No. 01

DIRECTORATE GENERAL AGRICULTURE(FIELD)
AGRICULTURE DEPARTMENT
GOVERNMENT OF PUNJAB
ISLAMIC REPUBLIC OF PAKISTAN

# BASIC DESIGN STUDY REPORT
# ON
# THE PROJECT FOR EXPLOITATION OF GROUNDWATER
# AT
# PROVINCE OF PUNJAB
# IN
# THE ISLAMIC REPUBLIC OF PAKISTAN

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BASIC DESIGN STUDY REPORT ON THE PROJECT FOR EXPLOITATION OF GROUNDWATER AT PROVINCE OF PUNJAB IN THE ISLAMIC REPUBLIC OF PAKISTAN
OCTOBER 1996

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# PREFACE

In response to a request from the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a basic design study on the Project for Exploitation of Groudwater at Province of Punjab and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Pakistan a study team from June 1 to July 6 , 1996.

The team held discussions with the official concerned of the Government of Pakistan, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Pakistan in order to discuss a draft basic design, and as this result, the present report was finalized.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the teams.

October, 1996

Kimio Fujita
President
Japan International Cooperation Agency

October, 1996

# LETTER OF TRANSMITTAL

We are pleased to submit to you the basic design study report on the Project for Exploitation of Groudwater at Province of Punjab in the Islamic Republic of Pakistan.

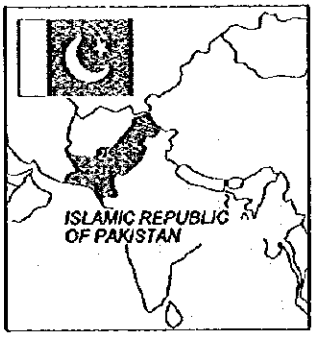
This study was conducted by Japan Techno Co., Ltd., under a contract to JICA, during the period from May 27, 1996 to October 31, 1996. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Pakistan and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Shigeyoshi Kagawa
Project Manager
Basic Design Study Team on
The Project for Exploitation of
Groundwater at Province of Punjab in
The Islamic Republic of Pakistan
Japan Techno Co., Ltd.

# BASIC DESIGN STUDY ON THE PROJECT FOR EXPLOITATION OF GROUNDWATER AT PROVINCE OF PUNJAB IN THE ISLAMIC REPUBLIC OF PAKISTAN

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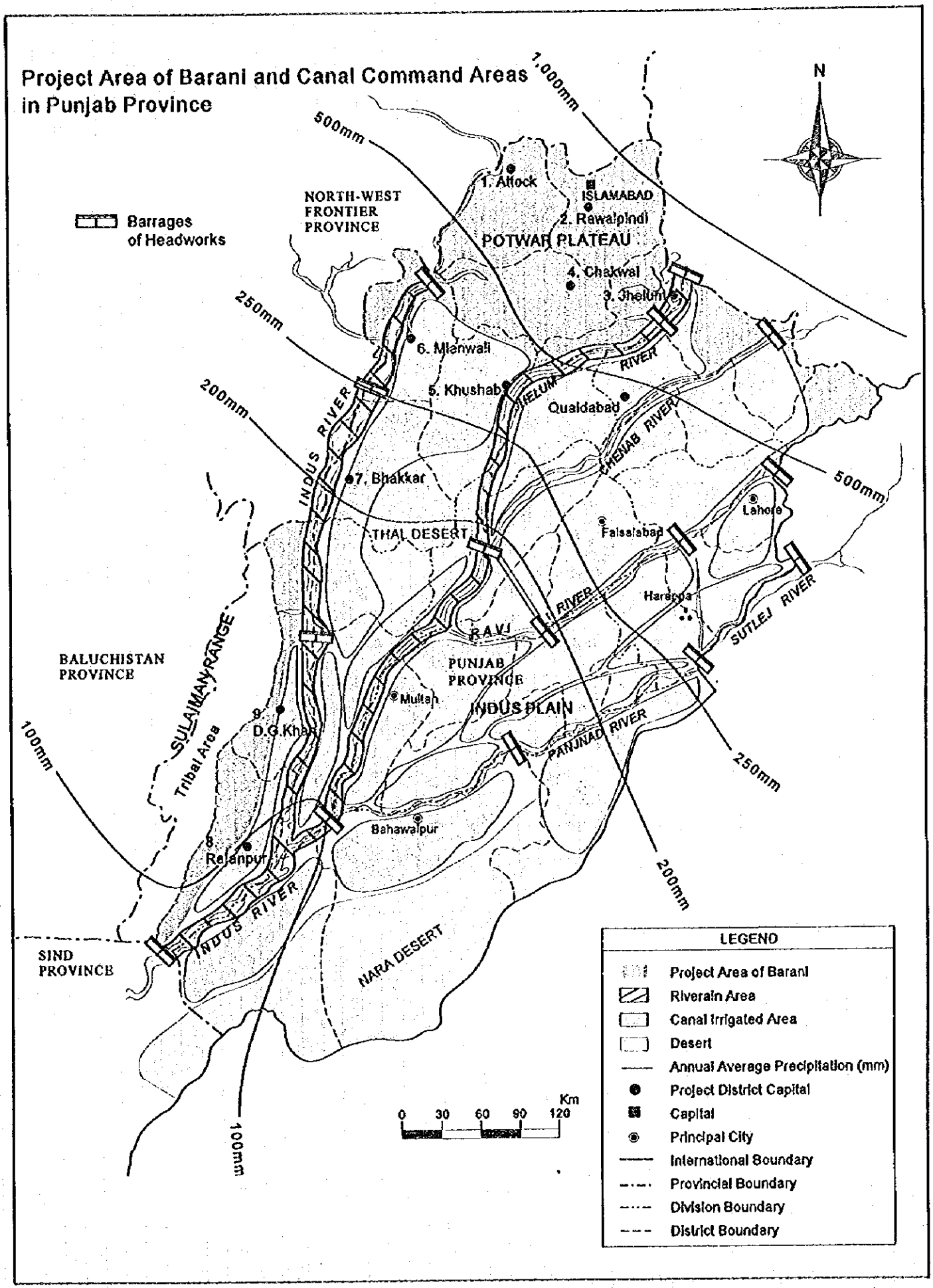
| Project Areas of 9 Districts in the Punjab Province | |
|---|---|
| ①Attock | ⑥Mianwali |
| ②Rawalpindi | ⑦Bhakkar |
| ③Jhelum | ⑧Rajanpur |
| ④Chakwal | ⑨D. G. Khan |
| ⑤Khushab | |

TADZHIKISTAN
CHINA
NORTHERN AREA
NORTH-WEST FRONTIER PROVINCE
PESHAWAR
ISLAMABAD
RAWALPINDI
KASHMIR
POTWAR PLATEAU
FATA
SIALKOT
FAISALABAD
LAHORE
INDUS PLAIN
AFGANISTAN
QUETTA
SULAIMAN RANGE
INDUS
MULTAN
BAHAWALPUR
PUNJAB PROVINCE
BALUCHISTAN PROVINCE
IRAN
SUKKUR
INDIA
SIND PROVINCE
GWADAR
HYDERABAD
KARACHI
ARABIAN SEA

LEGEND
- PROJECT AREA (PUNJAB PROVINCE)
- PROJECT AREA
- NATIONAL CAPITAL
- PROVINCIAL CAPITAL
- PRINCIPAL CITY
- INTERNATIONAL BOUNDARY
- PROVINCIAL BOUNDARY
- MAIN ROAD

0 100 200 300 400 Km


Project Area of Barani and Canal Command Areas in Punjab Province
N
Barrages of Headworks
NORTH-WEST FRONTIER PROVINCE
POTWAR PLATEAU
1. Attock
ISLAMABAD
2. Rawalpindi
4. Chakwal
3. Jhelum
6. Mianwali
5. Khushab
Qualdabad
7. Bhakkar
THAL DESERT
Faisalabad
Lahore
Harappa
BALUCHISTAN PROVINCE
SULAIMAN RANGE
Tribal Area
8. D.G.Khan
Multan
PUNJAB PROVINCE
INDUS PLAIN
Bahawalpur
8. Rajanpur
SIND PROVINCE
NARA DESERT
INDUS RIVER
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
PANJNAD RIVER
1,000mm
500mm
250mm
200mm
100mm
0 30 60 90 120 Km
LEGEND
Project Area of Barani
Riverain Area
Canal Irrigated Area
Desert
Annual Average Precipitation (mm)
Project District Capital
Capital
Principal City
International Boundary
Provincial Boundary
Division Boundary
District Boundary

# CONTENTS

# LIST OF FIGURE

# LIST OF TABLE

# Abbreviations

| | |
|---|---|
| AD | Agricultural Department |
| BHN | Basic Human Needs |
| DAE | Directorate of Agricultural Engineering |
| DGA | Directorate General Agriculture (Field) |
| EAD | Economic Affairs Division, Ministry of Finance and Economic Affairs |
| E/N | Exchange of Notes |
| EOJ | Embassy of Japan |
| FATA | Federally Administered Tribal Areas |
| GDP | Gross Domestic Product |
| GNP | Gross National Product |
| ha | Hectare |
| hh | Household |
| JICA | Japan International Cooperation Agency |
| 2KR | Kennedy Round - II |
| Rs | Rupees |
| SAF | Structural Adjustment Facility |
| SAP | Social Action Programme |
| UNDP | United Nations Development Programme |
| US | United States |
| USAID | United States Agency for International Development |
| WAPDA | Water and Power Development Authority |

# CHAPTER 1 BACKGROUND OF THE PROJECT

# CHAPTER 1

# BACKGROUND OF THE PROJECT

## 1-1 Background of the Project

The Islamic Republic of Pakistan is located in southwest Asia bordered by Iran and Afghanistan to the west, India to the east and the Arabian Sea to the south. The total land area is about 796,000 $km^2$. The population is about 134 million persons (estimate for 1996) growing at an annual rate of 3.1% (average for 1985-1993). The GNP for 1994 is 55.6 billion US dollars and GNP per capita is about 430 US dollars. The sectional share in GDP shows agriculture leading at 25.0% with an improvement in GDP at an average growth rate of 5.0% during 1991-1996. Pakistan became an independent sovereign state in August, 1947 as a result of the division of the former British India. The country is administratively divided into four provinces of North-West Frontier, Punjab, Baluchistan and Sind, along with the Capital Federation of Islamabad, FATA and Asad Kashmir.

The economy of Pakistan is based on agriculture with about 47% of the working population earning their living through agriculture. However, since agricultural conditions are strongly affected by the weather, agricultural productivity is low and unstable. The productivities of Pakistan's main crops, wheat, rice and cotton, are low at about 60% of the world average productivity. Therefore, upgrading of agriculture productivities is urgently needed. In the Seventh Five Year Plan (1988-1993), the important policies promoted by the Pakistani government for agricultural development are (1) achievement of self-sufficiency in basic food items, (2) increase in food production through improvement in agricultural basics, (3) increase the employment opportunities in the rural area aiming to balance the economic conditions with the urban area. Presently, in the Eighth Five Year Plan (1993-1998), under the continuation of previous agricultural development policies, the government of Pakistan is promoting agricultural land improvement through new bulldozers, and construction of tubewell irrigation facilities including groundwater development. These objectives will contribute to the national improvement of social welfare for the Islamic Republic of Pakistan.

The project province of Punjab has about 68 million in population which is about 53% of the national population. The area is about 206 thousand $km^2$ or about 26% of the country, whereas the cultivated land area of Punjab is 11.85 million ha, which is about 57% of the cultivated land in the country. The main products of Punjab are wheat, rice, sugarcane and cotton, in which productions cover about 70% of the total food products in the country. Therefore, Punjab is called Pakistan's food

storehouse. The climate of Punjab is divided into the rainy season in July and August and the dry season from September to June, with some rain in February and March. The average annual precipitation is low in the desert area at the southern part of Punjab with about 100mm, and about 200mm to 800mm in the Barani and Indus plain where there are more agricultural activities. The Barani of rainfed agriculture and dessert areas depend upon groundwater for irrigation. Therefore, the government of Punjab is aiming to increase food production through development of new agricultural irrigation land and increase in productivity. To attain this goal, the executing agency, Directorate General Agriculture (Field) of the Government of Punjab, Lahore (DGA), is constructing tubewells and providing rental services for construction equipment such as bulldozers and tractors based on farmers' requests,.

Presently, the DGA is managing 16 power drilling rigs and 6 of them have been in use for over 20 years. In consequence, the demands for tubewell drillings from farmers cannot be met sufficiently and farmers are waiting several months to several years to have their tubewells. The other 10 power rigs were procured by the Japanese government in 1988 under the Increase of Food Supply, Kennedy Round II. To improve the present conditions, the government of Pakistan made a request for Japanese grant aid to procure tubewell drilling equipment and materials necessary for groundwater development. This project aims to develop groundwater in the Barani and desert areas where unstable agricultural activities and poor surroundings are evident. Therefore, farmers are awaiting groundwater supply for irrigation and drinking to improve the agricultural productivity and living standard of the rural area.

## 1-2 Outline of the Request

This request for groundwater development was prepared in August, 1989. When the discussion and confirmation of the request were made during the Basic Design Study in June, 1996, a revised request was proposed by the executing agency, DGA. The requested equipment are listed below.

