No. 4

BASIC DESIGN STUDY REPORT

ON

TERAI GROUNDWATER DEVELOPMENT PROJECT

IN

THE KINGDOM OF NEPAL

JUNE 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

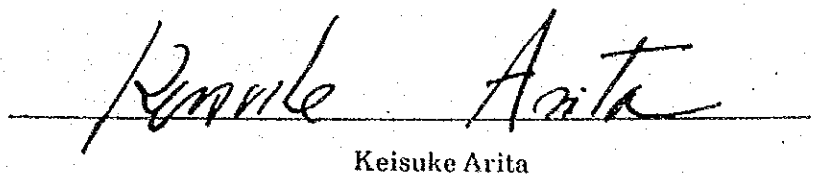
In response to the request of His Majesty's Government of Nepal, the Government of Japan has decided to conduct a basic design Study on the Terai Groundwater Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Nepal a study team headed by Mr. Masanori FURUYA, Grant Aid Division, Bureau of Economic Cooperation, Ministry of Foreign Affairs, from January 7 through March 6, 1987.

The team had discussions on the Project with the officials concerned of the Government of Nepal and conducted a field survey in the Terai plain of the Janakpur Zone. After the team returned to Japan, further studies were made, a draft report was prepared and a mission to explain and discuss it was dispatched to Nepal. As a result, the present report has been prepared.

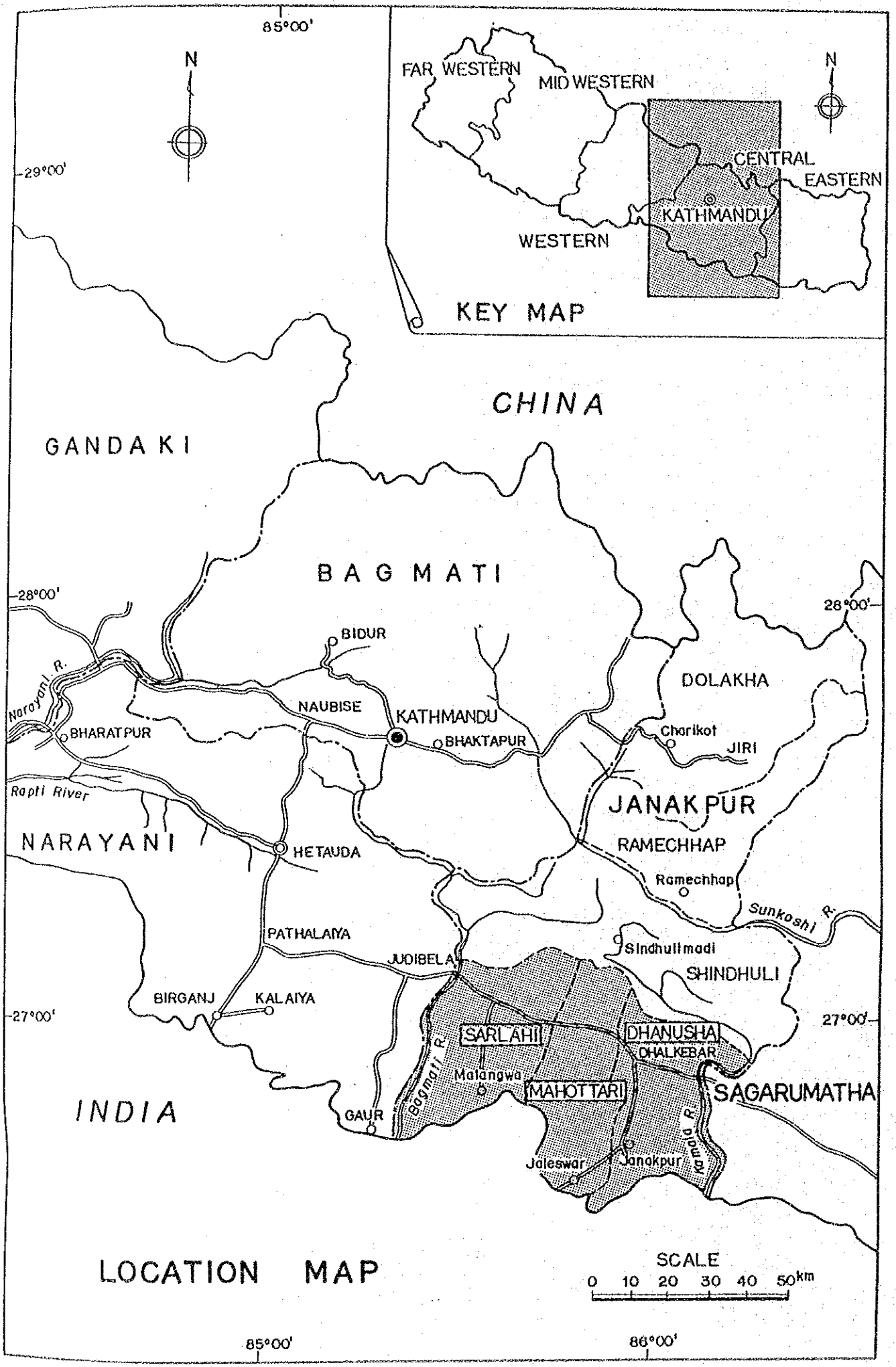
I hope that this report will prove to be useful as a reference material for the execution of the basic design study phase II scheduled for the near future.

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.

June, 1987



Keisuke Arita
President
Japan International Cooperation Agency


85°00'
N
29°00'
FAR WESTERN
MID WESTERN
CENTRAL
EASTERN
KATHMANDU
WESTERN
KEY MAP
CHINA
GANDAKI
BAGMATI
28°00'
BIDUR
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NAUBISE
KATHMANDU
BHAKTAPUR
BHARATPUR
DOLAKHA
Charikot
JIRI
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JANAKPUR
NARAYANI
HETAUDA
RAMECHHAP
Ramechhap
Sunkoshi R.
PATHALAIYA
Sindhulimadi
JUDIBELA
SHINDHULI
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KALAIYA
27°00'
SARLAHI
DHANUSHA
DHALKEBAR
Bagmati R.
Malangwa
MAHOTTARI
SAGARUMATHA
INDIA
GAUR
Jaleswar
Janakpur
Kamala R.
LOCATION MAP
SCALE
0 10 20 30 40 50km
85°00'
86°00'

SUMMARY

1. The Kingdom of Nepal is a landlocked country extending along the southern slope of the Himalayas in a long rectangular shape, surrounded by Tibet of Chainese teritory in the north and Indo-Asian continent in the south. Its area is about 150 thousand square kilometers, which is approximately 1.9 times larger than Hokkaido island in Japan, about 900 kilometers long in east to west and at most 200 and tens kilometers wide in north to south. Since it forms a southern slope of the Himarayas, its land has a big difference in elevation; high in the north and low in the south. In case of an inhabited land, it slopes sharply from a highland of more than 4,000 meters down to the Terai plain of around 100 meters. Cultivated lands occupy about 18 percent of the whole national land, while 38 percent is forest lands and the remaining 44 percent is pastures, mountains and barren lands.

   The Kingdom of Nepal is an agricultural nation; about 90 percent of the population engages in agriculture, forestry and fishery, which produce 62 percent of GDP, while the industrial production occupies merely 4.6 percent of GDP. Its annual income per capita is 172 U.S. dollars (esimate in 1982) and also income differentials among the nation are considerably big. Hence, it is counted as one of very poor countries in the world.

2. The Kingdom of Nepal executed six times of Five Year Development Plan from 1956 till 1985 and presently it is in the second year of the Seventh Five Year Devolopment Plan. Owing to the efforts for development so far made, the production of rice and wheat as well as the supply capacity of electricity have increased and the movement of commodities within the country has started after the completion of trunk roads such as East-West Highway. Educational and medical sectors have also been improved considerably. The targets of the Seventh Five Year Development Plan are the following three points, i.e., (1) acceleration of production expansion, (2) increase of productive employment opportunity and (3) response to minimum needs of the nation, which are the same to those of the Sixth plan. The development strategy is put priority on the agricultural sector followed by the development of forest resources and the land conservation.

3. The target of efforts is set to raise a per capita income by 1.8% annually throughout the period of the Seventh Plan and, for this purpose, an investment of total 51,410 million Rupees (1984/85 price level) is scheduled in order to attain 4.5% of annual increase of GDP within which growing rate of the agricultural sector is 3.5% (non-agricultural sectors 5.7%), assuming the population increase be 2.66% annually. Among the above investment, total government expenditure is 29,000 million Rupees and 20,480 million Rupees (71% of the total amount) are expected to foreign aids as its financial source. For agricultural, forestry and irrigation sector, which is the biggest in expenditure, 17,280 million Rupees (34.3% of total expenditure) of investment by both sectors of the government and the private are anticipated. Target of production increase for major agricultural products and target of expansion of irrigation area in the Seventh Plan are as follows.

Target of Production Increase for Major Agricultural Products

Crops	1884/85 (ton)	1988/89 (ton)	Rate of Increase (%)
Rice	2,733,000	3,400,000	124
Wheat	600,000	900,000	150
Maize	843,000	916,000	109
Sugarcane	500,000	800,000	160
Mustard	77,000	95,000	123
Tobacco	7,000	8,000	114
Potato	409,000	521,000	127

Target of Expansion of Irrigation Area

Description	Ministry of Water Resources (ha)	Ministry of Agriculture (ha)
On-going projects	106,003	-
New projects	29,490	-
Small scale irrigation	-	50,000
Tubewell irrigation	-	50,000
Total	135,493	100,000

4. Janakpur zone, which includes the project area, belongs to the central development region, one of the development regions which divide the Kingdom of Nepal into five. The project area covers plain fields (a part of Terai plain) of three districts of Dhanusha, Mahottari and Sarlahi and the gross arable land is about 195,000 ha. Janakpur, a central city of the plain, is about 8 hours drive from Kathmandu, the capital of Nepal, by East-West Highway (road distance is about 390 km) and about 35 minutes from Kathmandu by air. TIATSP center (Tubewell Irrigation Agriculture Training and Services Project center) is situated about 19 km to the north from Janakpur city. The major industries in Janakpur district are agriculture and agro-industry. Farm products in the area is self-sufficient and excess products are shipped to Kathmandu, etc. Tobacco factory, sugar factory, paper factory, rice mills and other small scale domestic industries are comparatively well developed.

Although rainy season paddy is a main farm product, wheat, maize, sugarcane, mustard, tobacco, etc. are also much produced. As for the present cropping pattern, a single crop of paddy and paddy-wheat in case of paddy fields, and maize-mustard and maize-tobacco in case of upland are common in the area and their crop intensity ranges between 150 and 180 percent.

5. Under grant aid and technical assistance of the Government of Japan (GOJ), His Majesty's Government of Nepal (HMGN) commenced the Janakpur Zone Agriculture Development Project (JADP which covers five districts except Dolakha out of the six districts in the zone) in 1971 and executed various kinds of programs and projects which aimed at increase of farm income and leveling up of local farmers' living standard by raising land productivity and increasing agricultural production until July, 1985. As for irrigation projects in the three districts in the Terai plain (Sarlahi, Mahottari and Dhanusha), the Shallow Tubewell Irrigation Program (STWP, which enabled increase of cropping from twice a year to three times a year in 13,800 ha by constructing 1,977 shallow tubewells from 1981 to June. 1986) and the Intensive Irrigation and Agriculture Program (IAP which realized irrigation of 420 ha by cnstructing nine deep tubewells and about 10.6 km of canals), etc. were executed. However, the area which can be irrigated by shallow tubewells is limited within a belt like area of about 51,000 ha which extends east to west at the center of the three districts in the Terai plain. Out of 195,000 ha of the total arable land in the Terai three districts, the area of about 110,000 ha other than the areas to be irrigated by the surface water and the shallow tubewells is therefore obliged to depend upon the deep tubewell irrigation by developing the deep aquifer.

6. In January 1971, HMGN established TIATSP (Tubewell Irrigation Agriculture Training and Services Project) under the Seventh Five Year Development Plan (1985-90). The functions and the facilities of JADP were tranferred to TIATSP aiming at expansion of the irrigation area by shallow and deep tubewells. The shallow tubewell irrigation program of JADP/TIATSP has greatly contributed to the increase of the agricultural products in the Terai plain within Janakpur zone by increasing the irrigation area, with the increase of the number of shallow tubewells. Since its construction cost and operation/maintenance cost are low and the drilling requires rather easy technical skill, its sound and smooth development are expected to continue in the future.

   On the other hand, the deep tubewell irrigation program, which was commenced in 1976 and drilled 24 tubewells (including 9 tubewells of IAP) by 1984, was also transferred to TIATSP. In 1985 and 1986, 39 deep tubewells (of which 15 tubewells were drilled by a Japanese drilling contractor) were drilled using the equipment and materials granted under KR-2 grant aid program of GOJ and further a drilling of 18 deep tubewells is scheduled in 1986/87. However, the deep tubewells being utilized for irrigation as of February 1987 are limited to 9 tubewells of IAP(completed under guidance of Japanese experts dispatched under technical assistance of GOJ), 1 pump well in the Nawalpur horticulture farm and 7 artesian wells. The low progress of the deep tubewell irrigation program is attributable not only to incomplete knowledge and planning ability on deep tubewell irrigation development, insufficient hydrogeological technique for determination of location of deep tubewells, and incomplete

technology of deep tubewell drilling but also to short of fund for constructing deep tubewells and their irrigation facilities, and to insufficient operation and maintenance of the deep tubewell irrigation facilities.

In April 1986, under the background described above, HMGN requested GOJ to provide the former with grant aid assistance to construct 150 deep tubewells and their irrigation facilities which will irrigate about 3,000 ha of cultivated land, using the equipment and materials granted by GOJ under the KR-2 grant aid in order to facilitate the deep tubewell irrigation program aiming at increasing agricultural production and improving income and living standard of the local farmers in the area.

7. In reply to the request, GOJ dispatched a preliminary study mission through JICA to Nepal from August to September 1986 and confirmed the strong desire of HMGN for the implementation, the executive organization of HMGN and the significance of the Project and consequently judged that the Project would have the possibility of implementation from the technical and economic points of view. Based on the results of the preliminary study, JICA dispatched a basic design study mission headed by Mr.Masanori FURUYA (an official of Grant Aid Division, Bureau of Economic Cooperation,Ministry of Foreign Affairs) from 7th of January through 6 th of March, 1987.

The study mission investigated the hydrogeological conditions by 4 test borings and the distributions of groundwater potential by pumping-up test of the existing deep tubewells, etc. in the project area, evaluated usability of the deep tubewell construction equiment and materials granted by the KR-2, determined 23 development blocks including topographic survey of 3 blocks, examined present constraints and their solutions, collected the data and information required for the basic design and made discussions with TIATSP (an executive body of the Project in the ministry) and Ministry of Agriculture (a superintendence ministry of the Project).

Through the above field survey and a home analysis, which includes an examination on the requested project, it has been confirmed that the Project has the following propriety and significance.

(1) It is fully possible to construct about 115 deep tubewells and their irrigation facilities for irrigation of about 4,600 ha if necessary equipment and materials are added to the equipment and materials for the construction of deep tubewells and their irrigation facilities granted under the KR-2 aid by GOJ (propriety).

