JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)
THE DEPARTMENT OF IRRIGATION,
THE MINISTRY OF WATER RESOURCES
HIS MAJESTY'S GOVERNMENT OF NEPAL

THE MASTER PLAN STUDY
ON
THE TERAI GROUNDWATER RESOURCES
EVALUATION AND DEVELOPMENT PROJECT
FOR IRRIGATION

FINAL REPORT

VOLUME I : MAIN REPORT

MARCH, 1995

SANYU CONSULTANTS INC.

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PREFACE

In response to a request from His Majesty's Government of Nepal, the Government of Japan decided to conduct a Master Plan Study on the Terai Groundwater Resources Evaluation and Development Project for Irrigation and entrusted the study to Japan International Cooperation Agency (JICA).

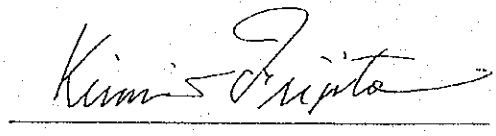
JICA sent a study team headed by Mr. Mitsuru YOSHIKAWA, Sanyu Consultants Inc., to Nepal six times between November, 1991 and December, 1995.

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 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.

March, 1995



Kimio Fujita
President
Japan International Cooperation Agency

March, 1995

Mr. Kimio FUJITA
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit the master plan report on the Terai Groundwater Resources Evaluation and Development Project for Irrigation. The report is compiled to reflect 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 comments made by the Department of Irrigation of His Majesty's Government of Nepal during the discussions which were held in Kathmandu, are reflected in the report.

The study had been carried out in the three districts of Jhapa, Mahottari, and Banke (including a part of Bardiya). Based on this study, the groundwater potential is considered to be sufficient for deep tubewell irrigation. It has also been confirmed under the study that a deep tubewell irrigation plan is economically feasible.

In regard to Jhapa District, immediate implementation of project for 30 irrigation units (4,500 ha) is recommended for the purpose of demonstration and corroboration of DTW irrigation in the Eastern Terai. As the other two districts require detailed groundwater resource evaluation, further surveys and studies on a feasibility study level should be conducted.

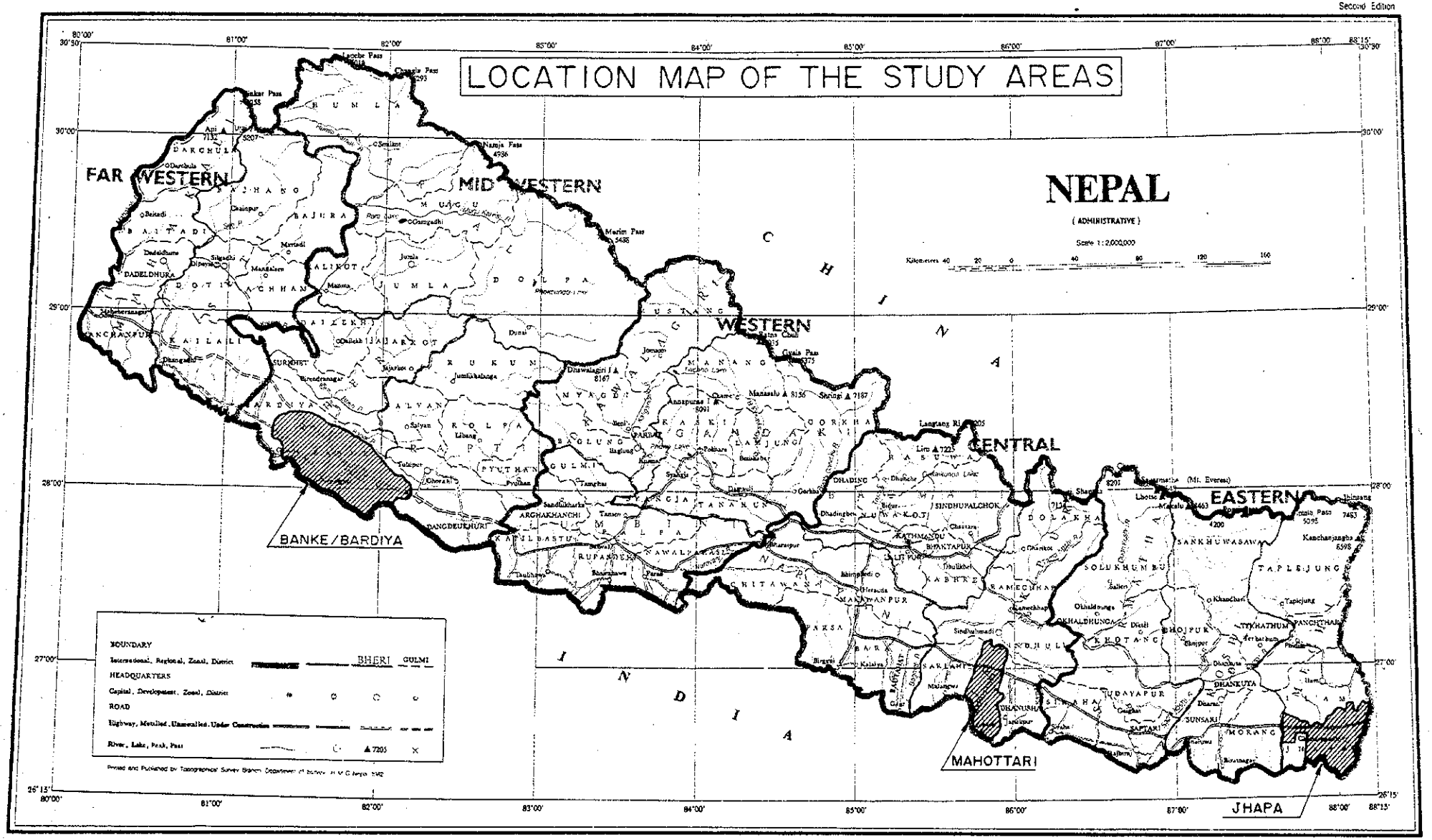
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Agriculture, Forestry and Fisheries. We also wish to express our deep gratitude to the Department of Irrigation and other authorities concerned of His Majesty's Government of Nepal for the close cooperation and assistance extended to us during our investigation and study.

Very truly yours,

吉川 満

Mitsuru YOSHIKAWA
Team Leader
Master Plan Study on the
Terai Groundwater Resources Evaluation
and Development Project for Irrigation

Second Edition



Summary

Summary

1. Background

The food self-sufficiency of the Kingdom of Nepal has been declined as a result of the stagnating agricultural production and population growth. In order to address this situation, one of the major goals of the government's National Development Plan is to increase agricultural production, mainly through the expansion of irrigated agriculture.

The Department of Irrigation of the Ministry of Water Resources, which is responsible for irrigation development in Nepal, is operating a "Deep Tubewell Irrigation Project" to develop the abundant deep-seated groundwater resources in the Terai as one of the water resources for irrigation. As a series of projects, the Department of Irrigation requested, through the Government of Nepal, to the Government of Japan to conduct the "Master Plan Study on Terai Groundwater Resources Evaluation and Development Project for Irrigation." In response to this request, the Government of Japan implemented the Study through the Japan International Cooperation Agency.

2. The Study

The Study covered the three districts of Jhapa, Mahottari, and Banke (includes a part of Bardiya), which are located in the east, central, and western parts of the Terai. The Terai is located in the southern part of Nepal forming the granary of nation. The major objectives of this Study include "selection of areas irrigable by deep tubewell," "evaluation of groundwater resources," and "establishment of a master plan related to deep tubewell irrigation." The Study Team dispatched by JICA conducted this Study over a 36 month period, from October 1991 to July 1994, together with counterpart personnel from the Department of Irrigation.

3. The Study Areas

The Study Team selected and conducted the necessary studies in the southeastern part of Jhapa District (command area 17,000 ha); in two irrigable areas in the southern (4,000 ha) and northern part (3,000 ha) of Mahottari District (total 7,000 ha); and in the southern part (8,000 ha) of Banke District.

4. The Scope of Study

This Study covers the fields related to deep tubewell irrigation, which include the socio-economy, meteorology, hydrology, topography, geology, hydrogeology, groundwater, agri-

culture, and irrigation in the Study Areas and adjacent areas. Specifically, intensive field studies were conducted for the Study Areas in Jhapa District as the "representative area." This Study consists of meteorological and hydrological observations, drilling and testing of exploratory wells (total of 20 wells, maximum depth 300 m), groundwater observation, and agricultural and irrigation studies (includes topographical survey of the sample area).

Based on the results of the above Study, the Study Team worked out an "evaluation of groundwater resources," "formulation of master plan for deep tubewell irrigation," " formulation of guideline for deep tubewell irrigation," as well as the formulation of a "database" related to meteorology, hydrology and hydrogeology; and the formulation of a plan for a "monitoring network operation."

5. Nepal in Overview

(1) Natural Environment

Nepal situates at the center of the Southern slope of Himalayan Mountains and is a landlocked country surrounded by China to the north and India to the east, west, and south. Nepal occupies an area of approximately 147,000 km2. The topography and geology can be classified into five zones, which stretch in parallel to the Himalayan Arc. These zones consists of, from south to north, alluvial and diluvial sedimentary layers in the Terai which is the granary of Nepal; the Churia Hills which consist of sedimentary layers up to the Pleistocene; mountainous areas of Precambrian rock; the Himalayas; and the Himalayan hinterland.

The wide range of meteorological conditions from the tropical type in the Terai to the alpine type in the mountain areas can be observed in Nepal. The extreme precipitation ranges from 6,000 mm to 250 mm annually depending on the area. Mean precipitation is in the range of 1,500 mm to 2,500 mm, and 80% of the precipitation is concentrated in the monsoon period between June and September. All of the rivers flowing through Nepal are tributaries of the Ganges River. The rivers that originate in the Himalayas flow throughout a year, and other rivers flow seasonally through the monsoon period. Meteorological and hydrological observations in Nepal are conducted by the Department of Meteorology and Hydrology of the Ministry of Water Resources, and observation records are published on an irregular basis.

(2) Socio-economy

The population of Nepal as of 1991 is 18.49 million. The annual population growth is 2.1%, and the population density is 126 per km2.

Agriculture is the predominant industry in Nepal occupying 49% of the gross domestic product in 1991/92 and 81% of the economically active population. The gross national product in 1991/92 was 126.2 billion Rs (approximately US$3 billion) and US $180 per capita.

(3) Agriculture

Major agricultural products in Nepal consists of rice, maize, wheat, barley, millet and pulses. Approximately 2.9 million ha were cultivated in 1992/93 and 4.9 million tons of grain and 330,000 tons of other cash crops were produced. Until the middle of the 1980s Nepal was a food exporting country; however, the rate of food self-sufficiency has dropped to 85% to 90% because of a demand increase caused by population growth in recent years. The gross farmland area in Nepal as of 1989/90 is approximately 3 million ha, of which 42% (1.2 million ha) is located in the Terai. The irrigable area reaches to 2.2 million ha nationwide, but the net irrigated area at present is 940,000 ha, of which 65% of the area (610,000 ha) is located in the Terai.

(4) Political and Administrative System

Nepal's political system is a constitutional monarchy. The country's constitution was issued in 1962, and the partyless Panchayat (political council) system was established. The king dissolved the Panchayat System in 1990, and a new constitution based on a multi-party system was created in 1991. Shortly after a new government was elected through the general election. His Majesty's Government of Nepal consists of 21 ministries and agencies under the Council of the Ministers which is chaired by the prime minister. Nepal is divided into five development regions, 14 development zones, and 75 districts as development and administrative units. The central ministries and agencies in charge of development projects have offices in each region for supervising these projects.

Among the government agencies, the Department of Irrigation of the Ministry of Water Resources is responsible for the planning and execution of new irrigation projects as well as the operation and maintenance of completed large-scale projects. The Department of Irrigation consists of central bureaus which include Irrigation Management, Large & Middle-Scale Irrigation Projects, Groundwater Utilization, Planning and River Training, as well as a Project Management Department for each national project and a Regional Irrigation Directorate which supervise the District Irrigation Offices in the five development regions. The Department of Agriculture of the Ministry of Agriculture is responsible for agricultural extension programs. The Agricultural Development Bank of Nepal offers financial assistance to the agricultural sector. One example of this financial assistance is the loans provided for the Shallow Well Irrigation Program, which covered

61,000 ha by 1988. The Agricultural Inputs Corporation is responsible for the import and distribution of chemical fertilizers, improved seeds, agro-chemicals, and farm machinery.

(5) National Development Plans

Seven plans were implemented under the Panchayat System beginning with the First National Development Plan in 1956. Having evaluated and reviewed the existing results of previous plans, the new government has established the "Eighth National Development Plan (1992-1997)." The major targets of this plan include the sustainable economic growth, the alleviation of poverty and the reduction of regional imbalances, while priority measures include the intensification and diversification of agriculture, the energy development, the development of rural infrastructures, the employment generation and human resources development, and the regulation of population growth.

His Majesty's Government of Nepal formulated a "Program for the Fulfillment of Basic Needs (1985-2000)" in order to satisfy basic needs in six sectors, including food, clothing, housing, health, education, and security by the year 2000. The food production plan, which is related to the most important basic need, outlines the major food production target at 6.6 million tons (9.8 million tons unprocessed) based on the minimum requirement of 2,250 calories/capita/day and an estimated population of 23 million by the year 2000. This target represents a two-fold increase of production in 4.8 million ton at 1984/85, and an annual average increase rate of production at 6.5% must be achieve to accomplish this goal. Irrigation facilities, improved seed, and improved agricultural practices are necessary in order to achieve this target, and irrigated farmland must be increased to 1.25 million ha.

Upon the establishment of the Program for the Fulfillment of Basic Needs, the Department of Irrigation established in 1990 the "Master Plan for Irrigation Development in Nepal" with the cooperation of the United Nations and the World Bank. A major target of this plan includes the expansion of irrigable areas to 1.25 million ha by the year 2000 based on government projects, which means irrigating an additional 60,000 ha of farmland every year. Other major measures include the management improvement of existing irrigation projects; groundwater irrigation in Terai; medium- and small-scale surface water irrigation in Terai; small-scale irrigation in hilly areas; and large-scale surface water irrigation in Terai.

6. The Study Areas

(1) Irrigable Areas by Deep Tubewell

The objective of the "Phase I" study in the Master Plan Study is to select areas irrigable by deep tubewell in the target districts and a representative area with the highest potential among others.

Through a review of the existing data related meteorology, hydrology, topography, hydrogeology, the agricultural society, agriculture, and the social infrastructure, areas irrigable by deep tubewell were selected after field inspection and discussions with Department of Irrigation. These areas include the southeast part of Jhapa District (net command area of 17,000 ha), two irrigable areas in the northern and southern part of Mahottari District (total of 7,000 ha), and the southern part (8,000 ha) of Banke District (include a part of Bardiya District). The representative area, which is the Study Area for the "Phase II" study, is selected in the southeast part of Jhapa District.

(2) Natural Environment

Jhapa District situates in the southeastern edge of Nepal, facing India to the south and to the east. The total area is 1,600 km2, and the Kankai River flows toward south through the central part of the district. The majority of the district is located on the alluvial Terai (altitude 80 mags to 120 mags), while a portion is also located in the Churia Hills in the north and the Terrace consisting of the central forest zone. The geology of Jhapa District is divided into an alluvium layer, terrace deposits, and the Churia Formation. The alluvium is composed of sand and gravel beds in the north, and alternating of beds of sand, gravel, silt, and clay in the plain area. The thickness of the alluvium layer in the northern part of the Terrace may be 150 m or more and the Churia Formation is deemed to underlie it. The Gangetic alluvium, which extends south of the terrace, has abundant gravel beds with single thicknesses of 50 m and a total layer thickness of 300 m or more. The thickness of the terrace deposit is approximately 10 m and consists of sand, silt, and clay. Although the Churia Formation is not exposed at the surface, the results of exploratory wells show that the Upper Churia Formation consists of clay, silt, sand, and gravel. Annual precipitation in Jhapa District is highest in the Terai at 1,600 mm to 3,600 mm, with an average of approximately 2,500 mm. Precipitation in July during the monsoon period exceeds 700 mm. The mean average temperature is 15°C to 29°C, and the average maximum and minimum temperatures are 38°C and 5°C respectively. The major rivers in this district include Ratuwa Khola, Kamal, Kankai, Biring, and Mechi. Kankai and Mechi are the largest rivers, originating in the mountain areas. A runoff discharge station is located at Mainachuri (basin area 1,180 km2) on the Kankai River. According to the runoff discharge analysis over a 14 year period, the runoff discharge is 2.79 billion m3, as opposed

to an annual precipitation of 3.75 billion m3, which means that the runoff coefficient is 74%. The runoff coefficient for the Deoniya and Budhajhora rivers, as conducted by the Study, are 70% and 89% respectively. Both rivers are seasonal in nature and more than 90% of the runoff discharge is observed during the monsoon season.

The majority of Mahottari District is located on the Terai with an area of approximately 1,000 km2. Several rivers flow to the south-southeast on a seasonal basis. The altitude of this district is among the lowest in Nepal, with the altitude at the southern edge below 60 mamsl. The geology of the plain in this district consists of terrace deposits and alluvial layers. The Churia Formation is distributed in the northern hills, and the terrace deposits consist of clay, silt and gravel, but its thickness is unknown. According the deep tubewell record, the Southern Terai alluvium consists of alternating beds of sand and gravel where clay and silt are dominant. The annual precipitation of this district ranges from 600 mm to 2,600 mm, with an annual average of 1,310 mm. The monthly average temperature is 15°C to 30°C, and the average maximum and minimum temperatures are 39°C and 5°C respectively. The rivers flowing through this district include Bighi, Ratu, Janpha, Marha, and Hardi Nadi. Although some rivers flow throughout the year fed by groundwater, the rivers are generally seasonal in nature. Runoff discharge observation has not been conducted for these rivers.

The Study Area in Banke District, including the east bank area of Babai River in Bardiya District, is approximately 3,200 km2, which is the largest among three districts. One of the largest rivers, Rapti flows through the central part of the district. The minimum altitude of the area is 130 mamsl, but the overall area is located at higher altitudes. The geology of Banke District consists of the alluvium, terrace deposits and the Churia Formation. The alluvium layer can be divided into the Northern, Central, and Southern Ganges. The Northern Alluvium has a thickness of more than 200 m and consists of fan gravel and clay beds. The thickness of the Central Alluvium is approximately 30 m and the lower part is possibly a Churia Formation. Gangetic Alluvium has a record of drilling beyond 300 m and consists of sand and gravel where clay and silt are dominant. The Churia Formation consists of semi-consolidated shale, sandstone and conglomerate in the hills east of Rapti; however, silt and sandstone which belong to the lower Churia Formation are distributed north of Babai River. The annual precipitation in this district ranges from 500 mm to 2,600 mm, with an average of 1,386 mm. The monthly average temperature is 15°C to 30°C, and the average maximum and minimum temperatures are 41°C and 3°C respectively. The rivers flowing through this district include the Rapti, Manda, Dundawa Nala, Kirin, and Babai. Rapti and Babai rivers originate in the mountain area and flow throughout the year. Regular runoff discharge observations have been conducted in both rivers.

(3) Socio-Economy

The Terai occupies 14% of the land area of Nepal and 42% of the farmland. The plain consists of five development regions, 20 districts, and five industrial districts. The Terai holds 47% of the nation's population and 45% of the number of households. The industries located in this plain include agriculture, agricultural product processing, cement, and shoe manufacturing.

Jhapa District consists of nine administrative sectors, two towns and 49 villages. Its total area is 156,500 ha with farmland of 105,121 ha. The study area is 29,700 ha and includes 16 villages. The population of this district is 594,000 (1991), and the population density is 379 person/km2. The number of households is 111,000 and the average household consists of 5.4 persons. Sixty-six percent of the economically active population are engaged in agriculture. This district is noted as a production area for rice and tea, and other industries include agricultural product processing.

Mahottari District consists of nine administrative sectors, one town, and 77 villages. The total area is 101,000 ha with a farmland of 67,800 ha. The study area is 9,800 ha (2 residential areas) and includes 17 villages. The population of this district is 440,000 (1991), and the population density is 434 person/km2. The number of households is 80,400 and the average household consists of 5.5 persons. Seventy-nine percent of the economically active population are engaged in agriculture, and industries include agriculture and agricultural product processing.