Table 1-1 Contents of Requests, August, 1989 and June, 1996

| No. | Request (August, 1989) | | | Revised Request (June, 1996) at time of B/D Study | | |
|---|---|---|---|---|---|---|
| 1. | Rotary Drilling Rig | : | 10 units | Rotary Drilling Rig | : | 30 units |
| 2. | Survey Equipment | | | Survey Equipment | | |
| | 1) Resistivity Meter | : | 2 units | 1) Resistivity Meter | : | 9 units |
| | 2) Pumping Test Equipment | : | 2units | 2) Well Logging Equipment | : | 9 units |
| | 3) Well Logging Equipment | : | 2units | | | |
| 3. | Spare Parts | : | 1 lot | Spare Parts | : | 1 lot |
| 4. | Other Equipment | : | 1 lot | Other Equipment | : | 1 lot |
| | 1) Drill Pipe, Drill Collar, | | | 1) Drill Pipe, Drill Collar, | | |
| | 2) Bits, Stabilizer, Bit Sub | | | 2) Bits, Stabilizer, Bit Sub | | |
| | 3) Bit Breaker, Tools Kit | | | 3) Bit Breaker, Tools Kit | | |
| 5.. | Others | | | Others | | |
| | | | | 1) Computer | : | 20 units |
| | | | | 2) Compressor | : | 30 units |
| | | | | 3) Water Analysis Set | : | 9 units |
| | | | | 4) Mobile Workshop | : | 11 units |
| | | | | 5) Welding Equipment | : | 30 units |

In the revised request of June, 1996, the number of equipments was increased, and as a result of discussions between the basic design study team and the DGA on the necessity of each equipment, the following points were agreed upon.

1) The urgency of the mobile workshops and welding equipments were confirmed to be low.
2) The contents and quantity of equipments shall be decided based on the survey results of the Basic Design Study .
3) The basic request and priority of equipments were agreed between the Study team and the DGA, the executing agency, and concluded in the minutes of meeting as shown in Table 1-2.

Table 1-2 Contents of Request and Priority of the B/D Minutes

| | Items for Confirmation (June 12, 1996) | Priority |
|---|---|---|
| 1. | Tubewell Drilling Equipment with Drilling Accessories | A |
| 2. | Geophysical and Testing Equipment | |
| | 1) Resistivity Meter | B |
| | 2) Water Quality Analysis Equipment | C |
| 3. | Other Equipment | |
| | 1) Computer | B |
| | 2) Compressor | B |
| | 3) Pick-up Truck | B |
| 4. | Additional Request from Pakistani Side | |
| | 1) Spare Parts for Drilling Rigs so far Procured under Japanese Grant Aid. | |
| | 2) Training for Drilling Rig Operation and Tubewell Construction. | |
| | 3) Internal Transportation. | |

The contents and quantity of equipment were studied by the team in Tokyo based on the interpretation of field survey and discussions with the government of Japan. The explanation of the draft basic design was carried out from the end of August to the beginning of September, 1996 in Pakistan. As a result, the equipments for the Project were confirmed as listed below.

Table 1-3 Contents of the Project (September, 1996)

| No. | Equipment | Quantity | Description |
|---|---|---|---|
| 1. | Rotary Drilling Rig | 9 units | Truck Mounted Drilling Rig<br>Drilling Capacity of More Than 200 m Depth |
| 2. | Drilling Tools | 1 lot | 1)Standard Accessory<br>2)Drilling Tools<br>3)Others |
| 3. | Spare Parts | 1 lot | Minimum Required Quantity |
| 4. | Compressor | 3 units | Mobile Type |
| 5. | Pick - Up Truck | 2 units | Single Cab, 4 x 4 |
| 6. | Computer | 1 unit | Desk Top Type |

# CHAPTER 2 CONTENTS OF THE PROJECT

# CHAPTER 2

# CONTENTS OF THE PROJECT

## 2-1 Objectives of the Project

In the Eighth Five Year Plan (1993-1998), the Pakistani government is promoting important policies with objectives of a 7% annual growth in GDP along with increase in per capita income through restraint in population growth. In particular, since agriculture shares 25% of the GDP, growth and development in agriculture are the most important subjects for resource conservation, and through effective use of water and land resources, improvement in production is being strived for. The Directorate General Agriculture (Field) of the Government of Punjab, Lahore (DGA) is aiming to improve agricultural production through mechanization. This is being carried out by (1) land improvement with new bulldozers, (2) promotion of groundwater irigation by introducing well drilling rigs and (3) cultivation efficiency as a result of tractor introduction. To promote irrigation farming, the government of Punjab has enacted a subsidy system in 1972 where construction of irrigation tubewells and installation of motorized pumps based on farmers' requests are subsidized to reduce the cost burden on the farmers.

In this project, the government of Punjab has objectives to significantly increase agricultural production in rainfed agricultural fields called the Barani areas. In this respect, an irrigation plan through groundwater development will be implemented with objectives to improve production by increasing crop yield and converting to a cash crop cultivation pattern, and to increase the economical benefit efficiency of farmers. These objectives can be met by the procurement of tubewell drilling equipment and materials necessary for groundwater development.

## 2-2 Basic Concept of the Project

### 2-2-1 Confirmation of the Request

The contents of the request is based on the PC-1 of August, 1989, but in June, 1996, during the discussions between the basic design study team and the DGA, which is the executing agency, a revised request was submitted by the executing agency. In the revised request, the number of drilling rigs was increased from 10 to 30. However, since a sufficient justification for this

revision could not be confirmed, at the meeting of June 12, 1996, both sides have agreed as follows through confirmation of the equipment requirements and their priorities. The quantities and other detailed contents will be considered based on field survey and data analysis results relating to (1) irrigation plan and (2) tubewell drilling plan in the project areas.

| NO. | Items for Confirmation (June 12, 1996) | Priority |
|---|---|---|
| 1. | Tubewell Drilling Equipment with Drilling Accessories | A |
| 2. | Geophysical and Testing Equipment | |
| | 1) Resistivity Meter | B |
| | 2) Water Quality Analysis Equipment | C |
| 3. | Other Equipment | |
| | 1) Computer | B |
| | 2) Compressor | B |
| | 3) Pick-up Truck | B |
| Additional Request from Pakistani Side | | |
| 1) Spare Parts for Drilling Rigs so far Procured under Japanese Grant Aid. | | |
| 2) Training for Drilling Rig Operation and Tubewell Construction. | | |
| 3) Internal Transportation | | |

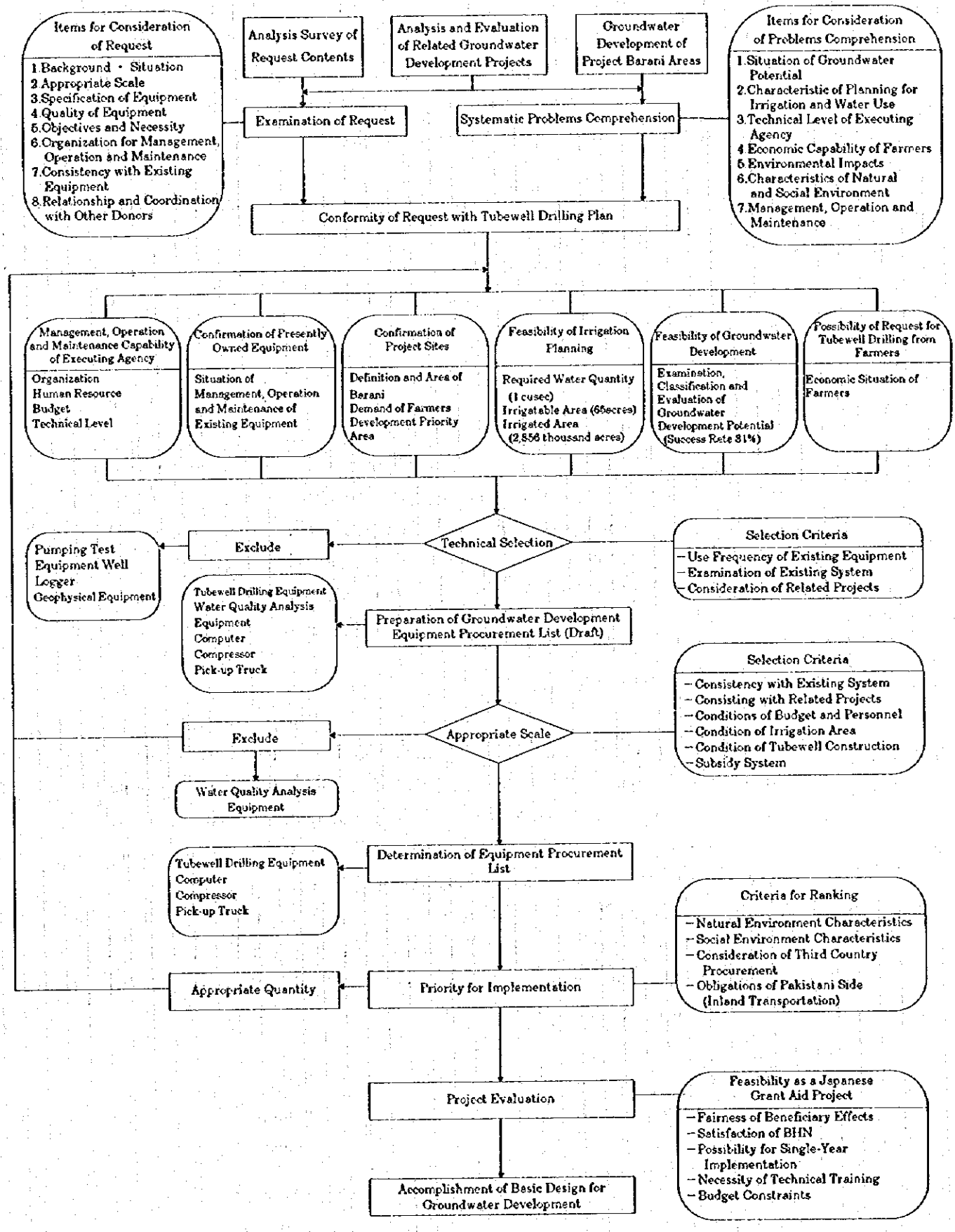
2-2-2 Examination of the Request

The request of the Pakistani government includes the procurement of tubewell drilling equipment necessary for groundwater irrigation in the Barani areas of Punjab Province; reinforcement of the tubewell construction organization of the executing agency; promotion of tubewell construction earnestly desired by the farmers; and improvement of agricultural production. The Barani areas of the project are widely spread out and about half of the presently operating drilling rigs are severely deteriorated because they have been in use over 20 years, and therefore, the demands for tubewell drillings by farmers cannot be met sufficiently. As a consequence, the necessity of power drilling rigs are considered since aquifers are found below 100 m depths and the formations are hard rock. The items for examination are shown in the flow chart of Fig. 2-1.

1) Definition of the Barani Areas

① The Barani areas of Punjab Province are areas where presently, agricultural cultivation is dependent only on rainwater.

Fig. 2-1 Flow Chart for Examination of Request



② The farmland area of the Punjab Barani areas is 1,501,700 ha according to the 1995 Agricultural Statistics. However, the groundwater irrigation area of the project sites is the total Barani area excluding previously developed areas and tenant farming areas, and where farmers want to carry out groundwater irrigation through expenses borne by themselves. This area is 1,157,000 ha (2,856,000 acres).

③ In the Punjab Barani areas, traditional shallow wells as well as recent tubewells are being used. The traditional shallow wells depend on unconfined groundwater with depths below 20 m. However, during the dry season, since water tables are lower and flow rates decrease, tubewells at depths between 100 m and 200 m using confined groundwater are in demand.

④ Hand boring plants of the Directorate of Agricultural Engineering (DAE) are used to drill in the thick (more than 200 m thick) Alluvium and Diluvium soft layers of riverain areas and canal irrigated areas. Of the nearly 3,000 irrigation wells (average depth 30 m) drilled annually, 80% are done by hand plants. On the other hand, in the Barani areas, since groundwater development is necessary in Pliocene and Miocene sedimentary rock formations below the thin Alluvium and Diluvium layers where use of hand plants are difficult, power drilling rigs which have high performance and efficiency are greatly in demand.

