	145	36	20
Lango	1	-	-	-	451	203	270	133	118	53
Tsento	-	-	65	-	478	126	382	78	62	27
Luni	-	-	-	-	227	263	200	116	66	40
Shaba	-	-	-	-	406	245	287	104	37	14
Dogar	-	1	151	105	963	201	976	4	176	61
Naja	1	-	-	-	608	-	224	-	50	60
Hore	-	-	30	9	84	131	56	98	25	11
TOTAL	3	2	292	114	3,772	1,984	2,999	1,175	744	419

Source : District Animal Husbandary Office, Paro

TABLE 3.10 PRIVATE OWNERSHIP OF FARM MACHINERY AND EQUIPMENTS AS OF 15TH NOVEMBER, 1989

Sl No.	Gewog	Tractor	Power Tiller	Power Thresher	Water Pump	Rice Mill	Winnower	Power Reaper
1.	Luni	7 (7)	14 (11)	4 (4)	1 (1)	16 (15)	18 (18)	1
2.	Dotey	3 (3)	4 (1)	- (-)	- (-)	11 (11)	5 (5)	-
3.	Wangchang	4 (3)	19 (12)	2 (2)	1 (1)	16 (15)	7 (7)	-
4.	Shari	5 (4)	21 (19)	3 (3)	4 (4)	17 (17)	10 (10)	5
5.	Lango	4 (4)	17 (11)	4 (3)	4 (4)	28 (23)	7 (7)	1
6.	Tsento	1 (-)	2 (2)	2 (2)	- (-)	15 (14)	3 (3)	-
7.	Dogar	2 (2)	- (-)	- (-)	- (-)	9 (9)	- (-)	-
8.	Hore	1 (1)	4 (2)	- (-)	- (-)	3 (3)	- (-)	-
9.	Shaba	1 (1)	10 (9)	1 (-)	2 (2)	4 (4)	6 (6)	-
10.	Naja	- (-)	1 (-)	- (-)	- (-)	4 (3)	- (-)	-
	Total	28 (25)	92 (67)	16 (14)	12 (12)	123 (114)	56 (56)	7
Total in Project Area		26 (23)	91 (67)	16 (14)	12 (12)	110 (102)	56 (56)	7

Note : Number in parenthesis denotes number of machinery as of 31st March, 1989.

Chapter 4. OUTLINE OF THE PROJECT

4.1 Objective

In Bhutan, 87.2% of the people are engaged in agriculture and related industries. However, since land available for agriculture is limited due to topographical conditions, Bhutan is still unable to feed its own people without relying on imports. Production of rice, Bhutan's staple food, was estimated at 84,700 tons of paddy in 1987, and 11,282 tons, or about 15% of the rice consumed, was imported. In order to remedy this situation, in the 6th National Development Plan, the Government of Bhutan plans to 1) raise its rate of self-sufficiency in food; 2) increase farmers' income through development of cash crops; and 3) improve productivity of the land and the labor force.

The Paro Valley which is the project area, is considered an advanced agricultural area, but infrastructure related to agricultural production there is still underdeveloped, as demonstrated in the Phase 1 survey. Hence, on the basis of the present situation, the current project aims to effectively rehabilitate the existing infrastructure by eliminating the obstacles to growth and raising farm productivity. This plan to consolidate Bhutan's infrastructure is designed to serve as a model for the Government of Bhutan in rehabilitating other areas in the future without drastically changing production methods and social conditions.

4.2 Contents of the Request

4.2.1 Validity and Necessity of the Project

In addition to being Bhutan's advanced agricultural area, the Paro Valley, as noted in 3.4, is an area known for its diversity of crops and hard-working farmers. As demonstrated by the Phase 1 and Phase 2 surveys in Bhutan, there is insufficient production and inadequate infrastructure. Furthermore, because of the delay in mechanization, there are still many places damaged by floods in 1968 and 1973 that have not yet been restored to their original form.

Although the Paro Valley area has recorded high yields in rice production, as demonstrated in the agricultural survey presented in Annex 6, there is still considerable room for improvement in land and labor productivity through fertilizer use and agricultural mechanization. To achieve improvement in these areas, the construction of farm roads, which make possible improvement of old irrigation facilities and transportation of agricultural products and agricultural input, and the preservation of farmland through river protection are indispensable. Consolidation of irrigation facilities and farm roads and river protection work will not only increase production in the Paro Valley area and contribute toward making Bhutan self-sufficient in food, but will also raise the national income level as a result of expanded acreage under cash crop cultivation and increased productivity.

Meanwhile, comprehensive consolidation of plots of farmland which are presently scattered over wide areas and which average only 0.05 ha per lot will not only increase labor productivity but also accelerate the introduction of farm machines. However, since most farmland is located on slopes and there are no concrete example of farmland consolidation that could facilitate the understanding of the farmers themselves, the most realistic approach would be to first build a pilot farm on nearly flat land in the project area and show the farmers how effective farmland consolidation can be.

In the past, Bhutan relied on foreign workers for virtually all of its construction work, but in the present project local inhabitants will be encouraged to participate in its execution. It is believed that by imparting facility-construction know-how to the beneficiaries, it will be possible to place them in charge of facility maintenance in the future.

From the foregoing discussion, the necessity of the project under consideration is judged to be consistent with Japanese grant aid system.

4.2.2 Operation and Maintenance

The project includes irrigation facilities, farm roads, river protec-

tion work and farmland consolidation. Even at present, repair work related to river protection is executed by farmers' cooperatives. Maintenance work of farm roads is slated to be transferred to the control of the farmers after a 2-year trial period following the completion of the roads. Irrigation facilities are scheduled to be maintained by the beneficiaries themselves, who will organize water user associations for this purpose. Also, as for river protection work, it is recommended that the current methods be employed where work is done by beneficiaries' groups upon receipt of construction materials from the government. The project calls for the construction of a crushing plant and a precast concrete plant; this will greatly contribute to the above-mentioned methods. Since the beneficiaries themselves participate in the work as laborers, it is believed that they can acquire maintenance skills during the work period. It is recommended that precast concrete products and other materials be supplied through the Agriculture Extension Centres.

Plants such as those for making precast concrete products will require about 15 workers. It is believed that by hiring workers from areas near Lango, the site of plant construction, and having them work under the guidance of a Japanese contractor for four years, or the duration of the construction, the project will help develop managerial personnel and skilled workers. There is a plant near the southern town of Phuntsoling that produces reinforced concrete pipes, but no plant for concrete flumes exists in Bhutan. Because of present conditions in Bhutan, although there is a serious shortage of construction workers, the demand for these precast concrete products is high, and with the exception of steel imported from India, it is presumed possible to procure all materials domestically. Thus, it is believed that the project will develop into an excellent enterprise and contribute to the development of Bhutan.

4.2.3 Relationship with Similar Projects and Other Assistance Programs

In the Paro area offices of both the National Seed and Plant Program (NASEP) and AMC are actively carrying out their respective operations. They aim to promote the production and supply of seeds and seedlings of cash crops, as well as agricultural mechanization. After the con-

solidation of agricultural infrastructure through the present project, it is believed that the infrastructure will contribute greatly to the modernization of agriculture in the project area, improve its land productivity and make farm work more effective.

4.2.4 Facilities Requested

The project components requested by the Government of Bhutan are classified into 4 items as shown below:

- Irrigation Facility (Irrigation channels and a pumping station in the Kesa-Tilikha area in Shaba Gewog),
- Farm Roads,
- River Protection Works, and
- Farmland Consolidation.

(1) Irrigation Facilities

Although the Paro area is rich in surface water, most of the existing canals are made of earth and their cross-sections are irregular in many cases, resulting in much leakage. Consolidation of irrigation channels, which makes effective water management possible, will improve the planting area of paddy fields, promote the introduction of cash crops such as potatoes, and expand arable land for growing high-yielding crops, which require a higher level of water management. Hence it is appropriate to rehabilitate irrigation canals including their intake structures.

A pumping station was proposed in Kesa-Tilikha, Shaba Gewog, where cash crops are cultivated widely but the main part of the arable land constitute terraced paddy fields on steep slopes. The proposed installation of a 40 m head pumping station here to provide irrigation for cash crops is considered inappropriate as a component of the present project at this point because the local farmers would find it difficult to operate and maintain.

(2) Farm Roads

Road networks in the Paro area are inadequate in terms of total road length. Most of the existing farm roads are routed along sites easily eroded by floods, and hence it is impossible for farmers to maintain them alone. In addition, farmers who do not own farm machinery, vehicles and the like are not sufficiently aware of the need to ensure a smooth traffic flow on the roads. In conclusion, it is recommended that farm roads be constructed which are not easily damaged by floods or mountain water, and which are easily maintained, so that agricultural mechanization and transportation of agricultural input and products can be promoted.