(2) Stable increase of the agricultural production would be secured by an expansion of the irrigation area (about 4,600 ha) and introduction of perennial irrigation (significance).

(3) Increase of farm income would be secured since the perennial irrigation would grately push up land productivity and consequently unit yield of crops would drastically increase (significance).

(4) Owing to the above, improvement of the farmers' living standard and promotion of the local farmers 'social welfare would be secured (significance).

(5) The deep tubewell development technique in Nepal would be improved by introducing Japanese technique (significance).

(6) This Project would become a model for operation and maintenance of future deep tubewell irrigation development projects in the Terai plain (signifncance).

8. The development plan of the Project, elaborated through the field survey and the home analysis, is outlined below :

1) Basic concept of the Project

(1) Objective area : 3 districts (Dhanusha, Mahottari, Sarlahi) of the Terai plain in Janakpur zone where the deep aquifer is only the conceivable water source for irrigation.

(2) Project component : Construction of 115 deep tubewells and their irrigation facilities for an aggregate area of about 4,600 ha in the objective area, which uses the equipment and materials granted by the KR-2 aid.

2) Development block

(1) Number of blocks : 23 development blocks, of which 8 blocks consisting of 4 in Dhanusha district, 2 in Mahottari and 2 in Sarlahi, have priority.

(2) Unit irrigation area in the block : Five deep tubewells are provided for each development block. Each tubewell generally has an independent commanding area of 40 ha on an average. So far as topgraphic conditions allow, however, a linked-tubewell system is introduced.

3) Groundwater development plan

(1) Type of deep tubewells : In due consideration of hydrogeological conditions of the development blocks, the following 4 types of the standard wells are applied.

Applicable Area and Blocks of 4 Standard Tubewells

Type	I	II	III	IV
A. Specification of tubewell				
Depth	89m	159m	205m	205m
Discharge	40 ℓ/sec	25~30 ℓ/sec	40~55 ℓ/sec	40 ℓ/sec
B. Applicable area	Northern part of Sarlahi district	Northern part of Dhanusha and Mahottari districts	Central part of Dhanusha district and southern part of Mahottari and Sarlahi districts	Central to northern part of Dhanusha and Mahottari districts and southeastern part of Dhanusha district
C. Applicable block				
Blocks (nos.)	4(1)	9(2)	9(5)	1
Tubewells (nos.)	20	45	45	5

Note : Figures in parentheses show numbers of the priority blocks.

(2) Drilling of test tubewells : Prior to construction of production tubewells, a test tubewell will be drilled in each development block to confirm possible discharge of production tubewells and their construction specifications.

4) Irrigation development plan

(1) Irrigation area : The irrigation area of the Project is estimated to be 4,625 ha in total on the basis of expected available pump-up discharge of 115 production tubewells.

(2) Irrigation method : The rotation irrigation method is applied to distribute irrigation water as even as possible.

(3) Irrigation facilities : The following facilities will be constructed in each of the unit irrigation areas.

- a pump house
- an operator hut
- main irrigation canals
- related structures such as turnouts, drops, road crossings, small passes, cattle passes, division boxes, corner boxes, pre-cast check plates, and a bathing pool (in a block)

5) Construction schedule

Total development blocks of 23 in number will be implemented for 4 years. In the first year, 5 blocks will be constructed, while in and after the second year 6 blocks a year will be constructed.

6) Construction materials and equipment

(1) Repair and maintenance of the existing equipment and materials : The following check, adjustment, repair and maintenance works are required prior to commencement of the construction;
- repair and adjustment of drilling rigs,
- reinforcement of Johnson screen, 2,600m long,
- expansion of pump shafts and lifting pipes of the 50 vertical turbine pumps, and
- repair and maintenance of transport equipment and vehicles

(2) Additional materials and equipment : The following materials and equipment shall be additionally provided to construct 115 production tubewells and irrigation facilities for 115 irrigation units of 23 blocks;
- materials and equipment for drilling and developing (tricone bits, ring base wire-wrapped screen, etc),
- transportation equipment,
- construction equipment,
- vehicles for operation and maintenance, and
- consumables and spare parts of the above.

7) Implementation plan

(1) Implementation organization : The Ministry of Agriculture is a superintendence ministry responsible for the implementation of the Project, and TIATSP is an executive agency of the Project. In accordance with a grant aid system of the Japanese Government, the construction works for the Project are carried out by a Japanese contractor, who will be awarded through tender procedure, and the detailed design and the construction supervision are rendered by a Japanese consulting firm.

(2) Operation and maintenance : Operation and maintenance works will be carried out by TIATSP, collecting necessary water charge from beneficial farmers.

(3) Construction of the on-farm facilities : On-farm facilities inclusive of branch canal will be constructed by beneficial farmers at their own expense. TIATSP will

organize a water users' group with the beneficial farmers in each irrigation unit.

9. The Project is implemented by dividing into four phases, taking into consideration the work size, work quantity, work capacity of KR-2 machinery and equipment, possibly workable days a year, maximum E/N (Exchange Note) term in frame of the Japanese grant aid system, and the climate in the project area.

The main components of the respective phases are as follows:

First phase	:	Construction of 25 production tubewells including 5 diverted from test tubewell and irrigation facilities for 25 irrigation units in 5 blocks, purchase of additional materials & equipment and drilling of test tubewells (one for each block, 6 in total) for 6 blocks of the second phase.
Second phase	:	Construction of 30production tubewells including 6 diverted from test tubewell and irrigation facilities for 30 irrigation units in 6 blocks, and drilling of test tubewells (one for each block, 6 in total) for 6 blocks of the third phase.
Third phase	:	Construction of 30 production tubewells including 6 diverted from test tubewell and irrigation facilities for 30 irrigation units in 6 blocks, and drilling of test tubewells (one for each block, 6 in total) for 6 blocks of the fourth phase.
Fourth phase	:	Construction of 30 production tubewells including 6 diverted from test tubewell and irrigation facilities for 30 irrigation units for 6 blocks.

Immediately after the conclusion of the Exchalnge Note for the first phase in the end of July, 1988 the consultant contract will be made and detailed design, pre-qualification, tendering, evaluation of tender documents and contract will require 5 months including 2 months for the detailed design works. The contractor will spend one (1) month for the preparatory works, therefore, the construction of the first phase could be started in February 1989. The construction period of the first phase will be 5 months. The machinery provided for construction by TIATSP will be returned by the contractor to TIATSP after the repair and maintenance by the end of July in 1989.

The Exchange Note for the second phase will be concluded in the end of July, 1989. The procedures from pre-qualification of tenderers to the contract for the construction will require 3 months from August to October, 1989 and the preparatory works of the contractor, 1 month. Therefore,the construction of the second phase could start in December, 1989 and end in June, 1990 with a 7 month-period. The machinery provided for construction by TIATSP will be returned by the contractor to TIATSP after the repair and maintenance by the end of July,1990.

The third phase and the fourth phase will follow the second phase in due course.

10. By executing the Project, not only such direct effects as expansion of products by perennial irrigation and increase of farm income and improvement of farmers' living standard due to raise of land productivity and unit yield of crops, but also such indirect effects as promotion of local farmer's social welfare, establishment of the deep tubewell irrigation technique, presentation of a model for operation and maintenance for future deep tubewell irrigation projects in the Terai plain, etc. are expected. There is no problem in the executive organization of HMGN side; the executive body is the Ministry of Agriculture and the executive agency is TIATSP. It is fully possible to execute this Project by reinforcing the present TIATSP organization.

    On the other hand, judging technically from the groundwater potential ditribution in the project area, the existing deep tubewell equipment and materials of KR-2 aid (considerable quantity of additional equipment and materials is required), etc.,construction of 115 deep tubewells (possible pump-up discharge per tubewell is 25 l/sec to 55 l/sec) and the respective irrigation facilities for 115 irrigation units in 23 development blocks is fully possible. HMGN is expressing that it will make assurance doubly sure to operate and maintain the completed facilities by organizing water users' groups, collecting water charge from the water users' groups, etc. Operation and maintenance of the facilities are thus possible from the view point of farm economy if a discharge per tubewell is more than 25 l/sec. However, it is extremely difficult for Nepal to carry out this Project with its own technology and funds since its hydrogeological survey technique, deep tubewell drilling / finishing technique, etc. are incomplete and also its national finance is depending on foreign aids.

11. In due consideration of the above situation, it is judged that the execution of the Project holds great significance and is appropriate to the grant aid cooperation of GOJ, besides the request of HMGN on implementation of the Project is proper and priming effect to future groundwater irrigation development projects in the Terai plain is also expected.

    In this basic design study, however, possible pump-up discharge of deep tubewells for each development block has not been confirmed yet because of absence of pumping-out test for the test borings, lack of points of the pumping-out test for the existing deep tubewells, lack of points of the electric sounding, etc., and therefore, specifications and sizes of the deep tubewells and the irrigation facilities have only been preliminarily determined. In addition, location of the 15 development blocks other than the 8 priority development blocks, measures for reinforcing the existing 8" Johnson screens, etc. have been left undetermined. These are grave matters which influence on the technical propriety of the Project and, therefore, require urgent solutions. From this point of view, it is strongly recommended to execute the basic design study-phase II detailed in Chapter 6 herein as soon as possible.

THE KINGDOM OF NEPAL
TERAI GROUNDWATER DEVELOPMENT PROJECT
BASIC DESIGN REPORT

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LIST OF TABLES AND FIGURES

1. INTRODUCTION

1. INTRODUCTION

The objective area of the Terai Ground Development Project is about 110, 000ha of cultivated land, a part of the Terai plain, located in the Janakpur Zone, covering the Dhanusha, Mahottari and Sarlahi Districts. About 34,000ha of irrigable area by surface water, consisting of about 12,500ha on the right bank of the Kamala river, about 18,500ha on the left bank of the Bagmati river and about 3,000ha on the left bank of the Manusmara river, extending downstream of the Bagmati, and about 51,000ha of the Shallow Tubewell Program (STWP) area being implemented in the central part of the above plain are excluded from the objective area.

In order to facilitate the irrigation and agricultural development in the large part of the Terai plain which is not feasible for surface irrigation, His Majesty's Government of Nepal (HMGN) commenced the Janakpur Zone Agricultural Development Project (JADP) with a grant aid and technical assistance of the Government of Japan in November 1971, and has implemented various groundwater development projects aiming at increasing agricultural production and improving income and living standard of the rural people living in this area. STWP, one of the projects implemented under JADP, has marked remarkable progress, and has completed the drilling of 2,256 shallow wells (out of the drilled wells, 1,977 wells were judged to be productive; the rate of success is 88%) as of June 1986 and created about 13,800 of irrigated farm land. In January 1986, JADP was reorganized and renamed TIATSP (Tubewell Irrigation, Agriculture, Training and Services Project) to develop wider area by ground water irrigation. STWP is successfully in progress as of March 1987 and will be continued until 1991.

While, HMGN had completed 24 deep tubewells by 1984 through JADP's activities, and in 1985 and 1986 completed 41 tubewells (of which, 15 tubewells were completed by a Japanese drilling company) using the drilling and construction equipment and materials provided under a KR-2 grant aid of Japan in 1982 and 1983. Besideds, the drilling of 18 tubewells was planned in the year of 1986/87, 3 tubewells of which have been completed as of the end of February 1987. However, among the deep tubewells drilled by JADP/ TIATSP, only 17 tubewells are in use for irrigation as of the end of February 1987, which are 9 tubewells completed under the technical assistance of Japanese experts as IAP (Intensive Irrigation and Agriculture Program) activity in 1977 (the pumps were installed in 1983), 1 pump well in the Nawalpur horticulture farm and 7 artesian wells. The 15 deep tubewells constructed by a Japanese drilling company will come into use after April 1987 due to some constraints on the operation and maintenance.

The cause of low progress of the deep tubewell irrigation program by JADP/ TIATSP seems to be not only incomplete knowledge and planning ability on deep tubewell irrigation, insufficient hydrogeological investigation technique for site selection of deep tubewell point and deep well drilling, but also short of funds for construction of deep tubewells and their irrigation facilities, which require huge amount of funds.

Under the background described above, in April 1986 HMGN requested the Government of Japan to provide the grant aid assistance to construct 150 deep tubewells and their irrigation facilities, which will irrigate about 3,000ha of cultivated land, using the equipment and materials granted by the Government of Japan under the KR-2 grant aid in order to facilitate the deep tubewell

irrigation program aiming at increasing agricultural production and improving income and living standard of the rural people in this area. In reply to this request, the Government of Japan dispatched a preliminary study mission of JICA to Nepal from August to September 1986 and confirmed the strong desire of HMGN for the implementation, the executive organization of HMGN and the significance of the Project and judged that the Project would have the possibility of implementation from the technical and economic points of view. Based on the results of the preliminary study, JICA sent a basic design study mission headed by Mr.Masanori Furuya (an official of Grant Aid Division, Bereau of Economic Cooperation, Ministry of Foreign Affairs) to Nepal from 7th January through 6th March in 1987, considering the significance and effect of the construction of deep tubewells and their irrigation facilities which use the equipment and materials granted by the KR-2 aid, and improving the living standard and welfare of the rural people in the project area.

The study mission investigated the hydrogeological conditions by drilling of 4 test borings and the distributions of ground water potential by pumping test of the existing deep tubewells, etc. in the project area, evaluated usability of the deep tubewell construction equipment and materials granted by the KR-2, determined 23 development blocks including topographical survey of 3 blocks, examined present constraints and their solutions, collected the data and information required for the basic design, and carried out the discussions with TIATSP (an executive body of the Project) and the Ministry of Agriculture (a superintendence ministry of the Project).

The main works carried out by the basic design study mission in Nepal were as follows:

(1) Explanation of Inception Report to and discussion with HMGN officials concerned;

(2) Preparation of minutes of discussions between the mission and HMGN;

(3) Collection and analyses of the data and information required for the basic design;

(4) Site investigation to grasp the present condition of the project area;

(5) Four (4) numbers of test boring;

(6) Topographic survey of 3 development blocks and preparation of the topographical maps (scale 1/ 1,000); and

(7) Confirmation and discussion on the scope of the project requested by HMGN.

The member list of the basic design mission, work schedule, the list of the collected data, the minutes of discussions, the list of the Government officials with whom the basic design mission discussed in Nepal and the list of counterparts of HMGN are attached as Appendices.

Based on the results of the investigation and survey in Nepal mentioned above and the consective home analysis works in Japan, the Basic Design Study Team prepared a draft final of the basic design report containing the background of the Project, the outline of the project area, the scope and components of the Project, the basic design of the facilities, the implementation plan of the Project, the plan of the basic design study-phase II , and the conclusion and recommendations. For the purpose of explaining the draft final report to and discussing with the officials concerned of HMGN about its contents, JICA sent a draft final explanation mission headed by Mr. Masanori Furuya (Ministry of Foreign Affairs of GOJ) to Nepal from 29th May through 5th June in 1987.

This basic design report is completed in the form of finalizing the draft final report based on the comments given by HMGN side in the discussions mentioned above.