2) Consideration with Related Projects

① The equipment listed below were procured by the DGA through the Punjab Agricultural Department Groundwater Development Project (Material and Equipment Supply for the Increase of Food Production, 2KR, 1988/89). As a result of the site survey, the use of these equipment were confirmed (See Fig. 2-2). However, since locations of casing screens are often determined on the basis of hydrogeological conditions found at the time of the drilling, only a few well log data are available. Furthermore, pumping tests are conducted by simple methods using compressors. Therefore, in this project, though well loggers and pumping test equipment are not necessary, the application of simpler methods is more appropriate.

a. Rotary rig and drilling accessories : 10 units
b. Compressor : 10 units
c. Resistivity meter : 2 units

| Project Areas of 9 Districts in the Punjab Province | |
|---|---|
| 1.Attock | JR-5 |
| 2.Rawalpindi | JR-7, JR-10 |
| 3.Jhelum | JR-6 |
| 4.Chakwal | JR-1, JR-9 |
| 5.Khushab | JR-2, JR-3, JR-4 |
| 6.Mianwali | -- |
| 7.Bhakkar | -- |
| 8.Rajanpur | JR-8 |
| 9.D. G. Khan | -- |

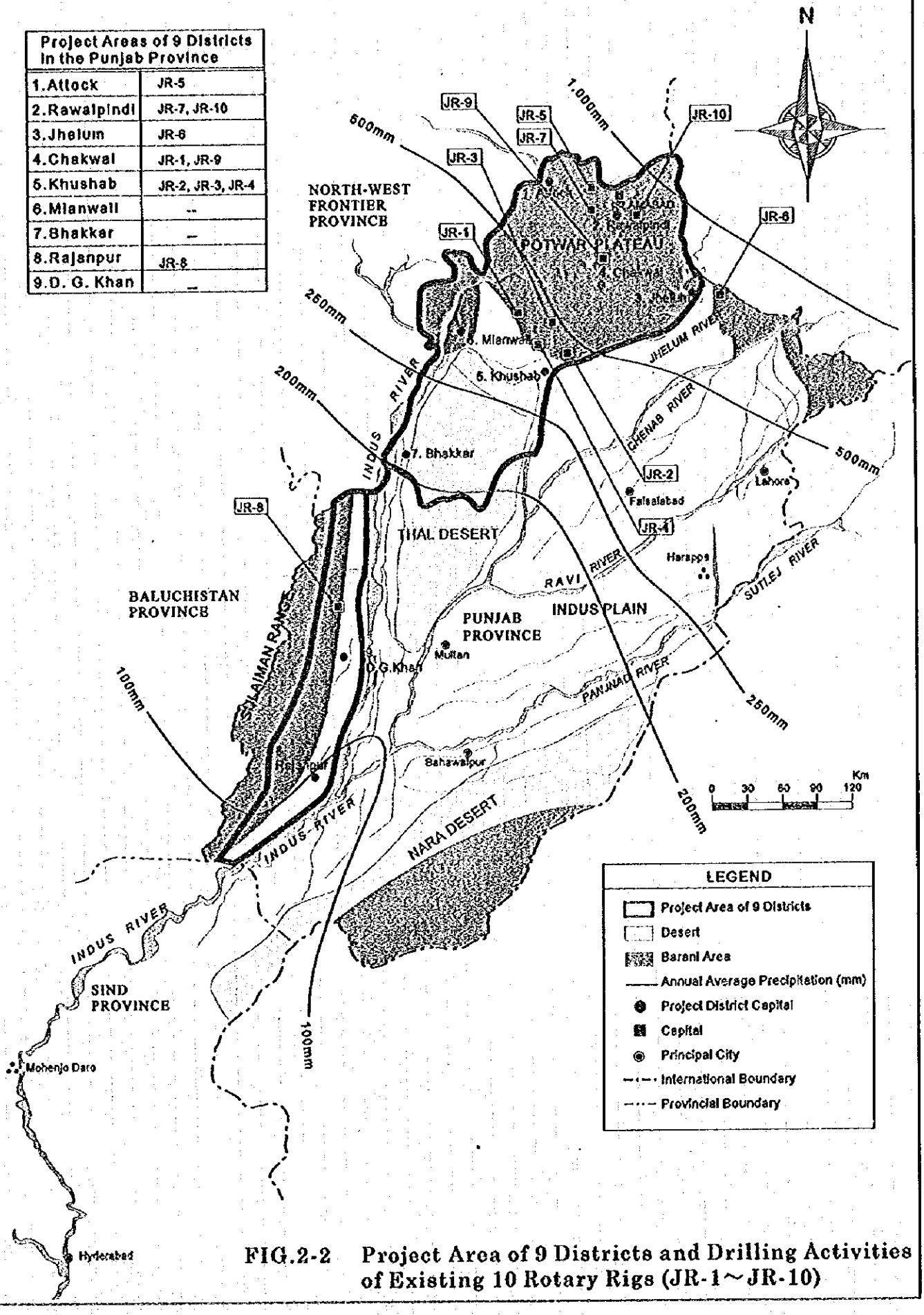



**FIG.2-2 Project Area of 9 Districts and Drilling Activities of Existing 10 Rotary Rigs (JR-1～JR-10)**

② The farmland area of the Punjab Barani areas is 1,501,700 ha according to the 1995 Agricultural Statistics. However, the groundwater irrigation area of the project sites is the total Barani area excluding previously developed areas and tenant farming areas, and where farmers want to carry out groundwater irrigation through expenses borne by themselves. This area is 1,157,000 ha (2,856,000 acres).

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|---|---|
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| 2.Rawalpindi | JR-7, JR-10 |
| 3.Jhelum | JR-6 |
| 4.Chakwal | JR-1, JR-9 |
| 5.Khushab | JR-2, JR-3, JR-4 |
| 6.Mianwali | – |
| 7.Bhakkar | – |
| 8.Rajanpur | JR-8 |
| 9.D. G. Khan | – |

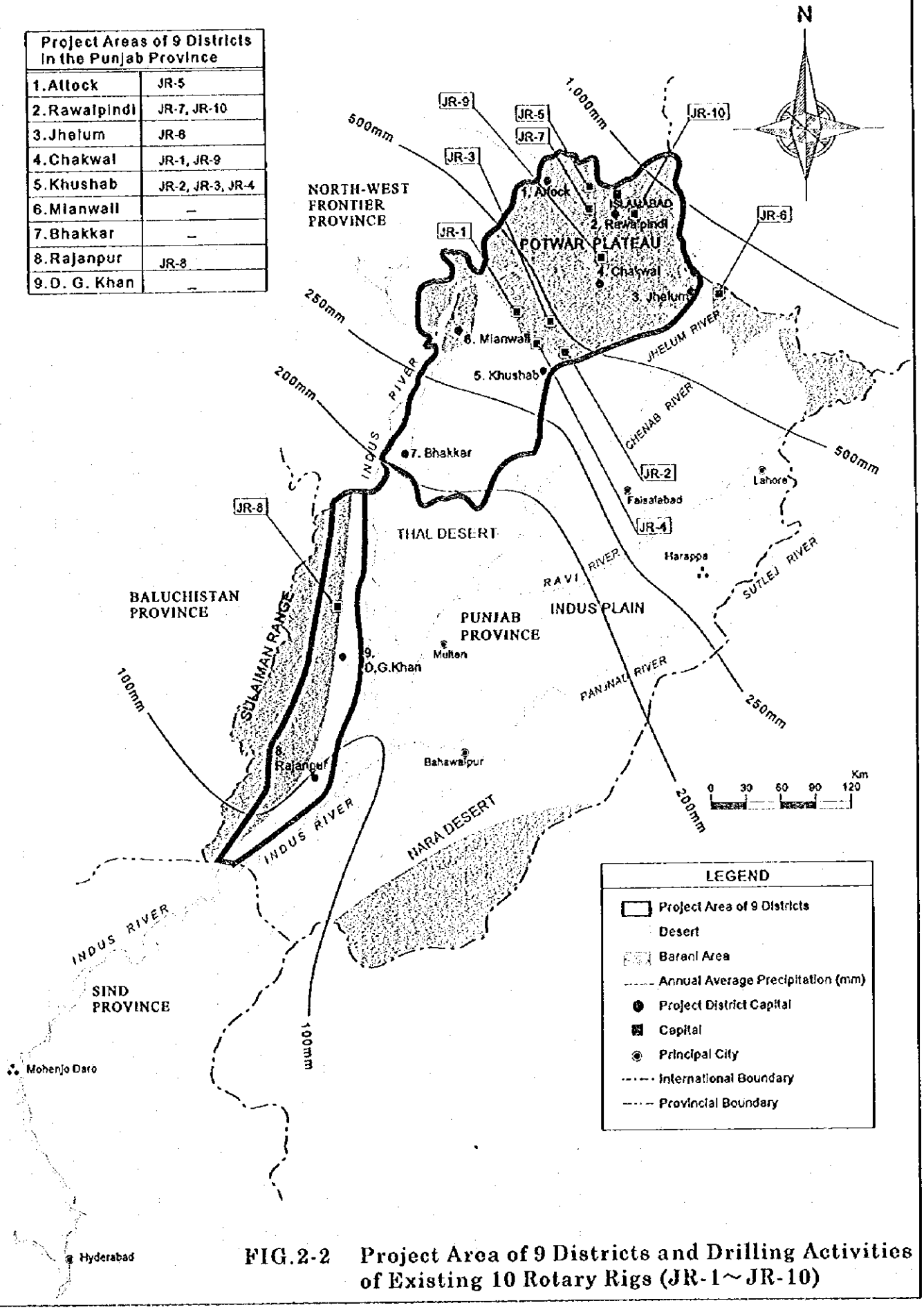


**FIG.2-2 Project Area of 9 Districts and Drilling Activities of Existing 10 Rotary Rigs (JR-1～JR-10)**

d. Well logger : 2 units
e. Pumping test equipment : 2 units
f. Water tanker : 2 units

② The below listed equipment were procured by WAPDA under the Project for Groundwater Development in Desert Areas of Pakistan (1993/94). The site survey confirmed the sufficient use of these equipment.

a. Rotary rig and drilling accessories : 2 units
b. DTH tools : 1 set
c. Compressor : 2 units
d. Welding equipment : 2 units
e. Resistivity meter : 1 unit
f. Well logger : 1 unit
g. Pumping test equipment : 1 unit
h. Wireless communication equipment : 5 units
i. Water quality analysis equipment : 2 units
j. 8 t crane truck : 2 units
k. Water tanker : 2 units
l. Pick-up truck : 2 units

WAPDA has been carrying out hydrogeological, groundwater potential, test drilling and other surveys in the Barani areas since the 1980's. Presently, the Hydrogeology Wing of WAPDA is conducting groundwater surveys in the Barani areas (D.G. Khan and Rajanpur) with special order from the Federal Government, and the rotary drilling rigs procured through the Japanese Grant Aid are being used for this purpose. Their groundwater study duties include evaluation of groundwater potential, aquifer depths, water quality and other factors, and preparation of reports. It has been confirmed that these will not overlap with this present project. Moreover, the tubewell construction operation of WAPDA is handled completely independently by a 12 member team who set up their own tents, procure and transport equipment and materials by themselves. Whereas, on the other hand, the DGA tubewell drilling team consists of 3 members per rig who operate in collaboration with the farmers, where the farmers supply 4 to 5 assistants and procure/transport bentonite, screens, casings and other material necessary for tubewell construction. Consequently, in comparison to WAPDA, equipment

procured by the DGA include less transport vehicles and survey equipment, and more tubewell rotary rigs. Likewise for this project, emphasizing tubewell construction as requested by the farmers, placing importance on procurement of rotary drilling rigs as the principal equipment is anticipated.

3) Consideration with Irrigation

① The total area of the target area of Punjab Province is 2,906,000 ha, of which 1,501,700 ha is the Barani area. The Barani groundwater irrigation area for this project is 1,157,000 ha as shown in the next table, which is 40% of the total target area of Punjab Province. Since realization on development of groundwater irrigated area and tenant farm area is unlikely, these are excluded from this project. Tenant farm land area was calculated from the owner farming ratios. (Table 2-1).

Table 2-1 The Barani Land Area and Irrigation Land Area to be Irrigated for this Project

| No. | Project Area (District) | Land Area (1,000 ha) | A) Barani Area (1,000 ha) | B) Irrigation Area (1,000 ha) | C) A) - B) | D) Owner Farming Ratio(%) | E) Area to be Irrigation (1,000 ha) |
|---|---|---|---|---|---|---|---|
| 1 | Attock | 336 | 255.7 | 0.9 | 254.8 | 77.9 | 198 |
| 2 | Rawalpindi | 244 | 198.5 | 2.8 | 195.7 | 95.8 | 187 |
| 3 | Jhelum | 147 | 82.2 | 1.0 | 81.2 | 91.0 | 74 |
| 4 | Chakwal | 313 | 233.5 | 1.8 | 231.7 | 87.7 | 203 |
| 5 | Khushab | 342 | 231.2 | 4.0 | 227.2 | 70.3 | 160 |
| 6 | Mianwali | 288 | 108.5 | 0.0 | 108.5 | 67.4 | 73 |
| 7 | Bhakkar | 588 | 330.7 | 0.0 | 330.7 | 65.4 | 216 |
| 8 | Rajanpur | 326 | 26.2 | 0.6 | 25.6 | 65.9 | 17 |
| 9 | D.G. Khan | 322 | 35.2 | 0.0 | 35.2 | 81.7 | 29 |
| | | 2,906 | 1,501.7 | 11.1 | 1,490.6 | 77.6 | 1,157 |

1990 Agricultural Statistics, Punjab Province

② The number of tubewells needed in the Barani areas is calculated as 43,950 with the assumption that for a pumping rate of 1 cusec (about 100 $m^3$/hr) per well, 65 acres (26.325 ha)of farmland can be irrigated.

$$1{,}157{,}000 \text{ ha} \div 26.325 \text{ ha / well} = 43{,}950 \text{ wells}$$

On the other hand, according to the records of the 10 drilling rigs procured through Japanese assistance in 1988/89, only 520 tubewells (average depth 95 m) were drilled in about 7 years, and the effective use of drilling rigs is being considered, but the large potential demand can be confirmed.

③ Analysis will be made to see if the farmers in Barani areas can procure / prepare the costs of irrigation tubewell constructions under the present registration system. The results of analysis are presented in the following Tables. For owner farming, procurement / preparation of tubewell construction costs is possible despite the size of farm acreage (5 to 20 acres).

a. The annual income of farmers consists of farm income, livestock income and off-farm income. The annual cash incomes with respect to farm size (5 to 20 acres) range from about Rs. 25,000 to 55,000.

b. The disposable incomes, which are annual cash incomes minus required expenditures, range from about Rs. 8,000 to 27,000.

c. According to the financial analysis of farm households (Type 1: average cropping intensity of 90% for 7 project sites of Attock, Rawalpindi, Jhelum, Chakwal, Khushab and Mianwali), assuming a groundwater irrigation land area of 65 acres as the unit area, the cost to be borne by each farmer is 3.6 to 4.3 times the disposable income, which means that with about 4 to 5 years savings, one irrigation tubewell can be constructed. In reality, there are many farmers that apply for the tubewell drilling based on a unit area of 25 to 40 acres and construct irrigation tubewells with the savings of 10 to 15 years.

d. In the financial analysis of Type 2 (average cropping intensity of 50% for 2 project sites Rajanpur and D.G. Khan), with savings for about 5 to 8 years, the construction cost for tubewells can be secured. Therefore, for present owner farmers having 5 to 20 acres farms, the cost for tubewell construction can be procured and prepared.

