Judging from a. and b. above, it was concluded that grounwater in this town may be developed with no problem at all so long as the adjacent wells are spaced 1,000 m or more apart from each other and the pumped volume of water Q is restricted to less than $Q = 180\ m^3/h$ each.

3-3-3 Water Source Plan

At present, drinking water for the town is supplied by one deep well (with the pumping rate of 68 m^3/h) and 397 hand pumps (in urban areas). River water is not used.

Studies on the future sources of drinking water supply - based on the prevalent state - resulted in the following conclusions.

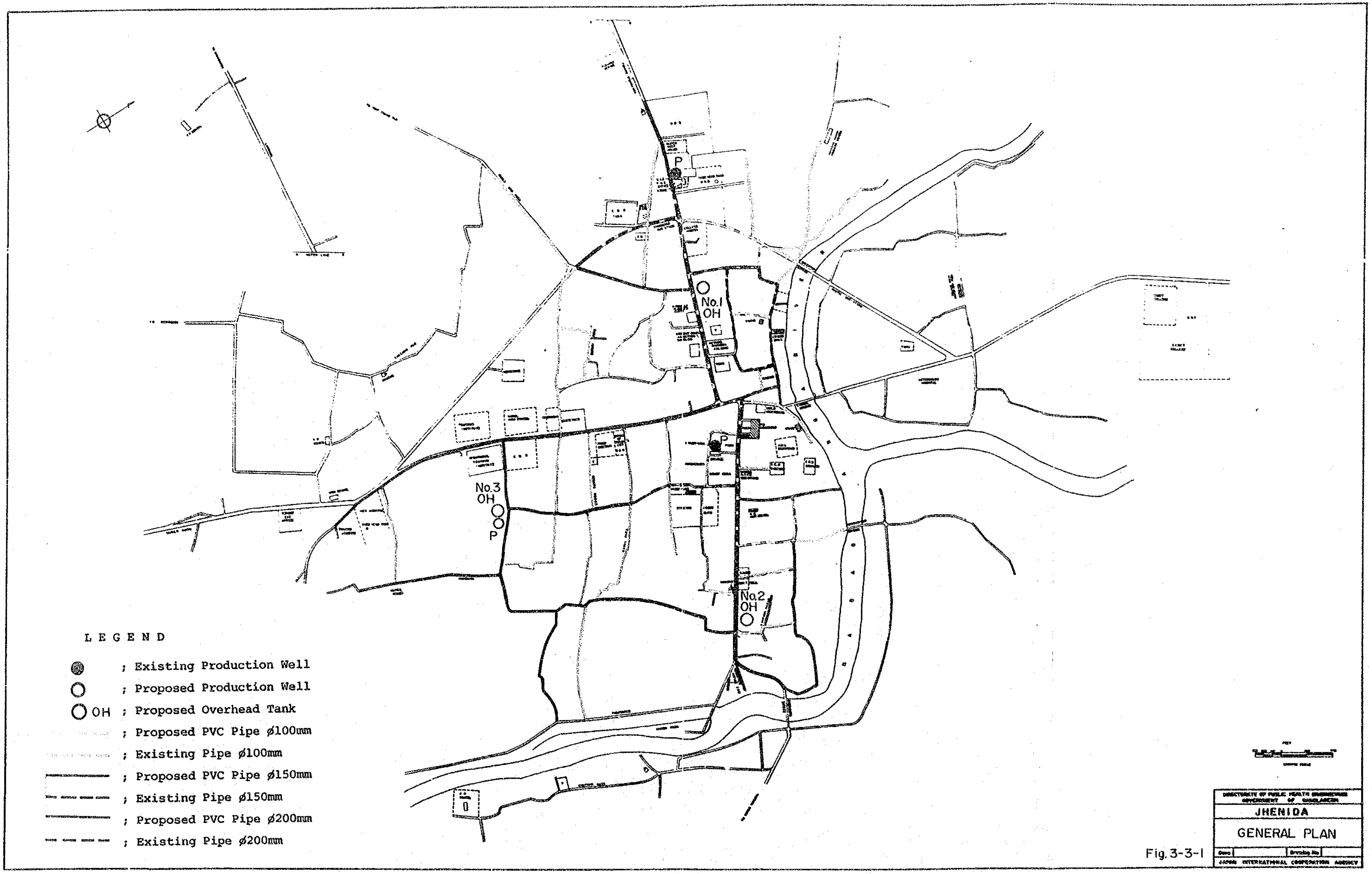
a. Groundwater

According to data on wells that are now under construction or already constructed, the layers in which a lot of groundwater tends to be readily stored (sand, gravel) are confirmed to exist starting from the shallow depth. In the pumping tests of such layers, the pumped volume of water is recorded to be in the range of 130 m^3/h to 165 m^3/h with a draw down of around 3 m. Also, as mentioned in Section 3-3-2, the development of groundwater in this town considered possible.

b. River water

During the dry season, the Nabaganga River which flows in the east of the town becomes only a trickle.

On the basis of a. and b. above, groundwater is judged to be better choice as the water source for the Project.



No.1 OH
No.2 OH
No.3 OH
P
LEGEND
; Existing Production Well
; Proposed Production Well
OH ; Proposed Overhead Tank
; Proposed PVC Pipe ø100mm
; Existing Pipe ø100mm
; Proposed PVC Pipe ø150mm
; Existing Pipe ø150mm
; Proposed PVC Pipe ø200mm
; Existing Pipe ø200mm
JHENIDA
GENERAL PLAN

Fig. 3-3-1

3-3-4 Water Supply Plan

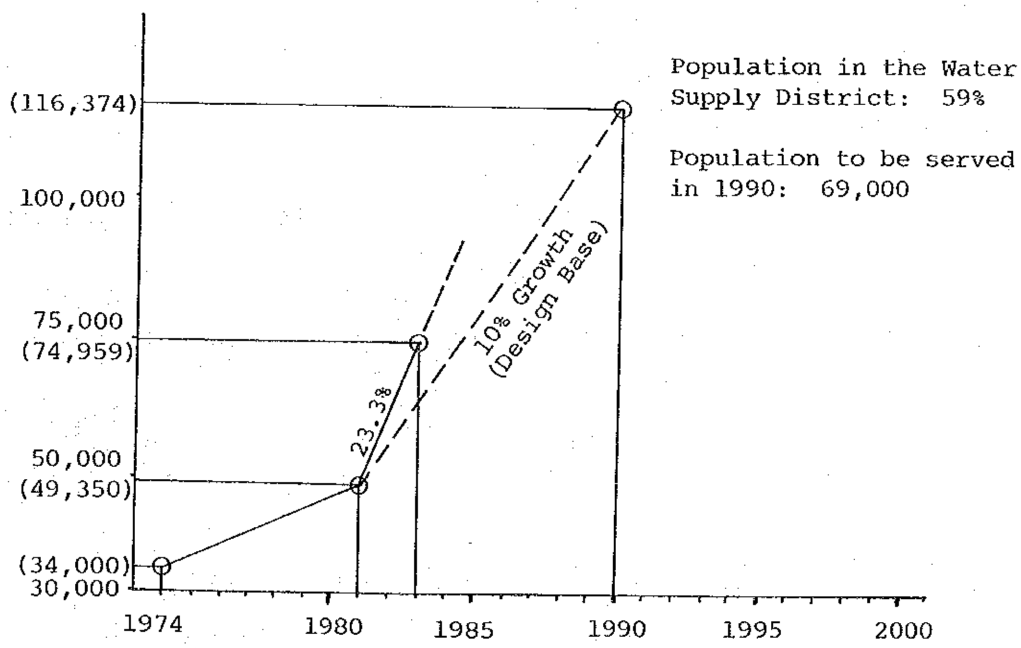
(1) Water Supply District and Population Supplied

Population at the time of censuses in 1974, 1981 and today (May 1984) are as follows:

Population at the 1974 census	:	34,002
Population at the 1981 census	:	49,355
Population as of May 1984	:	74,959

These data may be plotted as follows:

Population Growth in Jenidha Town



The average annual rate of population growth was 5.5% between 1974 and 1981 and 2.3% between 1981 and now. Recently, a large inflow of population from the rural areas is being recognized, but as there is little likelihood that the inflow will continue growing especially as the central or local governments, too, are expected to come out with countermeasures, the population growth rate from 1981 to the target year of this project (1990) was assumed to be 10% on average. Thus, the population in 1990 was projected to be 116,000.

The water supply district was determined in consideration of the present geographic distribution of population, the prevalent state of settlement formation and the direction of future development, and the population to which water is to be supplied was estimated to be 59% of the town's population. The population to which water would be supplied in 1990 therefore was estimated to be 69,000.

(2) Water Consumption

The estimated amount of water to serve a population of 69,000 would be as follows.

$$Q = 81 \text{ liters/man-day} \times 69{,}000 \text{ men} = 5{,}589 \text{ m}^3\text{/day}$$

(3) Water Supply Facilities Plan

(i) Production wells

a. Diameter of well and pumping rate

According to existing data available, the diameter of the well is 6" and the pumping rate is in the range of 130 to 165 t/h, and the draw down 3 to 4 m.

On pumping rate, a definite economic pumping rate has not been determined yet, but judging from existing data, a pumping rate of 180 t/h can probably be expected. As this pumping rate is large, the diameter would have to be 8".

b. Drawing depth

Judging from the inferred geological profile presented in Fig. 3-10-6, the gravel layer recognized at around GL -75 m and deeper would probably be the target drawing depth.

c. Number of wells

$$x = \frac{Q}{Qy} = \frac{5,589}{180 \times 12} = 2.6 \fallingdotseq 3$$

(ii) Pump facilities

If the suction level is (-) 20 m from the ground level (GL) and the discharge level 20.0 m above ground, which is high water level of the overhead tank, the actual head is 40.0 m.

A study of the pump facility for each well resulted in the following data.

Table 3-3-4 Principal Particulars of Pump Facilities

Description \ Well No.	1	2	3
1. Actual head, m	40.0	40.0	40.0
2. Pumping rate, ℓ/sec	43.1	43.1	43.1
3. Transmission pipe			
Kind of pipe:	Cast iron pipe	"	"
Diameter, mm	200	250	200
Length, m	530	690	40
4. Loss of head in the transmission pipe, m	8.51	3.73	0.64
5. Total head, m	48.51	43.73	40.64
6. Type of pump	Multi-stage turbine	"	"
7. No. of stages	7	7	6
8. Motor output, kW	30	30	30

(iii) Overhead tank

As the required total capacity of the overhead tank is

$$V = 5,589 \times 0.20 = 1,117.8 \text{ m}^3,$$

three overhead tanks with the capacity of 400 m^3 each will be planned with due consideration to their locational arrangement.

(iv) Distributing pipe

Arrangement (layout) of the distributing pipes was determined in consideration of the geographic distribution of population, the locations of existing wells and distributing pipes and the direction of future development of residential areas. PVC pipes will be used for all distributing pipes.

Hydraulic calculations for the pipeline network were carried out on the basis of the design conditions to secure a hydraulic pressure of 9.0 m (0.9 kg/cm^2) at every terminal end of the distributing main and branch.

(v) Public post

The discharge rate from a ø13 mm tap is 20 liters/min (14.4 m^3/12 h). Since the plan calls for supplying water to 50% of the inhabitants through public posts, the required quantity of water supply would be:

$$Q = 69{,}000 \text{ persons} \times 0.5 \times 34 \text{ liters/man-day}$$
$$= 1{,}173 \text{ m}^3\text{/day}$$

The required number of public posts would therefore be 82. Under this project, public posts will be constructed at 10 locations, and the balance by the Government of Bangladesh.

3-3-5 Contents of the Project

(1) Water Supply Facilities Already Completed by DPHE

The contents of water supply facilities already constructed by DPHE's own funds are as presented in Table 3-3-5.

(2) Water Supply Facilities to be Constructed under this Project

The contents of water supply facilities to be constructed under this project determined on the basis of the contents of water supply facilities of this project as a whole and the contents of facilities already completed by DPHE are as presented in Table 3-3-5, and the proposed plan for them is as shown in Fig. 3-3-1.

Table 3-3-5(1) Outline of the Water-Supply Systems to be Constructed in This Project

Jenidah

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
1. Production Well	ø380 mm x ø200 mm Depth: 135 mm Strainer: 24 m	3 Nos.	2 Nos.	1 No.
2. Pumping Facilities	B10D 7 stages x 30 kW x 2 unit B10D 6 stages x 30 kW x 1 unit	3 unit	0*	3 unit
3. Pumping House	Birck-and morter, pump room: 12.3 m² Driver's room: 8.8 m²	3 Nos.	1 No.	2 Nos.
4. Transmission Pipes	No.1 pumping station: ø200 mm	530 m	-	530 m
	No.2 pumping station: ø250 mm	690 m	-	690 m
	No.3 pumping station: ø200 mm	40 m	-	40 m
	Total	1,260 m		1,260 m
5. Overhead Tank	Capacity: 400 m³ Height: 17 m Reinforced concrete	3 units	0	3 units

(cont.)

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
6. Distributing Pipes	PVC Pipe: ø200 mm	6,686 m	1,186 m	5,500 m
	ø150 mm	6,378 m	3,348 m	3,030 m
	ø100 mm	13,693 m	2,103 m	11,590 m
	Total	26,757 m	6,637 m	20,120 m
	Breakdown by type of pavement as per attached sheet			
7. Related Structures of Distributing Pipes	Sluice valve (box): ø200 mm	33 units	4 units	29 units
	ø150 mm	28 "	6 "	22 "
	ø100 mm	64 "	3 "	61 "
	Blow-off:			
	ø200 mm	2 "	Wash-out	2 "
	ø150 mm	3 "	9 Nos.	3 "
	Pipe and work:			
	ø100 mm	10 "		10 "
	ø150 mm	3 "		3 "
	ø200 mm	2 "		2 "
8. Public Post		15 places	5 places	10 places

* The existing facilities can not be used.

Table 3-3-5 (2)

Breakdown of Transmission Pipes and Distributing Pipes by Pavement (Only Water-Supply Systems to be Constructed Anew)

Jenidah

Item / Type	By Type of Pavement: As	R.C	Bricks	Kutcha	Total	Remarks
1. Transmission Pipes						
ø8"(No.1)	690m				690m	
ø8"(No.2)	530				530	
ø8"(No.3)				40m	40	
Total	1,220			40	1,260	
2. Distributing Pipes						
ø4"(Parallel to the road)	720m	220m	4,290m	6,190m	11,420m	
ø4"(Crossing the road)	100	10	40	20	170	
Sub-Total	820	230	4,330	6,210	11,590	
ø6"(Parallel to the road)	940	-	830	1,250	3,020	
ø6"(Crossing the road)	-	-	10	-	10	
Sub-Total	940	-	840	1,250	3,030	
ø8"(Parallel to the road)	2,390	-	1,070	1,990	5,450	
ø8"(Crossing the road)	40	-	-	10	50	
Sub-Total	2,430	-	1,070	2,000	5,500	
Total	4,190	230	6,240	9,460	20,120	

3-4 Chuadanga Town

3-4-1 Outline of the Town

(1) Location and General Conditions

The town belongs to Chuadanga District of Kushutia Division and is located close to the border between India about 40 km west to Jenidah. The town has a total area of 112 square miles, of which 12.57 square miles is the municipal area.

As for traffic means, a railway which traverses the western side of Bangladesh cuts across the town while a national highway which crosses this railway also runs through it. Commercial activities that take advantage of these traffic means are brisk.

The town's population grew from 36,381 in 1974 to 45,185 in 1981 and to about 60,000 in 1984. There are six primary schools, four high schools, two colleges and three hospitals in the town.

(2) Topography and Geology

a. Topography

The town, being located on the delta formed by the Ganges River, has a flat surface of 12.0 m in elevation.

The town lies between the railway which cuts across its eastern side and the Mathabhanga River which cuts across its western side, and is largely divided into two sections, the north and the south, by the road (Meherpur-Jenidah line) which intersects the former two.

The town's urban area mainly extends along this road which runs through it. The outer periphery of the town comprises rural areas.

b. Geology

The soil of the town geologically consists of a thick deposit of Quaternary fluvial sediments. Stratigraphic facies of these sediments are clayey soil, sandy soil and gravel layers. Clayey soil is widely distributed on the surface in a layer about 8 m in thickness. The fine sand layer which contains a lot of clayey soil is distributed underneath this layer and is seen distributed in the southern part of the town but not in the northern side. Fine to medium grain sand layer with a thickness of around 50 m in the central section of the town is distributed underneath these two layers. Coarse particles forming medium grain sand to gravel are distributed at GL -60 m and deeper. Pebbles of 20 to 30 mm in diameter are found mixed in this layer.

(3) River System

The Mathabhanga River which flows from north to south on the eastern side of the town and past Darsana and Jessore merges at Khulna with the Madhumati River, a tributary of the Ganges River which originates in the Himalayas.

The Mathabhanga River displays a width of around 100 m, but during the dry season, the flow is reduced to a trickle.

(4) Climate

a. Rainfall

The town's annual mean rainfall is around 1,600 mm which is smaller than the national average. The amount of rainfall of the past five years is as presented in Table 3-4-1.

Table 3-4-1

(mm)

Month / Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1979*	1	35	2	79	33	142	372	252	154	71	28	8	1,177
1980*	3	43	51	1	207	203	176	253	96	201	0	0	1,233
1981*	2	74	101	232	237	69	432	258	258	0	0	54	1,717
1982*	11	0	65	95	41	104	281	198	81	61	73	0	1,010
1983*	1	15	80	88	160	67	170	366	154	311	0	16	1,428

A review of Table 3-4-1 shows that rainfall is abundant in the months from March to October with a particularly high concentration during April through September.

The months of little rainfall are from November to February which is the dry season. The amount of rainfall is particularly small in January.

b. Temperature

Since the temperature has not been regularly measured in Chadanga Town, the data recorded in Kushitia have been used as reference. The mean temperature during the monsoon season is 29°C and during the dry season, 18.5°C, with a relative temperature range of 10.5°C. Temperature changes during the 1979-1982 period are as presented in Table 3-4-2.

Table 3-4-2 Maximum and Minimum Temperature in Kushitia by Month (°C)

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	Max.	-	-	-	-	-	-	33.4	33.7	34.2	32.9	32.1	27.1
	Min.	-	-	-	-	-	-	26.4	25.1	25.7	23.5	20.0	14.2
1980	Max.	25.4	28.7	34.0	38.7	33.9	33.1	30.3	31.5	33.6	31.2	36.3	27.5
	Min.	11.1	13.6	19.2	24.5	23.3	26.3	26.5	26.3	26.4	24.0	18.3	13.9
1981	Max.	25.1	27.5	32.7	33.0	40.1	34.1	32.6	31.4	33.2	33.3	23.0	25.1
	Min.	12.1	14.5	17.9	21.9	29.6	26.3	24.3	26.4	25.1	23.1	17.0	13.1
1982	Max.	25.4	27.5	30.7	35.0	37.7	33.6	-	-	-	-	-	-
	Min.	12.2	14.7	18.8	22.8	25.8	26.4	-	-	-	-	-	-

A review of the record in Table 3-4-2 shows that the high temperature months are March to November with the maximum temperature being above 30°C and the minimum temperature above 15°C. The low temperature month is January, with the maximum temperature being 25°C and the minimum around 12°C.

3-4-2 Hydrogeological Outline and Possibility of Developing Groundwater

(1) Hydrogeological Outline

As indicated in the section on geology, layers of soil are geologically distributed beneath the ground surface in the sequence of clayey soil, fine sand layer mixed with clay, fine to medium grain sand layer and coarse grain (medium grain sand to gravel) layer. When these layers are evaluated for aquiferous capacity, the coarse grain layer is quite excellent, the fine to medium grain layers good, and the clayey soil poor.

As for use of groundwater in the town by means of deep well, there are altogether five wells: two wells by DPHE (one of which is under construction), one by WDB, one by the railway and another by a hospital. DPHE also has 162 hand pumps. Wells related to DPHE are as presented in Table 3-4-3.

Table 3-4-3

T/W No.	Total Depth	Soil of Aquifer	Screen		Pumpage	Static Water Level	Pumping Water Level	Time of Steady State Condition	Recovery Period	Water Quality			
			Length	dia.						pH	Fe	cl	T. Hard
			ft.	inch	IGPH	ft.	ft.	min	min				
1	349'6"	CS & G	80'	6"	26,760	23'0"	30'8"	720	7	7.1	0.7	15	
2	340'4"	CS & G	100'	6"	47,520	17'4"	34'6"	180	16	7.3	2.0		
Hand Pump	125'	FS & MS	-	1.5"	DPHE 162								

As shown in Table 3-4-3, hand pumps up water from the fine sand to medium grain sand layers, and the deep wells from the coarse grain layer.

Judging from the recovery period of the water level in the deep wells, the coarse grain layer is thought to contain much groundwater.

The groundwater level in T.W. No.1 was GL -6.9 m at the time of construction (August 3, 1983) and GL -6.7 m when checked this time (April 1984, and in T.W. No.2, GL -5.4 m at the time of its pumping test (on April 26, 1984) and GL -5.1 m when checked this time (April 18, 1984). From these data, the water level during the dry season is inferred to be GL -6 m to -7 m.

The water quality, according to existing data, is judged to present no problem as drinking water.