2. BACKGROUND OF THE PROJECT

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2.1 National Development Plan

2.1.1 General situation

The Kingdom of Nepal is a land-locked country bordered by Tibet in the north and by India in the south, situated at latitude 26°–30° N and longtitude 80°–88° E. The area of the country is about 150,000km^2, about 1.9 times size of Hokkaido, stretching about 900km in an east-west direction and only about 200 and tens km in south-north direction even at the widest point. Located in the southern slopes of the Himalayan Mountains, the difference of elevation from north to south is very big and the land where people live slopes sharply from 4,000m in the mountain area to 100m on the Terai plain. There is also a huge difference in rainfall between the mountain area and the west (400–600mm per year), and that of the Terai plain (1,300mm per year), as well as equally different agricultural styles.

As for the land utilization, 18% is cultivated land, 38% forest and 44% grass land, mountain area and unutilized land. The survey in 1980 indicates great increase of cultivated land and a corresponding decrease in forest.

Nepal people generally consist of the Indian Nepalee called "Madisi", the natives of Terai, the Parbate (native Hindu Nepalee), the Newar people, the natives of Himalaya and the Tibet people. The majority of the people (89.5%) are Hindu and the national religion is Hinduism. The present King's Family opened the country of Nepal under the royal government in 1951, overthrowing General Rana's dictatorship by a coup. From then to 1960, the form of government was by a political party cabinet system, but in December 1960 a panchayat system was adapted. The Rashutra Panchayat consists of 75 district panchayat members elected in each panchayat by villagers, and the members appointed by the King. Political party activities are not allowed at present.

Nepal is an agricultural country, where the production of agriculture, forestry and fishery represents 62% of GDP(Gross Domestic Products) and that of industry only 4.6%. 89.9% of the people are engaged in agriculture, forestry and fishery. The annual income per capita is estimated to be 172 US dollars in 1982, showing Nepal to be one of the poorest countries in the world. 10% of higher income level people generate 46.5% of the total income of the country indicating the great difference of income among the people. Nepal carried out its first to 6th five year plans from 1956 to 1985 and this year is the second year of the 7th five year plan (1986-90). Since the fourth five year plan (1970-75), administrative organization has been improved step by step and development investment has begun to increase along with increasing economic cooperation funds from foreign countries.

Since the fourth five year plan, the government has made efforts to promote economic development with target of a 4.0–4.3% annual average growth rate of GDP. The actual improvement in GDP was 2.3% annual average growth rate up to the fifth five year plan and 4.4% in the sixth five year plan. As the population growth rate at present is 2.7%, the per capita income increase is 1.7%. The development efforts up to now have gotten some achievements in some sectors, for example, increases of paddy and wheat product in an agricultural field and a remarkable increase of electric supply capacity. As for the road network needed for activating national economy, trunk roads constructed step by step have made domestic transportation of materials easy. In educational and

medical sectors, the construction of schools and hospitals was increased, though those substances are still in problem.

The revenue of government finance of Nepal greatly depends on customs and sales taxes. Imports are increasing year by year according to the promotion of developments, however exports are decreasing due to the increase of domestic demand of agricultural products, which are tradittionally main export articles. The unfavorable balance of trade reached about US$ 300 millions in the fiscal year 1984/85.

2.1.2 National development plan

Nepal is presently under its Seventh five year plan. Reviewing the Sixth plan, the challenges of the Seventh plan were given as follows:

(1) To narrow the gulf between planning and implementation, between word and deed, and to translate vision into reality;

(2) To focus the attention and endeavours of the nation on the tasks of increasing production and employment opportunities, and providing for the minimum basic needs of the common man as laid down so clearly in the Sixth plan;

(3) To build up the productive capabilities of the economy by developing the land and water resources of the country, which form the physical endowments of the nation;

(4) To devote proper attention to conserving and expanding the natural wealth; and

(5) To take steps to tackle the problems of an expanding population.

Further, from the strategical points of view, those challenges should be followed by severe selection of the projects and concentration of investments on higher priority projects to make best use of scarce funds and resources. The objectives of the Seventh five year plan, as same as for the Sixth plan, are:

(1) To increase production more quickly;

(2) To increase opportunities for productive employment; and

(3) To meet the minimum basic needs of the people.

The seventh five year plan aims at raising the GDP by 4.5% per annum. In order to achieve such growth rate, the agriculture sector is to be increaed by 3.5% and non-agriculture sector, by 5.7% annually, which result in increase of per capita income of 1.8% per annum. The total investment in the Seventh plan is estimated at Rs.51,410 million, of which 46 percent is provided by non-government sectors (private and panchayat sectors) and Rs. 29,000 million, by government sector.

Of the government outlay (Rs.29,000 million), about 71% is covered by the foreign aids and the remaining 29% (Rs.8,520million), by the government fund. The source of the government outlay is as follows.

Source of the Government Outlay in the Seventh Plan

(1984/85 constant prices)

	(in million rupees)
Surplus of revenue	3,090
Revenue	(22,060)
Regular expenditure	(18,970)
Additional financial resources	1,930
National bonds	3,500
Bank	(2,500)
Non-bank	(1,000)
Foreign aid	20,480
Total	29,000

Source: The Seventh Plan (1985-1990), HMGN, NationalPlanning Commission, June 1985

In the following table, the first priority for expenditure will be placed on the agriculture-irrigation sector, secondly on the industry, mining & power sector and thirdly on the transportation and communication sector.

Allocation of Total Development Outlay in the Seventh Plan
(At 1984/85 Constant Price)

(Million rupees)

Sector	Public Sector	Panchayat Sector	Private Sector	Total Development Outlay	Percentage
Agriculture, Irrigation and Forest	8,380	550	8,350	17,280	34.3
Industry, Mining & Power	7,040	30	3,370	10,840	21.5
Transportation and Communication	5,130	600	1,530	7,260	14.4
Social Service	6,450	820	7,760	15,030	29.8
Total	27,000	2,000 [1]	21,410 [2]	51,410	100.0

Note 1) Includes Rs.1,000 million development assistance from HMGN to Panchayats.
2) Includes total financial assistance of Rs.1,000 million that is to be distributed by HMGN.

Source : The Seventh Plan (1985-1990), HMGN, National Planning Commission, June 1985

Breakdown of the development expenditure by the Government is as follows.

Allocation of Development Expenditure in the Government Sector
(at 1984/85 prices)

(in million rupees)

Items	Amount	Percentage
A. Agriculture, Irrigation and Forestry	8,875.9	30.6
1)Agriculture	3,983.0	13.7
2)Irrigation	3,296.3	11.4
3)Land reforms	27.2	0.0
4)Cooperatives	17.7	0.0
5)Survey	202.4	0.8
6)Forestry	1,257.0	4.3
7)Resettlement	41.0	0.2
8)Meteorology	52.3	0.2
B. Industry, Mining and Electricity	7,546.5	26.0
1)Industry	208.3	6.9
2)Cottage indnstry	399.5	1.4
3)Mining	128.0	0.4
4)Electricity	4,812.7	16.6
5)Commerce	80.2	0.3
6)Labour	33.4	0.1
7)Tourism	44.0	0.3
C. Transport and Communication	5,132.5	17.7
1)Transport	4,594.8	15.8
2)Communication	537.7	1.9
D. Social Services	7,329.7	25.3
1)Education	3,010.2	10.0
2)Health	1,337.0	4.6
3)Drinking water	989.0	3.4
4)Panchayat	1,741.2	6.0
5)Housing and urban development	158.1	0.5
6)Information and publicity	16.1	0.1
7)Social welfare	78.1	0.3
E. Others	115.4	0.4
Total	29,000.0	100.0

Source : The Seventh Plan (1985 - 1990), HMGN, National Planning Commissiom, June 1985

The target of agricultural production of major crops in the Seventh Plan is as shown in the following tables.

Target of Agricultural Production of Major Crops in the Seventh Plan

(in thousand metric tons)

Crops	Estimated situation of base year 1984/.85	Situation at the end of the Seventh Plan	Growth	Growth in percent
Foodgrains	4,314.00	5,361.00	1,047.00	24
Pulses	88.00	95.00	7.00	8
Cash crops				
Sugarcane	500.00	800.00	300.00	60
Tea	0.900	1.569	0.669	74
Oil seeds	77.00	95.00	18.00	23
Cotton	1.70	16.00	14.30	841
Potatoes	409.00	521.00	212.00	27
Fruits				
Other fruits	298.00	383.00	85.00	28
Citrus fruits	45.00	79.00	34.00	76
Vegetables	742.00	870.00	128.00	17
Fish	6.20	8.30	2.10	34
Milk	705.00	842.00	137.00	19
Milk products	29.00	47.00	18.00	62
Meat	139.00	173.00	34.00	24
Eggs (million pieces)	210.00	232.00	22.20	11

Annual Growth Rate of Major Agriculture Crops

Crops	Weight base year 1984/85 (100)	Estimate of production		Production index 1988/89	Annual growth
		1984	1988/89		
		metric tons			
Foodgrains	83.720			122.13	4.10
Paddy	43.023	2,733,000	3,400,000	124.41	4.50
Maize	20.930	843,000	916,000	108.66	1.70
Wheat	11.628	600,000	900,000	150.00	8.40
Millet	6.976	115,000	120,000	104.35	0.90
Barley	1.163	23,000	25,000	108.70	1.70
Cash Crops	16.280			128.92	5.20
Sugarcane	1.163	500,000	800,000	160.00	9.90
Mustard seed	4.651	77,000	95,000	123.38	4.30
Tobacco	1.163	7,000	8,000	114.29	2.70
Jute	2.236	33,000	45,000	136.36	6.40
Potatoes	6.977	409,000	521,000	127.38	5.00
All major crops	100.000			123.24	4.30

2.2 Agricultural Situation

The agriculture sector accounted for almost 60-62% of gross domestic product (GDP) during the five years (1979/80-1983/84), engaging more than 80% of the whole population, and is still the biggest industry in support of the national economy in this country which has no other major sectors. Thus the economic growth of Nepal greatly depends on the growth of agriculture.

1) Land use

According to the Seventh Plan, the present land use of the country is as follows.

Type of Land Use	Area (in million ha)	Percent of Total Area
Agriculture area	2.65	18.0
Forest area	5.53	37.6
Himali area	2.25	15.3
Grazing area	1.98	13.4
Water area	0.40	2.7
Habitation area and roads	0.10	0.7
Others (barren land, land slide, etc.)	1.80	12.30
Total	14.71	100

2) Agricultural production

Agricultural products (including livestock, forestry and fishery) in 1983/84 reached 62% of GDP equivalent to Rs.22,100 million, and main crop is paddy which accounted for more than 60% of total grain production. However, the scale of paddy production is so unstable that the production in 1982/83 and 1983/84 were 1.83 million ton and 2.76 million ton, respectively, which makes national food balance and economy unstable.

The recent production and area of major crops in Nepal are as follows:

Production and Area of Major Crops

(Production : 1,000ton)
(Area : 1,000ha)

		1981/82	1982/83	1983/84	1984/85
1. Paddy	Production	2,560	1,832	2,757	2,709
	Area	1,297	1,264	1,334	1,377
2. Maize	Production	752	718	761	820
	Area	475	510	504	579
3. Wheat	Production	526	656	634	534
	Area	400	483	472	452
4. Millet	Production	122	121	115	124
	Area	122	129	124	134
5. Barley	Production	23	21	22	24
	Area	27	24	25	28
6. Potato	Production	320	373	383	420
	Area	52	59	59	66
7. Sugarcane	Production	590	616	509	408
	Area	25	25	23	17
8. Oil seed	Production	79	69	73	84
	Area	114	110	110	128
9. Tobacco	Production	5	6	7	6
	Area	7	8	9	9

Source : Statistical Pocket Book, Nepal, 1986

3) Land holding

Personal land holdings in Nepal are increasing in number and area year by year as shown in the following tables.

Number of Holdings by Tenure

(Unit : %)

Tenure	1961/62	1971/72	1981/82
Owned	59.64	81.01	90.48
Rented	7.17	4.38	1.34
Owned-Rented	33.19	14.61	8.19
Total Number	1,518,002	1,707,312	1,185,732
Percent	100	100	100

Source : A Comparative Study of the National Sample Censuses of Agriculture of Nepal, 1986

Area of Holdings by Tenure

(Unit : %)

Tenure	1961/62	1971/72	1981/82
Owned	51.84	73.58	86.86
Rented	9.79	6.48	1.45
Owned-Rented	38.36	19.94	11.89
Total Number	1,685,425	1,654,023	2,463,717
Percent	100	100	100

Source : A Comparative Study of the National SampleCensuses of Agriculture of Nepal, 1986

Also, the number and area of holdings by size are as shown in the following table.

Cumulative Percentage Distribution of Number and Area of Holdings by Size

Size of holdings (Hectare)	1961/62				1971/72				1981/82			
	No. of holdings		Area of holdings		No. of holdings		Area of holdings		No. of holdings		Area of holdings	
	Cum. No. (000)	Cum. %	Cum. No. (000)	Cum. %	Cum. No. (000)	Cum. %	Cum. No. (000)	Cum. %	Cum. No. (000)	Cum. %	Cum. No. (000)	Cum. %
<0.5	851.8	56.06	200.1	11.88	1,070.5	62.69	227.9	13.78	1,099.7	50.29	162.0	6.57
0.5<1.0	1,137.7	74.90	405.1	24.03	1,335.1	77.56	428.6	25.91	1,455.1	66.59	426.9	17.33
1.0<2.0	1,318.2	86.82	664.1	39.40	1,552.4	88.62	715.5	43.26	1,834.1	83.94	917.3	37.23
2.0<3.0	1.397.6	92.03	861.0	51.09	1,612.0	93.65	936.5	56.62	1,991.1	91.12	1,296.9	52.64
3.0<4.0	1,439.0	94.80	1,006.4	59.71	1,651.5	95.95	1,078.4	65.20	2,068.3	94.64	1,563.4	63.46
4.0<5.0	1,462.3	96.31	1,111.6	65.95	1,671.8	97.13	1,172.0	70.86	2,110.8	96.56	1,752.6	71.13
5.0<10.0	1,502.3	98.95	1,387.6	82.33	1,708.5	99.26	1,427.6	86.31	2,170.9	99.31	2,141.3	86.92
≧10.0	1,518.0	100.00	1,685.4	100.00	1,721.2	100.00	1,654.0	100.00	2,185.7	100.00	2,463.7	100.00

Source : A Comparative Study of the National Sample Consuses of Agriculture of Nepal, 1986

The number and area of holdings planted with major cereal crops are summarized in the following table.