Table 2-2 Present Financial Conditions of Farm Household
(Type-1 : Average Cropping Intensity 90% for 7 Project Sites)

| | | | Assumed Conditions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Farm Size | (acres) | 5.0 | 7.5 | 10.0 | 12.5 | 15.0 | 17.5 | 20.0 |
| 2. | Cropping Intensity | (%) | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| 3. | Farm Income | (Rs.) | 6,391 | 9,587 | 12,782 | 15,978 | 19,173 | 22,369 | 25,565 |
| 4. | Livestock Income | (Rs.) | 6,273 | 9,228 | 9,565 | 9,964 | 10,332 | 10,701 | 11,069 |
| 5. | Off-Farm Income | (Rs.) | 12,920 | 18,956 | 18,956 | 18,956 | 18,956 | 18,956 | 18,956 |
| 6. | Cash Income | (3.+4.+5.) | 25,584 | 37,771 | 41,334 | 44,898 | 48,461 | 52,026 | 55,590 |
| 7. | Expenditure | (Rs.) | 17,486 | 22,496 | 22,496 | 22,496 | 27,944 | 27,944 | 27,944 |
| 8. | Disposable Income | (6.-7.) | 8,098 | 15,275 | 18,838 | 22,402 | 20,517 | 24,082 | 27,646 |
| 9. | Area Share to 65 Acres | (%) | 0.08 | 0.12 | 0.15 | 0.19 | 0.23 | 0.27 | 0.31 |
| 10. | Shared Capital Costs | (Rs.) | 29,437 | 44,156 | 58,875 | 73,593 | 88,312 | 103,031 | 117,749 |
| 11. | Required Saving Years | (10/8.) | 3.6 | 2.9 | 3.1 | 3.3 | 4.3 | 4.3 | 4.3 |

Punjab Economic Research Institute, February, 1995

Table 2-3 Present Financial Conditions of Farm Household
(Type-2: Average Cropping Intensity 50% for 2 Project Sites)

| | | | Assumed Conditions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Farm Size | (acres) | 5.0 | 7.5 | 10.0 | 12.5 | 15.0 | 17.5 | 20.0 |
| 2. | Cropping Intensity | (%) | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 3. | Farm Income | (Rs.) | 1,718 | 2,577 | 3,435 | 4,291 | 5,153 | 6,012 | 6,871 |
| 4. | Livestock Income | (Rs.) | 6,273 | 9,228 | 9,596 | 9,964 | 10,332 | 10,701 | 11,069 |
| 5. | Off-Farm Income | (Rs.) | 12,920 | 18,956 | 18,956 | 18,956 | 18,956 | 18,956 | 18,956 |
| 6. | Cash Income | (3.+4.+5.) | 20,911 | 30,761 | 31,988 | 33,215 | 34,442 | 35,668 | 36,895 |
| 7. | Expenditure | (Rs.) | 17,486 | 21,102 | 21,102 | 21,102 | 21,102 | 21,102 | 21,102 |
| 8. | Disposable Income | (6.-7.) | 3,425 | 9,659 | 10,886 | 12,113 | 13,340 | 14,566 | 15,793 |
| 9. | Area Share to 65 Acres | (%) | 0.08 | 0.12 | 0.15 | 0.19 | 0.23 | 0.27 | 0.31 |
| 10. | Shared Capital Costs | (Rs.) | 27,681 | 41,521 | 55,362 | 69,202 | 83,042 | 96,883 | 110,723 |
| 11. | Required Saving Years | (10./8.) | 8.1 | 4.32 | 5.1 | 5.7 | 6.2 | 6.7 | 7.0 |

Punjab Economic Research Institute, February, 1995

4) Consideration with Tubewell Drilling Plan

① Presently, the DAE has 218 drilling equipment operating around Punjab Province with an annual tubewell construction rate of about 3,000. Of these, 55 teams are operating in the project target areas. However, 45 teams using power winches, hand plants and percussion rigs are limited to drilling in canal inigated areas or riverain areas. (Table 2-4) Furthermore, in the Barani areas where hard rocks are prevalent and aquifers deep, the only operable equipment are the 10 rotary rigs procured under Japanese assistance, and these are constructing about 60 to 100 tubewells annually. (see Table 2-5) Of the total arable land, the Barani areas cover 52.9%, riverain cover 1.3% and canal irrigated area cover 45.8%. Therefore, in the project Barani areas, new rotary rigs are immediately needed. The requested capacity of the rigs is for 200 m depth and ϕ 17-1/2 inch diameter. (Refer to Fig. 2-3)

② The drilling methods of the Agricultural Department and WAPDA are similar. The design depth of 100 to 150 m is first drilled at ϕ 8-5/8 to ϕ 10-5/8 inch diameter to confirm the aquifer and water quality. This requires about 15 days. Then for a production tubewell, the hole is bored to ϕ 17-1/2 inch, and screen and casing are installed, which takes about another 15 days. This means that the tubewell can be completed in about a month. Judging from this tubewell construction experience of the executing agency, in the Barani areas, one rotary rig can construct about 8 tubewells per year considering Ramadan and other holidays.

Table 2 - 4 Current Allocation of Tubewell Drilling Equipment

| | Area | Hand Plants | Power Winch | Drilling Rigs | | | Supporting Vehicle | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Japanese Assistance | | Percussion Rigs | Truck | Tractor | Pick-up Truck | Jeep | Water Tanker |
| | | | | KR-II | No. of Equipment | | | | | | |
| 1 | Faisalabad | 7 | | | | | | | | | |
| 2 | Jhang | 10 | | | | | | | | | |
| 3 | T.T/Singh | 5 | | | | | | | | | |
| 4 | Sargodha | 1 | 2 | | | | | | | 1 | |
| 5 | Khushab | 3 | | 3 | JR-2,3,4 | | 1 | | | 1 | 2 |
| 6 | Mianwali | 8 | | | | | *2 | *1 | | | |
| 7 | Bhakkar | 8 | | | | | *1 | *1 | *1 | *1 | |
| 8 | Lahore | 7 | 2 | | | | 1 | | | 1 | |
| 9 | Kasur | 6 | | | | | | | | | |
| 10 | Sheikhupura | 5 | 2 | | | | | | | | |
| 11 | Okara | 7 | 1 | | | | | | | | |
| 12 | Gujranwal | 1 | 6 | | | | | | | | |
| 13 | Gujrat | 11 | | | | 1 | | | | | |
| 14 | Sialkot | 10 | 1 | | | 1 | 1 | | | | 1 |
| 15 | Narowal | 10 | | | | | | | | | |
| 16 | Jhelum | 6 | | 1 | JR-6 | 1 | 1 | | | 1 | 1 |
| 17 | Chakwal | 5 | | 2 | JR-1,9 | 1 | *1 | *1 | | 1 | 1 |
| 18 | Rawalpindi | 4 | | 2 | JR-7,10 | 1 | 1 | 1 | | 1 | 2 |
| 19 | Attock | 5 | | 1 | JR-5 | 1 | 1 | 1 | | 1 | 1 |
| | Sub Total | 119 | 14 | 9 | | 6 | 10 | 5 | 1 | 8 | 8 |
| 20 | Multan | 6 | 1 | | | | | 1 | 1 | 1 | |
| 21 | Khanewal | 3 | | | | | | | | 1 | |
| 22 | Sahiwal | 7 | | | | | | | | 1 | |
| 23 | Vehari | 8 | 2 | | | | | | | 1 | |
| 24 | D.G.Khan | 3 | | | | | | | | 1 | |
| 25 | Rajan Pur | 3 | | 1 | JR-8 | | | | | 1 | |
| 26 | M.Garh | 6 | | | | | | | | 1 | |
| 27 | Layyah | 3 | | | | | | | | 1 | |
| 28 | B.Pur | 9 | | | | | | | | 1 | |
| 29 | B.Nagar | 7 | | | | | | | | 1 | |
| 30 | R.Y.Khan | 11 | | | | | | | | 1 | |
| | Sub Total | 66 | 3 | 1 | | 0 | 0 | 1 | 1 | 11 | 0 |
| | | 185 | 17 | 10 | 0 | 6 | 10 | 6 | 2 | 19 | 8 |
| | Grand Total | 218 | | | | | 45 | | | | |

: 9 Project Sites

* Owned by Drilling Section and Bulldozer Section

Table 2-5 Construction Record of Irrigation Tubewells in the Project Barani Area

| Project Site | No. of Rig | 1989/90 | | 1990/91 | | 1991/92 | | 1992/93 | | 1993/94 | | 1994/95 | | 1995/96 | | Total Numbers of Tubewells (1989-1996) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S | U | S | U | S | U | S | U | S | U | S | U | S | U | Total No. of Tubewells | Successful Tubewells | Unsuccessful Tubewells | Success Rate |
| Attock | JR-5 | 1 | 2 | 4 | 0 | 5 | 4 | 2 | 6 | 8 | 6 | 10 | 2 | 4 | 1 | 55 | 34 | 21 | 61.8% |
| Rawalpindi | JR-10 | 7 | 0 | 6 | 1 | 3 | 6 | 2 | 2 | 7 | 2 | 8 | 6 | 5 | 5 | 60 | 38 | 22 | |
| | JR-7 | 3 | 4 | 7 | 0 | 6 | 3 | 10 | 0 | 14 | 2 | 9 | 2 | 8 | 0 | 68 | 57 | 11 | 70.9% |
| | JR-8 | 0 | 5 | 10 | 3 | 2 | 3 | - | - | - | - | - | - | - | - | 23 | 12 | 11 | |
| Jhelum | JR-6 | 4 | 1 | 11 | 0 | 8 | 0 | 2 | 0 | 5 | 0 | 1 | 0 | 5 | 3 | 40 | 36 | 4 | 90.0% |
| Chakwal | JR-1 | 8 | 0 | 3 | 1 | 2 | 3 | 3 | 3 | 5 | 2 | 5 | 1 | 9 | 2 | 47 | 35 | 12 | 69.1% |
| | JR-9 | 4 | 1 | 8 | 2 | 4 | 3 | 8 | 6 | - | - | 3 | 3 | 5 | 3 | 50 | 32 | 18 | |
| Khushab | JR-2 | - | - | - | - | 6 | 0 | 13 | 0 | 10 | 0 | 13 | 0 | 5 | 0 | 47 | 47 | 0 | |
| | JR-3 | 2 | 0 | 5 | 0 | 4 | 0 | 5 | 0 | 5 | 0 | 12 | 0 | 8 | 0 | 41 | 41 | 0 | 100.0% |
| | JR-4 | 16 | 0 | - | - | 8 | 0 | 12 | 0 | 13 | 0 | 10 | 0 | 6 | 0 | 65 | 65 | 0 | |
| Rajanpur | JR-8 | - | - | - | - | - | - | - | - | 5 | 0 | 12 | 0 | 6 | 0 | 23 | 23 | 0 | 100.0% |
| D.G.Khan | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 0 | 1 | 1 | 0 | 100.0% |
| Total | 10 | 45 | 13 | 13 | 7 | 48 | 22 | 57 | 57 | 72 | 12 | 12 | 14 | 62 | 14 | 520 | 421 | 99 | 81.0% |

Note: S: Successful Tubewell
U: Unsuccessful Tubewell

5) Consideration under Groundwater Existence Conditions

① In the project Barani areas, during the 7 years from 1989 to 1996, 520 irrigation tubewells were drilled with 10 rotary rigs, which means an annual drilling rate of 7.4 wells / rig. 421 tubewells were successful and 99 unsuccessful, for a success rate of about 81%. (Refer to Table 2-5 and Appendix-6)

② In Rawalpindi District, test tubewells of 295 m and 250 m depths were drilled, but both tubewells did not produce groundwater making them unsuccessful. As for successful tubewells, 8.8% were of 150 to 200 m depths and about 80% were of 50 to 150 m depths. Therefore, rotary drilling rigs of 200 m capacity are required. (See Fig. 2-3 and Fig. 2-4)

③ The groundwater potential rate of the Barani areas is relatively low as compared to that of the plains of the Indus river basin in Punjab. Tubewells producing 1 cusec (about 100 $m^3/hr$) to cover an irrigation area of 65 acres is about 63%, when limiting the drawdown within the permissible amount. Therefore in 63% of the area, one tubewell is enough to irrigate 65 acres with 1 cusec, but in the other 37%, 1 cusec cannot be pumped, which means more than one tubewell needs to be drilled. (See Fig. 2-5 and Fig. 2-6)