(2) Possibility of Developing Groundwater

The possibility of developing groundwater was analyzed systematically hereunder on the basis of existing data shown in Paragraph (1).

a. Hydraulic constants

i. Coefficient of infiltration T in m^2/min

T.W. No.1 : $T = 2.5$ to $4.6\ m^2/min$

T.W. No.2 : $T = 0.9$ to $1.5\ m^2/min$

ii. Coefficient of permeability K in cm/sec

From $K = \frac{T}{m}$ where m is the strainer length,

T.W. No.1 : $K = 1.7$ to 3.2×10^{-1} cm/sec

T.W. No.2 : $K = 5.0$ to 8.0×10^{-1} cm/sec

iii. Specific yield of well S in m^3/day/m

T.W. No.1 : S = 1,270 m^3/day/m

T.W. No.2 : S = 1,006 m^3/day/m

Judging from the values calculated as above in which all of T, K, and S indicate large values, the coarse grain layer from which groundwater is intaken is known to contain a lot of groundwater.

b. Influence area of wells

As for the influence area of wells, intervals of 1,000 m or more between wells is presumed satisfactory judging from the data shown in Table 3-2-5 applicable to the layers from which groundwater is to be exploited, which are the medium grain sand to gravel layers.

Judging from a. and b. above, it was concluded that groundwater in this town may be developed with no problem at all so long as the adjacent wells are spaced 1,000 m (R = 500 m) or more apart from each other and the pumped volume of water is restricted to less than Q = 180 m^3/h per well.

3-4-3 Water Source Plan

The water sources which supply drinking water for the town now are one deep well (with the pumping rate of 122 m^3/h) and 162 hand pumps (of which about 20 are out of order). River water is not used.

Studies on the future sources of drinking water supply - based on the prevalent state - resulted in the following conclusions.

a. Groundwater

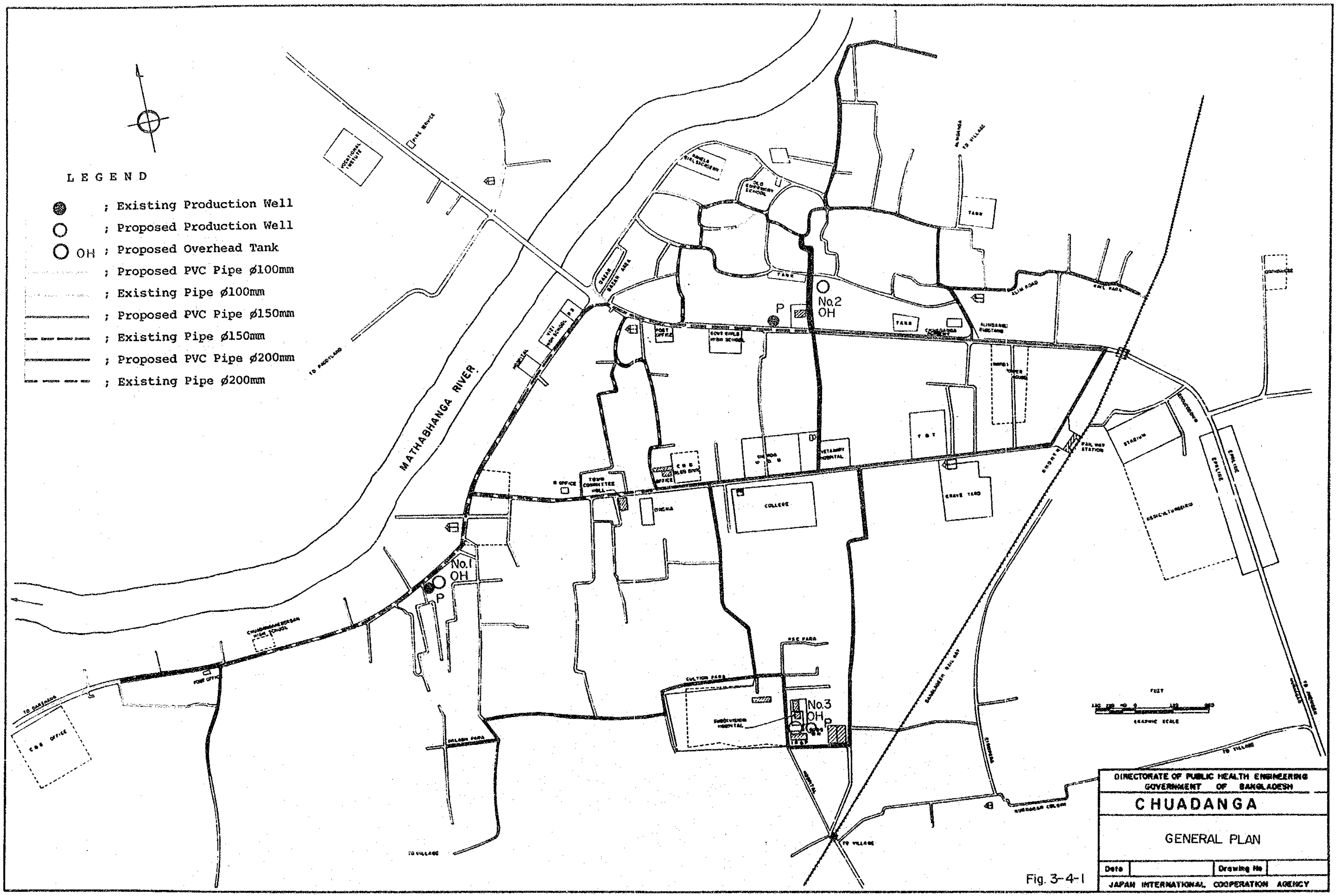
According to data on wells that are now under construction or already constructed, the layers in which a lot of groundwater is likely to contained are the medium grain sand to gravel layers distributed at GL -60 m and deeper. The data so far obtained indicate the potential pumping rate from these layers to range between 122 to 216 m^3/h.

As described in Section 3-4-2, the development of groundwater in this town is possible.

b. River water

As mentioned in the section on river system, the Mathabhanga River which flows south on the east side of town becomes a trickle during the dry season.

On the basis of a. and b. above, groundwater is judged to be the better choice as the water source for the town.


LEGEND
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; Existing Pipe ø150mm
; Proposed PVC Pipe ø200mm
; Existing Pipe ø200mm
MATHABHANGA RIVER
No.1 OH
P
No.2 OH
P
No.3 OH
P
COLLEGE
DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH
CHUADANGA
GENERAL PLAN
Date
Drawing No
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 3-4-1

3-4-4 Water Supply Plan

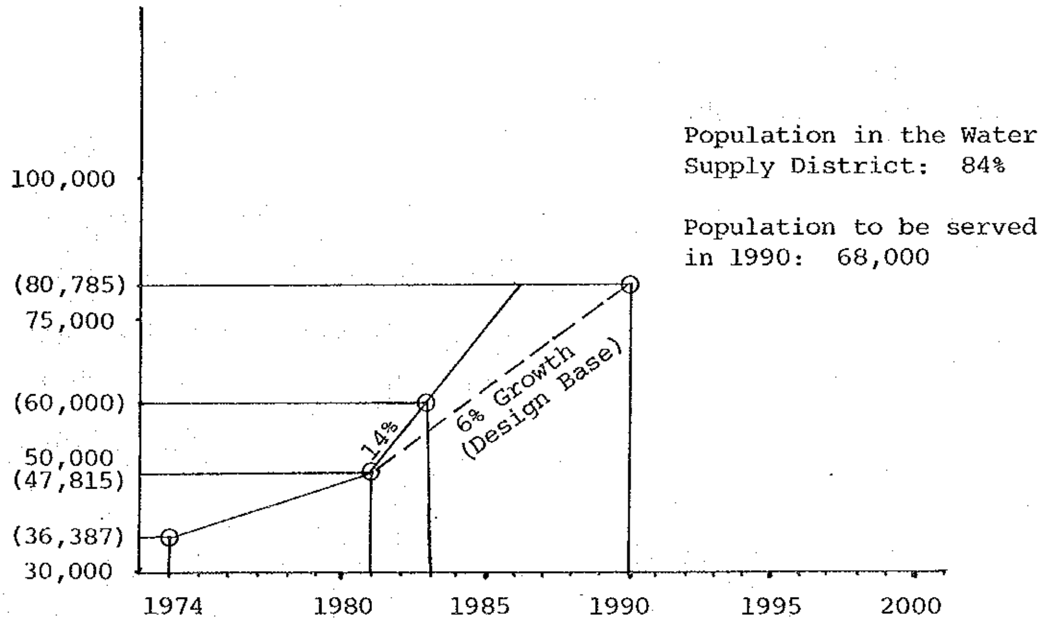
(1) Water Supply District and Population Supplied

The population data at the time of censuses in 1974, 1981 and today (May 1984) are as follows:

Population at the 1974 census	:	36,387
Population at the 1981 census	:	47,815
Population as of May 1984	:	60,000

These data may be plotted as follows:

Population Growth in Chuadanga Town



The average annual rate of population growth between 1974 and 1981 was about 4%, but the average annual growth rate between 1981 and now was 14% because of the large inflow of population from the rural areas. Since it is unlikely that the population will keep growing at this rate, as mentioned in the chapter on Jenidah, a population growth rate of 6% was assumed for the years up to 1990, the target year of this project. Thus, the population in 1990 was projected to be 81,000.

The water supply district was determined in consideration of the present geographic distribution of population, the prevalent state of settlement formation and the direction of future development of residential areas, and the population to which water is to be supplied was estimated to be about 84% of the town's population. The population to which water would be supplied in 1990 therefore was estimated to be 68,000.

(2) Water Consumption

The estimated amount of water supply to serve a population of 68,000 would be as follows.

$$Q = 81 \text{ liters/man-day} \times 68{,}000 \text{ men} = 5{,}508 \text{ m}^3\text{/day}$$

(3) Water Supply Facilities Plan

(i) Production wells

a. Diameter of well and pumping rate

According to existing data, the pumping rate is in the range of 112 to 216 m^3/h for a well of 6" diameter and drawdown of 2 to 4 m. As for pumping rate, a definite economic pumping rate has not been determined yet, but judging from existing data, a pumping rate of 180 m^3/h can probably be expected. As this pumping rate is large, the diameter would have to b 8".

b. Drawing depth

Judging from the inferred geologoical profile presented in Figs. 3-10-7 and 3-10-8, the drawing depth will be targeted to the medium grain sand to gravel layers distributed at GL -60 m and deeper.

c. Number of wells

$$x = \frac{Q}{Qy} = \frac{5,508}{180 \times 12} = 2.6 \fallingdotseq 3 \text{ wells}$$

As two producing wells have already been completed by DPHE so far, one other new well will be constructed under this project.

(ii) Pump facilities

When the suction level inside the well is assumed to be (-) 20 m from the ground level and the discharge level 20.0 m above ground, which is the same as the high water level in the overhead tank, the actual head would be 40.0 m

Studies of the pump facility for each well resulted in the following table.

Table 3-4-4 Principal Particulars of Pump Facilities

Well No. / Description	1	2	3
1. Actual head, m	40.0	40.0	40.0
2. Pumping rate, ℓ/sec	42.5	42.5	42.5
3. Transmission pipe			
Kind of pipe:	Cast iron pipe	"	"
Diameter, mm	200	200	200
Length, m	40	310	40
4. Loss of head in the transmission pipe, m	0.63	4.85	0.63
5. Total head, m	40.63	44.85	40.63
6. Type of pump	Multi-stage turbine	"	"
7. No. of stages	6	7	6
8. Motor output, kW	30	30	30

(iii) Overhead tank

The required total tank capacity is

$$V = 5,508 \times 0.20 = 1,101.6 \text{ m}^3.$$

Accordingly, three overhead tanks with the capacity of 400 m^3 each will be planned with due consideration to their locational arrangement.

(iv) Distribution pipe

Arrangement (layout) of the distributing pipes was determined in consideration of the geographical distribution of population, the locations of existing wells and distributing pipes, the road conditions, the direction of future development of residential areas, etc. All distributing pipes will be PVC pipes of ϕ200 mm or smaller.

The hydraulic calculations for the pipeline network were carried out on the basis of the design conditions so as to secure a hydraulic pressure of 9.0 m (0.9 kg/cm^2) at every terminal end of the distributing main and branch.

(v) Public post

The discharge rate of a ϕ13 mm tap is 20 liters/min (14.4 m^3/12 h). Since the plan calls for supplying water to 50% of the inhabitants by means of public posts, the quantity of water supply would be:

$$Q = 68{,}000 \text{ persons} \times 0.5 \times 34 \text{ liters/man-day}$$
$$= 1{,}156 \text{ m}^3\text{/day}$$

The required number of public posts, therefore, is 81. Under this project, public posts will be constructed at 10 locations while the balance would probably be constructed by the Government of Bangladesh.

3-4-5 Contents of the Project

(1) Water Supply Facilities Already Completed by DPHE

The contents of water supply facilities already constructed by DPHE's own funds are as presented in Table 3-4-5.

(2) Water Supply Facilities to be Constructed under this Project

The contents of water supply facilities to be constructed under this project, which have been determined on the basis of the contents of water supply facilities of this project as a whole and the contents of facilities already completed by DPHE, are as presented in Table 3-4-5, and the proposed plan for them is as shown in Fig. 3-4-1.

Table 3-4-5(1) Outline of the Water-Supply Systems to be Constructed in This Project

Chuadanga

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
1. Production Well	ø380 mm x ø200 mm Depth: 120 m Strainer: 30 m	3 Nos.	2	1 No.
2. Pumping Facilities	B10D 7 stages x 30 kW x 1 unit B10D 6 stages x 30 kW x 2 units	3 units	0 (The existing pumping facil-ities can not be used)	3 units
3. Pumping House	Brick-and-morter, pump room: 12.3 m² Driver's room: 8.8 m²	3 Nos.	2	1 No.
4. Transmis-sion Pipes of Dis-tributing Pipes	No.1 pumping station: ø200 mm	40 m	-	40 m
	No.2 pumping station: ø200 mm	310 m	-	310 m
	No.3 pumping station: ø200 mm	40 m	-	40 m
	Total	390 m	-	390 m
5. Overhead	Capacity: 400 m³ Reinforced concrete Height: 17 m	3 units	0	3 units
6. Distributing Pipes	PVC Pipe: ø200 mm ø150 mm ø100 mm	8,975 m 4,510 m 10,579 m	2,325 m 1,950 m 1,929 m	6,650 m 2,560 m 8,650 m
	Total	24,064 m	6,204 m	17,860 m
	Breakdown by type of pavement as per attached sheet			

(cont.)

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
7. Related Structures of Distributing Pipes	Sluice valve (box):			
	ø200 mm	39 units	9 units	30 units
	ø150 mm	29 "	7 "	12 "
	ø100 mm	74 "	13 "	61 "
	Blow-off:			
	ø200 mm	2 "	Wash-out	2 "
	ø150 mm	2 "	8 Nos.	2 "
	Pipe and work:			
	ø200 mm	0 "		0 "
	ø150 mm	3 "		3 "
	ø100 mm	24 "		24 "
8. Public Post		10 places	0	10 places

Tabel 3-4-5 (2)

Breakdown of Transmission Pipes and Distributing Pipes by Pavement (Only Water-Supply Systems to be Constructed Anew)

Chuadanga

Item / Type	By Type of Pavement: As	R.C	Bricks	Kutcha	Total	Remarks
1. Transmission Pipes						
ø8" (No.1)				40m	40m	
ø8" (No.2)	100m	170m	40m		310	
ø8" (No.3)				40	40	
Total	100	170	40	80	390	
2. Distributing Pipes						
ø4" (Parallel to the road)	900m	1,290m	5,570m	690m	8,450m	
ø4" (Crossing the road)	130	30	30	10	200	
Sub-Total	1,030	1,320	5,600	700	8,650	
ø6" (Parallel to the road)	780	670	1,080	-	2,530	
ø6" (Crossing the road)	20	-	10	-	30	
Sub-Total	800	670	1,090	-	2,560	
ø8" (Parallel to the road)	3,790	1,070	440	1,320	6,620	
ø8" (Crossing the road)	30	-	-	-	30	
Sub-Total	3,820	1,070	440	1,320	6,650	
Total	5,650	3,060	7,130	2,020	17,860	

3-5 Kurigram Town

3-5-1 Outline of the Town

(1) Location and General Conditions

The town belongs to Kurigram District of Rajshahi Division, and is located on the bank of the Jamuna River about 40 km to the east of Rangpur. The town has a total area of 106.4 square miles, of which 98.4 square miles is the municipal area.

As for traffic means, a railway leading to Tist cuts across the town while a road parallel to it leads to Rangpur. Another road which forms a T with this road runs south from the center of the town to Chilmari.

The town's population grew from 30,129 in 1974 to 46,132 in 1981 and 55,000 in 1984. There are 11 primary schools, four high schools, two colleges, two Madrashas and one hospital in the town.

(2) Topography and Geology

a. Topography

Due to the delta-like thick deposit of alluvial sediments formed by the Jamuna River that originates in China, the town has a flat surface of 27 m in elevation. The town is divided into three sections by the railroad that traverses it and by the road which forms a T with the railroad. An urban area that dates back to the early days is formed on the eastern side of town, while a new urban area is in the process of being formed on the western side. Rural areas extend to the north of town.

b. Geology

Geologically, Quaternary fluvial sediments are thickly deposited. Stratigraphic facies of this deposit consist of clayey soil, sandy soil and gravel layers as follows.

Clayey soil is deposited between GL 0 m and GL -9 m with the average thickness of 6 m. The clayey soil is mixed with sand. Underneath this layer is sandy soil mainly consisting of fine sand. The thickness of this layer ranges between 3 to 21 m with partial intercalation of medium grain sand. In the neighborhood of GL -25 m and deeper, layers composed of coarse sand and gravel are thickly distributed. Large pebbles (cobble stones) are intersparsed in this gravel layer.

(3) River System

The Dharla River which flows from north to east of the town and then southward, merges at the southeastern part of Rangpur District with the Jamuna River, which originates in China. This river displays a river width of around 180 m on the northern side of town but narrows down to around 60 m on the eastern side. During the dry season, it becomes only a trickle.

(4) Climate

a. Rainfall

The annual mean amount of rainfall in the town is about 2,100 mm or so, which conforms to the average rainfall of the country as a whole. Rainfall data of the past five years are shown in Table 3-5-1.

Table 3-5-1

(mm)

Month / Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1979	0	4	0	14	87	281	786	632	442	157	1	3	2,408
1980	0	18	27	117	425	240	318	284	381	61	0	3	1,873
1981	9	18	41	84	368	116	471	422	211	0	0	52	1,791
1982	0	0	34	64	183	625	279	286	636	62	4	0	2,172
1983	7	22	51	76	316	350	819	334	371	187	0	25	2,557

A review of the data in Table 3-5-1 shows a large amount of rainfall in the months of April to October, with a particularly high concentration during the months of May to September. This rainy season coincides with the monsoon period, and the rainfall during this period accounts for 90% or more of the annual amount of rainfall.

b. Temperature

As the temperature has not been regularly measured in Kurigram Town, the records of Rangpur were used for reference. The mean temperature during the monsoon period is about 28.5°C and in the dry season, 16.5°C, with a relative temperature range of 12°C.

Temperature changes during the past four years are as shown in Table 3-5-2.

Table 3-5-2 Maximum and Minimum Temperature by Month

(°C)

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1979*	Max.	-	-	-	-	-	-	-	32.2	32.2	30.0	27.8	23.9
	Min,	-	-	-	-	-	-	25.4	26.0	25.6	23.0	19.0	14.0
1980*	Max.	22.7	25.5	30.0	33.3	29.4	32.6	31.0	31.0	31.2	29.0	28.0	25.8
	Min.	10.2	13.0	17.5	24.8	22.6	25.9	25.7	26.5	24.7	23.0	17.0	13.9
1981*	Max.	22.9	24.8	30.1	29.9	29.9	31.9	-	-	-	32.3	28.7	24.8
	Min.	11.7	13.8	17.1	20.0	22.3	25.6	-	-	-	23.3	16.3	12.7
1982*	Max.	24.6	25.5	29.3	31.1	32.2	30.7	-	-	-	-	-	-
	Min.	11.6	12.5	16.2	20.8	23.7	25.1	-	-	-	-	-	-

A review of the records in Table 3-5-2 indicates that the high temperature months are March to October with the maximum temperature being about 30°C or more and the minimum above 15°C. The low temperature month is January with the maximum temperature being around 23°C and the minimum around 11°C.

3-5-2 Hydrogeological Outline and Possibility and Developing Groundwater

(1) Hydrogeological Outline

Soils distributed in the town geologically consist of clayey soil, sandy soil and gravel layers, as described in the section on geology. When these are evaluated for aquiferous capacity, gravel is quite excellent, sandy soil good, and clayey soil poor.

As for use of groundwater by means of deep well, there are two wells in the town, one built by DPHE (not used yet) and another by C&B. There are also 330 shallow wells (of which 50 are out of order) by DPHE.

The wells related to DPHE are as shown in Table 3-5-3.

