4. 2. 5. Number of development blocks to be constructed in each year

1) Number of development blocks to be constructed in first year

The numbers of development block and production tubewell which will be constructed in the first year are respectively 5 and 25, of which 5 are diverted from test tubewells dug at the basic design stage, considering the following conditions.

(1) Even if the Exchange of Notes is made at the end of July 1985 after the basic design study-phase II (the beginning of December 1987~middle of June 1988: tentative), the pre-qualification and the contract with the contractor will be made in October 1988 and at the end of December 1988, because it will take two monthes at least to prepare the detailed design including the preparation of the tender documents for the first year-construction. Then, the actual commencement of the first year-construction will be the beginning of February 1988 considering that it will take one month for contractor's mobilization.

(2) Therefore, the construction periods for the deep tubewells and the irrigation facilities are four months from the beginning of February to the end of May 1989 and four months from the beginning of March to the end of June 1989, respectively.

(3) In order to construct the production tubewells for the second year smoothly, it is necessary to drill the test tubewells, in paralell with the first year construction, in the blocks where production tubewells are scheduled to be constructed in the second year (six test tubewells for six development blocks).

(4) On the other hand, the number of tubewells which can be constructed for four months by seven drilling rigs provided under the KR-2 grant aid program will be 28 in maximum, considering that it will take about one month to complete the construction of one deep tubewell by one rig machine.

(5) Further, the number of development blocks of which irrigation facilities can be constructed for four months in maximum by the construction equipment provided under the KR-2 grant aid program will be five (25 irrigation areas, about 45 km - main irrigation canals).

Of the first priority eight blocks decided through the discussion with HMGN, the following five development blocks were selected for the first year implementation.

**Five Development Blocks for 1st year Construction**

| Name of Block | Reason of Selection |
|---|---|
| S-1 | High groundwater potential is expected. Good access. First priority block requested by HMGN. |
| S-7* | High groundwater potential block in the southern part of the Sarlahi district. First priority block requested by HMGN. |
| M-4* | Relatively high groundwater potential block in the northern part of the Terai plain. Good access. First priority block requested by HMGN. |
| D-15 | The reason is the same as mentioned above. |
| D-7* | Located in center of artesian area. Highest groundwater potential. Good access. First priority block requested by HMGN. |

Note : *: The blocks for which topographic surveys were completed during the Basic Design Study-Phase I .

2) Number of development blocks to be constructed in each year

The numbers of development block and production tubewell to be constructed for a year after the first year are 6 and 30 including 6 diverted from test tubewells drilled in the preceding year, respectively in consideration of the following conditions.

(1) It is possible to prepare during the first year-construction period the detailed design for the second year implementation including the test well drilling.

(2) If the pre-qualification is made immediately after the Exchange of Note for the second year implementation at the end of July 1989, and if the further arrangements such as tender, tender evaluation, contract with the contractor are made by the end of October 1989, it is possible to take seven months from the beginning of December 1989 to the end of June 1990 for the second year construction, considering one month for the contractor's mobilization.

(3) It is possible to complete the construction of 30 deep tubewells consisting of 24 production tubewells and 6 test tubewells for the third year implementation, using seven rig machines during five months from the beginning of December 1989 to the end of April 1990.

(4) In addition, it is possible to construct the irrigation facilities for six development blocks (30 irrigation blocks and about 54km of main irrigation canals) by the construction equipment provided under the KR-2 grant aid program during six months from the beginning of January to the end of June 1990.

(5) The third and fourth years-implementation will be made with the same manner as mentioned for the second year, but drilling of test tubewells is excluded from the work components for the fourth year. The development blocks to be constructed after the first year will be determined through the mutual discussion with HMGN at the implementation stage.

4. 2. 6. Construction equipment and materials

1) Adjustment and repair of equipment and materials

According to the inventory survey on the materials and equipment provided under the KR-2 grant aid program, it is essential to repair and adjust some of materials and equipment and to procure the additional materials and equipment in order to drill 23 test tubewells (one test tubewell per block, which is diverted to a production tubewell later on) and 92 production tubewells and to construct the respective irrigation facilities for the 115 irrigation areas.

The major adjustment and repair of the KR-2 equipment and material are as follows:

(1) Adjustment and repair of 7 drilling rigs, especially three rigs of YRD-501R;

(2) Overhaul and repair of the mud pumps for the above drilling rigs;

(3) Reinforcement of Johnson screen (total length: about 2,572.5m); and

(4) Expansion of the pump shaft and suction pipe of the vertical turbine pump sets (50 nos.). (expansion from 30m to 40m for 5 pumps, and from 30m to 55m for 45 pumps.)

2) Requirement of additional materials and equipment.

The quantities of materials and equipment required for constructing 115 production tubewells, including 23 test tubewells and irrigation facilities for 23 development blocks (115 irrigation areas) for four years as scheduled in the development plan set in Section 4.2.5 are summarized below.

(1) Materials and equipment for drilling and finishing

| | | | |
|---|---|---|---|
| [1] | Tricone bit | 17½" | 130 nos. |
| [2] | Tricone bit | 14¾" | 130 nos. |
| [3] | Hole opener | 14¾"→17½" | 70 nos. |

There is no stock for the above bits and opener. Based on the experience of drilling four test borings in the Basic Design Survey, it is judged to consume each one bit per one deep tubewell on an average, and 15% of contingency is included for the above items [1] and [2]. As for item [3], considering the rig capacity, it is assumed that a 17½" - bit is applied for drilling up to the depth of 60~70m and for the portion deeper than 60~70m the reaming from 14¾" to 17½" is made using a hole opener after drilling by a 14¾" - bit. Then, 0.5 number of the hole opener is required for one deep tubewell, and about 20% of contingency is included.

[4] High pressure-air compressor (20kg/cm$^2$, 20m$^3$/min.) : 1 no.

It is essential to additionally procure a high pressure-air compressor, because the present compressor does not have sufficient capacity (7kg/cm$^2$, 10.5m$^3$/min.) to develop the gravel-packed tubewell after 8" - Johnson type screen installed in the drilled hole of 17½" diameter.

[5] Threaded 4" - suction pipe (L=5.5m) : 390.5m

[6] Threaded 1" - air pipe (L=5.5m) : 506m

The required lengths are calculated deducting the lengths available at present from total required length of 561.5m on the assumption that the development of tubewells would be made

at four sites at the same time (120m class: 3 sites, 200m class: 1 site) after installing screens and casing pipes and packing gravels.

[7] Submersible motor pump (50m head, 40ℓ/sec) : 1no.

This type of submersible pump is not available at present, though required for pumping tests of production wells. However, the diesel generator is not required because there are 10 nos. of diesel generator at present.

[8] Notch tank for meaning pumped discharge (2.5 $m^3$): 5 nos.

One notch tank is available at site. Five tanks shall be added to carry out pumping tests at six sites at the same time. These tanks shall be manufactured at site using the steel plates to be locally purchased.

[9] DC engine welder (3.6 kVA): 5 nos.

The present seven DC engine welders are exhausted and not useful, then five numbers shall be added.

[10] 20" - conductor pipe (L=3m): present 84m + additional 1,368m

[11] 14" - casing pipe (L=6m): present 4,932 m + additional 612m

[12] 8" - casing pipe (L=6m): present 12,732m (not necessary to add)

The above additional pipes are required for constructing 115 production tubewells including 23 test tubewells.

[13] Reinforced Johnson screen (L=5.25m, L=3.25m): 2,572.5m

It is hardly possible to install the present Johnson type screens below 150m deep, even if these screens are reinforced. The above figure is the total length of the reinforced Johnson screen to be installed in the depth from 50m to 150m for 115 production tubewells including 23 test tubewells.

[14] New 8"-ring based wire-wrapped screen (L=5.5m): 1,996.5m

The above figure is the total length of the screen required for installing at the positions deeper than 150m in 115 production tubewells including 23 test tubewells.

[15] Centerlizer for 8" - casing pipes : 594 nos.

There is no stock. It is necessary to use a centerlizer per 3 nos. of 8" - casing pipes (18m) to install 8"-pipes vertically in the center of the drilled hole of $17\frac{1}{2}$".

[16] Pipes and shafts for Ebara turbine pump set: 200m for 8 sets

The above length is necessary for extending the pipe and shaft of the present Ebara turbine pump (8 nos.).

[17] Pipes and shafts for Okamoto turbine pump: 175m for 7 sets

The above length is necessary for extending the pipe and shaft of the Okamoto turbine pump (7 nos.).

[18] 8"-delivery pipes with elbow (L=1.2m): 68 nos.

[19] 6"-delivery pipes with elbow (L=1.2m): 47 nos.

There is no stock. The above number of delivery pipes shall be installed at the outlet of Ebara (68 nos.) and Okamoto (47 nos.) pumps.

[20] Portable water tank (3m$^3$, made of water-proof cloth): 24 nos.

There is no stock. The drilling of tubewells and the construction of canals will be made at twelve sites at the same time, and two numbers of tanks are necessary for one site. It is difficult to get water at site, therefore without water supply by tank lorry it is difficult to proceed with the drilling and construction.

[21] Portable diesel tank (2m$^3$, made of steel plate): 4 nos.

Two numbers of tanks are available at site. The drillings will be made at six sites at the same time. A tank will be set at each site, and three tank lorries will be used for the supply of diesel to six sites.

[22] Gas welder: 5 nos.

One is available at site. One set of welder is necessary for drilling and development at each drilling site.

[23] Wireless (host: 1 no., branch: 6 nos.): 1 set

It is necessary to communicate each other between a construction office and six drilling sites.

[24]

| | |
|---|---|
| Cement | 58ton |
| Bentonite | 460ton |
| Barite | 29ton |
| CMC | 18ton |
| Mud cleaner | 15ton |

The following quantities are necessary for construction of a production tubewell.

| | |
|---|---|
| Cement | 500kg |
| Bentonite | 4,000kg |
| Barite | 250kg |
| CMC | 150kg |
| Mud cleaner | 130kg |

The cement is used for constructing foundation from which the casing string (casing pipe + screen) is hung. The mud cleaner will be sent from Japan, but the other materials will be procured in local market.

[25] Gravel for packing: 2,127m$^3$

The gravel of which diameter is 2mm~9mm shall be used for gravel packing for Johnson type screen. Screening shall be made twice using sieves of 9mm and 2mm.

[26] Fuel (Diesel fuel): 1,135k$\ell$

The diesel of 300$\ell$/day will be consumed for drilling and development of deep tubewell.

(2) Transportation equipment

[1] 4t-cargo truck with 3t-crane: 1 no.

Available number of cargo-truck is five. The drilling and development will be made at six sites at the same time, and a cargo truck with crane will be required for each site.

[2] 4,000ℓ-diesel tank lorry: 1 no.

Available number is two. The drilling and development of tubewells and the construction of canals will be made at twelve sites at the same time, and one tank lorry will be required for every four sites.

[3] 4,000ℓ-water tank lorry: 1 no.

Available number is five. As same as mentioned above, much volume of water will be consumed at each site, and a tank lorry will therefore be required for every two sites.

[4] 1ton-pick-up truck: 6 nos.

The number of pick-up trucks usable for the construction of deep tubewells is zero. A pick-up truck will be necessary for each drilling and development site to transport spare parts, consumables, materials, etc.

[5] 5ton-fork lift: 1 no.

Available number is one. Since the casing pipes and screens are stored in the TIATSP center and the Newalpur Horticulture Farm separately, a fork lift shall be provided in each place for loading such pipes and screens on truck or trailer.

(3) Construction equipment

[1] 2.8m-motor grader: 1 no.

The motor graders which are kept at site are six consisting of one number of 2.8m-blade and five number of 3.1m-blade. One motor grader shall be added for construction and maintenance of access roads.

[2] 4ton-vibro road roller: 1 no.

Available number is five. The construction of canals will be carried out at six sites at the same time, and a roller will be necessary for compacting canal embankment at each site. It is hardly possible to use a vibro roller at two sites because the running speed of roller is too slow. If the canal embankment is not compacted sufficiently, the brick canal will be damaged due to the erosion of the embankment during the wet season.

[3] 3.5ton-dump truck: 2 nos.

Available number is ten. 10~20% of the embankment material of the canals constructed under KR-2 grant aid program was carried from the quarry site located 10~20km far from the site, and two dump trucks will therefore be necessary for each construction site.

[4] 0.5m$^3$ concrete mixer: 2 nos.

Available number is four. A concrete mixer will be necessary for the concrete mixing at each site (pump house: 1 no., operator hut: 1 no., brick canal: about 1.8km long).

(4) Vehicles for operation and maintenance

[1] Wagon type jeep: 3 nos.

Available number is three. A wagon type jeep will be necessary for operating the construction office of each party (consultant, drilling contractor and civil contractor). Besides, for the topographic survey by the consultant, three wagon type jeeps will be required. 12 survey engineers are required for surveying six development blocks per year.

[2] Jeep: 12 nos.

Available number of jeep is zero. It is necessary to assign 12 vehicles consisting of one for supervision by the consultant, three for Japanese drilling experts (one for two persons), one for each of mechanical engineers for drilling rig and construction equipment and six for canal construction by civil contractor.

The quantities of the materials and equipment required for constructing 115 production tubewells including 23 diverted from test tubewells and irrigation facilities for 115 irrigation areas during four years (construction of 25~30 production tubewells and irrigation facilities for 25~30 irrigation areas a year) are shown in Table 4.5 and Table 4.6 including those required additionally.

The comparison between the project components requested by HMGN and those planned in this chapter is shown in Table 4.7, and the details of the planned project are shown in Table 4.8 together with the HMGN's request and the results of the study thereof.

### 4.3. Japanese Technical Cooperation

Since JADP was established in 1971, the Government of Japan has executed the various technical cooperation for the programs and projects of JADP for 15 years till November, 1986 as well as the grant aid assistance. The Japanese experts in various kinds of field such as rice cultivation, horticulture, irrigation, groundwater development, extension, training, etc. were despatched during the period, and the following activities have successfully been performed:

(1) Operation of Hardinath Agricultural Farm and Sindhuli Agricultural Farm;

(2) Establishment and operation of Nawalpar Horticulture Center;

(3) Breeding and extension of Junar (Nepalee originated cytrus);

(4) Establishment of cultivation technique for Japanese grape;

(5) Establishment and operation of IAP;

(6) Construction of irrigated model farms;

(7) Promotion of shallow tubewell program;

(8) Guidance and training of agricultural extension officers and farmers; and

(9) Establishment of repair and maintenance technique of farm machinery.

However, technical knowledge on groundwater development, technique and method for hydrogeological survey, planning, drilling and finishing of deep tubewell, operation and maintenance of irrigation facilities, water management, repair and maintenance of pump and construction and transportation equipment, etc. and organization of water users' groups have not been established yet.

To improve such situation a technical cooperation is required in parallel with the implementation of the Terai Groundwater Development Project.

# 5. BASIC DESIGN

# 5. BASIC DESIGN

## 5.1. Basic Concept

The basic design is made for the selected three development blocks (15 irrigation areas) in accordance with the following basic concepts.

(1) Four types of deep tubewells planned in Section 4.2.3 are applied to 23 development blocks.

(2) The standardization is made as much as possible in the basic design of the irrigation facilities such as pump station, main irrigation canal and the related structures to facilitate design and construction works and to shorten construction period.

(3) The local construction materials are used as much as possible to facilitate both construction and operation and maintenance of the irrigation facilities after construction.

(4) Considering the local condition of Nepal, the facilities are of the structure as simple as possible to reduce the construction costs.

The total costs and work quantities for constructing all the facilities planned for 23 development blocks are estimated based on the results of estimate for the selected three blocks, and will therefore be subject to the results of further survey, investigation and study.

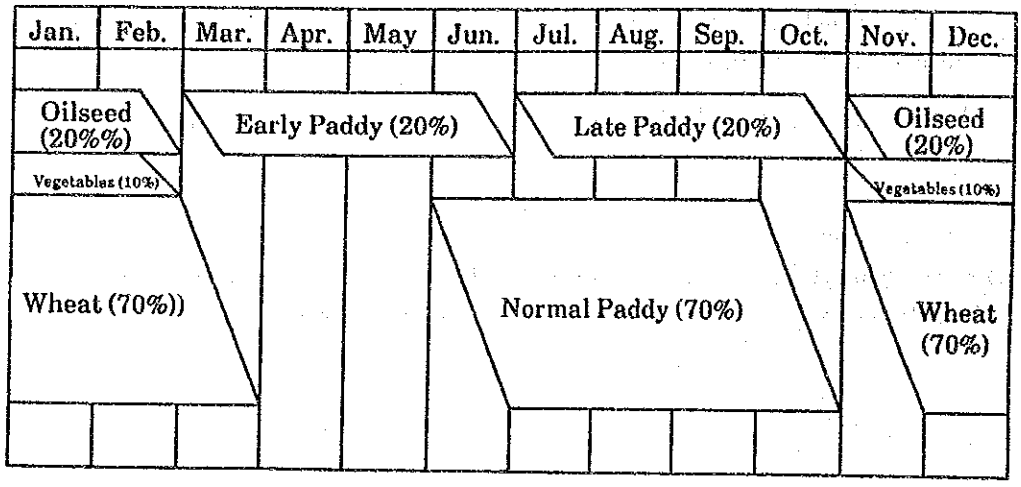
## 5.2 Basic Design Condition

Prior to the basic design, the following design conditions are determined.

1) Cropping pattern

The cropping pattern to be applied to the project area is determined as shown below, considering that of the STWP being implemented by TIATSP.

**Cropping Pattern**




Note : Cropping Intensity : 210%

The above cropping pattern may be modified or changed so as to meet the actual condition of each block such as soil condition, available irrigation water, etc. after the construction of the production tubewells and irrigation facilities, but the modified pattern will also be almost same to the above proposed pattern which is mainly composed of paddy and wheat.

2) Irrigation water requirement

The evapotranspiration which is used for calculating the net irrigation water requirement is estimated applying the modified Penman method, because the measured data are not available in and around the project area. Based on the estimated evapotranspiration, crop coefficient, percolation (2~5 mm /day), paddling water requirement (160 mm/month), effective rainfall and operation hours of pump (12 ha/day), etc., the net irrigation water requirement is calculated. The gross irrigation water requirement at turnout structures for branch canal is calculated monthly considering the conveyance efficiency of 90% to the net requirement as shown below.

**Monthly Gross Irrigation Water Requirement.**

(unit : ℓ/sec/ha)

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W. Req. | 1.04 | 1.08 | 1.26 | 0.84 | 0.74 | 1.36 | 0.87 | 0.98 | 1.22 | 1.06 | 0.66 | 1.16 |

In the basic design of the irrigation canals and their related structures, a pump operation hour of 12 hr /day and the unit irrigation water requirement of 1ℓ/sec. /ha. are adopted, but the operation hour of pump will be, when necessary, extended to the maximum 16 hours.

(3) Interval of tubewells.

The influence circle of each tubewell varies from 100 to 500m (tubewell interval : 200~1,000 m), because the permeability coefficient and available discharge are widely different from place to place due to the difference in hydrogeological condition of aquifers as shown in Table 3.2. As for the existing tubewells, the minimum interval is 500 m in the independent tubewells in Malangwa of the southern part of the Sarlahi District, and on the other hand, 330m in the linked tubewells in the IAP area in the center of the Mahottari District. Therefore, the interval of tubewells is determined to be more than 600m based on the above facts. Further, in order to avoid the uneven allocation of irrigation water and water charge in irrigation areas caused by different discharge of each tubewell, a linked tubewell system will be adopted as far as the topographic condition of the irrigation areas allows.

(4) Measures for land subsidence

In the southern part of the Terai plain where the clay layer is predominantly developed up to 170m deep and some attractive aquifers are laid above 170m deep, the main aquifer of the designed tubewell shall be below 170m deep (G6) to avoid the land subsidence.

(5) Protection of existing domestic-use shallow wells

In the villages in the project area there are many domestic-use shallow wells, utilizing phreatic water (or perched water) in the shallow aquifer, which are used by villagers for drinking and other domestic purposes. They are open wells with a depth of 10-20m and their borehole is protected with precast concrete pipes or bricks to avoid their collapse. In this meaning, in case of construction of deep tubewells in the project area, the existing domestic-use shallow wells should be protected from lowering of their water table and their drying which are resulted from falling phreatic water in the shallow aquifer down to deeper aquifers. Therefore, the deep tubewells to be constructed under this Project, particularly in the northern area where boulders, gravels and sands are predominant in the shallow layer, will be protected by filling clay, concrete, etc. between the casing pipes and the borehole surface down to 25m depth to prevent the phreatic water from falling down to lower aquifers.

## 5.3 Basic Design

### 5.3.1. Location of tubewells

The location of deep tubewell in each irrigation area is determined considering topography, system of tubewells (independent or linked tubewell system) and the following conditions.

- The location of tubewells shall be determined so as to keep the tubewell interval more than 600m to avoid the influence of tubewells each other. To secure the even distribution of irrigation water, the linked tubewell system is adopted as far as the topographic condition allows.
- The temporary access road between existing farm road and tubewell site shall be 500m in maximum.
- One tubewell out of five in a development block shall be located near village and equipped with a bathing pool for the domestic use of a part of the lifted water.
- On the approach road from major road or village to tubewell site, there shall be no obstruction such as river, canal, etc.
- The tubewell shall be located on the place where the elevation is higher in the irrigation block considering that the irrigation water is distributed to each farm plot by gravity flow through open canal.