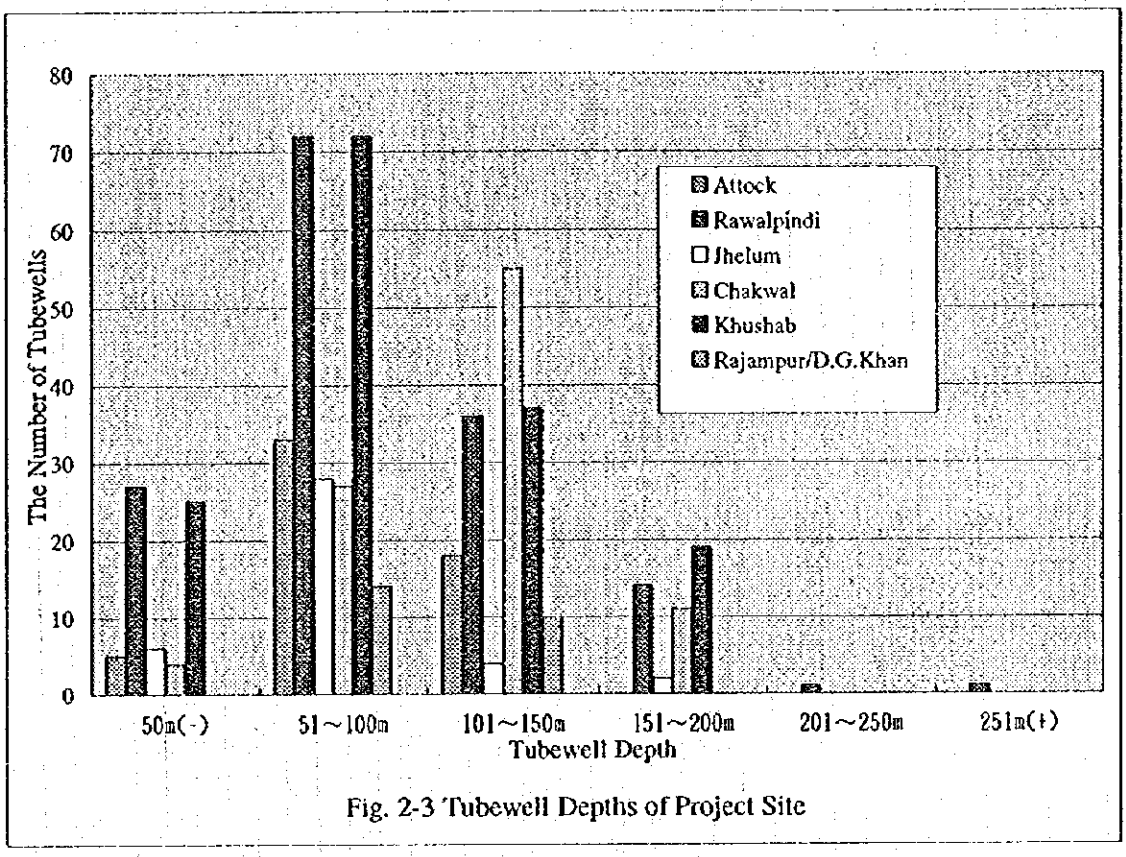


Fig. 2-3 Tubewell Depths of Project Site

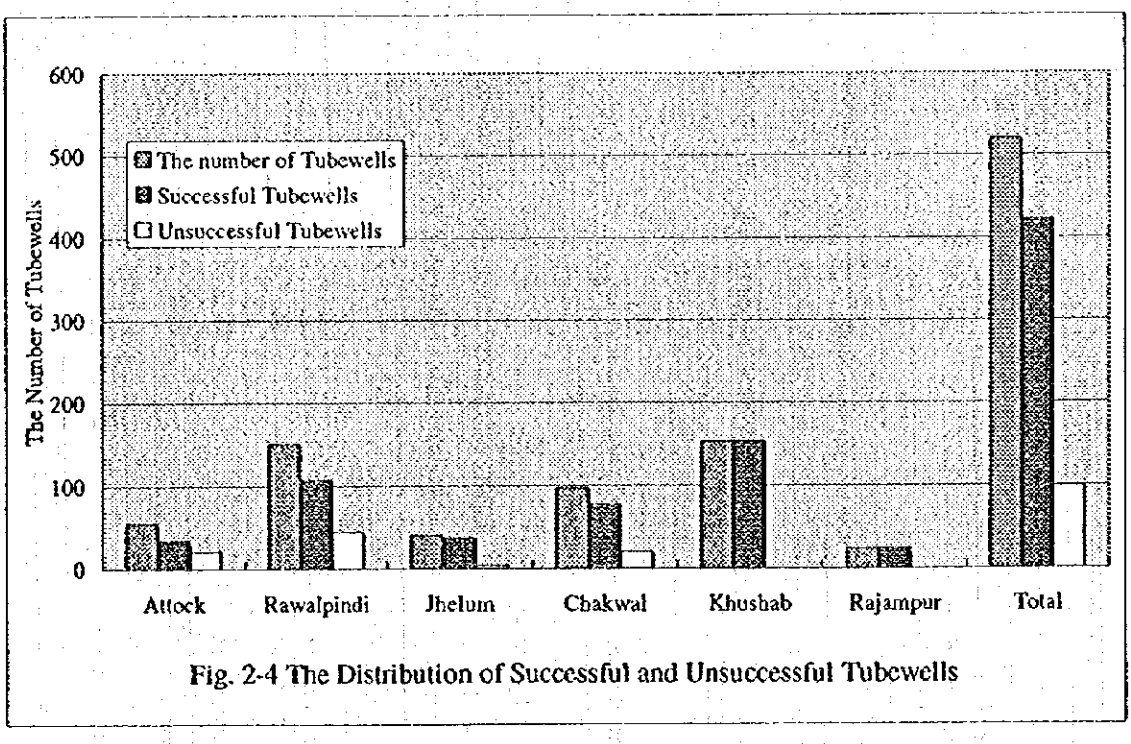


Fig. 2-4 The Distribution of Successful and Unsuccessful Tubewells

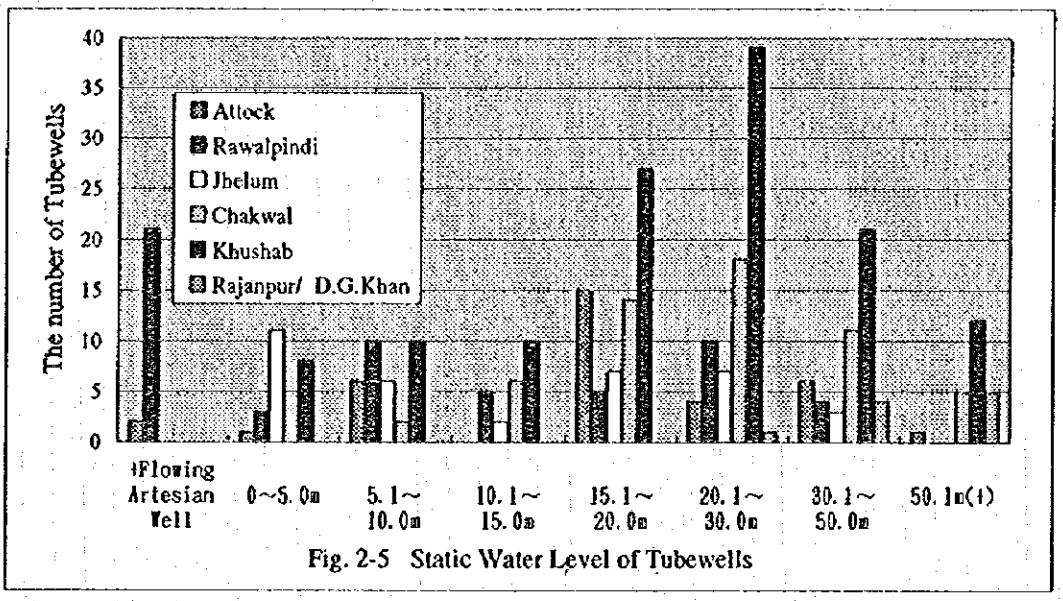


Fig. 2-5 Static Water Level of Tubewells

Table2-6 Static Water Level of Tubewells

| Static Water Level | Attock | Rawalpindi | Jhelum | Chakwal | Khushab | Rajanpur/ D.G.Khan | Total |
|---|---|---|---|---|---|---|---|
| +Flowing Artesian Well | 2 | 21 | 0 | 0 | 0 | 0 | 23 |
| 0~5.0m | 1 | 3 | 11 | 0 | 8 | 0 | 23 |
| 5.1~10.0m | 6 | 10 | 6 | 2 | 10 | 0 | 34 |
| 10.1~15.0m | 0 | 5 | 2 | 6 | 10 | 0 | 23 |
| 15.1~20.0m | 15 | 5 | 7 | 14 | 27 | 0 | 68 |
| 20.1~30.0m | 4 | 10 | 7 | 18 | 39 | 1 | 79 |
| 30.1~50.0m | 6 | 4 | 3 | 11 | 21 | 4 | 49 |
| 50.1m(+) | 1 | 0 | 0 | 5 | 12 | 5 | 23 |
| Total | 35 | 58 | 36 | 56 | 127 | 10 | 322 |

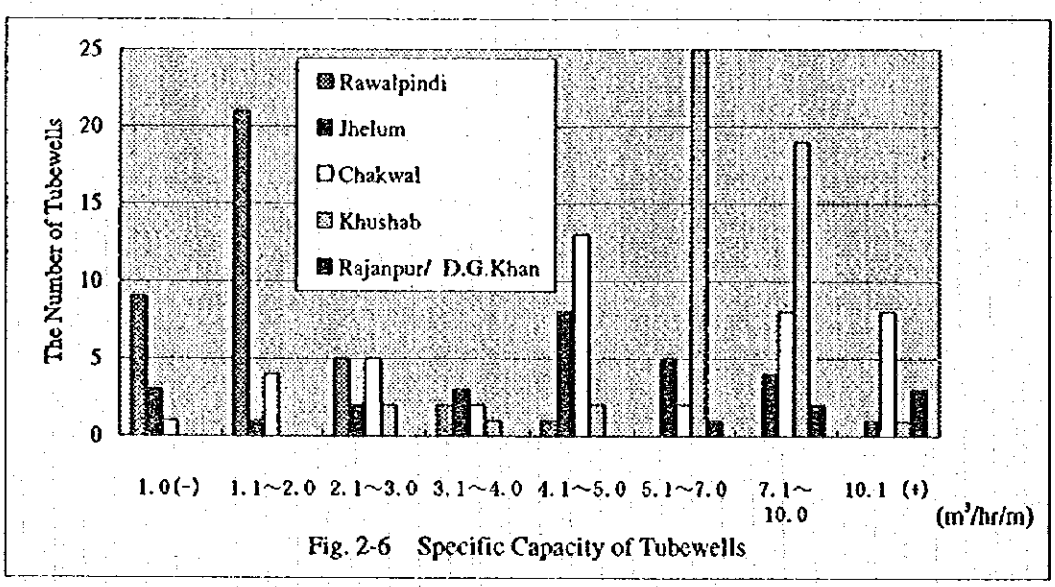


Fig. 2-6 Specific Capacity of Tubewells

Table2-7 Specific Capacity of Tubewells

| Specific Capacity ($m^3$/hr/m) | Rawalpindi | Jhelum | Chakwal | Khushab | Rajanpur/ D.G.Khan | Total |
|---|---|---|---|---|---|---|
| 1.0(-) | 9 | 3 | 1 | 0 | 0 | 13 |
| 1.1~2.0 | 21 | 1 | 4 | 0 | 0 | 26 |
| 2.1~3.0 | 5 | 2 | 5 | 2 | 0 | 14 |
| 3.1~4.0 | 2 | 3 | 2 | 1 | 0 | 8 |
| 4.1~5.0 | 1 | 8 | 13 | 2 | 0 | 24 |
| 5.1~7.0 | 0 | 5 | 2 | 25 | 1 | 33 |
| 7.1~10.0 | 0 | 4 | 8 | 19 | 2 | 33 |
| 10.1 (+) | 0 | 1 | 8 | 1 | 3 | 13 |
| Total | 38 | 27 | 43 | 50 | 6 | 164 |

## 2-2-3 Evaluation of Project Sites based on Groundwater and Irrigation Developments

### 1) Evaluation of Project Sites based on Irrigation Development

Irrigation development in the project sites is carried out on a request basis from the farmers. The priority is rated upon consideration of the Barani land area, area to be irrigated, farm scale, farmer income and other potential factors for irrigation development, as well as focus on eradication of poverty as an objective of the Eighth Five Year Plan, 1993-1998.

① The borderline for poverty is calculated based on the minimum required calorie intake rate of 2,550 cal / person / day. In 1990/91, this was calculated as an income of Rs.280 / person / month (Rs.3,360 / person / year), and in 1996, the poverty line is assumed as an income of Rs.380 / person / month (Rs.4,560 / person / year). On the other hand, the average monthly income for a farm household in all of Pakistan is Rs.2,931 / hh / month (Rs.35,172 / hh / year).

② Upon examining this borderline for an average farm household in the project sites, the net profit from farming dependent on rain is below the poverty line of all areas. The deficit is covered by income other than agriculture and livestock breeding. Especially, the income from crop farming in small farm areas of the southern dry areas and Potwar plateau is extremely low.

If tubewell irrigation is carried out through this project, in Khushab, Mianwali and Bhakkar of southern Potwar plateau where geologic and hydrologic conditions are suitable for tubewell irrigation, the net profit from crop farming alone will cross the poverty line. Even in other areas, net profit doubling can be anticipated through implementation of this project. Therefore, the unstable farm management dependent on rainwater can be transformed into a stable management based on groundwater irrigation.

③ The priority rating of the project sites from the viewpoint of irrigation development was carried out by weighted evaluation using poverty in relation to irrigation potential. (Refer to Table 2-8)

a. Below the borderline for poverty: Rawalpindi in the northern area, Rajanpur and D.G. Khan in the southern area(3 sites).

b. The borderline for poverty : Attock, Jhelum and Chakwal in the northern area (3 sites).

c. Above the borderline for poverty: Khushab, Mianwali and Bhakkar in the northern area (3 sites).