Table 3-5-3

T/W No.	Total Depth	Soil of Aquifer	Screen		Pumpage	Static Water Level	Pumping Water Level	Time of Steady State Condi-tion	Recov-ery Period	Water Quality			
			Length	dia.						pH	Fe	cl	T. Hard
	ft.		ft.	inch	IGPH	ft.	ft.	min	min				
1	140'0	CS	60'	8"	47,520	10'0"	20'0"	420	35	7.1	2.5	40	
Hand Pump	50'0"	FS .	-	1.5"	DPHE 330 (of which 50 are out of order)								

Of the wells shown in Table 3-5-3, the hand pumps draw water from the fine sand layer, and the deep wells from the coarse grain layer.

The groundwater level in T.W. No.1 was GL -3 m at the time of its construction (in July 1981).

As for the quality of water, results of test boring show a generally high iron content with a high Fe value of 4 to 9 ppm to the depth of GL -60 m. As shown in Table 3-5-3, a low Fe value of 2.5 ppm was obtained in T.W. No.1 at the same depth.

(2) Possibility of Developing Groundwater

The possibility of developing groundwater was systematically analyzed as follows based on existing data given in Paragraph (1).

a. Hydraulic constants

i. Coefficient of infiltration T in m^2/min

T.W. No.1 : T = 6.0 to 8.2 m^2/min

ii. Coefficient of permeability K in cm/sec

From $K = \frac{T}{m}$ where m is the strainer length,

T.W. No.1 : K = 5.6 to 7.6 x 10^{-1} cm/sec

iii. Specific yield of well S in $m^3/day/m$

T.W. No.1 : S = 288 $m^3/day/m$

As all of the calculated values of T, K and S have large values, the coarse grain layer from which groundwater is intaken is judged to be satisfactory for developing groundwater.

b. Influence area of wells (Sphere of interference between wells)

As for the influence area of wells, intervals of 1,000 m or more between wells are presumed satisfactory judging from the data of Table 3-2-5 applicable to the layers from which groundwater is to be exploited, namely the coarse grain sand to gravel layers.

From a. and b. above, it was judged that groundwater in this town may be developed with no problem at all so long as the adjacent wells re spaced 1,00 m or more apart and the pumping rate Q is restricted to less than 180 m^3/h. However, the iron content in this town is high according to the water quality test results which are available on hand. Accordingly, iron removal equipment must be considered for this town.

3-5-3 Water Source Plan

The water sources from which drinking water for the town is supplied now are the 330 hand pumps. River water is not used.

A study of the future water sources of drinking water supply - based on the prevalent state - resulted in the following conclusions.

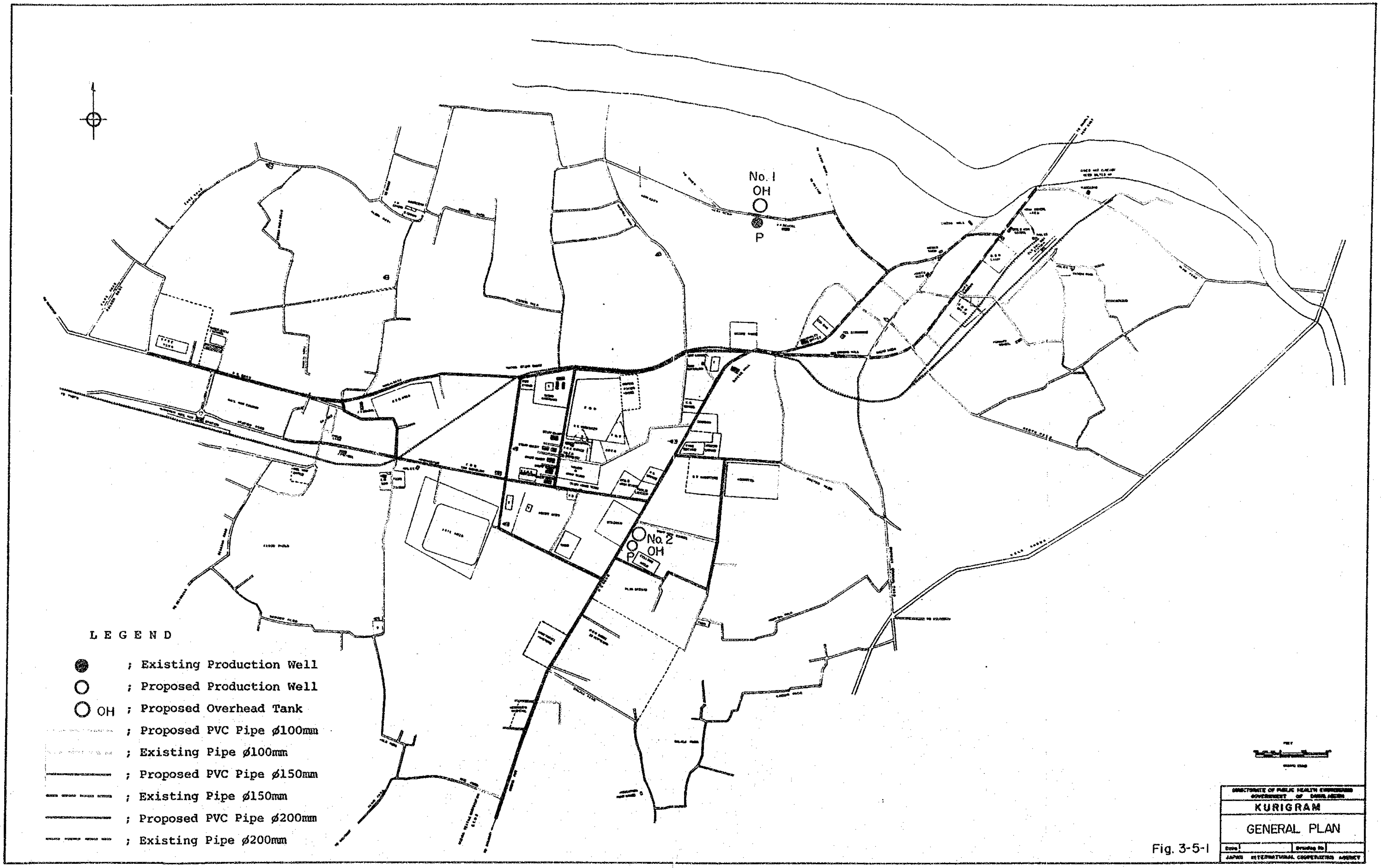
a. Groundwater

According to relevant data on wells, the layer in which a lot of groundwater is likely to be stored is judged to be the coarse grain layer distributed deeper than GL -25 m. The data show that the volume of water which can be pumped from this layer is 216 m^3/h. Also, as mentioned in Section 3-5-2, the development of groundwater in this town is considered possible.

b. River water

As mentioned in the section on river system, the Dharla River which flows from north to east of the town becomes only a trickle during the dry season.

On the basis of a. and b. above, groundwatet is judged to be the better choice as the water source for the town.


No. 1
OH
P
No. 2
OH
P
LEGEND
; Existing Production Well
; Proposed Production Well
OH ; Proposed Overhead Tank
; Proposed PVC Pipe ø100mm
; Existing Pipe ø100mm
; Proposed PVC Pipe ø150mm
; Existing Pipe ø150mm
; Proposed PVC Pipe ø200mm
; Existing Pipe ø200mm
KURIGRAM
GENERAL PLAN
Fig. 3-5-1

3-5-4 Water Supply Plan

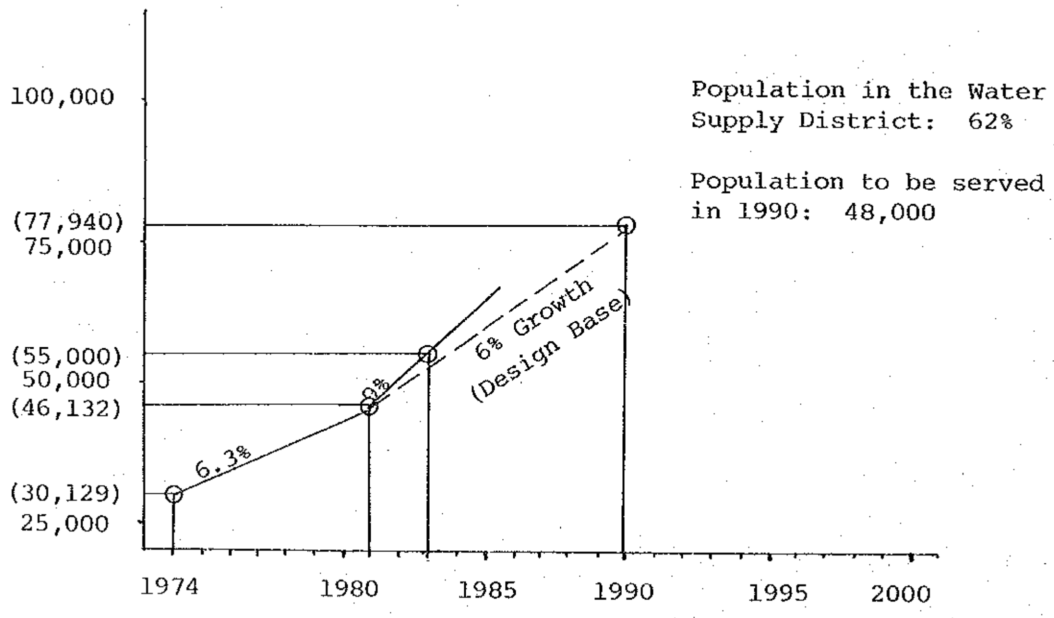
(1) Water Supply District and Population to Be Supplied

Population at the time of censuses in 1974, 1981 and today (May 1984) are as follows.

Population at the 1974 census	:	30,129
Population at the 1981 census	:	46,132
Population as of May 1984	:	55,000

These data may be plotted as follows.

Population Growth in Kurigram Town



The average annual rate of population growth was 6.3% between 1974 and 1981 and 9% between 1981 and now. As was the case with other towns, the population growth rate from 1981 to the target year of this project (1990) was assumed to be 6% a year on average. Thus, the population in 1990 was projected to be 78,000.

The water supply district was determined in consideration of the present geographic distribution of population, the prevalent state of settlement formation and the direction of future development of residential areas, and the population to which water is to be supplied was estimated to be about 62% of the town's population. The population to which water would be supplied in 1990 therefore was estimated to be 48,000.

(2) Water Consumption

The estimated amount of water to serve a population of 48,000 would be as follows.

$$Q = 81 \text{ liters/man-day} \times 48{,}000 \text{ men} = 3{,}888 \text{ m}^3\text{/day}$$

(3) Water Supply Facilities Plan

(i) Production well

a. Diameter of well and pumping rate

According to existing data, the pumping rate is in the range of $216 m^3/h$ for a well of 6" diameter and draw down of 3 m.

Judging from these results, a pumping rate of $180 m^3/h$ or more can be expected.

The wells are currently constructed with a diameter of 6", but since the pumping rate is large, it would be better to plan for a diameter of 8" for better efficiency and longer life.

b. Drawing depth

Judging from the inferred geological profile shown in Fig. 3-10-10, the drawing depth will be targeted to the coarse grain layer distributed at GL -25 m and deeper.

c. Number of wells

$$x = \frac{Q}{Qy} = \frac{3,888}{180 \times 12} = 1.8 \fallingdotseq 2 \text{ wells}$$

(ii) Pump facilities

Assuming that the suction level inside the well is (-) 20.0 m from the ground level and the discharge level is 20 m above ground which is the high water level of the overhead tank , the actual head would become 40.0 m.

A study of the pump facilities for each well resulted in the following table.

Table 3-5-4 Principal Particulars of Pump Facilities

Description \ Well No.	1	2
1. Actual head, m	40.0	40.0
2. Pumping rate, ℓ/sec	41.3	48.8
3. Transmission pipes		
Kind of pipe	Cast iron pipe	"
Diameter, mm	200	200
Length, m	40	40
4. Loss of head in the transmission pipes, m	0.59	0.81
5. Total head, m	40.59	40.81
6. Type of pump	Multi-stage turbine	"
7. No. of stages	5	5
8. Motor output, kW	30	30

(iii) Overhead tank

The required total overhead tank capacity is

$V = 3{,}888 \times 0.20 = 777.6\ m^3$

Accordingly, two overhead tanks with the capacity of 400 m^3 each will be planned with due consideration to their locational arrangement. The height of the overhead tank to be provided at the location of the producing well and the pump facilities which are now being constructed by DPHE shall be 22 m (the minimum water level of the water tower) in view of the loss of head. Other overhead tank shall be 17.0 m high.

(iv) Distributing pipe

Arrangement (layout) of the distributing pipes will be planned with due consideration to the geographic distribution of population, the locations of existing wells and distributing pipes, the road conditions, the direction of future development of residential areas, etc. All distributing pipes shall be PVC pipes with diameters of ø200 mm or less.

The hydraulic calculations for the pipeline network were carried out on the basis of the design conditions so as to secure the hydraulic pressure of 9.0 m at every terminal end of the distributing main and branch.

(v) Public post

The discharge rate from ø13 mm tap is 20 liters/min (14.4 m^3/12 h). As the scheme calls for supplying water to 50% of the inhabitants by means of public posts, the required quantity of water supply would be:

$$Q = 48{,}000 \text{ persons} \times 0.5 \times 34 \text{ liters/man-day}$$
$$= 816.0 \text{ m}^3\text{/day}$$

Thus, the required number of public posts is 57.

Under this project, water posts will be constructed at 10 locations while the balance will probably be constructed by the Government of Bangladesh.

3-5-5 Contents of the Project

(1) Water Supply Facilities Already Completed by DPHE

The contents of water supply facilities already constructed by DPHE's own funds are shown in Table 3-5-5.

(2) Water Supply Facilities to be Constructed under this Project

The contents of water supply facilities to be constructed under this project, which were determined on the basis of the contents of water supply facilities of this project as a whole and the contents of facilities already completed by DPHE, are as shown in Table 3-5-5, and the proposed plan for them is as shown in Fig. 3-5-1.

Table 3-5-5(1) Outline of the Water-Supply Systems to be Constructed in This Project

Kurigram

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
1. Production Well	∅380 mm x ∅200 mm Depth: , 63 m Strainer: 18 m	2 Nos.	1 No.	1 No.
2. Pumping Facilities	B10D 5 stages x 30 kW x 1 unit B10D 5 stages x 30 kW x 1 unit	2 units	0	2 units
3. Pumping House	Brick and mortar Pump room 12.3 m^2 Driver's room 8.8 m^2	2 Nos.	1	1 No.
4. Transmission Pipes	No.1 pumping station: ∅200 mm	40 m	-	40 m
	No.2 pumping station: ∅200 mm	40 m	-	40 m
5. Overhead Tank	Capacity: 400 m^3 Height: 17/22 m Reinforced concrete	2 units	0	2 units
6. Distributing Pipes	AC Pipe: ∅200 mm	300 m	300 m	-
	PVC Pipe: ∅200 mm	3,850 m	350 m	3,500 m
	∅150 mm	9,580 m	2,220 m	7,360 m
	∅100 mm	13,490 m	960 m	12,530 m
	Total	27,220 m	3,830 m	23,390 m
	Breakdown by type of pavement as per attached sheet			

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
7. Related Structures of Distributing Pipes	Sluice valve (box): ∅200 mm	17 units	-	17 units
	∅150 mm	43 "	4 units	39 "
	∅100 mm	69 "	2 "	67 "
	Blow-off: ∅200 mm	2 "	Wash-out	2 "
	∅150 mm	5 "	4 Nos.	5 "
	Pipe and work: ∅100 mm	23 "		23 "
	∅150 mm	2 "		2 "
	∅200 mm	-		-
8. Public Post		30 places	20 places	10 places

Table 3-5-5 (2)

Breakdown of Transmission Pipes and Distributing Pipes by Pavement (Only Water-Supply Systems to be Constructed Anew)

Kurigram

Type / Item	By Type of Pavement: As	R.C	Bricks	Kutcha	Total	Remarks
1. Transmission Pipes						
∅8"(No.1)				40m	40m	
∅8"(No.2)				40	40	
Total				80	80	
2. Distributing Pipes						
∅4"(Parallel to the road)	2,550m	930m	2,200m	6,700m	12,380m	
∅4"(Crossing the road)	120	10	10	10	150	
Sub-Total	2,670	940	2,210	6,710	12,530	
∅6"(Parallel to the road)	4,520	1,240	760	780	7,300	
∅6"(Crossing the road)	30	10	10	10	60	
Sub-Total	4,550	1,250	770	790	7,360	
∅8"(Parallel to the road)	1,850	1,630			3,480	
∅8"(Crossing the road)	10	10			20	
Sub-Total	1,860	1,640			3,500	
Total	9,080	3,830	2,980	7,500	23,390	

3-6 Gaibandha Town

3-6-1 Outline of the Town

(1) Location and General Conditions

The town belongs to Gaibandha District of Rajshahi Division and is located on the right bank of the Jamuna River about 60 km to the southeast of Rangpur. The town has a total area of 23.94 square miles, of which 2.33 square miles is its municipal area.

As for traffic means, a railway cuts across the town from north to south, and a road parallel to it extends to Rangpur. Another road which forms a T with this road extends to Pasbari. Commercial activities mainly dealing in farm products by the use of these traffic means have prospered from early on.

The town's population grew from 27,401 in 1974 to 38,342 in 1981 and 45,000 in 1984. There are 14 primary schools, six high schools, two colleges, one Madrasha and four hospitals in the town.

(2) Topography and Geology

a. Topography

Due to the delta-like thick deposit of alluvial sediments formed by the Jamuna River that originates in China, the town has a flat surface of 27 m in elevation. The urban area of the town is formed on the south of the railroad station, extending along the east-west road and the southern road. The suburbs are rural areas mostly comprising rice paddies and dry fields.

b. Geology

Geologically, Quaternary fluvial sediments are thickly deposited. Stratigraphic facies of this deposit consist of clayey soil, sandy soil, gravel and coarse sand layers as follows.

Clayey soil is distributed between GL 0 m to GL -6 m, forming a layer around 5 m in average thickness. The clayey soil is mixed with sand. Underneath this layer is the sand layer mainly composed of fine sand. Underneath these two layers, a gravel layer around 35 m thick is distributed. In this layer, two 3 m thick cobble stone layers have been confirmed.

Layers comprised of medium to coarse grain sand are distributed deeper than GL -55 m.

(3) River System

The Chaghat River which flows east on the northern side of the town merges at the eastern side of Gaibandha District with the Jamuna River, which originates in China. The Chaghat River displays a river width of around 60 m, but during the dry season, its flow becomes only a trickle.

(4) Climate

a. Rainfall

The town's annual mean rainfall is around 2,000 mm, which is slightly lower than the national average.

Rainfall data of the past two years are shown in Table 3-6-1. As a reference, the records of rainfall observed in Rangpur during the past four years are also shown.

Table 3-6-1 Monthly Rainfall in Gaibandha and Rangpur

(mm)

	Month / Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
Gaiban-dha	1983	1	3	4	100	328	78	197	274	417	490	0	30	1,922
	1984	9	1	23	29	-	-	-	-	-	-	-	-	
Rangpur	1979	-	-	-	-	-	-	422	513	441	131	22	43	
	1980	1	140	220	38	354	429	278	579	335	61	0	0	2,435
	1981	20	10	13	137	433	104	577	346	447	0	0	45	2,132
	1982	0	7	5	94	99	635	-	-	-	-	-	-	

A review of the rainfall data in Table 3-6-1 shows a large amount of rainfall in the months of April to October. This rainy season coincides with the monsoon season, and the rainfall during this period accounts for 90% or more of the annual amount of rainfall.

b. Temperature

As the temperature has not been regularly measured in Gaibandha Town, the records of Rangpur were used for reference. The mean temperature during the monsoon period is about 29°C, and in the dry season, 17°C, with a relative temperature range of 12°C.

Temperature changes during the past four years are as shown in Table 3-6-2.

Table 3-6-2 Maximum and Minimum Temperature in Rangpur by Month (°C)

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	Max.	-	-	-	-	-	-	-	32.2	32.2	30.0	27.8	23.9
	Min.	-	-	-	-	-	-	25.4	26.0	25.6	23.0	19.0	14.0
1980	Max.	22.7	25.5	30.0	33.3	29.4	32.6	31.0	31.0	31.2	29.0	28.0	25.8
	Min.	10.2	13.0	17.5	24.8	22.6	25.9	25.7	26.5	24.7	23.0	17.0	13.9
1981	Max.	22.9	24.8	30.1	29.9	29.9	31.9	-	-	-	32.3	28.7	24.8
	Min.	11.7	13.8	17.1	20.0	22.3	25.6	-	-	-	23.3	16.3	12.7
1982	Max.	24.6	25.5	29.3	31.1	32.2	30.7	-	-	-	-	-	-
	Min.	11.6	12.5	16.2	20.8	23.7	25.1	-	-	-	-	-	-

A review of the records in Table 3-6-2 indicates that the high temperature months are March to October with the maximum temperature being 30°C or more and the minimum above 15°C. The low temperature month is January with the maximum temperature being around 23°C and the minimum around 11°C.

3-6-2 Hydrogeological Outline and Possibility of Developing Groundwater

(1) Hydrogeological Outline

Soils distributed in the town geologically consist of clayey soil on the ground surface beneath which are sandy soil, gravel, and coarse sand layers as described in the section on geology. When these are evaluated for aquiferous capacity, the gravel to coarse sand layers are quite excellent, sandy soil good, and clayey soil poor.

