the street area, jute plants, foodstuff warehouses, etc. located by the Sitalakhya River. The means of transportation in the eastern district are restricted to rickshaw and baby motor cars in view of the bad conditions of the roads, and even these means have only a limited use.

(2) Geology

Geologically, Quaternary fluvial sediments are thickly deposited in the project area because it is located in a delta. This sedimentary deposit consists of clay, silt, fine to coarse sand, gravel, etc., and these strata present abrupt changes in terms of such characteristics as stratum thickness, soil texture, distribution depth and continuity, due to differences in the course, discharge, flow speed, etc. of the old rivers, resulting into complicated distribution conditions.

The following facts became plain in connection with the geology of the project area, by taking a wide view of the strata distribution conditions occurring therein on the basis of the existing data and results of electric prospecting. (Refer to Fig. 3-1 to 3-8.)

a) The actual course of the river is in the NS to NW direction, and continuity of the strata is observed in the direction parallel to that course (NS) in spite of changes in the strata thickness and soil texture. On the other hand, in the direction transversal to the river course (EW) the continuity of the strata becomes poor due to changes in the strata thickness and soil texture.

b) At the vicinity of the actual river course there is sedimentation of sand stratum at shallow places, but generally speaking there is sedimentation of clayey soil mixed with fine sand on the surface of the ground, and at some localities the stratum thickness reaches 50 to 70 m.

c) In terms of strata composition as a whole, the distribution of clayey strata consisting of impermeable clay and silts is predominant, but in areas by the Sitalakhya River the distribution of sandy strata is as conspicuous as clayey strata.

d) As for sand strata, which are the object of groundwater development, in some cases with depth within GL -200 m the stratum may pinch out due to changes in the thickness or change gradually to sandy soil, but on the other hand strata sedimented at depths of the order of GL -10 m to -60 m and GL -100 m to 200 m are presumed to be distributed over a considerably wide range.

e) The distribution of gravel layers and coarse sand layers which are regarded as good water-bearing strata is rather rare in the project area, and it seems that the acquifiers consist mostly of fine sand to medium sand strata.

The project area has the geological characteristics outlined in the foregoings, but in reality it cannot safely be said that the hydrogeological structure of the project area is perfectly identified because the existing survey data are concentrated mostly in the street area and are not sufficient to make a clear distinction between the alluvium deposit and sedimentary deposit and furthermore the analysis of electrical prospecting data reaches only a limited depth.

The soil classification, classification codes and specific resistivity of the strata distributed in the project area are shown comparatively in the following table.

Table 3-1 Properties of the Strata

Soil Name	Water-bearing characte-ristics	Classi-fication code	Geologic profile code	Specific resisti-vity Ω-m	Remarks
Coarse sand	Satisfactory	CS	CS - MS	98 - 136	Distributed locally and punctuated with pebble
Medium sand	Satisfactory	MS	MS		Accompanied with fine sand, but consisting mainly of medium sand
Medium sand, fine sand	Normal	FMS	FMS		Alternate distribu-tion of medium sand and fine sand
Fine sand	Rather poor	FS	FS	32 - 60	Tending to be accom-panied with silt
Sandy silt	Poor	SCL	SCL	19 >	In the aggregate mixed with fine sand
Silt	Bad	SI	SI・CL		Handled collectively because it is diffi-cult to make a clear distinction between silt strata and clay strata.
Clay	Bad	CL			

In the geologic profile (Fig. 3-4 to 3-8) the strata are classified by using the codes indicated in the table, and the values of the specific resistivity are indicated as well.

