JICA

MINISTRY OF WATER RESOURCES
HIS MAJESTY'S GOVERNMENT OF NEPAL

FEASIBILITY STUDY ON RAJKUDWA IRRIGATION PROJECT

MAIN REPORT

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JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF WATER RESOURCES
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MAIN REPORT

NOVEMBER, 1993

NIPPON KOEI CO., LTD
in Association with
HOKKAIDO ENGINEERING CONSULTANTS CO., LTD.

PREFACE

In response to a request from His Majesty's Government of Nepal, the Government of Japan decided to conduct a feasibility study on the Rajkudwa Irrigation Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Nepal a study team headed by Mr. Kensaku TAKEDA, Nippon Koei Co., Ltd., four times between June 1992 and October 1993.

The team held discussions with the officials concerned of His Majesty's Government of Nepal, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my sincere appreciation to the officials concerned of His Majesty's Government of Nepal for their close cooperation extended to the team.

November, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

November, 1993

Mr. Kensuke Yanagiya
President,
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to forward the feasibility study report on the Rajkudwa Irrigation Project in Lumbini Zone, the Kingdom of Nepal, in accordance with the Scope of Work agreed upon between the Department of Irrigation (DOI) under the Ministry of Water Resources, His Majesty's Government of Nepal (HMG/N) and Japan International Cooperation Agency (JICA) in February 1992. The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the formulation of the above mentioned project. Also included are comments made by DOI during technical discussions on the draft final report and on the additional geo-technical and soil mechanical surveys report which were held in Kathmandu.

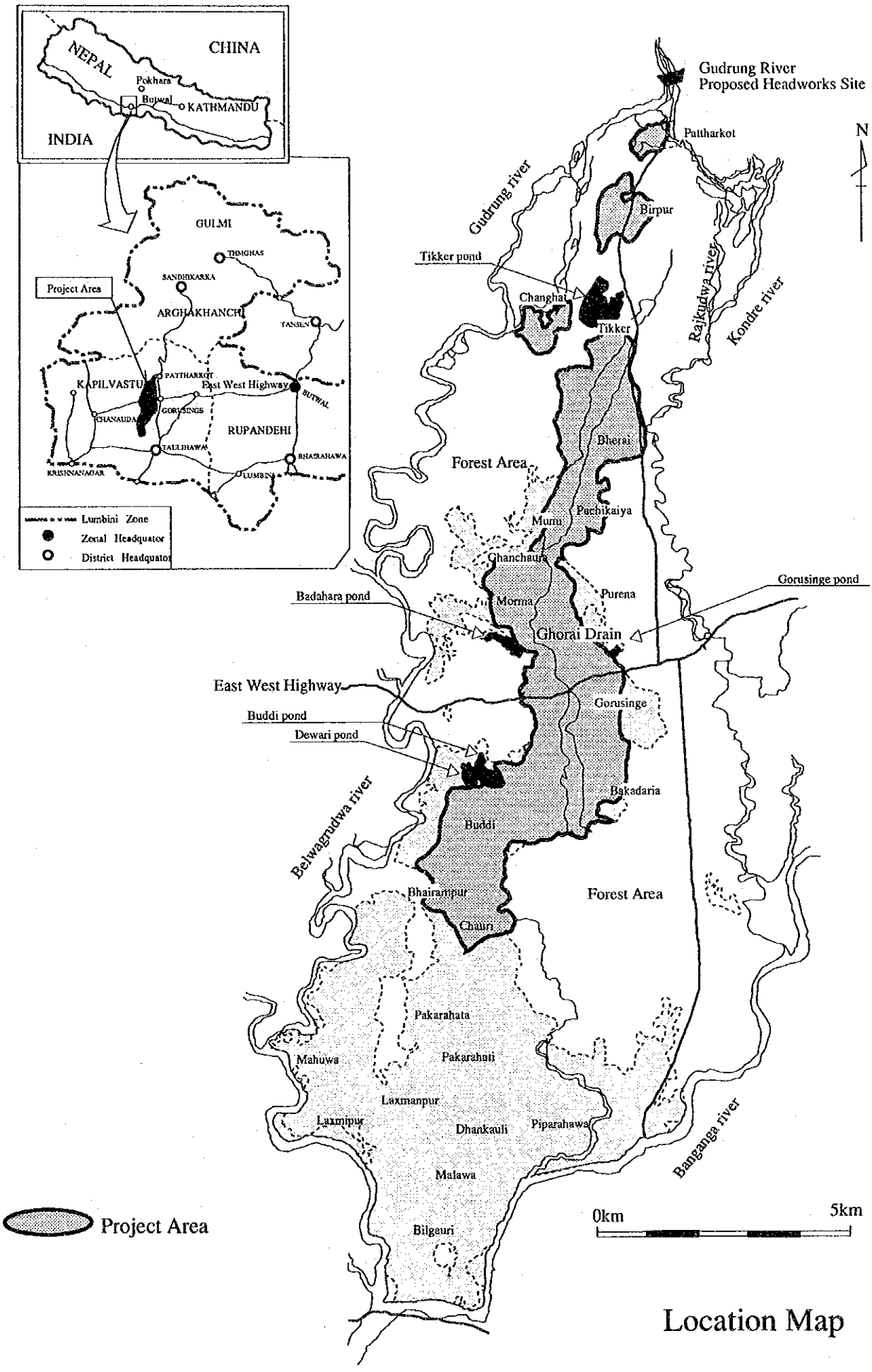
This report presents a pond irrigation project, irrigating 1,800 ha of arable lands by storing a part of excess discharge of a small river in five irrigation ponds and supplying irrigation water from the ponds. The project aims at increasing agricultural production and uplifting living standards by constructing such project facilities as a headworks, irrigation ponds, irrigation and drainage facilities, farm roads and agricultural support facilities and by organizing a farmers' association for O&M of the project facilities. The report concluded that the project is technically feasible and economically sound.

We believe that the success of the project will contribute to other success of considerable numbers of pond irrigation projects or schemes of which the water resources are small or medium-rivers running in the Terai plain. We recommend HMG/N to implement the project as soon as possible.

On this occasion, we wish to express our sincere appreciation and gratitude to your Agency and to the officials concerned of the Embassy of Japan in Nepal, JICA Kathmandu Office, JICA experts and the Ministry of Water Resources of HMG/N, especially DOI, for the courtesies and cooperation extended during the field surveys and studies.

Very truly yours.

Kensaku TAKEDA
Team leader,
Rajkudwa Irrigation Feasibility Study Team
Nippon Koei Co., Ltd.


NEPAL
CHINA
INDIA
Pokhara
Butwal
KATHMANDU
GULMI
TIMGHAS
SANDHIKARKA
Project Area
ARGHAKHANCHI
TANSEN
KAPILVASTU
PATTHARKOT
East West Highway
BUTWAL
GORUSINGE
CHANAUDA
RUPANDEHI
TAULIHAWA
BHAIRAHAWA
KRISHNANAGAR
LUMBINI
Lumbini Zone
Zonal Headquator
District Headquator
Gudrung River
Proposed Headworks Site
Pattharkot
N
Gudrung river
Birpur
Tikker pond
Changhai
Tikker
Rajkudwa river
Kondre river
Bhirai
Forest Area
Pachikaiya
Mumi
Ghanchaura
Purena
Morma
Gorusinge pond
Badahara pond
Ghorai Drain
East West Highway
Gorusinge
Buddi pond
Dewari pond
Bakadaria
Belwagrudwa river
Buddi
Bhairampur
Forest Area
Chauri
Pakarahata
Mahuwa
Pakarahati
Laxmanpur
Laxmipur
Dhankauli
Piparahawa
Malawa
Banganga river
Bilgauri
Project Area
0km
5km
Location Map

Summary

INTRODUCTION

01 This Final Report was prepared in accordance with the "Scope of Works" for the Feasibility Study on the Rajkudwa Irrigation Project (the Study) in Kapilvastu District, Lumbini Zone agreed upon between His Majesty's Government of Nepal (HMG/N) represented by the Department of Irrigation (DOI), Ministry of Water Resources and Japan International Cooperation Agency (JICA) on February 13, 1992.

02 The main objectives of the study were to formulate an agricultural development plan for irrigation of the project area selected from the study area of about 12,000 ha enclosed by four rivers, namely the Gudrung, Belwagurdwa, Kondre, and Banganga, and to transfer engineering knowledge on the feasibility study to the Nepalese counterpart engineers throughout the study period.

GENERAL BACKGROUND ON THE ECONOMY AND AGRICULTURE IN NEPAL

03 The Kingdom of Nepal is a landlocked country surrounded by India and China. The total area is 147,181 km^2. Administratively, Nepal is divided into five development regions, the Eastern, Central, Western, Middle Western, and Far West development regions. On the other hand, the country is ecologically divided into three areas: the mountain, hill, and Terai areas. The total population is 18,462,000 according to the preliminary results of a population census in 1991, and the population density is 131 persons per km^2. The population growth rate in Nepal was 2.08 % during the last 10 years.

04 The economy of Nepal achieved relatively stable growth during the last seven (7) years (1984/85-1991/92) with an overall annual growth rate of 4.9 %. The gross domestic product (GDP) was estimated to be NRs. 130,685 million in 1991/92. The agricultural sector shared 51 % of the GDP. The per capita GDP was NRs. 7,080 (about US$ 165) in 1991/92, and it is estimated that 49 % of the households are under the poverty line.

05 The total agricultural land in Nepal amounts to 2,653,000 ha or 18 % of the whole country. Taking the steep topography and environmental factors into consideration, it is hardly possible to enlarge the agricultural land. There are 943,000 ha of irrigated farmlands, of which 832,000 ha (88 %) are irrigated by surface water, and the rest by groundwater. About 267,000 ha (28 %) of the irrigated area are under DOI management and the rest is managed by farmers. Only about one-third of the irrigated area has permanent facilities.

06 The basic objectives of the agricultural sector in the Eighth National Development Plan (1992 to 1997) are: i) to contribute to the national economy by increasing agricultural production, ii) to meet the growing domestic food demand, iii) to enhance production and productivity of the raw materials for agro-industries, iv) to augment employment opportunities for the majority of small/marginal farmers, and v) to maintain a balance between agricultural development and the environment. HMG/N's policies for achieving these objectives are: i) implementation of large and medium-size irrigation projects by the government, ii) implementation of small-scale projects (less than 2000 ha in the Terai area) with farmers' participation, iii) handing over the irrigation facilities constructed by the government to farmers' groups for operation and maintenance (O/M), iv) involvement of

farmers in the project at all stages from planning to construction and collection of irrigation service fees by farmers' associations and groups, etc.

PRESENT CONDITION OF THE STUDY AREA

07 The study area is located in the south western part of the Western Development Region. Administratively, it belongs to Kapilvastu District, Ilaka No. 6. It covers 59 wards of seven Village Development Committees (VDCs).

08 The study area is situated on the Terai plain which slopes from north to south, of which the ground elevation varies from 90 m to 275 m. The East and West boundary areas are terraces of the Kondre, Banganga, Gudrung, and Belwagurdwa rivers, where there are natural forests. The study area slopes gradually from the forest areas to the central part where most of the cultivated fields exist. The Ghorahi Nala, a natural drain of the study area, runs through the central low-lying area and meets the Banganga river in its downstream reaches.

09 The total population of the study area was estimated at 33,260 in 1990, of which 52.3 % was male. The annual population growth rate from 1981 to 1990 was 2.3 %. About 50% (17,030 persons) of the total population was economically active, and most of these people were engaged in agriculture. The population density was 272 persons per km^2. The number of households was 5,153, out of which 4,580 or 89 % were independent farmers. The average family size in the area was about 6.5 persons.

10 The mean annual rainfall for the last 20 years in Pattharkot, which is situated close to the proposed Gudrung headworks site was 2,236 mm. About 86 % of the annual rainfall is concentrated in the four (4) months from June to September. Although, the annual rainfall itself is ample, the concentration of the rainfall in the rainy season hampers its year-round effective use for crops.

11 Judging from pumping test results and existing tube-well data, the discharge rate of the confined groundwater is estimated as follows : In major parts of the study area from Sitapur to Pattharkot, the discharge rate for deep tube-wells from 100 to 130 m in depth is around 4 l/s. The pumping rate increases southwestward and reaches 6 l/s in Bichwapur. These rates are insufficient for irrigation, though they are useful for domestic use or drinking water.

12 Of the study area (12,220 ha), about 47% (5,700 ha) is suitable for irrigation farming (paddy and upland) and the rest about 53% (6,440 ha) is forest. Of the suitable farmlands (5,700 ha) for irrigation, about 80% (4,560 ha) are arable lands, almost all of which are paddy fields at present.

13 Most of the paddy fields are put under rainfed conditions. The dominant summer crop in the rainy season is paddy which represents 95 % of the total cultivated area, and the other prevailing crops are maize and pulses. During the dry season, wheat is predominant and pulses, oilseeds, and vegetables are also planted to some extent. The present multicropping intensity is estimated at 132 % in the study area. In addition, the unit yields of the above major crops remain extremely low not only due to the shortage of irrigation water but also insufficient agricultural inputs and traditional farming practices.

14 The average land holding size in the study area is 1.00 ha, consisting of 0.97 ha of paddy field and 0.03 ha of upland field and/or kitchen garden. However, about 65% of the

total farm householders were classified as marginal size farmers whose land holding size was less than 1.0 ha. Average annual gross income for the average farmer is about NRs. 14,200, of which about 60% (NRs. 8,300) comes from farm income, and his annual average gross expenditure is about NRs. 13,800. Hence, the net reserve of the average farmer is about NRs. 400 only.

15 The irrigation systems being used at present are the Ranikudwa Farmers' Irrigation System, the Ghorahi drain irrigation system, and the small/medium-size ponds irrigation system. The command areas of the above irrigation systems are 630 ha, 200 ha, and 60 ha, respectively. Even if a rotation system was applied to tackle the problem of water scarcity in every system in the study area, extremely uneven distribution of irrigation water (more water in the head reaches and less in the tail reaches) would still prevail.

16 Agricultural extension services are provided by nine agricultural service centers in Kapilvastu District, and extension staff (Junior Technicians : JTs, Junior Technical Assistants : JTAs) are assigned under the Agriculture Development Officer (ADO). However, extension workers, facilities, and demonstration farms are still in short supply. Technological research by agricultural research centers, credit services by the Agricultural Development Bank (ADB/N), and agriculture inputs supply, storage, and delivery services by the Agricultural Inputs Corporation (AIC) in order to encourage farmers' activities, have barely been carried out.

FORMULATION OF THE BASIC DEVELOPMENT PLAN

17 In light of the assessment on land resources, irrigability, and drainability, the potential area for irrigation development will be 4,560 ha of the present farmland extending from Pattharkot to the confluence of the Banganga river and Belwagrudwa river, which is at the southernmost end of the study area.

18 The irrigation development plan, which is to irrigate 1,800 ha of paddy fields in the rainy season, 1,130 ha of upland crop fields in winter in the dry season and 100 ha of upland crop fields in spring in the dry season with the optimum use of the available discharge of the Gudrung river by a headworks and five irrigation ponds, is the sole irrigation development plan to be used in the study area from technical and socio-economic view points.

The technical reasons why Alt.-2 is to be the sole irrigation development plan are as follows:

1) It is essential for enlarging the irrigable area that the excess flow of the Gudrung river is stored in five irrigation ponds including a new one and four existing ones, since the irrigable area which can be directly covered by the river flow is only 340 ha with a cropping intensity of 155 %, consisting of 100 % paddy in the rainy season, 50 % winter crops, and 5 % spring vegetables. The bigger pond capacity gives rise to a larger irrigable area;

2) Therefore, the total capacity of the five ponds was set at 3.08 million m^3 from the following comparative study on the relationship between total effective storage and total irrigable area of the five ponds at a cropping intensity of 155 %.

Size of Pond	Effective Storage (10^6 m^3)	Irrigable Area (ha)
Max.	3,080	2,000
Medium	2,473	1,810
Small	1,390	1,390
Existing	391	630

3) Although the above study shows that the max. irrigable area at the cropping intensity of 155 % is 2,000 ha, the planned irrigation area was confined to 1,800 ha because of a topographical constraint, i.e., 200 ha of the arable lands are higher than the water level of the planned canals;

4) In connection with the planned irrigation area, the water balance of the five ponds was re-studied to enlarge the irrigable area of winter crops and spring vegetables where the total effective storage of the five ponds was 3.08 million m^3 and the irrigation area of the rainy season paddy was 1,800 ha. The cropping intensity was set at 168 %, consisting of 100 % paddy, 63 % winter crops, and 5 % spring vegetables from the following water balance of the five ponds:

Cropping Intensity (%)	Critical Storage ($10^3 m^3$)
155	542
165	209
168	13
170	0 (- 42)

AGRICULTURE AND IRRIGATION DEVELOPMENT PLAN

19 The project aims at stably increasing agricultural production, creating employment opportunities, raising farmers' income and thereby uplifting living standards in the project area through construction of irrigation and drainage facilities and agricultural support facilities, in line with the irrigation development target and policies set by HMG/N. The objective area contains about 4,280 ha of arable lands, most of which are paddy fields, consisting of the command area (630 ha) of the Ranikudwa Farmers' Irrigation Scheme, the arable lands extending south of the Ranikudwa command area, and the surrounding natural forests.