As for use of groundwater in this town, there are two deep wells, on built by PWD and another by NDTI, and also 150 shallow wells by DPHE. These shallow wells have the average depth of 15 m and draw water from the fine sand layer.

The groundwater levels measured in the test boring holes (on April 29, 1984) were: GL -4.3 m in hole Nos. 1 and 4, GL -3.5 m in hole No.2 and GL -3.6 m in hole No.3. Judging from these results, the water level during the dry season is inferred to be in the neighborhood of GL -4.0 m.

As for the quality of water, iron content is high at GL -60 m and shallower places, with Fe values of the order of 10 to 15 ppm. At GL -60 m and deeper places, a low Fe value of 2.00 ppm is indicated.

(2) Possibility of Developing Groundwater

a. Hydraulic constants

Although there is no production well related to DPHE in this town, the town's geological features are similar to those of Kurigram, and therefore, the hydraulic constants are considered to be about the same as those in Kurigram.

Accordingly, when the quality of water is taken into account, it is considered advisable to seek for aquifer in the coarse sand layers distributed at GL -60 m and deeper to develop groundwater.

b. Influence area of wells

As for the influence area of wells, intervals of 1,000 m or more between wells is presumed satisfactory, judging from the data of Table 3-2-5 applicable to the coarse sand layer from which groundwater is to be exploited.

From a. and b. above, it was judged that groundwater in this town may be developed with no problem at all so long as the coarse sand layer with low iron content distributed in the neighborhood of GL -60 m and deeper is selected as the target aquifer and adjacent wells are spaced 1,000 m or more apart and the pumping rate Q is restricted to 150 m^3/h or less.

However, since the iron content in the groundwater tends to be generally high, a design with due regard to these factors is considered necessary for this town.

3-6-3 Water Source Plan

The drinking water for the town is currently supplied by 150 hand pumps, and river water is not used.

A study of the future water sources of drinking water supply - based on the prevalent state - resulted in the following conclusions.

a. Groundwater

According to relevant data on wells, the strata in which a lot of groundwater is likely to be stored are judged to be the gravel layer and coarse sand layer distributed at GL -20 m and deeper. Of these, the gravel layer has the drawback of having high iron contents, but the coarse sand layer distributed underneath it is the layer with low iron contents.

Since this stratum with low iron contents is composed of coarse sand layers, it is judged to be the layer subject to groundwater development.

b. River water

As mentioned in the section on river system, the Chaghat River which flows eastwards on the northern side of town becomes only a trickle during the dry season.

On the basis of a. and b. above, groundwater is judged to be the better choice as the water source for the town.

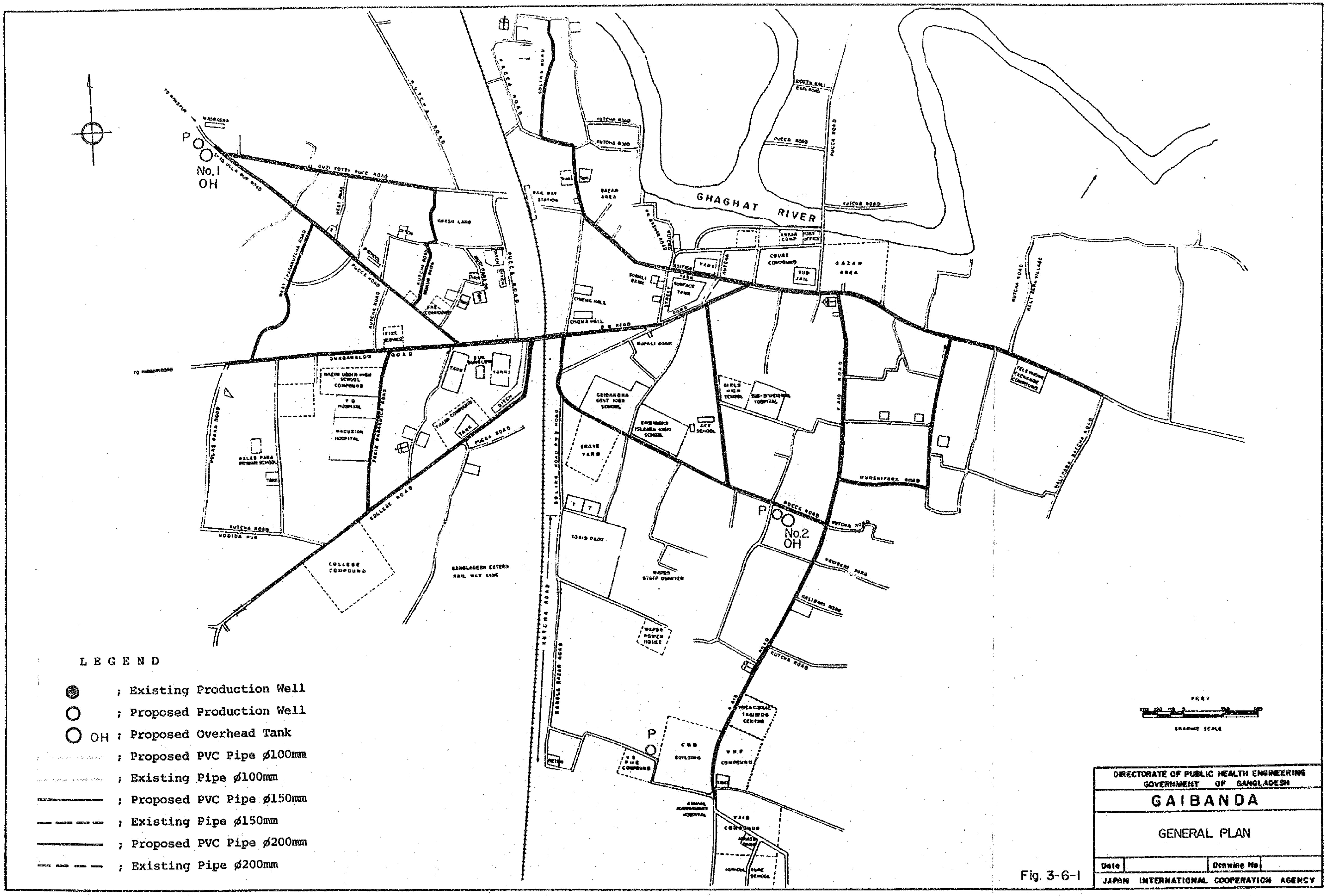

GHAGHAT RIVER
P
No.1
OH
P
No.2
OH
P
LEGEND
; Existing Production Well
; Proposed Production Well
OH ; Proposed Overhead Tank
; Proposed PVC Pipe ø100mm
; Existing Pipe ø100mm
; Proposed PVC Pipe ø150mm
; Existing Pipe ø150mm
; Proposed PVC Pipe ø200mm
; Existing Pipe ø200mm
DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH
GAIBANDA
GENERAL PLAN
Date
Drawing No
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3-6-1

3-6-4 Water Supply Plan

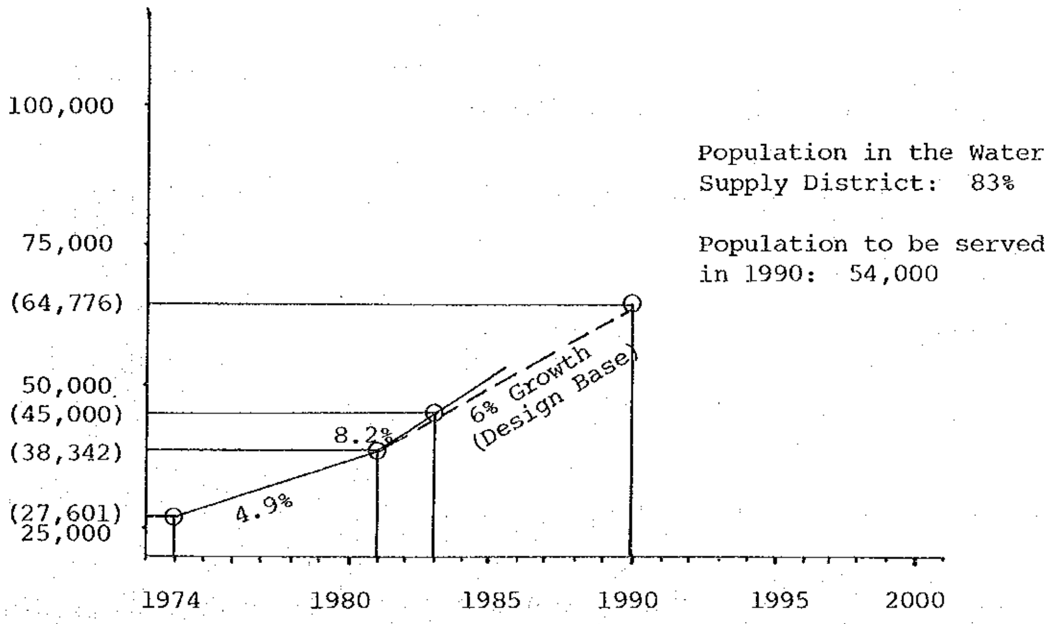
(1) Water Supply District and Population to be Supplied

Population at the time of censuses in 1974, 1981 and today (May 1984) are as follows.

Population at the 1974 census	:	27,401
Population at the 1981 census	:	38,342
Population as of May 1984	:	45,000

These data may be plotted as follows.

Population Growth in Gaibandha Town



The average annual rate of population growth was 4.9% between 1974 and 1981 and 8.3% between 1981 and now. As was the case with other towns, the population growth rate from 1981 to 1990 was assumed to be 6% a year for planning this project. Thus, the population in 1990 was projected to be 64,800.

The water supply district was determined with due consideration to the present geographic distribution of population, the prevalent state of settlement formation and the direction of future development of residential areas. The population within the water supply district was estimated to be about 83% of the town's population. The population to which water would be supplied in 1990 therefore was estimated to be 54,000.

(2) Water Consumption

The estimated amount of water to serve a population of 54,000 would be as follows.

$$Q = 81 \text{ liters/man-day} \times 54{,}000 \text{ men} = 4{,}374.0 \text{ m}^3\text{/day}$$

(3) Water Supply Facilities Plan

(i) Production well

a. Diameter of well and pumping rate

Since no production well of DPHE exists yet, data obtained in Kurigram were used as a reference, based on which it was considered advisable to plan for the pumping rate of $Q = 150 \text{ m}^3\text{/h}$ with 8" diameter well.

b. Drawing depth

Judging from the inferred geological profile shown in Fig. 3-10-9 and the groundwater conditions described in Section 3-6-2, the drawing depth will be targeted to the coarse sand layers distributed at GL -60 m and deeper.

c. Number of wells

$$x = \frac{Q}{Qy} = \frac{4,374}{150 \times 12} = 2.4 \fallingdotseq 3 \text{ wells}$$

(ii) Pump facilities

Assuming that the suction level inside the well is (-) 20.0 m from the ground level and the discharge level is 20 m above ground which is the high water level of the overhead tank , the actual head would become 40.0 m.

A study of the pump facilities for each well resulted in the following table.

Table 3-6-3 Principal Particulars of Pump Facilities

Description \ Well No.	1	2	3
1. Actual head, m	40.0	40.0	40.0
2. Pumping rate, ℓ/sec	37.5	31.9	31.9
3. Transmission pipes			
Kind of pipe	Cast iron pipe	"	"
Diameter, mm	200	150	250
Length, m	40	40	1,270
4. Loss of head in the transmission pipes, m	2.02	2.82	12.65
5. Total head, m	42.02	42.82	44.00
6. Type of pump	Multi-stage turbine	"	"
7. No. of stages	5	5	7
8. Motor output, kW	30	30	30

(iii) Overhead tank

The required total overhead tank capacity is

$$V = 4{,}374.0 \times 0.20 = 874.8 \text{ m}^3.$$

Accordingly, one overhead tank with the capacity of 400 m^3 and another one with the capacity of 500 m^3 (two sets of overhead tanks altogether) will be planned with due consideration to their locational arrangement.

(iv) Distributing pipe

Arrangement (layout) of the distributing pipes was planned with due consideration to the geographic distribution of population, the road conditions, the direction of future development of residential areas and other relevant factors. All distributing pipes shall be PVC pipes with diameter of ø200 mm or less.

The hydraulic calculations for the pipeline network were carried out on the basis of the design conditions so as to secure the hydraulic pressure of 9.0 m at every terminal end of the distributing main and branch.

(v) Public post

The discharge rate from a ø13 mm tap is 20 liters/min (14.4 m^3/12 h). As the plan calls for supplying water to 50% of the inhabitants by means of public posts, the required quantity of water supply would be:

Q = 54,000 persons x 0.5 x 34 liters/man-day
= 918.0 m^3/day

Thus, the required number of public posts is 64.

Under this project, water posts will be constructed at 10 locations while the balance will probably be constructed by the Government of Bangladesh.

3-6-5 Contents of the Project

(1) Water Supply Facilities Already Completed by DPHE

The contents of water supply facilities already constructed by DPHE's own funds are shown in Table 3-6-4.

(2) Water Supply Facilities to be Constructed under this Project

The contents of water supply facilities to be constructed under this project, which were determined on the basis of the contents of water supply facilities of this project as a whole and the contents of facilities already completed by DPHE, are as shown in Table 3-6-4, and the proposed plan for them is as shown in Fig. 3-6-1.

Table 3-6-4(1) Outline of the Water-Supply Systems to be Constructed in This Project

Gaibandha

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
1. Production Well	ø380 mm x ø200 mm Depth: 105 m Strainer: 24 m	3 Nos.	0	3 Nos.
2. Pumping Facilities	B10D 6 stages x 30 kW x 1 unit (No.3) B10D 5 stages x 30 kW x 2 units (No.1,2)	3 units	0	3 units
3. Pumping House	Brick and Mortar, Pump room 12.3 m^2 Driver's room 8.8 m^2	2 Nos.	0	2 Nos.
4. Transmission Pipes	No.1 pumping station: ø200 mm	40 m	0	40 m
	No.2 pumping station: ø150	40 m	0	40 m
	No.3 pumping station: ø250	1,270 m	0	1,270 m
5. Overhead Tank	Capacity: 400 m^3/500 m^3 (1 each) Reinforced concrete Height: 17 m	2 units	0	2 units
6. Distributing Pipes	PVC Pipe: ø200 mm	7,340 m	0	7,340 m
	ø150 mm	4,410 m	0	4,410 m
	ø100 mm	12,720 m	0	12,720 m
	Total	24,470 m	0	24,470 m
	Breakdown by type of pavement as per attached sheet			

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
7. Related Structures of Distributing Pipes	Sluice valve (box): ø200 mm	25 units	0	25 units
	ø150 mm	27 "	0	27 "
	ø100 mm	68 "	0	68 "
	Blow-off: ø200 mm	2 "	-	2 "
	ø150 mm	4 "	-	4 "
	Pipe and work: ø100 mm	20 "	-	20 "
	ø150 mm	2 "	-	2 "
	ø200 mm	2	-	2 "
8. Public Post		10 places	0	10 places

Table 3-6-4 (2)

Breakdown of Transmission Pipes and Distributing Pipes by Pavement
(Only Water-Supply Systems to be Constructed Anew)

Gaibandha

Item / Type	By Type of Pavement					Remarks
	As	R.C	Bricks	Kutcha	Total	
1. Transmission Pipes						
ø8"(No.1)				40m	40m	
ø6"(No.2)				40	40	
ø10"(No.3)	500m	480m	290m		1,270	
Total	500	480	290	80	1,350	
2. Distributing Pipes						
ø4"(Parallel to the road)		4,300m	4,450m	3,750m	12,500m	
ø4"(Crossing the road)	70m	120	20	10	220	
Sub-Total	70	4,420	4,470	3,760	12,720	
ø6"(Parallel to the road)	300	2,650	830	600	4,380	
ø6"(Crossing the road)	10	20			30	
Sub-Total	310	2,670	830	600	4,410	
ø8"(Parallel to the road)	1,070	5,300		950	7,320	
ø8"(Crossing the road)		20			20	
Sub-Total	1,070	5,320		950	7,340	
Total	1,450	12,410	5,300	5,310	24,470	

3-7 Feni Town

3-7-1 Outline of the Town

(1) Location and General Conditions

The town belongs to Feni District of Chittagong Division, and is located near the border between India, about 70 km to the south of Comilla. The town has a municipal area of 2.5 square miles.

As for traffic means, a railway that runs through the eastern part of Bangladesh passes the northern part of town. The road connecting Dhaka and Chittagong passes through the town in a V shape, and the road from the town to Maizdi extends westward from the central section of town. Commercial activities utilizing such traffic means have prospered from the early days.

The town's population grew from 15,428 in 1974 to 23,199 in 1981 and 27,000 in 1984. There are seven primary schools, six high schools, three colleges, one kindergarten and three hospitals in the town.

(2) Topography and Geology

a. Topography

There is a hilly district called Tripura Hills with a mean elevation between 200 to 400 ft. near the border between India and Bangladesh, from which the Chandina Deltaic Plain gently slopes toward the Bay of Bengal. The town is located on this deltaic plain and has the mean elevation of 2.5 m above sea level.

The town's central urban area is formed on the southern side of the railway that runs on the north of town, and houses are densely built along the roads that lead to other towns. Rural areas mainly comprised of rice paddies and dry fields extend in the suburbs.

b. Geology

Geologically, the Tertiary Oligocene system distributed near the border between India forms the basement, covered by a thick deposit of fluvial sediments of the Quaternary Holocene. Soils in the town consist of clayey soil on the ground surface beneath which are sandy soil, and coarse grain (medium sand to coarse sand) layers distributed as follows.

Clayey soil is distributed from GL 0 m to the vicinity of GL -85 m, with occasional intercalation of fine sand and medium sand layers. Underlying this layer is sandy soil distributed in thickness ranging between 30 m to 75 m, with overall mixture of clayey soil. At GL -150 m and deeper, the coarse grain layer mainly consisting of medium to fine sand is seen distributed in thickness estimated to range between 35 m and 45 m.

(3) River System

The Little Feni River which flows on the south of town gathers the small streams coming from the mountainous region of India and flows south in parallel to the Tripura Hills and into the Bay of Bengal.

This Little Feni River displays a river width of around 50 m but, during the dry season, it becomes only a trickle.

(4) Climate

a. Rainfall

The annual mean amount of rainfall in the town is about 3,100 mm or so, which surpasses the national average.

Rainfall data of the past one year and four months are as shown in Table 3-7-1.

Table 3-7-1 Monthly Rainfall in Feni

(mm)

Month / Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1983	47	84	166	557	840	591	779	960	492	467	49	13	5,045
1984	18	0	3	48	-	-	-	-	-	-	-	-	

Although the amount of rainfall was particularly large in 1983, a review of the rainfall data in Table 3-7-1 shows the general tendency of a large amount of rainfalls during April to October every year. This rainy season coincides with the monsoon period which accounts for 90% or more of the annual amount of rainfall.

b. Temperature

The mean temperature in the town is 27.5°C during the monsoon period and 19.5°C during the dry season, with a relative temperature range of 8°C.

Temperature changes during the past one year and four months are as shown in Table 3-7-2. As a reference, temperature record of Noakhali are also shown.

Table 3-7-2 Maximum and Minimum Temperature in Feni and Noakhali by Month (°C)

	Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
Feni	1983	Max.	28.0	30.0	33.0	34.0	36.0	35.0	34.0	34.0	34.0	34.0	33.0	28.0
		Min.	10.0	8.0	17.0	18.0	20.0	21.0	23.0	24.0	24.0	20.0	16.0	9.0
	1984	Max.	29.0	32.0	35.0	-	-	-	-	-	-	-	-	-
		Min.	9.0	11.0	12.0	-	-	-	-	-	-	-	-	-
Noakhali	1979*	Max.	-	-	-	-	-	-	30.3	31.0	30.9	31.3	31.2	26.2
		Min.	-	-	-	-	-	-	25.8	25.0	25.8	24.6	22.3	16.4
	1980*	Max.	25.8	27.3	30.7	33.1	31.6	30.3	29.4	29.6	30.8	30.1	29.8	26.9
		Min.	13.3	15.8	21.4	25.3	23.8	26.0	25.0	25.1	25.6	24.4	19.3	15.2
	1981*	Max.	24.9	22.2	29.1	31.1	32.3	-	29.9	29.9	29.8	30.6	29.7	25.4
		Min.	14.2	16.3	18.9	23.6	24.4	-	25.5	25.5	25.6	23.8	18.6	17.7
	1982*	Max.	26.4	27.2	31.1	32.0	33.8	29.9	-	-	-	-	-	-
		Min.	12.4	15.5	18.0	22.2	24.3	24.4	-	-	-	-	-	-

* Noakhali

A review of the records in Table 3-7-2 indicates that the high temperature months are March to November, with the maximum temperature being above 30°C and the minimum above 15°C. The low temperature month is January with the maximum temperature being around 28°C and the minimum around 12°C.

3-7-2 Hydrogeological Outline and Possibility of Developing Groundwater

(1) Hydrogeological Outline

As described in the section on geology, the soils distributed in this town are the Tertiary system which forms the basement, and Quaternary system distributed above it, facies of which consist of clayey soil, sandy soil, and coarse sand layers from upper to lower strata.