Number and Area of Holdings on Major Cereal Crops

Items	1971/72 (1)	1981/82 (2)	(2)/(1) (%)
Paddy			
Number of holdings	1,202,911	1,035,036	86.04
Area of holdings (ha)	995,071	1,394,123	140.10
Average area (ha)	0.83	1.35	162.65
Wheat			
Number of holdings	827,060	666,739	80.62
Area of holdings (ha)	255,747	389,172	152.17
Average area (ha)	0.31	0.58	187.10
Maize			
Number of holdings	1,177,739	846,525	71.87
Area of holdings (ha)	376,687	522,469	138.70
Average area (ha)	0.32	0.62	193.75
Millet			
Number of holdings	861,237	709,046	82.32
Area of holdings (ha)	140,749	154,420	109.71
Average area (ha)	0.16	0.22	137.50
Barley			
Number of holdings	289,884	183,834	63.34
Area of holdings (ha)	49,924	27,689	55.46
Average area (ha)	0.17	0.15	88.24
Buck Wheat			
Number of holdings	128,256	48,030	37.45
Area of holdings (ha)	17,253	10,814	55.46
Average area (ha)	0.13	0.23	176.92
All Cereals			
Number of holdings	4,487,987	3,489,210	77.76
Area of holdings (ha)	1,835,431	2,498,687	136.14
Average area (ha)	0.41	0.72	175.61

2.3 Irrigation Situation

The irrigation program by the government in Nepal started in 1956, the first year of the first five-year plan. In 1960s, the main program was the construction of main canals along the boundary of India and their seconday canals in the Terai plain (the former program of Narayani irrigation project, Sunsari Morang irrigation project, etc.) financed by India due to the necessity of water control of India, and in 1970s, the major programs were the maintenance of the above canals and the construction of secondary and tertiary canals. As the result, about 200,000 ha was irrigated up to 1980, the final year of the fifth five-year plan. Further, it is estimated that the irrigation facilities constructed during the Sixth Plan (1980-85) enabled to irrigate about 140,000 ha of arable lands. However, it is said that the irrigation facilities completed by 1980 have not functioned well because of mis-design and construction, insufficient agricultural development concerned, incomplete maintenance and operation, etc.and the actual irrigation area is only 100,000ha at present.

On the other hand, the irrigation facilities constructed by farmers themselves by 1980 are estimated to cover about 40,000 ha though, almost of such facilities have a function that supplies water from river to field only in the rainy season and don't contribute to the increase of production in the dry season.

Under the background of irrigation situations described above, one of the most important targets in the Seventh Plan (1985-90) is placed on the extension of 235,500ha of irrigation area, of which the breakdown is as follows :

Target of Extension of Irrigation Area in the Seventh Plan

Description	Ministry of Water Resources	Ministry of Agriculture
On-going Projects	106,003ha	
New Projects	29,490ha	
Small Scale Irrigation		50,000ha
Tubewell Irrigation		50,000ha
Total	135,493ha	100,000ha

The distribution of 135,493ha, proposed by the Ministry of Water Resources, is shown as follows by region and by topography, which indicates the priority is put on the central region where Janakpur zone belongs to.

Region	Terai Plain (ha)	Hill Area (ha)	Total (ha)
Eastern	39,235	2,385	41,620
Central	34,500	2,390	36,890
Western	8,666	5,227	13,893
Midwestern	5,500	1,560	7,060
Farwestern	10,950	3,480	14,430
Undecided	21,600	0	21,600
Total	120,451	15,042	135,493

The distributions of small scale irrigation area and tubewell irrigation area to be propelled by the Ministry of Agriculture are not clear though, the priority will be put on the on-going tubewell irrigation projects in Janakpur, Narayani and Lumbini zones in the Central region.

As for irrigation facilities, all the canals (from main canal to tertiary canal) are earth canals, and smaller canals and ditches below tertiary are usually constructed by beneficiary farmers. Related structures such as barrages, diversion works, siphons, bridges, etc. are made with concrete and other structures are generally constructed by brick masonry.

2.4 Trend of Foreign Aid

Nepal is one of the least level developing countries (LLDC), which is shown by the social and economic indxes of the country data attached to this report, and has therefore been made light for economic cooperation by donor countries and agencies since 1951, an opening year of Nepal to foreign countries. Per capita aid receipts of Nepal is about 12 US dollars in 1984/85, which is the second rank position together with Bangradish next to Sri Lanka (about 25 US dollars).

The yearly aid receipts of Nepal amounted to about 13 million US dollars during the first five year plan (1956 - 61) and after 1970, when donor systems by developed countries were strengthened and economic cooperations by international agencies became active, the aid amount has been increased rapidly, and reached 24 million US dollars in 1970, 175 million US dollars in 1982/83 and 186 million US dollars in 1984/85.

With the progress of the economic cooperation, not only the increase of aid amount but also form of aid, allocation to aid sectors and member of donor countries have gradually transformed. As for the form of aid, both grant aid and technical cooperation are major forms for the initial aid stage though, in 1970s, in the cooperations by international agencies active percentage of loan to economic cooperation had increased, and reached 44 percent in 1980/81 and 56 percent in 1984/85. Regarding aid sector, road, electricity, agriculture and irrigation have been put importance on since the beginning of aid and that is not greatly changed today. However, the aid-receiving policy of Nepal was changed in and after 1977, and majority of aid has been allocated to the construction of rural roads connecting with trunk roads, village roads and the rehabilitation of existing roads in road sector and the construction of power distribution network in electricity sector and the construction of tertiary, quartenary canals and medium - small scale projects in irrigation sector. As for the member of donor countries, India, China and U.S.A.had occupied a big portion of the total aids (90% of the aid's amount) in the initial stage, however in 1970 s the aid amount of China and U.S.A. decreased and that of IDA, ADB, UN group and Japan increased largely. In 1982/83, IDA occupied 19% of total aid and ADB 18%, and in the bilateral aid, Japan occupied 14% of total aid and ranked for the first position, India 12% for the second and China 7% for the third.

Japan's economic cooperation, ranked for the first position among bilateral aid countries, is contributing to social - economic development of Nepal, especially in the construction of Kulekhani power station, Tribhuvan hospital and power distribution network in Kathmandu, Janakpur zone agriculture development project, reception of trainees to Japan and technical cooperation by Japanese experts and overseas cooperation volunteers.

With increase of aid amount, Nepal's capacity for absorbing foreign aid is coming to constraint in terms of lack of domestic fund, lack of man power such as site engineers, supervisors, governmental staffs, etc. for project execution and increase of repayment following to the increase of loan portion. HMGN is therefore making effort to train man power by establishing various training centers and donor countries and agencies are also cooperating to educate man power by financing to education and technical training projects and through the on-the-job training, etc., and HMGN is requested by donors to make efforts to increase exports in order to correspond with increasing repayment of loan.

2.5 Details of the Project Requested by HMGN

His Majesty's Government of Nepal (HMGN) requested the Government of Japan in April 1986 to provide the former with a grant aid to construct 150 deep tubewells and the respective irrigation facilities covering about 3,000 ha in tatal using the equipment and materials granted under a KR-2 aid of the latter in1982 and 1983, for the purpose of 1) extension of irrigable area, 2) Stable increase of agricultural products, 3) increase of farmers' income and 4) improvement of farmars' living standard and social walfare in the Terai Plain in Janakpur Zone.

The details of the Project requested by HMGN for the grant aid mentioned above are summarized as follows.

1) Basic plan

(1) Objectives of project

- Extension of irrigation area
- Stable increase of agricultural products
- Increase of farmers' income
- Improvement of farmers' living standard and social welfare

(2) Project area

Terai Plain in Janakpur Zone

(3) Component of project

- Utilization of the deep tubewell construction equipment and materials provided under the KR-2 in 1982 and 1983
- Construction of 150 deep tubewells and their respective irrigation facilities covering about 3,000ha of arable land in total

2) Development blocks

(1) Development blocks and their priority

- Number of development blocks : 30 blocks
- Gross area of one development block : 800ha
- Number of development blocks by district and by priority are as follows :

District	Priority			Total
	1st	2nd	3rd	
Dhanusha	7	2	3	12
Mahottari	3	3	5	11
Sarlahi	5	0	2	7
Total	15	5	10	30

3) Groundwater development plan

(1) Deep tubewell plan

150 deep tubewells are to be constructed for 30 development blocks (5 tubewells for one development block).

(2) Equipment and materials plan

The main KR-2 equipment and materials which could be provided by HMGN are as follows:

(A) Deep tubewell equipment and materials

- Rig machine for drilling	7	units
- Air compressor (10.5m^3/sec)	7	units
- Submersible pump (for pumping test)	10	units
- DC engine welder	7	units
- Casing pipe (14")	7,500	m
- Casing pipe (8")	10,500	m
- Johnson type screen (8")	7,500	units
- Reducer (14" to 8")	150	units
- Tricone bit ($17\frac{1}{2}$")	60	units
- Tricone bit ($14\frac{3}{4}$")	105	units
- Turbine pump (60ℓ/sec.)	75	units
- Turbine pump (45ℓ/sec.)	75	units
- Truck (4 ton with 3 ton crane)	7	units

- Water tank lorry ($4m^3$) 5 units
- Fuel tank lorry ($4m^3$) 1 unit
- Pick-up truck (1 ton) 7 units

(B) Construction equipment

- Bulldozer (11ton) 5 units
- Motor grader (3.1m) 2 units
- Vibratory road roller (4ton) 3 units
- Tractor with trailer (2ton) 1 unit
- Dump truck (3.5ton) 5 units
- Concrete mixer ($0.5m^3$) 4 units

(C) Vehicles

- Jeep (wagon type) 3 units

However, according to the inventory survey on the KR-2 equipment and materials carried out in the basic design study, the quantities mentioned above are not necessarily correct (Refer to Section 6.1.5).

4) Irrigation and drainage plan

(1) Principle

① Irrigable area to be covered by one deep tubewell is 20ha on an average.

② Location of wells and layout of main canals are decided in the detailed design stage.

(2) Irrigation facilities

① Pump house : one for each pump,
: concrete made one storied house with
: a space of $17.64m^2$ (4.2m×4.2m)×2.7m

② Water supplying pipe : 500m long per each pump (PVC 8" and 6")

③ Operator house : one for each pump
concrete made one storied house with
a space of $17.28m^2$ (4.8m×3.6m)×2.4m

④ Main canal and related structures

- Main canal : 500m long concrete canal for each pump, canal section of $0.315m^2$ (0.525m×0.6m)
- Siphon : 2 siphons to each main canal, concrete made
- Aqueduct : 1 aqueduct to each main canal, concrete made

- Drop : 2 drops to each main canal, concrete made
- Turnout : 20 turnouts to each main canal, concrete made

5) Administration

(1) Responsible government office : Department of Agriculture, Ministry of Agriculture

(2) Executive agency : TIATSP (Tubewell Irrigation Agriculture Training and Services Project)

6) Allocation of the project cost

(1) Japan's responsibility

① Construction of deep tubewell, pump house and operator house, and installation of pump

② Construction of main canal and its related structures

③ Temporary access road for construction (construction of a new temporary access from existing road to pump house and canals, and improvement of existing road)

(2) Nepal's responsibility

① Construction of branch canals (earth canal)

3. THE PROJECT AREA

3. THE PROJECT AREA

3.1 General Condition

3.1.1 Location and geography

The Janakpur Zone where the study area is included is located in the Central Development Region, and is bounded by China in north, India in south, Bagmati Zone in north-west, the Narayani Zone in south-west and the Sagarmatha Zone in east. The major rivers in the zone are the Sun Koshi river, the Bagmati river forming the boundary with the Narayani Zone and the Kamala river forming the boundary with the Sagarmatha Zone.

The study area is located in the Terai plain of the Janakpur Zone and covers the Dhanusha, Mahottari and Sarlahi Districts. The area is measured to be about 2,410km^2 equivalent to about 70% of 3,441km^2, total area of these districts, and the gross farm land is about 195,000ha.The study area has a gentle slope from north (EL 210m of foothill of the Himarayan range)to south (EL 60m of the Indian border).

The rivers running north to south dissect the plain and form complicated topography. Janakpur, a commercial center of the zone, is located in the study area, and it takes about 8 hours by road (about 390km in road distance, but about 150km in a straight line) and about 35 minutes by air from Kathmandu.

Tubewell Irrigation Agriculture Training and Services Project Center (TIATSP Center, previously called JADP Center) is situated about 19km north from Janakpur along the road connecting among the East-West Highway, Janakpur and Jaleswar.

3.1.2 Socio-economy and industry

1) Population

The present population and its density in the 3 districts estimated from the annual average growth rate of population (2.66%) in the census of 1981 are indicated in the following table, though the real figures will be over these estimates due to rapid flow of population in the recent years from the mountain area to the Terai plain.

District	Area(km^2)	Population (estimated)	Density of Population (estimated)(perkm^2)
Dhanusha	1,180	519,000	440
Mahottari	1,002	433,000	430
Sarlahi	1,254	478,000	380
Total	3,436	1,430,000	416

2) Administrative unit

The smallest administrative Unit in Nepal is a Village called "Panchayat"and there exist 68 Panchayats in Dhanusha district, 55 Panchayats in Mahottari district and 59 Panchayats in Sarlahi distrisct. A Panchayat consists of 9 Wards in principle and a leader of Panchayat is elected by the public election. However, a chief of district and a governor of zone are appointed by the Kingdom Assembly.

There exist 20 city/town areas called "Town Panchayat" in Nepal, and there is only one Town Panchayat (Janakpur, estimated population is about 42,000, where the Dhanusha district office is placed) in Janakpur Zone. The Janakpur Zonal Office and Zonal Assembly are Placed in Jaleswar, located near the border of India, where the Mahottari district office also exists.

3) Economy and industry

The major industries in the project area are agriculture and agro-industry. The agricultural products are selfsufficient and some surplus products are shipped to Kathmandu or other major towns. Sugar mill, tobacco factory, rice mills and other small scale cottage industries are comparatively developed. As for the construction materials, there are about 10 brick factories in the project area, and almost all the construction materials such as cement, reinforcement bar, concrete pipe, timber, etc. and the drilling materials such as bentonite, barite, CMC, etc. are available in Janakpur.

4) Infrastructure

(1) Road:

The East-West Highway connecting Jhapa district of the East Development Zone and Banke district of the West Development Zone runs from east to west in the northern part of 3 districts along the foot of churia hills. The highway branch goes southward from Dhalkewar in Dhanusha district to Jaleswar in Mahottari district and reaches to Indian border. Besides, a gravel paved road connecting Nawalpur and Malangwa runs southward in the central part of Sarlahi district, which is passable by vehicles in the rainy season, though the maintenance condition is not so good. Furthermore, 4 logging roads (unpaved) run from north to south crossing the highway, but there is no connecting road from east to west each other. Due to the said condition, the deep tubewell irrigation development in the areas where locate far from the roads, will take a considerable period because of construction of temporary roads.

The road from Kathmandu to Janakpur via Daman Pass is shorter in distance though, the travels are often prevented by the falling or landslide of slopes in the mountain areas. Therefore, the highway going a long way via Bharatpur and Hetauda is usually utilized, though it takes 7 to 8 hours by car.

(2) Air route:

The regular flight is available between Kathmandu and Janakpur on every Monday ,Wednesday and Friday and takes 35minutes. However, in rainy days, flights are often canceled because of visual flying.

(3) Railway:

Janakpur-Janagar railway (52km long) is utilized for import and export from and to India though,this will not become a transportation measure of the materials for the project implementation because of local line.

(4) Electricity:

There are two sources for the electricity utilized in Janakpur Zone at present. One is bought from India (11KV in Malangwa, Sarlahi district and 11KV in Jaleswar, Mahottari district, supplying to Janakpur) and the other is generated by diesel generators in Janakpur (1,360KW).