20 Out of the 2,000 ha of irrigable area computed in Section 4.2.3, the irrigation area of the project is set at 1,800 ha of arable lands owing to the topographical limitation. The irrigation area comprises about 630 ha of the Ranikudwa command area and about 1,170 ha of arable lands extending south of the Ranikudwa area. It is divided into two parts by the East-West Highway: the northern part is about 850 ha including the 630 ha of the Ranikudwa area, and the southern part is about 950 ha.

21 The project area covers almost all of the northern half of the existing farmlands in the study area. Administratively, the area includes five VDCs: Mahendrakot, Dubiya, Jayanagar, Buddi, and Rajpur, and 29 wards in total. The population of the project area is about 16,000, and the total number of farm households is 2,180, consisting of 47 large-scale, 128 medium-scale, 472 small-scale, and 1,533 marginal-scale. Besides, there are 85 landless farm households. The project area covers the existing paddy fields of 1,840 ha, and the average area of paddy fields per farm household is 0.84 ha. This average paddy field figure is smaller than that (0.97 ha) of the study area. The agricultural labor force in the project area is estimated at about 7,700 including landless farm householders.

22 The proposed cropping intensity for the project is as follows:

Cropping Intensity	Summer Crops	Winter Crops	Spring Crops
168 %	100 %	63 %	5 %

For determination of the above cropping intensity, comparative studies were conducted in terms of profitability, labor requirements, and water requirements.

23 The following are the target unit yields of each crop estimated by referring to the unit yields of crops attained under full irrigation conditions in the Terai plain for the past 10 years (1983 to 1992).

(Unit : ton/ha)

Crops		Without-Project	With-Project	Increment
Paddy	: partially irrigated	2.20	4.50	2.30
	non-irrigated	1.42	4.50	3.08
Wheat	: partially irrigated	1.70	3.00	1.30
	non-irrigated	0.98	3.00	2.02
Oilseeds	: partially irrigated	0.71	1.20	0.49
	non-irrigated	0.46	1.20	0.74
Vegetables	: partially irrigated	3.85	12.0	8.15

24 The present unit yields of each crop are expected to increase drastically with the implementation of the project. The annual incremental production of paddy, wheat, mustard, and vegetables at the full development stage is expected to be 5,050 tons, 1,410 tons, 200 tons, and 3,710 tons, respectively.

25 The estimated economic crop budgets are tabulated below:

(unit: NRs. per ha)

		Without-Project			With-Project			
Crops	Cond -ition	Gross Income	Production Cost	Net Profit	Gross Income	Production Cost	Net Profit	Incremental Net Profit
Paddy	N.I.	13,720	6,130	7,590	-	-	-	25,280
	P.I.	21,250	6,490	14,760	-	-	-	18,110
	F.I.	-	-	-	43,470	10,670	32,870	-
Wheat	N.I.	13,830	6,280	7,550	-	-	-	23,360
	P.I.	23,990	6,540	17,450	-	-	-	13,460
	F.I.	-	-	-	42,330	11,420	30,910	-
Maize	P.I.	17,910	4,610	13,300	-	-	-	-
Oilseed	N.I.	6,860	3,550	3,310	-	-	-	6,800
	P.I.	10,590	3,820	6,770	-	-	-	3,340
	F.I.	-	-	-	17,890	7,780	10,110	-
Pulses	N.I.	7,090	3,930	3,160	-	-	-	-
	P.I.	8,350	4,300	4,050	-	-	-	-
Vegetables	P.I.	17,250	9,960	7,290	-	-	-	31,250
	F.I.	-	-	-	53,760	15,220	38,540	-

Note: N.I.: Non-irrigated, P.I.: Partially Irrigated, F.I.: Fully Irrigated

26 The irrigation water requirement was computed on a 10-day basis for 15 years from 1978 to 1992, from evapotranspiration calculated by the modified Penman formula on a 10-day basis, consumptive use of water by crops based on the evapotranspiration, deep percolation (in the case of paddy only), and effective rainfall. The evapotranspiration was based on such meteorological data as temperature, relative humidity, wind velocity and sunshine hours for 11 years (1976-86) at Bhairahawa agricultural station, located about 50 km east-south-east from the center of the project area. Then, the unit peak water

requirement was set at 1.2 l/sec/ha as an 80 % probable value (peak water requirement for paddy in August 1978) among annual peak water requirements for paddy for the 15 years.

27 The daily water balance between the irrigation water requirement and available water for the proposed cropping pattern (1,800 ha of paddy, 680 ha of wheat, 225 ha of mustard, 225 ha of winter vegetables, and 100 ha of spring vegetables) in the base year (1983) is summarized as follows:

(Unit: 1,000 m^3)

Month		Irrigation Water Requirement	Available Water	Water Balance	Month		Irrigation Water Requirement	Available Water	Water Balance
Jan.	1	492	189	-303	Jul.	1	698	977	279
	2	497	187	-310		2	1,489	463	-1,026
	3	108	341	233		3	0	893	893
Feb.	1	460	183	-277	Aug.	1	0	2,456	2,456
	2	152	181	29		2	924	1,154	230
	3	0	161	161		3	0	775	775
Mar.	1	15	160	145	Sept.	1	0	2,422	2,422
	2	29	156	127		2	0	2,046	2,046
	3	49	166	117		3	324	1,406	1,082
Apr.	1	84	145	61	Oct.	1	0	1,056	1,056
	2	49	181	132		2	0	1,198	1,198
	3	98	138	40		3	0	285	285
May	1	106	136	30	Nov.	1	116	200	84
	2	27	353	326		2	294	197	-97
	3	43	199	156		3	396	194	-202
Jun.	1	16	160	144	Dec.	1	339	191	-148
	2	772	230	-542		2	398	189	-209
	3	1,557	217	-1,340		3	0	717	717

28 The irrigation area was divided into five irrigation blocks in the form of a canal system and four pond systems as follows:

Irrigation Block	Irrigation Area(ha)
1. Primary feeder canal upstream (including springs)	209
2. Tikker pond	695
3. Badahara pond	79
4. Gorusinge pond	400
5. Dewari/Buddi pond	417
Total	1,800

29 The number and length of canals for the proposed irrigation system have been estimated as follows:

Canal Type	Nos.	Length (km)
1. Feeder Canals		
Primary	1	15.5
Secondary	3	5.3
Subtotal	4	20.8
2. Irrigation Canals		
Main	3	4.5
Secondary	25	26.8
Tertiary	64	57.0
Subtotal	89	88.3
Total	93	109.1

30 In order to store the surplus discharge of the Gudrung river and rainwater during the rainy season and to use the storage water effectively for both the rainy season paddy and the dry season crops, the four existing ponds will be improved and enlarged, and a new pond will be constructed in the state-owned forest outside the irrigation area. The total effective storage of the five ponds after construction and enlargement was set at 3.08 million m^3 as a result of the water balance study. The overall seepage loss of the proposed new pond, namely Tikker pond with a water surface area of 51.5 ha was estimated to be 1.5 mm a day (8.9 l/sec) by the additional geotechnical and soil mechanical surveys to the proposed five irrigation ponds conducted by JICA, including the field survey carried out by dispatching an expert of the study team to the site during the one month from September 17 to October 16, 1993 and the consecutive office works, including a seepage analysis for the Tikker pond, in Japan. In addition, the seepage losses of the other four existing ponds after enlargement ware judged to be much less than that of the Tikker pond, since these ponds are located in a flatter area of the Terai plain where has high groundwater levels and will have shallower water depth, after enlargement, compared to the Tekkar pond. Therefore, no seepage protection works is necessary for the Tikker pond as well as the other four existing ponds to be enlarged, bisides the drainability of the farmlands located downstream of each pond will not be worse because of a few seepage from each pond. However, in the water balance computation of the five ponds, by which the irrigation area was decided to be 1,800 ha, the overall seepage loss of the five ponds was set at 3.0 mm a day on an average, taking the indefinite factors in the seepage analysis into account.

31 The land acquisition necessay for the construction of a new pond and enlargement of four existing ponds is as follows:

Ponds	Proposed Pond area (ha)	Existing Pond area (ha)	Required Land Acquisi. (ha)
Existing Pond			
Badahara	18.2	7.4	10.8
Gorusinge	7.7	1.7	6.0
Buddi	28.6	19.2	9.4
Dewari	52.6	12.2	40.4
New Pond			
Tikker	55.5	0	55.5
Total	162.6	40.5	122.1

Note: The above figures include the dikes or levees of the ponds.

It is already confirmed by the Nepalese counterpart engineers that there exists no inhabitant to be removed as well as no house and farmland to be inundated in the proposed pond areas, and the extension area of the Gorusinge pond was set to be outside the present army camp located east of the existing pond.

32 A part of the discharge of the Gudrung river diverted at the headworks will first be used as irrigation water for 209 ha of paddy fields located upstream from the Tikker pond, the first irrigation pond, and the rest will be supplied to the five irrigation ponds one by one in order from north to south. The remaining 1,591 ha is divided into four subirrigation areas, each of which is commanded by an irrigation pond with a canal network.

33 No service roads have been proposed along the canals to avoid loss of farmland to road construction. The other reason for not providing such roads is that most of the major

canals are aligned close and parallel to either the East-West Highway or Gorusinge - Pattharkot road and other existing village or farm roads. Instead of constructing service roads, existing major village and farm roads will be improved by widening and gravelling for increasing the accessibility to different places, improving transportation facilities to supply agricultural inputs and outputs, and improving socio-economic conditions.

34 A Water Users' Group (WUG), the lowest unit of the Water Users' Association (WUA) will be organized in every tertiary unit of about 30 ha command area. All farmers of the tertiary unit will be a member of the WUG concerned and all WUGs under the secondary canal concerned will form a secondary WUA. Similarly, an upstream WUA and five pond WUAs will be organized by the secondary WUAs concerned, and a central level WUA (CLWUA) will be formed by the upstream WUA and five pond WUAs for the proposed irrigation system.

35 CLWUA will be responsible for the overall water management and O&M of the entire system including the five irrigation ponds, however, it will be especially responsible for the O&M of the headworks, headrace canal, and primary and secondary feeder canals. Decisions regarding canal discharges, pond operation, rotation mode, and rotation schedule will also come under the responsibility of CLWUA. The primary upstream canal WUA (PUWUA) or pond WUA (PWUA) will be responsible for the water management and O&M of the pond concerned and its main canal. The secondary level WUA (SLWUA) will be responsible for the water management and O&M of the secondary canals concerned and the equitable distribution of water among the tertiary canals. Supervision to prevent stealing of irrigation water will also come under its responsibility. The WUGs will be responsible for the water management and O&M of the tertiary, quaternary, and field channels concerned. They will also be responsible for the equitable water distribution among quaternaries and prevention of water stealing.

36 The CLWUA will employ the required number of gatemen for the O&M of the intake gate, spillway gate and sandflush gate in the headworks, cross regulator gates at the primary canal, turnout gates at the secondary canals, and intake and offtake gates at the irrigation ponds. The required cost including the salary of the employees, the repair and maintenance cost of the gates, and others will be collected from all the beneficiary farmers under the proposed system in proportion to their irrigated area. The CLWUA will also prepare the regulations of the WUA including penalty clauses to violators in support of the majority of the member farmers.

37 Routine O&M of the primary and secondary feeder canals, irrigation ponds, and main, secondary, and tertiary canals such as clearing weeds, desilting, maintaining pond levees and canal sections, etc will be carried out at the proper time by labor contribution as decided by CLWUA and PUWUA, PWUA, SLWUA, and WUG concerned. O&M of the drainage system will also have to be carried out by WUA concerned at respective levels as in the irrigation system.

PROJECT WORKS

38 The following irrigation and drainage works will be implemented to realize the formulated agricultural development:

1) Construction of the Gudrung headworks including a 40 m long tyrolean type weir, intake, sand excluder, spillway, etc.

2) Construction of a 450 m long headrace canal consisting of a 420 m long closed conduit and a 30 m long sand excluder including the spillway and wasteway.
3) Construction of 20.8 km of feeder canals, consisting of 15.5 km of primary feeders, 5.3 km of secondary feeders, and 278 related structures.
4) Improvement and enlargement of the four existing ponds and construction of a new pond.
5) Construction of irrigation canals of 88.3 km in length, consisting of main canals of 4.5 km, secondary canals of 26.8 km, tertiary canals of 57.0 km, and 1,032 related structures.
6) Construction of drainage canals of 69.2 km in length, of which 18.6 km is a primary drain, namely the Ghorahi natural drain to be improved and 24.2 km are secondary drains, small natural drains to be improved.
7) Improvement of major village and farm roads of 49.5 km in length.

39 The following agricultural support facilities will be constructed to strengthen the farmers' associations consisting of the farmers' cooperatives and WUAs:

1) a farmers' association center on 3,000 m^2 of land, which will consist of:
(1) an office (50 m^2) and a meeting hall (75 m^2) for the central level Farmers' Cooperative Office (FCO) and WUA; and
(2) a multipurpose warehouse (200 m^2) and drying yard (1,000 m^2).

2) five VDC farmers' cooperative offices, each of which will have an area of 500 m^2 and include:
(1) an office and meeting room (90 m^2) for the VDC level FCO and WUA; and
(2) a godown (160 m^2).

40 The regular construction of the irrigation and drainage works will commence in November 1994 and should be completed after about twenty months by the Contractor, awarded through an international tender (ICB) after pre-construction arranging, including budget arranging, by the executing agency, detailed designing by a consulting firm, tender for the work and the preparatory work by the Contractor, including mobilization of its staff and equipment. The agricultural support facilities will be constructed in pace with the construction progress of the irrigation and drainage works. The executing agency of the project will be the Department of Irrigation (DOI) under the Ministry of Water Resources, and the daily management and supervision of the works will be conducted by the project office to be provided by DOI. The completed irrigation and drainage facilities and agricultural support facilities will be handed over to the farmers' associations comprising the farmers' cooperatives and WUAs organized by the beneficiary farmers, and the management and O&M will be carried out by the associations which shall be totally responsible for these tasks and any expenses.

41 The initial investment cost for the project is summarized below:

(Unit: NRs.Million)

Description	F/C	L/C	Total
A. Direct Construction Cost			
(1) Irrigation and drainage works	190.0	200.3	390.3
(2) Agricultural support facilities works	4.7	9.5	14.2
B. Associated Cost			
(1) Administration cost	0	10.1	10.1
(2) Engineering services cost	55.0	25.0	80.0
C. Physical Contingency	38.9	42.0	80.9
Subtotal	288.6	286.9	575.5
D. Price Contingency	23.8	82.5	106.3
Total	312.4	369.4	681.8

42 The annual O&M cost of the project will include personnel expenses for water management and O&M of constructed irrigation and drainage facilities, labor and material costs for repair and maintenance of the irrigation facilities, etc. The annual O&M cost was estimated at NRs.2.4 million (equivalent to US$ 0.05 million), which is equivalent to 0.6 % of the direct construction cost of the irrigation and drainage facilities and corresponding to NRs.1,350 per ha, out of which Nrs.410 per ha (about 30 %) will be able to be paid by labour work of the member farmers.

PROJECT EVALUATION

43 The economic benefit of irrigation is defined as the difference between net profits from agricultural production in the with-project and without-project conditions in the future. The annual irrigation benefit was estimated at NRs. 67.56 million at the full development stage as follows:

(unit: 1000NRs)

Crop	Without-Project	With-Project	Incremental Benefit
Paddy	18,840	59,040	40,200
Wheat	6,220	21,020	14,800
Maize	330	0	-330
Pulses	930	0	-930
Oilseed	620	2,280	1,660
Vegetables	360	12,520	12,160
Total	27,300	94,860	67,560

44 The Economic Internal Rate of Return (EIRR) calculated on the basis of the above initial investment cost, annual O&M cost, and irrigation benefit is 11.4 %. The annual net farm income of the average farmer (farm size of 0.84 ha) is expected to increase by 4.7 times, from NRs 5,460 under the without-project condition up to NRs. 25,720 under the with-project condition.