On the other hand, it is not considered reasonable at this point to construct roads on steep slopes with little possibility of agricultural mechanization or on sites where there would be few beneficiaries and maintenance by farmers themselves would be difficult. The proposed farm roads are trunk roads, and access roads to farmhouses and farming fields will be constructed by the farmers themselves. As for the two bridges examined in Phase 2, it is proposed that the bridge at Lango be constructed after the above work, and construction machinery be transported by using a temporary structure. In Shaba, there are 35 houses on the right bank of the river, and only the existing suspension bridge located at the upper reach is used for transportation. Although there is a strong need for construction of a bridge for vehicle traffic, topographical conditions render construction of access roads to farmhouses highly difficult. Thus, for the time being, construction of a bridge is not recommended.

(3) River Protection Work

The discharge estimated from the traces of the 1968 flood in the Phase 1 survey are given below.

Dotey River	330 cu.m/sec
Paro River (Upstream of the conjunction)	710 cu.m/sec
Paro River (Downstream of the conjunction)	1,040 cu.m/sec

The configuration of the riverbed changed significantly as a result of discharge during the rainy season from the end of the Phase 1 survey to

the beginning of the Phase 2 survey. The Lango area was damaged by a flood that hit the area in May 1989, but with a river discharge of only 151 cu.m/sec, which is much less than the above-mentioned discharge (the discharge data is shown in Annex 5). There was also a flood in 1987 with a discharge of 169 cu.m/sec. Thus, this is a level of river discharge that can be regarded as occurring with a probability of once every two years.

The national highway submerged by the flood in May 1989 is being maintained by the Government of India, but unless the work of raising the road surface is undertaken in this project, it is practically impossible to plan full-scale river protection work to deal with such flooding as that which occurred in the 1968 flood. Thus, in the section opposite the river revetments of the national highway and the Paro Airport, it is advisable to plan river revetments for the protection of farmland and farm roads so that it will be the same height as the crest of the national highway. In the Shaba district, where there is still a possibility of restoring the original configuration of the farmland, it is advisable to build an embankment about two meters high so that it will withstand a discharge of 1,040 cu.m/sec.

(4) Farmland Consolidation

The proposed area for farmland consolidation is composed of small paddy fields each approximately 0.05 ha in area, and there are 27 households owning on average 13.7 plots of arable land dispersed throughout the area. By enlarging each plot through farmland consolidation and building farm roads, farmers will be able to make their work more efficient and promote farm mechanization, thus shortening the time required for transportation of agricultural products and agricultural input. Furthermore, if irrigation and drainage channels are built, water management will be executed properly, thus making it possible to commence plowing, land preparation, transplanting and other work at the most suitable time. This in turn will enhance the possibility of increased production and expanded acreage.

Since many of the paddy fields in the area are on slopes, it is impossible to carry out farm consolidation throughout the Paro Valley.

It is therefore advisable to first take up a pilot project to increase the understanding of the local farmers by demonstrating the positive effects of farmland consolidation. At the present, the farmers are most anxious about the redistribution of land accompanying land substitution. Thus transferring the know-how involved in land substitution will be critical, and facility consolidation should be planned on a level that will enable the Bhutan side to implement it on its own in the future.

Regarding implementation of the project, the judgment was made that it be implemented with the assistance of the Japanese Grant Aid. There are two reasons for this judgment: (1) the project components requested by the Government of Bhutan were thoroughly examined and confirmed in the above examination during the course of the establishment of the master plan in Phase 1, and (2) benefits of the project and its suitability for implementation by Bhutanese agencies were fully confirmed. In the following sections, on condition that the Grant Aid by the Japanese Government would be extended to the project, the general outline of the plan will be examined, after which the basic design will be carried out. But with regard to the content of the plan, it is appropriate that the facilities requested should be altered in part as noted in the above discussion on the request.

4.3 Outline of the Project

(1) Agencies for Implementation and Maintenance

Zonal Administrations, as noted earlier, were established to realize the objectives of the 6th National Development Plan. Their organization is shown in Fig. 4.1. The Paro Dzong will be the agency in charge of post construction maintenance. But actually, facilities will be maintained on behalf of the government by the staff of the six existing Agriculture Extension Centres and by the water user associations organized by the beneficiaries of the various waterways. The typical water user association consists of the following members:

- Village Headman 1

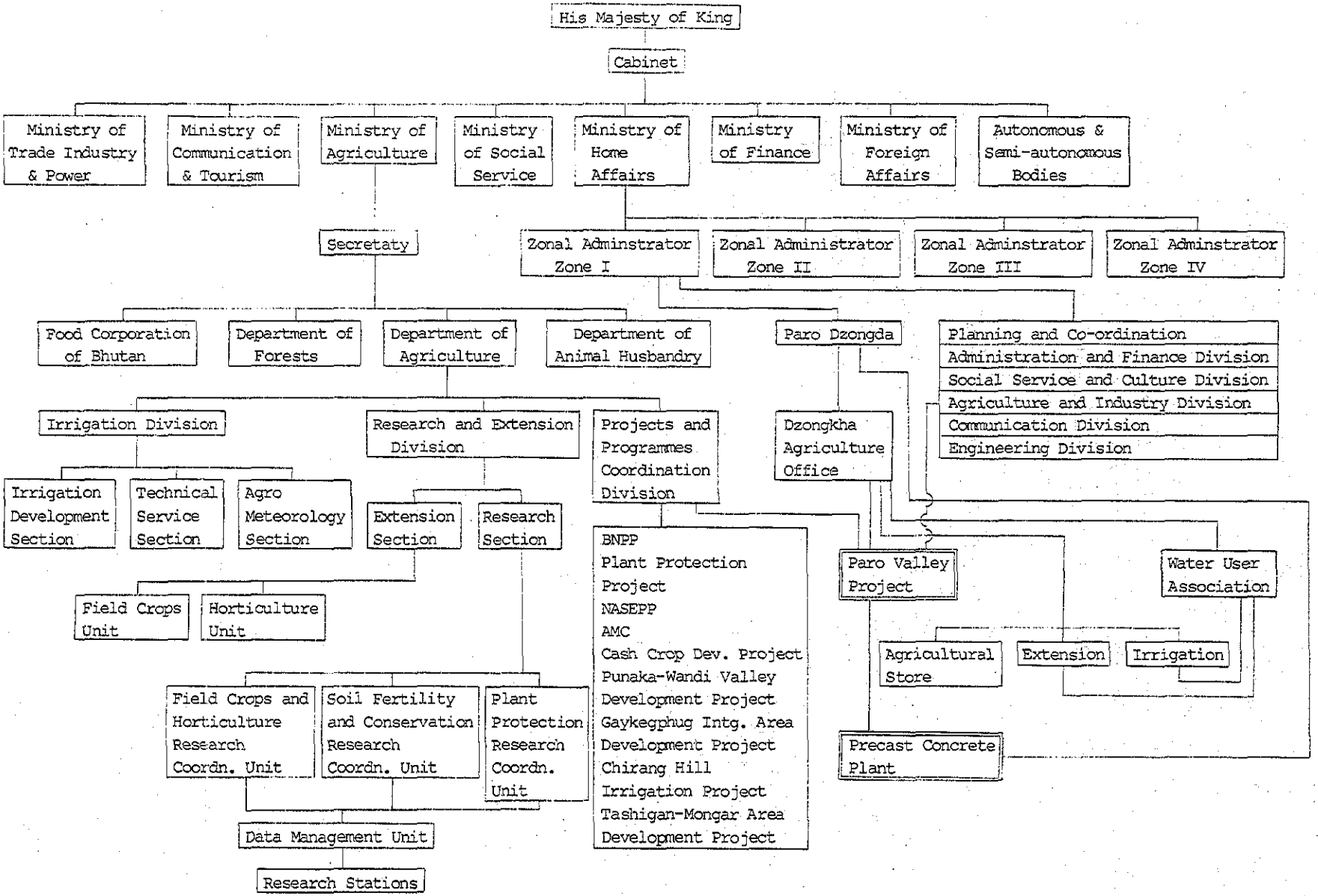


Fig. 4.1 STRUCTURE OF GOVERNMENT

- Irrigation Engineer 1
- Agriculture Extension Worker 1
- Secretary 1
- Accountant 1
- Paid Caretaker 1

A precast concrete plant is scheduled to be operated subsequently under government management. The staff of the plant will consist of about 15 workers. The construction machinery procured for the project will be used under the management of AMC in agricultural development projects in other areas after the completion of this project. Twenty machine operators and 15 repairmen are scheduled to be trained for the project. They will be also slated to be employed by AMC and to work for other agricultural development projects after this project. Training for 30 persons in total, mainly composed of 22 persons being staff of AMC, was commenced in Geylegphug Area Development Project in January 1990. It is scheduled that persons for training be increased in number, and workshop and storage yard for equipment and machinery be expanded and improved.