Banke District consists of nine administrative sectors, one town, and 46 villages. The total area is 226,000 ha with a farmland of 49,000 ha. The study area is 12,100 ha. The population of this district is 286,000 (1991), and the population density is 126 person/km2. The number of households is 49,100 and the average household consists of 5.8 persons. Sixty-eight percent of the economically active population are engaged in agriculture, and industries include agriculture and forestry.

(4) Agriculture and Irrigation

The Terai consists of five types of soil including sandy loam/clay loam, silt loam/clay loam, loam/sandy loam/silt loam and sandy loam/loam. Major grain products (1992/93) in the Terai include rice at 1.84 million tons (71% of national total), wheat 430,000 tons (57%) and maize 330,000 tons (25%). More than 30% of the livestock is raised in this area. Forty percent (610,000 ha) of the 1.24 million ha of farmland in the Terai is irrigated which represents 65% of the irrigated farmland nationwide.

The farmland of Jhapa District is 105,000 ha and the irrigated farmland is 47,900 ha. The cropping intensity is 151%. The number of farm households including landless farmers (1991/92) is 74,700 and the average farms size is 1.41 ha/farm. Farm households less than one hectare occupy 52% of the total number of farms. There are approximately 12,000 farm households in the Study Area. The dominant cropping patterns in this district are "monsoon paddy-wheat" or "spring paddy-monsoon paddy-wheat" for irrigated farmland. For rainfed farmland, the dominant crops are "monsoon paddy-fallow" or "monsoon paddy-pulses/oilseed crops" or "maize-pulses/oilseed crops/millet". Monsoon paddy-fallow is most dominant in the Study Area and the cropping intensity is only 126%. Major products (1992/93) in this district include paddy at 203,000 tons (7.8% of national total), maize 18,600 tons (1.4%), wheat 13,100 tons (1.7%), potatoes 13,000 tons (1.8%), and tobacco 730 tons (12.1%). The production for paddy is the highest among the 75 districts nationwide. Paddy is marketed via farm households-brokers-wholesalers-rice polishers-retailers-consumers. Vegetables are occasionally sold directly to retailers or consumers from farm households. There is a district agricultural development office, six agricultural service centers, two agricultural research stations, one branch of the Agricultural Development Bank of Nepal, as agriculture supporting agencies including two branches of the Agricultural Inputs Corporation, and 27 cooperative societies as farmer organizations.

The farmland in Mahottari District is 63,800 ha and the irrigated farmland is 17,300 ha. The cropping intensity is 171%. The number of farm household including landless farmers (1991/92) is 58,600 and the average farms size is 1.09 ha/farm. Farm households less than one hectare occupy 60% of the total number of farms. There are approximately 6,400 farm households in the Study Area. The dominant cropping patterns in this district are "spring paddy-monsoon paddy-wheat" or "spring paddy-monsoon paddy-maize" for irrigated farmland. For rainfed farmland, "monsoon paddy-fallow" or "monsoon paddy-wheat-fallow" are the dominant patterns. "Monsoon paddy-fallow" dominates in the Study Area.

Major products (1992/93) in this district include paddy at 52,000 tons (2.0% of national total), maize 8,200 tons (0.6%), wheat 26,500 tons (3.5%), tobacco 1,200 tons (19.1%), and pulses 9,500 tons (4.7%). The marketing system of agricultural products is similar to Jhapa District. There are six agricultural service centers under the supervision of the Regional Agriculture Directorate in Kathmandu, two agricultural research stations, one branch of the Agricultural Development Bank of Nepal, one branch of the Agricultural Inputs Corporation and 31 cooperative societies.

The farmland in the Banke District is 49,100 ha and the irrigated farmland is 3,300 ha. The ratio of irrigation area is the lowest compared with the other two districts, and the cropping intensity is 142%. The number of farm household including landless farmers (1991/92) is 35,900 and the average farms size is 1.37 ha/farm. Farm households less than one hectare occupy 50% of the total number of farms. There are approximately 5,900 farm households in the Study Area. The dominant cropping patterns in this district are "monsoon paddy-fallow" or "maize-millet-mustard" or "pigeon peas".

Major products (1992/93) in this district include paddy at 36,000 tons (1.4 % of national total), maize 21,000 tons (1.6%), wheat 10,400 tons (1.4%), and potatoes 4,600 tons (0.6%). The marketing of agricultural products is basically similar to the other two districts. There are a District Agriculture Office, four agricultural service centers, two agricultural research stations, one branch of the Agricultural Development Bank of Nepal, as agriculture supporting agencies including one branch of the Agricultural Inputs Corporation and 17 cooperative societies.

(5) Social Infrastructure

Each area is accessible by air from Kathmandu. It is an overnight journey to the Jhapa and Banke districts using the highway which runs east and west through the Terai , and it takes one day to Mahottari District. All-weather roads in the three districts are very poor, and the majority of the roads are mud which are impossible for vehicle traffic during the rainy season.

The power transmission network in Nepal consists of a 132 KV, 33 KV, 11 KV, and 220V power transmission lines.

Jhapa District has 132 KV and 33 KV transmission lines which run along the E-W Highway and power is transformed to 11 KV at Birtamod. It is possible to use power from the power transmission line near the highway. There is a future plan to extend three 11 KV lines to areas south of the highway.

The power in Mahottari District is transformed from 132 KV and 33 KV lines running along the highway at Jaleswar, and the power is used only in the adjacent areas. Construction to expand the system is currently underway in the southern area, and power will be distributed to the overall southern area in the future.

The Kohalpur and Nepalganj substations are located in Banke District, and a 11 KV line extends to the east; this line will be further extended to the Western Bardiya District in the future.

Wireless telephone relay stations in every district in Nepal are connected with Kathmandu. There are 775 telephone lines in Jhapa District,165 in Mahottari District, and 1,310 in Banke District.

7. Evaluation of Groundwater Resources

In the Phase I Study, the clarification of hydrogeological and groundwater conditions in three districts was made by mean of review of the existing groundwater studies and deep tubewell records; and then an average yield of standard deep tubewell by each district were evaluated as shown below:
The definition of standard deep tubewell is to be 150 m depth, 250 mm casing diameter, 15 m drawdown, 20 % screen opening, 3 cm/sec critical flow velocity and 30 m screen length.

Areas		;	Average Yield (l/s)
Jhapa		;	91
Mahottari	(south)	;	66
	(north)	;	97
Banke		;	110

The average yield in Jhapa, 91 l/s was reevaluated to be 120 l/s based upon the pumping test made on the explanatory and existing deep tubewell conducted during the Phase II Study.

As per the representative area selected in Jhapa District, a dynamic mathematical model was constructed for simulation studies of groundwater resource evaluation. The model covered a basin area of 719 km2 inclusive of the representative area and adjacent; and characterized in the results of detailed surveys in topography, meteorology, hydrology, hydrogeology and so forth. Applying the constructed model, the groundwater resource was evaluated through simulation studies for a 14-year period in the current and future conditions.
As the results of simulation studies, the current mean hydrologic balance in the study basin is shown as 1,903 million m3/annum (MCM/a) (100%) of rainfall, 555 MCM/a (29%) of evapo-transpiration, 3,790 MCM/a of surface inflow (inclusive of inflow from the Kankai River), 4,874 MCM/a of surface outflow, 1,048 MCM/a (57%) of a difference between in- and out-flows, 369 MCM/a (19%) of groundwater recharge; and 3 MCM/a of groundwater draft. A total expenditure reaches to 105% against the total revenue (rainfall). This is caused by the difference of total storage in the basin during a 14-year period. Focusing on the balance in the groundwater system, out of 369 MCM/a of recharge, 3 MCM/a is only pumped up for use, and the remained 360 MCM/a flows out of the basin.

In case that the irrigation (with peak water requirement at 0.8 l/s/ha) is conducted in a full-scale (17,000 ha), the total water requirement in the design year is reached at 131 MCM/a or 36% of the mean groundwater recharge of the basin. In accordance with simulation studies in case of a full-scale development for 14-year period, the groundwater heads at every aquifers never reach

to the critical level set forth at 30m below the ground surface. Another case of simulation shows that a groundwater draft at 206 MCM/a or 57% of the mean groundwater recharge or 1.35 times of the designed water requirement is necessary to reach at the critical heads. As the simulation studies concluded, the groundwater resource in the study basin in Jhapa is deemed to be some 200 MCM/a; and 35% surplus be left even in case that the full-scale development of DTW irrigation has been spread out.

Any simulation study has never been constructed for Mahottari and Banke. However, the groundwater potential in Mahottari is deemed to be same level in Jhapa since there is not so much difference between both districts in the groundwater environment such as meteorology, hydrology hydrogeology and so forth.
A large-scale groundwater development in Banke district seems to be limited only at the southern strip as the rainfall and river density are far less than in other districts and the Gangetic aquifers are spread out only at the strip.

8. Master Plan for Deep Tubewell Irrigation Development

(1) Agricultural Development Plan

The basic strategies of the Agricultural Development Plan include a crop diversification, expansion of productivity and an improvement in farm incomes. The scheduled cropping pattern and intensity in the study areas are summarized as below:

District	Jhapa	Mahottari	Banke
Cropping Pattern			
(without project)	Wheat • Maize • Monsoon paddy	Pulses • Wheat • Monsoon paddy	Mustard • Pulses • Maize • Wheat • Monsoon paddy
(with project)	Wheat • Maize • Spring paddy • Monsoon paddy	Onions • Potatoes • Wheat Spring Paddy • Monsoon paddy	Mustard • Pulses • Potatoes • Maize • Monsoon paddy
Cropping Intensity			
(without project)	126%	140%	140%
(with project)	200%	200%	200%

(2) Irrigation Plan

Based on conditions in each district, including precipitation, soils, and cropping patterns, the peak irrigation water requirement (facility design discharge) for each district is determined as follows: Jhapa 0.8 l/s/ha; Mahottari 1.0 l/s/ha; and Banke 0.7 l/s/ha. The annual water requirement for the design year on the irrigation area in each district is as follows: Jhapa 131 MCM; Mahottari 72 MCM; and Banke 66 MCM.

(3) Water Sources Plan

The number of irrigation units which cover the average command area of deep tubewell and the overall study area, determined by the average yield of a standard deep tubewell (depth 130-150 m; diameter 250 mm; water drawdown 20 m) are summarized as follows;

District	Jhapa	Mahottari		Banke
		(south)	(north)	
Deep tubewell yield (l/s)	120	66	97	110
Average command area (ha)	150	66	97	157
Number of irrigation units	113	31	61	51

(4) Facility Plan

The irrigation unit will be required to have following facilities: water source facility (deep tubewell, pump equipment, power transmission line within the unit), distribution system (pipeline system, valve etc.), on-farm canal (command area 4-6 ha), drainage system (unit discharge 4 l/s/ha, density 40 m/ha), village road (width 6 m, density 4-5 m/ha), and connecting road (width 3 m, density 4-5 m/ha).

(5) Project Plan

Based on the above facility plan, the project plan is summarized as follows:

Items	Jhapa	Mahottari	Banke
Irrigable area (ha)	17,000	7,000	8,000
Beneficial Farm Household	12,080	6,420	5,850
Beneficial Population	64,750	35,180	33,930
Number of deep tubewells	113	92	51
Pump stations			
• Number of pumps	113	92	51
• Total length of power transmission line (km)	170	70	80
Pipeline system			
• Total length (km)	680	300	320
• Number of valves	4,070	1,750	1,940
Total length of on-farm canals (km)	1,240	560	610
Total length of drainage system (km)	770	330	360
Total length of road (km)	170	74	77
Number of buildings	2	2	2

The implementation schedule for this project is planned as follows:

Items	Jhapa	Mahottari	Banke
Overall schedule (year)	10	9	8
Project preparation (year)	3	3	3
Land acquisition (year)	5	4	4
Road construction (year)	4	4	4
Facility construction (year)	6	5	4

(6) Organization, Operation and Maintenance System

The project executing agency is to be the Department of Irrigation, and the project is managed by a project office established in each area. The Project Office consists of the Agriculture, Farmers' Organization, Engineering, Operation and Maintenance, and Administrative Divisions. An agricultural subcenter is established under the Agricultural Division, which is in charge of the extension, the training and communication with farmers.

Throughout the project implementation period, the Farmer's Organization Division of the Project Office will provide guidance of establishment of and management of the Water User's Group which consists of every beneficial farmers within an irrigation unit and the Water User's Association which is composed of the Water User's Groups within the project area. During the initial period of project implementation, the operation and maintenance of pumps is the responsibility of the Project Office, but this will gradually be transferred to the Water Users' Association. At the completion of the project, the functions of each division, including the Agriculture, Farmers' Organization, and the Operation and Maintenance Divisions, will be transferred to the Water Users' Association. All functions (excluding the Engineering Division) including operation and maintenance, extension services, purchase of inputs, distribution, and marketing of agricultural products will be transferred to the Water Users' Association.

(7) Environmental Consideration

The most important environmental impact by this project is the existing groundwater right. According to the simulation in Jhapa District, a maximum 20 m groundwater drawdown may occur. The groundwater drawdown will affect the yield of domestic shallow well and the existing deep tubewells for town water supply. Countermeasures such as converting water sources will, therefore, be necessary during the execution of the project.

The potential for other environmental impacts related to groundwater development, including water pollution and land subsidence, is considered to be small.

(8) Project Cost

Based on the unit prices employed in recent construction works by DOI, the total project cost in each area, including construction cost, equipment cost, engineering and administrative fees, contingencies and price escalation are estimated as follows:

Jhapa	:	Rs 2.889 billion (US$57.8 million, US$3,400/ha)
Mahottari	:	Rs 1.584 billion (US$31.7 million, US$4,500/ha)
Banke	:	Rs 1.510 billion (US$30.2 million, US$3,800/ha)

(9) Project Evaluation

The financial and economic costs for construction and annual operation and maintenance in each area are estimated as follows:

(unit: million Rs)

		Construction cost		Annual operation and maintenance cost	
		Financial cost	Economic cost	Financial cost	Economic cost
Jhapa Area	:	2,889	1,932	39	36
Mahottari Area	:	1,584	1,098	21	19
Banke Area	:	1,510	1,019	16	15

The incremental agricultural benefits (unit: million RS/year) are evaluated as follows: Jhapa Area 585; Mahottari Area 203; and Banke Area 210.

As a result of a comparison between the above construction cost and incremental agricultural production benefits, the economic internal rate of return in each area is evaluated as follows; and projects in each area are considered to be economically feasible.

		Economic Internal Rate of Return (%)
Jhapa Area	:	21.0
Mahottari Area	:	13.5
Banke Area	:	14.3

As a result of financial analysis of a farm household, disposable income of the average farm household in each area without and with the project are as follows:

		Farm Size (ha)	Disposable Income (Rs)
Jhapa Area	(Without project) :	1.41	1,473
	(With project) :	1.41	2,680
	(Difference) :		1,207
Mahottari Area	(Without project) :	1.09	6,769
	(With project) :	1.09	8,581
	(Difference) :		1,812
Banke Area	(Without project) :	1.37	4,790
	(With project) :	1.37	9,038
	(Difference) :		4,248

(10) Guidelines for Deep Tubewell Irrigation

As a result of the above, the following two items are considered important as the guideline for the formulation of a deep tubewell irrigation plan in the Terai:

"LFCA and LFWY"

An economical Least Feasible Command Area dominated by one deep tubewell in the Terai is 30 ha, both east and west, as far as an electric pump is applied. And, the Least Feasible Well Yield necessary to irrigate this area is 30 l/s.

Based on these figures, deep tubewell irrigation is not considered economically appropriate for an area where the deep tubewell potential is less than 30 l/s.

"Aquifer and Production Well"

The deep tubewell yield of 60-100 l/s can be obtained in the alluvial aquifer in the Terai. However, the Churia aquifer may be of low permeability and low transmissivity, and the prescribed deep tubewell yield may not be obtained. Therefore, a sufficient hydrogeological examination is necessary to determine the distribution of the Churia Formation when formulating a deep tubewell irrigation plan.

Details of the production wells with yields up to 120 l/s in the Terai alluvial aquifer are as follows: screen diameter 250 mm; opening 25%; total length 30 m; total housing length 50 m; and tubewell depth 100-150 m.

The cost-efficient drilling method for production wells in the boulder including area in the Bhabar Zone is the percussion method. The rotary method can be used in the other areas. The circulation fluid should be carefully selected for production well drilling: Ordinary bentonite fluid can be used when the natural water head is below the surface. However, a combined fluid of bentonite and barite should be used when the water level shows high

artesian pressure. The use of excessively dense circulation fluid must be avoided as it will significantly reduce the well yield. The screens used for production wells in the Terai must be a reinforced wire-wrapped, with an opening of 25% or more and a collapse pressure resistance of 30 kg/cm2 or greater. Stainless steel is desirable depending on the water quality.

9. Conclusion and Recommendations

As a result of this Master Plan Study, the groundwater potential in the study areas is considered to be sufficient for deep tubewell irrigation. Furthermore, it has been confirmed that a deep tubewell irrigation plan is economically feasible.

This Study demonstrates the time-series observations for groundwater use, meteorology, hydrology, and groundwater behaviors are essential in the evaluation of groundwater resources. The establishment of observatory network and sustainable time-series observation in the three districts are strongly recommended for the Department of Irrigation in order to formulate proper DTW irrigation projects.

In regard to Jhapa District, an immediate implementation of project for 30 irrigation units (4,500 ha) is recommended for the purpose of demonstration and corroboration of DTW irrigation in the Eastern Terai.

As the other two districts require detailed groundwater resource evaluations, further surveys and studies in a feasibility study level are recommended to conduct. From the viewpoint of feasibility, this should be performed in Banke District first, followed by Mahottari.

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Abbreviation

ADB	:	Asian Development Bank
ADB/N	:	Agricultural Development Bank/Nepal
AIC	:	Agricultural Inputs Corporation
AMD	:	Agricultural Marketing Division
AO	:	Association Organizer
ASD	:	Agricultural Statistics Division
BNP	:	Program for Fulfillment of Basic Needs
CBS	:	Central Bureau of Statistics
CDO	:	Chief District Officer
CDR	:	Central Development Region
DMH	:	Department of Meteorology and Hydrology
DOA	:	Department of Agriculture
DOI	:	Department of Irrigation
DTW	:	Deep Tubewell
DTWIP	:	Deep Tubewell Irrigation Project
EIRR	:	Economic Internal Rate of Return
ESE	:	East-south-east
E-W	:	East-west
GCA	:	Gross Command Area
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GOJ	:	Government of Japan
GWRDB	:	Ground Water Resources Development Board
GWRDP	:	Ground Water Resources Development
HMGN	:	His Majesty's Government of Nepal
HYV	:	High Yielding Variety
IAP	:	Intensive Irrigation and Agriculture Program
IDA	:	International Development Association
JADP	:	Janakpur Zone Agricultural Development Project
JICA	:	Japan International Cooperation Agency
JTA	:	Junior Technical assistants
LLDC	:	Least Level Development Country
MOA	:	Ministry of Agriculture
MOWR	:	Ministry of Water Resources
MPID	:	Mater Plan for Irrigation Development in Nepal
MSL	:	Mean Sea Level
NCA	:	Net Command Area
NNE	:	North-north-east
O&M	:	Operation and Maintenance
PVC	:	Polyvinyl Chloride
SSW	:	South-south-west
STW	:	Shallow Tubewell
STWIP	:	Shallow Tubewell Irrigation Program
SWL	:	Static Water Level
TIATSP	:	Tubewell Irrigation Agriculture Training and Services Project
UNDP	:	United Nation Development Program
UPVC	:	Unplastixised Polyvinyl Chloride
ASAID	:	United State Agency for International Development
WNW	:	West-north-west
WUA	:	Water Users Association
WUG	:	Water Users Group

Glossary

a	:	Annum
av.	:	Average
bgl	:	Below ground level
mags	:	Meter above ground surface
masl	:	Meter above sea level
m	:	Meter(s)
mm	:	Milli-meter(s)
km	:	Kilo-meter(s)
km2	:	Square kilometer(s)
sq.km	:	Square kilometer(s)
m3	:	Cubic meter(s)
cu.m	:	Cubic meter(s)
MCM	:	Million cubic meter(s)
t	:	Ton(s)
Mt	:	Metric ton(s)
kg	:	Kilogram(s)
ha	:	Hectare(s)
°C	:	Degree centigrade
%	:	Percent
yr	:	Year(s)
hr	:	Hour(s)
min	:	Minute(s)
sec	:	Second(s)
l	:	Liter(s)
S/cm	:	Siemens per centimeter(s)
in	:	Inch(es)
"	:	Inch(es)
kw	:	Kilowatt(s)
KVA	:	Kilo-volt-ampere
Rs	:	Nepal Rupee(s) (US$0.02; ¥2.24; End of 1993)
MRs	:	Million Rupee(s)
¥	:	Japanese Yen(s) (Rs0.446; US$0.0089; End of 1993)
M¥	:	Million Yen
US$	:	US Dollar(s) (Rs50.0; ¥112; End of 1993)
M$	:	Million Dollar
EC	:	Electric Conductivity
k	:	Permeability (Water Conductivity)
pH	:	Potential of Hydrogen
S	:	Storage Coefficient
T	:	Transmissivity
ND	:	Nominal Diameter
ID	:	Internal Diameter
OD	:	Outer Diameter
MAX.	:	Maximum
MIN.	:	Minimum

CHAPTER ONE

INTRODUCTION

CHAPTER-ONE: INTRODUCTION

This report summarizes the results of the "Master Plan Study on the Terai Groundwater Evaluation and Development Project for Irrigation" which was requested by His Majesty's Government of Nepal (HMGN) and conducted by Japan International Cooperation Agency (JICA).