The length of temporary access roads for the three blocks of which the basic design was made is tabulated below.

**Length of Access Road from Farm Road to Site**

| Basahiya Block (D-7) | | Kisannagar Block (M-4) | | Bramhapuri Block (S-7) | |
|---|---|---|---|---|---|
| No. | Length of Access | No. | Length of Access | No. | Length of Access |
| 1 | 130m | 1 | 70m | 1 | 0m |
| 2 | 0m | 2 | 0m | 2 | 0m |
| 3 | 0m | 3 | 0m | 3 | 490m |
| 4 | 390m | 4 | 90m | 4 | 230m |
| 5 | 0m | 5 | 0m | 5 | 430m |
| Total | 520m | Total | 160m | Total | 1,150m |

5.3.2 Standard deep tubewell

1) Design of production tubewell

(1) Length of pump housing

The distribution of specific capacity and the transmissivity in the project area are presented in Fig 3.9 and Fig 3.10 which are based on the results of hydrogeological survey described in Chapter 3. The additional requirement to the 14"-casing pipe provided under the KR-2 grant aid program depends mainly on the structure of production tubewell, especially on the length of pump housing. The table shows the length of pump housing (length of 14"-casing pipe) for each type of tubewell calculated based on the above specific capacity, etc.

**Required Length of 14"-Casing Pipe (Pump Housing)**

| Description | Type- I | Type-II | Type-III | Type-IV |
|---|---|---|---|---|
| Groundwater Elevation | 15m | 30m | 0m | 0m |
| Specific Capacity (ℓ/sec/m) | 4.0 | 1.5 | 2.0 | 1.1 |
| Design Discharge (ℓ/sec) | 40 | 30 | 50 | 40 |
| Design Depth of Dynamic Groundwater Level | 25m | 50m | 25m | 36m |
| Installation Depth of Pump | 30m | 55m | 30m | 40m |
| Length of 14"-casing Pipe | 36m | 60m | 36m | 48m |
| (nos. of pipe) | (6) | (10) | (6) | (8) |

(2) Standard specification of production tubewell

As mentioned in Section 4.2.6, the production tubewells in each development block should be constructed utilizing such KR-2 materials and equipment as pumps, screens, etc. as fully as possible. While, specification of the four standard tubewells designed in Section 4. 2. 3 is summarized below.

Standard Specification of Production Tubewell

| Description | Type- I | Type-II | Type-III | Type-IV |
|---|---|---|---|---|
| Drilled Depth (17½") | 89m | 159m | 205m | 205m |
| Casing Depth | 84m | 154m | 200m | 200m |
| 14"-Casing Length ∠1 | 36m | 60m | 36m | 48m |
| Thickness of Aquifer (Length of Screen) | 30m | 40m | 50m | 50m |
| Design Discharge | 40ℓ/sec | 30ℓ/sec | 50ℓ/sec | 40ℓ/sec |
| Packed Gravel (Dia. 2~9mm) | 9.2m³ | 16.6m³ | 24.0m³ | 23.2m³ |

Note : ∠1: The groundwater level, the design dynamic water level and the position of installed pump for determining the 14"-casing pipe length are as tabulated in the preceding table.

(3) Screen

The following three types of screens are applied to the production tubewells, considering the strength and the installed depth of screen.

① The present Johnson screens are applied to the shallow aquifer down to 50m deep (105m).

② The reinforced Johnson screens are applied to the middle aquifer from 50 to 150m deep (2,572.5m). The screen is reinforced to 9.2kg/cm² for 50~100m depth and 16kg/cm² for 100~150m depth.

③ The ring based wire-wrapped screens are applied to the deep aquifer from 150 to 200m (1,996.5m).

However, the detail of the above design is subject to the results of drilling test tubewells.

2) Drilling and development

The drilling of production tubewells is made with the diameter of 17½" to install the pipes such as 8"-casing pipe, 8"-screen and 14"-pump housing. The centerlizers are therefore attached to the pipes at the interval from 15 to 30m, and the casing string is hung on the turn table of the drilling rig with casing band until the pump-up test is completed. The diameter of gravels to be packed is from 2 to 9mm, and the packing is made steadly and continuously. The manners of drilling and development shall be as follows.

(1) Installation of 20"-conductor pipes (average depth : 12m)

(2) Construction of reinforced concrete base around the pipe (3 days). Check of drilling rig and mud pump. Preparation of mud and digging of mud pond.

(3) Drilling and enlargement of hole to the design depth with a diameter of 17½".

(4) Electric logging (0.5 days)

(5) Installation of casing pipes, reinforced Johnson screens and ring based wire-wrapped screens (the casing string shall be hung with hoist or casing band).

(6) Gravel packing (2 days) (diameter : 2~9mm)

(7) Welding of top of 20"-conductor pipe and casing with more than two pieces of L-steel.

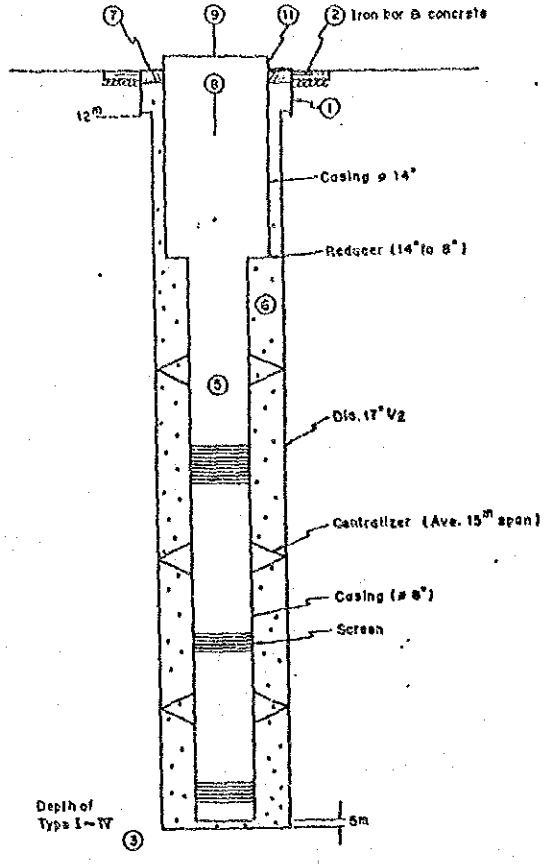
(8) Development (4 days) and pump-up test (7 days).

(9) Removal of hoist or casing band.

(10) Removal of drilling rig and materials (1 day).

(11) Preparation of concrete plug, hole for gravel packing and pump base.

**Drilling and Development of Tubewells**




The development of the tubewell shall be made after gravel packing in the following manner.

(1) Lifting-up by bailer and cleaning by water circulation (when surface water is available at site).

(2) Preparation of mud cleaner.

(3) Cleaning of screen by water jet with mud cleaner.

(4) Cleaning of bottom of tubewell by bailer.

(5) Air lifting (from top position to lowest position of the sreen)

It will take four days to complete the above works.

3) Reinforcement of Johnson screen to be applied up to 150m deep.

(1) Study on side pressure and collapse strength.

A) Calculation of side pressure to screen at the depth of 150m.

① In case the borehole is stable

The gravel pressure ($P_A$) to the outside circle of 8"-pipe (0.6m) is calculated as follows.

$P_A = K_A \gamma h$

Where : $K_A$ : active earth pressure coefficient,

$$K_A = tan^2(45° - \frac{\Phi}{2}) - \frac{2c}{\gamma h} tan(45° - \frac{\Phi}{2})$$

$\gamma$ : specific gravity of gravel,

$\gamma = 1.6$ (0~50m deep), 0.6 (50~150m deep).

h : depth from the top of casing

c : cohesion of clay, c = 0, and

$\phi$ : angle of internal friction, $\phi = 30°$

$K_A = 0.33$, $\gamma = 1.6$ , 0.6, h = 50m, 100m, safety factor Fs = 1.5,

$P_A = 1.5 K_A \gamma h = (1.5 \times 0.33 \times 1.6 \times 50 + 1.5 \times 0.33 \times 0.6 \times 100)$

$= 69$ ton/m$^2$ = 7.0kg/cm$^2$

② In case the borehole is easily collapsed

The following earth pressure formula shall be applied to estimate a collapse strength necessary for reinforcing the present Johnson screen, because it is widely employed in the oil field in U.S.A. and other oil countries to calculate a collapse strength of the pipes and screens to be set in the oil well.

$P = 1.5 h \times PSI$

where, 1.5 = safety factor, h = depth of well, and PSI = 1/14kg/cm$^2$.

In case the depth of well is 150m and 200m, the respective earth pressures are calculated as follows:

P(150m) = 1.5 × 150 × 1/14 ≒ 16kg/cm$^2$

P(200m) = 1.5 × 150 × 1/14 ≒ 21kg/cm$^2$

Therefore, the present Johnson screen shall be reinforced up to 9.2kg/cm$^2$ for 100m depth and 16kg/cm$^2$ for 150m depth, assuming that the borehole and screens will be easily collapsed by the earth pressure calculated above. Because, in the northern part of the project area a draw-down of deep tubewells reaches 50m deep, while in the southern part main aquifer consists of fine and coarse sand, and thus the borhole and screens are apt to easily collapse. It is also recommended to use a ring based wire-wrapped screen for the depth from 150m to 200m and deeper, duly considering the conditions as stated below:

- The collapse strength of 21kg/cm$^2$ is required for the depth of about 200m;

- It is technically difficult to reinforce the present screens so as to increase the collapse strength from the present 4.6 to the required 21kg/cm$^2$, and the reinforcement cost is nearly same to purchase cost of the other strong sreens available in market; and
- It is essential to pump up groundwater from the main aquifer (fine sand) laying deeper than 150m in the southern part of the project area.

B) Study on tensile strength of screen due to subsidence of packed gravel.

$$rfs = \frac{qc}{200} \quad or \quad rfs = \frac{N}{5}$$

Where : qc : average cone penetration resistivity of gravel (ton/m$^2$).

N : average N-value, assumed to be 1.

Total friction resistivity of 8"-pipe length from 50 to 200m deep is calculated below.

$$R_F = (200-50) \times 0.6 \times rfs = 150 \times 0.6 \times \frac{1}{5} = 18 ton$$

Total weight of 50m-screen and 150m-casing pipe is about 4ton.

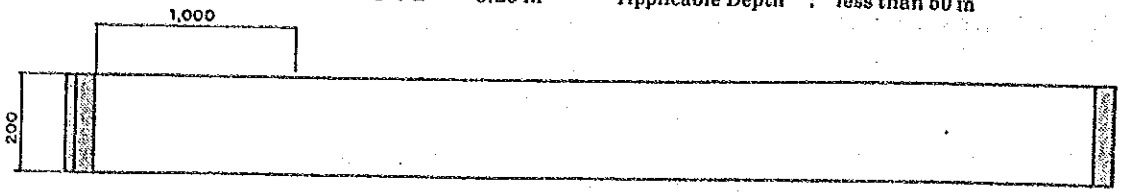
The tensile strength of the present screen (29ton) is sufficient against 22ton (total weight + the above friction resistivity).

(2) Method of reinforcement

The method of reinforcement for the present screens was examined taking into consideration a collapse test of the Johnson screens in Japan, and the most suitable method is to insert into the present screen the rings which are manufactured by cutting the pipes (out-side diameter : 193.7mm, API standard : 7⅝,thickness : 4.5 mm) to 20-50 mm or 100mm length. The rings are fixed on eight rods (thickness : 6mm, width : 16mm, flat bar) at an interval of 300mm (in case of 9.2kg/cm$^2$) and 30mm (in case of 16kg/cm$^2$) by welding. The reinforcement proposal which is based on the above test results is illustrated below.

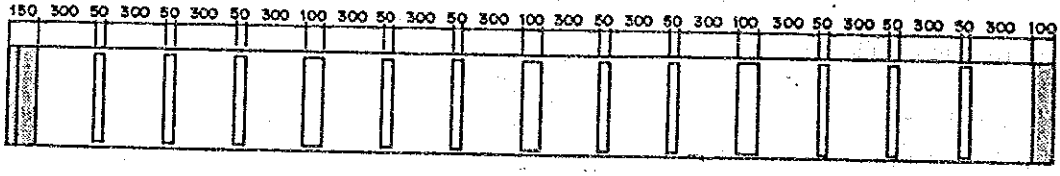
## Reinforcement of Present Screen

Present Screen 1 : L = 5.25 m Applicable Depth : less than 50 m

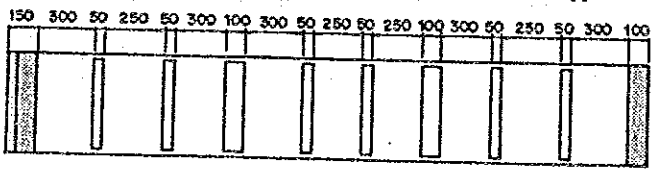



Present Screen 2 : L = 3.25 m Applicable Depth : less than 50 m

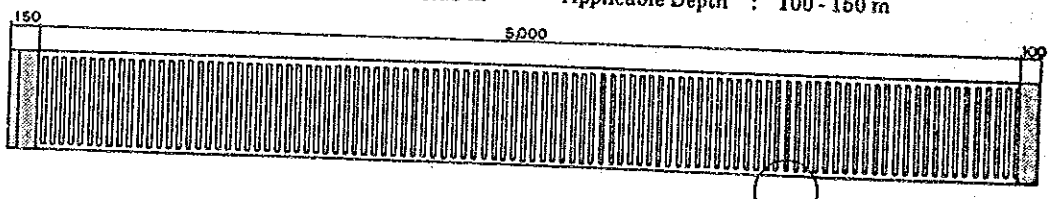
Proposed Reinforcement 1 : L = 5.25 m Applicable Depth : 50 - 100 m



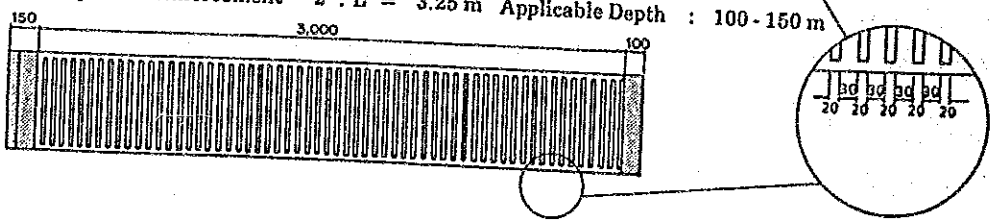

Proposed Reinforcement 2 : L = 3.25 m Applicable Depth : 50 - 100 m




Proposed Reinforcement 1 : L = 5.25 m Applicable Depth : 100 - 150 m




Proposed Reinforcement 2 : L = 3.25 m Applicable Depth : 100 - 150 m



The application of the above screens to 115 production tubewells is recapitulated as follows.

| Depth | Screen to be Applied | Required Length for 115 Production Tubewell |
|---|---|---|
| 30~50m | Present screen (Strength: 4.5kg/cm$^2$) | 105m |
| 50~100m | Reinforced screen (Strength: 9.2kg/cm$^2$) | 1,758.75m |
| 100~150m | Reinforced screen (Strength: 16kg/cm$^2$) | 813.75m |
| 150~200m | Ring based wire-wrapped screen (Strength : 28kg/cm$^2$) to be procured newly. | 1,996.5m |

However, the above-mentioned application is subject to the result of test tubewells to be drilled prior to the construction of production tubewells.

4) Casing program

The casing program is made based on depth and thickness of aquifer as shown below, but in the southern part of the Mahottari district and the central part of the Dhanusha district, where there exists the possibility to cause land subsidence, the screens will be installed below 170m deep.

| Type | Objective Area | Average Depth of Aquifer | Aquifer (Average Thickness) |
|---|---|---|---|
| I | Northern Sarlahi | 30~35m<br>45~70m | G1 (5m)<br>G2 (25m) |
| II | Northern Mahottari,<br><br>Northern Dhanusha | 35~45m<br><br>90~110m<br>125~140m | (10m) ··· STWP area is excluded.<br>G3 – 1 (20m)<br>G5 (15m) |
| III | Southern Sarlahi,<br>Southern Mahottari,<br>Central Dhanusha | 70~80m<br>130~140m<br>160~170m<br>175~190m | G2 (10~20m)<br>G3 – 1 (10m)<br>G5 (10m)<br>G6 (15m) |
| IV | Central to Northern Mahottari,<br>South-eastern Dhanusha | 70~80m<br><br>100~130m<br>140~160m | G2 (10)<br><br>G3 (20m)<br>G5 (20m) |

As stated in the preceding section, the collapse strengths of the present Johnson screen, the reinforced Johnson screen and the ring based wire-wrapped screen are 4.6kg/cm$^2$, 9.2kg/cm$^2$ (for 100m depth), 16kg/cm$^2$ (for 150m depth) and 28kg/cm$^2$, respectively. The necessary length of the applied screen is tabulated below. However, the detail of the program may be modified based on the drilling results of test tubewell in each block and the result of the application test of the reinforced screen to be made during the basic design study-phase II.

**Position and Length of Screen for Standard Tubewells**

| Description | Type- I | Type-II | Type-III | Type-IV | Total∠5 |
|---|---|---|---|---|---|
| Depth of tubewell | 89m | 159m | 205m | 205m | – |
| Depth of casing | 84m | 154m | 200m | 200m | – |
| Number of tubewell | 20nos. | 45nos. | 45nos. | 5nos. | 115nos. |
| Groundwater level | 15~20m | 20~30m | 0~5m | 0~5m | – |
| Dynamic Water Level | 25m | 50m | 25m | 35m | – |
| Position of Pump | 30m | 55m | 30m | 40m | – |
| Length of 14"-casing | 36m | 60m | 36m | 48m | 5,544m |
| Length of Screen | 30m | 40m | 50m | 50m | 5,145m |
| 30~50m ∠1 | 5m | – | – | – | 105m |
| 50~100m ∠2 | 25m | 15m | 10m | 10m | 1,758.75m |
| 100~150m ∠3 | – | 15m | – | 20m | 813.75m |
| 150~200m ∠4 | – | – | 40m | 20m | 1,996.5m |

Note: ∠1: The present Johnson screen is applied.
∠2 & ∠3: The reinforcedf Johnson screen is applied.
∠4: The ring based wire-wrapped screen is applied.
∠5: The lengths of casing pipe and screen include 5% of contingeny.

5.3.3. Layout of irrigation facilities

The following conditons are considered in planning the layout of irrigation facilities.

- The location of pump house is determined considering the conditons itemized in Section 5.3.1.
- The operator hut is provided apart from the pump house to prevent it from the bad affection caused by noise and vibration of engine and pump.
- The irrigation canal system is so planned as to follow the topography as much as possible to decrease the embandment volume and as to follow the existing farm border as much as possible to reduce loss of land.
- Since a rotative irrigation method of seven days is applied, seven or fourteen turnout structures are provided and all the plot sizes commanded by the respective turnouts shall be the same.
- The drop structure is provided where the topographic slope is steep and makes too high velocity in canal.
- The cross drain is provided at the crossing of irrigation canal and natural drainage or river.

- At the crossing of irrigation canal and existing road, the road crossing structure is provided for smooth traffic.
- When the irrigation canal is constructed in the area where cattle such as cow, sheep, goat, etc. seems to often cross the canal, the cattle pass is provided with proper interval.
- At the point where two or three irrigation canals are branched out, the division box is provided to facilitate water distribution.
- Where the canal is bent suddenly, the corner box is provided to assure the smooth water flow.
- The precast check plate is provided downstream of turnout structure on the main irrigation canal to supply water properly to the branch canal.
- The bathing pool is attached to a baffle tank of the pump house located nearest main village in the block.

The required quantity of the irrigation facilities for the designed three blocks are summarized in Table 5.1.

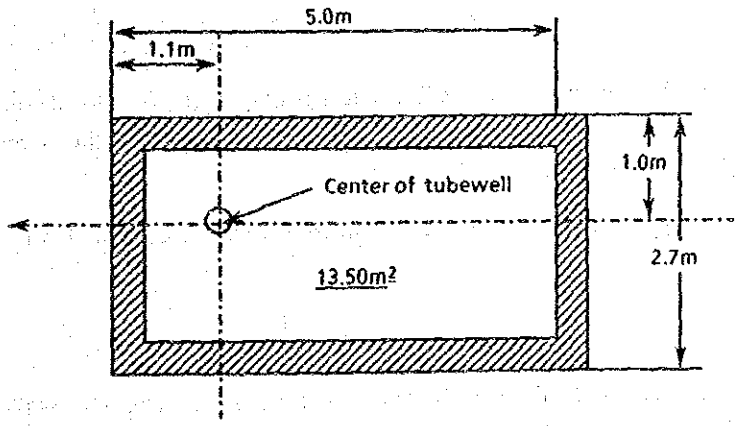
### 5.3.4. Basic design of pump house and operator hut

1) Pump house

The pump house is planned as follows, though the definite elevations and dimensions will be determined in the detailed design in the future.

(1) The scale of pump house is determined to be 13.50m² (5.0m×2.7m) ×2.7~2.8m high considering that of existing TIATSP pump house, and size of pumps and engines to be installed.

**Plan of Pump House**




(2) The pump house will be constructed with the brick masonry walls of 25cm-thickness and the reinforced concrete roof with the hole of 0.9m × 0.9m necessary for pump installation. The foundation will also be made with brick and the floor is plane concrete. The roof will be finished with mortar plastering.