(2) Project Components

Components of the project based on the objective and schedule described in the preceding sections are given below.

a) Irrigation Facilities

Each facility is capable of supplying the area benefiting from it 4.73 ltr/ha/sec of water from the Paro River, the Dotey River and other mountain streams. Since this amount of water is the maximum required for paddy growing, it is enough to meet the water needs of all other crops. To secure this capacity, a plan was made to either improve or build anew, depending on the condition of each facility, intake, channels, diversion facilities, and water shedding adjustment and control facilities. To ensure their maximum performance, maintenance and repair are indispensable, for example, removing trash from screens, removing sand that has settled at the bottom of settling basins, weeding along waterways and replacing old gates.

b) Farm Roads

The proposed roads are main farm roads and so approach roads connecting them to farmlands will have to be built by the farmers themselves. Since the farmers in the Paro Valley area are all well-informed and very positive about agricultural mechanization, it is believed that the farmers will actively build approach roads.

The proposed farm roads are slated to be one-way gravel roads 3.0 m in width, with an expected daily traffic volume of around 100 vehicles. It is hoped that these roads will foster agricultural mechanization and serve as roads for transportation of agricultural products and agricultural input. To preserve the optimum functioning of these farm roads, maintenance of the paved surface, gutters and slopes will be indispensable. It will be particularly important to make certain that the roads will be able to adequately drain water during the rainy season.

c) River Protection

Revetments are planned with top priority placed on the protection of farmland. Both the Paro and Dotey rivers are rapid streams, and their enormous power to sweep away obstacles on the riverbed accelerates changes in the riverbed, so that revetments and the safety of farmland will be greatly affected by the condition of the riverbed. Thus it is necessary to deal with obstacles, such as reduced cross-section and meandering rapids, even after revetments have been installed.

d) Farmland Consolidation

Irrigation facilities for farmland have the same function as the irrigation facilities noted earlier. Since this is the first farmland consolidation pilot farm in Bhutan, to gain the understanding of the beneficiaries, farmers in general and the organization concerned, it will be necessary to continue monitoring the project.

(3) Outline of the Facilities

a) Irrigation Facilities

Irrigation channels to be rehabilitated within the scope of the project are as follows:

Name of Channel	Length in m	Command area in ha
Shaba Shengo	1,906.0	10.11
Shaba Bara	2,240.0	18.20
Dujey Dingkha	1,672.0	28.20
Serekha	1,398.2	32.00
Tshetey Yuva	666.9	19.60
Kempa Tangaul	1,912.0	15.90
Gesse Chawa	1,623.0	34.00
Sharimochu	1,230.0	24.00
Gangyul	2,547.0	21.60
Damjimayu	2,390.0	42.00
Jangsa	5,234.0	60.80
Chendo Chukha	2,990.7	48.00
Bamdoley	1,904.0	40.00
Kothuphu Tangyu	837.0	24.20

b) Farm Roads

The following routes are all scheduled to be constructed as new farm roads under the project:

Name of Route	Length in m	Benefited area in ha	No. of farmhouses
Bamdoley = Jangsa	6.5	116	95
Sa-Tsan Chorten = Tshongdu	8.6	310	174
Nyemi-Zam = Khangku	1.7	43	38
Name of Route	Length in m	Benefited area in ha	No. of farmhouses
Bondey = Gebji	1.6	50	20
Shorten Sarpa = Deankha	3.3	50	32

c) River Protection Works

Name of Route	Distance in km	Site
Chuba & Atso = Shangsa	3.7	Right bank of Dotey River
Bamdoley = Jangsa	6.8	Left bank of Paro River
Sengo-Tsekha = Sorten-Sarpa	3.0	Left bank of Paro River
Nyemi-Zam = Khangku	1.75	Right bank of Paro River
Gyebjana Rongchu	2.05	Right bank of Gyebjana Rongchu

d) Farmland Consolidation

Land readjustment, setting up of farm roads and installation of irrigation canals are to be carried out on farmland of 18.50 ha in area in Changkha-Thang.

(4) Maintenance Plan

After their guarantee period, the facilities should be handed over to the aforementioned water user associations (WUA) for operation and maintenance. The WUA will normally be convened once a month, and an engineer from Dzongkhang will be assigned to travel around the various blocks to inspect the facilities.

Under normal conditions, weeding and cutting down of bushes on the slopes of channels, farm roads and river protection works, removing of sand from channels and road gutters and other maintenance work will be performed twice a year, once before and once after the rainy season. The damaged parts of each facility will be repaired under the direction of WUA. Labor costs shall not be paid for this work since it will be regarded as community work. Since the construction of the facilities will be carried out by enlisting the participation of their beneficiaries, it is expected that the necessary maintenance know-how will be transferred to them. Materials for performing repair work will be stored in the Agriculture Extension Centres and supplied whenever the need arises. The materials supplied by the centres and their estimated annual quantities are shown below.

U-shaped flume (U-300)	:	40
" " (U-450)	:	20
L-shaped flume (L-600x300)	:	20
Cement (50 kg)	:	10 sacks
Gabion material	:	100 meters

Approximately 60 cu.m of crushed stone is estimated to be used annually for repairing roads, and this amount will be supplied by the crushing plant. The cost is estimated to be around ¥ 300,000- (Nu. 34,880-) per year. A fund for operation and maintenance should be set up and administered by WUA. During a five-year establishment period from

handing over of the facilities, the government will contribute to the operation and maintenance costs of the facilities, starting with a 50% share of total costs in year 1 and dropping to 10% in year 5 and zero in year 6. The materials stored in warehouses will be managed by using the existing Agriculture Extension Centres. There is no plan to appoint anyone to perform this duty full time.

The construction equipments will be transferred to AMC, and their maintenance will be carried out under the normal budget.

Chapter 5. BASIC DESIGN

5.1 Irrigation Facilities

5.1.1 Design Policy

Firstly, the system of irrigation channels will be examined. The channels need to recover their necessary functions. Water management shall be carried out in order to meet local demand. The following items, therefore, shall be considered:

i) Security of water intake,
ii) Discharge capacity,
iii) Division, confluence and control of channel water,
iv) Security of irrigation channels,
v) Water management,
vi) Economic efficiency of repair and operation costs, and
vii) Conservation of the environment.

Design Policy of Each Facility

1) Intake Facility

At the proposed sites for channel intakes, the present longitudinal riverbed gradients are 1/80 - 1/200 in the Paro and Dotey rivers. Their tributaries, on the other hand, the Rong, Ri and Gebiolumi, have much steeper gradients of about 1/10. The riverbed material is boulders with diameters of 30-50 cm on average, and sometimes reaching a maximum of 2m. The Paro and Dotey water courses are unstable in particular at their middle reaches and thereafter. The water routes are thought to have been changed every year by floods and sedimentation. Basically, it appears that subsidence of the riverbeds is occurring. Accordingly, reform of the intake facilities are to consist of i) protection of riverbed subsidence and stabilization of intake water level by construction of a low-height diversion weir made of concrete and by mattress work, ii) stabilization of waterway with groins, and iii) securing intake facilities by revetment work around each facility.

As for the height of the diversion weir, in general a higher one is preferable when one considers incoming earth and sand. In this project, however, it is planned that the height be lowered as much as possible from the viewpoint of soil sedimentation upstream of the weir, drainage capability owing to the backwater close to the weir, and fish (mainly brown trout) going up the river. Incoming earth and soil will be prevented by constructing settling basins for sand or gates for drainage in waterways.

2) Channel Works

Channel works in the project consist of open channels made of wet masonry, earth, and steel plates, conduits, water bridges, siphon works, drops, chutes, etc.

Present problems on the existing channel works are:

a) Many channels are made of earth, and most of the channels have irregular cross-sections and variable longitudinal gradients at several points.

b) Where open channels pass through mountains, there has been considerable channel-collapse, and a great deal of sediment has built up in the channel due to slope erosion.

c) At the above points, alteration of the channel route is almost impossible since it would result in the enlargement of the slopes.

d) Open channels installed along the rivers easily slip down due to river slope erosion.

e) There is a great deal of sediment in channels due to lack of facilities for settling basins/drainage.