Major objectives of the study include the evaluation of groundwater resources, the formulation of master plan of deep tubewell (DTW) irrigation projects in Jhapa, Mahattori and Banke (inclusive of a part of Bardiya) Districts which situate in the eastern, central and western Terai respectively.

The study divided into two phases.
The "Phase I Study" aimed mainly at selection of areas irrigable by DTW in each District as well as a "representative area" with the highest groundwater potential amongst the selected irrigable areas. As the result of the study the southeastern area in Jhapa District has been selected as the "representative area".
The "Phase II Study" was to cover an intensive survey and study on the representative area, formulation of master plan and guideline for DTW irrigation and so forth. The intensive survey includes the establishment of monitoring network; monitoring of meteo-hydrology and groundwater; geophysical prospecting; drilling and testing of 20 exploratory deep tubewells; topomapping of a sample area; socio-economic and agricultural survey; and so forth. Based upon the results of survey, the evaluation of groundwater resources, formation of master plan and guideline for DTW irrigation were conducted. A series of systems in groundwater monitoring, meteohydrological and hydrogeological database and groundwater management were constructed.

Through the study period, technical transfers have been conducted for the counterpart personnel of Department of Irrigation (DOI) in the On-The-Job basis and the training in Japan.

The "Phase I" and "Phase II" studies were conducted from October 1991 to March 1992 and from September 1992 to September 1994 respectively.
The total study was conducted over a 36-month period.

This report is volume one of three volumes as below;

Volume One	:	Main Report
Volume Two	:	Sector Report
Volume Three	:	Appendices

The Study Team wishes to express its deep appreciation to the officers of the Department of Irrigation of the Ministry of Water Resources, particularly to the counterpart personnel, and the officers of related agencies of Japan.

CHAPTER TWO

THE STUDY

CHAPTER-TWO: THE STUDY

2.1. Background of the Study

In the current Eighth National Development Plan, His Majesty's Government of Nepal (HMGN) formulated a major plan to drastically transform rainfed farmland into irrigated land and to establish a basis for the expansion of food production in Nepal.

In order to implement this plan, the Department of Irrigation (DOI) of the Ministry of Water Resources (MOWR) which is responsible for irrigation development of Nepal has been engaged in surface and groundwater development schemes in the Terai where has the highest development potential in Nepal in terms of land, water resources and agriculture. DOI, however, faces various constraints in coordinating,implementing and managing groundwater development through deep tubewells.*

In this connection, HMGN requested in 1988 for the Government of Japan to extend its technical cooperation for the Master Plan Study on Terai Groundwater Resources Evaluation and Development Project for Irrigation (the Study). In response to this request, the Government of Japan sent, through the Japan International Cooperation Agency (JICA), a preliminary survey team to Nepal in March 1991 and made discussions with DOI in relation to the scope of the work involved.

Based on these discussions, JICA organized an implementing team (the Study Team) for the Study. The Study Team submitted an Inception Report to DOI in October 1991 which outlined the plans of approach and operation of the Study. Both parties agreed to the plan of approach and operation of the Study and work was immediately begun by a joint team consisting of the Study Team and the counterpart personnel from DOI.

* The definition of deep tubewell (DTW) and shallow tubewell (STW) is set forth, in many countries, at a depth of 30 m (100 feet). This definition in Nepal is not clear. A well in depth of 40 to 50 m is often called a STW when it taps water within the first unconfined aquifer or the installed pump is a centrifugal type. While, a tubewell drilled to 50 m or more and installed deep-well type pump (mostly a vertical turbine type) is called a DTW.

2.2. Scope of the Study

The scope of the study and the plan of operation agreed upon between JICA and HMGN are as listed below:

(1) Objectives

The objectives of the Study are as follows:

- to evaluate the groundwater potential in the three districts of Jhapa, Mahottari, and Banke, which are located in the Terai;
- to formulate a project master plan on groundwater development in a selected district where the groundwater potential is highest; and
- to carry out technology transfers to the Nepalese counterpart personnel during the course of the Study.

(2) The Study Area

The study area includes the following three districts:

- Jhapa District, excluding the area covered by the Kankai Irrigation Project.
- Mahottari District.
- Banke District, including a part of the Bardiya District on the left bank of the Babai River.

(3) Scope of the Study

The scope of the Study set forth in the scope of work includes the following:

a) Phase I Study

- to collect and review the existing data and information,
- to examine topography, meteorology, hydrology, geology, soil, agriculture, irrigation, organization, hydrogeology, groundwater resources, and the existing irrigation projects and water resources development plan in three target districts,
- to evaluate the groundwater resources for irrigation,
- to identify the groundwater irrigation potential,
- to formulate a technical and management concept for groundwater irrigation; and
- to select a "representative area" which has the highest potential for deep tubewell development for irrigation.

b) Phase II Study

- to conduct hydrogeological surveys, geophysical prospecting, drilling of exploratory wells, groundwater monitoring and evaluation of groundwater resources in the selected representative area,
- to formulate a plan for groundwater monitoring in the representative area,
- to formulate a plan for the development and management of groundwater in the representative area; and

- to formulate a master plan for deep tubewell irrigation projects in the target districts.

(4) Implementation of the Study

Implementation of the Study was carried out by the Study Team organized by JICA together with the counterpart personnel from DOI.

(5) Plan of Operation for the Study

a) Schedule of the Study

The Study is divided into two phases and stages as listed below.

Table 2.2.1 Schedule of the Study

Phase	Stage	Schedule of Work	Report Schedule
I	Preparatory Work	Oct. 1991	Inception
	Field Work (I)	Nov. 1991 to Jan. 1992	Progress (I)
	Home Work (I)	Feb. to March 1992	
II	Field Work (II)	Sept. 1992 to May 1993	Interim/Progress (II)
	Home Work (II)	Aug. to Sept. 1993	
	Field Work (III)	Oct. 1993 to Jan. 1994	Progress (III)
	Home Work (III)	June to July 1994	
	Report Explanation	Dec. 1994	Draft Final Report
	Report Submission	Mar. 1995	Final Report

b) Outline of the Phase I Study

- Preparatory Works
  - [1] Review of the existing data and information
  - [2] Formulation of the plan of operation
  - [3] Preparation of the Inception Report
- Field Work (I)
  - [4] Explanation and discussion of the Inception Report
  - [5] Collection and review of related data and information
  - [6] Field inspection
  - [7] Provisional discussion on the selection of a representative area
  - [8] Investigation on subcontracts for the drilling of exploratory wells
  - [9] Preparation and discussion of the Progress Report (I)

- Home Work (I)

  [10] Review of the existing plans for water resource development and irrigation projects

  [11] Evaluation of the groundwater potential for irrigation

  [12] Formulation of a basic strategy for the development and management of groundwater resources

  [13] Selection of potential areas and a representative area in the target districts

  [14] Preparation of an Interim Report

c) Outline of Phase II Study

- Field Work (II)

  [15] Explanation and discussion on the Interim Report

  [16] Geophysical prospecting

  [17] Drilling and testing of the exploratory wells

  [18] Meteo-hydrological and groundwater observations

  [19] Survey on agriculture and irrigation

  [20] Preparation and discussion of the Progress Report (II)

- Home Work (II)

  [21] Analysis of the results of Field Work (II)

  [22] Examination of the additional field investigation

- Field Work (III)

  [23] Collection and review of the supplementary data and information

  [24] Additional meteo-hydrological and groundwater surveys

  [25] Analysis of the surface water balance

  [26] Analysis of the groundwater balance

  [27] Formulation of a basic strategy for groundwater resource development

  [28] Preparation and discussion of the Progress Report (III)

- Home Work (III)

  [29] Comprehensive evaluation of the groundwater resources

  [30] Formulation of a master plan for deep tubewell irrigation in the representative area

  [31] Formulation of a plan of operation and management for groundwater monitoring network

  [32] Formulation of a plan for a hydrogeological and meteo-hydrological database

  [33] Formulation of guidelines for deep tubewell irrigation for the two areas other than the representative area

  [34] Preparation of a Draft Final Report

- Final Report

  [35] Explanation and discussion of the Draft Final Report

  [36] Preparation and submission of the Final Report

CHAPTER THREE

NEPAL IN OVERVIEW

CHAPTER THREE: NEPAL IN OVERVIEW

3.1. Natural Environment

3.1.1. Topography and Geology

The Himalayan Range swings in an enormous arc at the north of the Indian subcontinent. The Kingdom of Nepal situates close to the central part of this arc. Nepal is a land-locked mountainous country which shares common boundaries with China to the north and India to the south, east and west.

The country has a rectangular feature, located in between the latitudes of N26° 21' 35" and N30° 26' 55", and a longitude of 80° 03' 51" E to 88° 12' 21" E. The average axis is 885 km in the east-west and 193 km in the north-south, with a total area of approximately 147,000 km2.

Nepal's topographical features, geological characteristics, and climatologic zoning are closely related due to the presence of the Himalayas.

The topography and geology are divided into the following five areas, which parallel the Himalayan arc:

(1) Terai

The Terai is a plain area with an altitude ranging from 60 m to 200 m at the southern end and a north-south width of 20 km to 50 km. The plain consists of the Gangetic alluvial beds of clay, sand and gravel, which is brought down from the Himalayan mountains and its foothills. The Terai has abundant land and water resources and is considered as the granary of Nepal.

(2) Churia Hills

The Churia Hills skirt the Terai with an altitude less than 1,300 m. Its north-south width is 20 km to 30 km. The Churia Hills consist of the Churia Formation, which is composed of sandstone, conglomerate and silt formed in the Miocene to Pleistocene age.

Some geological texts call this formation as "Siwalik Formation", which, in the Report, is referred to as "Churia Formation" meaning the formation consists of the Churia Hills.

(3) Mahabharat Hills and Midlands

Topographically, Nepal is divided into the Midlands in the central part of the country (north-south width, 40 km to 60 km) and the Mahabharat Hills (north-south width, 30 km

to 40 km). Geologically, these areas belong to the Midlands Zone and consists of granite and schist in the Precambrian age.

(4) Himalayan Mountains

The Himalayan mountain range includes the major summits of the Eastern Himalayas and consists of gneiss and migmatite.

(5) Inner Himalayan Valley

The higher peaks of Sagarmatha (Everest), Dhaulagiri and Annapurna massif underlie in the inner Himalaya and the area underlain by sedimentary rocks such as limestone and dolomite, and intruded granite of geologic age from Cambrian to Cretaceous.

3.1.2. Meteorology and Hydrology

(1) Meteorology

Nepal lies near the northern limit of the tropics; but because of the exceptionally rugged terrain, the climatic range varies greatly, from summer tropical heat and humidity of the Terai, to a colder dry continental and alpine winter climate of the middle and northern mountainous regions.

The mean annual precipitation ranges from more than 6,000 mm along the southern slope of the Annapurna Range in the central Nepal, to less than 250 mm in the north-central region near the Tibetan Plateau. Varying precipitation amounts, from 1,500 mm and 2,500 mm, dominate a majority of the country, with a distinct maximum along the southern slope of the Mahabharat and Himalayan ranges in the eastern two-thirds of the country; however, minimum precipitation stretches east and west across the middle of the country. On an average, approximately 80% of the precipitation is confined to the monsoon period, from June to September.

The maximum temperature in the summer and late spring ranges from more than 40°C in the Terai to about 28°C in the mid-region of the country. The winter average maximum and minimum temperatures in the Terai range from a mild 23°C to a brisk 7°C, while the central valleys experience a chilly 12°C maximum and a -0°C minimum. Much colder temperatures prevail at higher elevations.

(2) Hydrology

All rivers in Nepal are tributaries of the Ganges River, which flows into India. Discharge hydrographs for most rivers are sharp during the monsoon season between July and September, but significantly drop in November and are at their lowest in February. The discharge begins to increase again as the snow melts.

Snowfed rivers are mostly perennial in nature; however, the fluctuation between their low and high flows is often very large due to heavy rainfall during the monsoon season.

Most of the rivers in the Terai are seasonal, being nearly dry in winter but active during the monsoon season. The main source of water for these rivers is rainfall.

(3) Meteorological and Hydrological Stations

Department of Meteorology and Hydrology (DMH) of Ministry of Water Resources which is responsible for monitoring and recording of meteorology and hydrology in Nepal, has recorded data which includes precipitation, temperature, humidity, wind, sunshine, and river discharge.

Meteorological monitoring began in 1947 at several locations, and as of 1990, there are 215 stations measuring rainfall in Nepal. Among these stations, approximately 40 stations measure agro-meteorological data such as temperature, humidity, sunshine, wind, and evaporation. Meteorological data is made available in part by the "Climatological Records of Nepal," which is published by DMH on an irregular basis. Furthermore, only monthly data is made available by this publication though the measurements are taken on a daily basis.

Hydrological measurements began at the Karnali River in 1960, and there are approximately 40 stations currently measuring the water discharge of the major rivers. Hydrological data is made available in part by the "Surface Water Records of Nepal," published by DMH; however, publication ceased in 1976.

3.2. Socio-Economy

The population of Nepal as of 1991 is 18.49 million, and the annual population growth rate since 1981 has been 2.1%. Nepal occupies an area of 147,000 km2 and has a population density of 126/km2 (1991).

Nepal is an culturally diverse country composed of many races and ethnic groups. These people can be divided into Tibet-Nepalese and India-Nepalese races. The Tibet-Nepalese races, which settled mainly in the hill and mountain districts, are represented by Tibetan and ancient Nepalese groups. Similarly, the India-Nepalese races, which settled mainly on the Terai, are represented by Nepalese and Indian groups.

The agricultural sector forms the mainstay of Nepal's economy, contributing 49% of the GDP in 1991/92, compared with other sectors such as construction and manufacturing. As of 1991/92, Nepal's GDP is 126.2 billion Rs (approx. US$ 3 billion) and US$180 per capita.

Foreign trade in 1991/1992 reflected a deficit of Rs 19 billion, with exports and imported valued at Rs 13.9 and 32.9 billion, respectively.

3.3. Agriculture

Six food grains, including paddy, maize, wheat, barley, millet, and pulses, dominate agricultural production of Nepal. In 1992/1993, approximately 2.9 million ha of farmland were cropped, producing some 4.9 million ton of food grains and about 3.3 million ton of other cash crops.

Livestock also plays an important role in Nepal's economy. The total number of cattle and buffalo is 9.31 million, or approximately 4.2 head per household.

Until the mid-1980s, Nepal was a food-grain exporter. In recent year, however, food demand has exceeded production. Nepal is estimated to be 85% to 90% self-sufficient in the production of food grains. Farming is carried out under irrigated conditions in large areas of the Terai and in smaller areas in the hill and mountain districts. Rainfed agriculture dominates in the latter areas. The total arable area in Nepal was 2.97 million ha in 1989/1990, of which 1.2 million ha, or 42%, are located in the Terai region. The irrigable land area has reached 2.2 million ha. The actual irrigated area in Nepal is 940,000 ha, of which 610,000, or 65%, are also located in the Terai region. The productivity of the agricultural land in most parts of Nepal is significantly lower than in neighboring countries.

3.4. Political and Administrative System

3.4.1. Political System

The Kingdom of Nepal is a constitutional monarchy. Its written constitution was set forth in 1962, establishing a party-less Panchayat System, after many political and administrative attempts following the royal takeover in 1951. In accordance with the 1962 constitution, there are three levels of Panchayats, or political councils - village, district, and national assemblies.

In April 1990 a pro-democracy movement was initiated, and His Majesty the King dissolved the Rastriya Panchayat and the Panchayat System in mid-April 1990. An interim government was formed to create a new constitution, and a new constitution based on a multi-party system was set forth in early 1991.

3.4.2. Administrative System

(1) His Majesty's Government

HMGN is composed of 21 ministries, including among others, ministries for finance, law and justice, foreign affairs, local government, defense, agriculture, and water resources, as well as a National Planning Commission in the Secretariat of the Council of Ministers, under the chairmanship of the prime minister.

(2) Local Administration

Nepal is divided into five development regions, 14 zones and 75 districts for administrative and development purposes, as shown in Figure 3.4.1. Each development region consists of two to three zones and several districts. Each district is divided into nine wards, with several villages. Most ministries related to development sector have regional and district offices.

(3) Government Agencies Related to the Irrigation Subsector

Government agencies have been actively involved in new irrigation schemes and in assisting farmer groups to construct or rehabilitate low-cost Farmer Managed Irrigation Systems (FMIS). DOI has been the leading agency involved in the development of new irrigation works, though the Agriculture Development Bank of Nepal (ADB/N) now plays an

important role in promoting and financing the Shallow Tubewell (STW) Development Program.

a) MOWR and DOI

MOWR is responsible for the planning and implementation of HMGN's policy for the development, management, control, and conservation of water resources and electric power. MOWR is composed of the Secretary's Administration, Department of Irrigation, Department of Meteorology & Hydrology, Groundwater Resources Development Board, Nepal Electricity Authority, and the Water & Energy Commission.

DOI, within MOWR, is the most important government agency involved in the irrigation subsector. Its mandate is to plan and implement new irrigation schemes as well as to manage large completed projects. DOI is composed of five central divisions: Irrigation Management & Water Utilization; Medium & Large-Scale Irrigation; Groundwater Utilization; Planning; and River Training. As well as these divisions, there is a Project Management Board for each national project and a Regional Irrigation Directorate which supervises several District Irrigation Office in each of the five development regions.

b) Department of Agriculture (DOA)

DOA is responsible for agricultural extension programs throughout the nation, with exception of the project-specific programs for several of the large projects managed by DOI in the Terai.

c) ADB/N

ADB/N is responsible for the provision of agricultural credit on an organized basis throughout Nepal. Its STW program, through which subsidies are provided to individual farmers to construct STWs, has reportedly been successful. ADB/N reports that the STW program had provided irrigation facilities to an estimated net command area (NCA) of 61,000 ha by mid 1988.

d) Agricultural Inputs Corporation (AIC)

AIC is responsible for the importation and distribution of chemical fertilizers, improved seeds, agro-chemicals, and farm machinery.