45 The annual O&M cost was estimated at NRs. 2,430,000 or NRs. 1,350 per ha, out of which NRs.730,000 or NRs.410 per ha will have to be paid in cash, and the remaining will be able to be paid by labor performed by the member farmers. On the other hand, the average annual incremental net profit per ha is expected to be about NRs. 24,000. Since the O&M cost to be shared by the farmers in cash is equivalent to about 1.7 % of the net profit, the farmers will have the capacity to pay the O&M cost.

46 The farm labor requirement after implementation of the project will be increased by 130,000 man-days per year: from 292,000 man-days under the without-project condition to 422,000 man-days under the with-project condition. The ratio of farm laborers to the total available labor force in the project area is expected to increase from the present 13 % up to 19 % under the with-project condition.

47 The local transportation will be greatly improved by the upgrading of the existing village and farm roads, resulting in smooth transport of farm inputs and outputs, convenient village life, and closer relations between villages.

48 Since the project is aimed at irrigating existing non-irrigated and partially irrigated paddy fields, no substantial change will be caused in villagers' life, economic activities, institutions, and customs. No existing water right has been confirmed for the Gudrung river besides that for the Ranikudwa irrigation system.

49 Since the four irrigation ponds have been proposed to be enlarged and one newly constructed in the project area, the inundation areas will be extended into the government forest by about 122 ha in total. It was confirmed by the field survey of the feasibility study that no one lived in the inundation area, therefore, no resettlement or compensation was required for this project. On the other hand, it was agreed in a series of discussion meetings between the study team and the farmers that the lands necessary for the construction of the new canals would be granted by the beneficiary farmers, and that the irrigation water to the existing irrigation areas should be assured by the existing canals or temporary diversion canals untile the new irrigation systems will be in use.

50 Since a 10 m deep dug-well in Pattharkot village, located about 500 m downstream from the proposed headworks site may be affected to a certain extent by constructing the headworks on the Gudrung river at Ranikudwa point, continuous observation of the groundwater level of the dug-well is required.

51 As already mentioned, it was justified that the project would not significantly affect the environmental conditions. However, considering unexpected impact, the following monitoring and measures are recommended:

- Monitoring of the water table in a 10 m deep well in Pattharkot. In the case that the water table becomes too low for use due to the construction of the proposed headworks, necessary countermeasures should be taken as soon as possible.
- Establishment of a process for reporting and clearing up the cause of contamination of fish ponds.
- Public health education for villagers on water-related infectious diseases.
- Provision of soil conservation works on the upstream side of the irrigation ponds, if necessary.
- In the case that land is acquired from small-scale or particular farmers for the construction of canals and related structures, necessary coordination including compensation, reallocation of land, etc. shall be carried out by the chairman of VDC or the chief of the Ward concerned.

CONCLUSION AND RECOMMENDATION

52 The project is not only technically viable, but also economically and financially sound. The project will have little negative impact on the present natural environment in the

project area, though the state-owned natural forest will be partly cleared and reduced by about 122 ha, in constructing an irrigation pond of 55.5 ha and enlarging the four existing ponds by 66.5 ha. Also no specific animal or plant is found in the natural forest. Even if the project had a little negative impact on the present environment, it would be compensated by the positive impact of implementing the project.

53 It is recommended that HMG/N should implement the project immediately after the detailed design, understanding that the project is a pond irrigation project storing a part of the excess discharge of a small river and thereby playing the role of a pilot project for implementation of a considerable number of pond irrigation projects or schemes of which the water resources are small or medium-rivers running in the Terai plain.

54 It is recommended that DOI should estimate more reliable water availability figures for the Gudrung river from more accurate monthly hydrographs to be prepared through continuous observation of both the daily and hourly rainfall in Pattharkot and Basantapur and the daily discharge of the Gudrung river at the proposed headworks site, particularly continuous measurement of the river discharge for a flood cycle, since the source of the Gudrung river is a small river of which the flood shape shows an extremely inverse V.

55 It is also recommended that the emphasis in the detailed design should be placed on the following:

1) To carry out an accurate topographic survey on both the proposed routes of the primary and secondary feeder canals and the main, secondary, and tertiary irrigation canals and the proposed pond areas, since the northern most one third and next one third of the project area have steeply sloping land with an average slope of over 1/200 and over 1/600, respectively;

2) To produce a proper structural design of the ponds, particularly the dikes and their foundation, taking into due consideration the safety of the ponds in terms of the seepage, piping and sliding, because the initial success of the project depends on the fact that the excess discharge of the Gudrung river can be efficiently stored in the proposed five irrigation ponds including a new pond; and

3) To design a supply system and irrigation systems (distribution systems), enabling simple water management and easy O&M of the irrigation facilities.

56 Because the success of the project depends on both the sustainable use of the constructed irrigation and drainage facilities and agricultural support facilities and the establishment of irrigation farming by beneficiary farmers, it is recommended that the constructed irrigation and drainage facilities and agricultural support facilities should be handed over to WUAs and farmers' cooperatives newly organized by the beneficiary farmers, respectively and then the management and O&M of such facilities should be carried out by the same associations and cooperatives which shall be totally responsible for these tasks under the technical guidance of DOI and DOAD, through steps involving the beneficiary farmers in the detailed design and construction works of the project as already practiced in the field survey and investigation of this feasibility study. This recommendation follows HMG/N's present irrigation policy stipulating that in the Terai plain government irrigation systems commanding less than 2,000 ha of irrigation area shall be handed over to farmers' associations organized by beneficiary farmers and the O&M of the systems shall be carried out by the farmers' associations. Therefore, it is recommended that HMG/N carries out the following measures prior to the detailed design:

1) Advice and guidance to the VDCs concerned about their relief measures for the farmers whose farmlands will decrease owing to the acquisition of construction sites for the irrigation and drainage facilities and agricultural support facilities;

2) Technical guidance and necessary coordination for establishing WUAs and farmers' cooperatives in line with the proposed organization;

3) Technical guidance and training of farmers to enable them to become acquainted with the proposed less control-rotative irrigation method and practice;

4) Expansion of agricultural extension services by DADO and the Buddi Agricultural Extension Service Center for early return on the project by the proposed irrigation farming;

5) Timely supply of agricultural inputs, particularly fertilizer by District AIC; and

6) Expansion of agricultural loans by ADB/N to the beneficiary farmers whose initial investment will be considerably increased by introducing irrigation farming.

FEASIBILITY STUDY
ON
THE RAJKUDWA IRRIGATION PROJECT

MAIN REPORT

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Abbreviations

ADB/N	: Agricultural Development Bank of Nepal
ADO	: Agricultural Development Officer
AIC	: Agricultural Input Corporation
APM	: Adjustable Proportional Module
APO	: Assistant Production Officer
CA	: Catchment Area
CDO	: Chief District Officer
DADO	: District Agricultural Development Office
DIO	: District Irrigation Office
DOAD	: Department of Agricultural Development
DOC	: Department of Cooperative
DOI	: Department of Irrigation
EAP	: Economically Active Population
FAO	: United Nations Food and Agriculture Organization
GDP	: Gross Domestic Product
GOJ	: Government of Japan
HMG/N	: His Majesty's Government of Nepal
JICA	: Japan International Cooperation Agency
JTAs	: Junior Technical Assistants
JTs	: Junior Technicians
LRMP	: Land Resource Mapping Project
NRs	: Nepalese Rupee
O&M	: Operation and Maintenance
PDSP	: Planning and Design Strengthening Project
RID	: Regional Irrigation Directorate
SFDP	: Small Farmers Development Project
SPT	: Standard Penetration Test
S/W	: Scope of Works
VDC	: Village Development Committee
WUA	: Water Users' Association
WUG	: Water Users' Group
SLWUA	: Secondary Level Water Users' Association
CLWUA	: Central Level Water Users' Association

ABBREVIATIONS OF MEASUREMENTS

Length

mm	=	millimeter		
cm	=	centimetre		
	=	0.39 in.		
m	=	meter	=	1.09 yd
	=	3.28 ft.		
km	=	kilometre	=	0.62 ml
in.	=	inch	=	2.54 cm
ft.	=	foot	=	30.48 cm
yd.	=	yard	=	91.44 cm
ml.	=	mile	=	1.61 km

Area

cm^2	=	square centimetre		
m^2	=	square meter		
km^2	=	square kilometre		
	=	100 ha		
ha	=	hectare	=	0.01 km^2
	=	2.5 ac		
ac	=	acre	=	0.41 ha
	=	4,050 m^2		
ft^2	=	square feet		
	=	0.09 m^2		
mile	=	square mile	=	2.59 km^2

Electrical Measures

kW	=	kilowatt	=	1,000 watt
MW	=	megawatt	=	1,000 KW
GW	=	gigawatt	=	1,000 MW
kV	=	kilovolt	=	1,000 volt

Other Measures

%	=	percent
o	=	degree
'	=	minute
"	=	second
^oC	=	degree in Celsius
lakh	=	10^5
crore	=	10^7

Volume

lit.	=	litter		
cm^3	=	cubic centimeter		
m^3	=	cubic meter		
	=	1,000 lit.		
MCM	=	million m^3		
	=	1 x 10 m^3		
ft^3	=	cubic feet	=	0.028 m^3
	=	28.32 lit.		
ac-in.	=	acre inch	=	88.05 m^3
ac-ft.	=	acre feet	=	1,234 m^3

Weight

g	=	gram		
kg	=	kilogram		
t	=	metric ton	=	1,000 kg
lb	=	pound	=	375 g

Weight

sec	=	second	
min	=	minute	=60 seconds
hr	=	hour	=60 minutes
	=	3,600 seconds	
day	=	24 hrs	=1,440 minutes
	=	86,400 seconds	
yr	=	year	

Derived Measures

m^3/sec	=	cubic meter per second (Cumec)
ft^3/sec	=	cubic foot per second (Cusec)

Monetary

US$	=	US dollar
¥	=	Japanese yen
NRs	=	Nepalese rupee

MEASUREMENT UNIT

Land Measurement

1 Bigha = 20 Katha = 0.677 ha
= 1.676 Acre = 13.31 Ropani
1 Katha = 20 Dhur = 339 m^2
1 Dhur = 182 sq. feet = 16.9 m^2
1 hectare = 2.47 acre = 1,477 Bigha
= 29.5 Katha = 19.6 Ropani
1 $mile^2$ = 640 Acre = 259 ha
= 2.59 km^2
1 Acre = 0.4047 hectare = 43,563 ft^2
= 0.5966 Bigha

Volume

1 litre = Mana 3 Chauthai = 1.0567 US quart
= 1.76 pint = 1,000 millilitre
= 0.881 imperial quart
1 Mana = 598 millilitre = 33.264 cubic inch
1 cup = 16 tablespoon = 240 c.c
= 8 ounces
1 fluid ounce = 2 tablespoon
1 gallon = 3.785 millilitre = 3.785 litres
= 16 cups = 128 fluid ounces
= 227.42 cubic inches
1 standard table spoon = 1.5 general table
1 tea spoon = 5 c.c
3 table spoon = 6 tea spoons
1 kerosene oil tin = 20 litres = 5 gallons
1 muri = 90.910 litres
3 pathi = 4.546 litres
1 quarter or chouthai = 124 millilitre
2 mana = 1 kurua
4 kurua = 1 pathi
20 pathi = 1 muri
1 Hectolitre = 22.01 gallons
1 gallon = 4,564 litres

Weight

1 kg = 2.2046 ponds = 86 tolas
= 5 pau
= 1 seer 1 chhatank 1 tola
= 0.42 Dharni
1 gram = 15.43 grains = 0.035 ounce
100 kg = 1 quintal = 231 pounds
= 2 mounds 27 seers 14 tolas
40 kg = 1 mound 2 seers 14 tolas
= 1 mound (Prevalent now a days)
1 pound = 16 ounces = 454 grams
1 mound = 37.32 kg
1 seer = 933 grams
1 Chhatank = 58 grams
1 Tola = 11.66 grams
5 Tola = 1 chhatank
16 Chhatank = 1 seer
= 2.057 pounds
= 0.933 kilogram
= 933 grams
40 seer = 1 maund
= 82.28 pounds
= 37.325 kilogram
4 chhatank = 1 pau
1 pau = 1 seer
5 seer = 1 panseri
8 panseri = 1 maund
1 tola = 180 grain = 0.4114 ounce
= 11.66 gram
1 chhatank = 5 tola = 0.1286 pound = 0.583 kg
1 seer = 16 chhatank = 2,057 pound = 0.933 kg
1 mound = 40 seer = 82.28 pounds = 37,325 kg
1 quintal = 2,679 maunds = 107,169 seers
1 Md/B = 54.9 kg/H
1 ton/ha = 18 maunds/Bigha
1 kg/ha = 1.12 pound/acre = 0.677277 kg/Bigha
= 0.33863 kg/katha = 0.90874 kg/ropani

CONVERSION FACTORS

GRAIN VOLUME

1 muri = 20 pathi = 160 mana = standard

1 local muri = 16 local pathi
= 64 standard mana - Jumla
(Source farme information)

Muri to kg.

	kg
Paddy	48.768
Wheat/maize	68.048
Barley/oat	45.360
Buckwheat	54.432
Fingermillet	65.776
Common millet	72.663
Crams	65.696
Bean	71.809
Pigeon pea	70.799
Soyabean	63.500
Mustard	56.700
Mung/black gram/lentil/horsebean	72.580
Chick pea	68.050
Sesame	54.415

Source: Department of Mint, Weight Measures

	kg
Peanut	38.200
Potato/sweet potato	83.667
Ginger	54.533
Linseed	58.560
Cow pea	68.800
Coriander	25.760

Source: Measured on Farm

Note: 1 gun = 16 mani
1 mani = 16 sai
5 mani = 1 muri
40 rajiya = 1 muri

Source: Information from Farmers

WEIGHT CONVERSION

Unit		kg
1 Md = 40 seers = 8 paseri	=	40
1 Quintal	=	100

Source: Common usage

COMPOST

Unit	kg
1 Doka	25
1 Case	1,000
1 Tractor	3,000

Source: Field estimation

AREA CONVERSION

Nepali Unit	Hectare
1 Bigha = 20 Katha = 400 Dhurs	0.677276
1 Ropani = 16 Aana = 64 Paisa	0.0508735
1 Muri land	0.0127183

Source: Department of Mint, Weight Measures

CHAPTER I INTRODUCTION

1.1 General

This Final Report was prepared in accordance with the "Scope of Works" for the Feasibility Study on the Rajkudwa Irrigation Project (the Study) in Kapilvastu District, Lumbini Zone agreed upon between His Majesty's Government of Nepal (HMG/N) represented by the Department of Irrigation (DOI), Ministry of Water Resources and the Japan International Cooperation Agency (JICA) on February 13, 1992.

This report presents the results of studies on the technical and economic feasibility of the Rajkudwa Irrigation Project .

The report covers the present natural, social, and economic conditions of the study area, assessment of available water and land resources, proposed development plan, and economic and financial analysis of the project.

This Main Report is supported by the following Annexes:

Annex A	Meteorology and Hydrology
Annex B	Geology and Geohydrology
Annex C	Soils and Landuse
Annex D	Agriculture, Farmers' Organizations and Agricultural Support Services
Annex E	Agricultural Economy
Annex F	Irrigation and Drainage
Annex G	Planning, Design and Cost Estimate of the Civil Works
Annex H	Project Evaluation
Annex I	Drawings
Attachment 1	Summary of Farm Survey
Attachment 2	Results of Additional Geotechnical and Soil Mechanical Surveys and Seepage Loss of the Proposed Tikker Pond

1.2 Background to the Project

At present, the average per capita income of farm households in Kapilvastu District, including the study area are lower than the national average, and social infrastructures are also not well developed. HMG/N has embarked upon the fulfilment of basic needs by the implementation of the integrated rural development plan, the goal of which is alleviation of poverty through the increasing of people's income and upgrading of their living standards.

Although DOI had carried out the prefeasibility study on the Rajkudwa Irrigation Project and constructed a part of the main canal in 1987, the construction work was suspended due to an immature plan and designs, and a shortage of funds. Under such circumstances, HMG/N requested the Government of Japan (GOJ) to conduct the Master Plan Study for Integrated Rural Development in Lumbini Zone including Kapilvastu District. In response to the request,

GOJ dispatched a study team for the formulation of the master plan for the Lumbini Zone through JICA from September 1988 to November 1989. In the master plan, the Rajkudwa Irrigation Project was recommended as the top priority project in the irrigation sector, taking into consideration the background mentioned above.

In line with the recommendation of the master plan study, in January 1991 HMG/N requested GOJ to extend the technical cooperation programme for the Rajkudwa Irrigation Project (the Project), and in February 1992 the Preliminary Survey Team was dispatched by JICA to Nepal and the Scope of Works for the feasibility study of the project was concluded on February 13, 1992 between JICA and DOI.