As a result, channel reform will involve, i) modification of cross-sections in places where the present area is insufficient, ii) modification of longitudinal gradients, and iii) improvement and strength-

ening of river revetments.

3) Facilities for Distribution, Regulation and Confluence

Most of the present division works merely consist of openings in channel walls, and there are practically no facilities with water gates, in particular regulating gates for controlling water levels. Water levels have been controlled up until now by putting stones into channels.

The type of crossing of the existing channels is a level crossing, not being over/underpass types, at all points, with the exception of Damjimayu Channel. There are no permanent facilities made of materials such as concrete, and channels at some places have broken through their walls.

To make openings in channel walls for division works without due consideration would result in excess distribution, and in particular doing it upstream would cause a water shortage downstream. Hence, permanent facilities made of concrete or wet masonry will be planned for channels which have many upstream division points. The regulating gate to maintain water levels will be of wooden stop-logs, taking future replacement costs into consideration.

The crossing will be done by means of confluence facilities, taking into consideration the most effective use of the discharge of the stream, although there are alternatives of the underpass method and over-shoot work.

4) Protection Facilities

As mentioned above in item 2), slope protection works and additional construction of settling basins and drainage gates are necessary for proper management of the channels. They will be arranged in order to facilitate operation and maintenance.

5) Maintenance Facility

In the project, wooden stop-logs will be installed at water intake

points for the convenience of cleaning of channels and for other maintenance, although it will be necessary to construct maintenance roads and install screens in the future.

5.1.2 Study of Design Conditions

(1) Hydraulic Conditions

1) Design Discharge

Sizes of facilities are to be in principle determined based on the maximum design discharge of water demand. However, in the event of incoming water, facilities for confluence and overflow should also be considered. The maximum design discharge of channels is to be based on the product of a unit of water requirement for paddy fields, 4.73 lit/sec/ha, and command areas. The maximum design discharge for each channel is given in Table 5.1. (For more detail, refer to Annex 11).

TABLE 5.1 MAXIMUM DESIGN DISCHARGE

Sl.No.	Name of Channel	Command Area in ha	Maximum Design Discharge in cu.m/sec
1	Shaba Shengo	10.11	0.048
2	Shaba Bara	18.20	0.086
3	Dujey Dingkha	28.20	0.133
4	Serekha	32.00	0.151
5	Tshetey Yuva	18.51	0.088
6	Kempa Tangyul	15.90	0.075
7	Gesse Chawa	34.00	0.161
8	Sharimochu	24.00	0.114
9	Gangyul	21.60	0.102
10	Damjimayu	42.80	0.202
11	Jangsa	60.80	0.288
12	Chendo Chukha	48.00	0.227
13	Bamdoley	40.00	0.189
14	Kothuphu Tangyu	24.20	0.114

2) Velocity

a) The minimum permissible velocity

- For open channels
  - earth channels : More than 0.7 m/sec, preventing sands from settling and plants from growing
  - concrete or steel channel : More than 0.5 m/sec

- For box culverts : 1.3 times open channels
- For siphons : 1.5 times open channels

b) The maximum permissible velocity

- For earth channels (consisting of sandy clay) : 1.2 m/sec
- For channels made of wet masonry or concrete : 3.0 m/sec
- For precast concrete flumes : 1.5 m/sec
- For steel-corrugated flumes : 3.0 m/sec

3) Hydraulic Design

a) Hydraulic Formula

The following formula, the Manning Formula, will be used for the calculation of design discharge and dimensions of open channels.

$$V = 1/(n \times R^{2/3} \times I^{1/2})$$

where V : average velocity of flow in m/sec
R : hydraulic radius in m
n : roughness coefficient of the channel
I : hydraulic gradient (slope of channel)

The following formula, the Hazen Williams formula, will be used for pipeline planning.

$$i = 10.666\ C^{-1.85}\ D^{-4.87}\ Q^{1.85}$$

where i : hydraulic gradient
C : velocity coefficient (polyethylene pipe : 150)
D : pipe diameter in m
Q : discharge in cu.m/sec

b) Roughness Coefficient

The roughness coefficient to be defined with type of material and condition of the channel is as follows. For the project, maximum values of the coefficients are employed, considering that channels have considerable meandering and will have sand deposits.

Material of channel and condition	Coefficient
Concrete and wet masonry	0.016
Concrete (Precast flume)	0.016
Steel plates (Smooth surface painted)	0.017
Steel plates (Corrugated surface)	0.030
Earth (with some weeds)	0.033

c) Loss of head

In the hydraulic calculation, as a general rule, losses caused by i) friction, ii) inlet and outlet, iii) change of cross section, and iv) screen are to be considered.

d) Freeboard

In general, freeboards are determined with consideration of i) change of roughness coefficient on account of age and accuracy of the work, ii) change of dynamic head into static head, and iii) height of waves caused by wind. In the project, the following freeboards are employed, considering that channels are small in scale.

Height of channel in mm	300-450	500	600-1,300
Freeboard in mm	50	100	150

(2) Structural Conditions

As no design standards exist in Bhutan, structural conditions such as loads, foundations, climatic conditions, etc., will be based upon the "Design Standards for Land Improvement Projects (Water Canals No.1), 1986" established by the Agricultural Structure Improvement Bureau, the Ministry of Agriculture, Forestry and Fisheries, Japan, taking local work conditions and economical efficiency into account.

1) Loads

Various loads such as dead load, live load, water pressure, buoyancy or uplift, earth pressure, truck load, dynamic load and crowd load will be selected for consideration, according to the type of structure, materials to be used, sites of structures, work conditions, transportation conditions of materials, environmental conditions, etc.

a) Dead Load

The following unit weight will be used for calculation of dead loads:

Materials	Unit weight in ton/cu.m
Steel	7.85
Reinforced concrete	2.50
Plain concrete	2.35
Water	1.00
Earth	1.80

b) Earth Pressure

In principle, Ranking's Formula will be used.

c) Truck Load and Dynamic Load

- Truck load : 14 ton truck at crossing points of farm roads.
  9 ton tractor at other places.
- Dynamic Load :

Earth covering in m	Less than 1.5	1.5-2.5	Above 2.5
Coefficient of Impact	0.4	0.3	0.2

d) Crowd Load

The crowd load is set as 300 kg/sq.m, and it is supposed that crowd load would not occur simultaneously with truck load.

5.1.3 Basic Design

A basic design of 14 irrigation channels was carried out based on the survey results of Phases 1 and 2. The outline of the 14 channels is described in 4.3.(2) "Project Components", and the location of the channels is shown at the top of the Basic Design Drawings.

(1) Jangsa Channel

1) Intake Facilities

An old intake facility located 57 m upstream of the starting point (Point No.0) of the open channel has been out of service because of soil and sedimentation, and at present water intake is tentatively done

through a wooden opening on the gabion wall placed in a temporary earth channel starting at Point No.4+15.5. The required water level at the intake point is +2,324.18 m and the elevation of the channel bed is +2,323.0 m. Thus, a weir with a height of about 90 cm is necessary for water intake, considering the 30 cm of water depth. For the purpose of stable intake, it is necessary to construct a fixed weir made of 4-step wooden mattress, in addition to the component decided in Phase 1.

Judging from the river discharge conditions, location of the intake should be at the present intake site. At the intake site, a chamber for settling basins should be constructed, judging from sediment conditions downstream.

2) Channel

The span between Point No.110+8.8 and a point of the open-channel end is of zinc plates with wooden frames, forming a rectangular cross-section. The channel was constructed by farmers with government assistance in the supply of the materials. At present, it is leaking in several places and is in urgent need of repair. The reformed structure of the said span is planned to be of smooth steel-plate flumes, as a result of a study of the present cross-section, the minimum permissible velocity, discharge capacity, ease of construction work and construction cost. The channel's cross-section dimensions are given in Table 5.2. Parts of wet masonry, steel plates and structures being at section-turning points are scheduled to be partly reformed.

3) Division Works

Most of the division works of the channel are made in spans of wet masonry structure. Although there is some sediment at the large-scale division sites, rehabilitation of the division works will not be taken up by this project, since the sedimentation is minor and will not seriously affect the channels' function. However, division works for domestic water supply in 5 sites on steel-plate spans, and for drainage/division in 2 sites attached to channel chambers, will be reformed together with work on the channels.

4) Slope Protection Facility

Slope protection work will be executed on spans of Points No.169+14.0 to No.170+8.0 and Points No.249+10.5 to No.249+14.0 where slope sliding has occurred.