No. of Districts

		Far Westrn	Mid Western	Western	Central	Eastern	Total
	Terai	2	3	3	7	5	20
	Hill	4	7	11	9	8	39
	Mountain	3	5	2	3	3	16
	Total	9	15	16	19	16	75

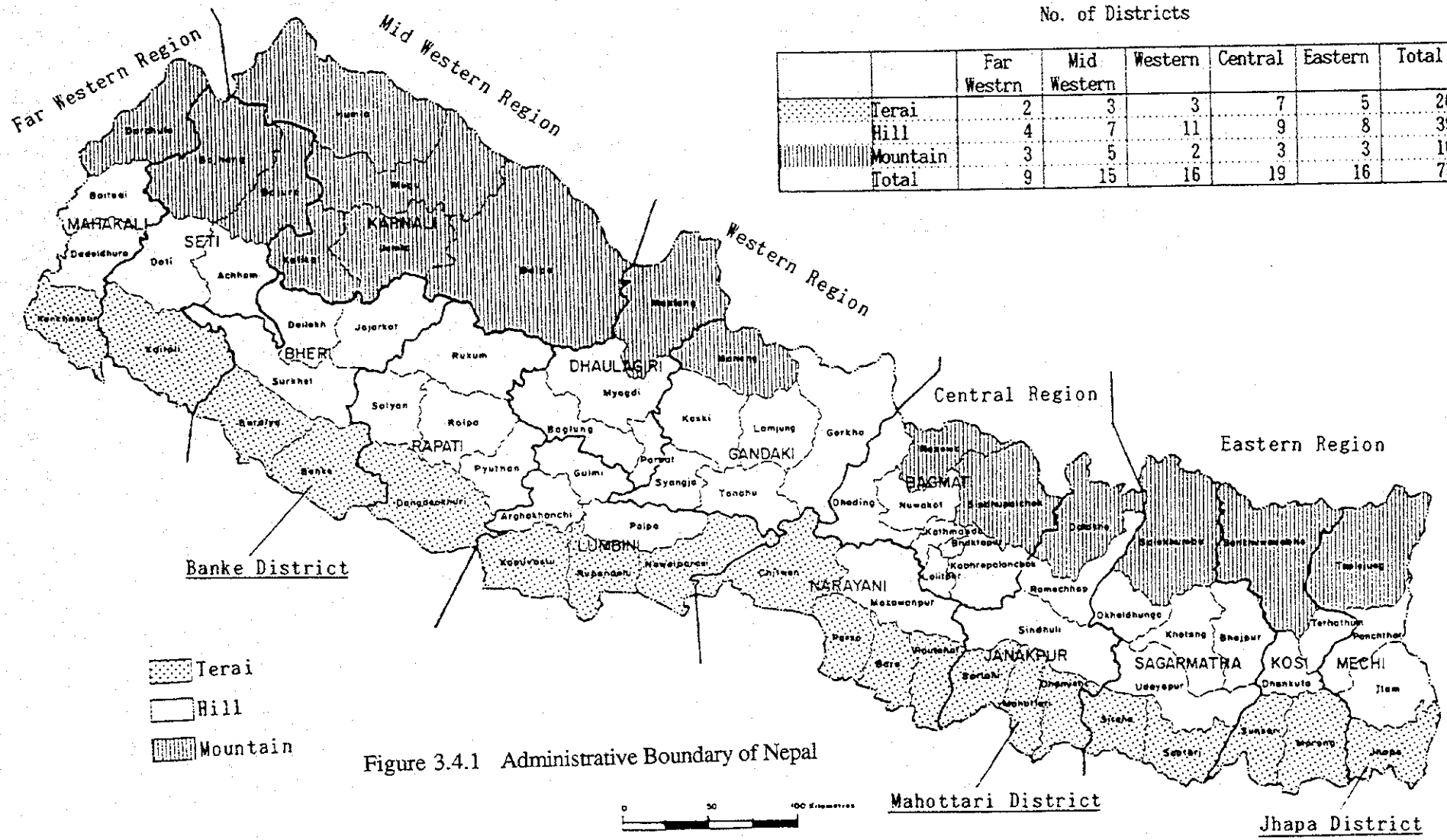


Figure 3.4.1 Administrative Boundary of Nepal

3.5. Development Plan

3.5.1. National Development Plan

(1) Previous National Development Plans

Since the First National Development Plan was implemented in 1956, a total of seven plans have been promoted under the Panchayat System. The major targets of each plan included the improvement of the social infrastructure and social welfare as well as an increase in agricultural production.

After dissolution of the Panchayat System, the new government evaluated the results of previous national development plans over a 30 year period, and concluded that Nepal remains one of the poorest countries, even after a large amount of investment. Although slight progress is observed throughout society and the development of social infrastructure, rapid progress is impossible because of the inability to initiate structural changes in the production sector. The government has concluded that the following present major obstructions to future development: low savings rate, increasing foreign debt, low industrialization, weak agricultural productivity, limited exports, and high population growth.

(2) Eighth National Development Plan (1992-1997)

Based on an assessment of the previous plans, the government is promoting the Eighth National Development Plan (1992-1997). The major targets of this plan include "Sustainable Economic Growth," "Alleviation of Poverty," and a "Reduction of Regional Imbalances"; as well, programs receiving special priority in the plan include "Agricultural Intensification and Diversification," "Energy Development," "Development of Rural Infrastructure," "Employment Generation and Human Resource Development," and "Regulation of Population Growth."

The total investment amount of the plan is Rs 170 billion, which is being allocated to the major sectors of "Agriculture, Irrigation, and Forestry," "Finance & Real Estate" and "Electricity, Gas, and Water Supply" and "Traffic and Communications" are 26%, 20%, 16% and 15%, respectively.

3.5.2 Basic Needs Program (1985-2000, hereafter BNP)

HMGN established the "BNP (1985-2000)," beginning with the Sixth National Development Plan, in order to meet the basic needs of its people in six sectors by the year 2000. These sectors include food, clothing, housing, health, education, and security.

Food is the most important basic item among the basic needs. The food production plan in this program is determined based on the minimum requirement of 2,250 calories/person/day. The program emphasis is to satisfy the necessary caloric requirements through the provision of inexpensive food produce, such as maize, wheat, millet, barley, pulses, and potatoes. The required domestic food production is 6.6 million tons, or 9.8 million tons on an unprocessed basis, based on the required caloric intake from grains, pulses, and potatoes and the population increase by the year 2000 (estimated at 23 million). The food production volume in 1984/85 was 4.8 million tons, and an annual average rate of increase at 6.5% is required in order to achieve the goal of this program.

In order to meet the above target, development and the wide use of improved seeds, improved agricultural practices, farmer education, and technical innovations are necessary, accompanied by an increase in irrigated farmland to 1.25 million ha by the year 2000.

BNP's main goal is to achieve self-sufficiency in the six major grain products. The program also highlights the diversification of agriculture in hilly regions where the self-sufficiency rate is especially low. In order to achieve these goals, it is necessary to provide irrigation facilities, improved seeds, agro-chemical, farm machinery, agricultural financing, storage facilities, and other agricultural expansion measures; and this will require an investment estimated at Rs 46.420 billion (1984/1985 value).

3.5.3. Master Plan for Irrigation Development

Following BNP, a master plan for irrigation development in Nepal was prepared in early 1990 with the assistance of UNDP/World Bank. The plan was designed to provide a long-term strategy for irrigation development; to develop short-term investment programs within this long-term strategy; and to provide a sound database and planning methodology.

(1) Objectives and Targets

The Master plan has established two goals, which are the same described in BNP, for the irrigation subsector: a food grain production goal and an irrigated area development goal.

The first goal is to produce food sufficient to meet the minimum daily requirement of 2,250 calories per capita per day by the year 2000. This is equivalent to the production of 9.8 million tons of food grains, or approximately double the actual production of the mid-1980s.

The second goal calls for an expansion of the areas benefiting from government-assisted irrigation, from the 1987 level of 434,000 ha to a total area of 1,250,000 ha by the year 2000. The implied rate for implementation of newly irrigated areas is 60,000 ha/year or greater. The maximum sustained rate of development achieved during the Sixth National Development Plan was only 35,000 ha/year.

(2) Available Investment Options

Nepal's irrigation investment programs to date have emphasized in construction of new large projects in the Terai and small to medium projects in the hills; assistance to existing Farmer Managed Irrigation Systems (FMIS) in all areas; and promotion of groundwater development in the Terai. The strategy now set forth is for irrigation management and agricultural support programs; low-cost demand-driven assistance to FMISs; and the development of new small schemes and shallow tubewells.

Because of BNP's emphasis on food production targets, investment options in the master plan have evaluated food grain-dominated cropping patterns and related assumptions.

The evaluated investment options are listed in descending order below.

a) Irrigation Management Improvements for Existing Projects

Relatively low-investment costs can be effective in the improvement of existing irrigation. The investment priority is as follows:

- Transfer DOI's small-scale irrigation projects to Water Users' Groups (WUG).
- Assistance to existing FMIS.
- Irrigation management programs and some rehabilitation works in DOI's large-scale projects in the Terai.

b) Groundwater Irrigation in the Terai

Three development models were considered, including shallow tubewells (STW), deep tubewells (DTW) based on large projects, and DTW on small projects; and approximately 90,000 ha of the estimated 290,000 ha potential has been developed by STW irrigation, while about 2,000 ha of estimated 70,000 ha potential has been developed by DTW irrigation.

- Shallow Tubewells

  Economic analyses indicate that EIRRs of over 40% can be realized from STW investment in rainfed areas, and that EIRRs of over 20% can be obtained from conjunctive use areas. Financial analyses confirm that standard STW investment is attractive to irrigable farmholdings larger than 1.0 ha. Promotion of group ownership and/or water sales is needed to expand the service area per STW and to permit small holdings to receive the benefits from STW irrigation.

- Deep Tubewells, large-scale project model

  Experience with the Bhairawa-Lumbini DTW project indicates that large-scale DTW project models can generate relatively high benefits. Project-specific irrigation management and agricultural support programs promote the attainment of future levels of agricultural production and command area utilization, and the operating costs are minimized by the use of electric motors. EIRR's of over 20% are indicated for this DTW model for future levels and approximately 10% for the present level. Problems have been encountered in achieving full recovery of O&M costs for DTW projects operated by DOI; however, DOI intends to address this problem through programs which promote the formation of WUGs and profitable cash cropping.

- Deep Tubewells, small-scale project model

  Individual DTWs can be developed to serve 60 ha to 120 ha, based on group ownership of wells, pumping equipment, and the distribution system. Analyses indicates that such investments are comparable with the large-scale DTW model. Problems have arisen for many small-scale DTWs in only partial use of the command areas because of the reluctance of farmers to cover the operating costs.

c) Small- and Medium-Scale Surface Water Projects in the Terai

The potential for small- and medium-scale surface water projects in the Terai is limited as the water resources of the many small Terai streams have already been exploited by existing DOI projects and FMISs. The most economic form of irrigation investment in small-scale surface projects is the rehabilitation of existing FMISs using low-cost implementation models.

d) Small-Scale Irrigation Projects in the Hill and Mountain Districts

Some 70,000 ha of irrigable land is available for new irrigation projects in the hills and mountains. Investment in new projects can be economically viable: EIRR'S of 10% to 20% can be realized as long as costs are consistent with the expected benefits.

e) Large-Scale Surface Water Irrigation Projects in the Terai

Some 80% of the irrigable land resources in Nepal as well as most of the potential areas for expanding irrigation are in the Terai.

HMGN, therefore, places a high priority on implementing large-scale surface irrigation projects in the Terai, utilizing the area's surface water resources.

Seven large-scale surface water projects have been completed, or are currently under construction, and seven other potential projects have been economically assessed.

(3) Proposed Strategies and Programs for the Irrigation Subsector

In the master plan, four long-term objectives to guide the development of the irrigation subsectors are recommended as follows:

- to increase agricultural production and benefits from existing irrigated lands by combining the agricultural and irrigation management programs;
- to improve the delivery efficiency of irrigation-related services through institutional improvements within government agencies and the maximum possible use of the private sector;
- to implement small- and medium-scale irrigation projects which meet sound technical and economic criteria; and
- to select and implement new large-scale irrigation projects in the Terai as a mean of significantly augmenting national agricultural production.

(4) Investment Program Options for the 1990s

The recommended investment program for DOI is based on the Cost-Effective Program, but it also incorporates elements of the DOI Official Program. Budgetary items are divided into the following three categories: "Core Items," "Highest Priority Projects and Programs," and "Additional Projects and Programs."

The recommended investment program includes all of the items in the first category; most of the items in the second; and selected items depending on the availability of external financing and the experience of DOI's implementation capacity in the third.

The recommended approach in formulating the investment program for the irrigation subsector is intended to emphasize selection of cost-effective investments.

CHAPTER FOUR

THE STUDY AREA

CHAPTER FOUR: THE STUDY AREA

4.1. Selection of Area Irrigable by DTW

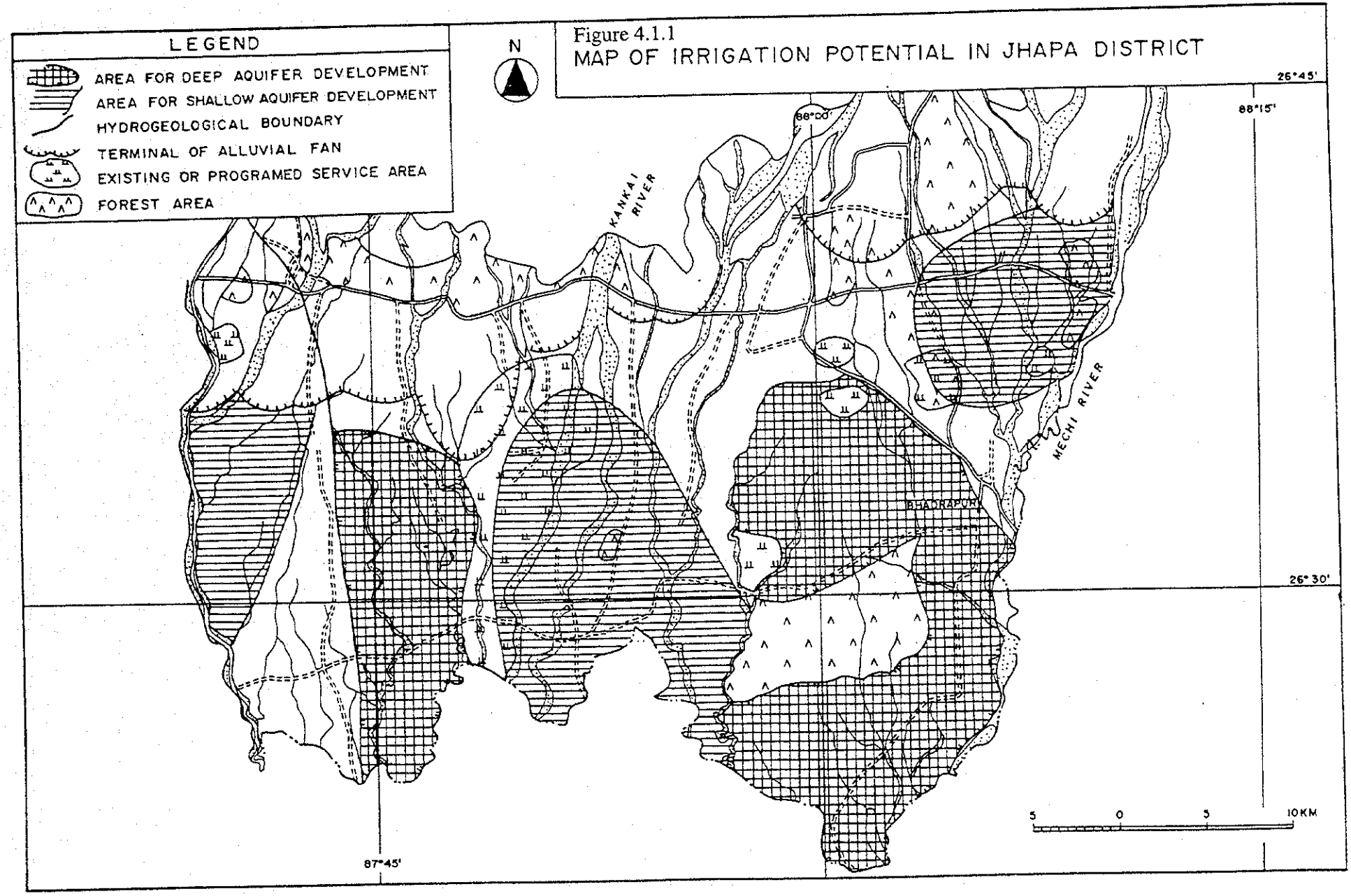
The Phase I study aimed to select, through review of the existing data and information, an area (around 10,000 ha size) irrigable only by DTW in each district under the study exclusive of those areas where surface-water and STW are available, and to decide a representative area where the groundwater potential is higher than any other.
The representative area thus selected is to be covered by Phase II study composed of further survey and studies in meteorology, hydrology, hydrogeology, groundwater, agriculture, irrigation, formulation of master plan and so forth.
A definition is set forth in this study that DTW is to exploit groundwater stored in confined aquifers deeper than the uppermost unconfined aquifer which extend to around 40-m depth from the ground surface.

The result of Phase I study is as summarized in Table 4.1.1. and Figures 4.1.1. to 4.1.3.
Although there are no remarkable differences in the DTW yield among three districts under the study, they could be listed in the order of Banke, Mahottari and Jhapa. While, the potentials of groundwater recharge were deemed to be excellent in Jhapa and Mahottari; and poor in Banke in view from the density of rivers flowing down in the districts, based on the preliminary field reconnaissance of the areas.
The acreage of irrigable area around 10,000 ha are in the southeastern area (17,000 ha) and the western area (10,000 ha) in Jhapa, the southern and northern areas (7,000 ha in total) in Mahottari and the southern strip (8,000 ha) in Banke. The situation in social infrastructure such as road, power supply, tele-communication is not so much difference in three districts.
As the results of integrated conclusion on the conditions mentioned above and consultation with DOI, the southeastern area in Jhapa District was finally selected as the "representative area".

Table 4.1.1 Groundwater Potential for Deep Tubewell Irrigation in Three Districts

Districts	Jhapa	Mahottari	Banke
Location of Irrigable Area	Southeast/West	South/North	South
Transmissivity (m2/day)	1,660/1,660	820/5,500	1,000
Average Well Yield (l/s)	91/91	66/ 97	110
Irrigable Area (ha)	17,000/10,000	4,000/3,000	8,000
Future Road Plan	Yes	Yes	No
Future Power Plan	No	No	Yes

The general features of the districts under the study and the selected irrigable areas in each district are outlined in the following paragraphs.


LEGEND
AREA FOR DEEP AQUIFER DEVELOPMENT
AREA FOR SHALLOW AQUIFER DEVELOPMENT
HYDROGEOLOGICAL BOUNDARY
TERMINAL OF ALLUVIAL FAN
EXISTING OR PROGRAMED SERVICE AREA
FOREST AREA
N
Figure 4.1.1
MAP OF IRRIGATION POTENTIAL IN JHAPA DISTRICT
26°45'
88°00'
88°15'
KANKAI RIVER
MECHI RIVER
BHADRAPUR
26° 30'
5 0 5 10KM
87°45'