(3) The wall will be finished with ruled pointing.

(4) The width of entrance will be 1.2m from which the facilities such as engine, etc. are brought into the house and the double swinging doors will be installed. To facilitate ventilation and lighting, two windows will be provided and a lattice will also be fixed for protecting the facilities from robbery.

(5) The pump and engine will be installed on a common foundation base.

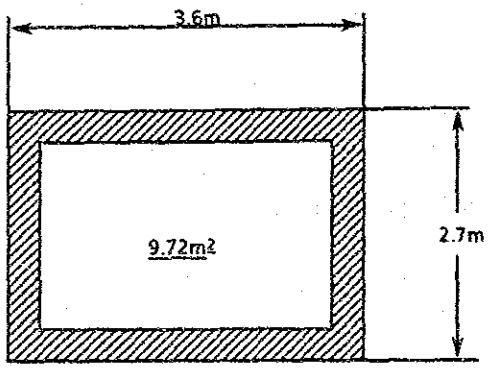
(6) No lighting facility will be provided because the pump is operated for only 12 hours in day time. When the night time operation is necessary a kerosene lump is used.

2) Operator hut

The operator hut is provided adjacent to the pump house for the operator's rest during the pump operation. Though the exact location and the definite dimensions and elevations will be determined during the detailed design, the preliminary design is made as follows.

(1) The size of the operator hut is 9.72m² (3.6m ×2.7m) × 2.7~2.8m high as shown below.

**Plan of Operator Hut**




(2) The operator hut will be constructed with 25cm-thick brick walls and mortar-finished roof as same as the pump house.

(3) The walls will be finished with ruled pointing and the floor will be finished with mortar.

(4) Two windows will be provided to facilitate lighting during the day time, and no lighting facility will be provided because the pump will be operated only during the day time. When the night time operation is made, a kerosene lump will be used.

(5) The lattice will be provided on windows for protecting the operator from robbery.

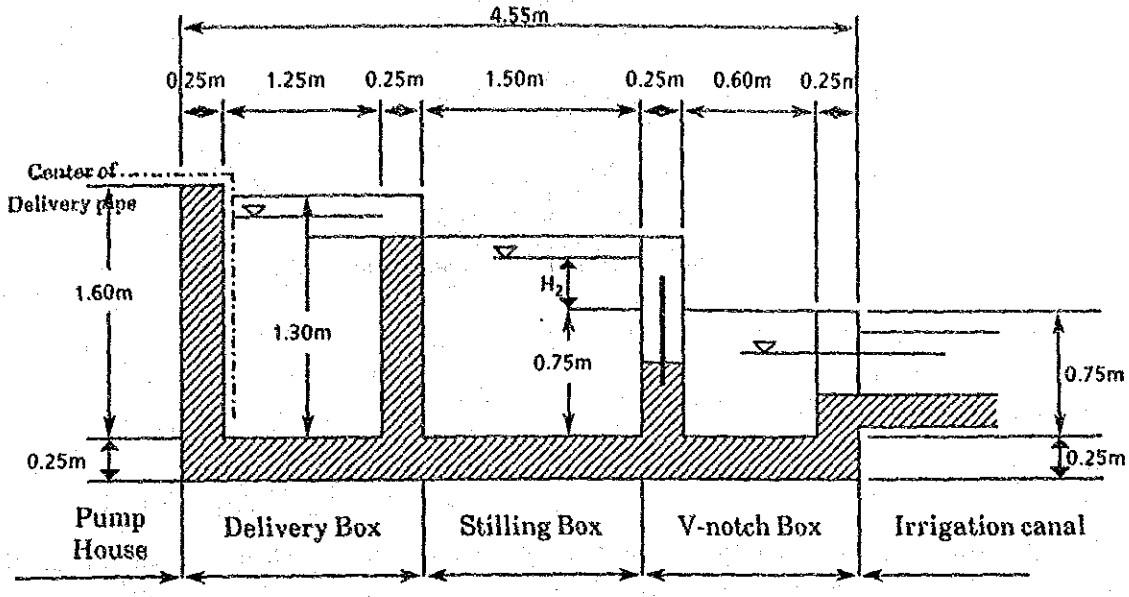
3) Baffle tank

A baffle tank is provided adjacent to the pump house to still the water discharged from the pump. The preliminary design of baffle tank is made as stated below.

(1) The baffle tank is composed of the delivery and stilling boxes separated by the wall of 25cm thickness. The width of both boxes is determined to be 0.8m considering the diameter of the delivery pipe. The pumped water is received in the delivery box and flows into the stilling box. The V-notch (90°) and the water level gauge are installed to measure the pump discharge. The lengths of the

delivery and the stilling boxes are 1.25m and 1.5m, respectively. The following profile shows the principal dimensions of the baffle tank.

**Profile of Baffle Tank**



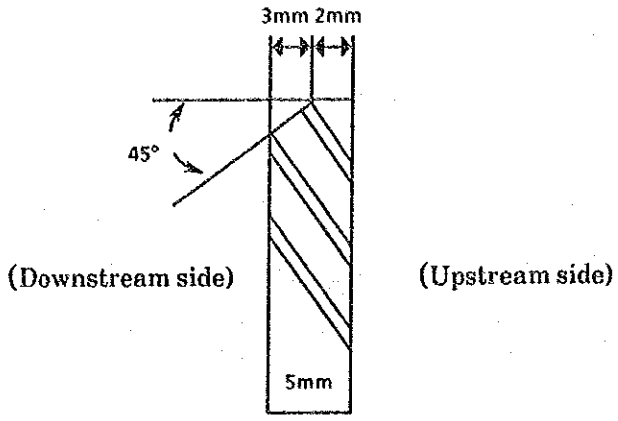

$$Q = 1.41 H_2^{5/2} = (0.14 + 8.57 H_2 + 37.8 H_2^2) \cdot H^{1/2}$$

**Detail of V-notch**

| Q | $H_1$ | $H_2$ |
|---|---|---|
| 50ℓ/sec | 26cm | 10cm |
| 40ℓ/sec | 24cm | 9cm |
| 25ℓ/sec | 23cm | 7cm |

(2) The V -notch of 5mm-thick steel plate will be manufactured as indicated below.

**Detail of V- Notch**




4) Bathing pool

The bathing pool is attached to a baffle tank of the pump house which is located nearest the village. The pool is preliminarily planned as follows.

(1) The dimensions of baffle tank are 2m wide, 1m high and 4.95m long.

(2) The steps are provided in the pool, and the concrete floor outside the pool.

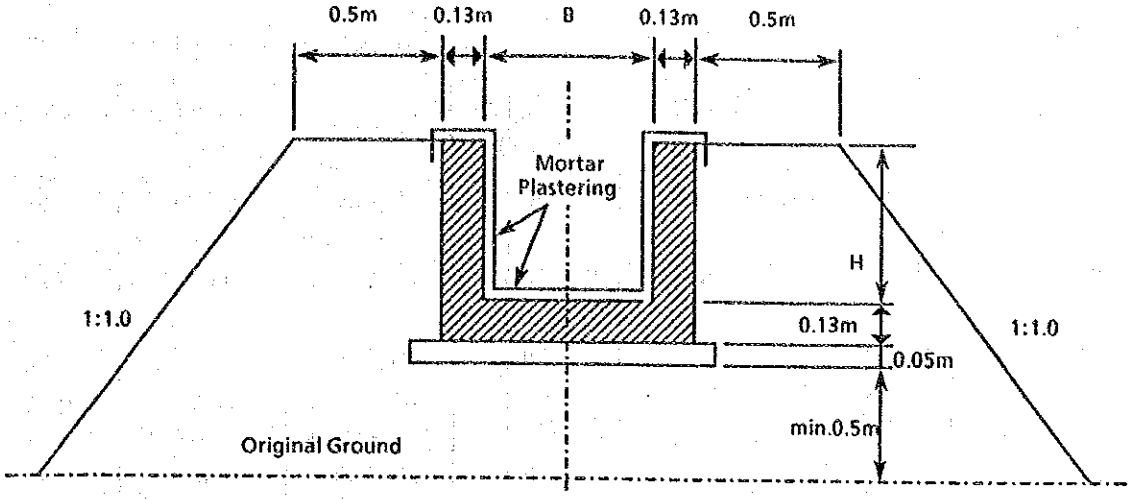
(3) The pool will be constructed with the brick masonry wall of 25cm-thickness as same as the baffle tank.

5.3.5 Basic design of irrigation canals and related structures

1) Irrigation canals

The main irrigation canals is constructed with one layer brick masonry because of cheep construction cost and simple repair and maintenance. The canal section will be same throughout the entire canal length. The following three types of canal will be applied to the development blocks, depending on the design discharge of the production tubewells constructed in the blocks.

**Cross Section of Irrigation Canals**




| Description | | Type- I | Type-II | Type-III |
|---|---|---|---|---|
| Size | B | 0.35m | 0.35m | 0.28m |
| | H | 0.42m | 0.35m | 0.28m |
| Design Discharge | | 50ℓ/sec | 40ℓ/sec | 30(25) ℓ/sec∠1 |
| Gradient | | 1/1,200~1/350 | 1/1,200~1/300 | 1/600~1/250 (1/850~1/200) |
| Velocity | | 0.48~0.77m/sec | 0.46~0.77m/sec | 0.55~0.77m/sec (0.46~0.78m/sec) |
| Water Depth | | 0.09~0.30m | 0.15~0.25m | 0.14~0.20m (0.11~0.19m) |

Note : ∠1 : The discharge of 25 ℓ/sec is applied to only the Kisannagar block.

The hydraulic calculation is made by the Maning formula, and one third of canal hight is taken for canal free board.

The embankment will be made by bulldozers and vibration rollers up to the bottom elevation of the foundation concrete, and after placing the foundation concrete (5cm thick) the brick masonry canal will be made manually. The inside face of canal will be finished with mortar plastering. The embankment of both sides of the brick masonry canal will be made by manpower and bulldozer which will gather soils from the fields.

The principal features of the main irrigation canals in the designed three blocks are shown below.

**Principal Features of Designed Main Canals (1/2)**

| Canal Name | Canal Type | Length (m) | Discharge (ℓ/sec) | Gradient | Velocity (m/sec) | Water Depth (m) |
|---|---|---|---|---|---|---|
| BSY−1−1 | I | 613 | 50 | 1/1,050 ~1/350 | 0.50 ~0.77 | 0.29 ~0.19 |
| BSY−1−2 | I | 732 | 50 | 1/1,200 ~1/350 | 0.48 ~0.77 | 0.30 ~0.19 |
| BSY−1−3 | I | 991 | 50 | 1/1,200 | 0.48 | 0.30 |
| BSY−2−1 | I | 548 | 50 | 1/800 ~1/300 | 0.56 ~0.81 | 0.26 ~0.18 |
| BSY−2−2 | I | 1,066 | 50 | 1/1,200 ~1/350 | 0.48 ~0.77 | 0.30 ~0.19 |
| BSY−3−1 | I | 876 | 50 | 1/1,000 ~1/350 | 0.51 ~0.77 | 0.28 ~0.19 |
| BSY−3−2 | I | 582 | 50 | 1/1,000 ~1/350 | 0.51 ~0.77 | 0.28 ~0.19 |
| BSY−4−1 | I | 406 | 50 | 1/350 | 0.77 | 0.19 |
| BSY−4−2 | I | 160 | 50 | 1/350 | 0.77 | 0.19 |
| BSY−4−3 | I | 567 | 50 | 1/1,000 ~1/350 | 0.51 ~0.77 | 0.28 ~0.19 |
| BSY−5−1 | I | 465 | 50 | 1/1,200 | 0.48 | 0.30 |
| BSY−5−2 | I | 673 | 50 | 1/1,200 | 0.48 | 0.30 |
| BSY−5−3 | I | 532 | 50 | 1/1,200 ~1/350 | 0.48 ~0.77 | 0.30 ~0.19 |
| KSN−1−1 | III | 1,341 | 25 | 1/850 ~1/200 | 0.46 ~0.79 | 0.19 ~0.11 |
| KSN−2−1 | III | 1,023 | 25 | 1/850 ~1/200 | 0.46 ~0.79 | 0.19 ~0.11 |
| KSN−2−2 | III | 134 | 25 | 1/200 | 0.79 | 0.11 |
| KSN−3−1 | III | 920 | 25 | 1/550 ~1/200 | 0.54 ~0.79 | 0.16 ~0.11 |
| KSN−3−2 | III | 514 | 25 | 1/200 | 0.79 | 0.11 |
| KSN−4−1 | III | 965 | 25 | 1/250 ~1/200 | 0.73 ~0.79 | 0.12 ~0.11 |
| KSN−4−2 | III | 93 | 25 | 1/200 | 0.79 | 0.11 |
| KSN−4−3 | III | 128 | 25 | 1/200 | 0.79 | 0.11 |
| KSN−4−4 | III | 159 | 25 | 1/550 ~1/200 | 0.54 ~0.79 | 0.16 ~0.11 |
| KSN−5−1 | III | 1,561 | 25 | 1/200 | 0.79 | 0.11 |
| KSN−5−2 | III | 45 | 25 | 1/400 | 0.61 | 0.15 |
| BRM−1−1 | II | 896 | 40 | 1/1,200 ~1/350 | 0.45 ~0.73 | 0.25 ~0.16 |

**Principal Features of Designed Main Canals (2/2)**

| Canal Name | Canal Type | Length (m) | Discharge (ℓ/sec) | Gradient | Velocity (m/sec) | Water Depth (m) |
|---|---|---|---|---|---|---|
| BRM-1-2 | II | 569 | 40 | 1/1,000 ~1/300 | 0.49 ~0.77 | 0.23 ~0.15 |
| BRM-2-1 | II | 403 | 40 | 1/1,200 ~1/300 | 0.45 ~0.77 | 0.25 ~0.15 |
| BRM-2-2 | II | 1,296 | 40 | 1/1,200 ~1/300 | 0.45 ~0.77 | 0.25 ~0.15 |
| BRM-3-1 | II | 624 | 40 | 1/1,200 ~1/600 | 0.45 ~0.59 | 0.25 ~0.19 |
| BRM-3-2 | II | 628 | 40 | 1/1,200 ~1/300 | 0.45 ~0.77 | 0.25 ~0.15 |
| BRM-4-1 | II | 560 | 40 | 1/1,200 | 0.45 | 0.25 |
| BRM-4-2 | II | 1,068 | | 1/1,200 | 0.45 | 0.25 |
| BRM-5-1 | II | 794 | 40 | 1/1,200 ~1/300 | 0.45 ~0.77 | 0.25 ~0.15 |
| BRM-5-2 | II | 524 | 40 | 1/500 ~1/270 | 0.64 ~0.80 | 0.18 ~0.14 |

2) Road crossing and cattle pass

In case that the canals cross the existing roads and run across the area where cattles pass frequently, a road crossing and a cattle pass will be provided. These structures are of precast concrete slab with soil covering of 20~30cm. The following types of structure will be applied.

| Kind of Crossing | Length |
|---|---|
| Road Crossing (Large) | 6m |
| Road Crossing (Small) | 1m |
| Cattle Pass | 4m |

The cattle pass will be provided every 400m along the main canal, and the following two types of the precast concrete slab will be applied.

| Type | Canal Type | Width (m) |
|---|---|---|
| I | I ,II | 0.48 |
| II | III | 0.41 |

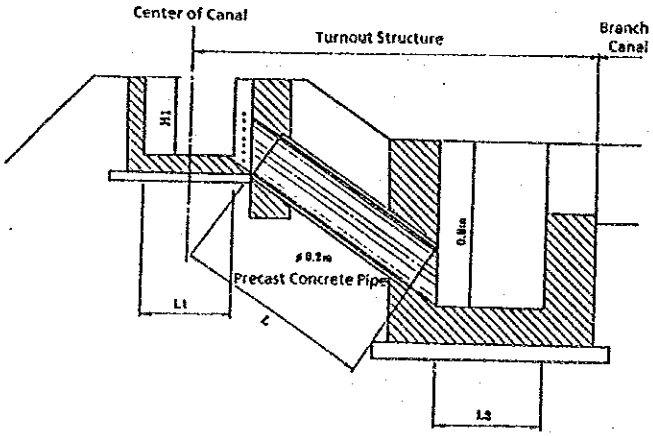
To facilitate manual installation, the length and thickness of the slab will be 1m and 12cm, respectively.

3) Turnout

Where the irrigation water is taken into the branch canal from the main canal, the orifice type turnout structure is provided. The stilling box which is installed at the begining point of the branch canal, and the main canal and the stilling box are connected with precast concrete pipe of 20cm-diameter. To seal the entrance of the turnout with soil and grass when not used, the iron bars are fixed at the entrance. At the downstream side of the main canal, a precast check plate is fixed to stop the flow to the downstream of the main canal when the water is taken into the branch canal.

The size of the turnout structures is as follows.

**Size of Turnout Structures**




| Type of Tunout | Canal Type | $L_1$ | $L_2$ | L | $H_1$ |
|---|---|---|---|---|---|
| I | I | 0.35m | 1.0m | 2.5m | 0.42m |
| II | I | 0.35m | 1.0m | 5.0m | 0.42m |
| III | II | 0.35m | 0.75m | 2.5m | 0.35m |
| IV | II | 0.35m | 0.75m | 5.0m | 0.35m |
| V | III | 0.28m | 0.5m | 2.5m | 0.28m |
| VI | III | 0.28m | 0.5m | 5.0m | 0.28m |

The discharge (Q) to be taken from the main canal is calculated by the following equation.

$$Q = 0.0188\sqrt{2gH}$$

Where, H = water depth of main canal

The water depth of main canal by design discharge is tabulated below.

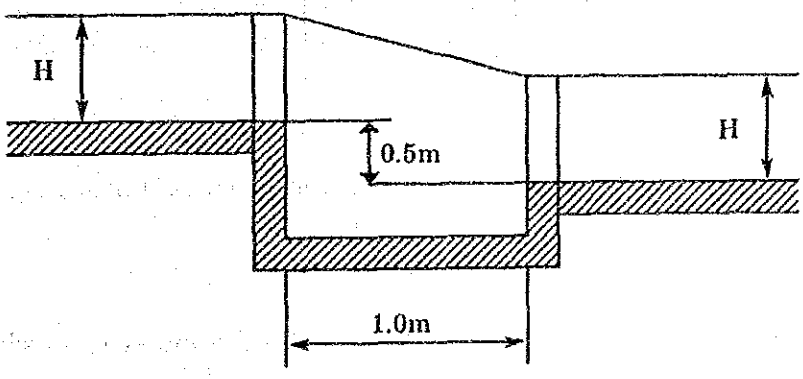
| Canal Type | Design Discharge (ℓ/sec) | Water Depth of Main Canal (m) |
|---|---|---|
| I | 50 | 0.36 |
| II | 40 | 0.23 |
| III | 30 | 0.13 |

The details of the turnout structures will be determined in the detailed design in the future.

4) Drop

When the canal slope is so steep that the flow velocity therein exceeds the designed maximum one, a drop structure is provided to reduce the velocity to the allowed one. The drop hight will be 0.5m and the length of stilling box is 1.0m. The following three types of drop will be applied.

| Drop Type | Canal Type | H (m) | L (m) |
|---|---|---|---|
| | | | (Width) |
| I | I | 0.42 | 0.35 |
| II | II | 0.35 | 0.35 |
| III | III | 0.28 | 0.28 |



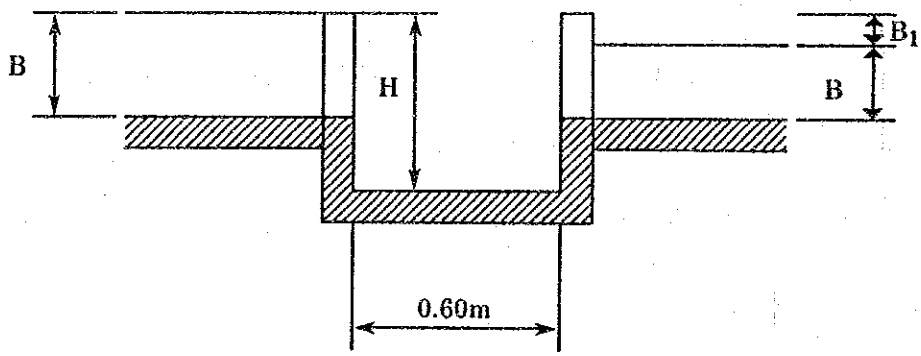

The details of the drop structures will be determined in the detailed design.

5) Division and corner boxes

The division box and the corner box are provided at the places where the sub-main canal is branched off from the main canal and where the main canal is suddenly bent in the shape of larger than 40°. These boxes are designed so as to have a function of drop structure, when the place requires it. The boxes are of brick masonry of 25cm-thick wall and 13cm-thick bottom. The following nine types of boxes are applied from place to place.

(unit : m)

| Type of Box | Canal Type | A (Canal Width) | B | $B_1$ | H |
|---|---|---|---|---|---|
| I - I | I | 0.35 | 0.42 | 0.00 | 0.62 |
| I - II | I | 0.35 | 0.42 | 0.25 | 0.87 |
| I - III | I | 0.35 | 0.42 | 0.50 | 1.12 |
| II - I | II | 0.35 | 0.35 | 0.00 | 0.48 |
| II - II | II | 0.35 | 0.35 | 0.25 | 0.73 |
| II - III | II | 0.35 | 0.35 | 0.50 | 0.95 |
| III - I | III | 0.28 | 0.28 | 0.00 | 0.48 |
| III - II | III | 0.28 | 0.28 | 0.25 | 0.73 |
| III - III | III | 0.28 | 0.28 | 0.50 | 0.98 |




The details of elevation, dimension, etc. will be determined in the detailed design.