(2) Chendo Chukha Channel

1) Intake Facility

As the channel water level is +2,348.77 m at the intake site, the river water level must be +2,348.80 m. In the dry season, the river water level at this point is +2,348.3 m to +2,348.4 m, so the water level should be raised by 50 cm by means of a backwater created by a weir. The height of the weir is to be 1.8 m. Considering the height of the weir and the conditions of the Paro River at this point, viz., the riverbed is composed of boulders and cobblestones which are more than 50 cm in size, the weir shall be strong and made of concrete, rather than simple wooden mattress. Since the height of the weir is comparatively high, it is to be equipped with a fish-way.

2) Channel

The channel is made of wet masonry in the span between Points No.15+8.0 and No.25+1.0, and of earth in other spans with the exception of strategic points where the channel is made of wet masonry. The plan of the reform of the main spans is as follows:

The span between the starting point and Point No.2+10.0 has gentle gradients like natural slopes. That permits a slow inlet velocity, which is convenient for the prevention of grit coming in. As the left bank of the span has steep slope sides, ideally, the channel route should approach from the right side. Thus, this span shall be made of precast concrete flumes (L-600x300), with a channel gradient of 1/400.

The span between Points No.2+10.0 and No.7+0.0, having a steep gradient of 1/24, is planned to be of concrete, since an earth channel is unsuitable from the viewpoint of erosion and the drop work for the

slope-adjustment is inferior in terms of grit sediments and construction cost. Here, the cross-section of the channel is planned to be same as that upstream, and larger freeboards will be necessary.

In the span between Points No.7+0.0 and No.15+9.0 there exist a partial flume, an overflow, a one-side channel wall and pedestrian bridges. Some parts are occasionally flooded by water coming from upper side-slopes where no protection work was done. Further along in this span, there are steep slopes on the left bank and the Paro River is located near the right bank, making space narrow and land unstable. Thus, this span is also planned to be reconstructed with precast concrete flumes (L-600x300). Its gradient is designed as 1/250.

The span between Points No.15+8.0 and No.25+1.0 is of wet masonry as described before, and has 2 points where slope protection has been done and a repaired site.

Other spans, Points No.25+1.0 to No.90+0.0 (channel-bed gradient I=1/250), Points No.90+0.0 to No.120+0.0 (I=1/90), and Points No.120+0.0 to the terminal No.149+10.7 (approx. I=1/55) are planned to be an earth channel, as are parts having insufficient or irregular cross-section areas.

3) Division Works, Facilities for Control and Confluence

a) Division Works

The channel has 47 division works for irrigation and 1 for another purpose. Most of the facilities are made of wet masonry, and there has been no serious damage to them, although some are partially broken. It is believed that they will be maintained and repaired by beneficiaries of their functions and so they will not be part of the project.

b) Control Facility

It is proposed that a spillway be constructed at Point No.7+0.0, since the intake weir there is of a fixed-weir type and excess intake is feared due to drop-down likely to be caused by steep gradients near

the intake. The spillway will have the dual functions of serving as a stilling basin and setting basin.

c) Confluence Facility

There are 2 confluences along the channel. One is the existing structure, made of wet masonry, which functions as a distribution facility, and the other is that described in the preceding section.

4) Protection Facility

Protection facilities required in this channel are i) slope protection work on the left bank in the spans between Points No.12+0.0 and No.13+17.0, Points No.18+5.0 and No.18+13.0 and Points No.19+8.8 and No.19+13.6, ii) river revetment work on the Paro River in the span between Points No.13+0.0 and No.15+0.0 and iii) crossing drainage work at Point No.140+5.0. They are proposed to be worked into the project taking the safety of the channel into account.

(3) Bamdoley Channel

1) Intake Facility

Based on the water level of +2,353.18 m at the starting point of the channel, the river water level needs to be above +2,353.28 m. As the water level of the river in the dry season is +2,352.2 m - +2,352.0, the water level has to be raised by 100 cm by means of a weir to be constructed in Stage 1. The weir will be made of cobblestones and boulders. Water depth at this point of the Paro River exceeds 3 m, even in the dry season, hence the height of the weir is to be above 4 m. Around the site, rolling rocks of 2-3 m are commonly seen, and deeper depths continue about 300 m downstream. If the weir was merely planned for irrigation intake, a fixed-weir type concrete weir would be considered. However, taking into account the difficulty of construction, which would involve temporary construction, construction costs and protection of fish, a weir made of concrete would not be effective. Consequently, the weir is planned to be made of stone masonry work.

2) Channel

The existing channel is made of wet masonry in the span between the starting point and Point No.38+0.0, and of earth in most of the remaining parts. The rehabilitation plan is described as follows:

In the wet masonry span, from the starting point to Point No.38+0.0, the longitudinal gradient is almost constant. The cross-sections can be classified by 5 spans. Hydraulic calculations showed that sections below Point No.2+0.0 are insufficient. Located at a narrow point, this span should be rehabilitated with L-shaped concrete flumes (L-600x300). The gradient is planned to be 1/800, a little steeper than that of the present one, in order to minimize excavation volume.

Also in the span between Points No.38+0.0 and No.53+0.0, the cross-section is insufficient. This span will be rehabilitated as an earth channel having a cross-section of 600 mm bottom width x 600 mm height, a slope of 1:1, and a channel gradient of 1/800.

The span between Points No.53+0.0 and the terminal point is of steeper gradients and of inverse gradients at many points. The rehabilitation will be carried out partially to create a gradient of 1/80 so as to keep the flow velocity within permissible levels.

3) Division Works, Facilities for Regulation and Confluence

a) Division Works

The channel has 9 division works for irrigation. Most of them merely consist of openings in the earth wall and have almost all deteriorated. They are to be rehabilitated together with channel rehabilitation work.

b) Regulation Facility

An overflow weir as a regulation facility exists at Point No.18+16.0. It is planned to be rehabilitated as a settling basin, together with the channel rehabilitation work.

c) Confluence Facility

The channel crosses a valley stream at Point No.34+15.0. The possibility of the entire flow of the valley stream pouring into the channel in times of flooding, is a risk for the channel, as the valley has a wide area of 4.5 sq. km. Accordingly, the confluence facility will planned so that an ordinary flow of the stream enters the channel, but in the case of flooding it bypasses the channel by way of a grade separation.

4) Protection Facility

There exist seven blow-offs for operational purposes, of which one of them has a settling basin. Four of them were constructed by beneficiaries. Some are installed in orchards. All of them will be rehabilitated in the project.

Slope protection work will be required in five spans, totaling 55.5 m in length.

(4) Kothuphu Tangyu Channel

1) Intake Facility

As the present structure permits the intake of water, the construction of a weir for intake purposes will not be considered. The Paro River in the vicinity of the channel is changeable in terms of its riverbed. It is, therefore, not expected to be possible to take in water at a steady level by rigid structures which would require higher construction costs. In the project, the present facility, formed of cobblestones on the riverbed, is planned to be replaced with gabions.

2) Channel

In addition to the intake point, a span between the starting point and Point No.7+10.0 of the present channel is made of cobblestones. It will be replaced by a gabion wall for the same reason as that of the

intake facility. The left bank of the channel is a slope which has been eroded by the river and which has collapsed in some places. The channel wall on the slope side is therefore scheduled to be rehabilitated with gabions which will have the additional role of protecting the wall.

The span between No.7+10.0 and the end of the channel will not be rehabilitated, with the exception of a drop work at Point No.41+10.0.

3) Division Works, Facilities for Confluence

a) Division Works

In the channel there are four division works, openings in the earth channel wall. Although they are in poor condition, rehabilitation work is to be left to the beneficiaries, since the work is not all that heavy.

b) Confluence Facility

The channel is crossed by two small streams at Points No.13+10.0 and No.40+5.0. These points will be treated in addition to the division works, since the catchment area of the stream is very small.

4) Protection Facility

Three sites, totaling 75.0 m in length in the span between Points No.7+10.0 and No.14+0.0, need slope rehabilitation and will be repaired with gabions.

(5) Kampa Thangyul Channel

1) Intake Facility

Judging from the water level of +2,299.44 m at the starting point of the channel, the water level of the river needs to be +2,299.54 m. As the river water level in the dry season is around +2,298.5 m, the height of the required weir will be 1.50 m. It will be made of five-

stepped wooden mattress.

2) Channel

The channel is such that its gradient is almost constant from the starting point to the end and most of the division works are gathered in the downstream part. Accordingly the channel gradient is planned to be 1/105, almost the same as the present one.