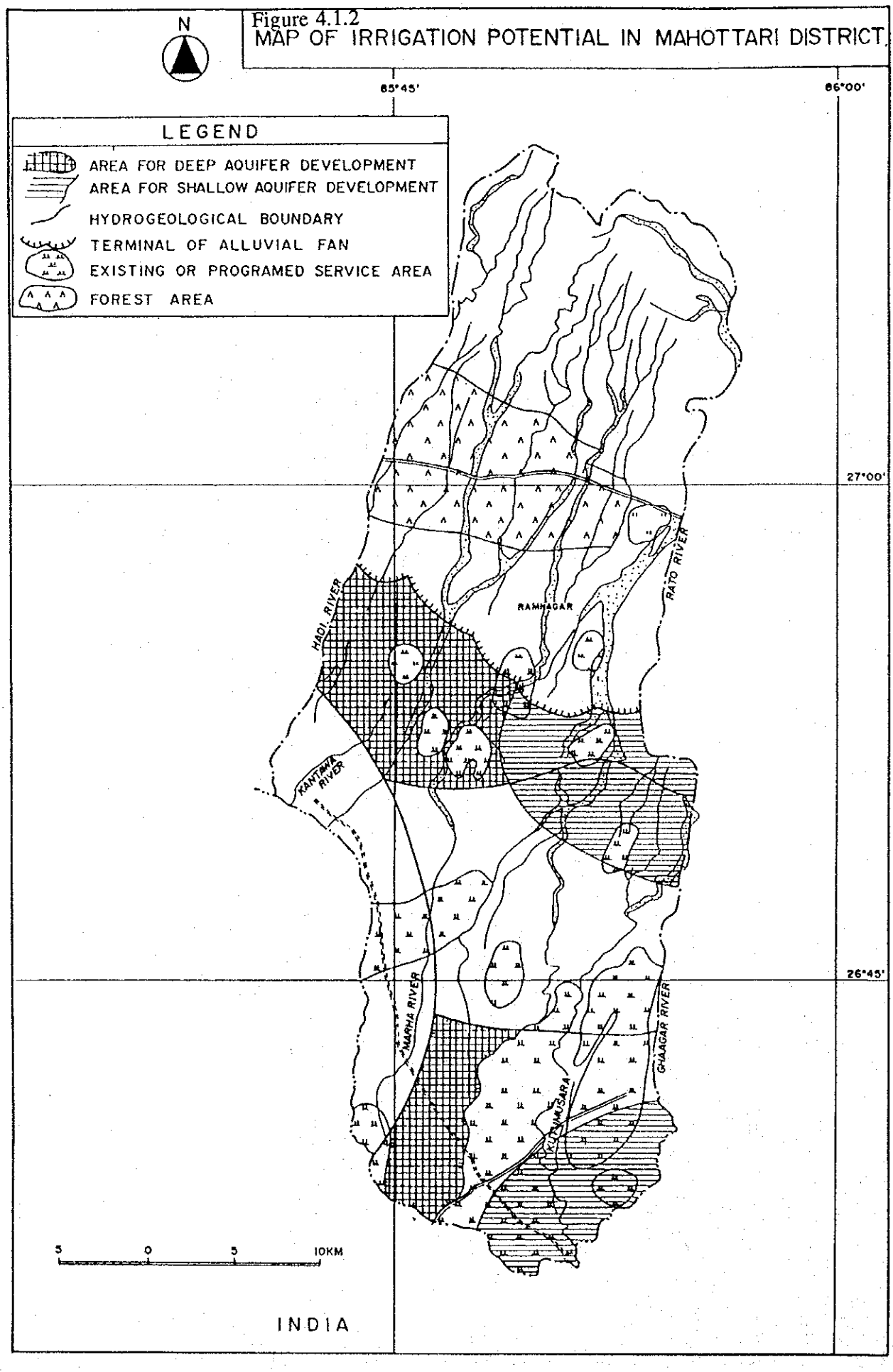
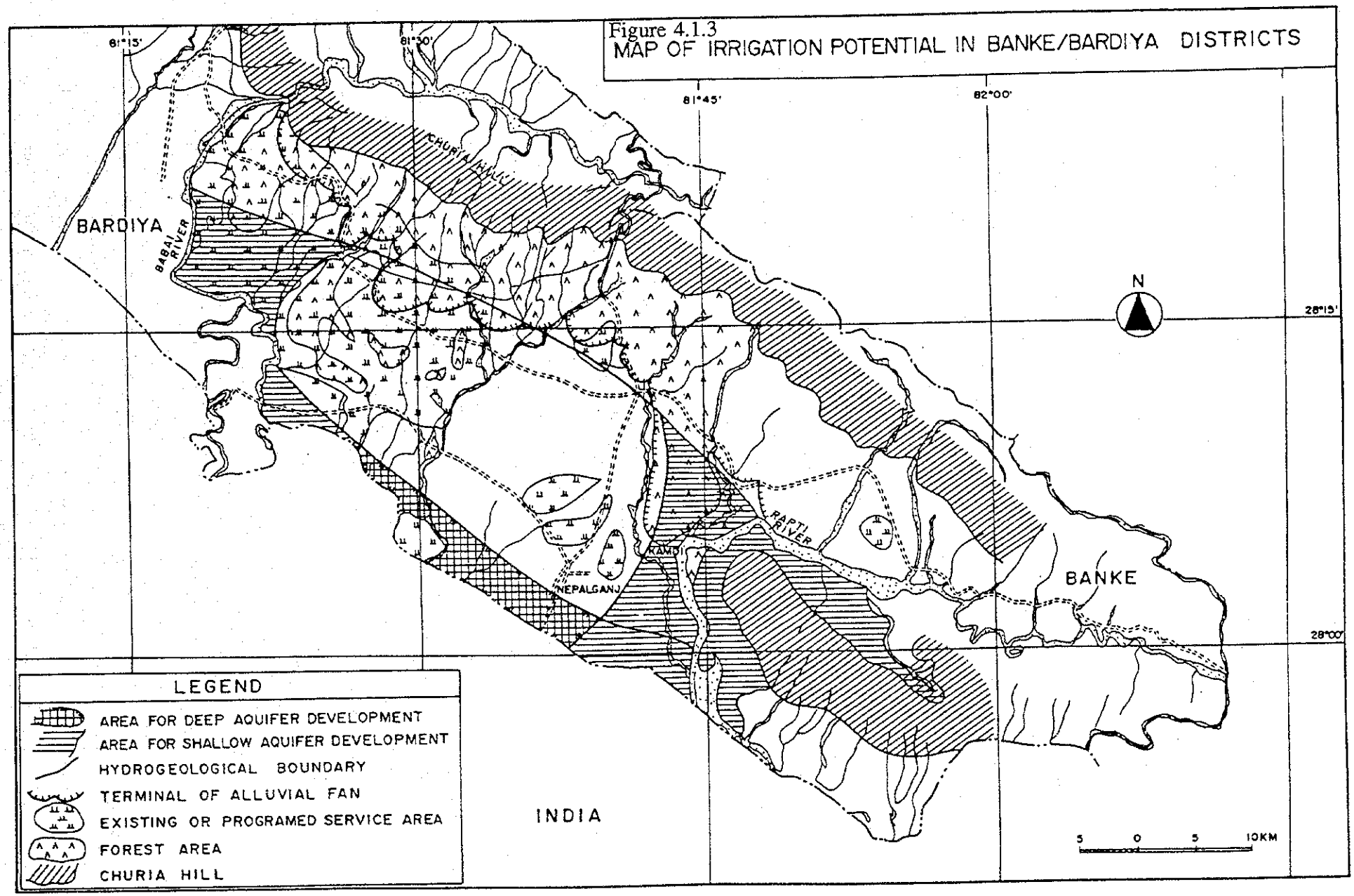


Figure 4.1.2
MAP OF IRRIGATION POTENTIAL IN MAHOTTARI DISTRICT
N
85°45'
86°00'
27°00'
26°45'
LEGEND
AREA FOR DEEP AQUIFER DEVELOPMENT
AREA FOR SHALLOW AQUIFER DEVELOPMENT
HYDROGEOLOGICAL BOUNDARY
TERMINAL OF ALLUVIAL FAN
EXISTING OR PROGRAMED SERVICE AREA
FOREST AREA
HADI RIVER
RAMNAGAR
RATO RIVER
KANTHA RIVER
KARHA RIVER
GHAAGAR RIVER
5 0 5 10KM
INDIA

Figure 4.1.3
MAP OF IRRIGATION POTENTIAL IN BANKE/BARDIYA DISTRICTS



4.2. Natural Environment

4.2.1. Topography

(1) Jhapa District

Jhapa is the most eastern district in Nepal, bordering India to the east and to the south. The district is limited by Ratuwa Khola in the west, the border river Mechi in the east, and the Churia Hills in the north; and the southern district opens towards the vast Indo-Gangetic Plain. The district extends 56 km from east to west, and 49 km north to south, with a total area of approximately 1,606 km2, and the Kankai river flows through its center.

Two topographic units, an alluvial plain and terrace terrain, underlie in the plain area of Jhapa District.

A broad alluvial plain extends from the Churia Hills to the Indian border. The terrain near the Churia Hills is an undulating, fan-shaped terrain that extends to the E-W Highway. Its altitude ranges from 120 to 210 mamsl, with a gradient of 1/100, which reflects typical topographic features of the Bhabar Zone.

A flat alluvial plain extends south of the Bhabar Zone; its altitude ranges from 80 to 120 mamsl, with gradient of 0.3/100, which is gentler than the Bhabar Zone. The plain extends to the forest-covered terrace terrain south of Bhadrapur, at a width of approximately 15 km, and marshy land appears in the southern part of the zone.

A widely uplifted terrace terrain extends south of the study area near Prithivinagar. The terrace is covered by thick forests, except for the eastern part. Small-scale terrace terrain is located in Dangibari, in the northwestern part of the region, and it is utilized for agriculture.

A broad alluvial plain extends south of the terrace, up to the border. Its altitude ranges from 60 to 80 mamsl, with a gradient of 0.2/100, which is gentler than the northern alluvial plain. Topographically, the plain is part of the Gangetic alluvial plain.

(2) Mahottari District

The outline of Mahottari District is like a long, flat N-S ellipse, with a long axis of approximately 62 km and a short axis of approximately 24 km. The total area of the district is approximately 1,002 km2.

Several rivers flow through the district; most are seasonal and flow from NNE to SSW. The flood plain in the northern part is very wide, but decreases smoothly into narrow streams in the southern part of the district. Physiographically, a majority of the district lies in the Terai Plain, but it also includes the Churia Hills in the most northern area.

The Bhabar Zone, with its original fan shape and thick forest covering, lies at the foot of the Churia Hills and gently inclines toward the SSW. Although not topographically distinct, the terrace terrain of the Bhabar Zone can divided into upper, middle, and lower terrace. The geological age of the higher and middle terrace may be Pleistocene because of the laterite deposited on top of the terraces.

The southern margin of the Bhabar Zone gradates into a marshy area and is a transition zone to the Southern Terai Plain. There is no actual marsh in the area but the ground slope becomes gentler and many of gravelly flood plains terminate at the southern edge of the area, and many of shallow wells at the southern margin are artesian.

The Southern Terai Plain occupies almost half of the Mahottari District, or approximately 400 km2. The land is nearly flat and many streams heavily meander toward the south. The altitude of the area is the lowest among the entire Terai Zone in Nepal, with the elevation of less than 60 mamsl at the southern end of the district.

(3) Banke District

The study area includes the entire Banke District and a part of Bardiya District, the east bank area of the Babai River. The total study area is 3,230 km2, which is the largest area among three study districts.

The area is bordered by the Babai River to the west, by the Churia Hills to the north and to the east, and by the Indo-Nepal border to the south, with its long axis approximately 80 km in a east-west direction and 40 km in a north-south direction.

The Rapti River, one of Nepal's major rivers, flows through the area. Besides the Rapti and Babai rivers, there are many minor rivers such as the Bharda Nala as well as other small seasonal rivers.

The Terai Plain in this area lies at a high altitude and is approximately 130 mamsl in its lowest point. The Bhabar Zone in this district occupies a very large area, lying primarily between the E-W Highway and the Churia Hills and the east side of the Dundawa Nala. The zone is roughly estimated at 640 km2, including the terraces and a wide valley along the Rapti.

The very flat Southern Terai Plain lies in a narrow belt, approximately 5 to 8 km in width, along the Indian border, and its altitude is less than 150 mamsl.

4.2.2. Geology

(1) Jhapa District

The Study Area is underlain by alluvium, terrace deposits and the Churia Formation, with only exposures of the first two at the surface.
Alluvium in the Bhabar Zone is composed mainly of sand and gravel in shallow areas, with a depth of more than 20 m, which increases to 150 m or more in the south, alternating with beds of sand, gravel, and silt.
The Northern Alluvium, north of the terrace, is 150 m or more in thickness and is deemed to be underlain by the Upper Churia Formation as mentioned later. Gangetic Alluvium in the south is mostly thick sand and gravel beds, more than 300 m thick, with single beds thicker than 50 m.
The terrace deposits are composed of clay, silt and coarse sand of approximate 10 m thickness.

Churia Formation does not expose on the ground surface. However, borehole samples reveal that the Upper Churia Formation underlying the alluvial plain is composed of unconsolidated clay, silt, sand and gravel. This is the new interpretation on the geological log of Terai Plain, which is discussed in detail at the section 5.2. Hydrogeology and groundwater.

(2) Mahottari District

The geology of the alluvial plain of the Mahottari District consists of terrace deposits and Gangetic Alluvium. Although the Churia Formation underlies in the northern hills, the Upper Churia Formation is probably overlain by the terrace deposits and composed of unconsolidated clay, silt, sand, and gravel.

(3) Banke District

The area is underlain by the Churia Formation; and the terrace and alluvium deposits.
The alluvial deposits can be subdivided into Northern Alluvium in the Bhabar Zone, Central Alluvium in the undulating plains and Gangetic Alluvium in the southern strip.

Drilling to a 200-m depth penetrated unconsolidated sand and gravel layers and silt layer in the Northern Alluvial area. The Central Alluvium is deemed to be 30 m thick, and layers underlain are probably the Churia Formation.

Drilling record to a 300-m depth reveals that the Gangetic Alluvium is composed of unconsolidated clay, silt, sand, gravel, and that it is more permeable than the other alluvial formation.

The Churia Formation is composed of slightly consolidated shale, sandstone and conglomerate in the east of the Rapti River; however, in the north of the Babai River, it is composed of well-consolidated shale and sandstone.

4.2.3. Meteorology and Hydrology

(1) Jhapa District

a) Meteorology

The Jhapa District lies mostly in the Terai Plain and is broadly demarcated by the foothills of Mahabharat in the north and the Mechi River in the east. The altitude of the district ranges from 63 m to 476 mamsl. A glimpse of long-term average data reveals that the district is generally characterized by a subtropical to tropical climate.

The area receives abundant rainfall compared with the other districts in the Terai Plain as a result of the monsoon which carries high humidity from the east. The annual precipitation, averaged by the Thiessen Network, based on the Kankai, Sanischare, Anarmanibirta, and Chandragadhi stations, ranges from 1,600 mm to 3,600 mm, with an average of approximately 2,500 mm, as shown in Figure 4.2.1. The mean monthly precipitation during the winter is approximately 10 mm to 20 mm, increasing to over 700 mm in July during the monsoon season.

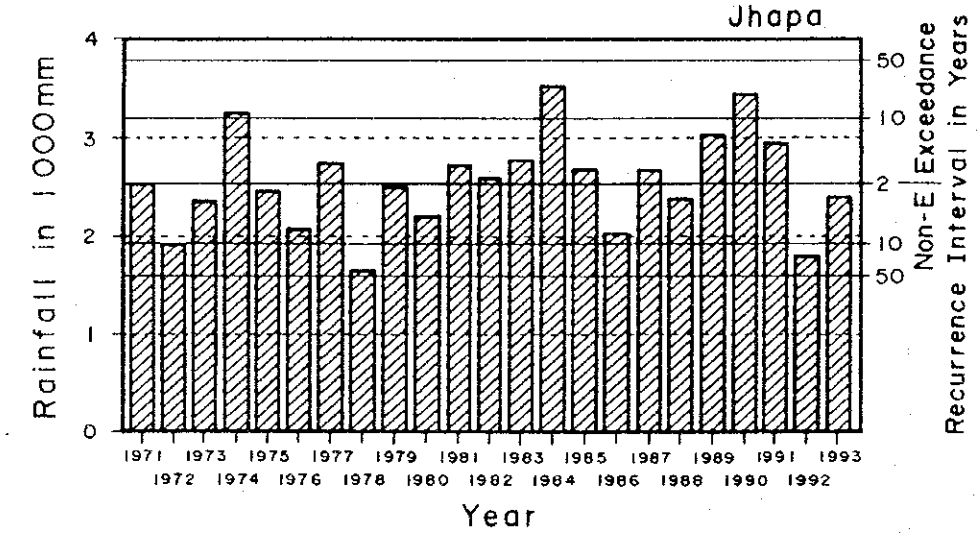


Figure 4.2.1 Annual Rainfall Averaged by the Thiessen Network (Jhapa)

Based on the above annual rainfall, the drought frequency is analysed by the Gumbel Method. As shown below, this area is relatively abundant in rainfall: 1,911 mm in 10 year recurrence interval ; 1,762 mm in 20 year recurrence interval.

Recurrence interval, year :	2	5	10	15	20	30	50	100
Probable annual rainfall, mm:	2524	2110	1911	1819	1762	1692	1616	1533

The district's coldest temperatures occur in December and January; mild temperatures occur in April and May; and high temperatures and high humidity occur between June and August. The mean monthly temperatures range from 15°C to 29°C, and the mean monthly minimum temperature drops to 5°C, while the mean monthly maximum temperature reaches to 38°C. The humidity drops between 60% and 70% during March and April, immediately before the monsoon period; humidity rapidly rises at the beginning of the monsoon and shows 80% to 90% during the monsoon period.

The sunshine hours are 4-6 hours per day during the monsoon period and greater than 7 hours during the other seasons. The maximum sunshine hours reach 9 hours during May. The wind velocity has been measured at Biratnagar, located at the boundary of western India, and Kankai. The wind velocity at Kankai is 1.0 to maximum 4.0 km/hr and 2.0 to maximum 9.0 km/hr at Biratnagar, which shows the wind velocity for the latter to be approximately double.

Although evaporation is not measured in the district, according to the records at the Tarahara observation station, located 55 km west of Kankai, the maximum monthly mean

evaporation is 6 mm/day immediately before the monsoon period, approximately 5 mm/day during the monsoon period, and a minimum of 2 mm/day during the winter.

b) Hydrology

All of the rivers and streams in the district, whether seasonally or perennially, are rainfed. Five major rivers, Ratuwa, Kamal, Kankai, Biring and Mechi flow through the district. Among these rivers, the Kankai and Mechi are the largest. The minor rivers are seasonal and mostly the tributaries of the major rivers.

Some hydrological data is available only for the Kankai River, which is largest in the district. The river's gauging station is located at Mainachuli and covers a drainage area of 1,180 km2. According to the water balance calculation of the past 14 years, the annual mean precipitation is 3.750 billion m3, while the annual average discharge is 2.786 billion m3, and the runoff coefficient is 74%. According to DMH the discharge coefficient reported at this station is between 60% and 70%.

During this Study, the runoff discharge at Deoniya River and Budhajhora River was measured between January 1993 and January 1994. The runoff coefficients are 70% and 89%, respectively, which are considerable discharge amounts. Furthermore, more than 90% of the discharge is confined during the monsoon season.

(2) Mahottari District

a) Meteorology

As a result of the varying topographical characteristics in the ground elevation, which ranges from 56 m to 904 mamsl, there is little uniformity in the climate within the district. The district experiences tropical, subtropical, and mostly mild temperate types of climate. In general, the hot and humid climate are the dominating features of the district during the summer months, and the air becomes very humid when the monsoon rain begins in June. In the winter, the climate is mild and comfortable for a couple of weeks and generally dry in terms of precipitation.

There are no meteorological stations in the district, but there is one precipitation station at Gaushara. The records of the meteorological station at Janakpur Airport, in the adjacent Dhanusha District, may be applicable to the southern part of the Mahottari District. Similarly, precipitation data from the Tulsi station in Dhanusha District may be applicable to the northern part of the district.

Based on the data from these stations, the annual precipitation ranges from approximately

600 mm to 2,600 mm. The mean monthly precipitation ranges from trace in the winter to as high as 480 mm in July during the monsoon season. The following shows a time-series annual precipitation at the Janakpur Airport station.

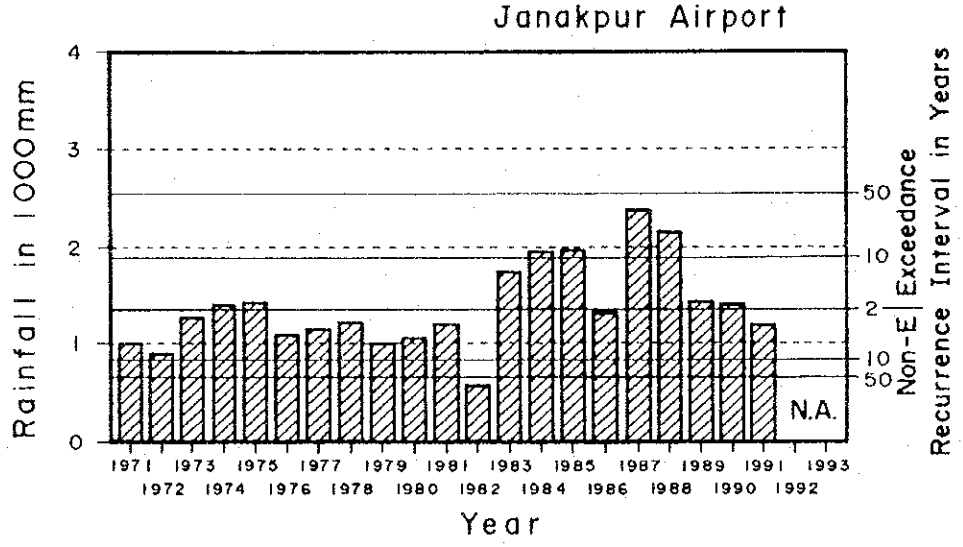


Figure 4.2.2 Annual Rainfall at Janakpur Airport Station

Based on the above, the drought frequency is analysed using the Gumbel Method. As shown below, the 10 year recurrence interval is 858 mm and the 20 year recurrence interval is 774 mm, which is approximately 1,000 mm less than those in Jhapa District.

Recurrence interval, year :	2	5	10	15	20	30	50	100
Probable annual rainfall, mm:	1310	987	858	804	774	738	703	669

Temperature records are available at Janakpur Airport Station. The mean temperature ranges from 15°C to about 30°C, and the minimum and maximum temperatures are approximately 5°C and 39°C, respectively. The humidity drops to approximately 65% immediately before the monsoon period; humidity rapidly rises at the beginning of the monsoon and shows 80% to 90% during the monsoon period.