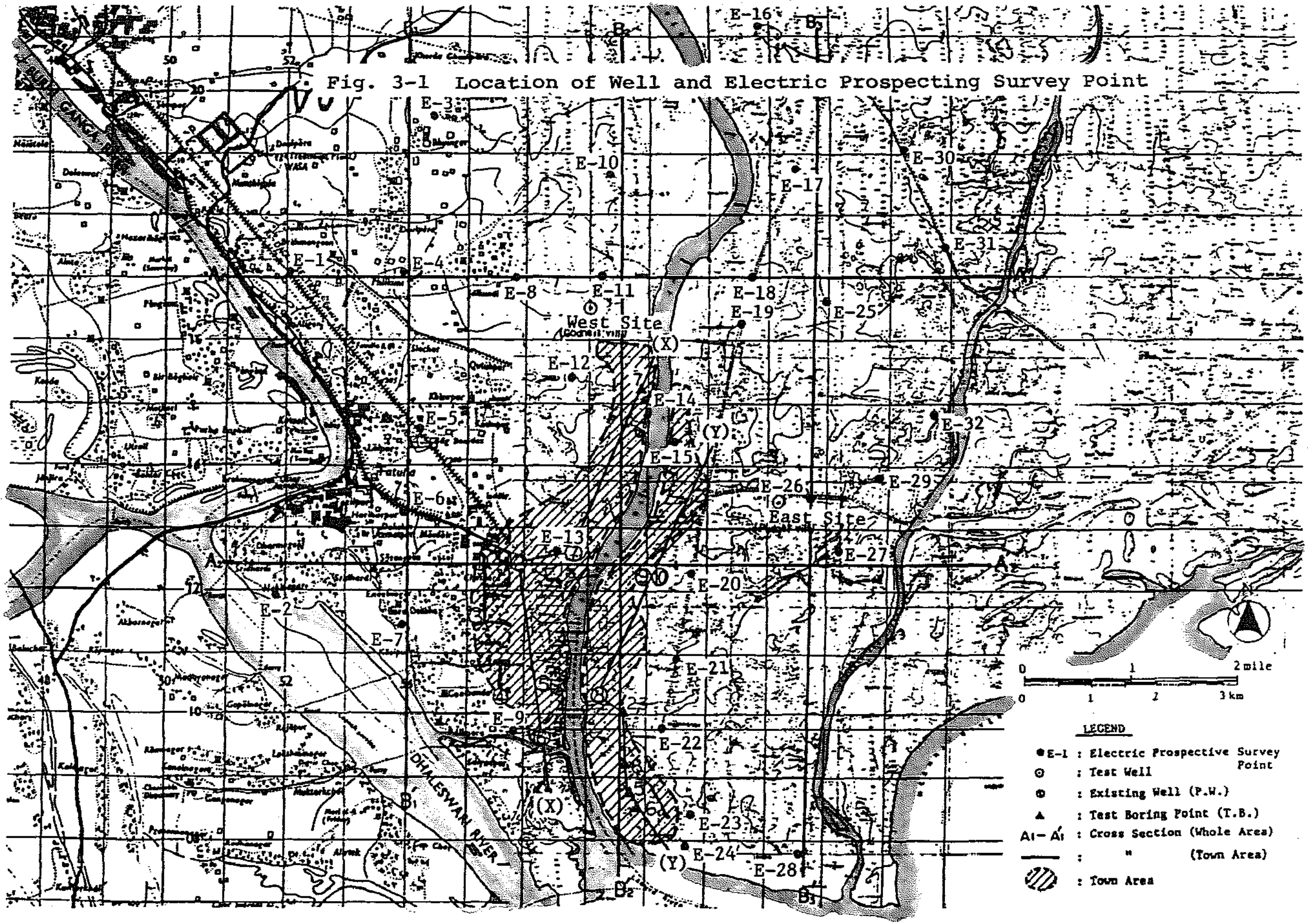


Fig. 3-1 Location of Well and Electric Prospecting Survey Point

Fig. 3-2 Narayanganj West Site (X)