The transmission line (132KV) along the highway between Biratnagar and Hetauda was completed in 1985, from which the electricity will be available for distribution in the near future. The electricity cost for lifting water from deep tubewell will be lower than fuel cost of diesel engine, which is estimated to be 30 ~ 40% lower. However, there is no plan on electric distribution in the project area at present and the granted diesel engine pumps have to be used for the Project. The utilization of electricity for the project's implementation will therefore be out of scope in this study.

(5) Telecommunication:

Telephone is available in Janakpur city, between Janakpur city and Kathmandu, and between TIATSP and Janakpur city though, the telecommunication network in the project area is not yet constructed. An international call is available at the central telephone office in Janakpur.

A wireless is installed between the TIATSP center and the liaison office set up in the agricuture department in Kathmandu.

(6) Water supply:

For domestic water, dug wells (10 – 20 meters in depth) shared by several families are generally used in the villages in the project area.

3.1.3 Agriculture and irrigation

1) Agriculture

There are much difference in cultivation condition between the mountain area and the Terai plain including 3 districts in Janakpur Zone. The project area consisting of 3 districts, located in the Terai plain, has a superior condition for cultivation compared with the mountain area. The gross area, arable land and rate of arable land are as shown below.

District	Gross Area(ha)	Arable Land(ha)	Rate of Arable Land(%)
Dhanusha	118,000	79,815	67.6
Mahottari	100,200	81,549	81.4
Sarlahi	125,900	52,874	42.0
Total	344,100	214,238	62.2

As for crops, paddy is a main crop in the rainy season and sugarcane, maize,wheat, potato,barley, mustard and tobacco are also widely grown in three (3) districts of the Terai plain. Especially, tobacco is a special product of Janakpur Zone and occupys 54% of the total national product with 3,700ha of cultivated area. Therefore, a tobacco factory in Janakpur is the largest one in Nepal.

The present cropping pattern in the Terai Plain is usually mono-cropping of paddy or paddy-wheat in case of wetland and maize-oil seed or maize-tobacco in dryland and the multi-crop index ranges between 150 and 180 %. The cultivation areas and production of major crops in three (3) districts in the Terai Plain are summarized in the following table.

Cultivation Area and Production of Major Crops

Crop	Year	Dhanusha Dis.		Mahottari Dis.		Sarlahi Dis.	
		Area (ha)	Product (ton)	Area (ha)	Product (ton)	Area (ha)	Product (ton)
Rice(unhusked)	1975/76	58,000	110,200	60,230	110,820	39,230	71,390
	1980/81	54,800	104,200	68,500	122,850	33,680	63,650
	1985/86	52,830	105,660	47,930	95,860	52,900	105,800
Maize	1975/76	6,200	7,470	6,390	8,110	5,470	6,340
	1980/81	3,180	5,290	4,700	7,520	6,870	11,000
	1985/86	3,230	6,450	3,250	6,360	10,360	19,470
Millet	1975/76	1,920	1,550	1,000	1,020	1,050	590
	1980/81	2,730	2,540	1,450	1,360	1,150	1,030
	1985/86	540	500	1,000	800	530	530
Wheat	1975/76	15,895	18,120	12,140	13,839	10,043	12,149
	1980/81	17,940	24,220	14,670	18,340	10,890	14,160
	1985/86	17,750	21,540	16,610	19,930	12,570	16,850

Crop	Year	Dhanusha Dis.		Mahottari Dis.		Sarlahi Dis.	
		Area	Product	Area	Product	Area	Product
Barley	1975/76	280	217	260	210	220	170
	1980/81	870	430	790	400	320	280
	1985/86	510	410	130	120	260	230
Potato	1975/76	460	3,275	480	3,119	490	3,861
	1980/81	310	1,550	450	2,250	240	1,220
	1985/86	400	1,955	610	2,930	880	4,400
Oilseed	1975/76	1,800	846	2,000	1,000	3,500	1,750
	1980/81	2,400	1,680	1,880	1,110	2,790	1,450
	1985/86	2,250	1,130	1,520	910	4,930	2,960
Sugarcane	1975/76	540	8,801	140	2,240	440	7,040
	1980/81	250	5,000	2,080	19,440	530	10,600
	1985/86	800	16,000	550	11,000	1,760	45,760
Tobacco	1975/76	1,340	1,007	1,220	1,008	500	351
	1980/81	1,140	910	1,100	800	1,200	960
	1985/86	1,480	550	830	500	2,060	1,230

Source:Agricultural Statistics of Nepal,1983 and Additional Bulliten of the Left, 1986

2) Surface water irrigation

National level agricultural development projects by surface water irrigation in Janakpur Zone are the following three (3):

(1) Bagumati Irrigation Project

Using the Bagumati river as water resources, the project is to irrigate 5,600ha on the right bank of the said river (Narayani Zone) and 18,500ha on the left bank (Janakpur Zone) and is under construction, aiming at completion in 1990.

(2) Kamla Irrigation Project

Using the Kamla river as water resources, the project is to irrigate 12,500ha on the both banks of the said river (Janakpur and Sagarmatha Zones). The main facilities, completed in 1980 though, don't work sufficiently due to defects of construction and lack of maintenance. The rehabilitation work was done under the finance by Asian Development Bank (ADB), however, at present the irrigation area is about 8,500ha against the target (12,500ha) and the irrigation in the dry season is not practised because of lack of water.

(3) Manusmara Irrigation Scheme

Using the Manusmara river, a branch of the Bagumati river, as water resources, the project is to irrigate 5,200ha on the left bank of said river. The construction completed in 1985, however the real irrigation area is 3,000ha (only 500ha in the dry season).

In all the projects mentioned the above, the canals are of earth lining except partial protection works or lining by wet brick masonry for protecting the canals from erosion and scouring, and commonly the big structures such as head works, diversion works, bridges, siphons, drainage culverts etc. are constructed with concrete and the small structures such as turnouts, culverts, division boxes, etc. are made with wet brick masonry. As for the maintenance roads (farm roads), main roads are almost paved by gravel and branchs are unpaved.

3) Groundwater irrigation

A number of 112 deep tubewells has been drilled by the end of February, 1987 in the Terai Plain in Janakpur Zone. The details are as follows.

Existing Deep Tubewells and Their Utilization in the Project Area

Project	Number	Kind		Utilization			
		Artesian	Pump	Irrigation	Water Supply	Multiple	Unutilized
FAO(Terai ground water study)	6	5	1	5	1	0	0
JADP (IAP) (the Other)	9 15	0 5	9 2	9 1	0 1	0 5	0 8
JADP/ TIATSP(KR-2 materials)	26	2	3	0	0	2	24(3)
(Japanese contractor)	15	0	15	0	0	0	15(15)
Ground-water irriga-tion(Ministry of Water Resources, Irrigation Department)	26	1	4	3	0	1	22(1)
Small scale irrigation (Ministry of Water Resources, Irrigation Department)	11	0	11	11	0	0	0
Sugarcane factory	2	0	2	0	2	0	0
Water Supply Department	2	0	2	0	2	0	0
Total	112	13	49	29	6	8	69(19)

Note: (1) Bracketed figures mean the number of wells with canals completed or under construction, which will be utilized for irrigation in the near future.
(2) Multiple utilization means a combined use for irrigation, fishpond, drinking / living, etc.
(3) Almost of the unutilized wells seem to have so small yields that the pumps cannot be installed.

The deep tubewells listed the above are concentratively located in the east of Mahottari district, the west of Dhanusha district and in the south-west of Sarlahi district though, the yields and irrigation areas are not grasped clearly. However, nine (9) deep tubewells of IAP, completed under the technical assistance and supervision by Japanese experts assigned under the technical cooperation program of Japan, have irrigated about 420ha through about 10.6km of canals since 1977. All the tubewells were of artisian for the five (5) years after construction and equipped with diesel engine type volute pump in 1982/83. The present yield is about 35 ℓ/sec/well on an average.

In the central part of 3 districts in the Terai plain, extending from east to west like a belt (about 10km from south to north, about 60km from east to west, the border of north is about 10km south from the East - West Highway), approximately 2,000 shallow tubewells were constructed and it is reported that the yield is 7 to 15 ℓ/sec/well and the total irrigation area is about 14,000ha, however, it is unclear that one well actually irrigates 7ha on average, since irrigation canals are not constructed yet.

3.2 Natural Condition

3.2.1 Meteorology and hydrology

1) Meteorology

The climate in Janakpur Zone varies largely according to the ground elevation and is classified into the following three (3) categories;

① Low temperature mountainous climate zone in the Himalayan Range

② Temperate climate zone at the foot or hilly area of the Himalayan Mountains

③ Tropical or subtropical climate zone in the Terai plain

The climate in the foot or hilly area and the Terai plain is cleary divided into the rainy season (5months, from the end of May to the beginning of October) and the dry season (7months, from the mid. October to the mid. May). More than 80% of the annual rainfall concentrate in the rainy season from June to September in the hilly and plain area. The annual average rainfall and annual average maximum and minimum temperature in Janakpur Zone are as follows.

Climate Zone	Annual Average Rainfall (mm)	Annual Average Temperature (°C)	
		Max.	Min.
A. Tropical/Subtropical Terai Plain (Dhanusha,Mahottari,Sarlahi)	1,300	30.3	19.3
B. Subtropical/Temperate Hilly area (Sindhuli)	1,420	28.3	15.3
C. Temperate Hilly area (Dolakha)	2,040	19.0	8.0

The meteorological data of Hardinath Farm bordering the south - east of TIATSP center are given in the following table.

Meteorological Data of Hardinath Farm
(Average in 1971 – 82)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/ Average
Average Rainfall (mm)	10.6	11.8	14.4	44.3	89.2	231.4	377.0	285.1	159.8	62.9	4.9	3.7	1,295.0
Temperature(°C)													
Max.	23.6	26.0	32.5	37.2	36.6	34.7	32.5	32.7	32.4	31.8	29.8	25.1	
Min.	8.7	9.9	13.9	18.3	17.6	18.4	20.3	24.3	21.0	13.2	9.2	9.2	
Ave.	16.4	18.3	22.8	27.4	28.5	29.4	28.8	28.7	28.2	26.3	22.2	17.6	24.6
Humidity (%)	78	71	55	51	64	76	82	83	85	81	76	77	73
Sunshine (hr)	8.1	8.6	9.2	9.6	9.7	5.9	6.4	7.7	6.7	8.4	8.9	8.5	8.1
Wind Velocity (km/hr)	3.3	4.2	5.5	8.7	10.6	10.4	9.9	8.2	6.6	3.5	2.6	2.5	6.3
Evaporation (mm/day)	1.9	2.7	4.7	6.7	6.9	5.9	4.8	4.6	4.1	3.2	2.7	2.2	4.2

In the rainy season, vehicle traffic, construction of temporary access road, earthfilling of canal embankment, etc.are hardly possible. The construction period of the Project is therefore limited to 7months from December to June of the next year. Especially in the south of the project area, there are many mal-drainage fields where have stagnant water until November, which results in poor accessibility and difficult construction in November.

2) Hydrology

The major rivers in Janakapur Zone are the Tama Koshi river flowing down southward in Dolakha district, originating from the Himalayan Mountains, the Likhu river flowing down southward along the boundary between Ramechhap district and Sagarmatha Zone (the above 2 rivers are tributaries of the Sun Koshi river), the Sun Koshi river running from west to east in Ramechhap district, the Bagmati river, the Hardinath river, the Ratu river and the Kamala river originating the hilly area of Sindhuli district. However, discharge records are available only for the Bagmati, the Kamala and the Sun Koshi river. The monthly discharge of the above rivers are extremely decreased in the dry season as shown below. Furthermore, all of other small rivers dry up in the dry season and will be hardly expected for water resources of irrigation in the dry season, unless dams are constructed.

Average Monthly Discharge of 3 Major Rivers in Janakpur Zone

(Unit : m^3)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Bagmati River ∠1	22.5	17.2	16.4	14.8	29.3	263.8	585.8
Kamala River ∠2	0.3	7.8	6.1	5.0	10.7	54.5	169.3
Sun Koshi River ∠3	194.3	164.7	149.8	155.6	241.1	694.8	1,743.1

	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Bagmati River ∠1	546.7	393.4	174.6	47.6	25.4	176.6
Kamala River ∠2	211.4	131.6	58.0	39.9	14.7	59.2
Sun Koshi River ∠3	2,200.4	1,567.9	739.2	363.2	241.7	709.5

Note ∠1 Average discharge of the year 1965 - 75 at Karmaiya (Catchment Area : 2,700 km^2)
∠2 Average discharge of the year 1957 - 69 at Chisapani (Catchment Area : 1,550 km^2)
∠3 Average discharge of the year 1948 - 77 at Kampugaht (Catchment Area : 17,600 km^2)

3.2.2 Topography

Janakpur Zone is topographycally classified into two areas, one is the northern part where is occupied by the Himalayan Mountains and their mountanous hilly area,and the other is the southern part where the Terai plain involves the project area. The Terai plain in Janakpur Zone, extending east-westward with a strip of about 30km wide stretching the Indian border to south, forms a fan-like plain with very gentle slopes from the Churia Hill in north to the Indian border in south.

The land ranges in elevation from about 210m to 60m. From the topographical point of view, the Terai plain is classified into the following four (4) terraces (See Fig. 3.2).

I . High terrace, about 50m high from the Bagmati or Kamala present river bed,

II . Middle terrace, about 20m high from the river bed mentioned above,

III . Lower terrace, about 6 to 7m high from the above- mentioned river bed,

IV . Present flood plain of the Bagmati and Kamala River.

The surface of the high and middle terrace is covered by lateritic soils with brown color and partly used as the materials of brick and pottery.

In the project area, there are many middle and small rivers flowing from north to south and the arable land is longitudinally dissected by those rivers. There exist two major rivers with perennial flow in Janakpur zone. The Bagmati river (an annual mean discharge of 177m^3/sec) running along the western border of Janakpur zone and the Kamala river (do. 59m^3/sec) along the eastern boundary. Besides, many middle or small rivers such as the Ratu, the Marha, the Jim, etc. run in the middle area between the above two large rivers. It is reported that the total average annual discharge of

those rivers is 578m^3/sec though, the flows are hardly seen except the flooding time in the rainy season. Therefore, the seepage water from those river beds seems to be an important resources for recharging groundwater in the plain.

3.2.3 Hydrogeology

1) Outline

The geology in the project area and its surroundings is shown in Fig. 3.1 (Hydrogeological map) and Fig. 3. 2 (Hydrogeological profile) and the stratigraphy is summarized as follows.

Stratigraphy in the Project Area

Formation (thickness)	Geologic age	Facies	Hydrogeology
Recent Deposits	Holocene	Present river deposit Flood plain deposit	Aquifer
	(Quaternary)	(Alluvium) Fan deposit	(G1 - G4)
(170m~300m)	Middle to late Pliocene (Quaternary)	Terrace deposit (Diluvium)	(G5 - G6)
Upper Siwalik (700m)	Pleistocene to early Pliocene (Tertiary - Quaternary)		Aquifer
Middle Siwalik (1,200m)	Pleistocene (Tertiary)		Aquitard
Lower Siwalik (2,000m)	Miocene (Tertiary)	(thrust)	Aquitard
Basement	Pre - Cambrian to Paleozoic.		Aquiclude

(1) Basement rock, which crops out in the northern parts, 30 – 50km far away from the project area, is assumed to be originated materials of the Siwalik Formation and Recent sediments. The geologic age is said to extend from Cambrian to Late Paleozoic, composed of granitic rocks, metamorphic rocks and chart-like rocks of Gondwuna System. Hydrogeologically, this bed is classified into impermeable layer (aquiclude).