When these are evaluated for their aquiferous capacity, the coarse grain layer is quite excellent, sandy soil layer good, and clayey soil poor.

As for current use of groundwater in the town, DPHE has two deep wells and 368 shallow wells.

Data on these wells are as presented in Table 3-7-3.

Table 3-7-3

T/W No.	Total Depth	Soil of Aquifer	Screen		Pumpage	Static Water Level	Pumping Water Level	Time of Steady State Condi-tion	Recov-ery Period	Water Quality			
			Length	dia.						pH	Fe	cl	T. Hard
	ft.		ft.	inch	IGPH	ft.	ft.	min	min				
1	650'0"	MS	80'	6"	19,000	2'8"	40'1 1/2"	540	240	6.8	2.0	17	136
2	480'0"	MCS	80'	6"	21,240	spring	29'0"	180	60		1.8	15	
Hand Pump	67'	SCL & FS	-	1.5"	DPHE 368								

Of the wells shown in Table 3-7-3, the deep wells draw groundwater form the coarse grain layer and the hand pumps from the fine sand layer.

The groundwater level is generally shallow, having been GL -0.8 m at the time of construction (May 14, 1980) and GL -0.9 m when checked this time (May 16, 1984) in T.W. No.1. In the case of T.W. No.2, veins of groundwater erupted during its construction (May 13, 1983) and when checked this time, the water level was GL -0.5 m (May 16, 1984). Also in the test boring hole of DPHE, eruption of the veins of water were still confirmed.

As for the quality of water, it is judged that there is no problem to use the water for drinking, on the basis of existing data.

(2) Possibility of Developing Groundwater

The possibility of developing groundwater was systematically analyzed as follows based on the existing data given in Paragraph (1).

a. Hydraulic constants

i. Coefficient of infiltration T in m^2/min

T.W. No.1 : T = 0.22 to 2.6 m^2/min

T.W. No.2 : T = 0.51 to 0.63 m^2/min

ii. Coefficient of permeability K in cm/sec

T.W. No.1 : K = 1.5 to 1.8 x 10^{-2} cm/sec

T.W. No.2 : K = 3.5 to 4.4 x 10^{-2} cm/sec

iii. Specific yield of well S in m^3/day/m

T.W. No.1 : S = 185 m^3/day/m

T.W. No.2 : S = 266 m^3/day/m

When values calculated as above are reviewed, T and K exhibit large values even though S is slightly too small. Hence, the coarse grain layer from which groundwater is drawn is judged to be satisfactory for developing groundwater.

b. Influence area of wells

As for the influence area of wells, intervals of 800 m or more between adjacent wells are presumed satisfactory judging from the data of Table 3-2-5 applicable to the layers from which groundwater is to be exploited, namely medium to coarse grain sand layers.

From a. and b. above, it was judged that groundwater in this town may be developed with no problem at all so long as the adjacent wells are spaced 800 m or more apart and the pumping rate Q is restricted to less than 85 m^3/h.

3-7-3 Water Source Plan

The water sources from which drinking water for the town is supplied now are two deep wells and 368 hand pumps. River water is not used.

A study of the future water sources of drinking water supply - based on the prevalent state - resulted in the following conclusions.

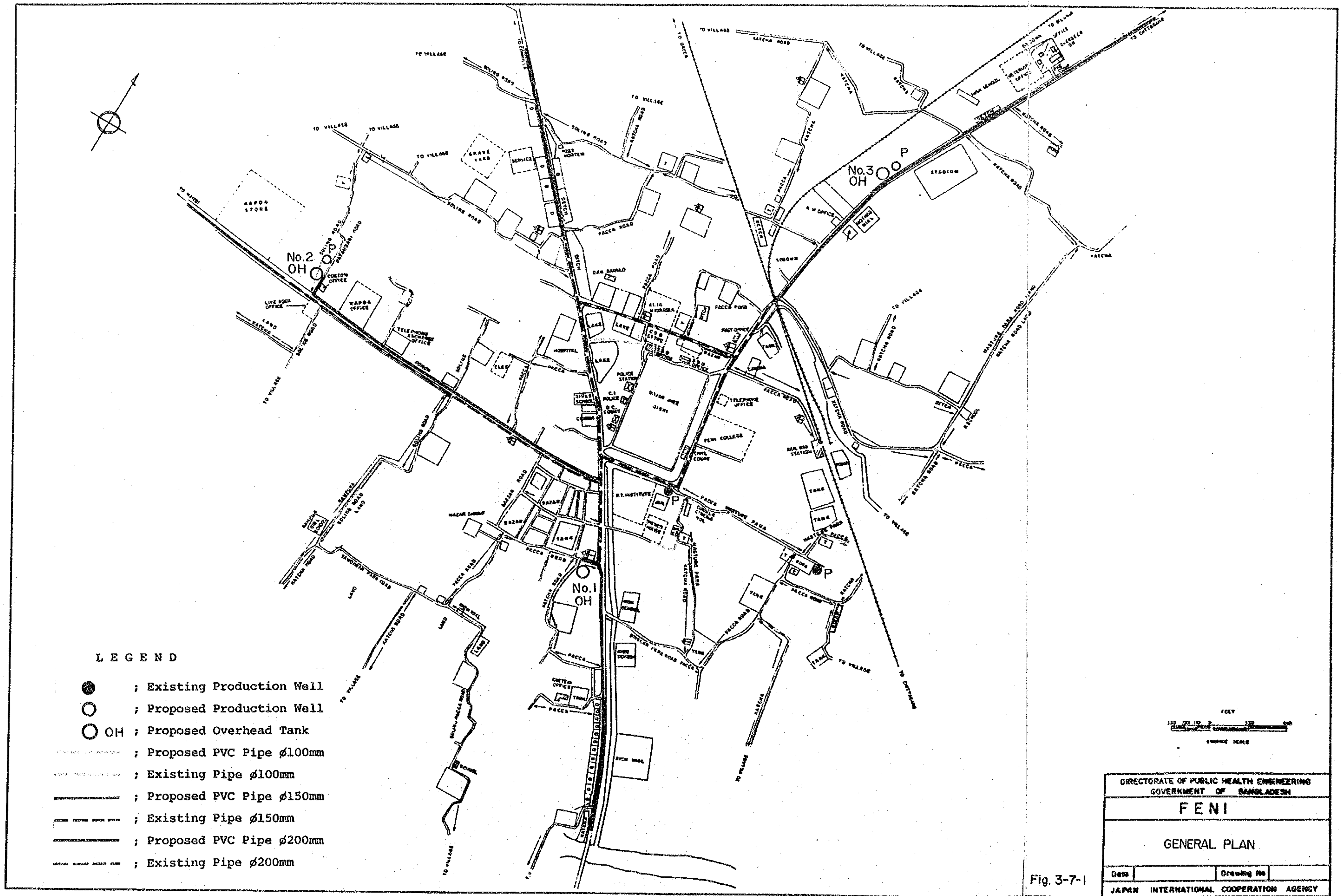
a. Groundwater

According to relevant data on wells, the layer in which a lot of groundwater is likely to be stored is judged to be the coarse grain layer distributed deeper than GL -150 m. Available data show that the volume of water which can be pumped from this layer is in the range of 72 to 97 m^3/h. Also, as mentioned in Section 3-7-2, the development of groundwater in this town is considered possible.

b. River water

As mentioned in the section on river system, the Little Feni River which flows on the south of town becomes only a trickle during the dry season.

On the basis of a. and b. above, groundwater is judged to be the better choice as the water source for this town.


No.2
OH
P
No.3
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No.1
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LEGEND
; Existing Production Well
; Proposed Production Well
OH ; Proposed Overhead Tank
; Proposed PVC Pipe ø100mm
; Existing Pipe ø100mm
; Proposed PVC Pipe ø150mm
; Existing Pipe ø150mm
; Proposed PVC Pipe ø200mm
; Existing Pipe ø200mm
DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH
FENI
GENERAL PLAN
Date
Drawing No
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 3-7-1

3-7-4 Water Supply Plan

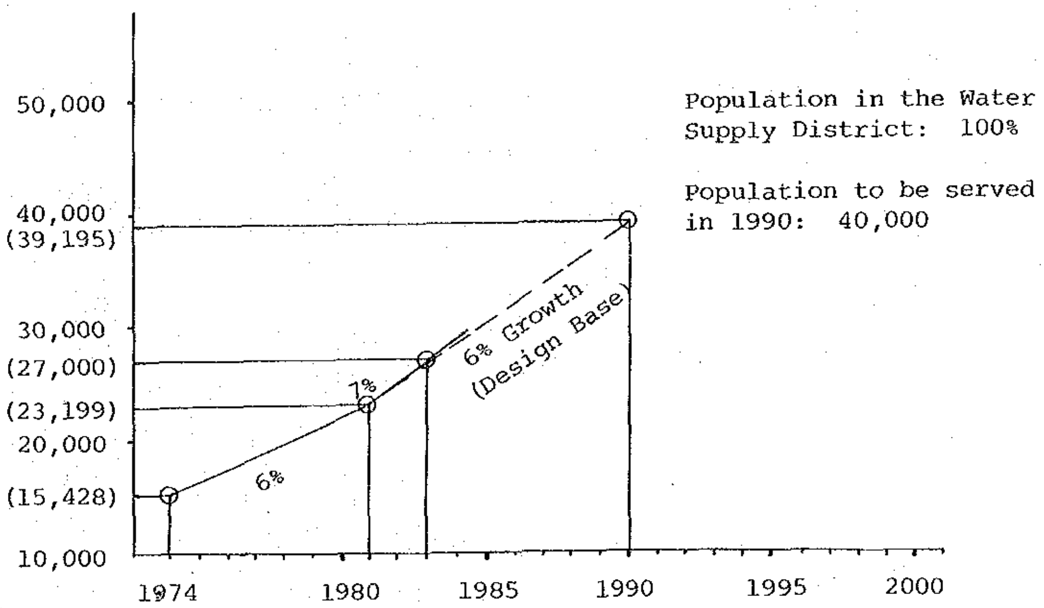
(1) Water Supply District and Population to be Supplied

Population at the time of censuses in 1974, 1981 and today (May 1984) are as follows.

Population at the 1974 census	:	15,428
Population at the 1981 census	:	23,199
Population as of May 1984	:	27,000

These data may be plotted as follows.

Population Growth in Feni Town



The average annual rate of population growth was 6.0% between 1974 and 1981 and 7.9% between 1981 and now. As was the case with other towns, the population growth rate from 1981 to 1990 was assumed to be 6% a year for planning this purpose. Thus, the population in 1990 was projected to be 40,000.

The water supply district was determined with due consideration to the present geographic distribution of population, the prevalent state of settlement formation and the direction of future development of residential areas. As the water supply district thus delineated approximately coincides with the town's present municipal area, the population to which water would be supplied in 1990 was assumed to be 40,000.

(2) Water Consumption

The estimated amount of water to serve a population of 40,000 would be as follows.

$$Q = 81 \text{ liters/man-day} \times 40,000 \text{ men} = 3,240 \text{ m}^3\text{/day}$$

(3) Water Supply Facilities Plan

(i) Production well

a. Diameter of well and pumping rate

According to existing data, the pumping rate is in the range of 85 to 97 m^3/h for a well of 6" diameter and draw down of 9 to 12 m.

Judging from these results, it was decided that the diameter should be 6", and the pumping rate $Q = 85\ m^3/h$ because the draw down is rather large.

b. Drawing depth

Judging from the inferred geological profile shown in Figs. 3-10-13 and 3-10-14, the drawing depth will be targeted to the coarse grain layer distributed at GL -150 m and deeper.

c. Number of wells

$$x = \frac{Q}{Qy} = \frac{3,240}{85 \times 12} = 3.2 \fallingdotseq 4 \text{ wells}$$

(ii) Pump facilities

The suction level inside the well shall be (-) 20.0 m from the ground level (GL) and the discharge level shall be (+) 20.0 m from the ground level, which is the maximum water level of the overhead tank. The actual head therefore would be 40.0 m

A study of the pump facilities for each well resulted in the following table.

Table 3-7-4 Principal Particulars of Pump Facilities

Well No. / Description	1	2	3	4
1. Actual head, m	40.0	40.0	40.0	40.0
2. Pumping rate, ℓ/sec	19.5 (38.9)	19.5 (38.9)	20.0	17.9
3. Transmission pipes				
Kind of pipe	Cast iron pipe	"	"	"
Diameter, mm	150, 200	150 (200)	150	150
Length, m	10, 600	460 (600)	40	40
4. Loss of head in the transmission pipes, m	8.12	14.88	0.63	0.51
5. Total head, m	48.12	54.88	40.63	40.51
6. Type of pump	Multi-stage turbine	"	"	"
7. No. of stages	13	15	11	11
8. Motor output, kW	19	22	15	15

(iii) Overhead tank

The required total overhead tank capacity is

$$V = 3,240.0 \times 0.20 = 648.0 \text{ m}^3.$$

Accordingly, altogether three overhead tank - two with a capacity of 200 m^3 each and one with a capacity of 300 m^3 - will be planned with due consideration to their locational arrangement.

(iv) Distributing pipe

Arrangement (layout) of the distributing pipes will be planned with due consideration to the geographic distribution of population, the locations of existing wells and distributing pipes, the road conditions, the direction of future development of residential areas, etc. All distributing pipes shall be PVC pipes with diameters of ϕ200 mm or less.

The hydraulic calculations for the pipeline network were carried out on the basis of the design conditions so as to secure the hydrualic pressure of 9.0 m at every terminal end of the distributing main and branch.

(v) Public post

The discharge rate from a ϕ13 mm tap is 20 liters/min (14.4 m^3/12 h). As the plan calls for supplying water to 50% of the inhabitants by means of public posts, the required quantity of water supply would be:

$$Q = 40{,}000 \text{ persons} \times 0.5 \times 34 \text{ liters/man-day}$$
$$= 680.0 \text{ m}^3\text{/day}$$

Thus, the required number of public posts is 48.

Under this project, water posts will be constructed at 10 locations while the balance will be constructed by the Government of Bangladesh.

3-7-5 Contents of the Project

(1) Water Supply Facilities Already Completed by DPHE

The contents of water supply facilities already constructed by DPHE's own funds are as shown in Table 3-7-5.

(2) Water Supply Facilities to be Constructed under this Project

The contents of water supply facilities to be constructed under this project, which were determined on the basis of the contents of water supply facilities of this project as a whole and the contents of facilities already completed by DPHE, are as shown in Table 3-7-5, and the proposed plan for them is as shown in Fig. 3-7-1.

Table 3-7-5(1) Outline of the Water-Supply Systems to be Constructed in This Project

Feni

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
1. Production Well	ø300 mm x ø150 mm Depth: 200/219 m Strainer: 30 m	4 Nos.	2 Nos.	2 Nos.
2. Pumping Facilities	B8D 12 stages x 19 kW x 1 unit B8D 11 stages x 15 kW x 3 units	4 unit	0	4 unit
3. Pumping House	Birck-and morter, pump room: 12.3 m² Driver's room: 8.8 m	4 Nos.	2 Nos.	2 Nos.
4. Transmission Pipes	No.1 pumping station: ø150 + 250	10 + 600 m	-	10 + 600 m
	No.2 pumping station: ø200	460 m	-	460 m
	No.3 pumping station: ø150 mm	40 m	-	40 m
	No.4 pumping station: ø150 mm	40 m	-	40 m
5. Overhead Tank	Capacity: 200 m³x2 300 m³x1 Height: 17 m Reinforced concrete	3 units	0	3 units

(cont.)

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
6. Distributing Pipes	AC Pipe: ø200 mm	1,765 m	1,765 m	-
	ø150 mm	1,700 m	1,700 m	-
	PVC Pipe ø200 mm	3,600 m	-	3,600 m
	ø150 mm	2,670 m	840 m	1,830 m
	ø100 mm	15,980 m	4,640 m	11,340 m
	Total	25,715 m	8,945 m	16,770 m
	Breakdown by type of pavement as per attached sheet			
7. Related Structures of Distributing Pipes	Sluice valve (box): ø200 mm.	24 units	4 units	20 units
	ø150 mm	12 "	4 "	8 "
	ø100 mm	87 "	20 "	67 "
	Blow-off:			
	ø200 mm	2 "	Wash-out	2 "
	ø150/ø100 mm	2/3 "	ø4-3 Nos.	2/3 "
	Pipe and work:			
	ø100 mm	22 "		22 "
	ø150 mm	3 "		3 "
	ø200 mm	1 "		1 "
8. Public Post		20 places	10 places	10 places

Table 3-7-5 (2)

Breakdown of Transmission Pipes and Distributing Pipes by Pavement
(Only Water-Supply Systems to be Constructed Anew)

Feni

Item / Type	By Type of Pavement: As	R.C	Bricks	Kutcha	Total	Remarks
1. Transmission Pipes						
ø10" (No.1)	540 m	60 m		10m	600 + 10 m	
ø8" (No.2)	450 m			10	460 m	
ø6" (No.3)				40	40	
ø6" (No.4)				40	40	
Total	990	60		100	1,150	
2. Distributing Pipes						
ø4" (Parallel to the road)	650m	6,550m	2,390m	1,670m	11,260m	
ø4" (Crossing the road)	60	20			80	
Sub-Total	710	6,570	2,390	1,670	11,340	
ø6" (Parallel to the road)	1,820				1,820	
ø6" (Crossing the road)	10				10	
Sub-Total	1,830				1,830	
ø8" (Parallel to the road)	2,380	1,210			3,590	
ø8" (Crossing the road)	10				10	
Sub-Total	2,390	1,210			3,600	
Total	4,930	7,780	2,390	1,670	16,770	

3-8 Sunamganj Town

3-8-1 Outline of the Town

(1) Location and General Conditions

The town belongs to Sunamganj District of Chittagong Division, and is located near the border between India, about 70 km to the northwest of Sylhet. The town has a municipal area of 1 square mile.

As for traffic means, the only arterial road is the one which connects this town with Sylhet. Another means of traffic is by boat on the Surma River that flows on the north of town. As for industry, a big fish processing factory is now under construction. There are also about 25 small factories, including rice mill, wood mill, brick works, etc.

The town's population grew from 14,516 in 1974 to 21,565 in 1981 and 25,653 in 1984. There are 10 primary schools, four high schools, one college, five Madrasha, one kindergarten and one hospital in the town.

(2) Topography and Geology

a. Topography

The northern area of Bangladesh including this town is called Sylhet Trough and was once a huge depression, but it came to take on the current topographic form as a result of having been filled by the Surma River that flows from India. Broadly viewed, this area therefore gently slopes along the Megna River to the Bay of Bengal.

Being located on such a topography, the town has a flat surface of 9 m in elevation.

As for land use, the town's central urban area is formed in the south of the Surma River, and the rural areas mainly comprised of paddy fields and dry fields extend in the suburbs.

b. Geology

Since this town is located on Sylhet Trough as stated in the section on topography, its geology consists of a thick deposit of Quaternery lacustrine sediments. The thickness of this deposit reaches several hundred meters according to Mr. Abu Bakar, Director General of Geological Survey of Bangladesh, even though accurate data are unavailable.

This deposit mainly consists of clayey soil distributed as follows according to existing data.

Clayey soil is distributed from GL 0 m to GL -90 m, from GL -100 m to GL -140 m, from GL -150 m to GL -185 m, and at GL -200 m and deeper, and is mixed with sand here and there.

Sandy soil is seen distributed as if being intercalated between these clayey soil layers in thickness of 10 m to 15 m from GL -90 m to GL -100 m, GL -140 m to GL -150 m, GL -185 m to GL -200 m. Facies of this sandy soil is from fine to coarse grain sand.

(3) River System

The Surma River which flows west on the north of town originates in India. After it flows past this town, it changes its name to the Kalni River at Markuli and to the Megna River on the north of Narsingdi which flows into the Bay of Bengal.

This Surma River has the river width of around 150 m. The records of its water level and discharge during the 1977-1981 period are as shown in Tables 3-8-1 and 3-8-2.