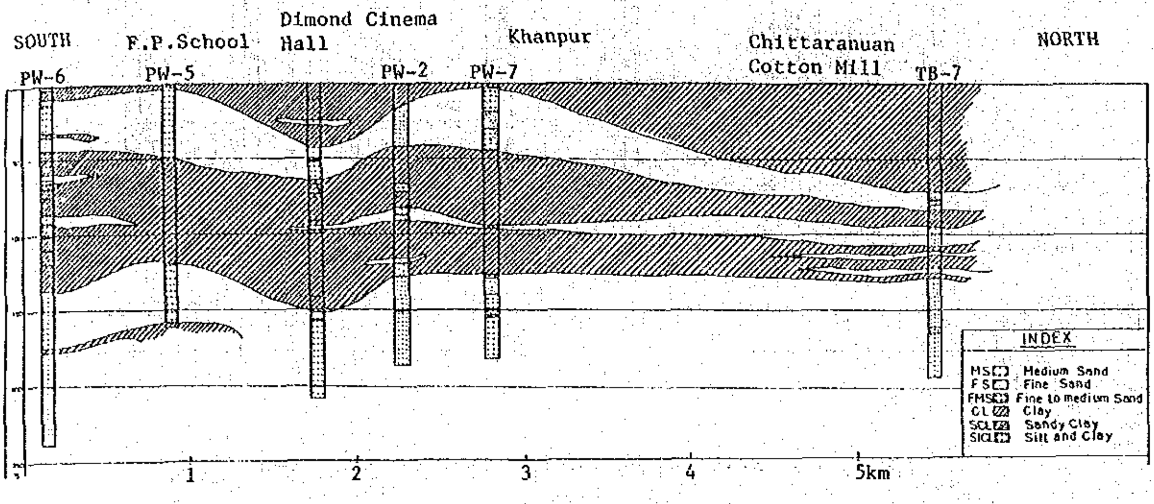


Fig. 3-3 Narayanganj East Site (Y)

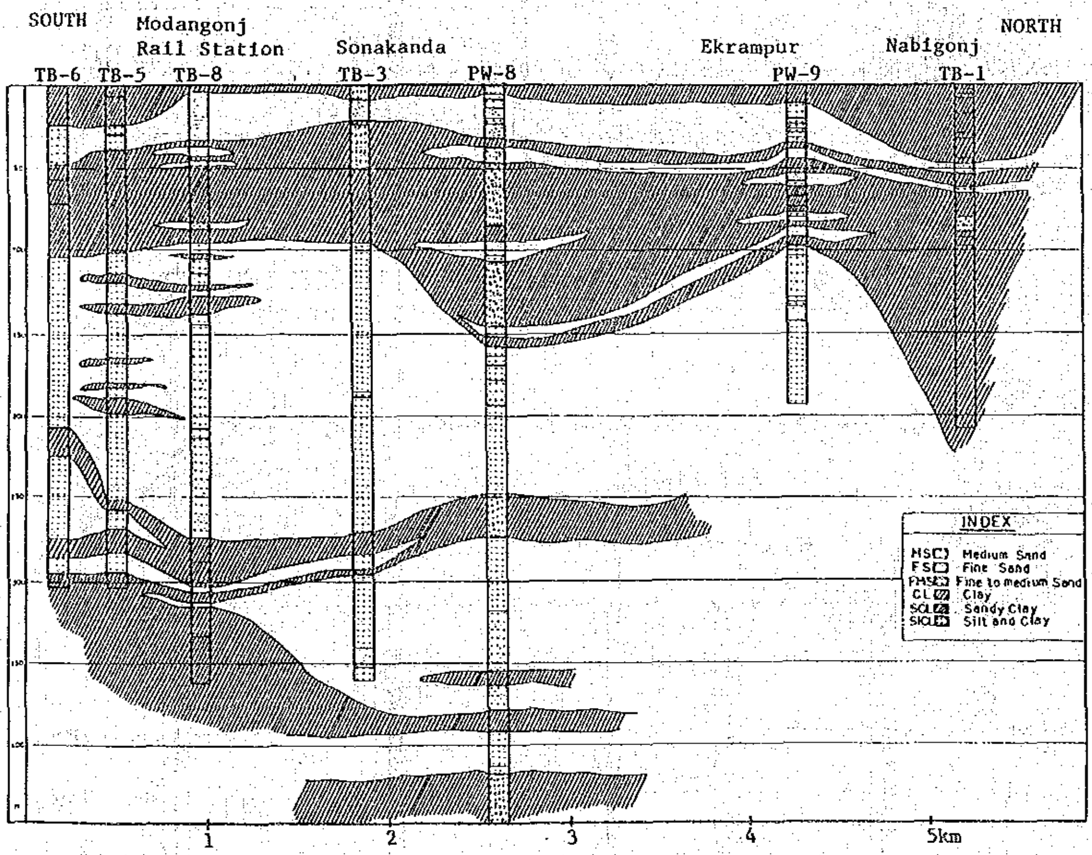


Fig. 3-4 Profile of Electric Prospecting (A_1-A_1')