1.3 Objectives of the Study

The objectives of the study were:

a) to formulate an agricultural development plan for irrigation of the project area, selected from the study area, and

b) to transfer technical and engineering knowledge on the feasibility study to the Nepalese counterpart personnel during the study period.

1.4 Study Area and Project Area

(1) Study Area

The study area is about 12,000 ha in size enclosed by the proposed headworks site and the Gudrung, Belwagurdwa, Kondre and Banganga rivers in Kapilvastu district in Lumbini Zone. The area covers the seven Village Development Committees (VDCs) of Mahendrakot, Dubiya, Jayanagar, Buddi, Rajpur, Mahuwa, and Dhankauli.

(2) Project Area

The project area covers about 2,000 ha of existing cultivated land which is divided into northern and southern parts by the East-West Highway. The northern part is about 850 ha in size, including about 630 ha of the command area of the existing Ranikudwa Farmers' Irrigation System, and the remaining southern part includes the existing pond irrigation systems.

1.5 Main Features of the Study

JICA organized a study team composed of eight experts for the execution of the Feasibility Study for the Project as shown in Table 1.1.

The study consisted of Fieldwork and Home work. The fieldwork was executed in the rainy season of 1992 and the dry season of 1993. Apart from the fieldwork, a 1/ 5,000 topographic map of about 5,000 ha land including the project area was prepared by JICA in the period between the rainy and dry season fieldwork. The dry season study was performed using the topographic map.

All the fieldwork was carried out by the study team in collaboration with the Nepalese counterpart personnel assigned by HMG/N (DOI), transferring technical and engineering knowledge on the feasibility study to them throughout the work period.

1.5.1 Fieldwork

(1) Fieldwork in the Rainy Season (June 30 - August 27, 1992)

i) Presentation of the inception report
The inception report was presented to DOI on July 1, 1992. Based on the report, an explanation and discussion meeting was conducted between HMG/N (DOI) and the study team on the scope of works, approach to the project, plan of operation, and work schedule. The minutes of the meeting are shown in Attachment - 2.

ii) Fieldwork in the rainy season
The fieldwork in the rainy season was carried out from the end of June to the end of August 1992.

The major activities of the fieldwork were data collection and field investigation on rainfall, river discharge, sediment load, soils, landuse, agriculture, agricultural support system, irrigation and drainage, geology and geohydrology, besides the farm survey for the study area which was carried out by a local consulting firm contracted by the JICA study team.

At the end of the fieldwork, a progress report was prepared by the study team and explanation and discussion of the report were conducted between the study team and DOI. The minutes of the meeting are given in Attachment - 4.

iii) Explanation and discussion meetings with the farmers concerned
Two explanation and discussion meetings on both the scope of the study and the basic development plan for the project were held between the study team and the farmers concerned in the study area on the condition that the explanation meetings were aimed at confirming the farmers' attitudes in the expected project area towards the basic development plan proposed in the investigation and planning stage and therefore, the meetings didn't directly lead to the proposed plan for implementation.

In the meetings the following were mutually confirmed as the conditions for implementing the project:

a) he necessary land for construction of the proposed irrigation and drainage facilities should be provided by the farmers who would benefit from the proposed project;
b) construction of tertiary and quaternary canals by the beneficiary farmers themselves;
c) establishment of Water Users' Associations (WUAs) by the beneficiary farmers;
d) transfer of the constructed irrigation and drainage facilities to the established WUAs; and

e) management and operation and maintenance (O&M) of the transferred irrigation and drainage facilities by WUAs which fully shall be responsible for these tasks.

The minutes of the above explanation meetings with the farmers concerned are given in Attachments-9 and 10.

(2) Fieldwork in the Dry Season (January 7 - March 25, 1993)

i) Fieldwork in the dry season

The fieldwork in the dry season was carried out from the beginning of January to the end of March 1993.

The main activities of the fieldwork were data collection and field investigation on rainfall, river discharge, sediment load, soils, landuse, agriculture, farmers' organizations, irrigation and drainage, geology and geohydrology in succession to those in the rainy season. In addition, the topographic survey for preliminary design of major irrigation and drainage facilities as well as the agri-economic survey were carried out.

Apart from the above-mentioned fieldwork, core boring was also executed at the proposed headwork site in the Gudrung river, by a local contractor contracted by the JICA study team.

During the absence of the study team from Nepal between the fieldwork in the two seasons, the observation and measurement of rainfall, river discharge, and sediment load were carried out continuously by Nepalese local staff under the supervision of the Nepalese counterparts.

ii) Explanation and discussion meetings with the farmers concerned

In succession to the rainy season, three explanation and discussion meetings on the project were held between the study team and the farmers concerned. In these meetings the farmers' strong desire for early implementation of the Project and their positive attitude for participation in the project were confirmed as well as re-confirmation of the conditions for implementation of the project.

The minutes of the above-mentioned meetings with the farmers concerned are presented in Attachments-11, 12 and13.

iii) Preparation of the interim report

An interim report, highlighting the basic development plan for the project was prepared in line with the results of the fieldwork carried out in the rainy and dry seasons. The interim report including the basic development plan was accepted by DOI representing HMG/N in the explanation and discussion meeting held between DOI and the study team. The minutes of the meeting are presented in Attachment - 6.

iv) Additional geotechnical and soil mechanical surveys

In order to estimate the seepage loss of the proposed irrigation ponds as well as to sound the usability of the existing soils in and around the pond areas for the dike or levee of the ponds, the additional geotechnical and soil mechanical surveys to the proposed five ponds including the Tikker pond to be constructed were conducted by an expert of the study team during the one month from September 17 to October 16, 1993, and the seepage analysis for the Tikker pond was carried out by the study team in Japan, using the surveys results. The results of the surveys and seepage loss of the Tikker pond are given in Attachment - 2 in the Annex Report.

1.5.2 Home work

(1) Home Office Works and Preparation of the Draft Final Report

In succession to the fieldwork in Nepal, further studies were carried out as the home office works in Japan for about two months from the beginning of May to the beginning of July 1993. The study results were compiled as the Draft Final Report on the Feasibility Study for the Rajkudwa Irrigation Project.

1.6 Explanation and Discussion on the Draft Final Report

The explanation and discussion meetings on the draft final report were held between the study team and the officials of HMG/N concerned during about one week from July 22 to 26, 1993, and the draft report was accepted by the Nepalese side with some comments to it. The minutes of the meeting are shown in Attachment - 7.

1.7 Preparation of the Final Report

The Final Report on the Feasibility Study for the Rajkudwa Irrigation Project was prepared in the form of finalizing the draft report by reflecting the comments of the Nepalese side and involving both the summary of farm survey and the results of additional geotechnical and soil mechanical surveys and seepage analysis for the proposed Tikker pond in Attachments of the Annex Report.

CHAPTER II GENERAL BACKGROUND ON THE ECONOMY AND AGRICULTURE IN NEPAL

2.1 Land and Population

The Kingdom of Nepal is a landlocked country surrounded by India and China. The total area is 147,181 km^2. The total population is 18,462,000 according to the preliminary results of a population census in 1991, and the population density is 131 persons per km^2.

Administratively, Nepal is divided into five development regions: the Eastern, Central, Western, Middle Western, and Far West development regions, with 14 zones, 75 districts, 4,015 VDCs, and 33 municipalities. On the other hand, the country is ecologically divided into three areas: the mountain, hill, and Terai areas.

(1) The Mountain Area: The mountain area lies between 4,000 m and 8,848 m above sea level. It is the most sparsely populated area because of its cool climate and steep topography.

(2) The Hill Area: The elevation of the hill area varies from 275 m to 4,000 m above sea level. This area has a food deficit due to the high population density and limited agricultural land, therefore, a considerable amount of food has to be supplied from the Terai area.

(3) The Terai Area: The Terai area is part of the Ganges plain and therefore is flat, lying 90 m to 275 m above sea level, with a subtropical climate. It includes most of the fertile land in Nepal, and is a major agricultural production area. The population growth rate of this area is high due to migration from the mountain and hill areas.

The population growth rate in Nepal was 2.08 % during the last 10 years. More than 90 % of the total population still lives in rural areas and most of them are engaged in agricultural activities.

Ecological Area	Population (1,000) 1981		1991 *		Average Annual Growth Rate (%)
Mountain Area	1,303	(8.7%)	1,444	(7.8%)	1.04
Hill Area	7,163	(47.7%)	8,411	(45.7%)	1.62
Terai Area	5,557	(43.6%)	8,606	(46.6%)	2.76
Total	15,023	(100.0%)	18,462	(100.0%)	2.08

Remark: *, Preliminary results of the population census in 1991.
Source: Statistical Pocket Book Nepal, CBS, 1992.

2.2 National Economy

The economy of Nepal achieved relatively stable growth during the last seven (7) years (1984/85-1991/92) with an overall annual growth rate of 4.9 %. The gross domestic product (GDP) was estimated to be NRs. 130,685 million in 1991/92. The agricultural sector shared

51 % of the GDP. The per capita GDP was NRs. 7,080 (about US$ 165) in 1991/92, and it is estimated that 49 % of the households are under the poverty line.

Foreign trading by Nepal has been increasing both in respect to imports and exports, however, the balance constantly shows a deficit. Trade with India shares 20 to 30 % of the total amount. The major export commodities are raw materials, edible oil, jute, dried ginger, livestock, etc., though the food grain levels are low due to the increase in domestic demand in recent years.

2.3 Agriculture and Irrigation

The total agricultural land in Nepal amounts to 2,653,000 ha or 18 % of the whole country. Taking the steep topography and environmental factors into consideration, it is hardly possible to enlarge the agricultural land. Cereals, such as paddy, wheat, and maize, are the major crops amounting to about 80 % of the total cropped area. Though Nepal was an exporting country of food grain in the 1970's, in recent years, the production and consumption of food grain has been barely balanced due to stagnating production. Although food grain production has gradually been increasing since the middle 1980's, it still remains at a low level. The Terai area provides a large part of the nation's total agricultural production, especially of paddy and wheat. Table E.1.6 in Annex E shows the cropped area, total production, and unit yields of major crops; and the following table shows the averages for the last five years:

	Nepal			Terai Area		
	Area	Production	Yield	Area	Production	Yield
	(1,000ha)	(1,000ton)	(ton/ha)	(1,000ha)	(1,000ton)	(ton/ha)
Cereal Crops						
Paddy	1,435	3,276	2.28	1,054	2,440	2.31
Wheat	593	809	1.36	308	474	1.54
Maize	732	1122	1.53	153	267	1.73
Millet	188	204	1.08	13	13	1.04
Barley	30	27	0.19	3	3	.0.94
(Subtotal)	(2,978)	(5,438)	(1.82)	(1,531)	(3,197)	(2.09)
Other Crops						
Pulses	266	155	0.59	211	123	0.58
Oilseeds	154	94	0.61	123	75	0.61
Sugar Cane	32	1,021	31.52	30	979	32.73
Potatoes	83	671	9.08	19	202	10.86
Tobacco	7	7	0.83	7	6	0.84
(Total)	(3,520)			(1,921)		

Note: Figures show the average in the period from 1987/88 to 1991/92
Source: Statistical Year Book Nepal (1991, CBS), and DFAMS

There are 943,000 ha of irrigated farmlands, of which 832,000 ha (88 %) are irrigated by surface water, and the rest by groundwater. About 267,000 ha (28 %) of the irrigated area are under DOI management and the rest is managed by farmers. Only about one-third of the irrigated area has permanent facilities.

2.4 National Development Plan

The Eighth National Development Plan (1992 to 1997) was launched in 1992, succeeding the Seventh Plan (1984/85 to 1989/90). The principal objectives of the Eighth Plan

are: i) sustainable economic growth, ii) alleviation of poverty, and iii) reduction of regional imbalances.

Special priority has been placed on: i) agricultural intensification and diversification, followed by ii) energy development, iii) development of rural infrastructure, iv) employment generation and human resource development, v) reduction in population growth, vi) industry and tourism development, vii) export promotion and diversification, viii) macro-economic stabilization, ix) administrative reform, and x) monitoring and evaluation.

The basic objectives of the agricultural sector are: i) to contribute to the national economy by increasing agricultural production, ii) to meet the growing domestic food demand, iii) to enhance production and productivity of the raw materials for agro-industries, iv) to augment employment opportunities for the majority of small/marginal farmers, and v) to maintain a balance between agricultural development and the environment.

The policies to achieve these objectives are: i) formulation and implementation of an agricultural development program for each agro-economic region, ii) commercialization and diversification of agricultural products, iii) encouragement of the production of crops which can be used as raw materials for industry, iv) unification of agricultural extension services through farmers' groups at a village level, v) encouragement of the private sector to produce, import, and distribute agricultural inputs including improved seeds and technology, vi) simplification of agricultural credit disbursement, and vii) revitalization of cooperatives. Agricultural development programs lead mainly to intensification, diversification, and commercialization. Consequently, the target production increases per year for the plan are 5.4 % for food grain, 9.1 % for cash crops, 5.4 % for horticultural products, and 3.8 % for livestock products.

In order to increase agricultural production, the investment plan has put emphasis on the irrigation sector. The basic objectives of the irrigation sector are: i) to increase agricultural production through the proper application of irrigation technologies, ii) to improve the management of existing irrigation systems, and iii) to realize the efficient use of irrigation facilities through farmer participation.

The policies to achieve these objectives are: i) implementation of large and medium-size irrigation projects by the government, ii) implementation of small-scale projects (less than 2000 ha in the Terai area) with farmers' participation, iii) handing over the irrigation facilities constructed by the government to farmers' groups for O&M, iv) involvement of farmers in the project at all stages from planning to construction and collection of irrigation service fees by farmers' associations and groups, etc.

The target of the irrigation sector in the Eighth Plan is to increase the irrigated farmlands by 294,000 ha, of which 108,000 ha, 53,000 ha, and 133,000 ha are to be attained by large-scale projects, medium to small-scale projects, and private sector projects assisted by ADB/N, respectively.

CHAPTER III PRESENT CONDITION OF THE STUDY AREA

3.1 Location and Population

3.1.1 Location

The study area is located in the northern part of Kapilvastu District of Lumbini Zone in the Western Development Region. The study area is situated on the Terai plain which slopes from north to south towards the India - Nepal border. The ground elevation varies from 90 m to 275 m. The East-West Highway passes through the study area and divides it into northern and southern parts.

3.1.2 Administrative Division

The study area, administratively, belongs to Kapilvastu District, Ilaka No. 6. It covers 59 wards of seven VDCs as shown in Table 3.1 and summarized below:

Name of VDC	No. of Wards	Area (km^2)	Total Population	Population Density (person/km^2)	Cultivated Area (ha)	Ratio (%)
Mahendrakot	9	28.8	5,885	204	506	11
Dubiya	5	9.5	1,530	161	396	9
Jayanagar	9	22.5	4,943	220	677	15
Buddi	9	13.3	4,321	325	447	10
Rajpur	9	11.5	6,844	595	816	18
Mahuwa	9	12.0	3,912	326	734	16
Dhankauli	9	24.6	5,822	237	984	21
Total	59	122.2	33,257	272	4,560	100

3.1.3 Population and Labor Force

The total population in the study area was estimated at 33,260 in 1990, of which 52.3 % was male. The annual population growth rate from 1981 to 1990 was 2.3 %, which was slightly higher than the national average of 2.2 %. The population density was 272 persons per km^2.

The number of households was 5,153, out of which 4,580 or 89 % were independent farmers. The average family size in the area was about 6.5 persons. The demographic and land conditions by ward are presented in Table 3.1 and summarized in the following table:

Name of VDC	Male	Female	Total	No.of. Households	Family Size	No. of farm Households	Ratio (%)	EAP*
Mahendrakot	2,938	2,947	5,885	919	6.4	746	(81.1)	3,010
Dubiya	790	740	1,530	272	5.6	270	(99.3)	780
Jayanagar	2,564	2,379	4,943	598	8.3	566	(94.6)	2,530
Buddi	2,257	2,064	4,321	760	5.7	756	(99.5)	2,210
Rajpur	3,660	3,184	6,844	814	8.4	764	(93.9)	3,510
Mahuwa	2,016	1,896	3,912	707	5.5	618	(87.4)	2,000
Dhankauli	3,170	2,652	5,822	1,083	5.4	860	(79.4)	2,980
Total	17,395	15,652	33,257	5,153	6.5	4,580	(88.8)	17,030

Note: EAP*: Economically Active Population

3.2 Topography

The study area, including about 4,600 ha of arable land slopes towards the south from the north. It also has transverse sloping from both the east and west boundaries towards the center. The longitudinal slope decreases as one proceeds to the south. The average slope in the northernmost reach, starting from Pattharkot Village (EL 187 m at the cultivated fields) to Murmi Village (EL 121 m), is 1 in 130. Similarly, the central reach of the study area, starting from Murmi to the East-West Highway, where the elevation varies from 115 m to 117 m, has a relatively gentle average slope of 1 in 600. The southernmost reach of the study area, extending from the highway to Bishambapur Village (EL 100 m), has a rather flatter slope of 1 in 800 on average.