Table 3-8-1 Water Level at Sunamganj

(m)

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1977	Max.	3,415	2,255	6,530	6,185	6,215	8,760	8,740	8,330	7,730	6,695	5,135	3,765
	Min.	2,285	1,750	1,705	3,170	5,030	5,965	7,765	7,710	6,605	5,180	3,810	2,575
1978	Max.	2,510	1,935	3,690	7,520	7,835	8,185	8,290	8,475	8,085	7,405	5,730	4,495
	Min.	1,815	1,570	1,875	3,155	6,690	7,895	7,855	2,570	6,590	5,595	4,555	3,290
1979	Max.	3,270	2,225	1,950	2,820	7,070	8,335	8,275	8,085	7,620	6,895	5,235	3,905
	Min.	2,235	1,800	1,495	1,890	2,775	6,920	7,560	7,040	6,875	5,305	3,930	2,680
1980	Max.	2,650	2,025	2,240	7,184	7,260	8,199	8,397	8,489	7,596	7,367	6,797	4,563
	Min.	1,805	1,540	1,480	1,814	6,529	7,001	7,559	7,544	7,154	6,087	4,618	3,222
1981	Max.	3,191	2,134	2,652	4,923	7,077	7,742	8,839	8,662	8,748	7,361	4,862	3,816
	Min.	2,155	1,743	1,713	3,769	5,238	6,929	8,264	8,080	7,991	6,035	4,141	3,175

The maximum and minimum water levels recorded during the 1965-1981 period:

Max. : 9,455 m (on July 29, 1974)
Min. : 1,370 m (on March 12, 1968)

Table 3-8-2 Discharge at Sylhet

(m^3/sec)

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1977	Max.	57.7	15.9	44.7	923.0	891.0	1,830.0	2,120.0	1,960.0	1,760.0	1,080.0	453.0	82.1
	Min.	16.7	6.1	5.6	15.6	156.0	159.0	1,580.0	784.0	716.0	334.0	64.8	19.8
1978	Max.	19.2	6.5	8.1	447.0	744.0	911.0	2,290.0	2,050.0	1,500.0	1,340.0	773.0	99.6
	Min.	6.7	4.7	4.2	2.6	122.0	396.0	719.0	860.0	769.0	299.0	106.0	24.8
1979	Max.	24.2	9.2	549.0	657.0	492.0	2,120.0	2,480.0	1,720.0	1,380.0	671.0	74.1	17.0
	Min.	9.2	3.9	4.3	13.3	137.0	342.0	1,320.0	1,170.0	410.0	82.9	13.6	6.9
1980	Max.	6.8	6.0	21.6	1,280.0	1,510.0	1,820.0	1,790.0	1,830.0	1,600.0	872.0	239.0	28.9
	Min.	5.4	4.2	4.4	16.1	348.0	1,420.0	1,240.0	1,040.0	291.0	99.6	30.8	10.6
1981	Max.	10.4	5.9	4.4	149.0	1,010.0	1,170.0	1,860.0	1,810.0	1,850.0	597.0	42.1	10.7
	Min.	6.1	4.5	3.4	20.5	30.1	419.0	944.0	774.0	458.0	44.5	9.1	5.8

The maximum and minimum discharge recorded during the 1965-1981 period:

Max. : 2,480.0 m^3/sec (on July 1, 1976)
Min. : 2.6 m^3/sec (on April 5, 1975)

A review of the water levels shown in Table 3-8-1 indicates that the water level becomes higher from April to October and becomes gradually lower from November, and reaches its lowest around March. The highest water level ever reached during 1965 and 1981 was 9.455 m, and the lowest, 1.370 m.

Discharges show the same tendency as the changes in water level, as apparent from Table 3-8-2, with the highest discharge ever reached during 1965 and 1981 being 2,480 t, and the lowest, 2.6 t.

(4) Climate

a. Rainfall

Since rainfall has not been measured regularly in this town, the records of Sylhet were used as a reference, according to which the annual mean amount of rainfall is in the neighborhood of 4,000 mm, which indicates that this area has a large amount of rainfall compared to other parts of Bangladesh.

Rainfall data during the 1978-1980 period are as shown in Table 3-8-3.

Table 3-8-3

(mm)

Month / Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1978	0	1	49	199	744	1117	717	259	383	172	2	0	3,639
1979	0	4	62	118	361	929	1324	295	528	235	6	26	3,888
1980	0	29	121	512	767	473	317	359	720	484	0	0	3,782

A review of the records shown in Table 3-8-3 indicates a large amount of rainfall in the months of April to October. This rainy season coincides with the monsoon season which accounts for 90% or more of the annual amount of rainfall.

b. Temperature

Since temperature has not been regularly measured in this town, the records of Sylhet were used for reference. The mean temperature during the monsoon period is about 28°C and in the dry season, 17.5°C, with a relative temperature range of 10.5°C.

The records for the 1978-1980 period are as shown in Table 3-8-4.

Table 3-8-4 Maximum and Minimum Temperature in Sylhet by Month (°C)

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1978	Max.	23.3	27.2	30.6	31.7	28.9	30.0	30.6	32.2	30.6	31.7	28.3	26.7
	Min.	10.6	13.3	16.7	20.6	22.2	23.9	24.5	25.6	24.4	22.8	18.3	13.3
1979	Max.	26.7	27.2	31.1	32.8	32.2	31.7	30.0	31.1	30.0	30.0	29.4	25.6
	Min.	12.2	12.8	17.2	21.7	22.8	24.4	24.4	25.0	23.9	21.7	19.4	14.4
1980	Max.	24.4	-	29.4	31.7	28.9	31.1	31.1	31.1	30.6	29.4	29.4	27.2
	Min.	11.7	-	18.3	21.1	21.1	25.0	25.0	25.0	24.4	21.7	17.2	14.4

A review of the records in Table 3-8-4 indicates that the high temperature months are March to October with the maximum temperature being above 30°C and the minimum above 15°C. The low temperature month is January with the maximum temperature being around 25°C and the minimum around 12°C.

3-8-2 Hydrogeological Outline and Possibility of Developing Groundwater

(1) Hydrogeological Outline

The soils distributed in this town consist of a thick deposit of lacustrine sediments as stated in the section on geology. According to data related to wells, this deposit has been confirmed to the depth of 850 ft. but has not been confirmed to further depth yet. Also, according to Mr. Abu Bakar, Director General of Geological Survey of Bangladesh, the thickness of this sedimentary deposit is quite thick and the distribution of gravel layer that constitutes good aquifer is hardly to be found even drilled to a deeper depth. Also, from the depth of 500 ft. and more, gas reservoirs are said to exist here and there.

As for the use of groundwater in such geological circumstances, there are altogether eight wells that use the motor; one well by DPHE (which has not been used yet) and seven wells by hospitals and official residences. In the case of wells that use the hand pump, there are 100 wells by DPHE and 70 wells by private individuals, totalling 170 wells.

The wells related to DPHE are as shown in Table 3-8-5.

Table 3-8-5

T/W No.	Total Depth	Soil of Aquifer	Screen		Pumpage	Static Water Level	Pumping Water Level	Time of Steady State Condition	Recovery Period	Water Quality			
			Length	dia.						pH	Fe	cl	T. Hard
			ft.	inch	IGPH	ft.	ft.	min	min				
1	702'0"	MCS	82'	6"	8,400	11'4"	92'1"	840	1,440		4.0		
Hand Pump	500'0"	FMS	-	1.5"	DPHE : 100 Private individuals: 70 } Total 170								

Layers from which groundwater is drawn are the 10 m medium grain sand layer distributed in the neighborhood of GL -150 m for the hand pumps and the 15 m thick coarse sand layer distributed around GL -190 m for the tube wells.

The groundwater level in T.W. No.1 was GL -3.4 m at the time of its construction (February 28, 1982) and GL -1.5 m when checked this time (on May 26, 1984).

As for the quality of water, a high Fe value of 4 ppm was indicated.

(2) Possibility of Developing Groundwater

The possibility of developing groundwater was systematically analyzed as follows based on the existing data given in Paragraph (1).

a. Hydraulic constants

i. Coefficient of infiltration T in m^2/min

T.W. No.1 : T = 0.07 to 0.12 m^2/min

ii. Coefficient of permeability K in cm/sec

T.W. No.1 : K = 4.7 to 8.1 x 10^{-3} cm/sec

iii. Specific yield of well S in m^3/day/m

T.W. No.1 : S = 37 m^3/day/m

As all of T, K, and S calculated as above have small values, and the thickness of the layer from which groundwater is to be drawn is thin at around 15 m, the overlying sand layers (from which groundwater is drawn by hand pumps) must also be considered for exploitation of water if a tube well is to be built. Consequently, pumping water by motor could be drying up the water source for the hand pump. Also, as fe content is high at 4 ppm as mentioned in Paragraph (1), a iron removal plant must also be taken into account.

Thus, the ground water situation of Sunamganj Town has little potential for further exploitation.

The whole neighbourhood area of Sunamganj is topographically a land filled with deposit on a huge depression, and encompasses Sylhet to the east (about 40 km away), Manlvi Baganj (about 70 km away) to the south and near Kishorganj to the west (about 40 km away).

The land on this Sylhet Trough has thickly accumulated lacustrine sediments consisting of clayey soil, which is also presumed to be the land of Sunamganj. The Sylhet Trough lacustrine sediments is more than 300 m thick, and mix sometimes natural gas in them as well as scarecer water-bearing thinner gravel layers.

Furthermore, the gas company exploiting natural gas around the area, BADC promoting agricultural developments making use of the ground water and BWDB indicate through their information given by their experts in geology and ground water that it is very difficult to further exploit the ground water in the area.

From all the data above, the neighbouring area of Sunamganj Town as well as the town itself is estimated to have small possibility of developing the ground water.

3-8-3 Water Source Plan

The water sources from which drinking water for the town is supplied now are the 170 hand pumps. River water is not used.

A study of the future water sources of drinking water supply - based on the prevalent state - resulted in the following conclusions.

a. Groundwater

According to the data related to wells, the layers in which groundwater is stored are the sand layers with a thickness of between 10 to 15 m which are distributed at around GL -100 m, GL -150 m and GL -200 m. Of these, a 15 m thick sand layer distributed at around GL -200 m exhibits a low pumping rate of 38 m^3/h and a big draw down of 25 m according to existing data. Also, as stated in the preceding paragraph, development of groundwater is questionable.

b. River water

As is hown in Table 3-8-6, the minimum discharge in 20 years probability of the Surma River calculated based on the discharge records in the past 15 years is 2 - 3 m^3/sec. The planned quantity of water supply is 2,977 m^3/sec, and assuming that facilities are to be operated 12 hours a day, the intake is 0.06 m^3/sec. Accordingly, the flow rate of the river is more than adequate to allow that much water intake.

As for the water quality of the Surma River, data collected by DPCB (Enviornment Pollution Control Board) of Bangladesh in 1983 and by us in our study in August, 1984 (see Table 3-8-10 - 13).

According to the survey results in August, 1984, the water quality of the river was as follows:

Turbidity	22°
Color	32°
pH	7.4°
Alkalinity	21.5°
KmnO4 consumption	5.4°
Coli bacilli	+
General bacteria	+

The EPCB data in 1983 does not tell about turbidity and color, but the values through the year were as follows:

PH	6.5 - 7.8
EC	3.8 - 17 mg/l
Total Alkali	54 - 120 mg/l
DO	6.05 - 7.5 mg/l
BOD	0.8 - 2.7 mg/l
T.S	102 - 198 "
S.S	33 - 69 "
COD	34 - 61 "

Analysis on heavy metals was made in August, 1984, detecting zinc only at 0.014 ppm (WHO allowance being 5.0 - 15 ppm), and nothing such as copper lead, cadmium, hexad chrome, cynogen and mercury.

In the results, COD value is a bit high, but is easy to deal with by purification. Thus, the water quality of the Surma River has, in our opinion, no problem as our raw water.

Further, the jar test made in August, 1984 showed aluminum sulfate readily available in the local area could easily lower the turbidity and the color.

Tabe 3-8-6 Provable Water Level and Discharge of the Surma River

Probability of Occurrence in Years	LLWL	HHWL	Qmin	Qmax
Once every five years	1.50 (m)	8.80 (m)	2.90 (m^3/s)	2,270 (m^3/s)
Once every ten years	1.45	8.9	2.54	2,370
Once every twenty years	1.40	9.0	2.30	2,460
Once every a hundred years	1.34	9.2	1.90	2,650

Fig. 3-8-1 Hazen Plot

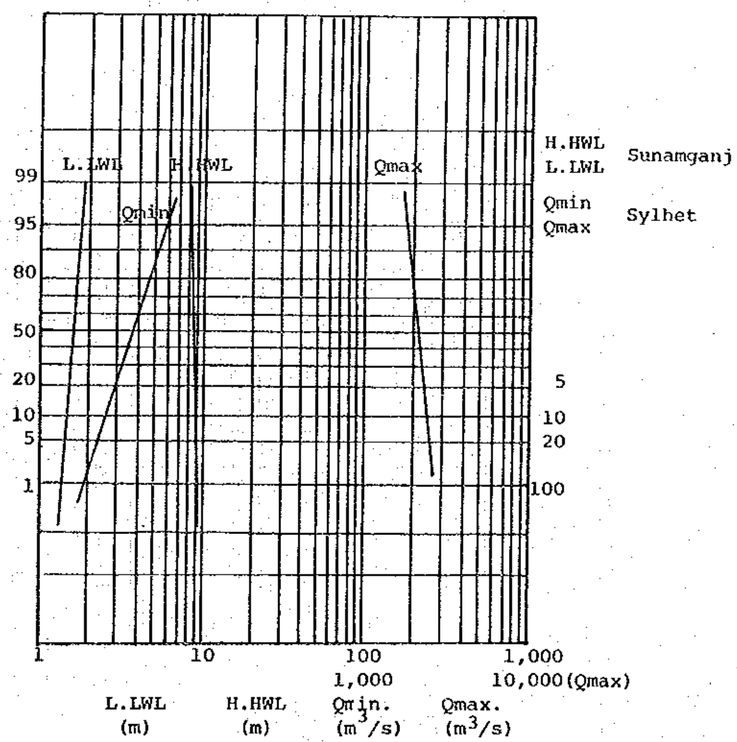


Table 3-8-7 Water Level and Discharge of the Surma River

	Year	Lowest Water Level (LLWL m)	Minimum Discharge (m^3/sec)	Highest Water Level (HHWL m)	Maximum Discharge (m^3/sec)	Remarks
1	1964/65	x	5.6 (11)	x	2,120 (5)	
2	1965/66	1.51 (4)	7.0 (12)	8.35 (14)	1,630 (12)	
3	1966/67	1.63 (9)	5.2 (10)	8.59 (8)	2,340 (2)	
4	1967/68	1.37 (1)	x	8.41 (12)	x	
5	1968/69	1.52 (5)	x	8.39 (13)	x	
6	1969/70	1.64 (11)	3.2 (4)	8.32 (16)	2,120 (6)	
7	1970/71	1.63 (10)	4.0 (7)	8.58 (9)	2,090 (8)	
8	1971/72	1.65 (12)	x	8.71 (4)	x	
9	1972/73	1.61 (8)	2.7 (2)	8.62 (6)	1,790 (11)	
10	1973/74	1.88 (16)	3.0 (3)	8.61 (7)	2,240 (4)	
11	1974/75	1.76 (15)	4.2 (8)	9.45 (1)	2,120 (7)	
12	1975/76	1.70 (13)	2.6 (1)	8.68 (5)	2,290 (3)	
13	1976/77	1.57 (7)	4.2 (9)	8.76 (3)	2,480 (1)	
14	1977/78	1.49 (3)	3.4 (5)	8.47 (11)	1,830 (10)	
15	1978/79	1.48 (2)	x	8.33 (15)	x	
16	1979/80	x	x	x	x	
17	1980/81	1.71 (14)	x	8.48 (10)	x	
18	1981/82	1.53 (6)	3.5 (6)	8.83 (2)	1,860 (9)	

Note: The water level is that measured at Sunamaganji. The flow rate is that measured at Sylhet. Numbers in parantheses represent the order.

Table 3-8-8 Discharge of the Surma River by Month (measured at Sylhet)

(Unit: m^3/sec)

Year		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1964/65	Max. Min.	1,100 15.8	1,360 150	1,940 140	2,050 1,260	2,120 948	1,880 716	1,080 424	439 62	62.0 12.9	12.3 7.5	78.1 7.0	6.76 5.6
1965/66	Max. Min.	110 10.8	469 54.3	1,380 166	1,440 958	1,630 948	1,070 773	873 348	348 55.7	53.2 19.5	18.7 10.8	10.8 7.9	8.7 7.0
1966/67	Max. Min.	97.5 5.2	956 32.5	2,340 1,030	1,990 1,510	1,880 1,420	1,610 956	1,320 275	250 71.0	97.5 20.4	19.6 6.9	11.9 5.6	17.3 5.2
1969/70	Max. Min.	262 5.7	467 16.7	1,880 226	1,760 1,290	2,120 1,150	1,890 300	475 65.1	60.3 11.2	10.8 5.5	5.5 4.6	4.7 3.5	447 3.2
1970/71	Max. Min.	574 28.0	1,180 181	1,640 422	2,090 860	1,780 750	1,400 458	1,530 334	340 50.6	46.7 11.2	10.9 6.6	7.0 4.7	4.7 4.0
1972/73	Max. Min.	767 12.8	945 164	1,790 173	1,480 812	1,340 792	1,030 227	908 83.8	80.4 26.1	25.4 9.7	9.5 5.0	6.0 3.9	9.5 2.7
1973/74	Max. Min.	365 3.0	1,190 208	2,190 756	2,240 699	1,920 1,050	1,100 651	724 203	979 154	242 60.6	57.7 16.7	15.9 6.0	44.7 5.6
1974/75	Max. Min.	923 15.6	891 156	1,830 159	2,120 1,580	1,960 784	1,760 716	1,080 334	453 64.8	82.1 19.8	19.2 6.6	6.4 4.6	8.0 4.2
1975/76	Max. Min.	447 2.6	744 122	911 396	2,290 719	2,050 860	1,500 769	1,340 299	773 106	99.6 24.8	24.2 9.1	9.1 3.9	549 4.2
1976/77	Max. Min.	657 13.3	492 137	2,120 342	2,480 1,320	1,720 1,170	1,380 410	671 82.9	74.1 13.6	17.0 6.9	6.8 5.3	5.9 4.2	21.6 4.3
1977/78	Max. Min.	1,280 16.1	1,510 348	1,820 1,420	1,790 1,240	1,830 1,040	1,600 291	872 99.6	239 30.8	29.8 10.6	10.4 6.0	5.9 4.4	4.3 3.4
1981/82	Max. Min.	149 20.5	1,010 30.1	1,170 419	1,860 944	1,810 774	1,850 458	597 44.5	42.1 9.1	10.7 5.8	5.6 3.7	6.9 3.5	114 4.3

Table 3-8-9 Water Level of the Surma River (measured at Sunamganj)

(Unit: m)

Year		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1965/66	Max.	4.49	6.32	7.77	8.09	8.35	7.80	7.10	5.82	4.22	2.82	1.95	1.98
	Min.	1.92	4.02	5.44	7.39	7.60	7.16	5.89	4.28	2.88	1.96	1.63	1.51
1966/67	Max.	3.70	6.87	8.59	9.20	8.58	8.00	7.11	5.59	4.22	3.14	2.05	2.56
	Min.	1.63	3.12	7.05	7.60	7.43	7.05	5.67	4.28	3.17	2.33	1.70	1.93
1967/68	Max.	5.32	6.63	7.86	8.41	7.59	7.40	7.40	5.53	3.94	2.51	1.93	2.47
	Min.	1.78	4.05	5.35	7.19	7.13	6.76	5.59	3.99	2.52	1.84	1.57	1.37
1968/69	Max.	5.23	7.40	7.95	8.39	8.08	7.70	7.12	5.47	3.90	2.54	1.98	2.60
	Min.	2.13	3.54	6.93	7.61	7.60	7.17	5.50	3.95	2.58	1.88	1.54	1.52
1969/70	Max.	5.36	6.88	7.95	8.32	8.12	8.09	6.57	5.16	3.72	2.60	2.15	4.97
	Min.	1.97	3.09	6.14	7.48	7.40	6.63	5.22	3.79	2.63	2.15	1.64	1.64
1970/71	Max.	6.02	7.59	8.32	8.58	8.47	8.07	7.74	6.54	4.72	3.30	2.53	2.50
	Min.	3.77	5.93	6.73	7.37	7.56	7.06	6.62	4.77	3.34	2.42	1.86	1.63
1971/72	Max.	4.87	4.39	7.47	8.71	8.26	7.93	7.67	6.25	5.31	4.14	2.40	2.88
	Min.	2.62	3.18	4.22	7.29	7.40	7.07	5.96	5.36	4.17	2.41	1.85	1.65
1972/73	Max.	6.39	7.08	8.62	8.17	7.91	7.52	6.67	5.10	3.51	2.40	2.07	2.22
	Min.	3.13	5.79	5.98	7.14	7.16	6.32	5.14	3.57	2.44	1.73	1.61	1.65
1973/74	Max.	6.34	7.14	8.61	8.55	8.23	8.02	7.31	-	-	-	2.82	3.04
	Min.	2.05	5.57	6.98	7.10	7.48	7.28	-	-	-	-	1.99	1.88
1974/75	Max.	7.22	7.20	7.97	9.45	9.18	8.77	7.85	6.18	4.57	3.42	2.34	3.02
	Min.	2.67	5.80	5.79	7.92	7.61	7.17	5.63	4.62	3.48	2.28	1.85	1.76
1975/76	Max.	5.30	6.74	7.32	8.68	8.36	8.03	7.88	6.15	5.05	3.41	2.25	6.53
	Min.	1.86	4.98	6.33	7.15	7.46	7.16	6.28	5.10	3.45	2.28	1.75	1.70
1976/77	Max.	6.18	6.21	8.76	8.74	8.33	7.73	6.69	5.13	3.76	2.51	1.93	3.69
	Min.	3.17	5.03	5.96	7.76	7.71	6.60	5.18	3.81	2.57	1.81	1.57	1.87
1977/78	Max.	7.52	7.83	8.18	8.29	8.47	8.08	7.40	5.73	4.49	3.27	2.22	1.95
	Min.	3.15	6.69	7.89	7.85	7.57	6.59	5.59	4.55	3.29	2.23	1.80	1.49
1978/79	Max.	2.82	7.07	8.33	8.27	8.08	7.62	6.89	5.23	3.90	2.65	2.02	2.24
	Min.	1.89	2.77	6.92	7.56	7.04	6.87	5.30	3.93	2.68	1.80	1.54	1.48
1980/81	Max.	7.18	7.26	8.19	8.39	8.48	7.59	7.36	6.79	4.56	3.19	2.13	2.65
	Min.	1.81	6.52	7.00	7.55	7.54	7.15	6.08	4.61	3.22	2.15	1.74	1.71
1981/82	Max.	4.92	7.07	7.74	8.83	8.66	8.74	7.36	4.86	3.81	2.66	1.81	2.45
	Min.	1.93	4.13	6.34	7.75	7.69	7.22	4.91	3.44	2.69	1.78	1.53	1.53

Table 3-8-10 Results of Water Quality Tests
(August, 1984)

Name of River	Surma	WHO EPCB
Sampling location	Sunamganj	
Date of sampling	Aug. 14, '84	
Temperature	35°C	
Water temperature	(31°C)	
Appearance	Slightly yellow	
Odor	No abnormality	
Turbidity	22°	5 to 25 25
Color	32°	5 to 20 30
pH	7.4	6.5 to 9.2
Alkalinity	21.5 ppm	
$KMnO_4$ consumption	5.4 ppm	
Dissolved Fe	up to 0.1 ppm	0.1 to 1.0 1.5 (5 max)
Mn ion	up to 0.05 ppm	0.05 to 0.5 0.5
NH4	0.1 ppm	
Coli bacilli	+ (entire red discoloration)	
General bacteria	+ (Partial blue discoloration)	

The water temperature of the Surma River was 28°C and that of the Sitalakhya River was 29°C at the time of sampling.