(2) Lower Siwalik Formation is distributed to the north of about 12 – 25km far from the project area, mainly composed of lacustrine arkose sandstone, mud stone and shale, classified into an aquitard.

(3) Middle Siwalik Formation is predominant components of the Churia Hills, exposed to the northern border of the project area. Geologically, the formation is dominated by brakish, arkose sandstone, and further, mudstone and shale are commonly seen with partly intercalations of calcareous layer. Generally the beds are weakly consolidated and sandstone is friable. This bed is classified into an aquitard.

(4) Upper Siwalik Formation is composed mainly of silt and sand gravel interbedded with mud and low or unconsolidated bed showing high permeability. The sand and gravel are especially a good aguifer. The conglomerate is chiefly originated from metamorphic rock, granitic rocks and chart - like rock and the gravel shows wide range of size from granule to cobble. This bed is difficult to confirm on the ground because of erosion. There occurs no evidence of exposure of this formation on the surface probably due to erosion.

(5) Recent deposits are composed of the Quaternary terrace sediment of Pleistocene and the alluvium of Holocene, widely distributed from the foot of the Churia Hill to the Terai plain. It is considered that the terrace sediment be formed in the middle to late Pleistocene judging from the lateritic soil condition lying on the top of the bed. This terrace sediment is unconsolidated sand/gravel composed of clay soil, silt and sand/gravel classified into high permeable layer. Alluvium is distributed as fan sediment and flood deposit (present river bed sediment), composed of sand/gravel, sand and clayey soil. The deposits retain great variety of lithology in both directions of south - north and east - west as shown in Fig. 3-2 (2/3).

2) Hydrogeology

In order to grasp the hydrogeological condition of the project area, the following surveys and reviews of the existing data were carried out.

Survey/Study Item	District			Total
	Sarlahi	Mahottari	Dhanusha	
Collecting data of existing deep tubewell (※)	19	32	60	111
Analysis of drill log of deep tubewell (reliable data)	10	26	50	86
Analysis of static water level of deep tubewell (reliable data)	13	23	41	77

Survey/Study Item	District			Total
	Sarlahi	Mahottari	Dhanusha	
Analysis of dynamic water level of deep tubewell (reliable data)	9	16	27	52
Measuring static water level of deep tubewell (by present study)	(1)	(5)	(5)	(11)
Analysis of water quality data of deep tubewell (by present study)	(4)	10(7)	9(6)	36(17)
Continuous pumping test of deep tubewell (by present study)	(4)	(2)	(7)	(13)
Measuring static water level of shallow tubewell (by present study)	(15)	(37)	(22)	(74)
Measuring water quality of shallow tubewell (by present study)	(10)	(11)	(7)	(28)

Note (※) Existing deep tubewells in the project area are as follows :

Project	District			Total
	Sarlahi	Mahottari	Dhanusha	
Minor Irrigation (before1972)	11	0	0	11
FAO Terai groundwater study (1972)	0	3	3	6
JADP (1975-1985)	4	3	17	24
JADP/TIATSP (1985-)	2	0	24	26
Groundwater by DIHM (1983-)	0	26	0	26
KR-2 assistance (1985-1987)	0	0	16	16
Private company (1985)	2	0	0	2
Total	19	32	60	111
Well for water supply	1 (Malangwa)	1 (Jaleswar)		2

The existing deep tubewells are shown in Fig. 3. 3 and the results of continuous pumping test, the data of existing deep tubewells and water quality data of deep tubewells are listed in the tables of 3. 1, 3. 2, 3. 3 respectively. As for the existing shallow tubewells (down to 30m deep), the contour of groundwater level, possible discharge and irrigable area by shallow tubewells are shown in Fig. 3. 4,

and the distribution of pH, electric conductivity and the temperature of water in Fig. 3. 5. Based on the Fig. 3. 4 and 3.5, the shallow groundwater condition is supposed to be as follows:

- In the northern area along the East - West Highway, the groundwater level is deeper than 20m from the ground surface and at some places it is difficult to get even domestic water. The contours of groundwater level are well corresponding with topographical relief.
- The area, where 7-17 ℓ/sec is extractable by shallow tubewells, is distributed in the central part of the project area, and suited to shallow well irrigation.
- The water temperature of the shallow wells ranges from 25 to 26°C in the northern area and 22 to 25°C in the southern area. The values of pH are involved in 5.5 – 6.6 in the north and 7.0 – 7.4 in the south. It is found that the area with low pH extends along the Ratu river basin. The electric conductivity shows low range locally in the north, however significant characteristic is not found.
- The results of the shallow wells study indicates that the shallow groundwater flows generally from north to south, especially main flow direction extends along the Ratu river basin. This presents a very important meaning to estimate the recharge condition for deep groundwater .

The conditions of deep groundwater can be estimated by the groundwater level contour and distribution of pH value of deep tubewells (Fig. 3.6) obtained from existing deep tubewells' data and the electric conductivity and water temperature (Fig. 3. 7) are summarized as follows :

- The ground water level of deep tubewells in the north along the East-West Highway lies 50 – 60m below the ground. The ground water level of shallow tubewells, standing approximately 20m deep from ground surface in this area, is supposed to be the levels in the perched groundwater lying in the shallow subsurface. The ground water level contour of deep tubewell generally corresponds with the present topographical contour line.
- The pH value of deep tubewell water ranges from 6.1 to 7.8 showing higher than that of the shallow tubewell water. It is supposed that the rainfall percolated into the deep aquifer during long time. The distribution of pH values is 6.2 – 6.5 in the north, 7.1 – 7.8 in the south and the highest value is found near Jaleswar, the south of Mahottari district. The distribution of electric conductivity ranges 100μ mho/cm in the north and 400μ mho/cm in the south, and it is found that a tendancy of a low conductivity belt extends southward along the Ratu river basin.
- The water temperatures are in the range of 25 to 27°C in the north, 24 – 25°C in the south, indicating that the deep groundwater flows in from and along the Ratu river.

From the study on the shallow and deep groundwater level and quality mentioned above, it is assumed that the deep groundwater of the project area is not recharged by flowing into east-westward from the deep groundwater underlying the Bagumati and the Kamala river basin but recharged by south-north flow of groundwater and vertical percolation of rainfall.

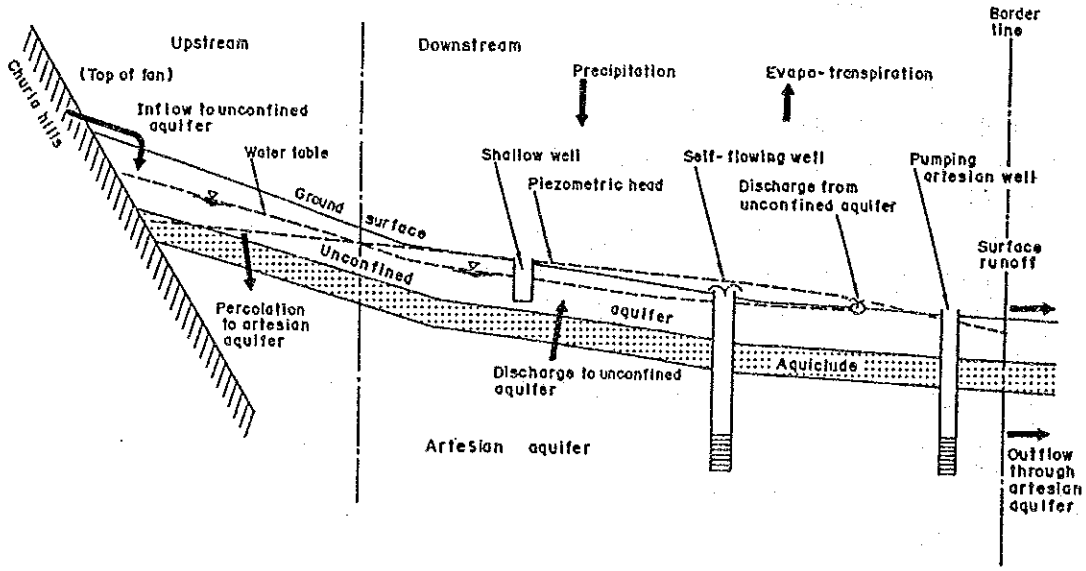
3) Groundwater Balance

The pumping test results of existing deep tubewells in the study area reveal that specificic capacity is in the range of 1 to 2 ℓ/sec/m and transmissivity of 200 to 2,000 m^2/day. In order to formulate a groundwater development plan, a water balance study is one of the most important

items. The study is tentatively conducted under the conditions of some assumptions, since the present data is insufficient for a groundwater balance study.

The model of groundwater balance is shown in the following figure that the confined aquifer is intercalated in the aquiclude and/or aquitard under the unconfined aquifer. The phreatic water is recharged by the in - flow from the surface river water and by the percolation of precipitation. Also, in and out - flow of groundwater between the unconfined aquifer and confined aquifer is supposed to occur from the difference between piezometric head and phreatic groundwater head. In addition, the horizontal flowing of groundwater will spring out as phreatic water from the tail end of the fan, and the confined water will flow out through the aquifer from the study area.

The Model of Groundwater Balance



(1) Recharge by percolation of precipitation

It is known that the shallow groundwater level rises during the rainy season and falls down with the outflow in the middle to lower reaches in the dry season. It fluctuates within the differnce of about 3m. The precipitation from June to September (rainy season) averages 1053.3mm in Hardinath.

Supposing that the effective porosity of the phreatic aquifers is 5%, the water head storaged in the phreatic aquifer corresponds to 14.2% of average precipitation in the rainy season, since 3000mm×5% equals to 150mm.

The percolation ratio of precipitation is assumed to be 15%, though it may exceed, since recharge of groundwater from the rivers exists even in the rainy season. The rest of 85% and the precipitation in the dry season is supposed to be lost by the surface run - off and evapotranspiration.

From the above assumptions, annual average percolation is calculated as follows:

$$1.0533\text{m} \times 0.15 \times 2410\text{km}^2 \times 10^6 / 365\,\text{day} \times 86400\text{sec} = 12.07\ \text{m}^3/\text{sec}$$

(2) Recharge of groundwater by the inflow from Churia hills

Judging from the features of groundwater table, electric conductivity and pH contours, phreatic groundwater in the study area is recharged mainly by the infiltration from the many river waters, such as the Ratu nadi river, which flow out from the Churia hills. Further, the deep groundwater seems to be recharged by the above river water. The phreatic groundwater in the area may be supplementally recharged by the infiltation from the river water of the Kamala river and the Bagmati river which are located at the east border and west boder of the area respectively . There occurs predominant infiltration recharged by the many rivers such as the Ratu river debouched from the Churia hills, which has a total catchment area of about 500km^2. The recharge quantity is estimated in the following procedure.

Since there is no discharge data for the rivers such as the Ratu river, the specific discharge data at the Chisapani station (the catchment area : 1550km^2) for the Kamala river is referred. An average discharge at this station in the dry season (Dec. to May) is 7.4m^3/sec (specfic discharge : 0.0048m^3/sec·km^2) and that in the rainy season (Jun. to Nov.) is 110m^3/sec (ditto ; 0.0715m^3/sec·km^2).

In almost all the rivers running from the Churia hills, all discharge in the dry season infiltrates at the top of the fan, moreover it is assumed that the 15% of the total discharge in the rainy season will recharge groundwater.

Recharge from Churia hills in the dry season ; $500\text{km}^2 \times 0.0048 = 2.40\text{m}^3/\text{sec}$

Recharge from Churia hills in the rainy season ; $500\text{km}^2 \times 0.0715 \times 0.15 = 5.36\text{m}^3/\text{sec}$

Annual average recharge ; $(2.40 + 5.36) / 2 = 3.88\text{m}^3/\text{sec}$

(3) Confined groundwater

It is considered that the confined groundwater is recharged by the infiltration from the phreatic aquifer in the upstream reach where the piezometric level of the confined groundwater is lower than the phreatic level. On the other hand,some of the confined groundwater will leak to the phreatic aquifer from the confined aquifer in the downstream area and will flow down outside from the study area, in case that the piezometric head of the confined aquifer is higher than the phreatic level.

Supposing that the recharge quantity to the confined groundwater from the phreatic aquifer is equal to the flowing volume at the place where the confined groundwater head and the phreatic water level are the same, the recharge quantity (=Q) by the infiltation from the phreatic aquifer in the upstream side is calculated from the transmissivity (T), the hydraulic gradient (i) and the groundwater flow width (L) as follows.

$$\Sigma Q = \Sigma T \times i \times L$$

	Sarlahi	Mahottari	Dhanusha	Total
Transmissivity (m^2/day)	340	600	400	
Hydraulic gradient (%)	0.56	0.47	0.43	
Flowing width (m)	15,000	22,500	12,000	49,500
Thicknss of aquifers (m)	40	40	60	
Groundwater flow volume (m^3/day)	28,560	63,450	20,640	112,650

Thus,the recharge quantity (Q) is esimated at 1.30m^3/sec. The permeability coefficient of the aquifer is calculated at 7.2×10^{-3}cm/sec ~ 1.7×10^{-2}cm/ sec. In the same way, the groundwater flow voume (Q) of the confined aquiter in the tail - end of the study area is calculated to be 0.17m^3/ sec.

Transmissivity (m^2/day)	250
Hydraulic gradient (%)	0.12
Groundwater flow width (m)	49,500
Thickness of aquifers (m)	30
Groundwater flow volume (m^3/ day)	14,850 (= 0.17m^3/ sec)

(4) Artificial groundwater abstraction

An artificial groundwater use is composed of domestic water by shallow wells (poulation, 700,000) and irrigation water by shallow wells and deep wells in the study area. Supposing that the domestic water use per capita is 50ℓ/day, pumping period of the wells for irrigation is four (4) months in the dry season, pumping time is eight (8) hours a day and artesian wells are always out of control, groundwater quantity for the artificial use is estimated as follows.

① Present domestic water use from wells :
$700,000\times0.05=35,000m^3$/day(=0.41$m^3$/sec).

② Present water use for irrigation by 2,000 shallow wells (10ℓ/sec/well) :
2,000×0.01×8×3,600×120=6912×10⁴m³ /year (2.19m³/sec)
Present water use for irrigation by the existing 14 deep tubewells :
14×0.04×8×3,600×120=1,935,360m³/year (=0.06m³/sec).

③ 13 artesian wells ;
13×31ℓ/sec × 86,400 = 35,000m³/day (=0.41m³/sec).
In addition, the following water use is planned in the near future ;
a. the existing deep tubewell operation (47−18=29wells) :
29×0.04×8×3,600×120=4,008,960m³/year (0.13m³/sec).
b. 115 production wells of the Project
114,218,000m³ (3.62m³/sec).

(5) Groundwater balance in future.