The route of the span between the starting point and Point No.6+0.0 needs to be moved on account of rehabilitation of the farm road. Two spans between Points No.6+0.0 and No.20+0.0, and between Points No.28+0.0 and No.41+0.0 will be the bank after channel rehabilitation work has taken place. At present, many cobblestones enter the channel and rehabilitation of the earth channel is judged to be difficult. In place of that, concrete U-shaped flumes (U-300) will be used for the channel.

The span between Points No.51+0.0 and No.89+15.0 is planned to be of earth channel, since the work will be done by means of earth-cutting.

3) Division Works

There are 41 division works for irrigation purposes in the channel. Most of them are openings on the earth walls and are in poor condition. They are to be rehabilitated together the with channel rehabilitation work.

4) Protection Facility

The existing channel does not have a settling basin. Judging from the present condition of the old intake facility of Jangsa Channel, entry of silt into the channel cannot be avoided. Thus, a settling basin is planned to be constructed at Point No.6. There are no suitable drainage channels around the channel and sand removal work is to be performed manually. Therefore, the settling basin will be situated along the farm road in order to facilitate the sand removal work.

(6) Gesse Chawa Channel

1) Intake Facility

Judging from the water level of +2,308.35 m at the starting point of the channel, the water level of the river needs to be +2,309.45 m. As the river water level in the dry season is around +2,309.0 m, the height of the weir required will be 0.85 m. It will be made of four-stepped wooden mattress.

2) Channel

The entire channel is made of earth. Major spans to be rehabilitated are as follows:

The span between Points No.0+0.0 and No.1+0.0, a connecting point of the intake facility and the succeeding settling basin, will be rehabilitated by means of concrete U-shaped flumes (U-450).

A span between Points No.1+10.0 and No.5+0.0 is a swampy pond with a width of about 20 m. The pond will be filled with soil and an earth channel will be reconstructed in its place.

The span between Points No.5+0.0 and No.15+0.0 and the span between Points No.20+0.0 and No.45+0.0 will be rehabilitated by means of excavation. Hydraulic analysis showed that the present channel cross-section of the latter was insufficient in discharge capacity.

The span between Points No.58+0.0 and No.65+0.0 showed considerable leakage in the field survey period. The span between Points No.58+0.0 and No.62+15.0 and the span between Points No.62+15.0 and No.65+10.0 will be made of concrete U-shaped flumes (U-300) because the former site is too narrow and the latter is in need of banking.

The span between Points No.65+10.0 and No.69+0.0 has steep gradients and the flow velocity in the channel exceeds the permissible velocity of the earth channel. Furthermore, this span is to be banked with earth. Thus, the span will be rehabilitated with concrete U-shaped

flumes (U-300).

The span between Point No.69+0.0 and the end of the channel will be rehabilitated in the same way as the above, for the same reason.

3) Division Works and Facilities for Confluence

a) Division Works

There are 25 division works for irrigation purposes in the channel. All of them are openings on the earth walls and are in poor condition. They are to be rehabilitated together with the channel rehabilitation work.

b) Confluence Facility

There four confluences in the channel, all of them have small streams and drain from paddy fields. The water is to be safely fed into the channel to be rehabilitated and utilized as an effective water source.

4) Protection Facility

This channel also does not have a settling basin. As in the case of Kempa Tangyul Channel, construction of a settling basin is planned between Points No.1+0.0 and No.1+10.0.

(7) Damjimayu Channel

1) Intake Facility

Judging from the water level of +2,280.80 m at the starting point of the channel, the water level of the river needs to be +2,280.90 m. As the river water level in the dry season is around +2,280.2 m, the height of the required weir will be 0.70 m. It will be made of four-stepped wooden mattress.

2) Channel

The span between the starting point and Point No.13+0.5 is made of wet masonry and other spans are mainly of earth, Facilities such as the intake facility are made of wet masonry. The channel is crossed by the national highway between Points No.23+7.5 and No.23+18.0, and by the Sharirong River at Point No.50. Major rehabilitation plans are as follows:

The span between the starting point and Point No.8+0.0 needs to be relocated on account of rehabilitation work on the farm road. Although a section of U-450 flume will provide enough discharge, this span is planned to be rehabilitated with concrete L-shaped flumes (L-600x300), taking the gentle gradient of the subsequent parts into account.

The span between Points No.8+0.0 and No.23+7.50 has inverse slopes in the latter parts. In order to reform them to proper slopes, the span is planned to be made of concrete L-shaped flumes (L-600x300) on earth banking.

The span between Points No.23+7.5 and No.23+18.0 is a site of grade separation with the national highway and a small drainage line. Based on the hydraulic analysis, the present structure was found to be sufficient as it stands, without the need for additional work.

The span between Points No.23+18.0 and No.50+0.0 will be consolidated by a 600x600 earth channel, and the span between Points No.59+0.0 and No.90+0.0, by a 500x400 earth channel.

Spans between Points No.90+0.0 and No.100+0.0 and between Points No.100+0.0 and No.117+0.0 will be 300x300 earth channels.

The span between Points No.117+0.0 and No.119+10.0 (the end of the channel) will be of concrete U-shaped flumes (U-300), since flow velocity will exceed the maximum permissible one.

3) Division Works and Facilities for Confluence

a) Division Works

There are 53 division works for irrigation purposes in the channel. They are to be rehabilitated together with the channel rehabilitation work.

b) Confluence Facility

There are nine confluences in the channel, all of them being of small streams and draining from rice fields. The water is to be safely fed into the channel to be rehabilitated and utilized as an effective water source.

4) Protection Facility

A settling basin exists at Point No.15+10.0. It is planned to be elevated, together with the channel rehabilitation work.

At a crossing point with the Sharirong River, between Points No.48+16.8 and No.50+0.0, the lower part of the channel, about 10 m, has collapsed. This is judged to be a result of subsidence of the river-bed. Rehabilitation will be carried out by using a siphon structure protecting revetment 170 m long as well as plain concrete bedding.

(8) Shaba Shengo Channel

1) Intake Facility

Judging from the water level of +2,208.75 m at the starting point of the channel, the water level of the river needs to be +2,208.85 m. As the river water level in the dry season is around +2,207.6 m, the height of the weir required will be 1.15 m. It will be made of five-stepped wooden mattress. A collapsed span, which makes up a 3 m length of the present intake facility, is to be rehabilitated.

2) Channel

The channel includes many spans made of wet masonry, totaling 720.1 m in length. There are three major spans (Points No.0+0.0 to No.12+10.0, Points No.32+3.8 to No.35+17.8, and Points No.47+15.0 to No.66+1.0) and

four other minor spans. In the planning of the channel rehabilitation, spans made of earth, other than the above masonry spans, will be so designed that the wet masonry spans will not be changed. The spans to be rehabilitated are as follows:

The span between Points No.12+19.4 and No.16+8.6 will be replaced with concrete L-shaped flume (L-600x300). Thus, the backwater caused at Point No.17 will not stretch back as far as Point No.15.

In addition to the above, the span between Points No.16+18.2 and No.17+9.2 is to be replaced with concrete L-shaped flumes (L-600x300) having smooth wall surfaces.

The span between Points No.20+7.8 and No.32+3.6 is insufficient in cross-section area and passes through the foot of a mountain. This span will also be replaced with concrete L-shaped flumes (L-600x300) which has a strong structure.

The span between Points No.67+2.0 and No.82+0.0 has an irregular longitudinal gradient and will be rehabilitated with earth.

The span between Points No.82+0.0 and No.88+0.0 is on a steep slope. The span will be rehabilitated with concrete U-shaped flumes (U-300) in order to avoid channel body erosion.

3) Division Works and Facilities for Confluence

a) Division Works

There are 25 division works for irrigation purposes located along the channel. They are to be rehabilitated together with the channel rehabilitation work.

b) Confluence Facility

The channel has an inlet at Point No.2+9.7, which was made by knocking down a small part of the channel wall. Water from the inlet comes from a small paddy field of about 0.1 ha and will not damage the

channel. The inlet will merely be renovated.

4) Protection Facility

There is an existing settling basin from Points No.12+10.0 to No.12+19.4. It can be rehabilitated easily by the beneficiaries with minor work and will not be included as part of the project.