In regard to the agricultural meteorology data, including sunshine hours, wind velocity, and evaporation, records are available between 1976 and 1983 at the Hardi Nadi observation station located in the north of Janakpur Airport. Sunshine hours are 6-7 per day during the monsoon period and more than 8 hours per day during the rest of the year. The maximum sunshine hours reaches 10 hours during May. The wind velocity is 2-4 km/hr during the winter, with a maximum of 10 km/hr during the monsoon period. Evaporation is a maximum 7 mm immediately before the monsoon period, approximately 5 mm during the monsoon period, and a minimum of 2 mm during the winter.

b) Hydrology

All of the rivers in the district originate in the Churia Hills. Rainfall is the main source of water for both perennial and seasonal rivers, and most of the rivers are dry during the winter season, except for the perennial rivers, which include the Bighi, Ratu, Janpha, Marha, and the Hardi Nadi. Rivers are fed by groundwater during the winter season.

No rivers in the district have been gauged so far, and hydrological data in the district is not available. However, runoff discharge records are available for the Bagmati River and Kamala River, which flow a distance of 30 km toward the west and the east, respectively, from the district border. The Bagmati River station is located at Paurai, and the gauge for the Kamala River is located at Chisapani. The drainage areas of each station are 1,750 km2 and 1,590 km2, respectively.

(3) Banke District

a) Meteorology

The entire district is under the influence of humid subtropic and tropic monsoon climates. Significant differences in temperature and rainfall has been observed, based on the topography which varies in ground elevation from 132 m to 1,131 mamsl. Because of the existence of the Churia Range and the Bhabar region at its foothills, the northern part of the district has relatively low temperatures and a higher degree of precipitation compared with the southern part. The southern part of the district is famous for its tropical climate, with extremely hot summers and warm winters. The maximum temperature in Nepalganji has occasionally been reported at 48°C.

Seven meteorological stations are located in and around the district. Based on the station records, the annual precipitation varies from 500 mm to 2,600 mm, while the mean monthly rainfall ranges from trace in the winter to about 600 mm during the monsoon season. The following shows a time-series annual rainfall at the Khajura station.

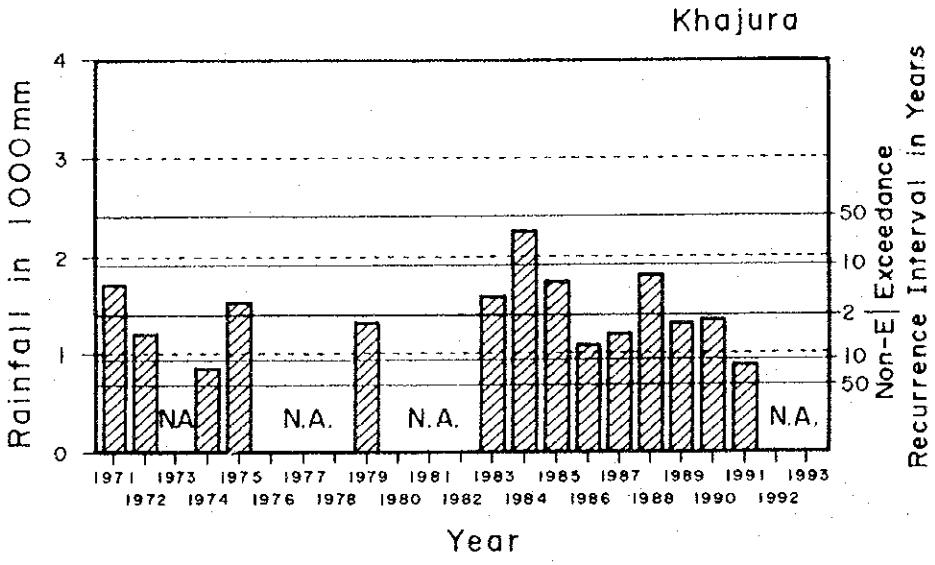


Figure 4.2.3 Annual Rainfall at the Khajura Station

Based on the annual rainfall at Khajura, the drought frequency is analyzed by the Gumbel Method. As shown below, the 10 year recurrence interval is 957 mm and the 20 recurrence year is 866 mm, which is approximately 900 mm less than those in Jhapa district.

Recurrence interval, year :	2	5	10	15	20	30	50	100
Probable annual rainfall, mm :	1386	1087	957	900	866	826	785	742

The mean monthly temperature at the Khajura station ranges from 15°C to 30°C, and the mean minimum and maximum temperatures are approximately 3°C and exceeding 41°C.

The meteorological data for agriculture at the Khajura station show the sunshine hours to be 6-7 hr/day during the monsoon period and more than 8 hr/day during the rest of the year. The wind velocity is 2-3 km/hr during the winter and a maximum of 7 km/hr during the monsoon period. Evaporation is a maximum of 8 mm immediately before the monsoon period, approximately 5 mm during the monsoon, and a minimum of 2 mm during the winter.

b) Hydrology

The major rivers in the district are the Rapti, Manda, Dundwa, Kirin, and the Babai; the minor rivers are tributaries of these rivers. With the exceptions of the Rapti and Babai rivers, all other rivers originate in the Churia Range and flow southward. Rapti River and Babai River, which are the largest rivers in the district, originate in the hill region. The two rivers flow east to west in the hill region, enter the district from its eastern border, and flows directly south.

The runoff discharge for the Rapti and Babai rivers has been gauged regularly. The Rapti station is located at Jalkundi and the Babai station at Bargadha. Their drainage areas are 5,150 km2 and 3,000 km2, respectively.

(4) Database

A database (JDBASE) has been created during the study period for the inventory of precipitation, river discharge, groundwater level, and well constants using Lotus 1 2 3 for the meteohydrological stations. As well, a program to detect these items and to plot precipitation, river discharge, and groundwater levels on a screen has been developed. The database and program in the attached floppy disc were handed over to DOI; its operation manual is shown in Appendix 3.

4.3. Socio-Economy

4.3.1. Terai

(1) District Division

The Terai, which is the northern stretch of the Indo- Ganges Plain, occupies 14.3% of Nepal and 41.6% of Nepal's cultivated area. The plain can be divided into five development regions and 20 districts. The districts of Jhapa, Mahottari and Banke, in which the study areas are selected, belong to the Eastern, Central and Mid-Western Development Regions, respectively.

(2) Population and Number of Households

As of 1991, the total population in the Terai accounted for 47% of the national population, followed by the hill districts at a rate of 46%. The Terai also accounts for 45% of the number of households in the country, followed by the hill districts' 47%; and the annual population growth in the area since 1981 has been 2.8%, which is higher than the national average (2.1%).

(3) Industrial Structure

In order to promote industrial development, HMGN has established 11 industrial districts throughout the country. There are five industrial districts in the Terai Plain and the remaining six districts are located in the hill districts. Existing industries, excluding the shoe and cement industries, are agriculture-based, such as rice and sugar mills, tobacco, and jute.

4.3.2. Jhapa District

(1) Administrative Division

The Jhapa District is divided into nine sectors, composed of 49 villages and two towns. The district's total area is 156,500 ha, of which 105,121 ha are cultivated. The Study Area extends 29,700 ha, covering 16 villages (refer to Figure 4.3.1 (1)).

(2) Population and Number of Households

As of 1991, the population is 593,737, with a density of 379 persons/km2. The population has grown at the rate of 2.15% per year, which is similar to the national average and the highest among the three study districts, which include Mahottari and Banke. The total number of households is 110,939, with 5.36 members on an average. The average village population is 11,640, with 2,170 families; and 66% of the economically active population are engaged in the agricultural sector as of 1991.

(3) Industrial Structure

This district is known as the paddy and tea producing district in the country. Agri-based industries are the major industries in the district. There are 762 rice/oilseed extract mills, 47 bakeries, and 2 jute, 40 tea, and 5 milk processing factories, among others. Rice mills are often combined with oilseed extract mills.

4.3.3. Mahottari District

(1) Administrative Division

The Mahottari District is divided into nine sectors, composed of 77 villages and one town. The district's area is 101,238 ha, of which 63,754 hectares are cultivated. The Study Area extends to two separate areas, covering a total of 9,800 ha, with 17 villages (refer to Figure 4.3.2).

(2) Population and Number of Households

As of 1991, the population is 440,146, with a density of 434 persons/km2, which is the highest among the three districts. The average growth rate since 1981 is 2.0%, which is lower than the national average of 2.1% and the lowest among the three districts. The total

number of household is 80,396, with 5.48 members on average. The average village population is 5,640, with 1,030 families; and 79% of the economically active population are working in the agricultural sector.

(3) Industrial Structure

There are 176 rice/oilseed extract mills located in the District.

4.3.4. Banke District

(1) Administrative Division

The Banke District is divided into nine sectors, composed of 46 villages and one town. The district's area is 225,836 ha, of which 49,072 ha are cultivated. The Study Area extends to 12,100 ha (refer to Figure 4.3.3).

(2) Population and Number of Households

The current population is 285,604; the district's population growth is 3.36%, which is the highest among the three districts. The population density is 126 persons/km2, which is the lowest among the three districts, though slightly higher than the national average of 125/km2. The total number of households is 49,059, with 5.8 persons on average. The average village population is 6,070, with 1,040 households, and 68% of the economically active population are employed in the agricultural sector.

(3) Industrial Structure

Agri- and forestry-based industries are located in the district include 247 rice/oilseed extract mills, 5 sawmills, 4 textile factories, 28 bakeries, and 4 milk processing factories, among others.