Table 2-8 Irrigation Potential and Farm Household Income (Estimated 1996)

| Project Site | Project Area (Thousand ha) | Farm Household Income (Rs / Year) |
|---|---|---|
| 1.Attock | 198 | 12,269 |
| 2.Rawalpindi | 187 | 5,368 |
| 3.Jhelum | 74 | 9,841 |
| 4.Chakwal | 203 | 11,630 |
| 5.Khushab | 160 | 19,553 |
| 6.Mianwali | 73 | 16,997 |
| 7.Bhakkar | 216 | 23,515 |
| 8.Rajanpur | 17 | 4,782 |
| 9.D.G. Khan | 29 | 3,440 |
| Total | 1,157 | — |

2) Evaluation of Project Sites based on Groundwater Development

① Situation of rotary drilling equipment : Ten rotary drilling equipment have already been procured, and these are operating properly without any big problems. Presently (1996), these are allocated as 3 in Khushab, 2 in Rawalpindi and 2 in Chakwal, where groundwater development is hydrogeological difficult due to a distribution of hard rocks. Also, in the northern Potwar plateau, 1 rig is located in Attock and another one in Jhelum. The latter 2 are also allocated in hydrogeologically suitable locations where aquifers are found in deep layers.

On the other hand, one rig is operating in common with D.G. Khan and Rajanpur in the southern area. The site survey revealed that an additional procurement is necessary in this area. As for sites in other Barani areas (Layyah and Gujrat), these were not included in the request of 1989, but have been proposed in the amended request of 1996. Presently, these sites are served by rotary drilling rigs transferred from nearby areas when the need arise. Therefore, the site survey also confirmed the necessity of independent rigs in these sites as well, in the future.

② Groundwater development plan in the Barani areas: Groundwater development is required for irrigation in the Barani areas. The project land area, excluding presently irrigated areas, is 1,157,000 ha (2,857,000 acres). Assuming a standard groundwater pumping rate of 1 cusec (about 100 $m^3$/hr) per tubewell, then the irrigation area is 65 acres, which means 43,900 tubewells are necessary in the entire project areas. Area-wise, Bakkar requires the most at 8,200 tubewells, and Chakwal, Attock and Rawalpindi each require more than 7,000 tubewells. Furthermore, depending on aquifer depth, problems with salt water intrusion are found in some areas.

To evaluate the groundwater availability, specific capacities were calculated from pumping rates and drawdowns of existing tubewells. Then, if the drawdown is less than 20 m, an evaluation was made to judge if the standard groundwater pumping rate of 1 cusec can be obtained from a unit tubewell. In Attock and Rawalpindi, the unit tubewell pumping rate is low with a large drawdown, and in order to pump 1 cusec of groundwater, 2 or more tubewells are required. The required irrigation tubewells in the Barani areas, as calculated from the specific capacities, is about 1.5 times the above assumed number, which means 65,800 tubewells.

③ Records of tubewell drillings: The number of tubewells constructed with the 10 rotary drilling rigs procured in 1988 through the Japanese assistance is 520 (average depth of 95 m) in about 7 years, or an annual average of 74, which means 7.4 wells / year / rig. However, this number includes unsuccessful tubewells. In the northern Potwar plateau area, unsuccessful tubewells are especially numerous due to thick clay layer. In this area, tubewell data is scarce and geophysical surveys are not sufficiently conducted. As a result, Attock has the lowest success rate at 61.8%, next is Chakwal at 69.1%, followed by Rawalpindi at 71.5%, Jhelum at 92.5% and the other 3 areas are 100%, for an average in all areas of 81%. From a hydrogeological viewpoint, in areas where groundwater development is difficult, the effective use of geophysical equipment is necessary to upgrade the success rate of tubewell drillings.

④ Allocation plan for new rotary drilling rigs: The allocation of rotary drilling rigs to be newly procured was considered. Seven years have elapsed since the request was submitted in 1989, and to cope with the rising demand of farmers for groundwater development, the executing agency has revised the original request for 10 drilling rigs to 30 rigs. Requirement restrictions on the number of drilling rigs were considered

through detailed evaluation on factors such as target land area, farm scale, farmer income, groundwater potential and irrigation tubewell demand in the project Barani areas from viewpoints of groundwater and irrigation developments. However, the feasibility of this project was confirmed for reasons such as, the project land area for irrigation is wide at about 11,570,000 ha; the farmers have on-going economic activities which include sound cash incomes and a distribution system for agricultural products; and owning irrigation tubewells create possibilities for growing cash crops such as sugarcane, cotton and rice, which can increase present cash incomes. Therefore, the procurement of power drilling rigs is required in the project areas. On the other hand, with regard to the number of power drilling rigs to be procured, the necessary number of power drilling rigs will be determined by evaluating the area to be irrigated in the Barani areas, farm scale, farmers' income, groundwater potential, and the demand of tubewells for irrigation based on groundwater and irrigation development.

⑤ In consideration of the above concepts, the overall evaluation of the project sites was made on the districts to be included in the project according to the scores they obtained. The references used for scoring are as follows.

(1) For project site Barani area rating, priority is given to larger Barani area sites.
(2) For farm size and produce income ratings, priority is given to lower values in consideration of poverty.
(3) Present operating situation of drilling rigs is evaluated, and priority is given to non-operating areas.
(4) For rating on design irrigation tubewell demand, priority is given to areas where predicated demand for tubewells is higher.
(5) For overall evaluation, areas of higher total scores are given priority. Especially, from the viewpoints of benefit to low income households and support to eradication of poverty, in this project, D.G. Khan and Rajanpur are used as the standard, since farm produce income is low and stands on the poverty borderline. Rajanpur was positioned below the poverty line due to the farmers' income, but was evaluated (B) because the project site land area is relatively small and presently, one rotary drilling rig is in operation; and therefore, the areas receiving total scores above that of Rajanpur is rated as "A" for drilling equipment necessity.

Rotary drilling rig requirement evaluation rating A) is given to the 7 sites of Attock, Rawalpindi, Jhelum, Chakwal, Mianwali and Bhakkar in the northern Potwar area, and D.G. Khan in the southern area. Overall evaluation rating B) goes to Rajanpur, and then, Khushab receives the overall evaluation rating C), where existing

3 rotary drilling rigs are now operating. For Attock and D.G. Khan, two rotary drilling rigs must be procured for each district because Attock has the highest demand for the number of planned tubewells for irrigation. D.G. Khan has the most urgent necessity for the agricultural development including the elimination of poverty.

Table 2-9 Evaluation for Project Site from the Viewpoint of Irrigation Development and Groundwater Development

| | | Project Area | | Farm Size | | Farm Household Income | | Presently Operating Drilling Rigs | | Designed numbers of Irrigation Tubewells | | Total Score | Overall Evaluation | Allocation of new Drilling Rigs (Plan) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | District | 1,000 ha | Rating | acre | Rating | Rs | Rating | No. | Rating | 1,000 | Rating | | | |
| 1 | Attock | 198 | 7 | 9.6 | 6 | 12,271 | 5 | 1 | 6 | 7.5 | 9 | 33 | A | 2 |
| 2 | Rawalpindi | 187 | 6 | 4.2 | 9 | 5,369 | 7 | 2 | 3 | 7.1 | 8 | 33 | A | 1 |
| 3 | Jhelum | 74 | 4 | 7.7 | 8 | 9,842 | 6 | 1 | 6 | 2.8 | 4 | 28 | A | 1 |
| 4 | Chakwal | 203 | 8 | 9.1 | 7 | 13,632 | 4 | 2 | 3 | 7.7 | 7 | 29 | A | 1 |
| 5 | Khushab | 160 | 5 | 15.3 | 2 | 19,557 | 2 | 3 | 1 | 6.1 | 5 | 15 | C | 0 |
| 6 | Mianwali | 73 | 3 | 13.3 | 4 | 17,000 | 3 | 0 | 9 | 2.8 | 3 | 22 | A | 1 |
| 7 | Bhakkar | 216 | 9 | 18.4 | 1 | 23,519 | 1 | 0 | 9 | 8.2 | 6 | 26 | A | 1 |
| 8 | Rajanpur | 17 | 1 | 13.9 | 3 | 4,775 | 8 | 1 | 6 | 0.6 | 1 | 19 | B | 0 |
| 9 | D.G. Khan | 29 | 2 | 10.0 | 5 | 3,435 | 9 | 0 | 9 | 1.1 | 2 | 27 | A | 2 |

### 2-2-4 Consideration on Appropriate Scale

This project will procure equipment and materials for groundwater development. Consideration on the appropriate quantity of the main equipment, tubewell drilling equipment, will be made.

1) Appropriate Scale based on Budget

The budget for the executing agency (DGA) was Rs. 250 million in 1991/92, and Rs. 382 million in 1995/96 which is about a 9% growth in the recent 5 years. The inflation rate in 1995/96 is similarly about 9%, which reveals that the actual growth rate in budget is zero. The budgets for DGA and the drilling section of DAE are Rs. 548 million and Rs. 35.8 million respectively in 1996/97. On the other hand, the cost for management, operation and maintenance of nine rotary drilling rigs are calculated as Rs. 11,320,000.

① The operation and maintenance cost for 9 rigs accounts for 2.1% of the DGA budget in 1996/97.

② The operation and maintenance cost for 9 rigs accounts for 31.6% of the budget in 1996/97 allotted to DAE.

③ Through the Japanese assistance (the Project for Increase of Food Production) to DGA in 1991/92 and 1992/93, the procured number of bulldozers were 140 and 113, respectively. Of the budget allotted to the Bulldozer Section, about 39.6% and 36.4% of the budget, for respective procurements, were used for management, operation and maintenance of these equipment.

As a consequence, if 9 rotary drilling rigs are procured, the budget allocation for management, operation and maintenance from DGA and Drilling Section should not present any problems

2) Human Resources

Presently, the Well Drilling Section manages 118 power rotary drilling rigs and hand boring plants. The required number of personnel is 550 as shown in Table 2-10. Because the Well Drilling Section has 566 registered workers, sixteen workers can be assigned to the newly procured power rotary drilling rigs. The tubewell drilling work is organized by a group of workers including one driller and two driller helper for each rig. Under the present situation, drivers, welders, and mechanics are supplemented from other section and each member is responsible for two power rotary drilling rigs. Therefore, as shown in Table 2-11, the minimum necessary number of workers for each power rotary drilling rig is 4.5 for a single sift and 7.5 for a 2-shift system.

Table 2-10 Number of Drilling Crew at Site(1996)

| | No. of rigs | Necessary no. of crew for each rigs | Total no. of crew | Remarks |
|---|---|---|---|---|
| Power rotary drilling rig | 10 | 3 | 30 | |
| hand boring plants and other drilling rigs | 208 | 2~3 (Average of 2.5) | 520 | To be reduced in proportion to the no. of newly procured rigs |
| Total | 218 | – | 550 | Essential crew |
| Present no. of drilling crew | – | – | 566 | 16 persons can be assigned to new rigs. |

If new power rotary drilling rigs are procured, the demand decreasing hand plants will be discontinued in quantity equal to the number of power rotary drilling rigs procured, and the hand plant operations will be promoted and reallocated so that new power rotary drilling rigs operators can be secured. Furthermore, the executing agency is planning to implement a 2-shift system to improve operation efficiency.

Table 2-11 Drilling Crew by Shift

| Classification | Required no. of personnel for a single-shift system | Required no. of personnel for a 2-shift system | Remarks |
|---|---|---|---|
| Driller | 1.0 | 2.0 | Permanently staying at site |
| Driller Helper | 2.0 | 4.0 | Permanently staying at site |
| Driver | 0.5 | 0.5 | Only when moving drilling rig |
| Welder | 0.5 | 0.5 | Only when inserting casing |
| Mechanic | 0.5 | 0.5 | When starting & repairing drilling rig |
| Total | 4.5 | 7.5 | 3 or 6 personnel permanently stay at site |

If nine rotary drilling rigs are procured in this project, the same number of hand boring plants will be canceled. Thus about 22 persons (2.5 x 9 = 22.5) and 16 persons (566 - 550 = 16) that can be relocated at present will be incorporated into the new system. In that case, as shown in Table 2-12 and Figure 2-7, because the necessary number of crew for a single-sift is 4.5, 2 personnel additions are required. On the other hand, for a 2-shift, 20 personnel additions are required. Thus, in the actual operation of the newly procured rotary drilling rigs, the Well Drilling Section at DAE must relocate the experienced workers and assign the experienced workers of drilling rigs as the drillers or the driller helpers of main part of tubewell drilling work for the better utilization of human resources in the Well Drilling Section. Then by assigning the newly employed 29 workers separately as the driller helpers, it will be possible to start tubewell drilling work at site while the new workers receive instructions from the experienced ones. As for training of new personnel, a technical training center is planned to be established in Talagang, Chakwal District. with the purpose of improving the technical level and the efficiency of work process management.

3) Subsidy System

① The subsidies to tubewell drillers differ according to well diameter from 30% to 71% as listed in Table 2-13. In this system, cash does not actually flow to the farmers, but instead the cost for tubewell drilling to be paid by the farmers is set at prices 30 to 71% below the market value. On the government side, this cost is appropriated as a subsidy and not paid in cash.