(9) Gargyul Channel

1) Intake Facility

The Sharirong River, a tributary of the Dotey River, is the channel's water source. Based on the water level of +2,407.35 m at the starting point of the channel, the river water level required is +2,407.45 m. The height of the present weir made of cobblestones is 1.75 m. The weir is planned to be reconstructed with concrete, since the weir height is high and the river is rapid. The right bank of the weir has collapsed on the side-slope for about 25 m. The collapse is new and still continuing. The soil is clayey and mixed with stones. To avoid the collapse, it would be necessary to relocate the weir site upstream and to take water from the left bank side. However, this would require the additional work of water transmission from the left bank to the right bank, an increase of construction costs and, in addition, it would cause environmental disruption due to tree cutting associated with the construction work. In conclusion, the collapse of the slope is planned to be repaired on the spot. It will be done by placing gabions at the foot of the slope and wooden pegs and willows trees on the slope, taking harmony with nature into consideration.

2) Channel

The whole of the channel passes through a sloping mountain flank and the longitudinal gradient of the channel is steep. Being made of earth, the channel has many sites which are eroded by water or deformed by grit inflow. The following are sites to be rehabilitated:

The span between Points No.0+0.0 and No.40+0.0 has a very steep

gradient of 1/27 on average and its flow velocity would not be within allowable limits for an earth channel. Construction of drops would be difficult from the viewpoint of topography. Accordingly, the span is planned to be lined with concrete. The channel will be made of wet masonry, due to the difficulty of transportation of concrete flumes to the site.

The span between Points 40+0.0 and No.65+13.0 is planned to be rehabilitated with an earth channel having a 1/42 gradient in order to lessen the steep gradient at Point No.57.

The span between Points No.65+13.0 and No.85+0.0 is in poor condition, particularly in the upstream part. The span is planned to be rehabilitated with an earth channel having a gradient of 1/55.

The span between Points No.85+0.0 and No.87+5.0 will be rehabilitated with wet masonry, since the span has a steep longitudinal gradient of 1/10.

The span between Points No.98+0.0 and No.126+0.0 will be rehabilitated with an earth channel so that the whole span will have a constant gradient and the steep gradient in the part between Points No.107+14.0 and No.110+10.0 will be improved.

3) Division Works and Facilities for Confluence

a) Division Works

There are 14 division works for irrigation purposes and two for domestic water supply. They are to be rehabilitated together with the channel rehabilitation work.

b) Confluence Facility

There is a confluence, from a small stream, at Point No.111+14.7 in the channel. The water is safely fed into the channel and is to be utilized as an effective water source.

4) Protection Facility

There are no settling basins in the channel. A settling basin with a spillway is planned to be constructed at Points No.0+0.0 to No.1+0.0.

(10) Tshetey Yuva Channel

1) Intake Facility

At present, The Paro River around the intake of the channel has the following particular conditions: i) river revetment work, continuing from the airport, has already been done to 110 m upstream of the intake; ii) at the end point of the river revetment, a drainage point crosses a road; iii) on the right bank, the Woochu River enters the Paro River 20 m downstream of the intake, and around that point the maximum water depth is about 4 meters; iv) there is a sand pile with a thickness of 1.4 m and 80 m width on the right bank; and v) there remains an old river course with 2 m depth and 13 m width on the right abutment.

The necessary water level for water intake is +2,220.37 m at the present intake site, and the river water level in the dry season is +2,219.1 m, while the riverbed is +2,218.3 m. Accordingly, the height of the weir needs to be 1.57 m. The height cannot be maintained by wooden mattress, but could be by a concrete weir. However, it is not desirable to construct a weir at this site because the weir foundation would not be securely constructed due to the reason mentioned above in iii). Hence, it shall be relocated, preferably to 60 m upstream of the present intake point, considering the above conditions i) and iii). The other conditions, ii), iv) and v), will not affect the relocation of the weir. The necessary water level for water intake at the new location is +2,220.52 m, and the river water level in the dry season is +2,219.9 m, while the riverbed is 2,219.1 m. Accordingly, the height of the weir needs to be 0.92 m. The height will be maintained by four-stepped wooden mattress to be installed. In relocating the weir, the stability will be improved and construction costs of the weir will be minimized. On the other hand, construction costs for extension work of the channel and river revetment will be increased. However, overall,

the total cost will be lessened.

2) Channel

The channel has gentle slopes throughout its length. There are wet masonry spans between Points No.0+0.0 and No.12+6.5, between Points No.15+5.5 and No.18+16.2, and between Points No.31+9.8 and No.33+6.9. The cross-section of the channel is sufficient for the design discharge through the whole length, although there is a somewhat disordered span between Points No.21+5.5 and No.29+15.4. The span between Points No.15+8.3 and No.20+9.1 passes along houses or under houses and under the national highway. The channel water is at one point discharged into a stream at Point No.20+9.1 and thereafter re-enters the channel at Point No.20+16.5. The re-entry system has an advantage from the viewpoint of effective use of the water source, since the stream keeps flowing even in the dry season, although it is easily polluted by households waste. This span has been left out of the rehabilitation work.

In consideration of the above, the channel is scheduled to be rehabilitated with concrete L-shaped flumes (L-600x300) only in the span from the starting point to 60 m. Its river slope will be protected by gabions.

3) Division Works and Facilities for Discharge

a) Division Works

There is a division work at the end of the channel. It is the sole division to the farmland to be consolidated by the project. According to the farmland consolidation planning, the present division work is planned to be used in its present condition. Thus, rehabilitation work will not be planned for the distribution facility.

b) Facilities for Discharging and Re-entering

There is a discharge point at Point No.20+9.1. The discharge facility has no particular problems and will be used as it is. As the re-entry

facility at Point No.20+18.5 connected with the settling basin, is broken and its anti-sedimentation function is insufficient downstream, it is planned to be reconstructed.

4) Protection Facility

This is as mentioned above.

(11) Shaba Bara Channel

1) Intake Facility

Judging from the water level of +2,297.09 m at the starting point of the channel, the water level of the river needs to be +2,297.19 m. As the river water level in the dry season is around +2,296.8 m, the height of the required weir will be 0.70 m. It will be made of four-stepped wooden mattress. Presently the existing training levee of about 25 m in length leads river water to the intake site because the existing intake site is located at a place where the waterway approaches the right bank. Accordingly, in the project, the training levee is to be rehabilitated and a weir will be constructed 15 m upstream of the existing intake site.

2) Channel

As seen in the span between Points No.0+0.0 and No.3+0.0, the channel has many spans made of wet masonry, located near distribution facilities. Most of them were constructed in 1988-89. The rehabilitation of the channel, therefore, will be done with utilization of the wet masonry spans as much as possible. The following are the main rehabilitation plans. The sectional area upstream will have some allowance, since water shortages will probably occur.

The span between Points No.0+0.0 and No.1+7.0 will take the same route as the proposed farm road and be newly constructed with concrete L-shaped flumes (L-600x300).

The span between Points No.1+7.0 and No.3+0.0 will be rehabilitated at

broken points, since the span is made of wet masonry and has enough sectional area for the design flow.

The span between Points No.3+0.0 and No.21+14.3 also has enough sectional area, but the middle of the span, between Points No.11 and No.17, has a lower slope and the water level upstream of Point No.4+8.5 is not secured. Thus, the span will be rehabilitated with concrete L-shaped flumes (L-600x300).

The span between Points No.21+14.3 and No.12.6 has a steep slope. The span between Points No.21+14.3 and No.23+2.6 is made of stone masonry and will be used in the future as it is. The remaining span is made of earth and so erosion occurs, hence it will be rehabilitated with concrete L-shaped flumes (L-600x300).

The span between Points No.24+12.6 and No.44+0.0 is made of earth and the span between Points No.24+12.6 and No.31+0.0 has undulations in its slope. The remaining span has an insufficient sectional area. As the above matters are not very serious, the span is planned to be repaired with earth.

The span between Points No.44+0.0 and No.46+0.0 is for rapid flow and will be rehabilitated with concrete U-shaped flumes (U-450).

In the span between Points No.46+0.0 and No.89+0.0, the portion from Point No.80+0.0 and beyond will be repaired with earth, since the span is not sufficient in flow capacity.

The span between Points No.89+0.0 and No.112+0.0 has sufficient discharge capacity.

3) Division Works

There is a large number of division works, at 98 points in the channel. All of them are for division to small wet fields. Unless proper water management is done, there will be water shortages. In the project, water stoppers will be installed on division works located in the channel spans to be rehabilitated under the project in order to avoid

water shortages in the downstream area and to improve water management.

4) Protection Facility

The channel has no settling basin nor spillway. Construction of a spillway is considered difficult due to the long distance between the Paro River and the channel. In the project, the intake facility is designed so as not to take excessive water. A settling basin will be constructed around Point No.20+10.00.