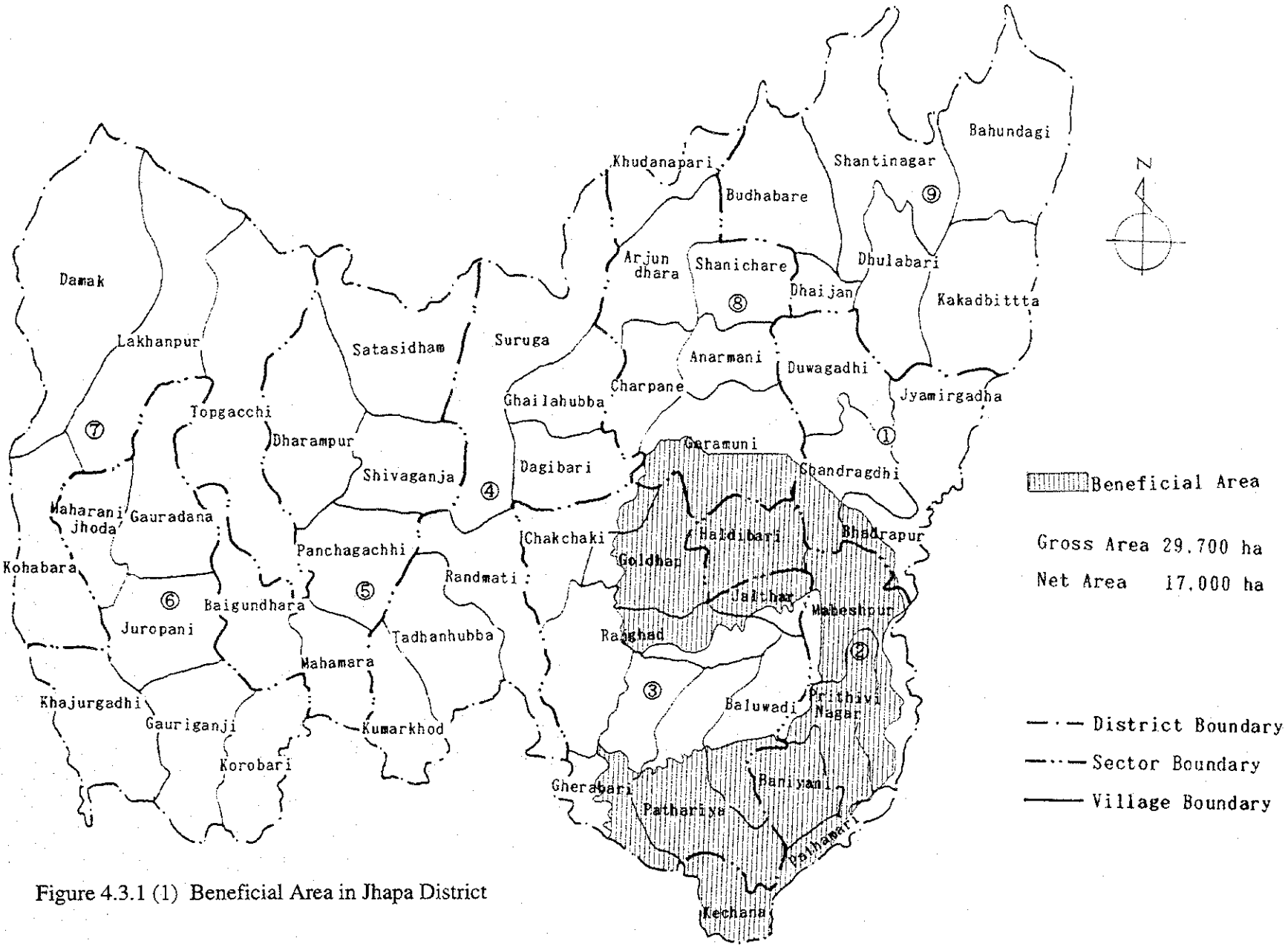


Figure 4.3.1 (1) Beneficial Area in Jhapa District

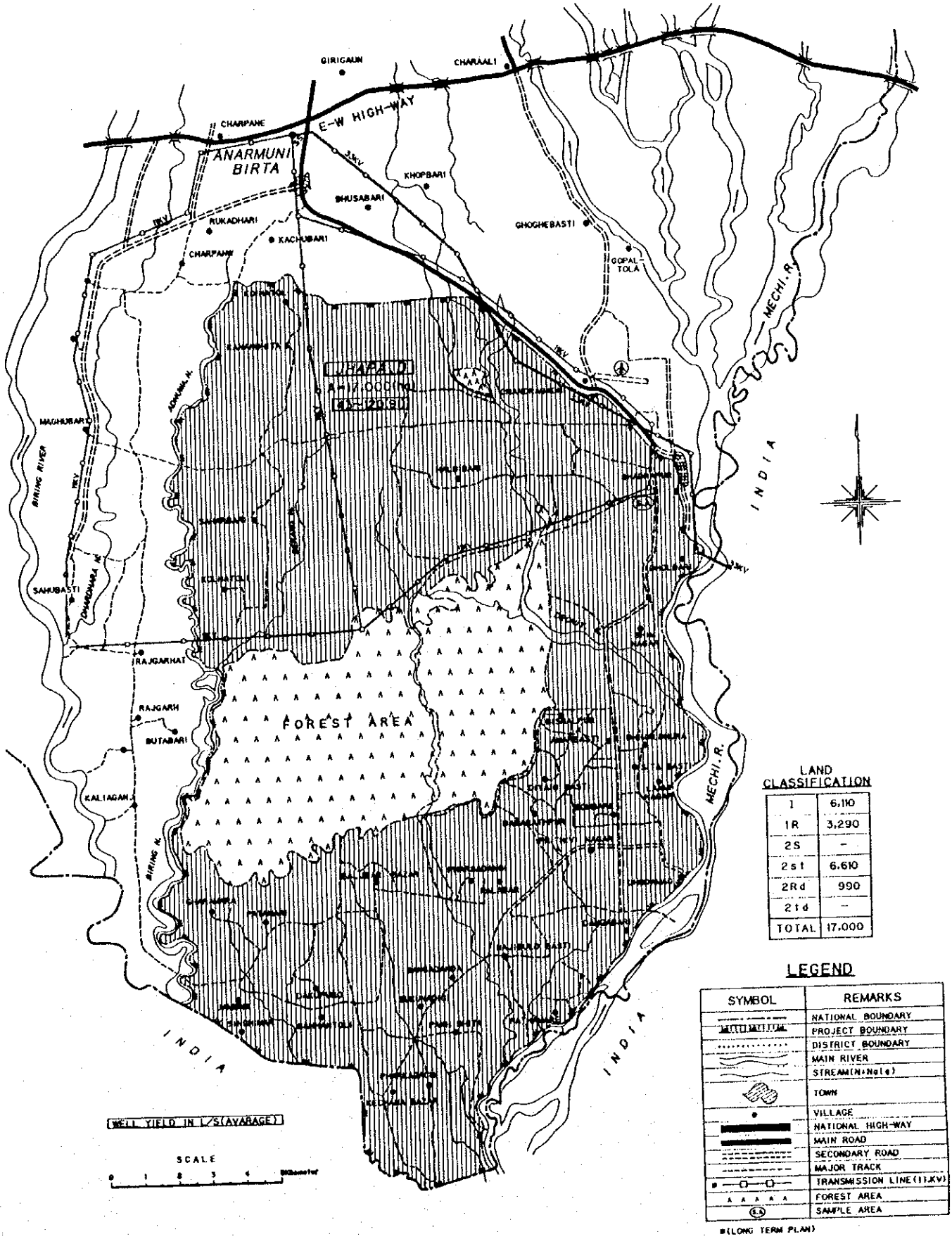


Figure 4.3.1 (2) Beneficial Area in Jhapa District

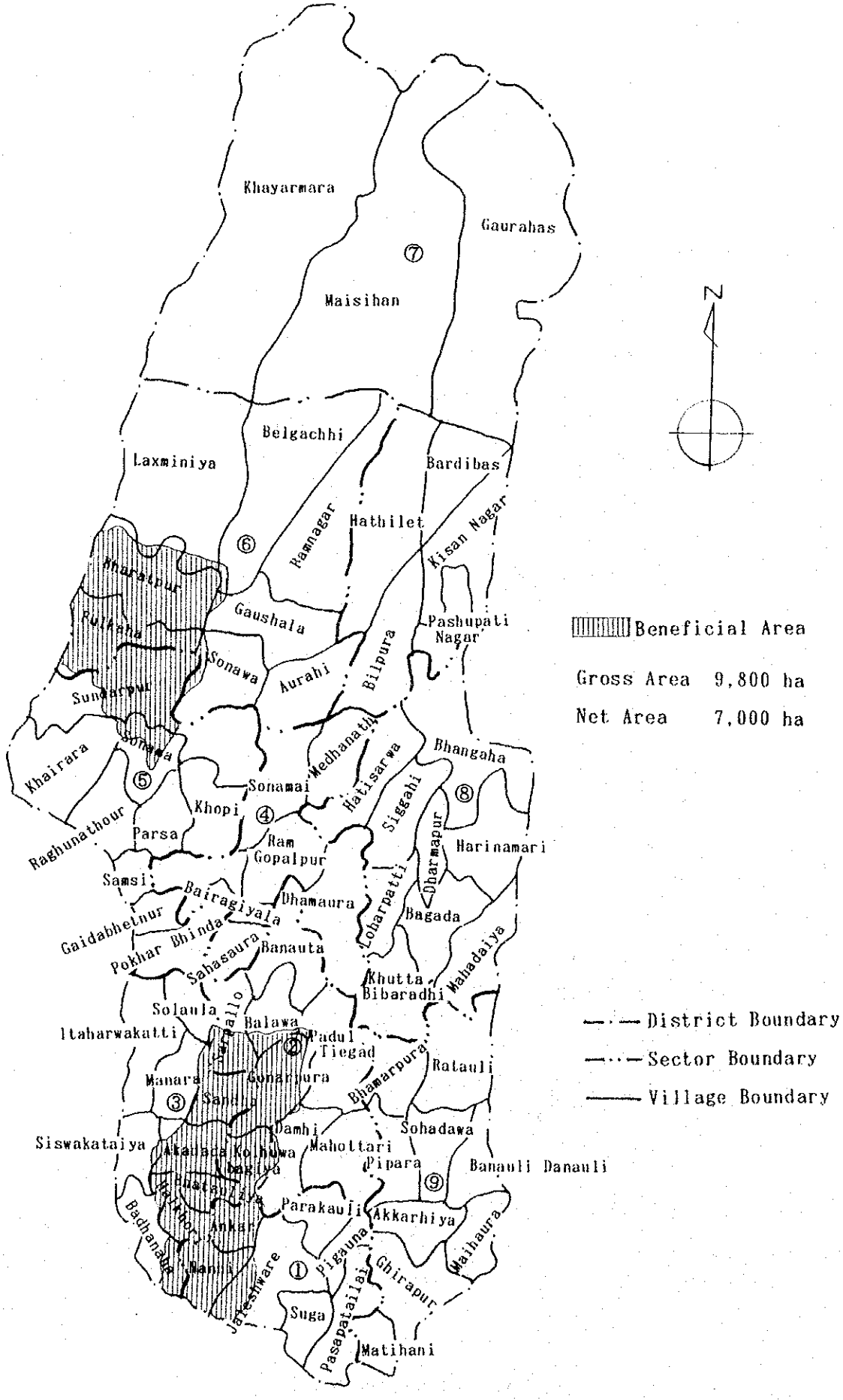


Figure 4.3.2 (1) Beneficial Area in Mahottari District

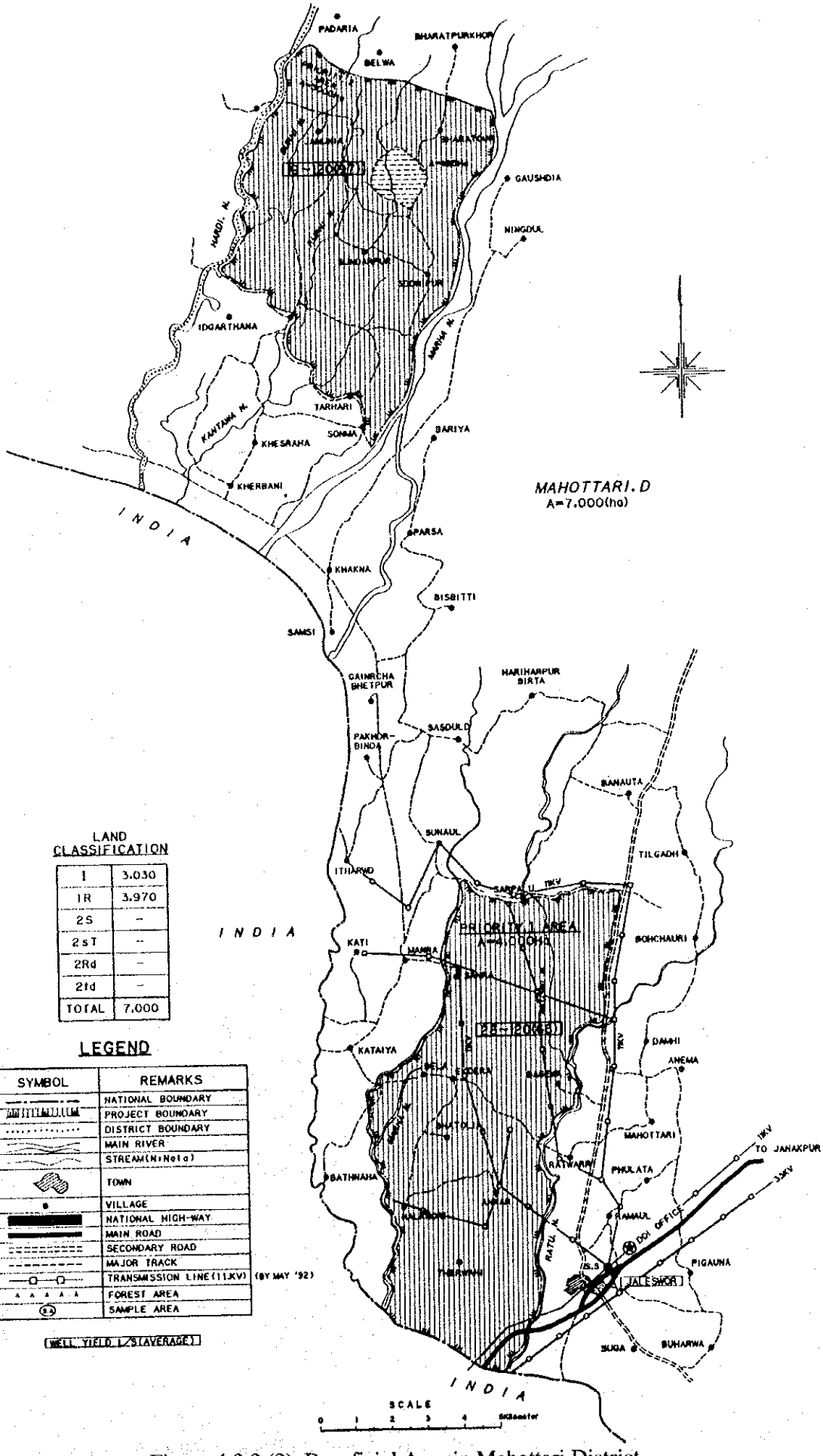


Figure 4.3.2 (2) Beneficial Area in Mahottari District

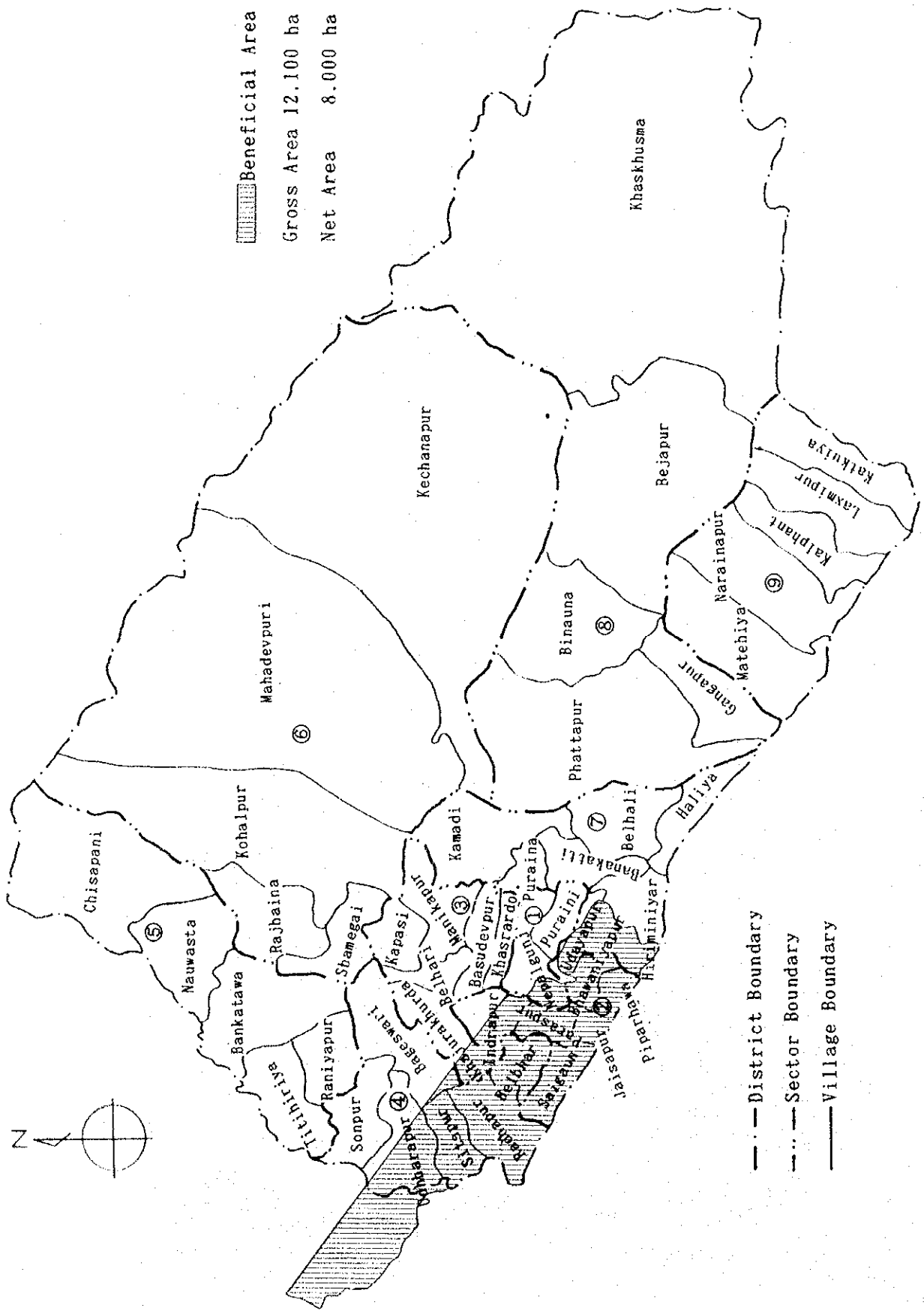


Figure 4.3.3 (1) Beneficial Area in Banke District

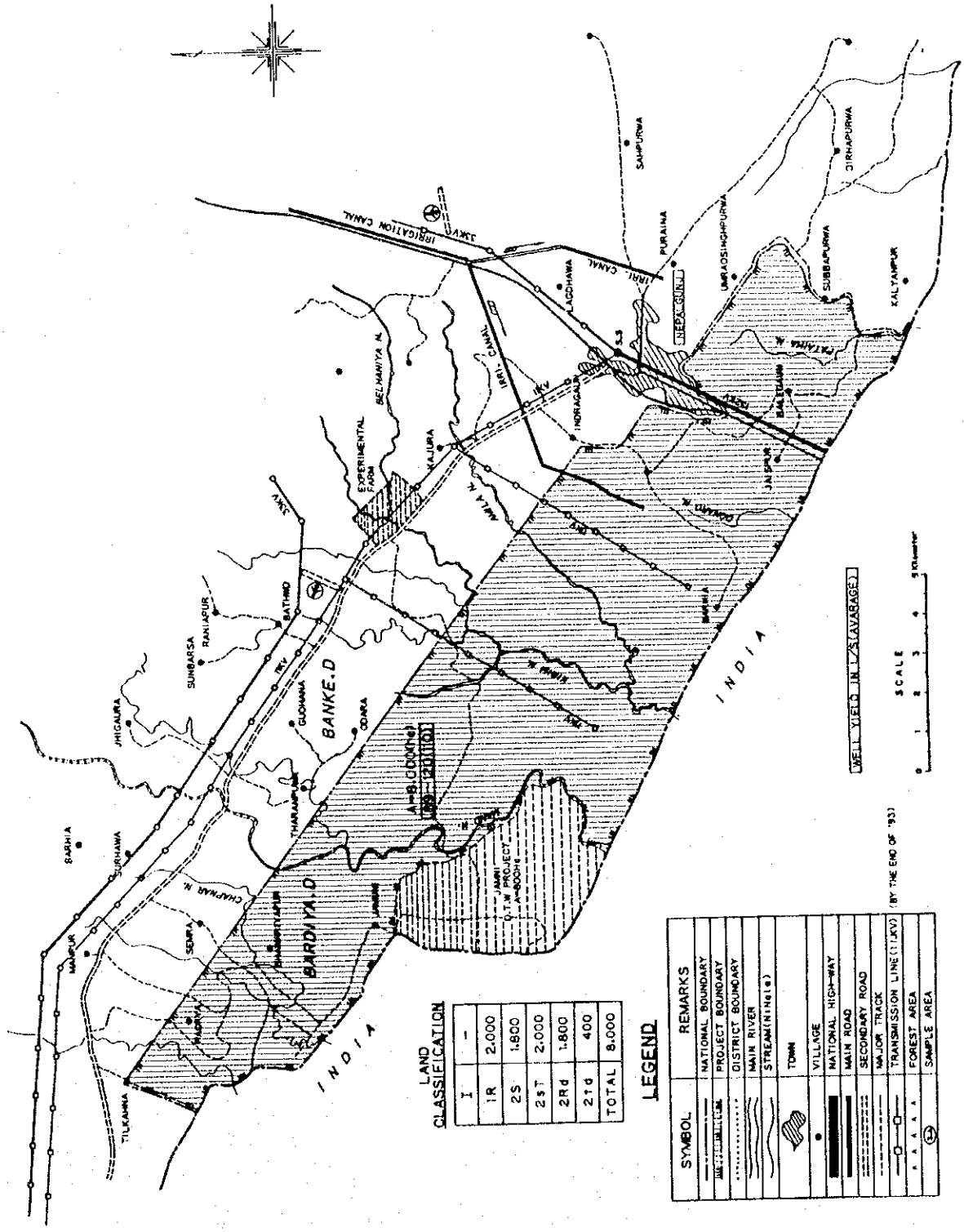


Figure 4.3.3 (2) Beneficial Area in Banke District

4.4. Agriculture and Irrigation

4.4.1. Terai

(1) Cultivated Area

The Terai accounts for 14% of the nation's land and 42% of the cultivated areas, as shown below.

	Acreage (1,000 ha)	Terai/National (%)
Cultivated area	1,234.6	41.6
Grazing land	49.7	2.8
Forest	591.3	10.5
Bush	1.4	0.2
Non-cultivated	117.1	11.9
Others	116.1	4.3
Total	2,110.2	14.3

(MOA, 1990)

(2) Soil

The soils of the Terai are developed mostly on recent alluvial sediments of the broad, nearly level to gently undulating plain in the southern part of the country. Soil textures can be classified into the following four types.

Type (I) Textures are mostly sandy loam to clay loam, and occasionally silty clay loam and silty clay textures. Soil reaction is moderately acidic to neutral, but some portions are alkaline.

Type (II) Textures are mostly silt loam, silty clay loam, silty clay, and occasionally sandy loam to loam. Soil reaction is neutral to moderately alkaline.

Type (III) Textures are mostly sandy loam or silt loam and occasionally loam. Soil reaction is slightly acidic to neutral.

Type (IV) Textures are mostly sandy loam or silt loam and occasionally loamy sand. Soil reaction is slightly acidic to mildly alkaline.

(3) Agricultural Production

Major food grain production in 1992/93, nationwide and in the Terai, is outlined below. The Terai shows higher production in paddy and wheat and is noted as the granary of Nepal.

	National	Terai
Paddy	2,584,900 t	1,840,620 t (71%)
Maize	1,290,500	325,440 (25%)
Millet	236,750	14,340 (6%)
Wheat	765,000	432,720 (57%)
Barley	27,610	2,860 (10%)

(MOA, 1993)

(4) Livestock

The number of livestock in 1992/93, nationwide and in the Terai, is listed below; the Terai Plain also produces 32% of the nation's milk.

	National	Terai
Cattle	6,237,231	2,256,660 (36.2%)
Buffalo	3,072,682	972,959 (31.7%)
Sheep	911,279	142,406 (15.6%)
Goat	5,451,710	1,545,170 (28.3%)
Pigs	604,902	170,224 (28.1%)
Ducks	391,718	334,466 (85.4%)
Milk Production	876,594 (t)	280,063 (31.9%)

(MOA, 1993)

(5) Irrigation

According to agricultural statistics for 1990, there are 608,877 ha of irrigated land in the Terai, which is 49% of the 1.235 million ha of farmland in the plain area. This figure is higher than the national average of 32%. Furthermore, 65% of the nation's total irrigated area of 941,299 ha are concentrated to the Terai because of land conditions.

4.4.2. Jhapa District

(1) Farmland and Land Use

The Jhapa District boats the largest farmland area, mounting to 105,121 hectares, out of three districts under the study. The use of farmlands of the Jhapa District consists mostly of the production of cereals, with rice being planted in the arable areas of flat lands and maize in the terraces. Since the climatic conditions of the area in question are favorable, as mentioned previously in this report, at places where the water availability conditions are appropriate it is possible to plant rice throughout the year. As things now stand, however, in the southeastern and southwestern parts of the Jhapa District only monoculture farming is being practiced during the rain season. The planted area by crop prevailing currently in this region is shown in the followings. From these data, it can be seen that the cropping intensity of the Jhapa District mounts to 151%.

Cereals	132,362 ha
Pulses	2,497
Root crops	2,514
Cash crops	7,061
Oilseed crops	5,898
Peppers	1,403
Vegetables	2,486
Fruit	4,491
Others	346
Total	159,058

(CBS, 1993)

(2) Soils

Alluvium is widely distributed throughout the Jhapa District. And there is predominance of sandy loam (clay content of 12.2 to 25%) and clay loam (clay content of 37.5 to 50%). The water holding capacity is good, and the soil has characteristics suited for irrigation. The chemical properties of the soil ranges from weak alkaline to neutral, and the content of humus is of the order of 0.2 to 5%. The content of nitrogen is rather low, and phosphates and potassium ranges from medium to high.

As per the soil conditions, there are no restrictions in particular against the cultivation of crops, and generally speaking there are large patches of farmland (Khet) suited for the cultivation of rice. However, there are also patches of farmland that are not suited for

cultivation of rice (Bari), and the cropping pattern comprising other kinds of crops, mainly maize, is predominant in those areas.

(3) Number of Farm Households and Land Holding

The number of farm households is 74,727, including landless farmers, and the average farm size is 1.41 ha, based on the National Sample Census of Agriculture in 1991/92.

Farmers who own less than one hectare occupy 52% of the total number of farm households, as shown below.

Landless	1,104	(1.5%)
Less than 0.1 ha	9,326	(12.4%)
0.1-0.2	4,663	(6.2%)
0.2-0.5	10,062	(13.4%)
0.5-1.0	13,620	(18.2%)
1.0-2.0	18,324	(24.5%)
2.0-3.0	9,898	(13.2%)
3.0-4.0	2,986	(4.0%)
4.0-5.0	2,004	(2.7%)
5.0-10	2,413	(3.2%)
Above 10 ha	327	(0.4%)
Total	74,727	
(CBS, 1993)		

The number of farm household in the Study Area is estimated at 12,080.

(4) Present Cropping Patterns

Major grain crops in Jhapa District are paddy rice, maize and wheat. Within the category of vegetables, potatoes are the most important crop. The predominant cropping pattern is described in the followings. Double and triple cropping is possible in irrigated farmland, but in rain-fed farmlands the predominance of single crop of rice during the rain season becomes unavoidable.

Irrigated Area	Monsoon Paddy-Wheat
	Spring Paddy-Monsoon Paddy-Wheat
Rainfed Area	Monsoon Paddy-Fallow
	Monsoon Paddy-Pulses/Oilseed Crops
	Maize-Pulses/Oilseed Crops/Millet

As for the monsoon paddy, the planting is made from July to mid August, and the harvesting period is from mid November to mid December. Maize, which is the second most important crop after rice, has its seeds sown since mid March, and the harvesting is made about mid June. In most of the cases, the rain-fed farmlands remain fallow after the rice cultivation during the rain season, but crops that require small amounts of waters, such as beans, mustard and the like are being planted in some areas. As a general rule, potatoes are planted from August to November, and are harvested in the second half of February. The cultivation of mustard, which is an oil crop, is being practiced very popularly as a second crop after the harvesting of rice, which is planted during the rain season in the rain-fed farmlands.

The cropping pattern which is predominant in the study areas consists of the "monsoon paddy - fallow" sequence, out of the various kinds of cropping patterns mentioned above. The other kinds of crops that are being planted popularly are barnyard grass, beans and the like. Figure 6.2.1 shows the cropping pattern that is being practiced currently in the study area. It consists of monsoon paddy, spring maize and wheat. The present cropping intensity is of the order of 126%, which is lower than the mean value prevailing in the Jhapa District as a whole.

(5) Agricultural Production

The following table shows the crop production in Jhapa District in 1992/93. Jhapa District produces the highest amount of paddy among the three study districts and is responsible for 7.8% of the nation's paddy production, which is also the highest among 75 districts in Nepal. Maize, wheat, and potatoes follow paddy, and the tobacco represents 12% of the national production.

	Production (t)	Ratio to National (%)
Paddy	202,630	7.8
Maize	18,630	1.4
Millet	2,190	0.9
Wheat	13,090	1.7
Barley	20	0.1
Oil-seed crops	1,790	1.9
Potatoes	12,960	1.8
Tobacco	730	12.1
Sugarcane	5,500	0.4
Pulses	890	0.4

(MOA, 1993)

(6) Farming Practice

As a general rule, plowing and paddling are carried out 2 or 3 times, by using buffalo or draft cattle as motive force. There is practically no use of agricultural machinery within the study areas. The timing of farming mentioned above varies from year to year depending on rainfall, the availability of cattle and manpower, etc. The required nursery area is of the order of 6 to 7% of the paddy field, and the nursery period takes approximately one month. The transplanting is widely practiced in this area. Weeding during the growing period is not so common. Weeds are seen very often in the paddy fields. It is presumed that the expensive price of the herbicides is the problem lying in the background of the said situation. In the same way as in the case of herbicides, the use of chemical fertilizes is also extremely limited, and the kind of fertilizer that is being used consists mostly of manure.

Harvesting is carried out by man power inclusive of women and children. Man power required for harvesting rice is of the order of 20 man-day per hectare. Harvested rice is submitted to preliminary drying during 5 to 6 days at the paddy field. After that, it is transported to the farm houses, where it is threshed by making use of cattle power or man power. Finally, the paddy is dried at the yards of the farm houses or on the roads. Most of the villages are equipped with a small rice mill, where the threshing operation is carried out. Frequently, these rice mills are also used for squeezing oil from the oil seeds. Part of the paddy is kept as seed, which is planted in the next year.