Table 2-12 Determining Table for Drilling Crew

| Procurement Quantity of Rigs | Single-Shift System | | Two-Shift System | |
|---|---|---|---|---|
| | Required Number | Personnel Balance | Required Number | Personnel Balance |
| 1 | 4.5 | 14 | 7.5 | 11 |
| 2 | 9.0 | 12 | 15.0 | 6 |
| 3 | 13.5 | 10 | 22.5 | 1 |
| 4 | 18.0 | 8 | 30.0 | -4 |
| 5 | 22.5 | 6 | 37.5 | -9 |
| 6 | 27.0 | 4 | 45.0 | -14 |
| 7 | 31.5 | 2 | 52.5 | -19 |
| 8 | 36.0 | 0 | 60.0 | -24 |
| 9 | 40.5 | -2 | 67.5 | -29 |
| 10 | 45.0 | -4 | 75.0 | -34 |
| 11 | 49.5 | -6 | 82.5 | -39 |
| 12 | 54.0 | -8 | 90.0 | -44 |
| 13 | 58.5 | -10 | 97.5 | -49 |
| 14 | 63.0 | -12 | 105.0 | -54 |
| 30 | 135.0 | -44 | 225.0 | -134 |

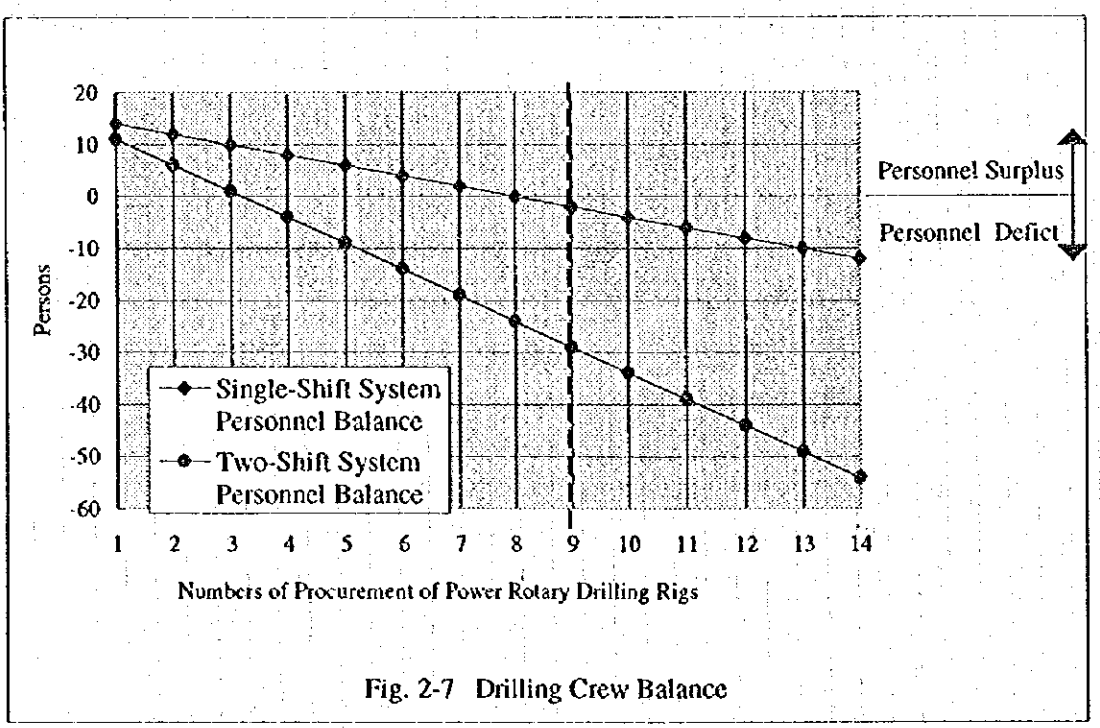


Fig. 2-7 Drilling Crew Balance

Table 2-13 Tubewell Drilling Cost and Subsidy Rate (July 29,1989)

| Well Dia. | Power Drilling Rig (1989) | | | Hand Boring Plant(1985) | | | Power Winch | | |
|---|---|---|---|---|---|---|---|---|---|
| inch | Unit Drilling Cost(Rs) | Unit Subsidy (Rs) | Subsidized Rate (%) | Unit Drilling Cost(Rs) | Unit Subsidy (Rs) | Subsidized Rate (%) | Unit Drilling Cost(Rs) | Unit Subsidy (Rs) | Subsidized Rate (%) |
| 4 | | | | | | | | | |
| 5 | - | - | - | - | - | - | | | |
| 6 | | | | | | | | | |
| 7 | | | | 17 | 5 | 71 | | | |
| 8 | 104 | 36 | 65 | 18 | 8 | 65 | 26 | 13 | 50 |
| 10 | | | | 22 | 11 | 50 | | | |
| 12 | | | | 36 | 21 | 46 | | | |
| 14 | 157 | 55 | 65 | 46 | 24 | 48 | | | |
| 15 | | | | 53 | 27 | 49 | | | |
| 16 | 188 | 94 | 50 | 53 | 27 | 49 | | | |
| 17 | | | | 56 | 30 | 46 | | | |
| 18 | | | | | | | | | |
| 19 | 313 | 188 | 40 | | | | | | |
| 20 | | | | | | | | | |
| 21 | 321 | 207 | 30 | - | - | - | | | |
| 22 | | | | | | | | | |
| 23 | | | | | | | | | |
| 24 | | | | | | | | | |

② There is also a subsidy system for motorized pumps, where the goods are supplied and the costs are appropriated as subsidy.

| Applicable Area | Subsidy per Tubewell | Allotted Ratio |
|---|---|---|
| Barani Area | Rs. 20,000 | 20.5% |
| Riverain Area | Rs. 18,000 | 21.0% |
| Canal Irrigated | Rs. 16,000 | 58.5% |

③ Presently 328,000 irrigation tubewells exist in Punjab Province, and the construction of 220,000 more tubewells is needed hereafter. The DAE is planning to subsidize 60,000 irrigation tubewells in 30 years.

a. Cultivated area of Punjab Province : 60,000 wells (30 years)

b. Cultivated area of Barani areas : 6,660 wells (30 years)

c. Drilling rigs in Barani areas :
222 wells per year
222 wells / year ÷ 8 wells / rig = 28 rigs / year
28 rigs - 10 existing rigs = 18 rigs
If a 2-shift system is introduced, 9 rigs

d. In relation to the subsidy system, at least 9 rigs are necessary in the Barani area for drilling irrigation tubewells.

4) Savings and Economics Conditions of Farmers

As economic foundation of farmers, the incomes according to farm area (5 to 20 acres) were considered. If the disposable income per farm household is saved for 4 to 8 years, and a group is formed to meet the requirement of "more than 25 acres, less than 65 acres" necessary for application of tubewell construction; From the statistical point of view, if the farmers organize a group by assuming the unit area of irrigation as 65 acres, the joint irrigation tubewells can be constructed by saving 4 to 8 years worth of excess income. However in the actual situation, the farmers groups are of small scale. Thus the farmers in Barani areas are constructing the irrigation tubewells based on the savings of 10 to 15 years worth of excess income.

## 2-3 Basic Design

### 2-3-1 Design Concept

In this project, tubewell drilling equipment necessary for groundwater irrigation in the Barani areas will be procured. The design policies will be considered from the viewpoints of irrigation planning, tubewell drilling plan and related natural and social environment.

1) Policy on Natural Conditions

The project areas can be divided into 3 areas according to the irrigation situation: (1) Barani areas, (2) riverain areas and (3) canal irrigated areas. Topographically, the canal irrigated and riverain areas are plains or flatlands of 100 m to 200 m elevation, and geologically, these areas have thick Alluvial and Diluvial sediments (over 200 m) with abundant groundwater. On the other hand, the Barani areas spread from the Potwar plateau in the northern part at elevations between 300 m and 500 m to the Rajanpur area in the southern part at elevations between 150 m and 300 m. The geology of the Barani areas consist of 10 m to 30 m Alluvial and Diluvial sediments and Pliocene to Miocene sedimentary rock formations below. Groundwater in the Barani areas can be found in the hard rock formations in the lower layers at depths below 100 m, where good quality confined groundwater exists. Therefore, groundwater development in the Barani areas requires power rotary drilling equipment. On the other hand, groundwater development should be carefully surveyed before drilling where thick clay sediments exist in Potwar plateau and saline water exists in

Rajanpur plains in the southern part.

Furthermore, in the project areas, effective precipitation rate needed for agriculture is low. In the southern, desert area, the rainfall is 100-200 mm / year, and even in the northern, Potwar plateau area, it is 200-800 mm / year. Therefore, effective use of water resources is necessary and groundwater development is important not only for irrigation by also for drinking as well. Consequently, the specifications and quantities of drilling equipment will be in accordance with these requirements for development.

2) Policy on Social Conditions

The main industrial foundation of Pakistan is agriculture. Since increase in agricultural production is linked to rise in income of farmers, agriculture is given high priority in the national development plan. To realize this policy, DGA is promoting procurement and rental of bulldozers, tubewell drilling rigs and tractors for mechanization and efficiency upgrading of agriculture. Furthermore, since groundwater development in the Barani areas is directly related to increase in agricultural production, the government of Punjab Province established a subsidy system in 1972 to promote construction of irrigation tubewells which are carried out through the request and cost sharing of farmers. This project is also an extension of this concept, and the necessity and effectiveness were confirmed. Therefore, the appropriateness and urgency of equipment for groundwater development will be considered and treated. Because the tubewell drilling is implemented from the request of farmers and with the partial cost born by the farmers, it is anticipated that the benefits might be greater to the wealthy farmers having larger cultivation areas. Thus it is necessary to instruct the relatively poor farmers having smaller cultivation area to submit a joint application for tubewell drilling.

3) Policy on Equipment for Groundwater Development

Rainfall is scarce in the project Barani areas, and groundwater is important for not only irrigation but drinking as well. However, good quality confined groundwater is found in aquifers below 100 m depths, and the layers are hard rocks of Tertiary sandstone and limestone. Therefore, selection of tubewell drilling rigs having appropriate capacity is significant.

Also, from experience in groundwater development in the Barani areas, the success rate is 60

to 80% which include areas of great difficulty. Therefore, effective use of geophysical equipment is necessary to raise the success rate. On the other hand, since groundwater development conducted by DAE is essentially development of irrigation tubewells, well logging and pumping tests to examine aquifer capacity are often times neglected. Therefore, survey equipment will be kept at a minimum and importance will be placed on considering the number of rotary drilling rigs, the main equipment for groundwater development.

4) Consideration on Implementation Structure

According to the explanation of tthe DAE, as for the personnel arrangements after the new drilling equipment are introduced, the presently operating 218 experienced drilling teams will be given priority, and promotion and staff reamangement will be made inside the Directorate. Moreover, new recruitment and training will be conducted to respond to the situation. In addition, part of the training will be held in conjunction with the operation guidance of the rotary drilling equipment to be procured in this project. For an effective drilling operation, a two-shift system needs to be considered to increase the annual drilling capacity. In the training, a suitable training manual will be prepared, to standardize operation and maintenance of rotary drilling rigs. Also, technical training on geophysical prospecting and analysis in order to improve their success rates of groundwater development will be conducted in this project to enforce the implementation structure.

5) Policy on Operation and Maintenance

The present operation and maintenance situation on tubewell drilling is very effective. Upon procurement of new equipment, the present level will be maintained; the manual will be prepared during the training period for technical improvement; and a training section will be established to handle newly employed staff. Maintenance and spare parts storage are presently carried out jointly by the well drilling section and the bulldozer section. Since this arrangement is functioning effectively, future cooperative relations should be further strengthened.

6) Policy on Schedule

In this project, operation guidance and technical training on groundwater development is to be conducted after internal transportation and delivery of the equipment. Consequently, sufficient consideration on the schedule with full cooperation of the executing agency is necessary.

7) Policy on Environmental Consideration

In relation to groundwater development for irrigation, water table lowering due to over pumping; land subsidence; salt water intrusion; and water contamination due to agricultural wastewater, have impact on the environment, but these are presently very rare. However, the executing agency must be considerate of these impacts in the future.

2-3-2 Basic Plan

1) Total Plan

This project aims to procure equipment necessary for groundwater development to irrigate the Barani areas of Punjab Province. The equipment to be procured are listed below as described in the basic concept of the project.

a. Tubewell drilling equipment
b. Drilling tools
c. Computer
d. Compressor
e. Pick-up truck
f. Spare parts

The main equipment are rotary drilling rigs required for tubewell construction. Also, operation guidance with manual preparation, and technical training at the project sites will be implemented.

2) Equipment Plan

① Tubewell Drilling Equipment

In the revised request (1996), the number of drilling rigs was increased from 10 to 30, but in consider of analysis results, operation and maintenance capabilities and priority in barani areas, 9 drilling rigs are to be procured.

The drilling method in the request (1989) was rotary table method, but in the revised request submitted to the study team during the basic design study (1996), the top drive method was proposed. From the viewpoints of manoeuvrability, economics and

adaptability to the geology, and also since top drive was adopted in a similar project for WAPDA in 1994, the top drive method is judged to be technically feasible (Refer to Table 2-13). In addition, the mud pump to be mounted on the rig was requested to be changed to the plunger type pump which has minimal discharge variations and can be maintained more easily. Upon returning to Japan, the study team made considerations on Japanese products and found that sales of plunger type pumps have increased in recent years.