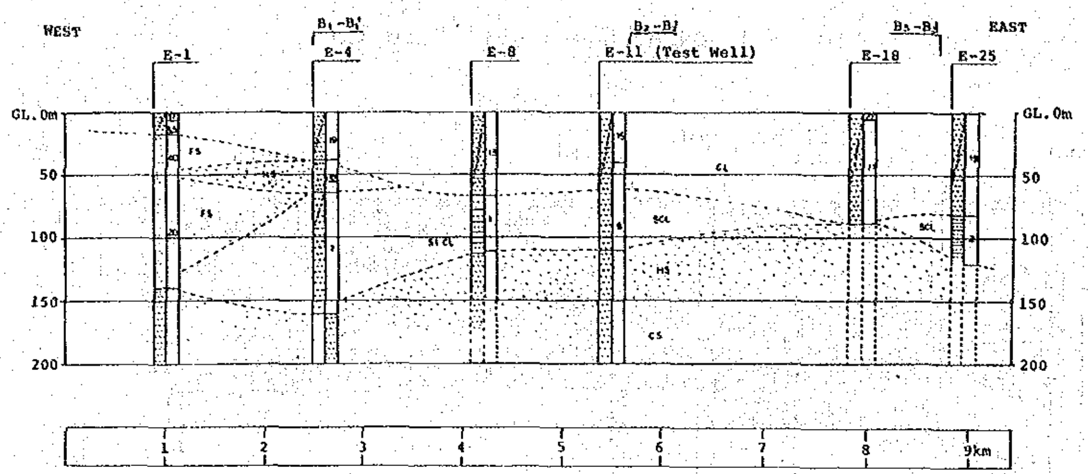


Fig. 3-5 Profile of Electric Prospecting (A_2-A_2')

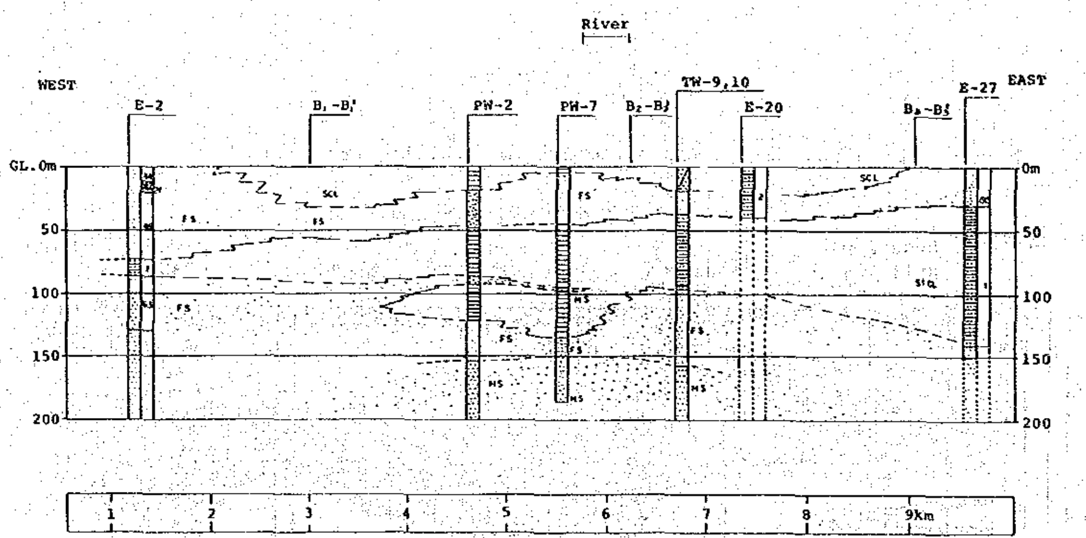


Fig. 3-6 Profile of Electric Prospecting (B_1-B_1')

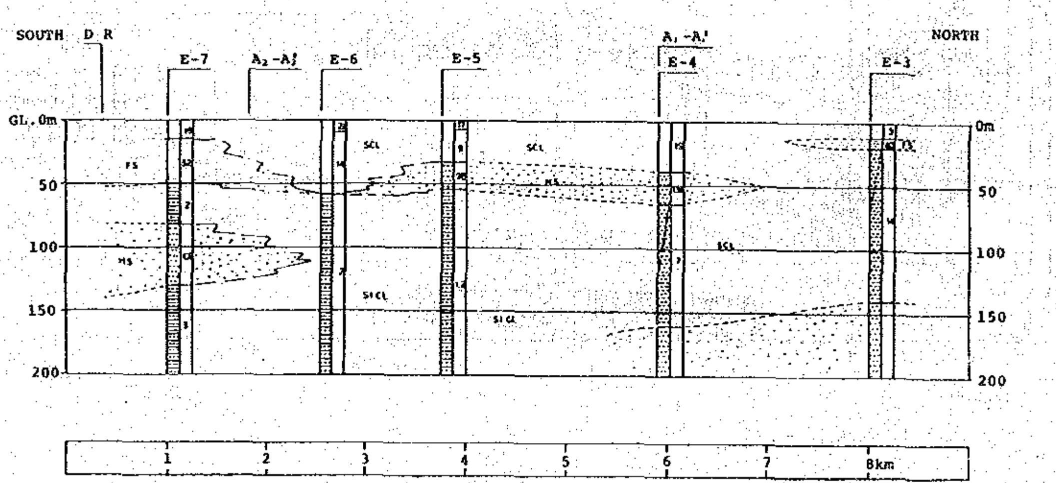


Fig. 3-7 Profile of Electric Prospecting (B_2-B_2')