The East and West boundary areas are terraces of the Kondre, Banganga, Gudrung, and Belwagurdwa rivers, where there are natural forests. The study area slopes gradually from the forest areas to the central part where most of the cultivated fields exist. The Ghorahi Nala, a natural drain of the study area, runs through the central low-lying area and meets the Banganga river in its downstream reaches.

There are six existing ponds, the size of which vary from 1 to 3 ha in the area north of the East-West Highway and three existing ponds which vary in size from 2.5 ha to 18 ha in the southern area. These ponds are constructed in natural depressions sloping north to south.

In light of the topography, most of the arable land in the study area can be irrigated by taking water at the existing intake site of the Ranikudwa Farmers' Irrigation System on the Gudrung river, if the river has abundant discharge. However, for the first 10 km stretch of the canal system (from Pattharkot to Murmi) a considerable number of drop structures are inevitable because of the steep terrain slope. Suitable sites for constructing five new ponds which would vary in size from 4 to 30 ha have also been identified in the natural forest of the northern part of the study area.

3.3 Meteorology and Hydrology

3.3.1 Meteorology

The study area is located below 200 m elevation and has a subtropical climate. Agro-meteorologically, a year can be broadly divided into three seasons:

	Season	Period	Characteristics
i)	Rainy season	June - September	high temperature, humid
ii)	Winter season	October - March	low/moderate temperature, dry
iii)	Spring season	April - May	max. temperature over 40 °C, dry

According to the records at the Taulihawa Meteorological Observatory, which is the closest to the study area, the mean monthly temperature varies from 15 °C in January to 31 °C in June, while the mean monthly relative humidity fluctuates between 45 % and 85 %. Annual evapotranspiration ranges from 1,200 mm to 1,700 mm.

3.3.2 Hydrology

(1) Precipitation

The mean annual rainfall for the last 20 years in Pattharkot, which is situated close to the proposed Gudrung headworks ("Gudrung headworks") site was 2,236 mm. Only two years, including 1992, received annual rainfall of less than 2,000 mm. The annual rainfall figure of 80 % dependability, which is generally used for irrigation planning, amounts to 2,100 mm.

About 86 % of the annual rainfall is concentrated in the four months from June to September. After the rainy season, sporadic rainfall occurs in October, but little rainfall is observed in November and December. It is generally dry with only occasional rainfall in January, February, and March . In April and May, occasional storms are brought on by the southeast monsoon.

Although, the annual rainfall itself is ample, the concentration of the rainfall in the rainy season hampers its year-round effective use for crops. In particular, the transplanting date of paddy rice, a predominant summer crop in the rainy season, largely depends on the rainfall in June, which varies greatly. In the case that the transplanting is delayed, the yield may be reduced due to water shortage in the late growing stage, and winter crop cultivation is sometimes abandoned.

(2) Runoff characteristics

The study area lies close to the meeting point of the Siwalik range and the Terai plain. In geographical terms, the study area is composed of piedmont fans in the north and flat plains in the south. The rivers originate from steep and small mountainous watersheds and form fans while flowing to the Terai plain. The flood concentration time is short, and the peak discharge is high because of such basin characteristics. A certain amount of the river water is lost as understream at the top of the fans. Some of the understream water appears as springs at the foot of the fans and/or the terrace scarp, while the rest recharges confined groundwater.

(3) Design flood discharge

Based upon the field observations and hydrological studies, a peak flood of 1 in 50-year return period (proposed design flood) was estimated for the Gudrung headworks site. Since the catchment of the Gudrung river at the proposed headworks site is steep and short, the peak discharge is big and the flood concentration time is short.

The design flood discharge at the Gudrung headworks site was estimated at about 500 m^3/sec.

3.4 Geology and Hydrogeology

3.4.1 Geology

(1) General Geology of the Study Area

The study area is located in the vicinity where the Siwalik range and the Terai plain meet. The Siwalik range is composed of mountains of about 1,000 m in height running east to west. A field reconnaissance survey on the geology of the area was carried out. The results are summarized as follows :

The basement rock in the area is composed mainly of the Siwalik Group sandstone of the Neogene Tertiary. The Siwalik Group is the molasse derived from the Himalayas and consists of sedimentary rock of the Miocene to Pleistocene. The basement is overlain by terrace deposits, fan deposits, talus deposits, and alluvial deposits of the Pleistocene to Holocene and the Quaternary. Terrace deposits were classified into three types depending on the relative height difference above the Gudrung river bed. Fan Deposits were divided by age into two groups, new deposits and old deposits.

The Siwalik Group consists of an alternation of coarse to medium sandstone and calcareous fine sandstone to siltstone. The coarse to medium sandstone is grayish, somewhat calcareous and hard. The calcareous fine sandstone to siltstone varies from shades of red to brown, and is somewhat hard to soft. X-ray analysis shows that these rocks are very calcareous. The general geological structure of the Siwalik Group in the area is the bed strikes N30°E and dips 30° to 60°NE. A fault extends parallel to the Gudrung River.

Most of the study area is located on the terraces of the Pleistocene, and is overlain by unconsolidated material such as sand, silt, and clay. The southern part of the study area is located on the alluvial plain.

(2) Geology of the Proposed Headworks at the Gudrung River

A boring survey of six holes, with a total length of 70 m, was conducted. The results are as follows :

i) Geology

a) The deposits, lower terrace deposits and alluvial deposits, of the proposed headworks site at the Gudrung river range from 0 to 9 m in depth, with most being around 5 m in depth.

b) Both the Siwalik Group basement rock, including the fault found in BNo.4 (below 9.0 m deep), and the deposits are sound and stable as far as the bearing capacity is concerned, for the construction of the headworks on the Gudrung river. The N-values of the headworks site obtained from the standard penetration tests (SPT) were found to be greater than or equal to 50, except in BNo.5, where the N-values varied from 43 to 48 up to 4 m in depth, and in BNo.3, where the

N-value was 41 at a depth of 4 m. Figures 3.1 and 3.2 show the geological map and the geological profiles of the Gudrung headworks site, respectively. The geological engineering problems for the design and construction are discussed in detail in Annex B.

ii) Distribution of Unstable Rocks and Landslides

a) The abutment on the right bank of the headworks site is on a skirt of a sharp ridge. The sandstone, which forms the edge of the ridge, has many open cracks caused by weathering and erosion. The maximum gap in the rock is around 50 cm. The rock in BNo.1, bored into the sandstone, was found to be unstable and permeable up to 4.1 m in depth from the ground level.

b) In the vicinity of the above-mentioned abutment and slope, surface landsliding was observed. The extent of landsliding could increase in the rainy season. However, it is mass wasting of a highly weathered zone near the ridge and is not large- scale.

c) Talus deposits exist on the left bank slope, 50 to 100 m downstream of the headworks site. In the rainy season, rockfalls and landslides occur in some places to a limited extent.

iii) Permeability

The permeability of the alluvial deposits and lower terrace deposits is a few orders higher than that of the Siwalik Group bedrock as shown in the table below:

Geological formation	Average Permeability K (*cm/sec*)
Alluvium	1.2×10^{-2}
Lower Terrace Deposits	5.2×10^{-3}
Siwalik Group	4.8×10^{-5}
Siwalik Group (Cracky Zone)	2.9×10^{-3}

Note: Since the injection method was used, the permeability for highly permeable layers such as alluvium and lower terrace deposits may be lower than the real values. The real values might be one or two orders higher than the values obtained.

(3) Geology of the Kondre River, 3 km Upstream from the East-West Highway

The geology of the Kondre river, 3 km upstream from the East-West Highway consists of sand, silt, and clay of the Pleistocene. The mean particle size is that of fine sand. The soils seem to be susceptible to piping. Soil tests show that the critical hydraulic gradient is 0.657 and 0.961 for the right and left banks, respectively.

3.4.2 Hydrogeology

(1) Summary of the Hydrogeology

At the foot of the Siwalik range, where major rivers in Nepal flow onto the Terai plain, piedmont fans are well developed. In this area, a deep layer composed primarily of pebbles and

boulders forms an excellent groundwater recharge area called the "Bhabar Zone". The width of the Bhabar Zone is more than 12 km in eastern Nepal, and the Tinau and Banganga river fans which are close to the study area are 8 km wide. However, the Gudrung river fan (the Pattharkot fan) is only a few km wide. Most parts of the study area are located on the Pleistocene terraces and overlain by impermeable layers such as fine sand, silt, and clay. Therefore, it is hard for rainfall to infiltrate. Figure 3.3 shows the hydrogeorogical map of the study area.

Only two tube-wells were used : One was a deep tube-well of 200 m in depth in Sitapur (JICA well : artesian), and the other was a shallow tube-well about 70 m deep in Gorusinge. In most cases, wells around 10 m deep are for domestic use or drinking water.

(2) Possibility of Groundwater Exploitation for Irrigation

The groundwater resources for exploitation in the study area can be classified into two types: confined and phreatic groundwater.

Judging from pumping test results shown in the following table and existing tube-well data, the discharge rate of the confined groundwater is estimated as follows : In major parts of the study area from Sitapur to Pattharkot, the discharge rate for deep tube-wells from 100 to 130 m in depth is around 4 l/s. The pumping rate increases southwestward and reaches 6 l/s in Bichwapur. These rates are insufficient for irrigation, though they are useful for domestic use or drinking water. For irrigation wells, the following pumping rates are generally required : 10 l/s for shallow tube-wells around 30 m deep and 25 l/s for deep tube-wells from 100 to 130 m in depth.

	Well No.	Location	Transmissivity T (cm^2/s)	Permeability K (cm/s)	Storage Coefficient S	Max. Discharge (l/s)
Present Study	STW-14*	Gorusinge	4.80	3.20×10^{-3}	4.93×10^{-4}	2.03 (176 m^3/d)
	K-23*	Dewari	0.366	1.22×10^{-4}	2.72×10^{-4}	2.07 (179 m^3/d)
	PW-1	Sitapur	0.56	5.39×10^{-4}	1.34×10^{-4}	3.90 (337 m^3/d)
	OW-1	Sitapur	4.58	1.02×10^{-3}	2.83×10^{-3}	3.90 (337 m^3/d)
Reanalysis of Existing Data	K-23	Dewari	0.790	2.63×10^{-4}	—	0.85 (73.3 m^3/d)
	K-24,25	Bichwapur	8.78	2.93×10^{-3}	6.55×10^{-3}	5.72 (494 m^3/d)
	K-29	Dhakeri	0.878	2.93×10^{-4}	—	2.22 (192 m^3/d)
	STW-10	Mahuwa	3.82	7.64×10^{-3}	—	2.22 (192 m^3/d)
	STW-13	Gorusinge	5.32	3.55×10^{-3}	—	4.00 (346 m^3/d)

* Shows study in the rainy season. Others are conducted in the dry season.

The low possibility of groundwater exploitation is due to the small recharge area, low river discharge, and low permeability of the confined aquifers. For instance, the annual mean discharge of the Tinau river and Banganga river, which are the main rivers in Lumbini Zone, are 22.2 m^3/s and 16.5 m^3/s, respectively. On the other hand, that of the Gudrung river is only 1.1 m^3/s. In addition, as pores in the confined aquifers are filled with sand and silt, the aquifers show low permeability, in the order of 10^{-3} to 10^{-4} cm/s, which is close to that of sand.

The phreatic groundwater of the Pattharkot fan, in the northern part of the study area, wells up at the southern border of the fan as the East Birpur springs, east of the Gorusinge-Pattharkot road, or the West Birpur springs on the terrace cliff, on the left bank of the Gudrung river. The spring water can be utilized for irrigation. The discharge in February was around 20 l/s for the East Birpur springs, and about 7 l/s for the West Birpur springs.

3.5 Soil and Landuse

3.5.1 Soils and Land Evaluation

(1) Soils

The soils in the study area are classified into six soil units according to Soil Taxonomy (Soil Survey Staff: 1975, The Keys to Soil Taxonomy: 1992). The characteristics of each soil unit are summarized below:

Soil Units	Physiography	Topography	Soil Characteristics			Drainability	Landuse
			Color	Texture	Depth		
Typic Ustifluvents	Erosional Terrace	Flat	Olive brown	SL	Mod. deep	Well	Farmland Grassland Forest
Aeric Endoaquepts	Recent Alluvial Plain	Almost flat	Yellowish olive	CL	Deep - Mod. deep	Imperfect	Farmland
Typic Endoaquepts	Recent Alluvial Plain	Slightly concave	Graysh olive	CL	Deep	Poor	Farmland Swamp
Fluventic Ustochrepts	Piedmont Plain	Gently undulating	Dark graysh yellow - Olive brown	SiL	Deep	Imperfect - Mod. well	Farmland Forest
Typic Ustochrepts	Old Terrace Terrace Remnant	Gently undulating Slightly convex	Brownish black - Olive brown	SiL	Deep	Imperfect - Mod. well	Farmland Forest
Typic Haplustolls	Piedmont Plain Old Terrace	Undulating	Brownish black	L	Deep	Mod. well	Forest

The soil map units were categorized according to their physiographic features. In the largest category in the legend they were classified into four physiographic units: (i) piedmont fan (F), (ii) old terrace (U), (iii) recent alluvial plain (P), and (iv) erosional terrace (ET). These physiographic units were further divided into nine land type units on the basis of their topographic condition, landuse condition, and vegetation. The correlation between the soil units and mapping units are shown in the following table:

Physiographic Feature	Land types	Mapping symbol	Associated type	Correlative soil units
Piedmont Fan	Open land	F1	Consociation	Fluventic Ustochrepts minor Aeric Endoaquepts
	Forest	F2	Association	Fluventic Ustochrepts Typic Haplustolls
Old Terrace	Open land	U1	Consociation	Typic Ustochrepts
	Forest	U2	Association	Typic Ustochrepts, Typic Haplustolls
Recent Alluvial Plain	Terrace Remnant	P1	Consociation	Typic Ustochrepts
	Flat plain	P21	Consociation	Aeric Endoaquepts
	Depressional plain	P22	Consociation	Typic Endoaquepts, minor Aeric Endoaquepts
	Old river course	P3	Consociation	Fluventic Ustochrepts, minor Aeric Fluvaquents,
Erosional Terrace	Lower Terrace	ET	Consociation	Typic Ustifluvents

The soil map for the project area is illustrated in Fig. 3.4. The extent of these soil map units are summarized below:

Physiographic feature (map symbol)	Northern Area of the East-West Highway		Southern Area of the East-West Highway		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Piedmont fan (F)						
Open field (F1)	150	3	0	0	150	1
Forest field (F2)	640	14	0	0	640	5
Old Terrace (Upland) (U)						
Open field (U1)	70	1	130	2	200	2
Forest field (U2)	2,480	55	3,400	44	5,880	48
Recent Alluvial Plain (P)						
Highland (Terrace remnant) (P1)	260	6	793	10	1,050	9
Flat plain (P21)	580	13	2,250	29	2,840	23
Depressional plain (P22)	360	8	780	10	1,130	9
Old river course(P3)	0	0	20	0	20	0
Erosional Terrace (Lower terrace)(ET)	10	0	300	4	310	3
Total	4,550	100	7,670	100	12,220	100

The soils of the study area mainly have a medium to fine texture. The piedmont plain and the old terrace have medium textured soils and the recent alluvial plain, which extends broadly in the study area, has fine textured soils. Soil acidity ranges from pH 4.5 to pH 10.0. High pH values (over 9.0) are found in a minor part of the southern study area, however, most of the soils range from pH 6.0 to pH 8.0 and alkaline conditions are rarely found in the study area. EC(1:2.5) values range from 0.02 to 0.5 mS/cm and saline conditions are not found.

(2) Land Evaluation

The land classification was carried out according to the FAO system (Framework for Land Evaluation , FAO, 1976) composed of five classes (three suitable classes and two non-suitable classes). The evaluation criteria, described in the Design Manual for Irrigation Development in Nepal; M4 Soil and Landuse Report (1990) were applied as specific criteria. In order to clarify the land suitability for the alternative crop production, the appraisal was conducted for both paddy and upland crops. The land evaluation map is presented in Fig.3.5. The following are the summary of the land evaluation of the study area:

	Paddy			Upland Crops	
classes	Area(ha)	(%)	Classes	Area(ha)	(%)
SR1	2,830	23	S1	1,050	9
SR2	2,560	21	S2	3,200	26
SR3	310	3	S3	1,450	12
Subtotal	(5,700)	(47)	Subtotal	(5,700)	(47)
NSR	6,520	53	NSR	6,520	53
Total	12,220	100	Total	12,220	100

Remark: NS and NSR: Non Suitable

Of the study area (12,220 ha), 5,700 ha (47%) are suitable for irrigation farming (paddy and upland).