6) Crossdrain

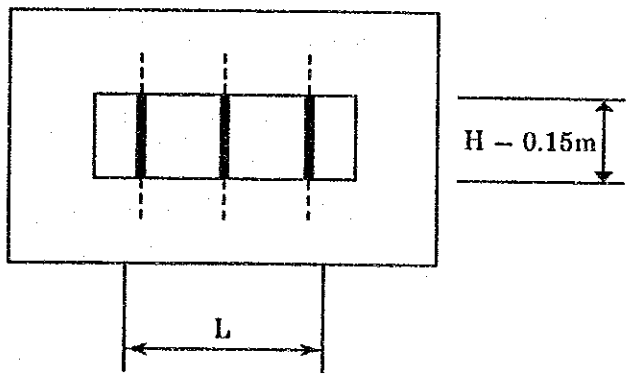
When the main irrigation canal crosses river and natural drain or depression where water stagnation occurs, a crossdrain is provided.

The crossdrain consists of the 0.8m-precast concrete pipe and brick walls at its both ends. To protect the canal embankment from erosion and scouring, the gabion mats are provided at the downstream side of the crossdrain.

7) Check plate

A precast check plate is provided downstream of turnout structure to facilitate water management service. The plate is composed of the frame of precast concrete and the iron bars, and the following three types of plate are applied.

| Type | Canal Type | H (m) | L (m) |
|---|---|---|---|
| I | I | 0.42 | 0.35 |
| II | II | 0.35 | 0.35 |
| III | III | 0.28 | 0.28 |




5.3.6 Preliminary specification of additional materials and equipment

The preliminary specifications of the additional materials and equipment proposed in the preceding Section 4.2.5 are described in Table 5.2. In determining the specification, the suitability and compatibility to the existing materials and equipment are fully considered.

# 6. BASIC DESIGN STUDY - PHASE II

# 6. BASIC DESIGN STUDY - PHASE II

## 6.1 Result of Basic Design Study and its Problems

### 6.1.1 General

A field survey of the basic design study (hereinafter referred to as the basic design study - phase I) was carried out from January 7, 1987 through March 6, 1987. Feasibility of the Project was then studied through a home analysis work of March 7, 1987 through April 30, 1987. Results of the major technical survey and problems found through the study, which were used as basic data for the feasibility study, are summarized below.

### 6.1.2 Test drilling

In order to confirm the hydrogeological structure and the distribution of groundwater in the project area in the direction from north to south, specifications of the planned production tubewells, possibility of the ground subsidence due to excess extraction of groundwater, condition of drilling rigs and their drilling capacity, etc., four test drillings were made on the line of Dhalkebar-Janakpur-Jaleswar in Dhanusha District. Fig. 3.3 shows the location of the test drillings.

Specifications of the four test drillings are as shown below.

| Name of Well | Diameter of Drilling | Depth (m) | Length of Casing (m) | Length of Screen (m) | Pump-up Discharge (ℓ/sec) | Remarks |
|---|---|---|---|---|---|---|
| TW-1 | 17 ½"<br>14 ¾" | 0~120<br>120~240 | Ø14" 0~72<br>Ø8" 72~240 | Ø8" 60 | 27 | Crush and collapse of screen |
| TW-2 | 17 ½"<br>14 ¾" | 0~82<br>82~230 | Ø14" 0~73<br>Ø8" 73~230 | Ø8" 60 | 0 | Ground settled.Casing reached up to 213m deep only. Abandoned |
| TW-3 | 17 ½"<br>14 ¾" | 0~78<br>78~150 | Ø14" 0~68<br>Ø8" 68~150 | Ø14" 10<br>Ø8" 40 | 5 | Crush and collapse of screen |
| TW-2' | 17 ½"<br>14 ¾" | 0~85<br>85~212 | Ø14" 0~58<br>Ø8" 58~212 | Ø8" 40 | 0 | Crush and collapse of screen |

The results of the above test drilling and the problems encountered are given below.

Results and Problems

(1) Condition of the three units of drilling rigs and their drilling capacity were made clear.

(2) Hydrogeological structure and distribution of aquifer on the line of Dhalkebar-Janakpur-Jaleswar were mostly made clear.

(3) Maintenance of the three units of drilling rigs, repair and maintenance (including procurement and transportation of liner, piston rubber, etc.) of three units of mud pumps attached to the rigs, etc. are required.

(4) As the present 8" Johnson type screens have not enough strength for construction of deep tubewells under the peculiar hydrogeological condition in the project area, they require reinforcement so that they can resist against at least 9.2kg/cm$^2$ (100m depth) and 16kg/cm$^2$ (150m depth) of side pressure. Measures for the reinforcement are detailed in Section 5.3.2. Besides, below 150m depth a ring base wire-wrapped screen, which has a 28kg/cm$^2$ of callapse strength, will be used.

(5) There is no stock of 17½" and 14¾" bits. Procurement of necessary quantity is required in conformity with the future drilling schedule.

(6) For pumping test, procurement of one unit of high pressure air compressor (20kg/cm$^2$, 20m$^3$), one unit of big discharge/ low head submersible motor pump, etc. is necessary.

(7) Since pumping test could not be made to the test borings, possible pump-up capacity has not been confirmed. It is necessary to confirm it by other test tubewells using the reinforced Johnson screens and 8" ring base wire-wrapped screens, etc.

(8) It is necessary to assign one Japanese driller to each drilling rig for drilling of test tubewells, because drillers (drilling technicians) of TIATSP have poor experience of deep tubewell drilling.

(9) It is desirous to drill deep tubewells by 17½" bits in the southern part of the project area where its aquifer is composed of fine sand layer, because, under such conditions, thickness of gravel packing should be made thicker in order to reduce inflow of fine sand through the screens. When the existing Johnson type screens (0.5 mm slit) or reinforced ones are to be used, diameter of gravel should be 2~9mm.

(10) Even in the case of using reinforced Johnson screens, it is necessary to keep casing pipe string (including screens) under suspended condition until completion of the pumping test.

(11) For the purpose to clarify the problem of the ground subsidence by excess extraction of groundwater in the southern part of the project area, it is necessary to take soil samples from test tubewells and to make grading analysis.

6.1.3 Hydrogeological survey

The following survey was carried out for the existing tubewells in the project area.

| Item | Number of Existing Well Surveyed | | | |
|---|---|---|---|---|
| | Sarlahi District | Mahottari District | Dhanusha District | Total |
| (1) Analysis of deep tubewell log | 10 | 26 | 50 | 86 |
| (2) Analysis of deep tubewell static water level | 13 | 23 | 41 | 77 |
| (3) Analysis of deep tubewell dynamic water level | 9 | 16 | 27 | 52 |
| (4) Measurement of deep tubewell static water level | 1 | 5 | 5 | 11 |
| (5) Examination of deep tubewell water quality | 4 | 7 | 6 | 17 |
| (6) Measurement of shallow tubewell static water level | 15 | 37 | 22 | 74 |
| (7) Examination of shallow tubewell water quality | 4 | 4 | 2 | 10 |
| (8) Continuous pumping-out test of deep tubewell (Refer to Table 3.1) | 4 | 2 | 7 | 13 |

Based on the results of the above analysis and existing electric sounding (total 299 points) and the results of new electric sounding (135 points) made this time, the following hydrogeological profiles, groundwater contour map and groundwater potential iso-map were prepared.

(1) Hydrogeological profiles on the direction of north to south in the project area (Refer to Fig. 3.2): Sarlahi District 2, Mahottari District 2, Dhanusha District 3, 7 profiles in total.

(2) Hydrogeological profiles on the direction of east to west in the project area (Refer to Fig. 3.2): 3 profiles.

(3) Groundwater contour maps in the project area (Refer to Fig. 3.4 and 3.6): one map for shallow tubewells and deep tubewells each.

(4) Groundwater potential iso-map in the project area (Refer to Fig. 4.1): one map.

The results and problems of this hydrogeological survey are summarized below.

Results and Problems

(1) Shallow tubewell development area in the project area could be delineated.

(2) Although the groundwater potential distribution in the project area was made clear this time, it is necessary to add more pumping test results for existing deep tubewells (about 20 tubewells) in order to increase precision of the groudwater potential iso-map.

(3) However, the above groundwater potential iso-map does not specify possible pump-up discharge for each development block. For such purpose, drilling of one test tubewell and about 20 points of electric sounding are required for each development block.

(4) For analysis of groundwater balance in the project area, additional collection of data on groundwater table, water quality, etc. in the existing deep tubewells and shallow tubewells are necessary.

### 6. 1. 4 Electric sounding

Among 30 development blocks roughly delineated in the preliminary study, total 135 points of electric sounding were carried out for the following 13 blocks which were considered to have high priority for development.

| District | Name of Development Block | Points of Electric Sounding |
|---|---|---|
| Sarlahi | S-1, S-2, S-4, S-7, a part of S-5 | 32 |
| Mahottari | M-1, M-2, M-3, M-4, M-7 | 44 |
| Dhanusha | D-6, D-7, D-8, D-12, a part of D-11 | 59 |
| | Total | 135 |

Based on specific resistance values of the above 135 points, total 18 lines of specific resistance profile were prepared; 8 lines on north-south direction and 10 lines on east-west direction(Refer to Fig. 4.3).

Its results and problems are given below.

(1) General characteristics of geological structures in the project area were made clear. It was also clarified that the geological structure up to 300m deep had a characteristic of having no continuity in east-west direction though it had considerable continuity in north-south direction.

(2) Due to the fact that the priority was given to clarification of the geological structure of the whole Project area though the planned points of the electric sounding were limited to 135, they were scattered over the whole project area widely. Therefore, about 20 points of additional electric sounding are required for each development block for the purpose to specify the hydrogeological structure of each development block and the location of deep tubewells in each block.

6.1.5 Evaluation survey on deep tubewell equipment and materials granted under KR-2

Since this Project is based on the condition that as many deep tubewells as possible are to be constructed by efficient use of the equipment and materials which were granted under the KR-2 for construction of deep tubewells, an evaluation survey on the remaining deep tubewell equipment and materials was carried out. The granted quantity and the present quantity of the major equipment and materials are as shown below.

| | Granted Quantity | Present Quantity |
|---|---|---|
| (1) Deep tubewell drilling equipment and materials | | |
| - Drilling rig (Including mud pump) (TRD500: 4 Units, YRD-501R: 3 Units) | 7 units | 7 units |
| - Bits 17½" | 28 nos. | 7 nos. ∠1 |
| 14¾" | 15 nos. | 0 nos. ∠1 |
| 12¼" | 81 nos. | 54 nos. ∠1 |
| - Well cleaning equipment and materials | | |
| Air compressor (7 kg/cm², 10.5m³/min) | 7 units | 7 units |
| 6" lifting pipe (L=5.5m) | 962.5 m | 731.5 m ∠1 |
| 2" air pipe (L=5.5m) | 962.5 m | 396 m ∠1 |
| - Pumping-out test equipment | | |
| 5" submersible motor pump (45ℓ/sec, 75m Head) | 2 units | 2 units |
| 6" submersible motor pump (45ℓ/sec, 35m Head) | 2 units | 2 units |
| 8" submersible motor pump (60ℓ/sec, 40m Head) | 2 units | 2 units |
| 8" submersible motor pump (90ℓ/sec, 45m Head) | 4 units | 4 units |
| Engine generator for submersible motor pump | 10 units | 10 units |
| Notch tank (2.5 m³) | 1 no. | 1 no. |
| - DC engine welder | 7 units | 7 units |
| - Pipe, screen, etc. | | |
| 20" conductor pipe (L=3m) | 84 m | 84 m |
| 14" casing pipe (L=6m) | 8,400 m (1,400 length) | 5,592 m ∠1 (932 length) |
| 8" casing pipe (L=6m) | 15,996 m (2,666 length) | 13,392 m ∠1 (2,232 length) |
| 8" Johnson type screen (L=5.25m, 3.25m) | 7,500 m | 5,076 m ∠1 |
| 14"–8" reducer | 216 nos. | 160 nos. |
| - Pumps for production tubewell | | |
| Vertical turbine pump (60ℓ/sec, 45m head) (But, the pumps have 30m pump shaft/ lifting pipe, respectively) | 109 units | 98 units ∠1 |
| Diesel engine (72 HP) for the above | 109 units | 98 units ∠1 |
| Vertical turbine pump (45ℓ/sec, 40m head) (Pump shaft and pump-up pipe are 30m long for each pump) | 88 units | 79 units ∠1 |
| Diesel engine (47 HP) for the above | 88 units | 79 units ∠1 |
| - Volute pump for water supply | 8 units | 8 units |

(2) Transportation vehicle

| | | |
|---|---|---|
| - 3ton cargo truck with 4 ton crane | 5 units | 5 units |
| - 4ton cargo truck | 4 units | 4 units |
| - Fuel tank lorry (4,000ℓ) | 2 units | 2 units |
| - Water tank lorry (4,000ℓ) | 5 units | 5 units |
| - 20ton trailer truck | 3 units | 3 units |
| - 1ton pick-up truck | 7 units | 7 units |
| - Fork lift truck | 1 unit | 1 unit |

(3) Construction equipment

| | | |
|---|---|---|
| - 6ton bulldozer | 1 unit | 1 unit |
| - 11ton bulldozer | 13 units | 13 units |
| - 0.8 $m^3$ wheel loader | 5 units | 5 units |
| - 1.2$m^3$ wheel loader | 6 units | 6 units |
| - 2.8 m motorgrader | 1 unit | 1 unit |
| - 3.1 m motorgrader | 5 units | 5 units |
| - 4ton vibrating road roller | 5 units | 5 units |
| - Tractor + 2ton trailer | 3 units | 3 units |
| - 3.5ton dump truck | 10 units | 10 units |
| - 0.5 $m^3$ concrete mixer | 4 units | 4 units |

(4) Maintenance vehicle

| | | |
|---|---|---|
| - Wagon type jeep | 5 units | 5 units |
| - Jeep | 4 units | 0 ∠2 |

Note: ∠1 means the remaining quantity after construction of deep tubewells by JADP/ TIATSP and Japanese contractor.
∠2 means that four jeeps were fully worn out.

The results and problems of this inventory survey are as summarized below.

Results and Problems

(1) It was clarified that 115 deep tubewells would be constructed by using the existing equipment and materials of KR-2. For this purpose, however, the following are required: check and repair of 7 drilling rigs including additional supply of spare parts for them, repair of 3 mud pumps equipped to the drilling rigs and additional supply of spare parts (liners, piston rubbers, etc) for 7 mud pumps including the said 3 mud pumps, additional supply of pipes (20" conductor pipes, 14" casing pipes, etc.), additional supply of transportation vehicles (4-ton cargo trucks with 3-ton cranes, 4,000 ℓ fuel tank lorries, 4,000 ℓ water tank lorries, 1-ton pick-up trucks, etc.) including supply of spare parts for them, additional supply of construction equipment for canal construction (3.5-ton dump trucks, 4-ton vibration roller, 2.8 m motorgrader, etc.) including supply of spare parts for them, additional supply of inspection vehicles (wagon type jeeps and ordinary jeeps) including supply of spare parts for them, etc. Quantity of necessary equipment and materials is detailed in Section 4.2.6.

(2) Reinforcement of the existing Johnson screens is indispensable. Measures for the reinforcement are detailed in Section 5.3.2.

(3) Because pump shafts and lifting pipes of the existing diesel engine driven turbine pumps are only 30 meters long, it is necessary to extend them by 10 to 25 m for 50 units of the pumps out of those to be installed to 115 deep tubewells. However, it is possible to extend them at the site if the pump shafts and the lifting pipes are additionally supplied by 375m each since 157 units of pump (with pump shafts and lifting pipes) are presently available at site.

### 6.1.6 Selection of development blocks

A study was made on possibility and soundness of development of 30 development blocks requested by HMGN after reconnaissance of the blocks referring to cadastral maps (scale of 1/2,400) copied at survey offices of Dhanusha, Mahottari and Sarlahi Districts, topographic maps (scale of 1 inch/1 mile), land use maps (scale of 1/50,000), the groundwater potential map (scale of 1/50,000), which were prepared based on synthetic analysis of the results of the hydrogeological survey, the electric sounding, four test drillings, etc. carried out this time. Based on the results of the above reconnaissance (mainly present land use, access and topography) and the groundwater potential map, 23 development blocks were selected and 8 priority development blocks were further determined after discussion with TIATSP.

Problems

As for the remaining 15 blocks other than the priority development blocks, there is possibility of change of locations after further study, since it is far from saying that the survey on access roads, present land use, etc. was detailed enough, and also since no full discussion with TIATSP has not been made.

### 6.1.7 Topographic survey and mapping for three development blocks

Out of the 8 priority development blocks, 3 development blocks (one form each District), which are to be representatives of the 23 blocks from the view points of possible pump-up discharge (25ℓ/sec, 30ℓ/sec, 40ℓ/sec, 50ℓ/sec, 55ℓ/sec), topography (northern, middle and southern parts of the project area), access, etc., were selected and then 15 planned irrigation areas (5 areas for each block) were set up. After that, topographic survey was carried out by the 100m mesh method and concise maps of 1/1,000 scale were prepared. Information on cadastral, land use, etc. was indicated on these maps and then layout of main canals and their related structures was made.

Since the land in the project area will become muddy in the rainy season, topographic survey of the remaining 20 development blocks will have to be made during the dry season (December - April of next year).

## 6.2 Purpose of Basic Design Study - Phase II

In the basic design study - phase I , the hydrogeological structure and the groundwater potential distribution in the whole project area were briefly clarified by the hydro-geological survey, including 4 test drillings and pumping-out tests of 13 existing deep tubewells, 135 points of the electric sounding, etc. Then, the 23 development blocks including the 8 priority development blocks were determined and topographic survey and mapping of the 3 representative development blocks were carried out. At the same time, 4 types of standard deep tubewells and their specifications were set out and the construction plan of the 115 deep tubewells and the irrigation facilities for 4,625 ha was worked out, and then a basic design of the 3 representative development blocks was performed.

However, due to absence of test tubewells (including pumping-out test), lack of points of the pumping-out test at the existing deep tubewells, lack of points of the electric sounding, etc., the possible pump-up discharge from the deep tubewells in each development block has not been determined yet and it is still not possible to decide the specifications and sizes of the deep tubewells and the irrigation facilities. In addition, it is hard to say that the locations of the 15 development blocks other than the 8 priority development blocks have been fixed.

In due consideration of the above results of the basic design study - phase I , HMGN requested GOJ a consecutive study including confirmation of the possible pump-up discharge in respective development blocks, determination of the locations of the above-mentioned 15 blocks (those of the 8 blocks have been determined), etc.

In order to respond such request, the basic design study-phase II is planned to execute for 5 development blocks, which are to be constructed in the first year of the project implementation out of the 23 development blocks, which are subject to a multi-year development, (1) drilling of test tubewells (one for each block, 5 in total) for confirmation of a possible pump-up discharge, (2) a topographic survey and preparation of 1/1,000 scale maps (those for 3 blocks have already been made) and (3) determination of sizes and basic design of deep tubewells and irrigation facilities, and also to perform (4) estimates of project cost for the said 5 blocks and the other 18 blocks to be constructed in and after the second year, (5) determination of an implementation plan of the whole 23 development blocks and (6) evaluation of the whole Project, etc.

## 6.3 Plan of Basic Design Study - Phase II

The basic design study - phase II includes preparatory home work, filed survey, home analysis work, preparation of basic design report and an explanation of the draft report to HMGN. Especially, it also includes procurement and transport of the additional equipment and materials necessary for drilling and pumping-up test of the 5 test tubewells.

### 6.3.1 Procurement and transport of additional equipment and materials

Out of the additional equipment and materials necessary for the site survey, especially for the drilling and pumping-up test of the 5 test tubewells, long ones and heavy ones, etc. (Ref. 6.6 hereinafter) which unfit to air cargo will be procured and shipped from Japan 3 months prior to the commencement of the filed survey and will be transported into the site before starting the field survey. The other additional equipment and materials (Ref. 6.6 hereinafter) will be brought to the site by air cargo at the time of departure of the survey team or by hands of the survey team member. It is indispensable to ship the additional equipment and materials 3 months prior to the commencement of the field survey in order to carry out smooth drilling work of the test tubewells.

### 6.3.2 Home preparatory work

1) Preparation of Inception Report

Prior to the field survey, home preparatory work will be made and an inception report will be prepared compiling a comprehensive plan of operation of the field survey, items to be surveyed, questionaire, etc. after discussions with JICA and other GOJ officials concerned.

In the inception report, enough examination will be made to the following problems which have been found in the basic design study-phase I .

(1) Facilities and conveniences to be provided by HMGN: Examination on equipment and materials, counterparts, office/accommodation, etc. to be provided by HMGN for the execution of the field survey.

(2) Work schedule of the field survey: Preparation of work schedule in due consideration of the schedule of a mission of GOJ and HMGN, etc.

(3) Review on the results of the basic design study - phase I , problems, etc.: Review on general matters including test drilling, hydrogeology, irrigation, etc.

(4) Hydrogeological survey and electric sounding: Examination on execution method, scheduled locations, etc. of various items of additional hydrogeological survey (groundwater table, water quality, pump-up discharge confirmation, electric sounding, etc.)