Present and future groundwater balance on annual average are calculated as follows ;

a) Phreatic groundwater	Present (m³/sec)	Future (m³/sec)
-Percolation of precipitation in the area	12.07	12.07
-Infiltration of river-water in the fan area	3.88	3.88
(Sub-total)	(15.95)	(15.95)
-Recharge to confined aquifer in the upper reach	−1.30	−3.98
-Recycle from confined aquifer	0.66	0
(Sub-total)	(−0.64)	(−3.98)
-Domestic water use	−0.41	−0.41
-Irrigation by shallow wells	−2.19	−2.19
(Sub-total)	(−2.60)	(−2.60)
-Out - flow to surface	−12.71	−9.37
Total	0	0

b) Confined ground water	Present (m³/sec)	Future (m³/sec)
-Recharge from pheratic aquifer in the upper reaches	1.30	3.98
-Artesian water from artesian deep well	−0.41	0
-Discharge by existing deep wells	−0.06	−0.06
-Out - flow to outside of the project area in the lower reaches	−0.17	−0.17
-Existing deep wells operation	0	−0.13
-115 deep tubewells of the Project	0	−3.62
-Recyclo to phreatic aquifer in the lower reaches	−0.66	0
Total	0	0

In case that the large quantity of the confined groundwater is abstracted, the hydrostatic head drops, and hence the recharge to the confined aquifer from the phreatic aquifer is generally increased. As a result, the phreatic water level may drop temporally. But, the pheratic water lerel is generally recovered to the former level by the percolation of the precipitation in the rainy season. Consequently, the decrease of the seepage in the dry season to the surface flow from the phreatic aquifer may be not so vigorous, and therfore this groundwater balance calaulation shows conservative result.

3.3 TIATSP

3.3.1 Project Activities

TIATSP was established in January 1986 in succession to JADP which had been implemented from 1971 to July 1985 under the grant aid assistance and technical cooperation of the Government of Japan.

JADP, aiming at increasing farmers' income and improving living standard and social welfare through the various programs of increasing agricultural products, covers 5 districts out of 6 districts of Janakpur Zone (Mountain area of Dolakha was excluded) and implemented the following schemes.

(1) Construction of JADP center in Naktajhij (Main office, Library-cum-Lecture hall, Workshop, Store house, Dormitory for trainees, Quarters for staff, etc.)

(2) Construction of Agricultural Development Offices (one office in each of 5 districts)

(3) Training for agricultural extension workers, agricultural technicians, farmers, etc.

(4) Operation and management of Sindhuri Agriculture Farm

(5) Operation and management of Janakpur Horticulture Farm

(6) Operation and management of Hardinath Agriculture Farm

(7) Establishment and operation of Nawalpur Horticulture Center

(8) Implementation of Intensive Irrigation and Agriculture Program (I A P) (Irrigation scheme by 9 deep tubewells)

(9) Implementation of Irrigated Model Farm (IMF)

(10) Shallow Tubewell Program (STWP)

(11) Deep Tubewell Irrigation Project (DTWIP)

Out of the above schemes, the groundwater irrigation programs of (8), (9) and (10) played the most important role for the agricultural development in the Terai plain. And DTWIP of (11), by which a remarkable increase of irrigation area was expected, was started just before ending the cooperation period by the Government of Japan, but suspended on the way because of constraints on finance, technique, materials, etc. and succeeded to TIATSP.

Under the background described above, the main programs of the TIATSP are set as follows.

(1) Promotion of Deep Tubewell Irrigation Project

(2) Continuation of Shallow Tubewell Program

(3) Construction of irrigation facilities for (1) and (2) above

(4) Extension of irrigated farming technique and training of farmers

(5) Establishment of water users' groups and water management

(6) Establishment of operation and maintenance system for irrigation facilities including pumps

(7) Acceleration of farm land consolidation

His Majesty's Government of Nepal expects Japan's grant aid and technical cooperation for execution of all the programs except (2) above.

3.3.2 Annual Expenditure and Budget

According to a report of TIATSP, annual expenditures of JADP / TIATSP for the past three years and the budget for 1986 / 87 are as follows :

Annual Expenditure and Budget of JADP / TIATSP

(Unit : NRs.1000)

Item No.	Description	1983/84	1984/85	1985/86	1986/87
1.	Salary of project staff	821	1,335	1,417	1,200
2.	Allowance of the above	414	14	19	15
3.	Traveling & daily allowance	82	125	125	125
4.1	Postage, registry & telephone expenses	33	25	20	20
4.2	Printing & advertisement	20	7	7	7
5.	House & store rent	35	24	11	20
6.	Repair & maintenance of houses, quarters, vehicles, canals, etc.	217	140	762	775
7.1	Stationeries for office	34	27	25	25
7.2	Books and journals	4	4	204	5
7.3.1	Fuel for vehicles	369	238	300	400
7.3.2	Fuel for generators, pump sets and machineries	705	150	231	250
7.4.1	Clothes for drilling &workshop	12	10	10	10
7.5.1	Other expendable goods	55	45	45	45
8.	Extension, training and drilling expenditure	1,531	2,072	5,209	4,803
9.	Public relation expenditure	16	9	8	8
10.1	Furnitures	73	18	0	0
10.2	Vehicles	0	0	0	0
10.3	Machineries	630	147	190	1,321
11.1	Land acquisition	0	300	0	0
12.1	Building construction	1,289	938	2,398	1,500
12.2	Other construction (canals, land development, etc.)	1,935	3,756	2,675	3,300
	Total	8,275	9,384	13,656	13,829

A part of KR-2 counterparts fund (incomes by selling KR-2 materials) has been applied for more than 50% of the expenditures. From the year of 1985/86, when TIATSP was established, the expenditures for extension, training and drilling were increased more than two times, which indicate putting an emphasis on the drilling of deep and shallow tubewells.

3.3.3 Organization and staffing

The present organization and staffing of TIATSP are the same to those of JADP, as shown in Fig 3.10, and it seems to be hardly possible to manage the Terai Groundwater Development Project successfully and to operate and maintain the facilities after the completion. Therefore, it is indispensable to fill up the vacancies in each section and to increase the capable staff.

3.3.4 KR-2 deep tubewell equipment and materials

The present situation of the KR-2 deep tubewell equipment and materials, which have to be effectively used for the Project, are summarized below in terms of paying attention for the implemantation, though the details are described in Item 6.1.5 of Chapter 6.

(1) The spare parts of all the rig machines (4 of Tone Boring, 3 of Yoshida-Kogyo) and mud pumps are totally consumed and considerable quantity of the necessary parts shall therefore be procured. Besides, as the 3 rig machines of Yoshida-Kogyo have not been well-maintained, the sufficient checking is required for use.

(2) Tri-cone bits of $17\frac{1}{2}$" and $14\frac{3}{4}$" are not stocked and considerable number of the both bits shall therefore be purchased.

(3) One air compressor with high pressure and big capacity (20kg, 20m^3) shall be procured for cleaning screens installed in deeper positions.

(4) 8"Johnson type screens shall be reinforced because of insufficient strength. Majority of the deep tubewells drilled by JADP/TIATSP are hardly possible to pump up water due to collapse of the screens mentioned above, etc. Besides, a ring base wire-wrapped screen will be required for the screen to be installed deeper than 150m below the ground.

(5) The length of pump shaft and lifting pipe of Ebara turbine pump and Okamoto turbine pump are 30m respectively. As the dynamic water level of the planned deep tubewells will be lower than 30m below the ground in northern part of the project area, the pump shafts and lifting pipes for two pump sets will have to be used for one well.

(6) As Okamoto turbine pumps are not used yet, a test run shall be done by a mechanical engineer of the maker.

(7) For pumping test of both test wells and production wells, one submersible motor pump (small capacity high pump head) shall be perchased. Besides, the number of V-notch tank (2.5m^3)for measuring discharge of tubewell should be increased to six (6) from the present one (1).

(8) One (1) fuel tank lorry and one (1) water tank lorry should be additionally purchased for smooth construction of tubewells and irrigation canals.

(9) Some vehicles should be additionally purchased for transportation of casing pipes, bricks, embankment materials for canals, etc.

(10) Considerable numbers of jeep and pick-up shoule be additionally purchased for smooth construction supervision of drilling of tubewells and constructionof canals.

4. THE PROJECT

4. THE PROJECT

4.1 Objectives of the Project

In 1971, HMGN launched the Janakpur Zone Agriculture Development Project (JADP) which covered five districts of Janakpur zone except Dolakha district under the technical assistance and the grant aid program of the government of Japan, and executed various programs to increase and level up the farmers' income and living standard by increasing the productivity of farm land and the agricultural production. Out of these programs, the following programs were executed for the irrigation development in three districts in the Terai plain of the Janakpur zone ; Sarlahi, Mahottari and Dhanusha districts.

- Shallow Tubewell Irrigation Program (STWP) which improved the number of crop harvest a year from twice to three times in the farm land of about 13,800 ha by constructing 1,977 of shallow tubewells from 1981 to June 1986.
- Intensive Irrigation and Agriculture Program (IAP) which realized the irrigation of 420 ha by constructing nine (9) deep tubewells and irrigation canals of about 10.6km.

However, the potential area for the shallow tubewell development, where the potential shallow aquifer can be developed from 20 to 40m below ground surface, is confined to the belt area of about 51,000 ha extending from east to west along the center of three districts of the Janakpur zone, and therefore, the irrigation development of the rest area of about 110,000ha, which is calculated deducting the above area being irrigated by surface water and shallow groundwater from the total arable land of 195,000 ha, depends on the deep aquifer. From this viewpoint, JADP constructed 24 deep tubewells including nine wells in the IAP area with the drilling equipment granted by the Government of Japan.

In January 1986 succeeding to JADP, HMGN established the Tubewell Irrigation Agriculture Training and Services Project (TIATSP) as one of the agricultural developments under the seventh five years plan (1985~90) in order to increase the farm land irrigated by shallow and deep tubewells.

The shallow tubewell development in TIATSP contributes to the increase of agricultural production in the Terai plain of the Janakpur zone by increasing number of shallow tubewells and irrigated farm lands, and it is expected to be successfully implemented in the future because of the cheap cost of the construction and operation and maintenance and the rather simple technique of drilling.

On the other hand, the deep tubewell irrigation project was commenced by JADP in 1976 and taken over by TIATSP in January 1986. Under the project 24 deep tubewells including 9 of IAP were constructed by 1984, and 39 deep tubewells in 1985 and 1986, including 15 completed by a Japanese contractor, using the deep tubewell drilling equipment and materials proveded under a KR-2 grant aid program in 1982 and 1983, besides 18 deep tubewells are planned in 1986/87. However, the deep tubewells being used for irrigation as of February 1987 are only seventeen (17) consisting of nine (9) of IAP completed under the guidance and supervision by Japanese expers dispatched under a technical cooperation program of the Japanese Government, one (1) in the Nawalpur Horticulture

Farm and seven (7) artesian wells. The reasons why the deep tubewell irrigation project has not progressed smoothly are not only insufficient knowledge and ability on its planning, incomplete techbology on hydrogeological investigation for finding deep aquifer and selecting deep tubewell sites and poor technique on drilling and developing of deep tubewells particularly in deeper than 150m, but also shortage of fund for the construction of deep tubewells and irrigaion facilities which require huge amount of fund and lack of ability on operation and maintenance of deep tubewell and its irrigation facilities.

To solve such problems and to promote the deep tubewell irrigation project quickly and effectively, HMGN planned the Terai Groundwater Development Project as the most important program of TIATSP (to construct 150 deep tubewells and irrigation facilities for about 3,000 ha using deep tubewell drilling equipment and materials suplied by a KR-2 grant aid of the Government of Japan), and requested the Government of Japan to provide the grant aid for implementing the Project.

In the light of such background and facts, the main objectives of the Project are set as follows:

(1) to increase the irrigated farm lands by constructing possible numbers of deep tubewell and the respective irrigation facilities using the deep tubewell drilling equipment and materials provided under a KR-2 grant aid of the Government of Japan;

(2) to increase and stabilize the agricultural production by supplyinhg deep tubewell-irrigartion water throughout a year;

(3) to increase the farmers' income by raising land productimity and increasing unit yield of crops, resulting from providing irrigation water timely;

(4) to level up farmers' living standards and to improve their social welfare in and around the project area through realization of (1), (2) and (3);

(5) to establish a technology of deep tubewell irrigation development by introducing the Japanese technology; and

(6) to establish a model of operation and maintenance for deep tubewell irrigation development in the Terai plain.

In order to achieve the objectives mentioned above, the Government of Japan will construct necessary deep tubewells and the respective irrigation facilities, using mainly the equipment and materials granted already to HMGN under the KR-2 grant aid in 1982 and 1983, under its grant aid cooperation program.

4.2. Study on the Requested Project and Outline of the Proposed Project

The Terai Groundwater Development Project requested by HMGN is to constract 150 deep tubewells and irrigation facilities for irrigating 3,000 ha utilizing the deep tubewell construction equipment and materials provided under a KR-2 grant aid program (1982 and 83) of the Government of Japan. Most of the equipment and materials, which were granted by a strong request of HMGN on the condition that HMGN should construct the tubewells and irrigation facilities mentioned above, have not been used by TIATSP up to now.

The request by HMGN was studied, and the proposed plan was made with an eye on the following items.

(1) The development blocks shall be selected in the area where the groundwater potential is more than 25 ℓ/sec so that the water charge per beneficial farmer does not become heavy for him.

(2) To confirm the available groundwater to be pumped up from five (5) production tubewells to be constructed in each development block, one test tubewell shall be drilled in each development block prior to the construction of the production wells and diverted to one of the five (5) production tubewells after confirming the yield, and the location of the production tubewells will be determined by electric sounding.

(3) The number of the production tubewells to be constructed under the Project shall be determined based on the remaining quantities of the materials and equipment provided under the KR-2 grant aid program, however, necessary spare parts for the KR-2 equipment, some additional equipment and materials, vehicles and consumables, etc. will be newly procured.

(4) The layout of irrigation canals and related structures shall be suitable for easy water management and even water distribution and the facilities shall be constructed, operated and maintained by technical level of Nepalese staff. The materials and methods of construction shall be selected so that those canals and structures can be repaired easily in case of damages.

(5) The canals and related structures shall be constructed after pumping test of each production well in order to make the type and size of the canals and structures suitable for the actual pumping discharge.

(6) Japanese technology on deep tubewell development will be transferred to Nepalese engineers and technicians as much as possible though the on-the-job training during the detailed design and construction stages.

(7) The water users' groups shall be established to facilitate smooth execution of operation and maintenance, water management, collection of water charge, etc. of the completed deep tubewell, pump and the irrigation facilities.

4.2.1 Basic concept of the project

1) Project area

In order to avoid an overlapping with the command areas of the other existing projects the following areas will be excluded from the project area requested by HMGN.