3.5.2 Present Landuse

Present landuse in the study area is broadly divided into: (1) Agricultural land and (2) Non-agricultural land.

(1) Agricultural land

Landuse units of the existing agricultural land were classified into three categories based on both the results of field survey and the review of the previous study (the Land Resource Mapping Project: LRMP), which was carried out by HMG/N and the Canadian International Development Agency. The details are described below:

i) Lower Paddy Fields
This land is composed of poorly to imperfectly drained soils of fine texture with less than 1 : 100 slope. They are small-sized fields (less than 0.01 ha) with high bunds. They are planted with paddy in the rainy season. In the dry season, almost all of these fields are planted with one or two mixed winter crops (wheat, linseed, or grass pea), or left as fallow due to poor drainability. A winter crop (wheat) and spring crops (maize or pulses for green manure) are practiced to a limited extent.

ii) Upper Paddy Fields
This is an intermediate land unit between the lower paddy fields and the dry land. These lands are located in a slightly higher area than the lower paddy fields and field size is also slightly larger (less than 0.02 ha). Drainability is more favourable than that of the lower paddy fields. Paddy is predominant in the rainy season. Although depending on the availability of water, mainly mustard, wheat, lentils or vegetables are cultivated in the dry season.

iii) Dry Fields (Paddy and Upland Crops)
This unit occupies high terraces or gentle slopes of less than 1:30, and is mainly composed of moderately well drained loamy soils. They are cropped under rainfed conditions. The dominant crops in the rainy season are paddy or maize, which are partly followed by mustard, pulses, vegetables, and fallow in the dry season.

(2) Non-Agricultural land

The non-agricultural land is subdivided into (i) forest and grassland, (ii) pond and swamp, (iii) grazing land (iv) existing facilities such as canals, drains, footpaths, etc. and (v) others, like roads, houses, house yards, etc.

The distribution of each landuse unit is presented in Fig.3.6. The area of agricultural and non-agricultural landuse is summarized as follows:

Description	Northern Area of the East-West Highway		Southern Area of the East-West Highway		Total	
Agriculture Land:	(ha)	(%)	(ha)	(%)	(ha)	(%)
Lower paddy fields	770	17	2,320	33	3,080	27
Upper paddy fields	340	7	1,010	14	1,350	12
Dry land	40	1	90	1	130	1
Subtotal	(1,140)	(27)	(3,420)	(48)	(4,560)	(40)
Non-Agricultural Land:						
Forest and grassland	3,090	68	3,350	44	6,440	53
Pond and swamp	30	1	50	1	80	1
Grazing land	40	1	110	1	150	1
Existing facilities	100	2	300	4	400	3
Others(Roads, House yards, etc.)	150	3	440	6	590	5
Total	4,550	100	7,670	100	12,220	100

3.6 Present Condition of Agriculture

3.6.1 Crops and the Cropping Pattern

The lands are cultivated to a large extent with paddy (97%) and upland crops (3%). Most of the paddy fields are put under rainfed conditions, excluding some irrigated fields (about 30%, 1300 ha) which exist under an irrigation system, with ponds and pumps, managed by farmers. Hence, the cultivation area and level of crop production change annually due to the rainfall patterns and available water.

The present condition of farmland in the study area is as follows:

(Unit: ha)

Name of VDCs	Paddy Fields			Upland	Total
	Irrigated	Non-irri.	Subtotal		
Mahendrakot	400	110	510	0	510
Dubiya	150	220	370	30	400
Jayanagar	60	570	630	40	670
Buddi	240	210	450	0	450
Rajpur	300	500	800	20	820
Mahuwa	50	640	690	40	730
Dhankauli	100	880	980	0	980
Total	1,300	3,130	4,430	130	4,560

The staple crop of the study area is paddy followed by wheat and maize. Vegetables are grown for only family consumption purposes, in the garden or house yard area. The present cropping calendar is as follows:

Crops	Seedling/ Planting	Harvesting
Summer Crops :		
Paddy, maize	June / July	October / November
Winter Crops :		
Wheat, pulses, oilseeds, vegetables	October / December	March / April
Spring Crops :		
Maize, pulses	March / April	June / July

The dominant summer crop in the rainy season is paddy which represents 95 % of the total cultivated area, and the other prevailing crops are maize and pulses. During the dry season in winter, wheat is predominant and pulses (lentils, pigeon pea, chick pea, and black gram), oilseeds (mustard), and vegetables (potatoes, cabbage, cauliflower, leaf mustard, onion, garlic, radish, tomato, etc.) are also planted to some extent. After the winter crops, spring crops (maize, pulses for green manure crops, etc.) are planted. However, production of the spring crops is limited due to little rainfall, hence they are used for animal feed and/or green manure.

The present multicropping intensity is estimated at 132 % in the study area including more than 200 % of the existing irrigation area. According to the agricultural survey carried out in the study area, the present cropping patterns, their cropping intensity and cropping area in the study area can be classified into seven types as shown in the following table:

Cropping Pattern	Cropping Intensity	Cropping Area
Irrigated Paddy Fields	(%)	(ha)
A-1 : Paddy - Wheat/ Oilseeds - Maize/ Pulses	300	40
A-2 : Paddy - Wheat/ Oilseeds/Pulses/Vegetables	200	480
A-3 : Paddy - Wheat/ Oilseeds/ Pulses	180	340
A-4 : Paddy - fallow	96	440
Subtotal		1,300
Non-irrigated Paddy Fields		
B-1 : Paddy - Wheat/ Oilseeds/ Pulses	170	940
B-2 : Paddy - fallow	100	2,190
Subtotal		3,130
Upland		
C : Maize/ Pulses - Pulses/ fallow	94	130
Total	132 (Ave.)	4,560

Pattern A-1 is observed in the upstream parts of the existing irrigation areas. Pattern A-2 and A-3 prevail in the irrigated paddy fields, which occupy about 63 % of the existing irrigation areas. Due to little irrigation water and rainfall in the dry season, very limited areas are planted with winter crops. Pattern A-4 is evident in the lower parts of the existing irrigation area which have no irrigation water due to poor irrigation facilities. Pattern B-1 with the double cropping of paddy and winter crops is observed in the non-irrigated fields areas, but the cultivation area is small. Pattern B-2 is common practice in lowland areas of existing paddy fields along small streams where there is high soil moisture content due to the high groundwater table. Pattern C is found in the dry field and upland field areas. These present cropping patterns and cropping areas are illustrated in Fig. 3.7.

3.6.2 Present Crop Yields and Production

The annually planted area, unit yields, and production in the study area were estimated from the agricultural statistics in Kapilvastu District and the farm survey (ref. Table D.4). Unit yields of major crops remain extremely low not only due to the shortage of irrigation water but also insufficient agricultural inputs and traditional farming practices.

The total planted area for summer crops was estimated at 4,100 ha on a 10 year average. The average planted area for paddy from 1982/83 to 1991/92 was 3,980 ha which was concentrated in the rainy season. The planted area for wheat was about 850 ha on average, corresponding to 20 % of the total paddy fields. Such a low cropping area or intensity is basically attributable to the shortage of water.

The average annual planted area, unit yields, and production of major crops in the study area are tabulated below:

Crops	Planted Area (ha)	Unit Yield (ton/ha)	Production (tons)
Summer Crops			
Paddy (partially irrigated)	1,280	2.20	2,820
Paddy (non-irrigated)	2,700	1.42	3,840
Maize (upland)	90	1.33	120
Pulses (upland)	30	0.56	20
Winter Crops			
Wheat (partially irrigated)	470	1.70	800
Wheat (non- irrigated)	380	0.98	370
Oilseeds (partially irrigated)	120	0.71	85
Oilseeds (non-irrigated)	95	0.46	40
Pulses (partially irrigated)	120	0.66	80
Pulses (non-irrigated)	620	0.56	350
Spring Crops			
Maize (partially irrigated)	40	1.72	70

3.6.3 Present Farming Practices and Farm Inputs

The present farming practices in the study area are labor intensive throughout the growing period from seedling to harvesting. Nursery bed preparation, plowing, harrowing, and paddling in the paddy fields are carried out using manual and animal power in June/ July before transplanting. Hand weeding is a common practice for removing weeds from the fields. Harvesting is carried out using sickles and the harvested paddy, wheat, mustard, and lentils are dried in the fields or house yards. After threshing, cleaning, and drying, grain is stored for home consumption or sale in local markets.

According to the farm survey, about 19% of the farmers use the seed of improved varieties. Most of the farmers use farmyard manure at the time of land preparation, but the application quantity depends on the land holding areas and the number of cattle owned by the farmers. 38 % of the farmers also use chemical fertilizers, mostly composite and urea, but the application is still small. Out of the total farmers, about 8 % apply fungicides, 24 % use herbicides, and 42 % spray insecticides.

3.6.4 Livestock and Fishery Production

Livestock plays an important role in tilling and transportation as draft power, and also as a source of protein. Bullocks (cow) and buffaloes are used for land preparation, threshing, and transportation. Animal products are used for home consumption and for obtaining cash by selling. Most of the livestock are grazed on the forest area and around the paddy fields. About 95 % of farmers have 5.9 cows and/or buffaloes on average, about 42 % of farmers keep goats, about 17 % breed pigs, and about 37 % keep chickens. The number of livestock in the study area is tabulated as follows :

(Unit: head)

Village	Cow	Buffalo	Goat	Sheep	Pig	Chicken
Mahendrakot	2,804	1,357	2,474	127	12	2,000
Dubiya	1,340	661	247	48	41	900
Jayanagar	2,487	1,481	1,509	10	62	1,664
Buddi	3,478	2,195	158	122	132	3,000
Rajpur	3,003	816	605	25	48	570
Mahuwa	2,421	965	1,982	-	535	400
Dhankauli	2,817	1,047	2,853	10	9	480
Total	18,350	8,522	9,828	342	839	9,014
Average per farmer	4.0	1.9	2.1	0.1	0.2	2.0

Aqua-culture (pond fishery) is carried out in the irrigation cum domestic water ponds surrounding the villages. The fish is an important farmers' protein food in the study area. Extension services are provided by the fishery extension workers of DADO, Taulihawa. Fingerlings are mainly supplied by the Fishery Development Centre, Bhairahawa and partly by the private sector. The production of aqua-culture is still low due to the shortage of in-pond water during the dry season.

3.7 Agro-Economy and Marketing

3.7.1 Farm Households and the Agricultural Labor Force

There are 5,153 households in the study area, out of which farm households accounted for 4,920 comprising 2,750 owner-farmers, 1,830 owner cum tenant farmers, and 340 tenant/landless farmers (Table 3.2).

Based on the total number of farm households, the agricultural population was estimated at 31,700. Further, the economically active population was estimated at about 51 % of the previous figure in the census of 1981. Accordingly, the total available agricultural labor force in the study area was estimated at 16,250 persons. This means that the average number of workers per ha of cultivated area was 3.6 persons. Marginal and landless farmers are generally hired by large and medium-scale farmers as farm laborers. Based on the assumption that a year has 80 % working days, the labor force was calculated at 4,745 x 10^3 man-days per year. On the other hand, the actual labor requirement for farming activities in the study area was estimated at 6.67 x 10^3 man-days per year on the basis of the present cropping pattern and land use conditions. This means that only 15 % of the yearly available labor force is utilized by farming activities.

3.7.2 Landholding and Land Tenure

The farm households in the study area are divided into four categories by landholding size: marginal, small, medium and large, excluding landless farmers. The average landholding size in the study area is 1.00 ha, consisting of 0.97 ha of paddy field and 0.03 ha of upland field and/or kitchen garden. The landholding condition is summarized below:

Category of Farmer	Farm Size (ha)	No. of Farmers (No.)	(%)	Total Area (ha)	(%)	Average Size (ha)
Marginal	under 1.0	3,105	67.8	1,127	24.7	0.36
Small	1.0 to 2.5	1,031	22.5	1,481	32.5	1.44
Medium	2.5 to 5.0	329	7.2	1,097	24.1	3.33
Large	over 5.0	115	2.5	855	18.8	7.43
Total		4,580	100.0	4,560	100.0	1.00

Note: No. of farmers excludes landless farmers (340 households)
Source: Land Registration Record, Land Revenue Office, Kapilvastu

The cultivated area of small and medium-scale farmers includes about 15 % of tenant land on average. In general, the tenant fees are paid by products by half-and-half sharing with landowners.

3.7.3 Marketing and Prices

(1) Marketable Products and Marketing Channels

The marketable products in the study area can be roughly estimated from per capita consumption, total population, and total production. About 340 tons/year of paddy and 55 tons/year of wheat, which is about 5 % of the total production of each crop, is marketable, however, the production of other crops is nearly equal to or less than the total demand in the study area and are not marketable at present.

About 50% of the marketed paddy is sold to local collectors or wholesalers at the local markets. The rest of it is handled by village merchants or sold to millers or wholesalers in Taulihawa by farmers themselves. Paddy bought by millers or wholesalers is sold to people in the hill area through Taulihawa, Bhairahawa, Butwal, or Narayanghat after milling. Some part of the milled rice is supplied to the Arghakanchi District, located north of the study area, to alleviate the food-grain shortage there.

Marketable wheat is in short supply because farmers consume most of it themselves. One of the marketing channels is formed by market traders at local markets, the other is by collectors at farm gates. The collectors and local market traders then sell the products to wholesalers or millers in Bhairahawa, Janakpur, Birganji, or Kathmandu.

Most of the mustard seed is consumed as cooking oil after milling by small-scale millers in the villages. Some of the seed is sold to oil millers in Butwal and Bhairahawa through middlemen. Vegetables, including potatoes, onions, cauliflower, etc., are almost always consumed by the farmers themselves or in the village. Only a small part of these are sold at weekly village markets or Taulihawa market by middlemen or the farmers themselves.

(2) Farm Input Supply

Farm inputs such as fertilizers, agro-chemicals, and seeds are supplied by the Agricultural Input Corporation (AIC) via cooperatives and the private sector. Selling prices are fixed throughout the country.

The farmers in the study area get farm inputs through two cooperatives located in Gorusinge (Arinko Cooperative) and Dhankauli (Janasewa Cooperative). The two cooperatives supplied about 120 tons of fertilizer in 1991/92. However, the inputs supply by AIC does not usually meet the farmers' demands both in terms of quantity and timing.

(3) Prices of Agricultural Products and Farm Inputs

The farm survey and farm economy survey indicate farm-gate prices of agricultural products and inputs in the project area as follows: Prices of the agricultural products are based on the average prices at marketing periods. Prices of inputs are based on the AIC prices in January 1993. Labor costs are NRs. 40 per day for male laborers and NRs. 35 per day for female laborers.

Product	Paddy	Wheat	Maize	Pulses	Oilseeds	Vegetables
NRs/kg	5.25	6.00	6.00	14.00	16.25	5.00

Inputs	Urea	TPS	KCl	Complex	DAP
NRs/kg	5.14	8.00	8.50	10.00	12.50

(4) Agricultural Credit

The agricultural credit is provided for farmers through ADB/N, cooperatives, and commercial banks. According to the farm survey, about 10 % of farmers in the study area seem to have utilized the credit. The Small Farmers Development Program (SFDP), which provides farmers with loans and technical assistance through ADB/N, to organize small-scale farmers' groups efficiently, has not been established in the area yet.

3.7.4 Agricultural Production Value and the Farmers' Economy

(1) Production Value and Net profit

The total crop production value and total net profit value were estimated from the cropped area, gross income, and net return per ha. The total crop production value and total net profit value are NRs. 52.86 x 10^6 and NRs. 25.97 x10^6, respectively, while those per ha are NRs. 11,590 and NRs. 5,700, respectively as follows:

Crop	Total Production Value	Total Net Profit Value
	(1,000 NRs)	(1,000 NRs)
Paddy	34,930	16,560
Wheat	7,020	2,950
Maize	1,130	690
Oilseeds	2,050	1,430
Pulses	6,190	3,590
Vegetables	1,540	750
Total	52,860	25,970

(2) Farmers' Economy

Based on the farm survey, an analysis of the farm economy was carried out on farm types in the study area. The small and marginal-scale farmers have no reserves or surpluses in their farm budgets, which the medium and large-scale farmers have some reserves. The farm budgets for the various farm types are presented in following table:

(Unit: NRs.)

	Farmers' Categories				
	Large	Medium	Small	Marginal	Average
A. Income	28,400	19,070	16,130	12,200	14,180
- Farm Income	21,660	13,080	9,290	2,840	5,700
- Livestock Income	2,880	1,210	2,610	2,720	2,580
- Non-farm Income*	3,860	4,780	4,230	6,640	5,900
B. Expenditure					
- Living Expenses **	24,690	17,440	16,130	12,200	13,790
C. Net Reserve	3,710	1,630	0	0	390

Note: *: Including farm labor income.
**: Including self-consumed agricultural products.