(5) Drilling of test wells:

- Detailed check of the additionally procured equipment and materials for drilling and pump-up test
- Selection of location of drilling test tubewells
- Examination of the detailed specifications for test tubewells

- Examination of method of drilling/ developping including gravel packing
- Detailed study on measures for reinforcement of Johnson screens

(6) Irrigation and drainage survey: Examination on location of the 15 development blocks, arrangement/study of problems on setting of irrigation units and location of irrigation facilities, designing structures, etc.

2) Discussion with GOJ officials concerned

Concerning the items which will become major problems in the discussions with HMGN officials, prior discussions will be made fully with JICA and GOJ officials concerned to unify opinion of Japanese side on such problems.

6. 3. 3 Field survey

The survey team for the basic design study-phase II will discuss with HMGN and determine the basic direction and general features of this Project based on the inception report. The survey team leader will cooperate with the GOJ mission and will engage in such works as confirmation on results of discussions with HMGN officials concerned.

Other survey team members, who are in charge of hydrogeology (A), drilling (A), (B) and equipment maintenance, will commence selection of locations for drilling of the test tubewells, check and maintenance of 3 drilling rigs, etc. in accordance with the field survey plan agreed between HMGN and GOJ.

1) Explanation on inception report to HMGN officials concerned and subsequent discussion with them

At the beginning of the survey, the outline and results of the basic design study-phase I , the purpose of the basic design study-phase II and the outline of the implementation plan of the Project will be explained to HMGN officials concerned and discussion with them will be made. At the same time, confirmation on purpose, method, period of the field survey and the facilities to be provided by HMGN, etc. will be made. Then the team will arrange necessary preparation for immediate commencement of the field work. These explanation and discussion will be made based on the result of discussions to be held with Embassy of Japan and JICA office in Kathmandu.

2) Survey on substance of the Project

In order to recheck the feasibility and effect, etc. of the Project, the latest data will be collected through the discussions with HMGN organizations concerned and the field reconnaissance. The stress of the survey will be put on the following items.

- Current movement of related projects
- Operation and maintenance of the existing groundwater irrigation projects
- Economic effects of the existing groundwater irrigation
- Latest data on construction materials, labour, construction methods, etc.

3) Drilling of 5 test tubewells

The 4 test drillings at the time of the basic design study-phase I were executed for the purpose to seize the hydrogeological structure of the whole project area. By the hydrogeological survey so far made, it was clarified that the aquifer in the project area remarkably changed in the direction of both north to south and east to west. On the other hand, the development blocks are scattered at 23 locations over the project area and, though the approximate groundwater potential of each development block could be estimated, several problems such as confirmation of the possible pump-up discharge in the respective blocks by drilling of test tubewells, detailed specifications of standard tubewells, adaptability of the reinforced screens, etc. are still left for clarification. Therefore, test tubewells will be drilled and their pump-up tests will be carried out; one in each of the 5 development blocks to be constructed in the first year of the project implementation.

Specification of the test tubewell is the same to that of the production tubewells to be constructed in the respective blocks. Casing program of the test tubewells is therefore composed of 14" and 8" casing pipes, 8" reinforced Johnson screens (9.2kg/cm$^2$ for 100m depth and 16kg/cm$^2$ for 150m depth) and 8" ring base wire-wrapped screen to be additionally supplied from Japan.

4) Hydrogeological survey and electric sounding

In order to clarify the problems mentioned in preceding 6.1.3 Hydrogeological survey and 6.1.4 Electric sounding and also in order to confirm or determine groundwater potential distribution, water balance of the groundwater in the project area, location of tubewells in the 5 development blocks to be constructed in the first year of the project implementation, etc., the following additional surveys will be carried out.

- Measurement of groundwater level and water quality of the existing shallow tubewells: More than 40 points
- Measurement of groundwater level and water quality of the existing deep tubewells: More than 20 points
- Pump-up test of the existing deep tubewells: 20 tubewells
- Continuous observation of groundwater level of the deep tubewells: One point in each block
- Grading analysis of soil samples taken from the test tubewells: Southern area
- Electric sounding: 20 points for each of 5 development blocks (total 100 points)

5) Survey on the equipment and materials for deep tubewells supplied under KR-2

In the basic design study - phase I , no detailed check on the condition of 7 drilling rigs (including mud pumps) and their related equipment, construction equipment, transportation equipment, etc. was made due to absence of person in charge of equipment maintenance. In the basic design study - phase II , therefore, detailed check of these equipment will be made, and necessity and method of maintenance will be clarified. At the same time, necessary spare parts will be listed up. In addition, possibility of reinforcement of the Johnson screens at the site, possibility of extension of pump shafts and lifting pipes of turbine pumps for the production tubewells, etc. will be fully studied.

6) Determination of locations of 15 development blocks

The following site survey and data collection will be made for examining feasibility of the 15 development blocks except the priority development blocks (8 blocks), of which locations have been fixed, among the 23 development blocks selected in the basic design study - phase I .

- Topography and geomorphology
- Present land use and land ownership
- Intention of the local people
- Enthusiasm of the local farmers for irrigated farming
- Condition of the existing roads and access

In performing these surveys, the results of the basic design study-phase I , etc. will be fully utilized. The complied survey results will be combined with the results of the hydrogeological survey to be carried out in parallel with these surveys and, based on them, a synthetic examination will be made. If there is any block whose feasibility is not justifiable, further surveys of the above kinds will be carried out after full discussions with HMGN officials concerned and then the locations of the 15 development blocks will be finally determined.

7) Topographic survey and mapping of the 2 priority development blocks

As mentioned in Chapter 4, the development blocks to be constructed in the first year of the project implementation are the 3 development blocks (D-7, M-4, S-7), whose topographic maps have been prepared in the basic design study-phase I , and other 2 development blocks of S-1 and D-15. In the basic design study-phase II , determination of irrigation units by topographic survey and mapping will be carried out for the latter 2 development blocks whose topo-map have not been prepared yet.

Prior to the topographic survey, detailed reconnaissance of the 2 development blocks will be made based on the results of the basic design study-phase I . Then, 5 irrigation units in each development block (10 units in total) will be selected and their survey areas will be determined. In doing the above, due consideration will be given to the possible pump-up discharge, access condition, etc. of each irrigation unit.

The topographic survey for the determined irrigation units will be made by the 100m mesh method, same to that adopted in the basic design study-phase I . Based on the above survey, topo-maps of 1/1,000 scale and 25 cm contour line interval will be prepared. The land ownership, land use, etc. will be shown in these maps.

8) Establishment of long-term groundwater observation system for production tubewells

In order to utilize the production tubewells to be constructed under this Project and the existing deep and shallow tubewells for longer period without drying them, pumping sands, damaging pumps, subsidence of ground, etc., it is essential to take timely the measures for the production wells, such as control of pump discharge, temporary suspension of pumping, etc. according as the results of regular observation on lowering of groundwater table in the observation wells to be caused by continuous pumping of those production wells.

From the above-mentioned point of view, long-term groundwater observation wells shall be provided, aside from production wells, at necessary places in the project area to measure the groundwater table regularly. It is desirable that the observation wells are located in the TIATSP's project lands including its farms and other government own lands, and that the numbers of the wells are 9-10 consisting of 3-4 per each of three districts, but acceptable to 4-5 in case that the land acquisition is hardly possible for constructing many observation wells.

Therefore, an establishment plan of the long-term groundwater observation system including number and location of wells, organization and staffing, operation and maintenance system, etc. will be worked out through a series of discussions with TIATSP's staff and other officials concerned of HMGN.

### 6. 3. 4 Home analysis work

Within 15 days, after completion of the field survey, each expert will compile the results of the field survey and will prepare a brief study report. This report will be utilized for subsequent home analysis work and preparation of the basic design study-phase II report after discussions and examinations with GOJ officials concerned.

The home analysis work will be performed for about 2.5 months after completion of the field survey and the results of the analysis will be complied in a draft final report. In preparing the said report, full discussions and examinations will be made with JICA and GOJ officials concerned.

Explanation of the draft final report to HMGN officials concerned will be made in the end of May, 1988 and the final report will be prepared by the middle of June, 1988, incorporating comments to be made by HMGN side (above dates are tentative).

General features of the home analysis work to be performed before the preparation of the basic design study-phase II report are described below.

1) Preparation of test tubewell drilling report

Process of drilling and finishing of the 5 test tubewells, drilling logs, electrical logs, casing programs, results of pump-up tests, problems of the drilling and finishing, etc. will be compiled in a report including recommendations on drilling and finishing of the production tubewells, casing programs, etc.

2) Review of groundwater potential iso-map and groundwater balance

Based on the results of the hydrogeological survey, the electric sounding and the pump-up discharge of the test wells, review of the groundwater potential iso-map will be made and precision of the estimated possible pump-up discharge in each development block will be heightened. At the same time, water balance calculation of the groundwater in the project area (including the shallow tubewell development areas) will be made and feasibility of the development of the 115 production tubewells will be made clear from the view point of hydrogeology.

3) Determination of locations of production tubewells in the 5 development blocks and their basic design

By analizing the results of the test tubewells to be drilled one for each development block and the results of the electric sounding of 20 points including the test tubewell, the hydrogeological structure of each development block will be made clear and then prospective locations for 5 production tubewells will be determined. At the same time, based on the actual results of drilling, finishing and pumping up the test tubewells, basic design of method of drilling and finishing, depth of drilling, casing program, location of pump installation, possible pump-up discharge, etc. of the production tubewells will be determined.

4) Basic design of irrigation facilities in the 5 development blocks

Since the basic design of 3 development blocks (D-7, M-4, S-7) out of the 5 development blocks to be constructed in the first year of the project implementation has been completed in the basic design study-phase I, basic design of the remaining 2 development blocks (S-1, D-15) will be carried out in the basic design study - phase II.

Layout of the irrigation facilities (pump houses, operator huts, main canals and related structures) which will be shown on the 1/1,000 scale maps to be prepared during the field survey will be carried out in due consideration of possible irrigation area, topography, locations of roads, streams and natural drains, villages, orchards, etc., present land use, and arrangement of the tubewells. Based on this layout, canal profiles will be prepared. In principle, the size of the canals, size and shape of the structures in the basic design will be the same as the standard ones applied in the basic design of the basic design study-phase I. However, when topographic conditions and/or possible pump-up discharge deviates considerably from the standard, different size and shape will be used.

Canals and structures will be of the brick construction as planned in the basic design study - phase I. Based on these basic design drawings, work quantities of the 5 development blocks will be calculated.

5) Determination of construction plan and project implementation schedule

Possible work quantities to be executed annually will be calculated based on the actual work performance and efficiency of the drilling rigs, the time necessary for the procurement of the equipment and materials, the work efficiency of the KR-2 construction equipment, possibility of employment of labour, etc., methods of construction and possible construction period (dry season) clarified in the basic design studies-phase I and phase II. Then, the number of the deep tubewells and the work quantities of the irrigation facilities to be possibly constructed in a year scheduled in the basic design study-phase I will be re-checked and a practical construction plan will be formulated.

On the other hand, an implementation schedule of the Project which includes a time for signing E/N, a period of detailed design, a period necessary for procurement of the additional equipment and materials, a period from tender up to determination of a contractor, a period for land acquisition of the construction sites, etc. will be worked out. The project implementation schedule determined in the basic design study-phase I will therefore be reviewed.

6) Estimate of the project cost

Based on the unit prices set by the work data (prices of equipment and materials, unit prices of works, etc.) collected in the basic design studies-phase I and II and the work quantities calculated in the basic design, the construction cost of the 5 development blocks will be calculated. Then, based on the cost, the construction cost of the 23 development blocks will be calculated. Further to this cost, cost of the equipment and materials to be granted additionally, consultant's detailed design cost and construction supervision cost, operation and maintenance cost, etc. will be added to estimate the total project cost. The project cost will be separated into the cost for the 5 development blocks to be constructed in the first year and the cost for the 18 development blocks to be constructed in and after the second year. The construction cost of branch canals and the land compensation cost for the construction sites to be borne by HMGN will be estimated separately.

7) Establishment of operation and maintenance plan

Based on the results of the basic design studies-phase I and II, problems on operation and maintenance system and organization, personnel arrangement, training of operation and maintenance personnel, equipment and materials for operation and maintenance, as well as organization for operation and maintenance of the farmers' side such as water users' groups, etc. under the existing groundwater irrigation projects will be examined and seized. Then, an operation system, an operation plan, a personnel arrangement plan, a training and extension plan, an operation and maintenance system for equipment and materials of the facilities, etc. after the implementation of the Project will be determined and at the same time an operation and maintenance cost will be calculated roughly.

8) Project evaluation and conclusion/recommendation

Execution of this Project is expected to largely contribute to the drastic improvement of agricultural production in the area and the groundwater development in the Terai plain. Therefore, the evaluation of the Project will be made not only by whether the facilities constructed by both the government and the farmers can be operated and maintained in future but also by the repercussion effect of this groundwater project to the whole Terai plain.

Judging synthetically the above evaluation and the determined plan, a conclusion on the Terai Groundwater Development Project will be made and a recommendation on the items to be considered in executing the Project will be presented.

## 6.4 Survey Schedule

The work schedule of implementing the basic design study - phase II is as shown in Fig. 6.1. The work is largely divided into (1) procurement and transportation of the additional equipment and materials for drilling and finishing of 5 test tubewells, (2) home preparatory work, (3) field survey and (4) home analysis work.

The procurement and transportation of the additional equipment and materials is to send by sea cargo long and/or heavy items, which cannot be sent by air cargo, in the additional equipment and materials mentioned in Section 6.6. It will require about 3 months for transportation of Tokyo - Calcutta (sea cargo), Calcutta - Birganj - Janakpur (truck cargo), custom clearance, etc. Therefore, these equipment and materials have to be shipped by the beginning of September, 1987 in order to commence the field work on 1st of December, 1987.

The home preparatory work to be made before departure of the survey team to Nepal is discussons with JICA, Ministry of Foreign Affairs, Ministry of Agriculture, Forestry and Fishery, preparation of an inception report, etc. and it will take 3 weeks.

The field survey is to supplement and complete the field survey in the basic design study-phase I, and its major work items are as given below.

(1) Drilling and pumping-up test of 5 test wells in the 5 development blocks, one for each block, to be constructed in the first year of the project implementation (including check, maintenance and repair of 3 drilling rigs to be used for the work)

(2) Electric sounding of total 100 points, 20 points in each of the above 5 development blocks, and a hydrogeological survey including pump-up test for 20 existing deep tubewells in and around the 23 development blocks to be implemented

(3) Survey on deep tubewell equipment and materials supplied under the KR-2 grant with emphasis on present conditions of drilling rigs, construction equipment, transportation equipment, vehicles, etc.

(4) Topographic survey and preparation of maps at a scale of 1/1,000 for the 2 development blocks out of the above 5 blocks (these works for the other 3 blocks have been completed in the basic design study-phase I )

The field survey will be commenced on 1st of December, 1987 by when the paddy field in the project area will become dry and hence access to the site will be secured. It will be completed after 3 months or by 28th of February next year. Schedule of respective works is as follows.

(1) Drilling of test tubewells (including check, maintenance and repair of drilling rigs):
1 December - 28 February (3 months)

(2) Hydrogeological survey: 1 December - 28 February (3 months)

(3) Survey on KR-2 deep tubewell equipment and materials: 1 January - 28 February (2 months)

(4) Topographic survey and preparation of maps of the 2 development blocks:
15 January - 28 February (1.5 months)

The major work items of the home analysis work are as shown below.

(1) Review of the groundwater potential iso-map and water balance of the groundwater in the project area

(2) Decision of the possible pump-up discharge in the 5 development blocks to be constructed in the first year of the project implementation and determination of the location and detailed specifications of the 25 production wells including 5 test wells

(3) Basic design of irrigation facilities in the 2 development blocks

(4) Determination of equipment and materials plan necessary for the construction of the 115 deep tubewells including 18 test tubewells and irrigation facilities in the 115 irrigation units

(5) Calculation of work quantities for the 5 development blocks to be constructed in the first year of the project implementation and the 18 development blocks to be constructed in and after the second year

(6) Calculation of construction cost of the above 5 development blocks and the 18 development blocks and calculation of total project cost

(7) Preparation of a brief study report and the basic design study-phase II report

The above home analysis work will require 2.5 months from 1st of March, 1988 until 15th of May (tentative) in the same year.

Explanation of a draft of the basic design study-phase II report to HMGN will be made within 2 weeks from 16th of May, 1988 (tentative) and a final version, in which comments of HMGN will be incorporated, will be completed by 15th of June, 1988.

## 6.5 Assignment Schedule

An assignment schedule of experts, synchronized with the work schedule for the execution of the basic design study-phase II is shown in Fig. 6.2.

1) Home preparatory work

The home preparatory work will be executed by a survey team leader (about 1 month), an expert in charge of hydrogeology A (about 1 month), and an expert in charge of facilities design A (about 0.5 month).

2) Field survey

Since 3 drilling rigs will be used for drilling of the 5 test tubewells, one drilling expert for each drilling rig, or 3 drilling experts, namely A, B and C, will be allocated and one mechanic will be dispatched for pre-work check, maintenance and repair of the drilling rigs. The mechanic will carry out a check and maintenance of the drilling rigs during the drilling work and further he will execute a detailed survey of the KR-2 equipment and materials.

The expert in charge of hydrogeology A will perform electric sounding of the 5 development blocks, pumping-out test of 10 existing deep tubewells, etc. An expert in charge of hydrogeology B will carry out the pumping-out test of 10 existing deep tubewells, etc.

Experts A & B in charge of facilities design will confirm location of the 15 development blocks out of the 23 development blocks (location of the 8 priority development blocks has been determined already) and will execute a topographic survey and prepare the 1/1,000 scale maps of the 2 development blocks.

The survey team leader will control the whole works during the field survey period and will perform necessary discussions and coordination between HMGN's and GOJ's authorities concerned.

3) Home analysis work

The expert in charge of hydrogeology A will perform an analysis of the results of the field survey, review of the groundwater potential iso-map and estimate of possible pump-up discharge in the project area, water balance of the groundwater, determination of possible pump-up discharge of the 5 development blocks, decision of locations and detailed specifications of the 25 production tubewells, and determination of construction equipment and materials for the 115 production tubewells including 18 test tubewells, and then will prepare a report of this field.

The expert A in charge of drilling test tubewells will prepare a drilling report of the 5 test tubewells and compile data necessary for determining equipment and materials required for the construction of the 115 deep tubewells including 18 test tubewells.

The mechanic will prepare a list of spare parts necessary for the maintenance and repair of drilling rigs, construction equipment, transportation equipment, vehicles, etc. and determine specifications of the additional equipment and materials.

The experts A & B in charge of facilities design will execute the layouting and basic design of irrigation facilities in the 2 development blocks and will calculate work quantities of the 5 development blocks and the 18 development blocks.

The expert in charge of cost estimate will finalize the unit prices of the equipment and materials, determine work efficiencies of equipment and labours and then calculate unit prices of respective work items. Further based on the above work quantities, he will calculate construction cost of the 5 development blocks and the 18 development blocks as well as the project cost. Besides, he will execute an estimate of operation and maintenance cost of the facilities and also evaluation of the Project.

The survey team leader will control the whole home analysis work and also will prepare the brief survey report and the basic design study-phase II report in cooperation with the experts in charge of hydrogeology and facilities design.

For the explanation of the basic design study-phase II report (draft) to HMGN, the survey team leader and the expert in charge of hydrogeology A will go to Nepal.