Table 3-8-12 Results of Jar Tests
(Surma River, Aug. 1984)

Aggregation	Feeding rate (ppm)	Flock conditions	Sedimentation	pH	Turbidity (degree)	Color (degree)	Alkalinity (ppm)
Sulfuric acid band	10	Medium	Good	7.6	4	6	38
	15	Large	Good	7.6	up to 2	up to 5	35
	20	Large	Good	7.4	up to 2	up to 5	32
	25	Large	Good	7.4	up to 2	up to 5	29
Postash alum	10	Medium	Good	7.4	5	12	39.5
	15	Large	Good	7.4	4.5	10.5	38
	20	Large	Good	7.4	2	6	37
	25	Large	Good	7.3	2	5	34.5
PAC	5	Small	Fair	7.8	23	25	42.5
	10	Large	Good	7.7	6.5	10	41
	15	Large	Good	7.7	2	6	40
Ferric sulfate	10	Small	Fair	7.1	29	27	36.5
	20	Large	Good	6.8	3	12	30
	25	Large	Good	6.8	2	10	28
	30	Large	Good	6.7	up to 2	7	25
Ferrome Sulfate	10	*No flock*	Poor	-	-	-	-
	20	Absent	Poor	-	-	-	-
	40	Hardly present	Poor	-	-	-	-

Remark: *In the "sedimentation", "good" represents 40 to 60 mm/min,* while "fair" represents 20 to 30 mm/min sedimentation velocity (the same also applies to the following page.

(Jar Test Conditions)

Rapid stirring (190 rpm) .... 3 rinutes
Medium speed stirring (80 rpm) .... 1 minute
Slow sirring (40 rpm) .... 6 minutes

The analytical tests were done after stirring the sample and leaving it alone for 10 to 30 minutes. The supernatant of the sample was used in the analysis.

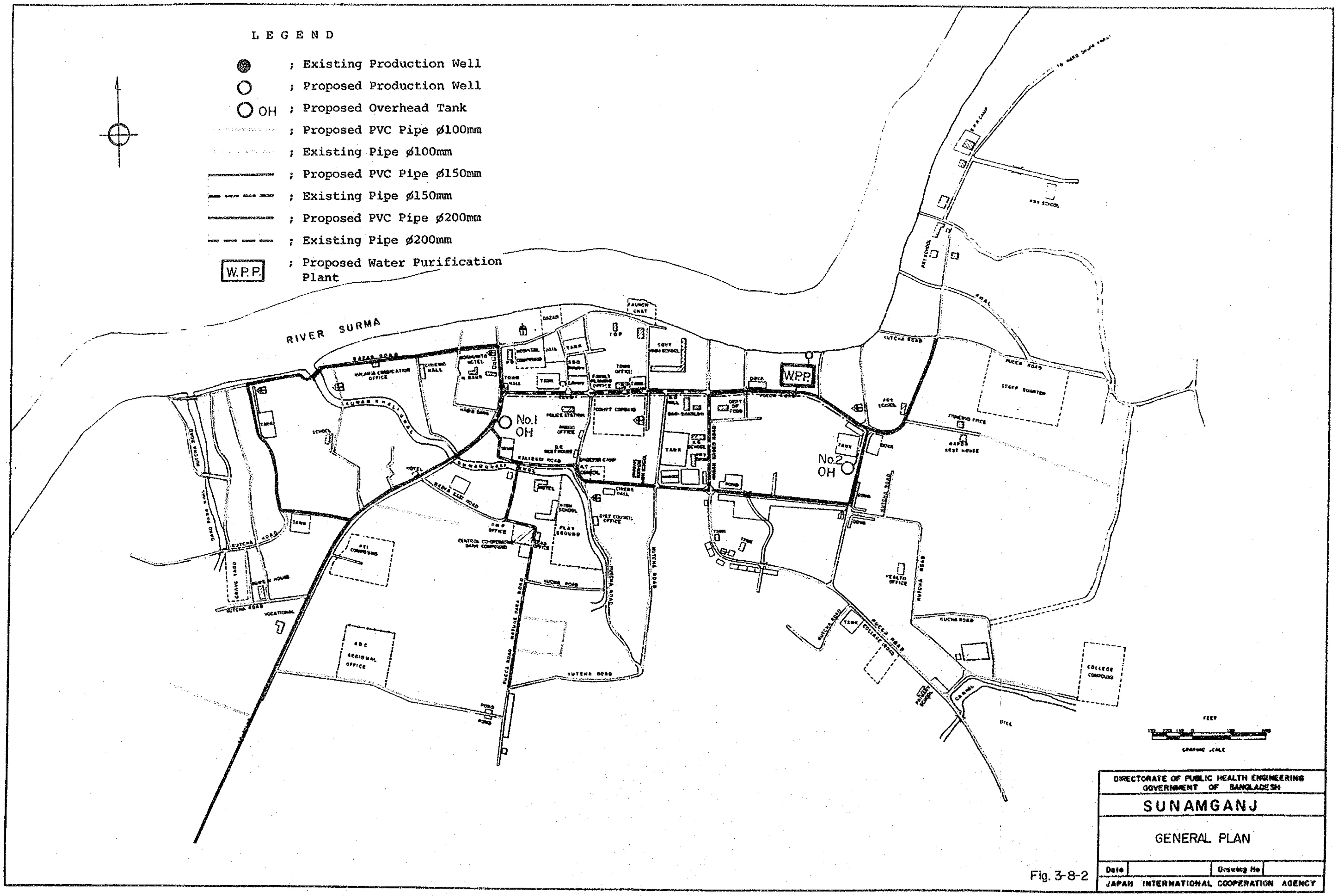
Table 3-8-11 Results of Heavy Metal Analysis (August, 1984)

	Surma	Quantitative limit	Standard value
Zinc (Zn)	0.014	0.01	5.0 to 15 (15)
Copper (Cu)	ND	0.02	0.05 to 15 (1.5)
Lead (Pb)	ND	0.05	0.1 (0.05)
Cadomium (Cd)	ND	0.005	0.01 (-)
Sexivalent chrome (Cr^{6+})	ND	0.01	n.d (0.05)
Cyanogen (CN)	ND	0.05	n.d (0.2)
Total Mercury (T-Hg)	ND	0.0005	n.d
Chloride iron (Cl)	ND	1.0	(600, max 1,000) 200 to 600
Fluorine (F)	ND	0.2	1.0 (1.0, max 2)

Remark: Standard values represent those specified by WHO, while those in parentheses represent those specified by EPCB.

Table 3-8-13 Water Quality Data of River Surma Near Chatak

Months	pH	EC micro cm^{-1}	Chloride mg/ℓ	P-alka mg/ℓ	T-alka mg/ℓ	DO mg/ℓ	BOD mg/ℓ	T.S. mg/ℓ	S.S. mg/ℓ	COD mg/ℓ	Temp °C	Coliform nos/100 mℓ	Remarks
JAN.													
Feb.	7.05	119	3.8	0	54	7.5	2.3	135.5	55	34	25		
March	7.15	156.5	10.0	0	54	7.5	0.8	102	34	37	30		
April													
May	7.6	158	14.0	0	67	7.10		198	44.5	40	30		
June	7.8	168	17	0	54	7.4	1.3	182	43.5	61	28		
July													
Aug.	7.3	165	10.0	0	120	6.8	1.5	114	33	39	27		
Sept.													
Oct.													
Nov.													
Dec.	6.5	222	8.2	0	112	6.05	2.6	275	59	41	21		



LEGEND
; Existing Production Well
; Proposed Production Well
OH ; Proposed Overhead Tank
; Proposed PVC Pipe ø100mm
; Existing Pipe ø100mm
; Proposed PVC Pipe ø150mm
; Existing Pipe ø150mm
; Proposed PVC Pipe ø200mm
; Existing Pipe ø200mm
W.P.P. ; Proposed Water Purification Plant
RIVER SURMA
No.1 OH
No.2 OH
W.P.P.
DIRECTORATE OF PUBLIC HEALTH ENGINEERING
GOVERNMENT OF BANGLADESH
SUNAMGANJ
GENERAL PLAN
Date
Drawing No
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3-8-2

3-8-4 Water Supply Plan

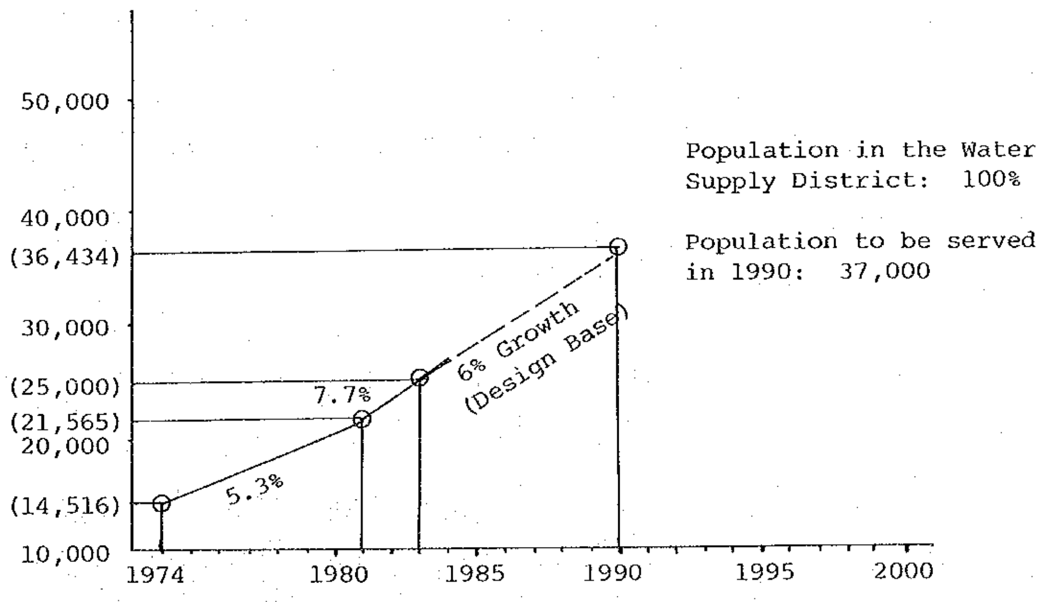
(1) Water Supply District and Population to be Supplied

Population at the time of censuses in 1974 and 1981 and today (May 1984) are as follows.

Population at the 1974 census	:	14,516
Population at the 1981 census	:	21,565
Population as of May 1984	:	25,000

These data may be plotted as follows.

Population Growth in Sunamganj Town



The average annual rate of population growth was 5.8% between 1974 and 1981 and 7.7% between 1981 and now. As was the case with other towns, the population growth rate from 1981 and the target year of this project (1990) was assumed to be 6% a year on average. Thus, the population in 1990 was projected to be 37,000.

The water supply district determined in consideration of the present geographic distribution of population, the prevalent state of settlement formation, the direction of future development of residential areas and other relevant factors almost entirely covers the municipal area of the town. Thus, the population to which water would be supplied in 1990 was assumed to be 37,000.

(2) Water Consumption

The estimated amount of water supply to serve a population of 37,000 would be as follows.

$$Q = 81 \text{ liters/man-day} \times 37{,}000 \text{ men} = 2{,}997.0 \text{ m}^3\text{/day}$$

(3) Water Supply Facilities Plan

(i) Water purification method and design conditions for water treatment facilities

A purification treatment system for raw water intake from surface water can be in slow filtration or rapid filtration method. Generally, the former method is applied to raw water with low turbidity, while for raw water with the turbidity exceeding a certain range, the rapid filtration system is more suitable when purification treatment capacity as well as maintenance and control are taken into account.

As the raw water for this project is from surface water anticipated to have the turbidity of average 40° and 200° and the highest, the rapid filtration system will be adopted.

The rapid filtration can involve the unit processes itemized below, and amongst them, those considered best in terms of (1) performance, (2) utilizability of local materials and equipment, (3) no need for advanced technical competence, and (4) easy maintenance and control, will be taken into our water purification treatment plan.

① Chemical sendimentation

Two methods are available:

a) High Rate coagulosedimetation basin

b) Side-channel type coagulosedimentation basin

Of these, although the size of the structure is larger, b) will be chosen, because its treatment functions are more flexible and its maintenance is easier.

② Mixing Basin

Four methods are available as follows:

a) Mechanical stirring type
b) Vertical baffling type
c) Diffusion pumping type
d) Weir type

In order to avoid mechanical structure and to make the maintenance easier, d) will be adopted. As indicators of mixing G value showing the degree of work load or shearing stress as well as G T Value are given as follows:

G value: 300 - 500 sec^{-1}
G T value: 15,000 - 100,000
Detention period: About 1 min.

③ Flocculation Basin

There are 3 methods as follows:

a) Vertical baffling type
b) Horizontal baffling type
c) Flocculator type

Of these, a) will be adopted as it is easy to operate and maintain. Requirements in planning the facilities will be as follows:

Detention period		30 min.
G value	Rapid zone	60 - 80 sec^{-1}
	Moderate zone	35 - 45 sec^{-1}
	Slow zone	15 - 25 sec^{-1}

④ Chemical Sedimentation

Three methods are available as follows:

a) Ordinary chemical sedimentation basin
b) Inclined parallel plates settling basin
c) Inclined tube settling basin

The a) will be chosen because land space is ample and it requires easier maintenance.

Detention period:	3 hours
Sludge collection:	Hopper to be set in 1 hour detention period zone downwards from the extreme upstream

⑤ Rapid Filter

Following 3 methods are possible:

a) Standard type
b) Selfwashing type (Valve).
c) Selfwashing type (siphon)

After comparing the 3 methods (See Table 3-8-14), b) will be selected in consideration of its simple structure and operation, inexpensive cost of equipment and small hydraulic loss.

Number of filters: 4

Filtering speed: 120 m/day (4 filters in operation)
150 m/day (3 filters in operation)

Bank washing: 0.6 m^3/m^2/min x 6 min

Surface washing: 0.2 m^3/m^2/min x 4 min, Fixed type

Minimum treatment water volume: To be set at 1/2 of the treatment capacity

Sand layer: Effective diameter of 0.6 m/m
Uniformity coefficient of 1.6 or less
Layer thickness of 0.6 m

Gravel layer: 2 - 4 m/m, 4 - 6 m/m, 6 - 10 m/m and 10 - 20 m/m
Layer thickness 50 m/m each

Underdrain system: Self-washing type porous blocks

Effective filtration waterhead: 1 m

make-up water: To be branched out from the transmission pipe

⑥ Clean water reservoir:

The capacity of a clean water reservoir is standardly 1 hour portion of its planned supply amount in Japan, but in the project 2 - hour supply portion of the planned water supply is set as the capacity of the reservoir since the reservoir is also gointo function as a suction well for the transmission pump.

⑦ Coagulant Chemicals feeding facilities

There types of coagulant are available as follows:

a) Solid aluminum sulfate
b) Liquid aluminum sulfate
c) PAC

c) is corsidered good because it is easy to handle and also easily coagulates, but in view of the special situation in Bangladesh, more inexpensive and more readily available solid aluminum sulfate will be used.
The solid aluminum sulfate (Al_2O_3 being 15%) will be dissolved and diluted to 3% Al_2O_3 solution for feeding.

Feeding formula:

$$P = 1.67 (8.7 + 2.2 \quad T),$$

where T: Turbidity

⑧ Disinfection Facilities

Following 4 types are the available sterlizing agents:

a) Bleaching powder
b) Chlorine gas
c) Sodium hypochlorite
d) Formed sodium hypochlorite (by electrolysis of salt)

In terms of low cost, safety and easy handling d) seems to be best, but it has some problems in mechanical maintenance. In the end, readily available a) will be chosen.

Bleaching powder (effective chlorine being 50%) will be dissolued and diluted to 10% effective chlorine solution for feeding.

Feeding rate:

P = 1.5 ppm (Average, and effective chlorine being %)

P = 15 ppm (Average)

Dissolution tank capacity: Capacity for

1 day feeding x 2 tanks

Table 3-18-4 Comparison of Rapid Filters

	Standard type	Self-washing type (valve)	Self-washing-type (siphon)
Filtration area	11.78 m^2/bed x 4 beds = 47.12 m^2	11.78 m^2/bed x 4 beds = 47.12 m^2	ditto
Rate of filtration	Normal: 112 m/day Backwash: 149.2 m/day	ditto ditto	ditto ditto
Amount of backwashing water (make up volume)	7.1 m^3/min x 6 min = 42.62 m^3	3.4 m^3/min - 5.1 m^3/min x 6 mon = 20.4 - 30.6 m^3	ditto
Equipment installed:			
Raw water inlet	Raw water inlet valve ø 200	Raw water inlet valve ø 200 + Distribution weir	Raw water siphon ø siphon tube : 1 Diaphragm valve: 2 Solenoid valve : 2 + Distributing weir
Backwashing water equipment	High tank	Self-filtered water + make-up water (transmission pipe)	ditto
	Backwashing water pipe ø 300	Make-up water pipe ø 250	ditto
	Backwashing water valve ø 300	Make-up water valve ø 250 (common equipment)	
Backwash drainage equipment	Drain sluice gate 300 x 300	ditto	Drainage siphon Siphon tube 200 x 400: 1 Diaphragm valve : 2 Solenoid valve : 2
Filtration adjustment device	Clear water valve ø 300 Flowmeter Filtration regulating valve ø 150	Filtration control weir (common equipment)	ditto
Inspection & maintenance equipment		Clear water valve ø 400	Clear water flat bottom valve ø 400
Others			Compressor Vacuum pump Vacuum tank (with flow regulating valve) Air piping Vacuum piping (All of foregoing area common equipment)

	Standard type	Self-washing type (valve)	Self-washing-type (siphon)
(Construction cost)			
Framework cost	1	0.9	1.3
Structure	The pipe corridor section is complicated, and the basin is shallows. Further, the pipe corridor section is very deep, and the bottom plate is uneven, making the work difficult.		
Equipment area	1	0.9	1.1
Equipment depth	Basin: 3.5 m Pipe corridor: 6.5 m	Basin: 4.2 m Pipe corridor: 4.5 m	Basin: 5 m Pipe corridor: 6 m
Volume of concrete	1	0.9	1.3
Equipment cost	1	0.75	0.8
	The sophisticated apparatus such as flow controller and the large equipment such as a backwash system make the cost dearer	Without highly complex equipment, 3 valves per basin are enough to operate this.	Many complex devices related to the siphon, though their scales are small.
Maintenance & operation cost	1	0.5	0.8
	Many kind of equipment such as a filtration controller requiring technical competence and operation	Very simple because operable only by fully opening or closing 3 valves: the raw water inlet valve, washing drain valve and surface washing valve	Necessary to operate many kind of equipment related to the inlet siphon and the washing drain siphon. Also, necessary to install such automared equipment as a vacuum pump and a compressor.
Others			
Hydraulic loss	3.75 m	1.5 m	2.0m

(ii) Capabiilty of water treatment facilities

The planned quantity of water supply is 2,997 m^3/day. According to the consultation with the Bangladesh Government, the water purification operation will be done for 15 h/day, with the quantity of water to be used in the purifcation plant beign 10% of the total. The water supply capability of the current plan will be as given below.

$$2,997 \text{ m}^3/\text{day} \times \frac{24}{15} \times 1.1 = 5,275 \text{ m}^3/\text{day}$$