3.8 Irrigation and Drainage

3.8.1 Irrigation and Drainage System

The potential irrigation water sources in the study area are identified as follows:

i) Gudrung river, Kondre river, Belwagurdwa river, Banganga river, and small streams such as the Ghorahi nala (natural drain),
ii) springs situated in the north-west of the area, and
iii) small/medium-size ponds scattered in the area.

Among these water sources, the Kondre river and Belwagurdwa river have not been utilized because of their extremely low river beds compared to the farm field level. Banganga river, flowing by the south end of the study area, has a low bed level and wide river course, which restrain the use of water except for some pumping systems. Consequently, the water sources being used at present are the Gudrung river, springs, Ghorahi drain, and small/medium-size ponds.

The Gudrung river is being diverted at Ranikudwa point, situated north of Pattharkot, for the Ranikudwa Farmers' Irrigation System. The Ranikudwa Irrigation System commands an irrigation network of about 600 ha from Pattharkot down to Purena. However, the actual

irrigation area varies from year to year due to flood damage to the intake facilities, leakage/seepage losses of the deteriorated canals, and small discharge in the dry season. The actual irrigation area in the dry season remains about one-third of that in the rainy season.

Ghorahi drain water has also been used for irrigation at different reaches by farmers with earthen bunds. These irrigation systems comprise of a series of canal networks, but the actual irrigation area is extremely small compared to the size of the facilities. This is due to the varying intake discharge from season to season and temporary nature of the diversion works.

The Department of Agriculture constructed a weir, "Jasbariya dam" in 1986 on Ghorahi drain near the southern end of the project area. Although the design command area of the dam was 670 ha, the actual irrigation area remains less than half that figure even in the rainy season because of the deteriorated intake facilities and the diversion of water in the upstream reaches.

About sixty ponds exist in the study area, most of which are small in size and have been abandoned due to sedimentation. Six (6) medium-size ponds, with canals, are presently used for irrigation. These ponds are mainly used for supplementary irrigation in the rainy season, while in the dry season their small storage capacities, except that of the Buddi pond, restrain the application of water for irrigation.

Irrigation by pumping water from the Banganga river is practised using small portable pumps for meeting the peak water requirements, such as for land preparation, transplanting and heading stages for paddy, and plowing and heading stages for wheat. The pumping sites are not generally fixed.

Even if the rotation system was applied to tackle the problem of water scarcity in every system in the study area, extremely uneven distribution of irrigation water (more water in the head reaches and less in the tail reaches) would still prevail. The following table shows the present irrigation area commanded by the different irrigation systems in the study area.

(Unit : ha)

	Summer crop (paddy rice)	Winter crop (wheat)	Spring crop (vegetables, etc)
1. Ranikudwa Farmers' Irrigation System (including the Birpur springs)	590	270	25
2. Pond irrigation system			
Buddi pond (including water fed from the Ghorahi drain)	140	110	0
Badahara pond	25	0	0
Dubiya pond	20	0	0
Pratrappur pond	10	0	0
Gelwar pond	5	0	0
Subtotal	200	110	0
3. Ghorahi drain irrigation system (in different reaches)	60	20	0
4. Jasbariya dam (Ghorahi drain)	300	0	0
5. Banganga pumping irrigation system	150	120	15
Total	1,300	520	40

The main drain in the study area is Ghorahi natural drain (small stream). Natural small drains running through the depressions are functioning as secondary drains. The irrigation canals for the Ranikudwa Farmers' Irrigation System are also partly used as drains, which is a common practice in the study area.

Since the water of the Ghorahi drain is dammed up by the farmers for irrigation at several locations, some paddy fields along a strip parallel to the drain, north of the East-West Highway, are subject to poor drainage. The drainage condition is also poor in the paddy fields close to the natural drains in the depressions.

3.8.2 Irrigation and Drainage Facilities

The existing irrigation systems as mentioned above, except two intakes, were constructed by the farmers . Since the structures were built without any technical background, they are technically primitive and thereby not functioning well.

An inundation type canal intake for diverting water to the headrace canal of the Ranikudwa Irrigation System, consists of a temporary weir made of boulders and gravel on the Gudrung river. No permanent structure exists in the headworks. Seepage/leakage loss along the 450 m headrace canal is serious as it was constructed using boulders and earth material without a lining. The main as well as the branch canals of the system are also unlined. However, some wet/dry masonry protection works have been provided in stretches that pass through densely populated areas such as Pattharkot. Major related structures for the irrigation system include concrete culverts for crossing the Gorsinge-Pattharkot road, wooden bridges, and tree-trunk aqueducts to cross the drains. No cross or head regulators have been provided at the bifurcation and turnout points. Water is distributed in proportion to the difference between bed levels of the main and branch canals. No drop structure exists there, hence, the canals have formed regime condition.

The canals and related facilities of other existing irrigation systems are similar to those of the Ranikudwa System. The brick masonry intakes constructed at the Ghorahi drain have been damaged and deteriorated by floods and, hence are not functioning well.

The East-West Highway crosses over the Ghorahi drain by a concrete bridge, while other drains across the highway are provided with culverts. Earthen bunds of a temporary nature have been provided to divert water from the Ghorahi drain to the canals.

3.8.3 Water Management and O&M

The water management and O&M of the Ranikudwa Farmers' Irrigation System have been carried out by the Ranikudwa Water Users' Association (RWUA) voluntarily organized by the beneficiary farmers without receiving financial assistance from HMG/N and technical guidance from DOI. The RWUA is organized by twelve Water Users' Groups (WUGs) formed by twelve villages (mouja) where the irrigation canals run.

The daily water management and O&M of each WUG have been carried out by an employed canal watcher (Chaukidar) under the control of both the canal chief (Badaghar) and the secretary (Sachiv) elected by the member farmers. However, both the water management and O&M of the Ranikudwa intake facility and headrace canal and the water distribution to the command area by a rotation system have been conducted by WUG of Pattharkot village located in the northern tip of the command area. The canal chief of Pattharkot WUG is an ex-officio chief of Pattharkot village, cum chairman of Mahendrakot VDC.

The restoration or rehabilitation of the intake facility and headrace canal damaged by floods, etc. has been executed by the member farmers of each WUG temporarily called out by the chairman of Mahendrakot VDC. WUG and its member farmers who did not obey the chairman's call must pay compensation by cash or other means for such a violation. In general, the water management and O&M of the Ranikudwa Farmers' Irrigation System have been smoothly carried out by such WUA and its rule as described above.

The water management and O&M of the Buddi Pond Irrigation System have also been smoothly carried out by the Buddi Pond WUA organized mainly by the beneficiary farmers in Buddi village, of which the chief is the ex-officio canal chief, without receiving financial and technical assistance from HMG/N or DOI, the same as the case of the Ranikudwa WUA. The water management and O&M of other farmers' irrigation schemes have been practised by the farmers' WUAs or WUGs which are similar to the Ranikudwa or Buddi WUAs or WUGs.

3.9 Farmers' Organization and Agricultural Support Services

3.9.1 Farmers' Organization

The cooperative society (Sajha) is a government guided farmers' organization, which has been indirectly guided and supervised by the Department of Cooperatives (DOC) since a change of HMG/N policy in 1992.(However, DOC and DOA were reorganized and combined into DOAD in 1993.). The operation fund of the cooperative society has been financed by ADB/N, and the agricultural inputs being handled by the society have been supplied by AIC.

In the study area there are two cooperative societies, belonging to the District Cooperative Union in Taulihawa, whose offices are located at Gorusinge and Dhankauli. These societies have mainly sold agricultural inputs to the member farmers. In addition, there is a dairy cooperative in Basantapur village, which collects milk from the farmers and sells it to buyers.

3.9.2 Agricultural Support Services

In Kapilvastu District agricultural extension services have been provided by nine agricultural service centers, each of which have such extension staff as Junior Technicians (JTs) and Junior Technical Assistants (JTAs) under the control of an Agriculture Development Officer (ADO). However, extension staff, facilities, and demonstration farms are still in short supply. Other agricultural support services being performed to encourage farmers in Kapilvastu District are: technological research and experiment by the Agricultural Research

Center, credit services by ADB/N, agriculture inputs supply, storage and delivery services by AIC, etc.

(1) Agricultural research

In the study area there is no agricultural research station and no experimental farm. However, in the country there are several research stations, which have conducted the respective commodity research programs under NARC as mentioned below:

(a)	Wheat Development Program	; Bhairahwa, Rupendehi in the Western Region
(b)	Rice Development Program	; Parwanipur, Bara in the Central Region
(c)	Pulses Development Program	; Khumaltar
(d)	Oilseeds Development program	; Nawalpur, Sarlahi in the Central Region

Under such programs as itemized above, growing tests, improvement of varieties and seed multiplication, etc. have been conducted as well as the upgrading and training of extension workers. In addition, variety application tests, introduction and demonstration of new varieties, technical guidance on farming practices, etc. have been carried out in farmers' fields by leading or advanced farmers in collaboration with agricultural service centers.

(2) Agricultural extension service

In the study area there exists the Buddi Agricultural Service Center (ASC), which has been managed and operated by a manager (Assistant production officer - APO), five extension workers (JTs and JTAs) and a statistician to cover nine VDCs. The major extension services are: regular meetings with leading farmers, technical guidance of farming practices, etc. However, the services are limited due to the shortage of funds, extension workers, transportation facilities, and training materials.

(3) Agricultural input supply

Agricultural inputs have been supplied to the farmers by a branch office of AIC at Taulihawa through existing cooperatives and wholesalers or dealers. However, the supply of such materials as improved seed, fertilizers, and agro-chemicals has not matched farmers' needs in relation to variety, price, and timing. Repayment of the credit for the purchase of inputs by the farmers has not been smooth.

(4) Credit services

ADB/N is the main source of institutional credit in the agricultural sector, and it provides short, medium and long-term loans for individual farmers, farmers' groups, and cooperative societies. There exists a branch office of ADB/N in Taulihawa, which covers the credit services of the study area. Although the branch mainly provides the farmers with credit for the purchase of seeds, fertilizers, etc. through the existing two cooperatives, the number of borrowers is limited and repayment by the borrowers is not always smooth.

CHAPTER IV BASIC DEVELOPMENT PLAN

4.1 Potential Development Area

4.1.1 Soil and Landuse

From the land resource point of view, the potential irrigation development area in the study area was clarified on the basis of the results of the land evaluation described in section 3.5. The results of the land evaluation are summarized below:

Paddy			Upland Crops		
Classes	Area(ha)	(%)	Classes	Area(ha)	(%)
SR1	2,830	23	S1	1,050	9
SR2	2,560	21	S2	3,200	26
SR3	310	3	S3	1,450	12
Subtotal	(5,700)	(47)	Subtotal	(5,700)	(47)
NSR	6,520	53	NSR	6,520	53
Total	12,220	100	Total	12,220	100

Remark : NS and NSR : Non Suitable

As shown above, about 47% (or 5,700 ha) of the study area, most of which is existing farmlands, is suitable for irrigation farming and thereby counted as a potential irrigation development area. However, the net potential area for irrigation development is limited to 4,560 ha of the existing farmlands, since the gross area of 5,700 ha includes villages, roads, grazing land, and existing facilities.

4.1.2 Irrigability

Irrigability is evaluated in terms of the topography and permeability. As mentioned in section 3.2, all the potential area for irrigation development, which slopes from north to south, could be irrigated if the irrigation water is taken at the northernmost tip of the study area, i.e. Pattharkot.

Permeability is evaluated by soil texture and the compactness of the subsurface layer . Since the soil texture of the potential area is loam to silty clay loam and its compactness is medium to compact with no cementation, it is evaluated that the permeability is moderately well to poor. In addition, the basic intake rate (I_B) measured using the cylinder in the dry season, was moderately slow to slow, such as 1 to 3 mm/hr in the piedmont fan, old terrace, and high land, and under 1 mm/hr in the other recent alluvial plain areas. Hence, it is assessed that the potential area is capable of retaining irrigation water for paddy cropping, and therefore has a good irrigability.

4.1.3 Drainability

Poor drainability is a major limitation for irrigation farming in the study area. Most of the depressional plain (P22) areas, which are about 1,000 ha in the study area, have been left

as fallow during the winter crop season, since the surface layer is still over-saturated when the winter crop seeds are sown.

The over-saturation is caused by:

(i) An imperfect drainage system; and

(ii) The dam-up of drains used for off-taking irrigation water and fishing by the farmers, which results in the high groundwater table.

However, if the drainage network is provided and adequately operated and maintained, the over-saturation will be overcome, and all the saturated fields in the potential area could be drained so that the winter crops can be cultivated.

Hence, the land evaluation was re-assessed by assuming that proper drainage improvement would be realized by constructing and maintaining a drainage canal network under the project. The results of the re-assessment of the land evaluation are as follows:

Paddy			Upland Crops		
classes	Area(ha)	(%)	Classes	Area(ha)	(%)
SR1	3,970	32	S1	3,880	32
SR2	1,420	12	S2	1,510	12
SR3	310	3	S3	310	3
NSR	6,520	53	NSR	6,520	53
Total	12,220	100	Total	12,220	100

Remark : NS and NSR : Non Suitable

4.1.4 Potential Development Area

In the light of the assessment on land resources, irrigability, and drainability, the potential area for irrigation development will be 4,560 ha of the present farmlands extending from Pattharkot village to the confluence of the Banganga river and Belwagrudwa river, which is in the southernmost end of the study area.

4.2 Water Availability and the Possible Irrigation Area

4.2.1 Available Water Sources

Three types of water source, namely rivers, ponds, and groundwater, are available for irrigation in the project area.

The three rivers of the project area, of which irrigation utility has been assessed, are (i) the Kondre river, which was originally considered as the source, (ii) the Gudrung river, on which the intake site could be located at the upper most point of the project area, and (iii) the Belwagurdwa river, flowing along the western boundary of the project area.

Generally two types of ponds are considered: i) ponds which store rainwater and surface run-off from their catchments and ii) ponds which not only store rainwater and surface runoff but which are also fed by the irrigation canals from the rivers. The former type of ponds have been termed as 'independent ponds' and the latter as 'canal-fed ponds', in this

report. Independent ponds have small irrigation areas compared with their inundation areas, resulting in low efficiency.

Groundwater potential was found to be very low for irrigation in the project area after a series of pumping tests and a hydrogeological study were conducted during the field survey.

(1) Source Rivers

Various features of the rivers under consideration were as follows:

i) Location of Intake

The proposed intake site on the Gudrung river is very close to the existing one. The site has an advantage of being located at the highest elevation of the project area. Originally the proposed headworks site on the Kondre river was to be located 500 m downstream from the confluence with its tributary the Rajkudwa river, and the command area under the headworks situated near the East-West Highway.

The bed level of the Belwagurdwa river is so low that the far southern area can only be irrigated wherever the headworks are located on the river. In addition, the idle length of the main canal will be very long and the river course at the intake site will be very wide. With all these disadvantages, the Belwagurdwa river is not a promising source of irrigation water (Fig. 4.1).

ii) River Discharge

Discharge measurement and daily water level observation were conducted at four points on the above-mentioned rivers. The observation points were: i) the proposed headworks site on the Gudrung river (catchment area CA=29 km^2), ii) 500 m downstream of the Kondre/Rajkudwa confluence ("Kondre confluence site", CA=24 km^2), iii) the East-West Highway bridge over the Kondre river ("Kondre bridge site", CA=43 km^2), and iv) the East-West Highway bridge over the Belwagurdwa river ("Belwagurdwa site", CA=153 km^2). The results are summarized in the following table:

(unit : m^3/sec)

Year	Month	Gudrung HW		Kondre confluence		Kondre bridge		Belwagurdwa	
		mean	minimum	mean	minimum	mean	minimum	mean	minimum
1992	9	0.54	(0.19)	1.03	(0.21)	1.63	(0.66)	11.00	(2.20)
	10	0.60	(0.26)	0.37	(0.10)	1.72	(0.45)	6.89	(2.00)
	11	0.22	(0.20)	0.09	(0.08)	0.40	(0.16)	1.44	(1.00)
	12	0.16	(0.13)	0.07	(0.07)	0.17	(0.16)	0.51	(0.32)
1993	1	0.14	(0.13)	0.07	(0.07)	0.16	(0.15)	0.29	(0.24)
	2	0.11	(0.09)	0.08	(0.07)	0.11	(0.09)	0.17	(0.17)
Mean		0.30	(0.17)	0.29	(0.10)	0.70	(0.28)	3.38	(0.99)

Since the Gudrung headworks site is located at the top of the fan, the rate of deep percolation and/or loosing stream within the catchment is small. As a result, the base flow is high among the three rivers compared to their catchment areas.

iii) Water Availability

Runoff analysis for the Gudrung and Kondre rivers at the considered headworks sites was carried out using the tank model method. Discharge and river gauge records collected at the headworks sites during the study period, and daily rainfall records of the last 15 years were used to generate models and represent river runoffs.