## 6.6 Equipment and Material Schedule

In the basic design study-phase II, drilling of the 5 test tubewells, a pumping-out test of the existing 20 tubewells, and topographic survey and mapping of the 2 development blocks will be executed. It is necessary to make doubly sure on the equipment and materials necessary for the drilling of the test tubewells by procuring and sending lacking ones, which have been clarified through the drilling of the 4 test borings in the basic design study-phase I, from Japan. The following shows the equipment and materials to be newly procured and sent to the site by GOJ and those to be provided by HMGN.

| Name (Specification) | Present Quantity | Required Quantity for 5 Test Tubewells | Quantity to be Additionally Procured and Transported by GOJ | Quantity to be Provided by HMGN |
|---|---|---|---|---|
| Equipment/Materials for Drilling Test Tubewells | | | | |
| Drilling rig & mud pump (Tone TRD-500) | 4 | 0 | 0 | 0 |
| Drilling rig & mud pump (Yoshida YRD-501R) | 3 | 3 | 0 | 3 |
| Tri-cone bit (17½") | 0 | 5(H type) | 5(H type)※ | 0 |
| Tri-cone bit (14¾") | 0 | 5(H type) | 5(H type)※ | 0 |
| Hole opener (14¾" → 17½") | 0 | 5 | 5※ | 0 |
| Rod(L=6m) | 1,368m | 600m | 0 | 600m |
| Conductor pipe (Ø20",L=3m) | 84m | 30m | 0 | 30m |
| Casing pipe (Ø14",L=6m) | 5,592m | 210m | 0 | 210m |
| Casing pipe (Ø8",L=6m) | 13,392m | 342m | 0 | 342m |
| Johnson screen (8",L=3.25m) | 5,076m | 21m | 0 | 21m |
| Reinforced Johnson screen (Ø8",L=3.25m) | 0 | 107.25m | 107.25m※ | 0 |
| Ring base wire-wrapped screen (Ø8",L=5.5m) | 0 | 88m | 88m※ | 0 |
| Centerlizer | 0 | 34 | 34※ | 0 |
| Air compressor (7kg/cm$^2$ or 12.5kg/cm$^2$) | 7 | 3 | 0 | 3 |
| 4"Lifting pipe (L=5.5m) | 170.5m | 363m | 192.5m※ | 170.5m |
| 1"Air pipe (L=5.5m) | 55m | 363m | 308m※ | 55m |

| Name (Specification) | Present Quantity | Required Quantity for 5 Test Tubewells | Quantity to be Additionally Procured and Transported by GOJ | Quantity to be Provided by HMGN |
|---|---|---|---|---|
| Submersible motor pump (5",45ℓ/sec,75mHead) | 2units | 2units | 0 | 2units |
| 〃 (6",40ℓ/sec,50mHead) | 0 | 1unit | 1unit※ | 0 |
| 〃 (6",45ℓ/sec,35mHead) | 2units | 1unit | 0 | 1unit |
| Engine generator | 10units | 6units | 0 | 6units |
| Water jet nozzle | 0 | 3nos | 3nos | 0 |
| Bailer | 0 | 3nos | 3nos※ | 0 |
| Triangular notch tank ($2.5m^3$) | 1no | 5nos | 4nos (to be processed at site) | 1no |
| Portable water tank, ($3m^3$, water proof cloth) | 0 | 6nos | 6nos※ | 0 |
| Portable diesel tank, (2m3, steel, plate) | 4nos | 3nos | 0 | 3nos |
| Gas welder (100kg, including assembly) | 1set | 4sets | 3sets | 1set |
| Current meter | 0 | 2sets | 2sets | 0 |
| Mud balance· Viscosimeter | 2units | 3units | 1unit | 2units |
| DC engine welder (3.6kVA) (Existing ones are remarkably deteriorated) | 7units | 3units | 1unit | 2units |

| Name (Specification) | Present Quantity | Required Quantity for 5 Test Tubewells | Quantity to be Additionally Procured and Transported by GOJ | Quantity to be Provided by HMGN |
|---|---|---|---|---|
| Vehicles | | | | |
| 4t- cargo trunk with 3t. crane | 5units | 5units | 0 | 5units |
| 4,000ℓ fuel tank lorry | 2units | 1unit | 0 | 1unit |
| 4,000ℓ water tank lorry | 5units | 2units | 0 | 2units |
| 3.5t-dump trunk | 10units | 2units | 0 | 2units |
| Wagon type jeep | 3units | 3units (survey) | 0 | 3units |
| Jeep | 0 | 6units (common use with survey) | 6units (rental at site) (same as the left) | 0 |
| Spare Parts for Drilling Equipment | | | | |
| Water swivel(main body, for YRD) | 0 | 3nos | 3nos※ | 0 |
| Suction hose and sheet valve | 0 | 3nos | 3nos※ | 0 |
| Hoisting wire (Sub) | 0 | 1set | 1set※ | 0 |
| Stabilizer (For 14¾" Diameter) | 4nos | 6nos | 2nos※ | 4nos |
| Cross saver sub (YRD501R) | 0 | 3nos | 3nos※ | 0 |
| Kelly drive bushing (YRD501R) | 0 | 3nos | 3nos | 0 |
| Meters for control box (YRD501R) | 0 | 1set | 1set※ | 0 |
| Plate lock for water swivel | 0 | 3nos | 3nos | 0 |
| Brake band for sub-hoisting | 0 | 3nos | 3nos | 0 |
| Oil filter for rig engine | 0 | 6nos | 6nos | 0 |
| Clatch plate | 0 | 6sheets | 6sheets | 0 |

| Name (Specification) | Present Quantity | Required Quantity for 5 Test Tubewells | Quantity to be Additionally Procured and Transported by GOJ | Quantity to be Provided by HMGN |
|---|---|---|---|---|
| Mud Pump (NAS-7) Spare Parts | | | | |
| Bearing roller (SL01-485) | 0 | 1no | 1no | 0 |
| 〃 (22315) | 0 | 1no | 1no | 0 |
| 〃 (22320) | 0 | 1no | 1no | 0 |
| Liner for crank case (D2750-205) | 0 | 1no | 1no | 0 |
| Piston liner(dia7½") | 0 | 6nos | 6nos ※ | 0 |
| Piston rubber(dia7½") | 0 | 6nos | 6nos | 0 |
| V-packing | 0 | 3sets | 3sets | 0 |
| Piston rod(with nut) | 6nos | 6nos | 0 | 6nos |
| Sheet conical valve | 0 | 6sets | 6sets ※ | 0 |
| Conical valve assembly | 0 | 6sets | 6sets ※ | 0 |
| Piston spring | 0 | 6sets | 6sets | 0 |
| Sheet rubber | 0 | 6sets | 6sets | 0 |
| Guide valve | 0 | 12sets | 6sets | 0 |
| O-ring (P-160) | 0 | 12nos | 12nos | 0 |
| 〃 (P-165) | 10nos | 6nos | 0 | 6nos |
| 〃 (P-235) | 24nos | 6nos | 0 | 6nos |
| Materials/Equipment for Investigation and Surrey | | | | |
| 1) For electric sounding (for 100 points) | | | | |
| Electric sounding instrument | 0 | 1unit | 1unit | 0 |

| Name (Specification) | Present Quantity | Required Quantity for 5 Test Tubewells | Quantity to be Additionally Procured and Transported by GOJ | Quantity to be Provided by HMGN |
|---|---|---|---|---|
| Electric logging instrument (Geologer 300) | 4units | 1unit | 0 | 1unit |
| Recording unit for the above | 0 | 1no | 1no | 0 |
| Recording paper for the above | 0 | 12rolls | 12rolls | 0 |
| Groundwater table meter | 138units | 6units | 0 | 6units |
| Current meter | 0 | 2units | 2units | 0 |
| Tool, tester | 0 | 2sets | 2sets | 0 |
| Grain size analysis instrument | 0 | 1set | 1set | 0 |
| 2) For survey (for 2 development blocks) | | | | |
| Theodolite (with tripod) | 0 | 2units | 2units | 0 |
| Level (with tripod) | 0 | 4units | 4units | 0 |
| Esron tape (100m) | 0 | 4nos | 4nos | 0 |
| Esron tape (50m) | 0 | 6nos | 6nos | 0 |
| Staff (5m) | 0 | 6nos | 6nos | 0 |
| Pole (3m) | 0 | 12nos | 12nos | 0 |
| Transceiver | 0 | 4units | 4units | 0 |

Consumables for Drilling (all to be procured by GOJ)

- Cement (10 bags/well ×5 wells) (to be procured in Nepal) — 50 bags
- Bentonite (4 tons/well ×5 wells) (to be procured in Nepal) — 20tons
- Gravel (8 $m^3$/well ×4 wells + 16 $m^3$×1 well) (to be procured in Nepal) — 48tons
- CMC (to be procured in Nepal) — 0.8ton
- Barite (to be procured in Nepal) — 1.3tons
- Mud cleaner (to be procured in Japan) — 0.7ton

"Required quantity for 5 test tubewells" in the above table includes that for pump-up test for the existing 20 tubewells.

※ : Items to be procured by the end of August, 1987 in Japan and to be shipped in the beginning of September, 1987

1) : Reinforcing components for the existing Johnson screen of 107.25m are to be procured in Japan and shipped to Nepal.

In addition to the above equipment and materials, the following fuel and lubricating oil will be borne by GOJ.

Fuel ..... 106,400 ℓ

- Drilling and pumping-out test ..... 49,500 ℓ

  Type I well 32 days/well×2 wells = 64 days

  Type II well 31 days/well×1 well = 31 days

  Type III well 35 days/well×2 wells = 70 days

  Total 165 days

  165 days×300 ℓ/day= 49,500 ℓ

- Pumping-out test of existing 20 deep tubewells ..... 6,000 ℓ
- Vehicles ..... 50,900 ℓ

  Diesel 295 unit.day × 100 ℓ/day = 29,500 ℓ

  Petrol 535 unit.day × 40 ℓ/day = 21,400 ℓ

Lubricating Oil ..... 10% of fuel cost

## 6.7 Facilities to be Provided by HMGN

In order to execute and complete the field survey work of the basic design study-phase II smoothly and successfully, HMGN shall accord the following facilities to a survey team of GOJ.

1) To furnish latest data

- Recent results of both deep and shallow tubewell irrigation (irrigation area, cropping pattern, production, operation hour of pumps, etc.)
- All the data on tubewell drillings and pumping-out tests executed by JADP/TIATSP in the past
- Latest market prices of construction materials

2) To undertake procedure for and to obtain necessary permissions for entering each development block, drilling test tubewells, executing pumping-out tests at the existing tubewells, carrying out topographic survey, etc. for the field survey period

3) To provide a survey team of GOJ with the following counterparts throughout the field survey period.

| | |
|---|---|
| - Irrigation Engineer | 1 person |
| - Agronomist | 1 person |
| - Hydrogeologist | 1 person |
| - Deep Tubewell Drilling Expert | 1 person |
| - Deep Tubewell Drilling Operator | 6 persons |
| - Deep Tubewell Drilling Assistant Operator | 6 persons |
| - Surveyor | 2 persons |

4) To provide free of charge a survey team of GOJ with the following major equipment and materials necessary for the drilling of 5 test tubewells, the pumping-out test of 20 existing tubewells, the hydrogeological survey and the electric sounding.

| | |
|---|---|
| - Drilling rig (YRD-501R, TRD-500) | more than 3 units |
| - Mud pump | more than 3 units |
| - Drilling rod | 600 m |
| - Drilling tool | 1 set |
| - Casing pipes | |
| 20"conductor pipe (L=3m) | 60m |
| 14"casing pipe (L=6m) | 210m |
| 8"casing pipe (L=6m) | 342m |
| - Johnson screen (8", L=3.25m) | 128.25m |
| - Air compressor | more than 3 units |

- Lifting pipe and air pipe for cleaning
  4" 170.5m
  1" 55 m
- Submersible motor pump for pumping-out test
  outer dia.5", 45 ℓ/sec, 75m head 2 units
  outer dia.6", 45 ℓ/sec, 35m head 1 unit
- Diesel engine generator 5 units
- Triangular notch tank (2.5m$^3$) 1 no.
- Portable diesel tank, (2m$^3$, steel plate) 3 nos.
- Gas welder 1 set
- Mud balance and viscosimeter 2 units
- DC engine welder 2 units
- Vehicles
  4t-cargo truck with 3t crane (with a driver) 5 units
  fuel tank lorry (4,000 ℓ, with a driver) 1 unit
  water tank lorry ( 4,000 ℓ, with a driver) 2 units
  3.5t dump truck (with a driver) 2 units
  wagon type jeep (with a driver) 3 units
- Spare parts of mud pump, etc. 1 lot (Ref. Section 6.6)
- Electric logging instrument, Geologger 300 1 unit
- Groundwater table meter 6 units

5) To furnish free-of-charge necessary spare parts and cosumables for the equipment and materials, which are to be provided by HMGN, to a survey team of GOJ with top priority.

6) To grant an import custom exemption for the whole equipment and materials to be imported from Japan for the execution of the basic design study-phase II

7) To furnish one office and three lodging houses to a survey team of GOJ, together with proper accommodation throughout the field survey period.

# 7. IMPLEMENTATION PLAN

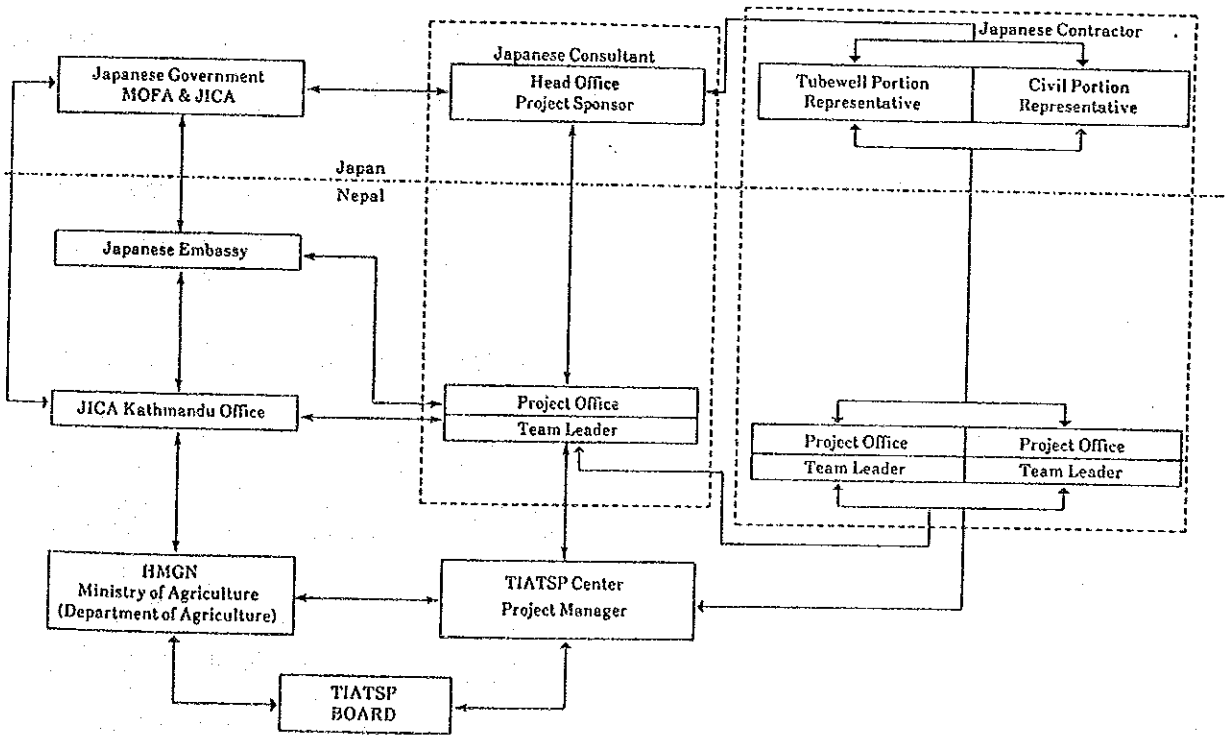
# 7. IMPLEMENTATION PLAN

## 7.1 Implementation Organization

The Terai Groundwater Development Project is incorporated in the groundwater development program to be implemented by TIATSP under the administrative control by the Department of Agriculture in the Ministry of Agriculture. Therefore, the Ministry of Agriculture is a governmental office responsible for the implementation of the Project, and TIATSP is an executive organization of the Project. TIATSP is controlled by the TIATSP Board because the system is already applied. In such organization, the Minister of Agricultutre has the sole responsibility for the implementation of the Project, though the actual responsible person is the Secretary of the Ministry of Agriculture who is fully assisted by two Joint Secretaries and one Director General of the Department of Agriculture.

In accordance with a grant aid system of the Japanese Government, the construction works for the Project will be carried out by a Japanese contractor, who will be awarded through tender procedure, and the construction supervision will be rendered by a Japanese consulting firm engaged in both of the basic design study and the detailed design.

The organization chart for the implementation of the Project is presented below.



However, the present TIATSP organization (refer to Fig. 3.11) is incomplete for the execution, operation and maintenance of the Project, therefore, the organization shall be reinforced by recruitment of capable staff as follws.

| Division | Number of Increment | | | | | |
|---|---|---|---|---|---|---|
| | Clerk | Accountant | Assistant Engineer | Overseer | Technician | Total |
| Construction Division | 0 | 0 | 2 | 2 | 0 | 4 |
| Drilling Division | 1 | 0 | 3 | 3 | 0 | 7 |
| Irrigation Division | 0 | 0 | 1 | 4 | 0 | 5 |
| Workshop Division | 3 | 1 | 1 | 1 | 7 | 12 |
| Agriculture Extension & Training Division | 0 | 0 | 3 | 0 | 3 | 6 |
| O & M Division (newly established) | 4 | 1 | 3 | 6 | 0 | 14 |
| Total | 7 | 2 | 13 | 16 | 10 | 48 |

## 7.2 Scope of Implementation

The major components of the Project to be provided by the Japanese Government, which are detailed in Chapter 5, are recapitulated as follows:

(1) to construct one hundred and fifteen (115) deep tubewells in twenty-three (23) development blocks selected (5 deep tubewells per development block);

(2) to construct the irrigation facilities such as pump house, operator hut, main canal and the related structures for one hundred and fifteen (115) irrigation blocks to be provided in twenty-three (23) development blocks (5 irrigation blocks per development block); and

(3) to provide additional equipment and materials against KR-2 ones, for the purpose of the construction mentioned above.

On the other hand, the following services shall be provided by HMGN:

(1) provision of data, reports, maps and drawings necessary for the detailed design;

(2) Steps and procedures necessary for custom clearance, tax exemption and for transportation between India and Nepal for the additional materials and equipment to KR-2 ones, construction equipment, vehicles, tools, spare parts and consumables;

(3) Issuing of visa, pass and necessary certificates for the Japanese persons concerned;

(4) Tax exemption for the Japanese persons engaged in the Project;

(5) Provision of KR - 2 materials and equipment, including construction equipment, vehicles, spare parts and consumables to Japanese contractors and consultant at free of charge;

(6) Contracts with Japanese consultant and contractors and payments to them;

(7) Land aquisition and compensation required for the construction of temporary access roads and irrigation facilities;

(8) Construction of branch canals and their related structures; and

(9) Operation and maintenance for the completed facilities.

The Consultant will assist the Ministry of Agriculture and TIATSP in executing the following detailed design and construction supervision:

(1) Confirmation of the basic design study through the site investigation including drilling of test wells necessary for the detailed design;

(2) Detailed design, estimate of the project cost and preparation of implementation plan for the Project;

(3) Preparation of tender documents, examination of pre-qualification, evaluation of tender and negotiation for contract;

(4) Construction supervision for deep tubewells and irrigation facilities, including an attendance for pumping tests for production wells;

(5) Approval of construction and workshop drawings, inspection for materials and equipment, examination for fabrication, adjustment and test of equipment;

(6) Discussion with Ministry of Agriculture, TIATSP Center and Contractor for smooth execution of the Project;

(7) Preparation of various reports during the implementation period, issuing of the payment certificates and final inspection on completion of facilities;

(8) Issuing of completion certificate, attendance on handing-over job of facilities, materials and equipments, and taking procedure for final completion;

(9) Preparation of O & M manual for pumps and irrigation facilities; and

(10) Technical guidance to site engineers and staffs of Ministry of Agriculture and TIATSP through the on-the-job training;

On the other hand, the followings works will be executed by the Contractor:

(1) Necessary procedures for purchase, export, packing and transport of additional materials and equipment (including construction equipment, transport equipment and vehicles), spare parts, consumables , foods and stationaries necessary for the execution of the Project;

(2) Repair and maintnance of KR - 2 deep tubewell materials and equipment;

(3) Construction of deep tubewells (including test wells) and pumping tests;

(4) Check and installation of pumps and engines (including necessary repairs), and test run of them under the Consultant's attendance;

(5) Repair and maintenance of KR-2 construction equipment, transportation equipment and vehicles;

(6) Construction of pump houses, operator huts, main canals and their related structures;

(7) Provision of insurance for construction & installation works;

(8) Procurement of construction materials for deep tubewells and civil works;

(9) Technical guidance to site engineers and staffs of Ministry of Agriculture and TIATSP through the on-the-job training; and

(10) One year-maintenance guarantee for irrigation facilities after handing over.

## 7.3 Implementation Schedule

The Implementation Schedule of the Project, including the Basic Design Study Phase II , is shown in Fig. 7.1.

The Project is devided into four phases, taking into consideration work size, work capacity, work capability of KR - 2 equipment, possible construction period, 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 twenty-five (25) production wells including 5 diverted from test wells and irrigation facilities for twenty-five (25) irrigation units in five blocks, purchase of additional materials & equipments, and drilling of test wells (one for each block, six in total) for six blocks of the second phase
- Second Phase : Construction of thirty (30) production wells including 6 diverted from test wells and irrigation facilities for thirty (30) irrigation units in six blocks, and drilling of test wells (one for each block, six in total) for six blocks of the third phase
- Third Phase : Construction of thirty (30) production wells including 6 diverted from test wells and irrigation facilities for thirty (30) irrigation units in six blocks, and drilling of test wells (one for each block, six in total) for six blocks of the fourth phase
- Fourth Phase : Construction of thirty (30) production wells including 6 diverted from test wells and irrigation facilities for thirty (30) irrigation units for six blocks

Immediately after the conclusion of the Exchange Note for the first phase in the end of July, 1988, the consultant contract will be made and detailed design (2 months including preparation of tender documents for the first phase), pre-qualification, tendering, evaluation of tender documents and contract will require five (5) months and the contractor will spend one (1) month for the preparatory works, therefore, the construction of the first phase will be started in February, 1989. The construction period of the first phase will be five months and the repair and maintenance of the equipment provided by TIATSP for construction will be completed by the contractor 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 tenderes to the contract for the second phase 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 starts from December, 1989. and ends in June, 1990 with 7 month-period, and the repair and maintenance of the equipment provided by TIATSP for construction will be completed by the end of July, 1990. The third phase and the fourth phase will start behind one and two years, respectively after completion of the second phase.