Water buffaloes and cattle play an important role as a motive force for plowing, transportation, marketing and other kinds of work. On the other hand, women and children are

important work force for the sake of such farming activities as harvesting, transportation, obtainment of animal feeds and the like.

After the harvesting of monsoon paddy, which is the principal crop, other kinds of upland crops such as wheat, mustard, beans, vegetables and the like are planted in some fields. As a general rule, plowing and leveling work are carried out 2 or 3 times before seeding the said crops.

(7) Marketing

Paddy is marketed in the following manner: farmer-middleman-wholesaler/miller-retailer-consumer. Vegetables are sold to retailers directly or marketed by farmers at the nearest local market. Crops are transported by cattle carts, bicycles, and human power.

(8) Livestock

Animal husbandry is not being practiced in commercial basis, but cattle and water buffaloes are an important motive force for farming and transportation because the use of agricultural machinery is very low in the country. Moreover, the sale of milk and calf is a source of 20% to 30% of the total farm income. On the other hand, poultry consisting of chicken, ducks and the like is being raised at the yard of almost every farmhouse. The composition of the flock of livestock of the Jhapa District as of 1992/93 is shown in the followings. The number of heads of cattle and water buffaloes that exist currently within the Jhapa District is the largest out of three Districts under the study. Therefore, the production of milk is also the largest out of the Districts.

	Number	Milk Production (ton)
Cattle	191,340	14,507
Buffalo	75,986	13,362
Sheep	51	
Goats	105,788	
Pigs	22,357	
Chickens	178,031	
Ducks	25,183	

(MOA, 1993)

(9) Farm Economy

Generally speaking, farm size less than 0.50 hectares is classified as small farm in Nepal. In the Jhapa District, the farms belonging to this category account for 32% of the total. Besides these small farms, there are 1,104 landless farm households.

According to the World Bank, it is presumed that 74% of the households of the rural areas of Nepal live on incomes below poverty line. According to the NPC, the poverty line at the Terai is estimated to be of the order of Rs28,000 per year for a household of 6 persons. According to data collected by the Study Team that authored this report, the annual income of a farm household ranges from Rs13,200 to Rs60,000, depending on the size of the farm. In view of the said figures as well as the existence of landless farmers, it is presumed that the rate of poverty incidence of farms is quite high also in the Jhapa District.

The agricultural production of the Jhapa District consists mostly of cereals, but the price levels of oil seeds, beans and vegetables tend to be higher compared with rice and maize. Income related to livestock account for 20% to 30% of the total farm income.

(10) Irrigation

Jhapa District has an arable land area of 105,121 hectares, with 47,854 hectares of irrigated land. In other words, 46% of the arable land of Jhapa District is being irrigated by rivers, wells and other sources. The irrigation rate of Jhapa District is the highest of three Districts under the study.

Jhapa District belongs to a subtropical climate, and its geology is an alluvium, crossed from the north to the south by many rivers of various sizes, including the Kankai and the Mechi. Jhapa District, therefore, has better conditions of irrigation than any other Districts under the study, and that is resulting into a larger percentage of irrigated areas compared with the other Districts. The irrigation projects that are operating presently in Jhapa District are mostly surface water type, including the Kankai Irrigation Project.

(11) Food Balance

According to the District Profile of 1988, the state of supply and demand of food in Jhapa District consists of a production of 97,041 tons compared with a demand of 96,841 tons. As can be seen, there is a surplus of 200 tons. The agriculture production in the District deemed to be unstable since the agriculture in the District depends largely on the rainfed condition; and is subject to be affected in some year by drought or flood.

(12) Supporting Services

a) Agricultural Development Office (ADO)

Jhapa's ADO office is under the control of Regional Agricultural Office in Dhankuta. There are six agricultural service centers and 11 subcenters under District ADO, which support farming activities. Junior technicians (JT) and junior technical assistants (JTA) are assigned to guide leader farmers who are selected by farmers and pass on agricultural techniques to other farmers. The main activities of the JTs and JTAs include training, demonstration, exhibitions, and visiting farmers on their fields.

b) Agricultural Research Station

There are two research stations - the Pakhribas Regional Research Station and the Rampur Multi-Purpose Farm Station. These stations research crop development, cropping patterns, the distribution of nurseries, experiments in the fields and training for farmers.

c) Agricultural Development Bank (ADB/N)

To support the farmers with credit, a branch office of ADB/N is located in Chandragadhi. Three types of credit are provided to farmers: short-, medium- and long-term loans, and the current interest rates are 16% to 19%. Despite this public service, many farmers use private loans at higher interest rates.

Since 1975 the ADB/N is carrying out the Small Farmer Development Program (SFDP). This program aims at promoting the alleviation of poverty, the improvement of the education level and the formation of leadership among small farmers. Within the context of that program, the ADB/N is providing financing that covers groups of small farmers, including the landless ones. The monetary resources provided by the said financing program are utilized for such initiatives as equipment of irrigation facilities, the transfer of cropping technology, the training related to household industry, etc. to exert impact of various kinds, such as the improvement of the living standards of the rural households, the creation of employment opportunities, etc., within the rural society.

d) Agricultural Inputs Corporation (AIC)

AIC, whose head office is located in Kathmandu, has 12 zonal offices and 73 branch offices. Two branch offices are located in Jhapa, Damak, and Bhadrapur. AIC functions in distributing farm inputs such as seeds, fertilizer, agro-chemicals, and machinery to farmers through cooperatives.

(13) Farmers' Organization

The representative Farmers' Organization is a cooperative which functions in distributing agricultural inputs provided from AIC to farmers, procuring paddy from members, and selling to Nepal Agriculture Corporation (NAC). There are 27 cooperatives at present in Jhapa District.

4.4.3. Mahottari District

(1) Farmland and Land Use

The acreage of the farmland in Mahottari District is 63,754 ha, which is the largest next to Jhapa District. Present cropping intensity in the district is estimated at 171% as shown below:

Cereals	77,711	ha
Pulses	19,190	
Root crops	1,263	
Cash crops	1,945	
Oilseed crops	4,892	
Peppers	769	
Vegetables	1,315	
Fruit	1,955	
Others	5	
Total	109,045	

(CBS, 1993)

(2) Soils

Similar to Jhapa District, the soil type is classified as Type (I). Soil textures are sandy loam or clay loam, and soil reaction is weak-acid to neutral.

(3) Number of Farm Households and Land Holdings

According to the National Sample Census of Agriculture in 1991/92, there are 58,559 farm households in the district, including landless farmers: this is second to Jhapa among the three districts.

The ratio of farm households who owns less than one hectare is 60%, the top among three districts, and the average farm size is 1.09 ha, which is the smallest among the three districts. The number of farm households by farm size is shown as follows:

Landless	485	(0.8%)
Less than 0.1 ha	3,516	(6.0%)
0.1-0.2	7,002	(12.0%)
0.2-0.5	13,611	(23.2%)
0.5-1.0	13,605	(23.2%)
1.0-2.0	11,398	(19.5%)
2.0-3.0	4,365	(7.5%)
3.0-4.0	2,031	(3.5%)
4.0-5.0	1,364	(2.3%)
5.0-10	1,000	(1.7%)
Above 10 ha	182	(0.3%)
Total	58,559	

(CBS, 1993)

The number of farm households in the Study Area is estimated at 6,420.

(4) Present Cropping Patterns

The following cropping patterns are observed in the district.

Irrigated Areas	Spring Paddy-Monsoon Paddy-Wheat
	Spring Paddy-Monsoon Paddy-Maize
	Spring Paddy-Monsoon Paddy-Pulses/Oilseed Crops
	Monsoon Paddy-Wheat-Pulses
	Monsoon Paddy-Potato-Pulses
Rainfed Areas	Monsoon Paddy-Fallow
	Monsoon Paddy-Wheat Fallow
	Monsoon Paddy-Pulses-Fallow
	Monsoon Paddy-Oilseed Crops-Fallow
	Maize-Pulses/Oilseed Crops/Millet

In the Study Area, the pattern of Monsoon Paddy-Fallow is dominant, and pulses, as represented by pigeon peas, and wheat are also planted. Plowing for monsoon paddy begins in the middle of June, after the land is soaked with rainfall, and crops are harvested from mid November to the mid December (refer to Figure 6.2.2 in Chapter 6).

(5) Agricultural Production

Mahottari District produced 3.5% of the wheat, 19.9% of the tobacco, and 4.7% of the pulses of national production in 1992/93 as shown below:

	Production (t)	Ratio to National (%)
Paddy	52,140	2.0
Maize	8,200	0.6
Millet	1,960	0.8
Wheat	26,510	3.5
Barley	220	0.8
Oilseed crops	2,360	2.5
Potatoes	8,140	1.1
Tobacco	1,200	19.9
Sugarcane	43,610	3.2
Pulses	9,540	4.7

(MOA, 1993)

(6) Marketing

The marketing of paddy is similar to that in Jhapa District: farmer-middleman-wholesaler/ miller-retailer- consumer. Vegetables and milk are sold directly by farmers to the nearest local market or sold directly to retailers; transportation is dependent on cattle carts, bi-cycles, and manpower.

(7) Livestock

The number of cattle and buffalo, along with milk production is one half that of Jhapa District as shown below:

	Number	Milk Production (t)
Cattle	97,854	4,190
Buffalo	39,882	8,918
Sheep	1,258	
Goats	106,065	
Pigs	1,970	
Chickens	85,016	
Ducks	6,671	

(MOA, 1993)

(8) Irrigation

Of the district's 63,754 ha of farmland, 17,313 ha, or 27%, are irrigated, which is second to Jhapa's 46% among the three districts.

(9) Food Balance

Food production in Mahottari District is 73,635 tons, while demand is 57,006 tons. There is a 16,629 ton surplus according to the District Profile in 1988.

(10) Supporting Services

a) ADO

Mahottari's ADO is under the control of the Regional Agricultural Office in Kathmandu. There are six agricultural service centers and 11 subservice centers under District ADO, and JTs and JTAs are dispatched to provide agricultural extension services to the selected leader farmers, who in turn guide other farmers.

b) Agricultural Research Stations

There are two agricultural research stations - a horticulture research station in Janakpur and a multi-purpose farm station in Rampur. These research stations are in charge of experimental crop testing, the distribution of nurseries as well as extension activities and others.

c) ADB/N

ADB/N, located in Jaleswar, supports short-, medium- and long-term credit for farmers.

d) AIC

The AIC branch office at Jaleswar supplies agricultural inputs such as seeds, fertilizer, agro-chemicals, and machinery to farmers through cooperatives.

(11) Farmer's Organization

There are 31 cooperatives with 1,110 members, which act as representative farmers' organizations through which farm inputs procured by AIC are distributed to farmers.

4.4.4. Banke District

(1) Farmland and Land Use

The acreage of farmland in Banke District is the smallest of the three districts at 49,072 ha. The present cropping intensity in 1991/92 is estimated at 142% as shown below:

Cereals	51,745 ha
Pulses	12,079
Root crops	555
Cash crops	29
Oilseed crops	4,253
Peppers	126
Vegetables	468
Fruit	323
Others	58
Total	69,618

(CBS, 1993)

(2) Soils

The soil type is classified as Type (I). The soil textures are sandy loam or clay loam, and soil reaction is weak acid to neutral.

(3) Number of Farm households and Land Holdings

As of 1991/92, there are 35,912 farm households, with an average size of 1.37 ha. The average farm size is the second largest among the three districts, following Jhapa District; and farmers who own less than one hectare accounts for 50% of the total.

Landless	694	(1.9%)
Less than 0.1 ha	2,372	(6.6%)
0.1-0.2	1,369	(3.8%)
0.2-0.5	4,899	(13.6%)
0.5-1.0	8,718	(24.3%)
1.0-2.0	9,701	(27.0%)
2.0-3.0	4,899	(13.6%)
3.0-4.0	1,659	(4.6%)

4.0-5.0	675 (1.9%)
5.0-10	810 (2.3%)
Above 10 ha	116 (0.3%)
Total	35,912

(CBS, 1993)

The number of farm households in the Study Area is estimated at 5,850.

(4) Cropping Patterns

The following cropping patterns are dominant in the district.

Monsoon Paddy-Fallow
Maize/Millet-Mustard
Pigeon Pea
Monsoon Paddy-Cereals

Figure 6.2.3 in Chapter 6 shows the present cropping pattern in the Study Area. Cultivation for monsoon paddy begins with the preparation of nursery beds, after the land is soaked by rainfall. Paddy is harvested from the mid November to mid December when wet season is over.

(5) Agricultural Production

The ratio of agricultural production in 1992/93 is 4.2% for pulses and 1.4% for paddy. The amount of rainfall and irrigated area are both the smallest among the three districts, and as a result, cropping conditions in the district are poor.

	Production (t)	Ratio to National (%)
Paddy	36,120	1.4
Maize	20,710	1.6
Wheat	10,400	1.4
Barley	20	0.1
Oilseed crops	2,430	2.6
Potatoes	4,600	0.6
Tobacco	40	0.7
Sugarcane	4,270	0.3
Pulses	8,580	4.2

(MOA, 1993)

(6) Marketing

The marketing channels for paddy and other crops are similar to the other two districts: farmer-wholesaler/miller-retailer-consumer. Vegetables and milk are transported to the nearest local market by farmers using cattle carts, bicycles, and human power.

(7) Livestock

The number of sheep is the largest among three districts, but milk production by cattle and buffalo is the lowest as shown in the following:

	Number	Milk Production (ton)
Cattle	81,342	2,437
Buffalo	53,326	7,483
Sheep	10,274	
Goats	81,120	
Pigs	11,197	
Chickens	109,476	
Ducks	1,505	

(MOA, 1993)

(8) Irrigation

Irrigated areas in Banke District represent only 3,317 ha or 6.8% of the cultivated areas in 1991/92, which is the lowest among three districts.

(9) Food Balance

Food production in Banke District is 48,079 tons, while demand is 45,757 tons. There is a 2,322 ton surplus according to District Profile in 1988.

(10) Supporting Services

a) ADO

Banke's ADO is under the control of the Regional Agricultural Office at Surkhet. District ADO is composed of seven divisions, including a crop, horticulture, livestock, and a fishery division, among others. There are four agricultural service centers and nine subcenters distributed under ADO, and JTs and JTAs are assigned to guide leader farmers who are selected from among the farmers.

b) Agricultural Research Station

There are two research stations - a regional research station in Nepalganj and a multipurpose farm station in Surkhet. These stations function in the development of crops, the distribution of nurseries, crop testing in fields, and so on.

c) ADB/N

ADB/N's District Office is located in Nepalganj and offers agricultural credit and deposit services. Recently, ADB/N's services have emphasized the Small Farmer Development Program (SFDP).

d) AIC

AIC's District Office in Nepalganj supplies agricultural inputs and agricultural machinery to farmers through cooperatives.

(11) Farmers' Organization

At present there are 17 cooperatives with 11,518 members to distribute agricultural inputs provided by AIC.

4.5 Infrastructure

4.5.1. Accessibility

(1) Air Route

In the case of Jhapa District, a local air field is located at Chandragadhi, with direct flights from Katmandu four times a week. Another access route is the 115 km drive via Biratnagar in Morang District, which also has daily flights from Katmandu. There is no airport in Mahottari District, but Janakpur in Dhanusha is available to access the site by driving 15 km. Janakpur Airport has a daily flight from Katmandu, and Nepalganji, capital of Banke District, has an airport which receives daily flights from Katmandu.

(2) Land Route

The main transportation route in the Terai is the "E-W Highway," which runs through the Terai Plain from Kakarbitta on the eastern border, to Mahendranagar on the western border, both of which border India. Although the highway is a paved surface road, considerable sections of the road are in rough condition as a result of the poor repair work per-

formed so far. In order to access to the sites, two routes join the E-W Highway crossing the Mahabharat Range: one route is via Mugling to Bharatpur Junction and the other is via Daman Pass to Hetauda Junction.

The land route to Jhapa District is approximately 530 km via the shorter route and takes one full day or two days. The route of the Mahottari District is approximately 310 km through Daman Pass and 400 km via Mugling; a one day drive is sufficient to arrive at the site from any route. For Banke District, the distance is between 530 km and 550 km but it takes two to three days to go to Nepalganj as the route passes through mountainous areas in long sections.

4.5.2. Road Conditions

(1) General

Roads in Nepal are classified and managed as below;

1) Pitched road ..... paved road
2) Gravel road ..... gravel constructed
3) Mud road ..... mud constructed

Among these road types, paved and gravel roads are adequate for vehicle traffic throughout the year, but mud roads are not suitable for vehicles during the rainy season.

(2) Jhapa District

Paved roads extend only 106 km, including 50 km of the highway. Most of the road system in the district is either gravel or mud roads, and the portion of gravel road is less than a quarter of the entire road system. Vehicles can use mud roads during the dry season but only if there are bridges to cross the small rivers.

There is no future plan to construct new roads in the district, and the current National Development Plan suggests only the extension of gravel roads and the repair of mud roads.

(3) Mahottari District

Two paved roads - the E-W Highway in the north and the Janakpur-Jaleswar road in the south - pass through the district. Most of the road system consists of mud roads, which are concentrated in the southern half, rough in the mid-north, and non-existent in the far north.

Only three gravel roads run south from the highway but these do not reach to the southern paved road.

The construction of two gravel roads connecting the two paved roads is planned for the district.

(4) Banke District

The road system in this district is the poorest among the three districts, as there is no road system in almost half of the district. Although the district has the largest area among the three, there is only 16 km of paved road and only 30 km of gravel roads; and the condition of the mud road system is remarkably poor, as there are many discontinuities and the road sometimes abruptly disappears into farmland.

There is only one mud road along the eastern bank of the Rapti, but no bridge crossing. As a future plan, two of the main mud roads are to be graveled and paved throughout: one is from Nepalganj to Balapur across the Rapti; the other shorter route is from the Nepalganj-Gulariya road to the E-W Highway.

4.5.3. Power Supply

(1) General

The power supply system is composed of four kinds of power lines: 132 KV, 33 KV, and 11 KV transmission lines, and a 220V distribution line.

At present, the power line network in all three districts is very thin, including the entire Terai Plain.

(2) Jhapa District

The major power line is a 33 KV line, which runs along the highway and terminates at the transformer substation in Birtmod. The substation transforms the power into 11 KV, which is delivered to Kakarbitta further along the highway to Sanischari in the north and Chandragadhi in the south. The line also extends to India, across the Mechi River, south of Badrapur. The power is distributed to nearby houses by reducing the voltage 220V via a power transformer on the electric pole in major town, such as Birtmod and Chandragadhi; however, power transmission lines have not be established further away from the highway (refer to Figure 4.3.1 (2)).

There is a future long-term plan to connect the E-W Highway area with the southern-most area by three 11 KV lines along the existing N-S gravel roads.

(3) Mahottari District

In the north, 132 KV and 33 KV lines pass along the highway, but there are no distribution lines. In the south, a 33 KV line passes along the Janakpur-Jaleswar road and branches at Jaleswar to Sursand and to Madwapur, both of which are in India. Only the villagers around Jaleswar benefit from electricity at the present time (refer to Figure 4.3.2 (2)).

In the future, a 11 KV line network will distribute power to the people living in the south-eastern corner of the district.

(4) Banke District

The 132 KV transmission line reaches Kohalpur, where a main transformer substation is located, from the central region along the highway. Another substation is located at Nepalganj, from where a 132 KV line extends to India. Both substations are connected by 33 KV and 11 KV lines. The 11 KV line further extends south across the border from Nepalganj and west to Gudhana and the resettlement area (refer to Figure 4.3.3 (2)).

As a future plan, the main transmission line will be extended to the west as far as Karnari, and 33 KV and 11 KV lines will connect Gulariya.

4.5.4. Telecommunication

In almost all districts in Nepal, there is at least one telephone exchange and one wireless station directly connected to Kathmandu, usually at the district center. Besides these, several public and private calling offices are located mainly in the large towns. Although local telephones have increased since 1951, their number remains small. In the three target district, there are only 775 telephones in Jhapa, 165 in Mahottari, and 1,310 in Banke.

4.5.5. Water Supply

The water supply system, including the sewerage system, is one of the least developed infrastructures in the country. In the Terai Plain, only a few towns, mostly regional or district centers, have pipe-born water supply systems. However, the Terai Plain is rich in