- Bagmati Irrigation Project area
- Kamala Irrigation Project area
- Manusmara Irrigation Project area
- Hardinath Irrigation Project area
- Shallow Tubewell Program area of TIATSP
- Deep Tubewell Irrigation Project area of DIHM

2) Project components

As requested by HMGN, the deep tubewells and the respective irrigation facilities will be constructed utilizing effectively the deep tubewell drilling equipment and materials provided under the KR-2 grant aid program, but the number of deep tubewells to be constructed and the area to be irrigated will be changed to be 115 and 4,625 ha respectively. However, the number of tubewells and hectarage of the irrigation areas will be subject to the results of further survey and design. Based on the results of inventory survey on the equipment and materials granted under the KR-2 aid program, the number of deep tubewells to be constructed is calculated to be 115, and the total area to be irrigated by these tubewells is estimated to be 4,625 ha applying unit water requirement of 1ℓ/sec /ha and the available discharge of each tubewell.

4.2.2. Development block

1) Number and priority of development blocks

Since the blocks of which groundwater potential is not sufficient or of which access is poor are included in 30 blocks requested by HMGN during the preliminarly study, some blocks will face troubles in the implementation (See Table 4.1). Therefore, the following eight blocks, which do not have such disadvantages, are selected with the first priority for implementation.

No. of Development Block	District	Name of Panchayat
S-1	Sarlahi	Hariwan
S-7	Sarlahi	Bramhapuri
M-4	Mahottari	Kisannagar
M-7	Mahottari	Ratauligohi
D-6	Dhanusha	Bengashibapur
D-7	Dhanusha	Basahiya
D-8	Dhanusha	Ghorgas
D-15	Dhanusha	Naktajhij

Out of the remaining 22 blocks, two blocks were considered to have some good feasibility but too poor access, and other 20 blocks were unfeasible and altered. Therefore, considering the possible discharge of a tubewell; more than 25 ℓ/sec, the request of HMGN, access and overlapping with the area of other projects, etc., fifteen development blocks listed in Table 4.2 were selected instead of the above 22 blocks.

The location of 23 development blocks including the eight blocks of the first priority is shown on the Groundwater Potential Map (Fig. 4.1) and the numbers of development block in each district are summarized below together with their priority.

District	First Priority	Second and Third Priority	Total
Dhanusha	4	7	11
Mahottari	2	2	4
Sarlahi	2	6	8
Total	8	15	23

The location of 15 development blocks having second and third priority may be changed based on the results of test drilling, hydrogeological investigation, electric sounding, etc. during the detailed design in the future.

2) Selection of five irrigation areas in each development block.

The forty irrigation areas of the eight development blocks with the first priority (gross area of each development blocks is 800 ha) were selected based on the results of field survey, the topographic maps (1 inch = 1 mile scale) and the land utilization maps (1: 50,000 scale). During the field survey, access road, topography, cropping pattern, location of forest, pond and village, ward boundary in each panchayat and intention of farmers, etc. were also confirmed.

The selected five irrigation areas of each development block with first priority are listed below.

Name of Development Block	Panchayat	Irrigation Area (Ward Number)
D-7	Basahiya	1, 2, 3, 5, 8A, 8B
D-8	Gorgas	1, 2, 3, 4A, 4B, 5
D-6	Bengashibapur	1B, 3A, 3B, 6B, 7A, 7B
D-15	Naktajhij	to be decided in the phase II study
M-4	Kisannagar	2A, 2B, 3A, 3B, 3C, 4A, 4B
M-7	Ratauligohi	1, 2A, 2B, 4, 6, 7
S-1	Hariwan	1B, 3C, 3D, 6A, 6B, 7A
S-7	Bramhapuri	1A, 2A, 7, 9A, 9B, 9C

In order to estimate the work volume and the construction cost of all blocks during this Basic Design period, three representative blocks were selected and topographic survey was made in five irrigation areas of each representative block for preparing topographic maps at a scale of 1: 1,000. The topographic maps prepared cover the following irrigation areas.

Name of Block	D-7	M-4	S-7
Name of District	Dhanusha	Mahottari	Sarlahi
Name of Panchayat	Basahiya	Kisannagar	Bramhapuri
Expected Discharge	50 ℓ/sec×5nos.	25 ℓ/sec×5nos.	40 ℓ/sec×5nos.
Irrigable Area	50 ha×5 sites (250 ha)	25 ha×5 sites (125 ha)	40 ha×5 sites (200 ha)
(Ward No.)			
1	1	2A + 2B	7
2	2 + 3	3A	7 + 2A
3	5 + 3	3A + 3B + 3C	9A
4	8A	3B + 3C	9B + 9C
5	8B + 4B	4A + 4B	1A

4.2.3. Groundwater development plan

1) Type of deep tubewells

The objective area of the Terai groundwqater development project is the farm land of about 110,000 ha, excluding the area of the surface irrigation projects (about 34,000 ha) and the STWP area of about 51,000 ha extending the center of the Terai plain in the Janakpur zone. Although the groundwater potential of the objective area is sufficient for irrigating 30 development blocks by 150 deep tubewells as illustrated in Fig. 4.1 (Groundwater Potential Map) according to the result of the

groundwater balance study (3.62 m^3/sec), the appropriate size of the project is to irrigate 4,625 ha of 23 development blocks by 115 deep tubewells taking the following reasons into account.

- The economical head of the granted turbine pump set is up to 55 m, according to the inventory survey on the equipment and materials provided under the KR-2 grant aid program and therefore, the areas where dynamic water level is deeper than 55 m are not suitable for the project area.
- The number of deep tubewells to be constructed is calculated to be 115 based on the result of the above inventory survey.
- The irrigation area of the deep tubewell shall be selected from among the areas where the groundwater potential is more than 25 ℓ/sec per tubewell, in order to set the water charge consisting of fuel and operator costs within payable amount by the beneficial farmers.
- It is necessary to avoid an overlapping with the objective area of the groundwater development project being implemented by DIHM.

As a result of the overall analysis on four test drillings, hydrogeological investigation and electric sounding, etc. (see Section 3.2.3), the four types of standard deep tubewell shown in Table 4.4 and Fig. 4.2 are recommended for the groundwater development in the project area.

The following table shows the areas and blocks where the standard tubewells can be applied in consideration of the location of blocks in the groundwater potential map.

Applicable Areas and Blocks of Standard Tubewells

Type	I	II	III	IV
A. Specification of tubewell				
Depth	89 m	159 m	205 m	205 m
Discharge	40 ℓ/sec	25~30ℓ/sec	40~55ℓ/sec	40ℓ/sec
B. Applicable area	Northern part of Sarlahi District	Northern part of Dhanusha and Mahottari Districts	Central part of Dhanusha District and Southern part of Mahottari and Sarlahi Districts	Central and northern part of Dhanusha and Mahottari Districts and south-eastern part of Dhanusha District
C. Applicable block				
Dhanusha District	–	D-13, D-14, D-15, D-16, D-17	D-6, D-7, D-8, D-18, D-19	D-10
(11 blocks)	(–)	(5 blocks)	(5 blocks)	(1 block)
(55 tubewells)	(–)	(25 tubewells)	(25 tubewells)	(5 tubewells)

Type	I	II	III	IV
Mahottari District	–	M-4, M-12, M-13	M-7	–
(4 blocks)	(–)	(3 blocks)	(1 blocks)	(–)
(20 tubewells)	(–)	(15 tubewells)	(5 tubewells)	(–)
Sarlahi District	S-1, S-2 S-4, S-8	S-9	S-7, S-10 S-11	(–)
(8 blocks)	(4 blocks)	(1 block)	(3 blocks)	(–)
(40 tubewells)	(20 tubewells)	(5 tubewells)	(15 tubewells)	(–)
Total				
23 blocks	4 blocks	9 blocks	9 blocks	1 block
115tubewells	20 tubewells	45 tubewells	45 tubewells	5 tubewells

Note: Underline shows the first priority block. The interval between deep tubewells shall be not less than 600m, and in the southern part of the objective area the aquifer deeper than 170m shall be pumped up to avoid the settlement of the ground.

2) Location of development blocks and deep tubewells

The electric sounding of 135 points was made in the project area to preliminarly determine the location of development blocks and deep tubewells from the hydrogeological view point (See Fig. 4.1). The points where the electric sounding was made are summarized below.

- Dhanusha District: D-6, D-7, D-8, D-12, a part of D-11, 59 points in total
- Mahottari District: M-1, M-2, M-3, M-4, M-7, 32 points in total
- Sarlahi District: S-1, S-2, S-4, S-7, a part of S-5, 32 points in total

In the fan extending on northern part of the project area where the resistivity value is high (500~700Ω · m) in 20m to 50m (sometimes 80m) deep and not expected to have much groundwater potential, the proposed development blocks and deep tubewell sites shall be located near large rivers like the Ratu that has high recharge potential for deep aquifer. In the central and southern parts of the project area, the proposed development blocks shall be located as much as possible in the southern part (near Indian border) where the artesian aquifer is much expected.

The following table suggests the appropriate location and depth of the deep tubewells (5 tubewells per one development block) which were decided from the electric sounding (See Fig. 4.3) carried out in the 8 development blocks with the first priority.

Name of Development Block	Depth of Tubewell (m)	Location of Tubewells
D-6	205	Any place can be selected for deep tubewell site because good aquifer in deeper than 110m extends in the entire block.
D-7	205	Center part of the block where good aquifer exists in deeper than 120m.
D-8	205	Western part where good aquifer in deeper than 100~150m is expected, but additional electric sounding is necessary for determining the exact tubewell site.
D-15	—	Details are not grasped yet, because this block was newly requested by HMGN while discussing about the draft report in June 1987. Location of wells is to be decided in the phase II study.
M-4	159	Any place can be selected for deep tubewell site, because the phreatic water exists in the entire block, though the groundwater level may be low (about 40m below the ground).
M-7	205	Western part where seems to have high groundwater potential, but additional electric sounding is necessary for confirmation.
S-1	89	Any place can be selected for deep tubewell, but deeper drilling may be necessary in the western part where sand and gravel layer is deeper and thicker than that of the eastern part.
S-4 (to be replaced with D-15)	89	Any place can be selected for deep tubewell. The phreatic aquifer extends 30 to 100m (sometimes 150m) deep in the entire block as same as S-1 block.
S-7	205	Northern part of the block where good aquifer in deeper than 100~140m is expected.

3) Drilling of test tubewell

As mentioned in the previous chapter, the results of the hydrogeological survey and investigation, the electric sounding and test drilling prove that the aquifer condition in the project area changes place to place both from north to south and from east to west. During the project implementation, therefore, it is necessary to carry out the drilling of a test tubewell prior to the construction of production tubewells in order to confirm available discharge of the production tubewells and specifications of drilling and tubewell, etc. The specifications of a test tubewell to be drilled in each block (five production tubewells) will be basically same as those for the production tubewellds in the same block. As for screen, it will be changed according to the installation depth; present 8" - Johnson screen for 30~50m deep, reinforced screen (see Section 5.3.2 for method of reinforcement) for 50~150m and ring base wire-wrapped screen to be purchased for depth below 150m. The test tubewell with a discharge of more than 25ℓ/sec is diverted to a production tubewell, which is counted as one of five production tubewells per each block.

4. 2. 4. Irrigation development plan

1) Irrigation area

The irrigation area is calculated to be 4,625 ha based on both the unit water requirement of 1ℓ/sec/ha (operation hour of pump set is 12 hrs/day) and the expected discharge of each tubewell as tabulated below. (Therefore, these irrigation areas are subject to change according to the results of further survey and design.)

Irrigation Area Based on the Expected Discharge of Deep Tubewells

Expected Discharge	Nos. of Tubewell	Irrigation Area
25 ℓ/sec.	5 (5)	125 ha (125 ha)
30 ℓ/sec.	35 (5)	1,050 ha (150 ha)
40 ℓ/sec.	35 (10)	1,400 ha (400 ha)
50 ℓ/sec.	30 (20)	1,500 ha (1,000 ha)
55 ℓ/sec.	10 (0)	550 ha (0 ha)
Total	115 (40)	4,625 ha (1,675 ha)

Note: The figure in parenthesis shows the number of and the irrigation area commanded by the first-priority tubewells.

2) Irrigation method

The rotation irrigation method will be applied to distribute irrigation water as even as possible. The operation hour of pump set is 12 hrs/day in day time, but during the peak irrigation period, it will be extended to 15~16 hrs/day. The regulation pond, which requires a complete leakage protection, is not provided to make the operation simple.

3) Irrigation facilities

(1) Pump house and operator hut

The pump house and the operator hut are one storied small houses of which walls and roofs are made of brick and mortar, and reinforced concrete, respectively. Considering the sizes of the pump set and the existing pump houses constructed by TIATSP, the sizes of the pump house and the operator hut are determined to be 5.0m×2.7m (13.5m^2) and 3.6m×2.7m (9.72m^2), respectively. The space of the operator hut is judged to be sufficient for stay of operator during the pump operation that will be 12 hrs/day in day time. The operator hut will be constructed apart from the pump house to avoid bad affection by noise and vibration of pump set. The sizes of the pump house and the operator hut requested by HMGN are too large and not economical for the Project.

A baffle tank with a V-notch and a bathing pool will be provided to the pump house, but the pipeline system for domestic use, of which construction, operation and maintenance costs are expensive, will not be provided.

(2) Main irrigation canals and related structures

As requested strongly by HMGN, one-layer brick masonry canal will be applied for the main irrigation canal, because the repair and maintenance of such brick canal are simple and the construction cost is also low. The canal sections of main irrigation canal are same throughout a block to apply a rotative irrigation method, and the following three types of canals are planned to meet the discharge of deep tubewells.

Three Types of Main Canal

Description	Type		
	I	II	III
Dimension (B×H) (cm)	35×42	35×35	28×28
Gradient	1/1,000~1/300	1/1,000~1/300	1/700~1/200
Design Discharge (ℓ/sec)	50~55	40	30
Design Velocity (m/sec)	0.56	0.50	0.73
Max. Discharge (ℓ/sec)	80	65	40
Max. Velocity (m/sec)	0.80	0.77	0.79

The related structures for the main irrigation canal are made of brick masonry because of the same reasons as mentioned for the main irrigation canals. The required number of the related structures estimated based on the topographic map of 1/1,000 are different block by block as tabulated below.

Required Number of Structures in the Surveyed Three Blocks

Description	Name of Block			Average
	D-7	M-4	S-7	
Expected Discharge (ℓ/sec)	50×5	25×5	40×5	–
Irrigation Area (ha)	250	125	200	–
Length of Access Road (m)	520	160	1,150	610
Bathing Pool (no.)	1	1	1	1
Length of Main Irrigation Canal (km)	9.0	7.6	7.4	8.0
Turnout (nos.)	63	35	49	49
Drop (nos.)	4	41	0	15
Cross Drain (nos.)	13	0	15	10
Road Crossing (nos.)	1	9	2	4
Small Pass (nos.)	50	30	30	37
Division Box (nos.)	3	7	2	4
Corner Box (nos.)	29	9	17	19
Precast Check Plate (nos.)	64	37	42	48
Cattle Pass (nos.)	19	13	18	17

The lateral canals branching off from the main irrigation canals are earth canal which is popularly used in Nepal, and those canals will be constructed by the beneficial farmers.

Drainage canals, farm roads and operation roads will not be constructed under the Project because of difficulty in land aquisition. The operation and maintenance of the main canal will be made using the small pass to be constructed on the top of the canal embankment beside the brick masonry canals, and the transportation of the agricultural inputs, machinery and products will be made through the existing farm roads (bull cart roads).