## 7.4 Procurement Plan for Materials and Equipment

### 7.4.1 Procurement of materials and equipment

1) Materials and equipment to be supplied

Of the materials and equipment listed in the previous chapter 4.2.6, the equipment and materials which can not be procured by the contractor of the first phase because of manufacturing and shipping period will be delivered to TIATSP center by the Japanese supplier decided through tendering, prior to the onset of the construction for the first phase (see Tables 4.5 and 4.6). The other equipment and materials, including spare parts and consumables, will be procured by the contractor of each phase immediately after the contract.

2) Construction materials

The contractor will be able to purchase cement, bentonite, barite, CMC and gravel which are available in Nepal. As for cement, Indian, Korean and Nepalese products are available in the market. Regarding bentonite, barite and CMC, Indian products are available. But, mud cleaner has to be brought into the site by the Japanese contractor.

The other construction materials such as bricks, concrete pipes, steel bars, steel plates timbers, glasses, etc. will be able to be purchased locally as well as fuel and lubricant oil.

### 7.4.2 Transportation

The import and export to and from Nepal are executed through India, therefore, the equipment and materials to be brought in for the Project are imported through India, excluding the goods to be carried by air.

The materials and equipment shipped from Japan are unloaded at Calcutta and transported via Laxaul in Indian border to Birganj by trucks and trailers. In this case, the custom clearance is required in Calcutta and Birganj. The commodities to be imported to Nepale via India, are not difficult for the custom clearance at Calcutta, provided that the documents are complete. However, the custom clearance at Birganj requires one (1) to two (2) weeks.

The road among Calcutta, Birganj and Janakpur is paved with asphalt, and thereby makes transport of the equipment and materials easy. The precision instrumement, spare parts of equipment, comsumables, etc. shall be packed in a sealed wooden case and others are packed in an open worked wooden case, except the construction equipment and vehicles to be transported by trailer and self-propelling, respectively.

It will take forty days for sea transport between Japan and Calcutta and take another fifteen days for offshore waiting. The custom clearance at Calucutta and Birganj and the inland transport between Calcutta and Janakpur (TIATSP Center) will be conducted by Nepalese or Indian agents and will take about five days for inland transport and fifteen days for custom clearance at Birganj. Therefore, it is conservatively estimated to be three months for transport of the required equipment and materials from Japan to the TIATSP Center.

## 7.5 Operation and Maintenance Plan

### 7.5.1 O & M for facilities

It is impossible for the farmers to operate and maintain pumps and irrigation facilities successfully. The O & M works of the completed pumps and irrigation facilities shall therefore be carried out by TIATSP, collecting water charge from the beneficial farmers. However, for the first operation year, the whole O & M cost shall be subsidized by HMGN. For the second and third years, a half of the O & M cost shall be subsidized by HMGN. During the initial three years, TIATSP shall organize a Water Users' Group in each irrigation unit (the irrigable area by one pump) and collect the wohle water charge from the water users' groups in and after the fourth year in the operation and maintenance of the pumps and irrigation facilities.

The water charge consists of fuel & lubricant cost, operator's cost for pumps and maintenance cost for irrigation facilities. The repair cost of the pumps shall be subsidized by HMGN until the farmers will reserve the sufficient capital.

An agriculture extension & training division of TIATSP is responsible for establishing the water users' group, and an O & M division for collecting the water charge.

The water charge, excluding maintenance cost for irrigation facilities, by the deep tubewell types planned in Chapter 4.2.3 is roughly estimated as follows.

Water Charge for Standard Deep Tubewells

| Well Type | I | II | | III | IV |
|---|---|---|---|---|---|
| Discharge (ℓ/sec) | 40 | 25 – 30 | | 40 – 50 | 40 |
| Irrigable area(hr) | 40 | 25 – 30 | | 40 – 50 | 40 |
| Pump | Okamoto | Okamoto | Ebara | Ebara | Ebara |
| Fuel consumption (ℓ/hr) | 5 | 5 | 8 | 8 | 8 |
| (1) Fuel cost (Rs/hr) (Rs. 7.4/ℓ) | 37.0 | 37.0 | 59.2 | 59.2 | 59.2 |
| (2) Lubricant cost (Rs/hr) | 3.7 | 3.7 | 5.9 | 5.9 | 5.9 |
| (3) Operator cost (Rs/hr) (Rs.800/Month (250hr)) | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| Total (Rs/hr) | 43.9 | 43.9 | 68.3 | 68.3 | 68.3 |
| Water Charge(Rs/hr/ha) | 1.1 | 1.8 – 1.5 | 2.7 – 2.3 | 1.7 – 1.4 | 1.7 |

### 7. 5. 2 Construction of on-farm facilities

In the Project the Jananese Government will construct pump houses, operator huts, main canals and the related structures (including intake structures for branch canals) and HMGN will construct the on-farm facilities such as branch canals and the related structures.

The rotative irrigation with one week cycle will be employed, therefore, number of branch canals branching off from main canal will be 7 or 14 and the irrigable area by one branch canal will be 2.9ha to 4.3ha. (The irrigable area by one deep tubewell will be 25ha to 50ha.) It is essential to construct the on - farm facilities for the equitable distribution of the irrigation water.

It is also essential for the successful goal of the Project to organize the water users' groups and to construct the on - farm facilities within one year after completion of the main irrigation facilities. TIATSP's guidance and supervision are indispensable for successful construction of the on - farm facilities and establishment of the water users' groups.

### 7. 5. 3 Education and training for farmers

The organized water users' groups will be responsible for construction of branch canals, O &M of the facilities and water management. For the purpose of successful implementation of the above, it is essential to teach farmers the irrigation farming and the rotative irrigation method and to convince them of those merits and the necessity of the water users' group. Also it is necessary to train the farmers to let them master the technique and skill for the above. Therefore, TIATSP shall be responsible to such education and training of farmers.

The construction division is responsible for guidance & supervision on construction of branch canals, the extension and training division for guidance & training on irrigation farming and for organization of the water users' groups, the irrigation division for education & training for rotative irrigation and water management, and the O & M division for guidance & supervision for maintenance of branch canals. For the promotion of such activities, a systematic technical cooperation is required because the TIATSP's staff don't have sufficient technique and experience at present.

# 8. CONCLUSION AND RECOMMENDATION

## 8. CONCLUSION AND RECOMMENDATION

The Terai Groundwater Development Project has not only attractive direct effects but also indirect effects when implemented. The direct effects are: 1) expansion of irrigated farm land; 2) stable increase of agricultural product; 3) increase of farmers' income by raise of land productivity and unit yield of crops; and 4) improvement of farmers' living standard by 1), 2) and 3) in the project area. The indirect effects are: 1) improvement of social welfare of villagers in the project area; 2) establishment of the engineering and technique for deep tubewell irrigation development; and 3) establishment of an operation and maintenance model for other deep tubewell irrigation projects to be implemented in the Terai plain in the future.

The project can be successfully superintended and controlled by Ministry of Agriculture and smoothly operated and managed by TIATS organization reinforced for the implementation, since the both organizations are capable.

On the other hand, it is technically possible to construct 115 deep tubewells of which possible pump-up discharge will be 25ℓ/sec to 55ℓ/sec and the respective irrigation facilities designed for 115 irrigation areas of 23 development blocks, judging from available equipment and materials granted under a KR-2 aid for construction of deep tubewells, distribution of groundwater potential in the project area, etc. However, for construction of such tubewells and irrigation facilities, it is essential to add considerable quantities of equipment and materials to the KR-2 ones.

The completed tubewells and irrigation facilities will be able to be operated and maintained by TIATSP organization, collecting water charge equivalent to the operation and maintenance cost from water users' groups which will be organized under the guidance and supervision by TIATSP. The water charge will be able to be collected from the water users' group when a pump-up discharge of deep tubewell is more than 25ℓ/sec, because the water charge to be allocated to the farmers is not so heavy for them in the view point of farmer's economy.

However, it is hardly possible for HMGN to implement and complete the Project by herself, since the national budget largely depends on foreign aids, and the engineering and technique on the hydro-geological investigation and the drilling and finishing of deep tubewell deeper than 150m are not fully established yet in Nepal.

In the light of such situations mentioned above, 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.

# TABLES AND FIGURES

## Table 3.1 Data of the Existing Deep Tubewell Water Quantity

| WELL No | ORGANIZATION | LOCATION (DISTRICT) | yield lit/sec | S.W.L m | P.W.L m | Pump depth installed (Total depth,Total screen) | Draw-down | Tested Time | Comment | MAKER (PUMP,ENGINE) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-5 | TONE TEAM | Godar (Dhanusa) | 9.7 | 23.5 | 43.9 | 46m (l=152.55m) | 20.4 | 22Hrs | 45 l/s or 47 l/s is reported by TONE | EBARA 45 l/S ISUZU 47HP4.5 ℓ/Hr oil consumption |
| N1 | JADP | Bilendr Bazar (Dhanusa) | 26.5 | 34.2 | 44.9 | 50m (l=124m,30m) | 10.66 | 8Hrs | 25 l/s repoted | EBARA 60 l/s FIAT 72 HP 7 l/Hr oil |
| 1-3 | TONE TEAM | Bharot Pur (Dhanusa) | 17.0 | 23.1 | 33.0 | 34m (l=101m,30m) | 9.9 | 8Hrs | 40 l/s reported, If Pump Housing is set more deep, Yield "Q" can increase. | |
| N6 | JADP | Lakhan Pur (Dhanusa) | 8.8 | 15.5 | 37.9 | 45m (l=104.8m, 30m) | 22.4 | 2.5Hrs | | EBARA 60 l/s FIAT 71 HP 7 l/Hr oil |
| M10 | Ground Water Project | Laximiniya (Mahottari) | 25 | 19.85 | 24.7 | 30m (l=120m,22m) | 4.8 | 1.5Hrs | | EBARA 45 l/s MITSUI 5 l/Hr |
| | JADP | Godar (Dhanusa) | 22 | 20.02 | 36.95 | Air Lifting (l=131m,34m) | 16.75 | 1 Hr | Under analysis of Pump Test data | |
| M11 | Ground Water Project | Ram Nagal (Mahottari) | 27 | 24.09 | 29.43 | 32m (l=147m,22m) | 5.34 | 5Hrs | MITSUI Engine cannot power up | EBARA 45 l/s MITSUI 4 l/Hr |
| | JADP | Bhaktipur (Sarlahi) | 7 | 1.15 | 43.0 | 50m (l=115m,20m) | 41.21 | 1.5Hrs | Screen at 166m depth broken | |
| TW-1 | JICA Team | Paukouli (Mahottari) | 27 ↓ 15 | 0.95 | 40.3 | 65m (l=240m,60m) | 39.35 | 6Hrs | Screens below 166m crashed. Before screen broken, 27 l/s of discharge ofserved at Air Lifting. | |
| M9 | Ground Water Project | Bhangaha (Dhanusa) | 20 | 7.22 | 28.9 | 30m (l=80m,23m) | 21.68 | 3Hrs | | EBARA 45 l/s MITSUI 4.4 l/Hr |
| N10 | JADP | Harihal Pur (Dhanusa) | 27 | 30.45 | 34.91 | 50m (l=120m,35m) | 4.46 | 3.5Hrs | At the condition of 27 l/s discharge or more, Water color change from clean to brown and suspended medium sands, 50 l/s value was reported by JADP. | EBARA 60 l/s FIAT 72HP 8.6 l/Hr |
| TW-3 | JICA Team | Jamnibas (Dhanusa) | (3 l/s) | 49.45 | 61.0 | (l=150m,52m) | 11.55 | 16 sec | | |
| J22 | JADP | Sarlahi,Nawalpur Horticulture | 40 l/s | No hole to measure | No hole to measure | (l=72.5m,21m) | No hole to measure | 3.1Hrs | Electric Motor cannot change R.P.N. | INDIA Johnston Generator 70HP 8 l/Hr |
| No.4 | Minor Irr. Project | Sathahi Malangwa | 39 l/s | No hole to measure | No hole to measure | (l=98m,16m) | No hole to measure | 3Hrs | Low power engine & pump capacity | INDIA Johnston 45 l/s |
| No.9 | Minor Irr. Project | Sarlahi Malangwa | 40 l/s | No hole to measure | No hole to measure | (l=104m,16m) | No hole to measure | 8Hrs | Low power engine & pump capacity | INDIA Johnston 2 cylinder Engine 25HP |

## Table 3.2 Data of the Existing Deep Tubewell(1/4)

| WELL No. | LOCATION | DISTRICT | Installation Date | Depth (m) | Diameter (Inch) | Artesian Discharge (ℓ/sec) | Pumping Discharge (ℓ/sec) | Static Water Level (m) | Pumping Water Level (m) | Drawdown (m) | Total Screen (m) | Specific Capacity (ℓ/sec) | Transmissibity (by graph) | ($m^2$/day) by Thiem | Permeability (cm/sec) | Storage Coefficient | Remarks | Well Intervals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PAO 1 | Hardinath | Dhanusa | 1972 | 133.1 | 10/8 | 27.8 | 48.6 | +5.5 | 0.23 | 5.53 | 30.2 | 6.2 | | 985 | $3.78\times10^{-2}$ | | | 694 |
| PAO 2 | Ghorgas | " | 1972 | 127 | " | 9.3 | 42.9 | +7.2 | 9.91 | 17.11 | 11 | 2.5 | | 299 | $5.17\times10^{-2}$ | | | |
| PAO 3 | Aurhi | Mahottari | 1972 | 113 | " | 19.6 | 47.4 | +2.6 | 4.10 | 6.7 | 30.2 | 7.1 | | 801 | $3.1\times10^{-2}$ | | | |
| PAO 4 | Rauja | " | 1972 | 176 | " | 23.0 | 34.7 | +9.5 | 2.65 | 12.15 | ? | 2.8 | | 329 | $1.5\times10^{-2}$ | | | |
| PAO 5 | Harigurgama | " | 1972 | 177 | " | 2.7 | 21.0 | +2.4 | 14.96 | 17.36 | 27.2 | 1.2 | | 138 | $5.89\times10^{-3}$ | | | |
| PAO 6 | Janakpur | Dhanusa | 1972 | 176 | " | 18.5 | 47.3 | +1.8 | 6.1 | 7.9 | 27.5 | 5.9 | | 685 | $2.89\times10^{-2}$ | | | |
| J1(=8) | Dhalkewar | Dhanusa | 1977-7 | 115 | 6/4 | - | - | - | - | - | 31.6 | - | | - | - | | Pump Installed | |
| J2 | TIATSP Naktajhig | " | 1975-1-3 | 135 | 6/6 | - | 11.0 | 14.35 | 27.5 | 13.15 | 27.0 | 0.8 | 320 | 88 | $3.77\times10^{-3}$ | - | Dry well<br>Pump Installed | 452 |
| J3 | Tobacco Factory | " | 1980-4-19 | 116.6 | 12/8 | - | 20.0 | 6.0 | 21.0 | 15.0 | 40.13 | 1.3 | | 147 | $4.24\times10^{-3}$ | | | |
| J4 | Hardinath No2 | " | 1977-4-1 | 160 | 12/8 | 16.6 | 30.0 | +3.43 | 27.605 | 31.035 | 33.0 | 0.9 | 112 | 117 | $4.10\times10^{-3}$ | $9.5\times10^{-5}$ | | |
| J5 | " No3 | " | 1980-6-13 | 104.5 | 12/8 | 15.0 | 40.0 | +2.0 | 27.0 | 29.0 | 30.25 | 1.4 | | 169 | $6.48\times10^{-3}$ | | | |
| IAP No.1 (J6) | Saphai | Dhanusa | 1976-3-21 | 130 | 12/8 | 28.0 | 58.0(II)<br>44.0(I) | +1.26 | 11.36 | 12.62 | 33 | 4.6 | 209 | 548 | $1.93\times10^{-2}$ | $1.74\times10^{-5}$ | Pump Installed | |
| IAP No.2 (J7) | " | " | 1976-4-10 | 130 | " | 15.0 | 36.3 | +1.30 | 15.4 | 16.7 | 33 | 2.2 | 151 | 256 | $8.99\times10^{-3}$ | $1.35\times10^{-4}$ | " | |
| IAP No.3 (J8) | " | " | 1977-2-19 | 130 | " | 18.0 | 35.3<br>46.5 | +3.20 | 9.94 | 13.14 | 33 | 3.5 | 559 | 418 | $1.47\times10^{-2}$ | $4.13\times10^{-4}$ | " | |
| IAP No.4 (J9) | " | " | 1975-3-25 | 146 | " | 14.4 | 39.9 | +5.43 | 17.022 | 22.452 | 33 | 1.8 | 254 | 215 | $7.53\times10^{-3}$ | - | " | |
| IAP No.5 (J10) | " | " | 1976-5-11 | 130 | " | 18.0 | 35.3<br>32.9 | +1.8 | 20.63 | 22.43 | 33 | 1.6 | 73 | 188 | $6.62\times10^{-3}$ | $6.32\times10^{-5}$ | " | |
| IAP No.6 (J11) | " | " | 1976-2-17 | 131 | " | 25.0 | 30.2 | +1.33 | 14.98 | 16.31 | 33 | 1.9 | 129 | 215 | $7.57\times10^{-3}$ | $1.1\times10^{-4}$ | " | |
| IAP No.7 (J12) | " | " | 1975-3-2 | 156 | " | Estimated 4 | 4.7 | - | - | - | 33 | - | - | - | - | - | " | |
| IAP No.8 (J13) | " | " | 1975-2-7 | 201 | " | 9.4 | 21.9<br>24.0 | +3.6 | Estimated 11.0 | 14.6 | 44 | 1.6 | 241 | 69 | $1.82\times10^{-3}$ | - | " | 486 |
| IAP No.9 (J14) | " | " | 1977-5-11 | 130.3 | " | 29.0 | 43.9 | +5.39 | 6.843 | 12.233 | 35.75 | 3.6 | 495 | 270 | $8.76\times10^{-3}$ | $2.6\times10^{-4}$ | " | |
| J15 | Janakpur Hort | " | 1976-12-2 | 139 | 12/8 | 20.1 | 35.0 | +1.0 | 4.935 | 5.935 | 33.6 | 5.9 | 367 | 359 | $1.24\times10^{-2}$ | $3.56\times10^{-4}$ | " | 450 |
| J16 | Janakpur Fisheries | " | 1979-2-16 | 140 | 12/8 | 5.0 | 35.0 | +1.2 | 13.692 | 14.892 | 25.6 | 2.4 | | 34 | $1.56\times10^{-3}$ | | | 350 |
| J17 | Ghorgas | " | 1979-6 | 166 | 12/8 | ? | 48.0 | +1.35 | 25.021 | 26.371 | 39.3 | 1.8 | | 224 | $6.62\times10^{-3}$ | | | |
| J18 | Ramnagar MR.B.B.Rana | Mahottari | 1979-2-4 | 81 | 6 | - | 20.0 | 20.0 | 51.0 | 31.0 | 24.4 | 0.6 | | 78 | $3.74\times10^{-3}$ | | | |
| J19 | Aurhi MR.Bedman | " | 1979-4-5 | 111 | 10/6 | - | 60.0 | 1.0 | 7.0 | 8.0 | 36.7 | 7.5 | | 904 | $2.85\times10^{-2}$ | | | |
| J20 | Sagarnath Forest | Mahottari Hatilet | 1985-8 | 94.54 | 8/8 | - | 25.0? | 42.3 | 60.0 | 17.7 | 24.7 | 1.4 | | 163 | $7.66\times10^{-3}$ | | | |
| J21 | Nawalpur Hort | Sarlahi | 1981-11 | 70 | 12/8 | - | 16.0 | 22.0 | 29.74 | 7.74 | 23.0 | 2.1 | | 219 | $1.11\times10^{-2}$ | | | 458 |
| J22 | National Oil Seed | " | 1979-6 | 72.5 | 12/8 | - | 40.0 | 21.3 | 37.5 | 6.2 | 21.0 | 2.5 | | 719 | $3.97\times10^{-2}$ | | Observed<br>Pump Installed | 662 |
| J23 | Sagarnath Forest | " | 1982-9 | 97.6 | 12/8 | - | 30.0 | 16.5 | 35.0 | 18.5 | 27.5 | 1.6 | | 186 | $7.84\times10^{-4}$ | | | |
| J24 | Sagarnath No.2 | " | 1982-10 | 110 | 12/8 | - | 40.0 | 15.525 | 29.0 | 13.475 | ? | 2.9 | | 340 | $1.43\times10^{-2}$ | | | |