(12) Dujey Dingkha Channel

1) Intake Facility

Judging from the water level of +2,215.68 m at the starting point of the channel, the water level of the river needs to be +2,215.78 m. As the river water level in the dry season is around +2,215.2 m, the height of the required weir will be 0.90 m. It will be made of four-stepped wooden mattress. The steep slope on the right bank of the channel has collapsed, ranging from 3 m in height and 20 m in length. The slope consists of sandy gravel with cobbles and the slope length is 15-20 m, with slope angles of 50-70 degrees; thus, controlling the collapse completely is difficult. Soil erosion at the intake site will increase the entry of silt into the channel, making maintenance difficult, and so it is to be rehabilitated. In the project, taking harmony with nature and low construction costs into consideration, the use of gabions, and wooden pegs and the planting of willows on the side slope are planned as means of rehabilitation.

2) Channel

The channel consists of the wet masonry span between the starting point and Point No.24+9.0 and the earth channel span from Point No.24+9.0 and beyond. The wet masonry span is in parallel with the above mentioned steep slope. Main spans to be rehabilitated are as follows:

In the span between Points No.24+9.0 and No.28+0.0, the span from the starting point to Point No.25+16.0 does not maintain the original

channel gradient due to soil sedimentation, and the remaining span has steep slopes. The whole span, therefore, will be rehabilitated with earth to improve the sectional area and slope gradient.

In the span between Points No.52+9.0 and No.77+17.0, the span between Points No.52+9.0 and No.59+0.0 and the span between Points No.69+0.0 and No.77+17.0 are planned to be rehabilitated with a cut-banking earthwork.

The span between Points No.77+17.0 and No.83+14.0 has a steep long-slope part, and work for longitudinal gradient adjustment will be done. It will be rehabilitated with concrete U-shaped flumes (U-300), since the span is to be a banking channel and the flow velocity will reach the maximum for an earth channel, which would cause erosion.

3) Division Works and Facilities for Regulation

a) Division Works

There are 30 division works in the channel. All of them are simple openings on the earth walls. Those which are included in the proposed channel rehabilitation work for the span are to be rehabilitated together with the channel. Others are to be consolidated by the beneficiaries of the channel.

b) Regulation Facility

The present channel is not outfitted with a settling basin or a spillway. But considering sedimentation in the channel at present, construction of such facilities is necessary. They will be located around Point No.27, since land acquisition at or near the starting point is difficult.

4) Protection Facility

The steep slope, as mentioned in the intake facility, continues in the span between Points No.0 and No.24. Along it, the span between Points No.0+0.0 and No.4+0.0 and the span between Points No.7+0.0 and

No.8+0.0, where land erosion has already occurred or is feared, will be protected with slope protection work. Its method will be the same as that of the intake facility.

(13) Serekha Channel

1) Intake Facility

The intake facility exists on the Gebiolumi River. The riverbed slope is 1/20 for 300 m both upstream and downstream from the intake site. There is a cliff consisting of rock having many cracks on the left bank of the river. The cliff, in consideration of the existing intake site, has rocks with relatively few cracks around the intake site and for 50 m both upstream and downstream. On the other hand, the land on the right bank is gentle with a land slope of 1/15 to 1/17 and almost all of it is utilized for paddy fields.

The base of the existing intake facility is placed more than 2 m higher than the riverbed. The original intake facility is assumed to be eroded for several meters by floods.

Under the above conditions, if the original function of the channel is recovered by construction of a new weir at the present intake site, the weir height would be about 2.5 m and the backwater would cause flooding damage to farmlands on the right bank. Accordingly, in the project, it is planned that the channel be extended, with a 1/500 gradient, for 50 m upstream of the existing intake site, and a concrete weir be constructed utilizing rock containing few cracks. In that case, the intake water level is +2,272.03 m and the river water level required would be +2,272.13 m, the elevation of the weir crest would be +2,271.83 m and the weir height about 0.5 m. As there are much grit and many stones in the river and the new weir would be in danger of being covered with them, the weir should be equipped with a blow-off having a fish way.

2) Channel

The span between the starting point and Point No.37+18.1 is on a

relatively steep gradient and is mostly of wet masonry, including drops and chutes. The remaining span is mostly an earth channel having gentle gradients, although including some wet masonry parts. In the project, the earth channel is basically planned to be rehabilitated in order to recover the channel's functions. The following are major plans for rehabilitation:

The span between Points No.(-2)-10.0 (new starting point) and No.0+0.0 will be newly constructed with concrete L-shaped flumes (L-600x300), with a channel gradient of 1/500, together with a protection facility, as mentioned in section on the intake facility.

In the span between Points No.2+17.2 and No.6+3.5, around Point No.4 the channel is filled with sediments which have entered it. Considering the steep gradients and drop-down by drops, the span is planned to be rehabilitated with concrete U-shaped flumes (U-450).

The span between Points No.6+5.5 and No.16+1.6 was found to have an insufficient sectional area to Point No.13 and flow velocity would exceed the maximum permissible one thereafter, as learned from hydraulic calculations. Thus, the span will be rehabilitated with concrete U-shaped flumes (U-450).

The span between Points No.16+9.6 and No.20+18.3 has an insufficient sectional area and will be enlarged to a 400x400 earth channel.

The span between Points No.20+18.3 and No.25+7.0 has not enough free-board and its wet masonry wall will be raised by 5 cm with additional concrete.

The span between Points No.25+7.0 and No.34+19.0 is of earth and its flow velocity exceeds the maximum permissible one, so the span is to be rehabilitated by concrete U-shaped flumes (U-450).

The span between Points No.53+14.0 and No.54+7.0 will be expanded to a 400x400 earth channel, since the present sectional area is small.

The elevation is high for the span between Points No.59+12.0 and

No.69+8.2, and the span will be rehabilitated mainly for the purpose of modification of the channel gradient.

3) Division Works and Facilities for Regulation and Confluence

a) Division Works

There are 14 division works in the channel, and 10 of them will be rehabilitated. Of these, those belonging to a steep gradient channel will have stop-logs to regulate water distribution and water level.

b) Regulation Facility

There are a grit chamber equipped with a spillway and drainage facility at Points No.1+2.0 and No.1+9.8. As it has deteriorated greatly and its present capacity is insufficient, it will be reconstructed.

c) Confluence Facility

There are three inlet points at Points No.4+9.0, No.17+4.0 and No.64+13.0. The inlet at Point No.4+9.0 will be reconstructed for grade separation, since traces of grit sediments were found. The other two inlets will be equipped with confluence facilities for the purpose of effective utilization of water.

(14) Sharimochu Channel

1) Intake Facility

The Shariron River, source of the channel, seeps into the ground at the top of its fan deposit during the dry season. In order to utilize the river water source effectively, it is planned to construct an intake weir upstream at the seeping point. As a result of the field reconnaissance, it was decided to place the location for the intake point around the elevation of +2,387-2,357 m. The location meets the above requirements and conditions of both banks. The weir, with its function of stopping seepage water, will have a deeper foundation, 3 m deep from the ground surface level, at the elevation of +2,354.20 m,

taking the present conditions of topography and grit-stones into consideration. There being many rolling stones around the intake site, many will be deposited upstream of the new weir. Accordingly, the weir height is to be raised to +2,359.80 m, viz., 2.6 m above the ground surface, which is a height that won't disturb land utilization on either bank. The intake water level is set at +2,359.30 m.

2) Channel

The channel had been reportedly located along the Shariron River's right bank, but due to flooding of the river, benefited farmlands and channels were washed away. The channel location, therefore, is planned to be moved to the national highway side, on the left bank of the Shariron River, for easy maintenance. Considering the intake water level of +2,359.30 m, benefited areas and the elevation of the channel, it will have a steeper gradient of about 1/12 or have 50-60 drops, causing higher construction costs, in the case of an open channel. In addition, its life span would be shortened and its water management would also become difficult. Furthermore, benefited areas of the channel are presently not used due to soil sediments from flooding and since the location of branch channels can not be confirmed. In the future, for the purpose of channel construction, a plan of the branch channels will be possible because the sediments will be removed by the project. Thus, the channel is planned to include pipelines which are easy to install, in order to meet the work site conditions. The pipeline system will have two tanks (H=2.5 m) at its terminals and four at turning points. These tanks will be connected with polyethylene pipes (Diameter=225 mm). Tanks other than at the starting point are for distribution to branches and for pressure regulation. The standard covering depth for the pipes will be 60 cm.

3) Facilities for Distribution and Regulation

a) Distribution Facility

Two valves for distribution will be installed at each of the above-mentioned distribution tanks.