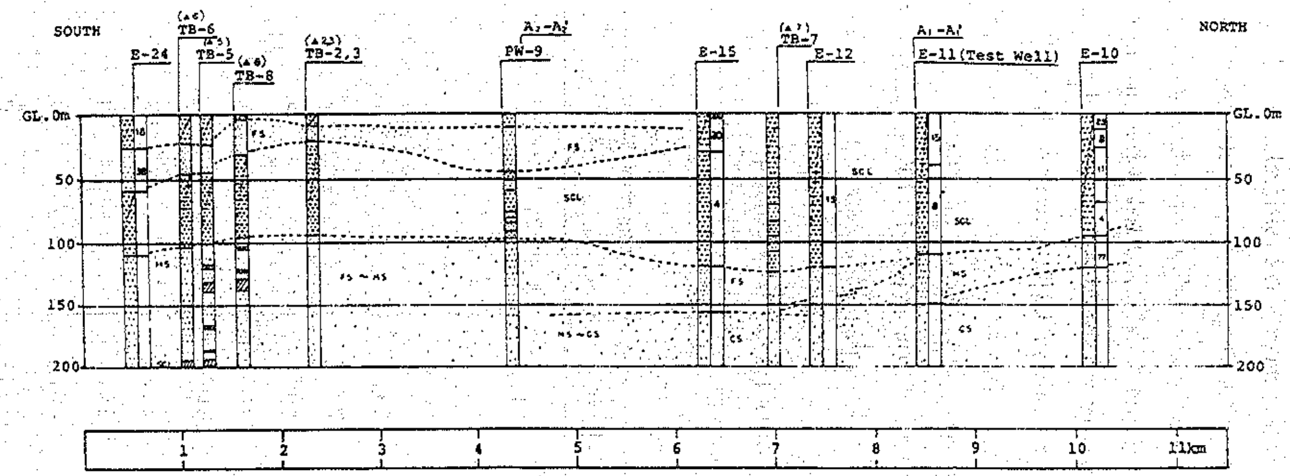
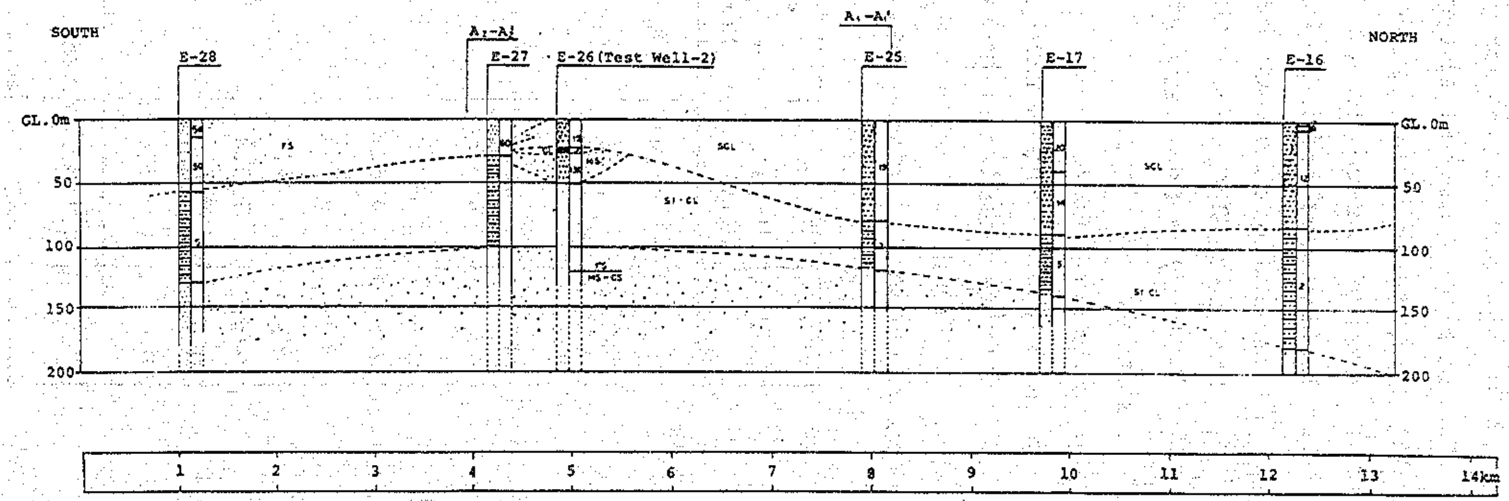