Table 2-14 Characteristic Comparison Table for Rotary Table Type and Top Drive Type Drilling Rigs

| Item | Top Drive Type | Rotary Table Type |
|---|---|---|
| Geological Condition | For mud drilling with tri-cone bit, no big difference. For hard rock formations, possibility of changing to DTH hammer and capability of hammer can be used to the maximum. | For mud drilling with tri-cone bit, no big difference. For hard rock formations, can change to DTH hammer, but cannot make best use of the hammer's capability. |
| Drilling Method | Mud as well as air drilling with tri-cone bit. When changed to DTH hammer, can make best use of its capability. Can also be applied to reverse circulation. | Mud as well as air drilling with tri-cone bit. When changed to DTH hammer, cannot make best use of its capability. Cannot be applied to reverse circulation. |
| Bit Rotation Speed | Since a hydraulic motor is used, no restriction on rotation speed. Applicable for DTH hammer to tri-cone bit. | Since power is transmitted through a transmission gear, rotation speed is restricted by gear. Only applicable to tri-cone bit. |
| Drilling Depth | Not appropriate for deep drillings. Economic depth are at maximum 600 to 800 m. | Appropriate for deep drillings. 1,000 m class depths are possible. |
| Bit Load | If insufficient bit load (at shallow drilling depths), load can be applied with pull down apparatus. | At shallow depths, drilling must be continued with insufficient load, and weights heavier than drill collar and drilling pipe cannot be loaded on. |
| Workability / Operation Performance | Since power is transmitted hydraulically, loss is minimal for easy operation. Spare parts for hydraulic components need to be sufficiently secured. | Since mechanical transmission is used, loss is great which makes operation complex. However, repair parts can be procured locally. |

The rotary drilling rig to be newly procured must be a mud drilling equipment capable of drilling a final tubewell diameter of $\phi$ 17-1/2 inch down to 200 m in depth and of the same drilling method as commonly used by DAE. To drill a $\phi$ 17-1/2 inch diameter tubewell, DAE uses a two-step method where first a $\phi$ 10-5/8 inch pilot hole is drilled to confirm the existence of groundwater, then the hole is enlarged to $\phi$ 17-1/2 inch.

This is a method peculiar to Pakistan which is suitable to the capability of presently owned rotary drilling equipment and local groundwater development technology. If a $\phi$ 17-1/2 inch well is to be drilled in one round, a class higher 300 m drilling rig would be needed, which will increase the cost and incidental equipment. Since local farmers and drilling technicians prefer the present drilling method, and that DAE wants to secure as much rigs as possible, the present 200 m class rigs will be selected. As a result of the site survey, hard rock areas requiring DTH hammer were found to be non-existent, and so DTH hammers and accessories will be excluded from this project.

From the view of maintenance by the executing agency, additional procurement of packing for mud pumps is requested because these are rapidly consumed and require frequent exchange. Also, mud pumps which are more easily maintained are requested. The drilling capacity of rigs depends on the capacity of the equipment itself as well as the capacity of the mud pump. If the mud pump flow rate decreases due to abrasion of the packing, slime cannot be effectively discharged and drilling speed decreases causing jamming of drilling tools. Therefore in this project, the plunger type mud pump will be adopted due to its simplicity in maintenance and small variation in discharge rate.

② Drilling Tools

As for drilling tools, since drilling collars and stabilizers for previously procured equipment are available and can be commonly used, the number of these tools will be minimized for this project, and consideration will be made to exchangeability of joints and connectors. The quantity of tri-cone bits for mud drilling will be in accordance with the requirements of the geologic conditions of the project sites.

③ Computer

At the present time, the DAE at Lahore is the only office with computers. However, the computers are old (CPU of 386 and 286), and since the capacities of hard disks are small and is mutually shared with other offices, they are used mostly for administrative document preparation with little allowance for organization and analysis of tubewell data. In this predicament, one computer at Lahore headquarters, to prepare technical reports, organize tubewell data and analyze geophysical survey results is needed. The computer having CPU of Pentium 166 Mhz, 32MB memory, HD: 1.2GB with built-in CD-ROM drive along with a 17-inch display and laser printer(capable of handling A3 size) is selected.

④ Compressor

This is to be used for tubewell completions and simple pumping tests. In the Project for Increase of Food Production (1988), 10 compressors were procured. The rate of 1 set of compressor and accessories to 2-3 rotary drilling rigs is judged to be feasible for areas using more than one rig. With consideration on distribution of the existing compressors, the minimum required 3 compressors will be procured and the capacity will be not less than 7.2 $m^3$/min, 12 bar. As accessories, riser pipes of 4 inch diameter and air pipes of 1 inch will also be included.

⑤ Pick-up Truck

For management and maintenance by the tubewell drilling team and effective operation of geophysical surveys, 2 pick-up trucks will be procured. The specifications of single cabin, 3 seating, 4-wheel drive is selected.

⑥ Spare Parts

Spare parts are required for tubewell drilling equipment, compressors, and pick-up trucks . The quantities will be calculated by attrition rate based on hourly wear. As for spare parts for rigs procured through the Project for Increase of Food Production (1988), the minimum quantity required for urgent repairs and maintenance will be considered. By our site survey, packing for mud circulation system, pistons for mud pump, power-transmission gear chain bearings are needed to be procured.

⑦ Other Equipments

A. Geophysical Equipment

The previously procured resistivity meters (the Project for Increase of Food Production, 1988) are presently distributed: one in Faisalabad and another in Multan. The frequency of use has increased since the operation guidance held in 1992, ranging from 12 to 22 sites per year, for a total of 74 sites in 5 years (Refer to Table 2-14). With geophysical prospecting, the aquifer depth can be predicted to determine the drilling depth; and an average of 4 points per site is surveyed so that these can be compared to select the point having the highest possibility of groundwater. Therefore, geophysical prospecting can increase the success rate of groundwater development. Moreover, analysis of Resistivity data can also reveal areas of saline water. When considering the characteristics and geologic conditions of the Barani areas, in the Faisalabad region, since the aquifers are located in deep layers and the area is widely spread, surveys cannot be sufficiently carried out with the present one unit. Therefore, procurement of another

resistivity meter can reinforce the survey activities. However, more important than the number of survey equipment is assurance of necessary survey personnel. In DAE, about 10 engineers/technicians can operate geophysical equipment, but cannot satisfactorily conduct basic analyses of hydrogeologic data, and therefore, the skill level of present technicians must be raised and new engineers technicians must be recruited. That is, engineers/technicians with knowledge of geology, hydrogeology or geophysics must be newly employed to reinforce the survey staff and foster personnel who can organize and analyze existing data and make comprehensive judgment on hydrogeologycal data and geophysical survey results. The executing agency has requested technical training on groundwater survey and analysis. Therefore, in this project, importance will be placed on technical training on operation, analysis and interpretation of results obtained from the existing 2 units of resistivity meters for more effective use of these equipments. However, 2 new units of power boosters will be procured to reinforce their geophisical survey as shown in Table 2-16.

Table 2-15 Record of Geophysical Surveys (1991-1996)

| | | | 1991/92 | 1992/93 | 1993/94 | 1994/95 | 1995/96 | Total | |
|---|---|---|---|---|---|---|---|---|---|
| Directorate of Agricultural Engineering (DAE) | Directorate of Agricultural Engineering Faisalabad | 1.Attock | 2 | - | - | - | - | 2 | 42 |
| | | 2.Rawalpindi | - | 2 | - | - | - | 2 | |
| | | 3.Jhelum | - | - | - | - | 4 | 4 | |
| | | 4.Chakwal | - | 1 | 1 | 3 | - | 5 | |
| | | 5.Khushab | | 13 | | | 5 | 18 | |
| | | 6.Mianwali | - | 3 | - | - | - | 3 | |
| | | 7.Bhakkar | - | - | - | - | - | 0 | |
| | | 8.Sargodha | - | 1 | - | 1 | - | 2 | |
| | | 9.Faisalabad | - | - | 1 | 3 | 2 | 6 | |
| | Directorate of Agricultural Engineering Multan | 1.Rajanpur | - | - | - | 2 | - | 2 | 32 |
| | | 2.D.G. Khan | - | - | - | 3 | - | 3 | |
| | | 3.Layyah | - | - | - | - | - | 0 | |
| | | 4.Multan | - | - | 10 | 10 | 7 | 27 | |
| Total | | | 2 | 20 | 12 | 22 | 18 | 74 | |

Table 2-16 Plan of Geophysical Surveys (1996-2001)

| | | | 1996/97 | 1997/98 | 1998/99 | 1999/00 | 2000/01 | Total | |
|---|---|---|---|---|---|---|---|---|---|
| Directorate of Agricultural Engineering (DAE) | Directorate of Agricultural Engineering Faisalabad | 1.Attock | 3 | 6 | 6 | 6 | 6 | 27 | 233 |
| | | 2.Rawalpindi | 5 | 10 | 10 | 10 | 10 | 45 | |
| | | 3.Jhelum | 2 | 5 | 5 | 5 | 5 | 22 | |
| | | 4.Chakwal | 6 | 12 | 12 | 12 | 12 | 54 | |
| | | 5.Khushab | 5 | 10 | 10 | 10 | 10 | 45 | |
| | | 6.Mianwali | 2 | 3 | 3 | 5 | 5 | 18 | |
| | | 7.Bhakkar | 2 | 5 | 5 | 5 | 5 | 22 | |
| | Directorate of Agricultural Engineering Multan | 1.Rajanpur | 8 | 15 | 15 | 15 | 15 | 68 | 127 |
| | | 2.D.G. Khan | 5 | 12 | 12 | 15 | 15 | 59 | |
| Total | | | 38 | 78 | 78 | 83 | 83 | 360 | |

B. Water Quality Analysis Equipment

Presently under the jurisdiction of the Punjab Province Agricultural Department, water quality and soil analysis laboratories are located in each District. Water quality analysis to determine the appropriateness of groundwater quality can be requested by farmers at a low price of Rs. 5 per sample. Therefore, procurement of new water quality analysis equipment is not necessary.

2) Consideration on Origin of Procurement

A) Tubewell Drilling Equipment

The 10 rigs procured through the Project for Increase of Food Production (1988) were of Japanese make. Since the operational situation as well as management, operation and maintenance by the executing agency of these rigs are presenting best conditions, procurement from Japan is desired. It is judged that procurement of drilling equipment from Japan is very appropriate.

B) Pick-up Truck

A number of assembly plants for Japanese vehicles are available in Pakistan. Considering the request of the executing agency as well as spare parts procurement and local repair possibilities, trucks of manufacturers having local assembly plants and those which can be procured locally will be examined.

C) Other Equipment

For other equipment, procurement from Japan or other countries will be considered.

3) Technical Training

Japanese engineers will be dispatched for training on assembly and operation of equipment to be procured by this project and for technical training related to groundwater development survey. The Japanese engineers, after arrival of the equipment, will conduct the following duties along with Pakistani counterparts during a fixed period of stay.

a. Technical training on assembly, test run and operation of well drilling equipment
b. Technical training related to operation and maintenance
c. Preparation of a manual on the above technical training
d. Technical training on groundwater development survey and analysis

4) Specifications and Quantities

| | | |
|---|---|---|
| A) Tubewell Drilling Equipment and Accessories | : | Rotary, top head drive type<br>Drilling capacity $\phi$ 17-1/2 inch, 200 m:<br>9 units |
| B) Resistivity Meter | : | This is excluded from the project, however technical training is to be carried out for efficient usage, and 2 sets of power boosters. |
| C) Water Quality Analysis Equipment | : | Since water quality and soil analytic laboratories are available at the project areas, this is excluded from the project. |
| D) Computer | : | 1 unit ( At Lahore) |
| E) Compressor | : | 3 units |
| F) Pick-up Truck | : | 2 units |
| G) Spare Parts | : | 1 lot for rigs of KR II project and for this project |

Table 2-17 List of Equipment to be Procured

| No. | Equipment | Main Items | Q'nty | Specifications |
|---|---|---|---|---|
| 1 | Tubewell Drilling Equipment | 1) Drilling Rig | 9 units | Type: Top drive type for mud drilling<br>Capacity: Minimum 4-2/1"o.d. drill pipe<br>Drilling depth 200 m |
| | | 2) Truck | | Power Source: Truck engine PTO<br>Mounted with rig<br>4 cycle<br>water-cooled engine<br>GVW: 16,000 kgf<br>4 x 4 drive<br>Max. Power: 215 HP (min.) |
| | | 3) Mud Circulation Pump | | Supply on Truck<br>Plunger type<br>Not less than 700 lit/min. x 20 kgf/cm$^2$ |
| 2. | Drilling Tools | 1) Drill Pipe | 1 lot | 4-1/2" O.D. flush, 3-1/2 IF std. Box/pin<br>6 m/pipe x 34 pipes (per truck) |
| | | 2) Hole Opener | | 17-1/2" x 10-5/8" (soft rock-hard rock) |
| | | 3) Hole Opener | | 14-1/2" x v9-5/8" (soft rock-hard rock) |
| | | 4) Tri-cone Bit | | 14-3/4" (soft rock-hard rock) |
| | | 5) Tri-cone Bit | | 12-1/4" (soft rock-hard rock) |
| | | 6) Tri-cone Bit | | 10-5/8" (soft rock-hard rock) |
| | | 7) Tri-cone Bit | | 9-5/8" (soft rock-hard rock) |
| | | 8) Fishing Tools | | Overshot, tap, hydraulic jack 30 t |
| 3. | Computer | | 1 unit | CPU: 166 MHz, Memory: 32MB, HD: 1.2GB |
| 4. | Compressor | | 3 units | 7.2 m$^3$/min., 12 bar |
| 5. | Pick-up Truck | | 2 units | Water-cooled diesel engine<br>4 x 4 drive, single cabin |
| 6. | Spare Parts | 1) For this Project | 1 lot | Minimum required parts. |
| | | 2) For KR-II Project | 1 lot | |