(iii) Capacities of facilities

Quantity of water to be treated: 15 hours operation

5,275 m^3/day = 219.8 m^3/h = 3.66 m^3/min
= 0.061 m^3/sec

(a) Water channel well

Number of well: 1

Dimentions:

width 2.2 m x length 5.0 m x effective depth 2.0 m

Capacity: 22 m^3

Residence period: $\frac{22.0 \text{ m}^3}{3.66 \text{ m}^3/\text{min}} = 6.0$ min

Inside flow velocity: $\frac{0.061 \text{ m}^3/\text{sec}}{2.2 \text{ m} \times 2.0 \text{ m}} = 0.014$ m/sec

Measuring weir: B = 2,200, d = 2,790, H = 210

(b) Mixing basins

Number of basins: 4

Water treatment capability per basin:
1,319 m^3/day = 55.0 m^3/h = 0.92 m^3/min = 0.015 m^3/sec

Dimensions:

width 0.7 m x length 0.4 m x effective depth 3.0 m

Capacity: 0.84 m^3

Residence period: $\frac{0.84\ m^3}{0.92\ m^3/min} = 0.91$ min

Structure: Verical reverse flow type (overflow weir 1)

G = 300 $\quad h = 0.117\ G^2T \times 10^{-6}$
$= 0.117 \times 300^2 \times 54.6 \times 10^{-6}$
$= 0.575$

$h = 3.5\ \frac{\nu^2}{2g} \qquad \nu = \sqrt{\frac{0.575 \times 19.6}{3.5}} = 1.79$ m/sec

Overflow water depth; 0.049 m

(c) Flock formation basins

Number of basins: 4

Dimensions: width 0.7 m x length 2.9 m x effective depth 3.0 m, 1 streak; 6.09 m^3

width 0.8 m x length 3.3 m x effective depth 3.0 m, 1 streak; 7.92 m^3

width 0.9 m x length 3.3 m x effective depth 3.0 m, 1 streak; 8.91 m^3

width 1.0 m x length 3.3 m x effective depth 3.0 m, 1 streak; 9.9 m^3

Capacity: 32.82 m^3

Residence period: $\frac{32.82\ m^3}{0.92\ m^3/min} = 35.7$ min

Structure: Vertical freverse flow type

1st streak: lower bending portions (2);
G = 57, h = 0.039, t = 0.046
G = 51, h = 0.031, t = 0.051

overflow weirs (2)
G = 60, h = 0.043, t = 0.023
G = 54, h = 0.035, t = 0.026

2nd streak: lower bending portions (2);
G = 45, h = 0.031, t = 0.045
G = 39, h = 0.023, t = 0.052

overflow weirs (2)
G = 48, h = 0.036, t = 0.022
G = 42, h = 0.027, t = 0.026

3rd streak: lower bending portions (2);
G = 33, h = 0.019, t = 0.051
G = 27, h = 0.013, t = 0.062

overflow weirs (2)
G = 36, h = 0.023, t = 0.025
G = 30, h = 0.016, t = 0.030

4th streak: lower bending portions (2);
G = 21, h = 0.009, t = 0.067
G = 15, h = 0.004, t = 0.100

overflow weirs (2)
G = 24, h = 0.011, t = 0.032
G = 18, h = 0.016, t = 0.044

Total water head loss: 0.366

(d) Settling basins

Number of basins: 4

Dimensions:

width 3.3 m x length 16.6 m x effective depth 3.0 m

Capacity: 164.34 m^3/basin x 4 basin = 657.36 m^3

Residence period: $\frac{164.34\ m^3}{55\ m^3/h}$ = 2.99 hours

Inside flow velocity: $\frac{0.092\ m^3/min}{3.3\ m \times 3.0\ m}$ = 0.093 m^3/min

Mud discharge pit

(e) Rapid filtration basins (self purification valve type)

Number of basins: 4

Dimensions:

width 3.1 m x length 3.8 m (= 11.78 m^2/basin)
(width 4.15 m x length 3.8 m x depth 4.5 m)

Filtration velocity: 4 basin opeartion time; 112.0 m/day

3 basin operation time; 149.3 m/day

Back wash: 0.6 m/min x 6 min

Back wash rate:

11.78 m^2/basin x 0.6 m^3/m^2/min = 7.07 m^3/min/basin

7.07 m^3/min/basin x 6 min = 42.4 m^3/basin

Water refilling rate:

3.41 m^3/min (at 100% opeartion time) -
5.24 m^3/min (at 50% opeartion time)

Water to be refilled from water towers.

Surface wash: 0.2 m^3/m^2/min x 4 min

Lower catchment device:

Self-purification type porous blocks

Filtration layer: Quarz sand effective diameter; 0.6

Mean coefficient 1.6 or less

Thickness of layer 0.6 m

Supporting layer:

Gravel 2.0 to 4 mm; 4 to 6 mm; 6 to 10 mm;
10 to 20 mm, each layer 50 mm

Raw water distribution:

width 0.8, square weir + ø200 butterfly valve

Drainage: ø300 water control door

Surface wash system:

ø125 surface wash main pipe + ø125 gate valve

Water feed equipment:

ø250 main pipe from the water tower + ø250 butterfly valve

Chlorine is placed before the filtration adjustment weir

(f) Purification basin/water feed pump well

Number of wells: 2

Dimensions:

width 5.0 m x length 14.7 m x effective depth 3.0 m

Capacity: 220.5 m³/basin x 2 basin = 441 m³

Residence period: $\frac{441\ m^3}{219.8\ m^3/h} = 2$ hours

(g) Aggregation agent feeding

Aggregation agent: Solid alumina (15% Al_2O_3)

Place it in 5% solution of Al_2O_3, and dilute and melt it.

Filling rate: Assuming 5% solution of Al_2O_3

$P = 8.7 + 2.2\sqrt{T}$, where T: raw water rate

Filling quantity:

Average raw water precipitaion; 83° : 28.7 ppm (Assuming 5% solution of Al_2O_3)

$5{,}275\ m^3/day \times 28.7 \times 10^{-6} = 0.151\ m^3/day$

Dissolution tanks: 0.2 m³ x 2 tanks

(h) Sterilization agent feeding

Strilization agent:

Bleaching power (50% effective chlorine)

Dulute and melt the bleaching power to the effective chlorine content of 10%, and feed it to the tank.

Feeding rate:

Effective chlorine content max 2 ppm

Average 1 ppm

If the solution of 10% effective chlorine content is assumed, the rate wil be max 20 ppm and the average 10 ppm.

Feeding velocity:

$5,275\ m^3/day \times 10 \times 10^{-6} = 0.053\ m^3/day$
(Solutionm of 10% effective chlorine content)

Melting tanks: $0.1\ m^3 \times 2$ tanks

(ii) Overhead tank

The required total overhead tank capacity is:

$V = 2,997.0 \times 0.20 = 599.4\ m^3.$

a water towr of 400 m^3 capacity and another water tower of 200 m^3 capacity should be planned, taking account of locations of such towers.

(iii) Distributing pipe

Arrangement (layout) of the distributing pipes will be planned with due consideration to the geographic distribution of population, the locations of existing distributing pipes, the road conditions, the location of the purification plant, the direction of future development of residential areas, etc. All distributing pipes shall be PVC pipes with diameters of ϕ200 mm or less.

The hydraulic calculations for the pipeline network were carried out on the basis of the design conditions so as to secure the hydraulic pressure of 9.0 m at every terminal end of the distributing main and branch.

(iv) Public post

The discharge rate from a ϕ13 mm tap is 20 liters/min (14.4 m^3/12 h). As the plan calls for supplying water to 50% of the inhabitants by means of public post, the required quantity of water supply for this would be:

$$Q = 37,000 \text{ persons} \times 0.5 \times 34 \text{ liters/man-day}$$
$$= 629.0 \text{ m}^3\text{/day}$$

Thus, the required number of public posts is 44.

Under this project, public posts will be constructed at 10 locations, while the balance will probably be constructed by the Government of Bangladesh.

3-8-5 Contents of the Project

(1) Water Supply Facilities Already Completed by DPHE

The contents of water supply facilities already constructed by DPHE's own funds are as shown in Table 3-8-15.

(2) Water Supply Facilities to be Constructed under this Project

The contents of water supply facilities to be constructed under this project, which were determined on the basis of the contents of water supply facilities of this project as a whole and the contents of facilities already completed by DPHE, are as shown in Table 3-8-15, and the proposed plan for them is as shown in Fig. 3-8-2.

Table 3-8-15 (1) Outline of the Water-Supply Systems to be Constructed in This Project

Sunamganj

Facilities	Specification	Project as a Whole	Existing Facilities Constructed by DPHE	Facilities to be Constructed Anew
1. Water Purification Plant	Treatment capacity: 3,000 m³/day	1 unit	0	1 unit
2. Pumping Facilities	No.1, ø250mm x 22kw x 1No. No.2, ø150mm x 11kw x 1No. Volute pump	2 units	0	2 unit
3. Transmission Pipes	No.1, ø250 mm	990 m	0	990 m
	No.2, ø150 mm	400 m	0	400 m
4. Overhead Tank	Capacity: 200 m³/400 m³ 1 unit of each Height: 17 m Reinforced concrete	2 units	0	2 units
5. Distributing Pipe	PVC Pipe: ø200 mm	760 m	0	760 m
	ø150 mm	5,786 m	1,806 m	3,980 m
	ø100 mm	16,850 m	0	16,850 m
	Total	23,396 m	1,806 m	21,590 m
	Breakdown by pavement as per attached sheet			
6. Related Structures of Distributing Pipes	Sluice valve (box): ø200 mm	4 units	-	4 units
	ø150 mm	47 "	12 units	35 "
	ø100 mm	92 "	-	92 "
	Blow-off: ø200 mm	-		-
	ø150 mm	6 units	Wash-out	6 units
	Pipe and work: ø100 mm	24 "	1 No. (ø6")	24 "
	ø150 mm	1 "		1 "
	ø200 mm	-		-
7. Public Post		10 places	0	10 places

Table 3-8-15 (2)

Breakdown of Transmission Pipes and Distributing Pipes by Pavement
(Only Water-Supply Systems to be Constructed Anew)

Sunamganj

Item \ Type	By Type of Pavement					Remarks
	As	R.C	Bricks	Kutcha	Total	
1. Transmission Pipes						
ø10" (No.1)	100m	840m		50m	990m	
ø6" (No.2)		350		50	400	
Total	100	1,190		100	1,390	
2. Distributing Pipes						
ø4" (Parallel to the road)	1,020m	8,260m	1,030m	6,330m	16,640m	
ø4" (Crossing the road)	60	120	10	20	210	
Sub-Total	1,080	8,380	1,040	6,350	16,850	
ø6" (Parallel to the road)	2,150	1,820			3,970	
ø6" (Crossing the road)		10			10	
Sub-Total	2,150	1,830			3,980	
ø8" (Parallel to the road)	760				760	
ø8" (Crossing the road)						
Sub-Total	760				760	
Total	3,990	10,210	1,040	6,350	21,590	

3-9 Project Cost

3-9-1 Cost to be borne by the Government of Bangladesh

In implementing this Project, the Government of Bangladesh shall also bear a part of the construction cost. The cost to be borne by the Government of Bangladesh is as follows.

1) Land acquisition/development cost

2) Import duties and other charges on articles to be imported from Japan

3) Cost of maintenance and administration facilities and equipment

4) Of the water supplying facilities, the construction cost of house connections and public posts other than ten public posts for each town covered under this Project. The foregoing construction cost, however, has not been included in the Project cost.

Cost breakdown for each item is as shown below.

(1) Land acquisition/development cost

This cost shall be borne by the Government of Bangladesh. According to the interview survey findings at DPHE's local offices during the field survey, land acquisition cost per acre is as follows.

Town	Urban Area (TK/Ac)	Suburbs (TK/Ac)
Junidah	1,000,000	800,000
Chuadanga	-	37,500
Gaibandha	1,000,000	-
Kurigram	1,200,000	40,000
Feni	2,000,000	-

In the Five Town Water Supply Project aided by ADB, 1,150,000 TK/Ac was adopted as the cost of acquiring land in urban communities of Bogra, Mymensingh, Jessore and Barisal. In the 12 Town Water Supply Project aided by the Netherlands, the land acquisition cost was appropriated in lump sum, the breakdown of which is unavailable.

Water towers, wells, purification plants, etc. planned in this Project will be constructed within the municipal areas. Using the results of field surveys and the costs in other projects as references the land acquisition cost in this Project was asuumed to be 1,200,000 TK (300 TK/m^2) under this Project.

Also, as most of the construction sites were selected in the already developed areas, land development cost is almost unnecessary, excepting a few sites selected in rice paddy fields, for which the land development costs shall be estimated.

Since the construction sites have been selected near existing roads, no access road was considered necessary and therefore no cost thereof was appropriated.

Table 3-9-1 Land Acquisition/Development Cost by Town

Unit = TK

Town	Wells and Pumping Stations	Overhead Tanks	Deironization Systems and Purification Plant	Land Filling	Total
Narsingdi	$11 \times 150m^2 \times 300=$ 495,000	$5 \times 500m^2 \times 300=$ 750,000	-	-	1,245,000
Jenidah	$1 \times 150m^2 \times 300=$ 45,000	$3 \times 500m^2 \times 300=$ 450,000	-	-	495,000
Chuadanga	$1 \times 150m^2 \times 300=$ 45,000	$3 \times 500m^2 \times 300=$ 450,000	-	-	495,000
Kurigram	$1 \times 150m^2 \times 300=$ 45,000	$2 \times 500m^2 \times 300=$ 300,000	$2 \times 250m^2 \times 300=$ 150,000	-	495,000
Gaibandha	$2 \times 150m^2 \times 300=$ 90,000	$2 \times 500m^2 \times 300=$ 300,000	$1 \times 250m^2 \times 300=$ 75,000	$1,300m^3 \times 53=$ 68,900	533,900
Feni	$2 \times 150m^2 \times 300=$ 90,000	$2 \times 500m^2 \times 300=$ 300,000	-	$2,300m^3 \times 53=$ 121,900	511,900
Sunammganj	-	$2 \times 500m^2 \times 300=$ 300,000	$5,000m^2 \times 300=$ 1,500,000	$2,000m^3 \times 53=$ 106,000	1,906,000
Total	810,000	2,850,000	1,725,000	296,800	5,681,800

Cost of land acquisition for each town is as shown in Table 3-9-1.

(2) Import duties and other charges on articles to be imported from Japan

Expenses such as import duties for each town are as tabulated below.

Table 3-9-2 Expenses such as Import Duties by Town

Town	Duties & Taxes	
Narsingdi	9,346	x 1,000 TK
Jenidah	2,863	
Chuadanga	2,246	
Kurigram	1,291	
Gaibandha	3,167	
Feni	2,723	
Sunamganj	11,910	
Maintenance & Administration Equipment	31,833	
Total	65,269	

(3) Cost of maintenance and administration facilities and equipment

As the room for pump operator is annexed to the pumping station, its construction cost is included in the cost of the new pumping station. As for existing pumping stations, the room for pump operator is assumed to be built by the Government of Bangladesh.

For the maintenance and administration of facilities, offices, storehouses, etc. will be necessary. These will presumably be arranged by the Government of Bangladesh in view of the fact that the organizational structure of the administrative organ and its position within Poroushoava have already been established. It is desirable to utilize the existing buildings for these facilities, but if these have to be newly built, the required space and construction cost for these shall be determined by referring to the projects aided by the Asian Development Bank and the Netherlands.

The maintenance and administration organ will also need vehicles, etc. for maintenance and administration of water supply facilities.

The cost of maintenance and administration facilities and equipment per one town is estimated as follows.

(Facilities)

Main administration office building:
92.9 m^2 (1,000 sft) x 1 bldg. x 3,250 TK/m^2
= 301,925 TK

Storehouse for spare parts, etc.:
185.8 m^2 (2,000 sft) x 1 bldg. x 1,625 TK/m^2
= 300,996 TK

Sub-Total 602,921 TK

(Vehicles, etc.)

Small jeep: 1 ea x 106,888 = 106,888 TK
Motor cycle: 2 ea x 14,982.5 = 29,965 TK

Sub-Total 136,853 TK

(Duties and taxes for importing vehicles, etc.)
136,853 TK

(Duties and taxes for importing water quality testing appratus) 57,014 TK

Total 933,641 TK

(4) Cost for improving equipment of DPHE's Mechanical and Electrical Division

The drinking water supplying facilities using wells as the major water source will be constructed by the aid of Japan but subsequent maintenance and administration will be carried out by the Government of Bangladesh. The total number of the wells to be constructed under this Project and the wells that have already been constructed by DPHE in the seven towns covered would add up to 29 wells. The seven towns covered by this Project are a part of the Water Supply Scheme for 27 Sub-Divisional Towns (which are now District Towns), and the water supplying facilities for the remaining 20 towns will presumably be constructed in the future.

Maintenance and administration of these facilities will be undertaken by DPHE for three years after their completion, but after that, these functions are to be transferred to the Poroushoava Office of each town. However, it would be impossible to set up a function which is able to perform maintenance and repair of water supplying facilities, particularly the wells, within each Poroushoava Office at this stage, and therefore, even after the jurisdiction over such facilities has been turned over, DPHE would have to undertake maintenance and repair of these water supplying facilities. Since this would increase the workload of the Mechanical and Electrical Division of DPHE which is now responsible for maintenance and administration of mainly wells, it would eventually necessitate the expansion of this Mechanical and Electrical Division which the Government of Bangladesh is already considering.

The expanded Mechanical and Electrical Division would require the facilities and equipment enumerated in the paragraph on maintenance and administration, among which, the following equipment will be borne by the Government Bangladesh.

. Boring machine		
Boring machine (ø550 mm, L = 350 m):	1 set	11,255,000 TK
Boring machine (ø750 mm, L = 150 m):	1 set	10,894,000 TK
. Micro bus	2 ea	962,000 TK
. Jeep	2 ea	502,000 TK
Total		23,613,000 TK

Duties and taxes and other necessary charges on import of these equipment amount to 23,613,000 TK. Besides these, the Government of Bangladesh shall also bear duties and other expenses on import of equipment for inspection and repair of the wells and on trucks, all of which will be included in the assistance package of Japan.

5) Construction cost of house connections and public posts which are not included in this Project but which are to be constructed by the Government of Bangladesh in future

The construction costs of house connections and public posts to be constructed by GOB for each town are shown in Table 3-9-3.

6) The cost to be borne by GOB for each town is shown in Table 3-9-4.

Table 3-9-3 Construction Cost of House Connections and Public Posts
(to be borne by the Government of Bangladesh)

Unit = 1,000 TK

Town	House Connections				Public Posts				Total	
	No. of House-holds	L.C	F.C	Total	No. of House-holds	L.C	F.C	Total	Total Construc-tion Cost	Duties & Taxes
Narsingdi	3,570	15,194	7,872	22,066	164	213	203	416	22,482	7,075
Jenidha	2,115	9,001	4,071	13,072	67	87	83	170	13,242	4,154
Chuadanga	2,270	9,661	4,370	14,031	71	92	88	180	14,211	4,458
Gaibandha	2,470	10,512	4,755	15,267	54	70	67	137	15,404	4,822
Kurigram	1,980	8,427	3,812	12,239	27	35	33	68	12,307	3,845
Feni	2,205	9,384	4,245	13,629	28	36	35	71	13,700	4,280
Sunamganj	1,630	6,937	3,138	10,075	34	44	42	86	10,161	3,180
Total	16,240	69,116	31,263	100,379	445	577	551	1,128	101,507	31,814
		(4,256TK/ea)	(1,925TK/ea)			(1,298TK/ea)	(1,236TK/ea)		133,321	

Note: The above house connections and public posts are to be completed by 1990. As the construction schedule remains undecided, the cost inflation has not been considered. The unit prices as of August 1984 were used.

Table 3-9-4 Total Cost to be borne by GOB for each town

Item		Narsingdi	Jenidah	Chuadanga	Kurigram	Gaibandha	Feni	Sunamganj	Total
1. Land Acquisition/ Development		1,245,000	495,000	495,000	495,000	533,000	511,000	1,906,000	5,680,000
2. Import duties and other charges on articles to be imported from Japan	• for construction works	9,236,000	2,863,000	2,246,000	1,291,000	3,167,000	2,723,000	11,910,000	33,436,000
	• for O/M equipment	194,000	194,000	194,000	194,000	194,000	194,000	194,000	1,358,000
	• for M/E Div., DPHE	-	-	-	-	-	-	-	30,476,000
	• for house connections and public posts	7,075,000	4,154,000	4,458,000	3,845,000	4,822,000	4,280,000	3,180,000	31,814,000
	• sub-Total	16,505,000	7,211,000	6,898,000	5,330,000	8,183,000	7,197,000	15,284,000	97,084,000
3. O/M facilities		603,000	603,000	603,000	603,000	603,000	603,000	603,000	4,211,000
4. O/M equipments		137,000	137,000	137,000	137,000	137,000	137,000	137,000	959,000
5. M/E Div. DPHE		-	-	-	-	-	-	-	23,613,000
6. House Connection		22,066,000	13,072,000	14,031,000	12,239,000	15,267,000	13,629,000	10,075,000	100,379,000
7. Public Post		416,000	170,000	180,000	68,000	137,000	71,000	86,000	1,128,000
Total		40,972,000	21,688,000	22,344,000	18,872,000	24,860,000	22,148,000	28,091,000	233,064,000

3-10 Data for Chapter 3