## Table 3.2 Data of the Existing Deep Tubewell(2/4)

| WELL No. | LOCATION | DISTRICT | Instal-lation Date | Depth (m) | Dia-meter (Inch) | Artesian Discharge (l/sec) | Pumping Discharge (l/sec) | Static Water Level (m) | Pumping Water Level (m) | Draw-down (m) | Total Screen (m) | Specific Capacity (l/sec) | Trans-missibity (by graph) | ($m^2$/day) by Thiem | Perme-ability (cm/sec) | Storage Coefficient | Remarks | Well Intervals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M 1 | Jaleswar | Mahottari | 1983 | 169 | 6 | Weak | 12 | 3.7 | 6.0 | 2.3 | 15 | 5.2 | | 519 | $4.01\times10^{-2}$ | | | 208 |
| M 2 | Matihani | " | 1983 | 157 | 10/6 | - | - | 3.7 | - | - | 18 | - | Failure | | | | | |
| M 3 | Ikraiya | " | 1983 | 150 | 10/6 | Weak | 49 | 1.8 | 24.3 | 22.5 | 16 | 2.2 | | 275 | $1.99\times10^{-2}$ | | | |
| M 4 | Siswaknka-taiya | " | | 144 | 10/6 | Weak | 3 | 1.8 | 39.8 | 38.0 | ? | - | | 9 | $4.01\times10^{-4}$ | | | 446 |
| M 5 | Pokhar Bhinda | " | 1983 | 162 | 10/6 | Weak | 3 | 0 | 14.0 | 14.0 | 23 | 0.2 | | 21 | $1.11\times10^{-3}$ | | | 262 |
| M 6 | Raghu Natkpur | " | | 136 | 10/6 | Weak | 2 | 0 | 23.0 | 23.0 | 17 | 0.1 | | 9 | $6.13\times10^{-4}$ | | | 276 |
| M 7 | Aurhi | " | 1984 | 150 | 10/6 | Weak | 20 | 4.0 | 19.0 | 17.0 | 27 | 1.7 | | 138 | $5.95\times10^{-3}$ | | | 800 |
| M 8 | Hathilet | " | | 79 | 10/6 | - | - | | | | 23 | | Failure | | | | | |
| M 9 | Bhangaha | " | 1984 | 135 | 10/6 | - | (28) | (9.4) | (29.4) | (20) | | (1.4) | | | | | (Informed data) | |
| M10 | Laximiniya | " | | 121 | 10/6 | - | 20<br>25 | 7.22<br>19.85 | 28.9<br>24.7 | 20<br>4.8 | 23<br>22 | 0.9<br>5.2 | 259 | 166<br>562 | $8.37\times10^{-3}$<br>$2.96\times10^{-2}$ | | Observed | |
| M11 | Ramnagar | " | 1985 | 147 | 10/6 | - | 27 | 24.09 | 29.43 | 5.34 | 22 | 5.1 | 257 | 552 | $2.91\times10^{-2}$ | | Pump Installed | 454 |
| M12 | Matihani | " | | | | | No information | | | | | | | | | | | 502 |
| M13 | Matihani | " | 1984 | 136 | 10/6 | | | 3.7 | | | 16 | | Failure | | | | | |
| M14 | Mahottari | " | | 133 | 10/6 | Weak | 29 | 0.6 | 23.2 | 22.6 | 18 | 1.3 | | 157 | $1.01\times10^{-2}$ | | | |
| M15 | Ratauli | " | 1984 | 150 | 10/6 | - | - | 1.5 | - | | 20 | | | | | | | |
| M16 | Bishambharpur | " | 1984 | 114 | 10/6 | Weak | 26 | +0 | 24.3 | 24.3 | 14 | 1.1 | | 131 | $1.08\times10^{-2}$ | | | |
| M17 | Shripur | " | | 150 | 10/6 | Artesian | 29 | +0 | ? | ? | 18 | | | | | | | |
| M18 | Sundarpur | " | 1983 | 148 | 10/6 | Weak | 48 | +0 | 23.8 | 23.8 | 20 | 2.0 | | 255 | $1.48\times10^{-2}$ | | | |
| M19 | Hathilet | " | 1984 | 107 | 10/6 | - | Estimated 36 | 30.5 | | | 22.5 | | | | | | | |
| M20 | | | | | | | | | | | | | | | | | | |
| M21 | | | | | | | | | | | | | | | | | | |
| M22 | Bhargarsar | " | 1985 | 141 | 10/6 | Weak | 33.0 | 1.82 | 17.83 | 16.01 | 20 | 2.1 | 686 | 250 | $1.45\times10^{-2}$ | 0.318 | Observed Pump Installed | |
| M23 | Ramnagar | " | | 140 | 10/6 | - | Estimated 36 | 38.1 | | | 21 | | | | | | | |
| M24 | Bijalpur | " | | 98 | 10/6 | - | 25.0 | 7.0 | 8.8 | 1.8 | 10 | 2.5 | | 1,401 | | | | 268 |
| M25 | Bijalpur | " | 1986 | 95 | 6 | - | - | 0.6 | - | - | 10 | | | | | | | |
| M26 | Saharwa | " | 1986 | 166 | | - | | | | | | | Failure | | | | | |
| G14 | Sundarpur | East Side of Kamla | | 87 | ? | Arterian | 13 | +0 | 15.2 | 15.2 | 18 | 0.9 | | 97 | $6.30\times10^{-3}$ | | | 600 |
| G15 | Belha | " | | 112 | | " | 13.3 | +0 | 25.9 | 25.9 | 24 | 0.5 | | 60 | $2.93\times10^{-3}$ | | | 808 |
| G16 | Arnama | " | | 114 | | " | 32.9 | +0 | 16.76 | 16.76 | 27 | 1.9 | | 238 | $1.02\times10^{-2}$ | | | |
| G17 | Thengi | " | | 138 | | " | 45.1 | +0 | 14.94 | 14.94 | 15 | 3.0 | | 371 | $2.87\times10^{-2}$ | | | |
| G18 | Sanaiha | " | | 132 | | " | 29.6 | +0 | 13.92 | 13.92 | 30 | 2.1 | | 254 | $9.80\times10^{-3}$ | | | |

## Table 3.2 Data of the Existing Deep Tubewell(3/4)

| WELL No. | LOCATION | DISTRICT | Installation Date | Depth (m) | Diameter (Inch) | Artesian Discharge (l/sec) | Pumping Discharge (l/sec) | Static Water Level (m) | Pumping Water Level (m) | Drawdown (m) | Total Screen (m) | Specific Capacity (l/sec) | Transmissibity (by graph) | ($m^2$/day) by Thiem | Permeability (cm/sec) | Storage Coefficient | Remarks | Well Intervals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N 1 | Birendra Bazar | Dhanusa | 1985-11 | 124 | 14/8 | - | 26.5 | 34.2 | 44.9 | 10.66 | 30.0 | 2.5 | 153 | 273 | $1.05\times10^{-2}$ | $2.3\times10^{-2}$ | Observed Pump Installed | 704 |
| N 2 | Chhayhatar Bigha | " | 1986-1 | 162 | 14/8 | - | 30.0? | 41.0 | ? | | 42.75 | | | | | | | |
| N 3 | Murgiya | " | 1986-1 | 124.85 | 14/8 | - | 20.0? | 52.0 | ? | | 26.0 | | | | | | | |
| N 4 | Lalvitti | " | 1986-4 | 105.0 | 14/8 | - | 15.0? | 62.0 | ? | | 35.0 | | | | | | | |
| N 5 | Dhalkevar Chaul | " | 1985-11 | 121.25 | 14/8 | - | 20.0? | 60.0 | ? | | 30.75 | | | | | | | |
| N 6 | Lakhanpur | " | 1986-2 | 104.75 | 14/8 | - | 8.8 | 15.5 | 37.9 | 22.4 | 30.0 | 0.4 | 101 | 42 | $1.63\times10^{-3}$ | $2.6\times10^{-1}$ | Observed Pump Installed | 580 |
| N 7 | Keshar-kutti | " | 1986-3 | 165.0 | 14/8 | - | 30.0? | 30.0 | ? | | 30.0 | | | | | | | |
| N 8 | Kishanpur | " | 1986-4 | 120.25 | 14/8 | - | 35.0? | 31.0 | ? | | 30.0 | | | | | | | |
| N 9 | Digambarpur | " | 1986-5 | 133.5 | 14/8 | - | 20.0? | 28.5 | ? | | 35.0 | | | | | | | |
| N10 | Haribarpur | " | 1985-11 | 120.0 | 14/8 | - | 27.0 | 30.45 | 34.91 | 4.46 | 35.0 | 6.1 | 61 | 628 | $2.08\times10^{-2}$ | 0.794 | Observed Pump Installed | 446 |
| N11 | Umaprempur | " | 1986-4 | 129.0 | 14/8 | - | 40.0? | 33.0 | ? | | 45.0 | | | | | | | |
| N12 | Singahimadan | " | 1986-4 | 87.7 | 8/8 | - | 40.0? | 1.0 | ? | | 21.0 | | | | | | | |
| N13 | Bakchaura | " | 1986-4 | 158.0 | 14/8 | - | 40.0? | 0.12 | ? | | 40.0 | | | | | | | |
| N14 | Hanuman Nagar | " | 1986-2 | 173.75 | 14/8 | ? | 50.0? | +0.5 | ? | | 27.5 | | | | | | | |
| N15 | Sonapada | " | 1986-3 | 175.0 | 14/8 | 6.0 | 50.0? | +0.5 | ? | | 33.0 | | | | | | | |
| N16 | Umaprempur | " | 1986-4 | 124.75 | 14/8 | - | 10.0? | 40.0 | ? | | 40.0 | | | | | | | |
| N17 | Kathapulla | " | 1986-1 | 144.0 | 14/8 | tr. | 10.0? | +0.0 | ? | | 40.0 | | | | | | | |
| N18 | Kumraha tole | " | 1986-2 | 154.0 | 14/8 | - | 10.0? | +0.0 | ? | | 30.0 | | | | | | | |
| N19 | Pusbalpur | " | 1986-4 | 125.25 | 14/8 | - | 8.0 | 45.0 | 60.0 | 15 | 22.0 | 0.5 | | 55 | $2.91\times10^{-3}$ | | | 446 |
| N20 | Bhimanchowk | " | 1986-2 | 120.0 | 14/8 | - | 15.0? | 42.0 | ? | | 33.0 | | | | | | | |
| N21 | Dada tole | " | 1986-2 | 100.0 | 14/8 | - | 15.0? | 38.0 | ? | | 35.0 | | | | | | | |
| N22 | Maltole | " | 1986-3 | 126.5 | 14/8 | - | 10.0? | 45.0 | ? | | 33.0 | | | | | | | |
| N23 | Janaki Temple | " | 1986-5 | 174.74 | 14/8 | 5.0 | 25.0 | +1.0 | 5.0 | 6.0 | 24.75 | 4.1 | | 449 | | | | |
| JADP 1987 | Hirapur | Sarlahi | 1987-2 | | 14/8 | - | Failure | | | | | | | | | | | |
| JADP 1987 | Bhaktipur | " | 1987-2 | 115.0 | 14/8 | - | 7.0 | 1.15 | 43.0 | 41.21 | 31.0 | 0.2 | 26 | 18 | | | Observed | |
| JADP 1987 | Godar | Dhanusa | 1987-2 | 131.0 | 14/8 | - | 22.0 | 20.02 | 36.95 | 16.75 | 34.0 | 1.3 | 32 | 146 | $5.0\times10^{-3}$ | | | |

## Table 3.2 Data of the Existing Deep Tubewell(4/4)

| WELL No. | LOCATION | DISTRICT | Instal-lation Date | Depth (m) | Dia-meter (Inch) | Artesian Discharge (ℓ/sec) | Pumping Discharge (ℓ/sec) | Static Water Level (m) | Pumping Water Level (m) | Draw-down (m) | Total Screen (m) | Specific Capacity (ℓ/sec) | Trans-missibity (by graph) | ($m^2$/day) by Thiem | Perme-ability (cm/sec) | Storage Coefficient | Remarks | Well Intervals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T2- 1 | Dharapani | Dhanusa | 1985-11-6 | (172.0) 160.0 | 14/8 | - | 30.0 | 46.48 | 68.10 | 31.62 | 30.0 | 0.9 | | 112 | $4.34\times10^{-3}$ | | Pump Installed | |
| T4- 2 | Puspalpur | " | 1985-8-6 | 130.0 | 14/8 | - | - | - | - | - | 35.5 | | | | | | Dry well | |
| T1- 3 | Bharatpur | " | 1985-6-21 | 101.0 | 14/8 | - | 16.7 | 23.10 | 32.61 | 6.75 | 30.0 | 1.7 | 95 | 225 | $9.86\times10^{-3}$ | $3.4\times10^{-2}$ | Observed | 430 |
| T2- 4 | Kumurha | " | 1985-7-9 | 180.0 | 14/8 | - | 10.0 | 31.60 | 44.46 | 12.86 | 50.0 | 0.7 | | 83 | $1.92\times10^{-3}$ | | Pump Installed | 468 |
| T1- 5 | Godar | " | 1885-12-13 | 152.0 | 14/8 | - | 9.7 | 23.50 | 43.9 | 15.5 | 55.0 | 0.5 | | 65 | $1.38\times10^{-3}$ | | Observed | 502 |
| T4- 6 | Dhalkewar | " | 1986-1-6 | 145.5 | 14/8 | - | 15.0? | 63.90 | 84.48 | 20.98 | 40.0 | 0.7 | | 79 | $2.29\times10^{-3}$ | | Pump Installed By Submissible Pump | 746 |
| T1- 7 | Gauripur | " | 1986-2-6 | 130.0 | 14/8 | - | (Estimated) 15-20 | 23.0 | 30.5 | 12.5 | 50.0 | 1.2-1.6 | | 174 | $4.04\times10^{-3}$ | | | 660 |
| T1- 8 | Rhadapur | " | 1986-1-25 | 150.0 | 14/8 | - | 36.5 | 24.0 | 34.0 | 10.0 | 35.0 | 3.7 | | 407 | $1.35\times10^{-2}$ | | Pump Installed | 808 |
| T3- 9 | Mangalpur | " | 1986-1-7 | 170.0 | 14/8 | - | 50.0? | 23.73 | 34.17 | 10.44 | 50.0 | 4.8? | | 553 | $1.28\times10^{-2}$ | | | |
| T3-10 | Sarsa | " | 1986-1-31 | 160.0 | 14/8 | - | 10.0 | 19.21 | 43.15 | 23.94 | 45.0 | 0.4 | | 46 | $1.20\times10^{-3}$ | | | 652 |
| T3-11 | Ghira | " | 1986-2-24 | 155.0 | 14/8 | - | 40.0? | 29.40 | 37.06 | 7.66 | 35.0 | 5.2? | | 577 | $1.91\times10^{-2}$ | | | 736 |
| T7-12 | Jankinagar | " | 1986-2-9 | 165.0 | 14/8 | - | 10.0 | 12.52 | 45.22 | 32.70 | 45.0 | 0.3 | | 34 | $8.93\times10^{-4}$ | | | 770 |
| T7-13 | Kajara Ramoul | " | 1986-2-11 | 170.0 | 14/8 | - | 10.0 | 9.31 | 51.38 | 42.07 | 40.0 | 0.2 | | 27 | $7.94\times10^{-4}$ | | Pump Installed | 880 |
| T7-14 | Laliya | " | 1986-3-15 | 165.5 | 14/8 | - | 30.0 | 4.60 | 16.40 | 11.87 | 75.0 | 2.5 | | 282 | $4.35\times10^{-3}$ | | | 796 |
| T8-15 | Hanspur Karapulla | " | 1986-2-27 | (186.0) 175.0 | 14/8 | Weak | 10.0 | +0 | 45.85 | 45.85 | 50.0 | 0.2 | | 25 | $5.86\times10^{-4}$ | | | |
| T8-16 | Jhatiyahi | " | 1986-3-2 | 160.0 | 14/8 | - | 20.0 | 2.28 | 35.95 | 33.67 | 60.0 | 0.6 | | 70 | $1.36\times10^{-3}$ | | Pump Installed | |
| S- 1 | Gair | Sarlahi | | 100.0 | 10/? | | | | Failure | | | | | | | | | |
| S- 2 | Birnagar | " | | 77.0 | 10/? | | 66.6 | 6.4 | 9.75 | 3.35 | 18 | 19.9 | | 2,285 | $1.47\times10^{-1}$ | | Pump Installed | 640 |
| S- 3 | Shinnagar | " | | 73.0 | 10/? | | 71.2 | 3.35 | 6.70 | 2.35 | 30 | 30.3 | | 3,418 | $1.32\times10^{-1}$ | | | 548 |
| S- 4 | Salimpur | " | | 98.0 | 10/? | | 73.1 | 6.1 | 9.76 | 3.66 | 18 | 19.9 | | 2,322 | $1.49\times10^{-1}$ | | Observed (=39ℓ/s) | 704 |
| S- 5 | Chainpur | " | | 99.0 | 10/? | | 52.9 | 9.14 | 14.02 | 4.88 | | 10.8 | | 1,257 | $4.85\times10^{-2}$ | | | 792 |
| S- 6 | Bhelhi | " | | 85.0 | 10/? | | | No Information | | | 30 | | | | | | Pump Installed | |
| S- 7 | Lakshimipur | " | | 107.0 | 10/? | | 80.4 | 2.74 | 5.79 | 7.05 | 30 | 11.4 | | 1,388 | $5.36\times10^{-2}$ | | | 1,050 |
| S- 8 | Kaurena | " | | 101.0 | 10/? | | 68.6 | 4.27 | 7.32 | 3.05 | 24 | 22.5 | | 2,574 | $1.24\times10^{-1}$ | | | 618 |
| S- 9 | Bishanpur | " | | 104.0 | 10/? | | 44.2 | 7.32 | 12.81 | 5.49 | 18 | 8.1 | | 930 | $5.98\times10^{-2}$ | | Observed (=40ℓ/s) | 618 |
| S-10 | Kaurena | " | | 101.0 | 10/? | | 65.6 | 4.27 | 7.93 | 3.66 | 30 | 17.9 | | 2,069 | $7.98\times10^{-2}$ | | Pump Installed | 666 |
| S-11 | Simra | " | | 107.0 | 10/? | | 76.2 | 2.13 | 5.18 | 3.05 | 22 | 25.3 | | 2,919 | $1.54\times10^{-1}$ | | | 658 |
| No.2 | Sugar Factory | " | | 60.3 | 12/6 | | 27.0 | 13.8 | 19.2 | 5.4 | 19.5 | 5.2 | | 559 | $3.32\times10^{-2}$ | | " | 510 |
| No.3 | Sugar Factory | " | | 60.0 | 12/6 | | 29.0 | 14.4 | 19.2 | 4.8 | 18.0 | 6.0 | | 673 | $4.33\times10^{-2}$ | | " | 498 |

Table 3.3 Data of the Existing Deep Tubewell Water Quality

| DISTRICT | WELL NO. | CONDUCTIVITY (MICRO MHO/CM) | PH | C° | TOTAL DEPTH (m) | AQUIFERS TAKEN GROUNDWATER | REMARKS |
|---|---|---|---|---|---|---|---|
| SARLAHI | J22 | 150 | 6.7 | 27.0 | 73 | G2 | |
| | JADP(1987) | 299 | 6.4 | 26.8 | 115 | G3-2, G4, G5 | Bhaktipur |
| | S4(MIP) | 460 | 7.1 | 25.5 | 98 | G3-1, G4 | |
| | S9(MIP) | 395 | 7.2 | 24.5 | 104 | G3-1, G4 | |
| MAHOTTARI | M10 | 190 | 6.8 | 25.0 | 123 | G3-1, G4 | |
| | M11 | 180 | 6.2 | 25.5 | 150 | G2, G3-1 | |
| | FA03 | 190 (190) | 6.5 | 25.0 (26.2) | 113 | G3-1 | (Existing data) |
| | J19 | 120 | 6.6 | 26.5 | 110 | G2-2, G3-1, G4 | |
| | M7 | 120 | 9.0 | 24.0 | 152 | G2-2,G3-1,G4,G5 | |
| | M9 | 86 | 7.0 | 27.0 | 138 | G2, G2-2, G3-1 | |
| | FA04 | 160 | 7.0 | 26.0 | No data | | |
| | M14 | 390 | 7.1 | 24.0 | 135 | G3-2, G5 | |
| | Jaleswar Water Supply | 345 | 7.8 | 20.0 | No data | | |
| | FA05 | 230 (225) | 6.7 (6.8) | 25.0 (25.5) | 177 | G3-2, (G4), G5 | (Existing data) |
| DHANUSA | JADP(1987) | 340 | 8.1 | 26.0 | 131 | G1, G2, G3-1 | Godar |
| | N1 | 160 | 6.2 | 27.0 | 125 | G3-1 | |
| | T1-5 | 260 | 7.0 | 26.0 | 135 | G2 | |
| | T1-3 | 190 | 6.2 | 26.0 | 85 | G1, G2 | |
| | T1-7 | 280 | 6.5 | 25.5 | 130 | G2, G3-1 | |
| | N6 | 250 | 6.9 | 26.5 | 105 | G1, G2 | |
| | N10 | 160 | 6.3 | 27.0 | 120 | G2, G4 | |
| | J6 | 150 | 6.4 | 26.0 | 132 | G2, G3, G4 | |
| | J4 | 180 | 6.6 | 25.0 | 160 | G2-2, G4, G5 | |
| | J5 | 220 | 6.8 | 25.5 | 105 | G2-2, G3-1, G4 | |
| | FA01 | Depth 65m=215,<br>Depth 83m=163,<br>Depth 96m=215, | 6.7<br>6.6<br>6.2 | 25.5<br>23.8<br>25.2 | 133 | =G2-2<br>=G3-1<br>=G4 | (Existing data) |
| | T8-16 | 300 | 6.9 | 25.0 | 160 | G3-1, G5 | |
| | FA06 | (220) | (6.9) | (26.8) | 171 | G4, G5, G6 | (Existing data) |
| | N14 | 330 | 7.1 | 26.0 | 174 | G3-2,(G4),G5,G6 | |
| | N15 | 380 | 7.6 | 25.0 | 175 | (G4), G5 | |
| | FA02 | 290 (335) | 7.3 (7.1) | 26.0 (26.2) | 127 | G3-1, (G4) | (Existing data) |
| | G14 | 690 | 6.8 | 26.0 | 87 | No data | East bank of Kamla R. |
| | G15 | 610 | 6.8 | 27.0 | 112 | | |