The Gudrung riverbed at the proposed headworks site consists of boulders and stones down to the bedrock which is 5 to 6 m below the riverbed. A certain amount of runoff is thought to be flowing below the riverbed level as an understream. The proposed headworks is being designed to connect to the bedrock and the understream, thus, percolation loss is expected to be reduced and the river discharge increased. This increase of discharge was also taken into account in generating models.

An annual runoff coefficient of 60 % was adopted with reference to those of other irrigation projects in Nepal. Runoff of the Kondre river at the considered headworks site (3 km upstream of the East-West Highway) was estimated based on the discharge and rivergauge records on upstream and downstream points. The estimated discharge in the last 15 years at the considered headworks sites is shown in Table 4.1.

As mentioned in Chapter 3, runoff of rivers in the study area is rapid and the peak flood discharge is quite large. Therefore, it is not reasonable to regard all the daily runoff estimated on an average basis as available water. In this study, effective runoff for irrigation, which was estimated based on a runoff hydrograph for a certain period of rainfall, was considered for the estimated runoff.

v) Water quality

Water quality in situ was examined on pH and electric conductivity (EC). The value of pH ranges from 7.4 to 8.2, whereas the EC varies from 0.13 to 0.48 mS/cm, both of which are within the permissible ranges.

vi) Sediment load

According to the results of field measurement, the suspended load content of the Kondre river varies from 16 mg/l to 7,480 mg/l, while that of the Gudrung river ranges from 4 mg/l to 96 mg/l. The suspended load content of the Kondre river was more than six times that of the Gudrung river for the same discharge. The physical characteristics of the sediments collected in the field indicate that most of the sediments originated from the riverbanks which were eroded by the meandering streams in the plain area. Located at the top of the fan, the Gudrung headworks site has the advantage of a low sediment load compared with that of the other sites in the plain.

(2) Ponds

i) Existing ponds

There are eight existing ponds in the project area, Dubiya, Pratapur, Gelwar, Badahara, Gorusinge, Dewari, Buddi, and Chamargunya, which will be effective for irrigation after the proper improvement. Among these, four ponds, Dewari, Buddi, Gorusinge,

and Badahara can be fed by the proposed irrigation canals, but the rest will remain independent and therefore ineffective for irrigation purposes. Canal-fed ponds cannot be proposed for the Kondre irrigation system due to a topographic disadvantage that the intake water level is rather low compared with the irrigation area and considered pond locations.

ii) New ponds

There are five locations where new ponds can possibly be located in view of size and topographic conditions, these are: Tikker, Murmy, Ganchaura 1, Ganchaura 2, and Purena, out of which Tikker is proposed to be a canal-fed pond, and the others will be independent ponds.

iii) Optimization of Canal-fed Ponds

The annual possible storage volume of canal-fed ponds is determined based on available river flow and their catchment area. In this study, optimization of canal-fed ponds was carried out with three sizes of ponds. Water balance was studied using daily rainfall records for 15 years. According to the relationship between the construction cost and the irrigation area by size, the optimum size of ponds was determined. The dimensions of these ponds are shown below:

	Tikker	Badahara	Gorusinge	Dewari	Buddi
Effective storage (x 1,000m^3)	2,000	120	200	270	490
Catchment area (ha)	80	43	33	49	115
Water surface area (ha)	51	14	16	27	51
Full water level (m)	141.5	118.0	118.1	114.5	114.5
Low water level (m)	134.3	116.3	116.3	113.3	113.3

iv) Dimensions of Independent Ponds

Independent ponds largely depend on rainfall and inflow from their own catchment. Therefore, storage potential of independent ponds is determined by the catchment area. Dimensions of eight independent ponds proposed in this study are shown below:

	---- New Ponds ----			---------- Existing Ponds ----------				
Parameter	Murmy	Gancha-ura 1	Gancha-ura 2	Purena	Dubiya	Pura-tapur	Gelwar	Chamar-gunya
Effective storage (x 1,000 m^3)	413	138	46	71	145	33	28	36
Catchment area (ha)	57	39	11	40	50	9	54	119
Inundation area (ha)	28	10	4	8	17	4	4	6
Full Water Level (m)	130	122	121	120	123	120	119	113
Low Water Level (m)	126	120	119	118	121	119	118	111

(3) Groundwater

i) Confined groundwater

In the project area, the discharge rate of tubewells for confined groundwater has been found to be too small for irrigation purposes. This is due to: i) small recharge area, ii) small river discharge, and iii) low permeability of aquifers, all of which were verified

by the results of the pumping test and the field study. Accordingly, further exploitation of groundwater for irrigation is not taken into account in the project.

ii) Unconfined groundwater (spring water)

Unconfined groundwater has been observed at springs situated in the north of the project area near Birpur. The east Birpur springs are situated east of the Gorusinge - Pattharkot Road, while the west Birpur springs are situated near the river terrace on the left bank of the Gudrung river.

The east Birpur springs are presently utilized for irrigation, of which the discharge is about 20 l/sec from January to February. This amount of water is expected for dry season cultivation. Discharge of the west Birpur springs was 6 to 7 l/sec as observed in February, which can be used for winter crops, but not for spring crops.

(4) Ghorahi Drain

Ghorahi drain water is presently being used as supplementary irrigation for paddy and as the first irrigation for the winter crops. Since the drainage course is appropriate for aligning the primary drain of the proposed system, it is not recommended for the drain water by obstructing its flow even with temporary earthen bands. The existing cultivated fields irrigated by the Ghorahi drain water will be under the command area of the proposed system(s).

The proposed command area of the Jasbariya headworks will be 670 ha, though 1,100 ha of arable land could be commanded according to the topographic map. It is expected that, after implementation of the project, discharge of the Ghorahi drain will increase at the Jasbariya headworks site, hence, the system could irrigate some 500 ha in the rainy season. Approximately 200 ha of the above mentioned command area could also have irrigation water for winter crops.

4.2.2 Water Requirement

The irrigation water requirement was calculated according to the procedures prescribed in the FAO Irrigation and Drainage Paper No. 24, "Crop Water Requirements". The calculation was based on the following conditions:

Equation for estimating evapotranspiration	: Modified Penman Method
Meteorological data	: Temperature, relative humidity, wind speed, sunshine hours in Bhairahawa, 1976 - 1986
Rainfall data	: Pattharkot (the closest station to the Gudrung catchment), 1978 - 1992
Planting (Sowing) period	
Paddy (rainy season)	: 1 - 30 June
Wheat (dry season , winter)	: 1 - 10 November
Winter vegetables (dry season)	: 11 - 20 November
Mustard (dry season, winter)	: 11 - 20 November
Spring vegetables (dry season)	: 1 - 10 March
Growth period:	
Paddy	: 100 days after transplanting
Wheat	: 120 days
Winter vegetables	: 100 days

Mustard	: 90 days
Spring vegetables	: 90 days
Crop coefficients	: Adopted from the FAO Irrigation and Drainage Paper vol.24 and other irrigation projects in Nepal
Percolation loss on the paddy field	: 3 mm/day
Evaporation loss on the paddy field	: 4 mm/day (land preparation)
Net land preparation requirement	: 10 mm/day
Overall irrigation efficiency:	
Paddy	: 0.60
Upland crops	: 0.50

According to the above mentioned conditions the 10-day water requirements for the last 15 years were estimated. Effective rainfall was calculated as 70 % of rainfall. The 10-day water requirements from 1978 to 1992 are shown in Table 4.2.

The fourth largest values were regarded as the proposed irrigation water requirements which are expected to be fulfilled in 4 years out of 5, i.e., 80 % probability. The requirement for paddy is 375 mm/season, for winter crops 227 to 366 mm/season, and for spring vegetables 586 mm/season.

On the other hand, the fourth largest peak water requirements are 1.2 l/sec/ha for paddy, 0.5 to 0.6 l/sec/ha for winter crops, and 1.4 l/sec/ha for spring vegetables. These peak water requirements are similar to those of another irrigation project in the Terai plain. Consequently, the irrigation water duty (unit water requirement) was determined to be 1.2 l/sec/ha, the peak water requirement for paddy. The unit water requirement of winter crops was determined to be the average of winter crops weighted by their irrigation areas.

4.2.3 Possible Irrigation Area

The possible irrigation area for each irrigation system was estimated by a water balance calculation based on the unit water requirement in l/sec/ha, total available water and an operational study of ponds. The cropping intensity is set as follows:

Paddy (rainy season)	:	100 %
Wheat (dry season, winter crop)	:	30 %
Mustard (dry season, winter crop)	:	10 %
Winter vegetables (dry season, winter crop)	:	10 %
Spring vegetables (dry season, winter crop)	:	5 %

In the project area, annual rainfall itself is ample, however, annual rainfall and runoff fluctuate greatly. Short dry periods of 10 to 20 days were observed even in the rainy season. Therefore, the possible irrigation area remains small during such short dry periods.

Taking these hydrological characteristics of the project area into consideration, possible irrigation area was estimated on a daily basis using the requirements and rainfall records of 1983, which was regarded as the standard year for the irrigation planning having, the fourth largest gross water requirement (375 mm/season for paddy).

(1) Gudrung Irrigation System

The Gudrung irrigation system consists of the river water itself, canal-fed ponds, and the Birpur springs. The total possible irrigation area of the system is as follows:

Paddy	(June - October)	: 2000 ha
Winter crops	(November - March)	: 1000 ha
Spring crops	(March - June)	: 100 ha

(2) Kondre Irrigation System

The Kondre irrigation system has a low intake elevation, therefore, canal-fed ponds, both new and existing, cannot be involved in the system. The system depends on the river water itself, and the possible irrigation area is reduced as follows:

Paddy	(June - October)	: 295 ha
Winter crops	(November - March)	: 385 ha
Spring crops	(March - June)	: 135 ha

(3) Independent Pond System

Rainfall from March to the beginning of June, in which spring crops are cultivated, is low, and therefore the unit water requirement becomes larger within the year. If the independent ponds are utilized for irrigating spring crops, a certain amount of seepage and evaporation loss is expected during the dry season (before starting spring crops cultivation). With this in mind, independent ponds should be utilized for supplemental irrigation for paddy and winter crops. The possible irrigation area by independent pond systems including the four new ponds near the East-West Highway is estimated as follows:

Paddy	(June - October)	: 60 ha
Winter crops	(November - March)	: 60 ha
Spring crops	(March - June)	: 0 ha

(4) Assessment of the Irrigation Development Potential

Taking hydrological conditions in the project area into account, the development of single irrigation water sources, such as rivers, groundwater, and irrigation ponds, is not effective. As for surface water, annual rainfall itself is abundant and stable, however runoff by the 10- day or one day method is extremely erratic and intermittent, which is the main constraint on irrigation water source development. According to the results of the survey and study, groundwater potential in the project area was found to be low for irrigation purposes.

Consequently, only the Gudrung irrigation system which involves canal-fed ponds is judged to be a feasible irrigation development plan from an engineering aspect. The Kondre irrigation system which depends on river flow only and the independent pond system and groundwater system all have extremely small irrigation areas compared to the scale of facilities required. Thus, these development plans with a single water source have an extremely low feasibility, both from engineering and economic points of view.

4.3 Needs and the Basic Concept of Development

4.3.1 Development Needs

In the study area there are large requirements on irrigated agriculture development which are summarized below:

1) The 8th 5-year development plan, started in 1992, has placed a particular emphasis on irrigation development required for the increase of agricultural production, and the target irrigation area to be developed during the five years has been set at 294,000 ha including 53,000 ha for small-scale development. The irrigation policies for achieving the target are: (1) promotion of large/medium-scale irrigation projects by HMG/N and implementation of small scale irrigation schemes with farmers' participation at stages from the investigation/planning through O&M of the completed facilities. (In the Terai plain the command area of the small-scale scheme is less than 2,000 ha); (2) handing over of the completed irrigation facilities to the beneficiary farmers to establish an O&M system of the irrigation facilities by the beneficiaries; and (3) farmers' participation in all the stages of the project and scheme and collection of irrigation service fees from the beneficiary farmers through the organized WUAs, particularly in large/medium-scale projects. All the farmers in the study area, who have become acquainted with the effect of irrigation on the increase of agricultural production, have become anxious to insure that agricultural development by irrigation matched with the target and policies set by HMG/N will be implemented in the study area as soon as possible.

2) In the northern part of the study area there is the Ranikudwa Farmers' Irrigation System, commanding about 630 ha of arable lands, where the construction and O/M have been carried out by the farmers settled from the hills without the technical and financial assistance of HMG/N for about 60 years. However, the actual irrigation area has fluctuated from year to year owing to the unstable irrigation water supply, attributed to the collapse of a conventional boulder weir and an inundation type canal intake by big floods, breaching, damage and leakage to a headrace canal constructed with boulders and gravel by big floods and falling stones from steep hills on the left bank, deterioration of primary, secondary, and tertiary canals and related structures by erosion and scouring. Therefore, the existing irrigation area will be able to be considerably extended by effective use of both the river discharge and the storage water in the rehabilitated and newly constructed irrigation ponds filled with a part of the ample flow of the river in the rainy season by reconstructing the existing headworks, headrace canal, and irrigation facilities to establish permanent or semi-permanent ones. On the other hand, all the farmers in the Ranikudwa command area and its southern outside area have become acquainted with the effect of irrigation on increasing agricultural production, and thereby strongly desire the extension of the irrigation area by improving the existing Ranikudwa system and accepting the condition that all the completed irrigation facilities be operated and maintained by them at their own expense without HMG/N's assistance or subsidy. Therefore, in such areas as mentioned above it is possible to implement agricultural development for irrigation by means of farmers' participation in line with the target of the 5-year plan and the irrigation policies set by HMG/N.

3) Almost all of the study area is a piedmont or alluvial fan overlain with sands, silts, and clays, which were formed by the Gudrung and Kondre rivers, originating in the Siwalik Range, and has a suitable topography and soil condition for agriculture. At present, however, agricultural productivity in the area is lower than that in other Terai areas since the area has rather limited water resources. Accordingly, most of the farmers in the study area are still involved in subsistence farming, and thereby their living standard is lower than that in other Terai areas, though the area has a high potential marketability due to the East-West Highway and the Gorusinge-Sandhikarka zonal road.

4) Although the Rajkudwa Irrigation Project preliminarily formulated by a local consulting firm in 1985 had been taken up by HMG/N (DOI) for implementation and a part of the primary canal was constructed in 1987 and the project was re-formulated by another local consulting firm in the pre-feasibility study in 1988, of which the irrigable area was located south of the existing Ranikudwa command area, the implementation was suspended owing to the immature plan and budget constraints. However, the project is an urgent one listed as the top priority for the irrigation sector in the Master Plan for the Integrated Rural Development in Lumbini Zone carried out by JICA in 1987 and 1988, taking into consideration that the farmers' irrigation demand in the project area has been extremely high because of frequent drought damage to the farm products, particularly paddy, as a result of the late coming of the rainy season, unreliable rainfall pattern, and mimimal rainfall in the season.

5) The raising of farmers' living standards in the Ranikudwa command area and the Rajkudwa area as already mentioned will be a result of the rise in their farm income attributable to a stable increase of agricultural production assured by the provision of proper irrigation facilities, since their average farm household is smaller than that in other Terai areas and most of their farmlands rely on rainfall. On the other hand, a considerable part of the Ranikudwa and Rajkudwa areas would be irrigated by effective use of the Gudrung or Kondre river discharge in the rainy season, which includes storing some of the discharge in irrigation ponds, though this discharge will drastically decrease during the dry season. Irrigation by the effective use of the river discharge will not be limited to the rainy season paddy, but will also be extended to such dry season crops as wheat, mustard, vegetables, etc.

6) The irrigation projects based on medium or small rivers running in the Terai plain have been implemented in limited numbers, since their economic feasibility was rather low, because of relatively small irrigation areas which were attributable to an unstable river discharge during the rainy season and reduced flow during the dry season. Besides, the actual irrigation areas of the projects which were not provided with storage ponds were far smaller than those planned and designed. Therefore, the irrigation project based on an effective use of the Gudrung discharge by storage ponds as mentioned already, particularly during the rainy season, will be a pilot or model for many irrigation projects and schemes which rely on medium or small rivers running in the Terai plain in the future.

4.3.2 Development Constraints

Most of the arable land of the project area contains paddy fields. Wheat, pulses, and mustard in winter and maize in spring are also grown in some limited parts of the cultivated