Fig. 3-8 Profile of Electric Prospecting (B_3-B_3')



(3) Meteorology and Hydrology

Narayanganj Town, like all other areas in Bangladesh, has the rainy season and the dry season. The annual rainfall is about 2,000 mm, most of which falls during the rainy season from May to September while there is hardly any rain during the dry season. The monthly maximum temperatures range between 27°C and 35°C, and the minimum between 12°C and 26°C. The temperature is low during the January - February winter season and high during March - June.

The monthly mean values from the 1971 - 1977 data are as tabulated below.

Table 3-2. Monthly Meteorological Record

Month	Rainfall (mm)	Mean Temperature (°C)		Maximum Wind Velocity (knots)
		Maximum	Minimum	
Jan.	1.8	27.4	11.8	17
Feb.	24.1	29.0	16.0	10
Mar.	62.0	32.2	19.9	30
Apr.	88.4	34.1	23.8	17
May	255.3	34.2	24.7	10
June	350.0	32.3	25.5	13
July	476.3	30.7	26.2	16
Aug.	358.4	31.2	25.2	23
Sept.	275.3	32.2	26.2	17
Oct.	135.4	33.4	24.9	13
Nov.	50.0	30.8	20.6	6
Dec.	43.4	28.3	19.1	5
Year	2,120.9	Aver. 31.3	Aver. 22.0	(From data recorded during 1967-1973)

The Sitalakhya River which flows through the center of Narayanganj Town originates in the Banar River which is a tributary of the Brahmaputra River that joins the Jamuna River with the Meghna River, and merges at the south of Narayanganj Town with the Burhi Ganga, a tributary of the Jamuna River, then flows into the Meghna River. Narayanganj Town and its vicinity on the Sitalkhya River is still within the range of being easily affected by the tidal level. A review of the hydrographic data of the Sitalakhya River since April 1975 indicates the lowest water level (LWL) during this period to have been EL 0.67 m and the highest (HWL), EL 5.52 m. Since the river discharge is affected by the tidal level, its observation is difficult. According to data, the maximum discharge during the flood season when unaffected by the tidal level is 2,540 m^3/sec. However, no data is available on droughty water discharge. The data on water level and discharge show that the water level is affected by the tidal level when it is below EL 2.50 m. At this threshold water level, the discharge is about 220 m^3/sec, occurring mostly during May - June and October - November. The water level of the river is lowest during January - February.

Table 3-3 Monthly Water Level and Discharge

Month	Water Level (m)		Discharge (m^3/sec)	
	Max.	Min.	Max.	Min.
Jan.	1.98	0.67	X	X
Feb.	1.88	0.69	X	X
Mar.	2.10	0.67	X	X
Apr.	2.56	0.93	X	X
May	3.47	1.56	459	232
June	4.53	2.02	1,560	470
July	5.18	3.17	2,150	959
Aug.	5.47	4.36	2,320	1,130
Sept.	5.52	4.27	2,540	1,110
Oct.	4.86	1.97	1,720	258
Nov.	3.74	1.18	637	220
Dec.	2.75	1.19	X	X

Note) X: No data available.

3-3 Outline of Social Facilities

(1) Road and Transportation

The major roads that connect the town with the other areas are the Banga Bandhu Road that directly connects the town with Dhaka and the Adamjee Nagar Road which connects with the Dhaka-Chittagong Road, both of which are on the West Bank of the Sitalakhya River. The latter is linked to the Issakhan Road and the Nawab Salimulla Road within the town and connects with the former Banga Bandhu Road near the railway crossing. This crossing is a rotary crossing with regulated traffic flow, and th Banga Bandhu Road which starts from here and runs into town is a wide road with sidewalks and a center belt for segregating traffic flow and is the main street of the town. Roads other than these major ones are narrow in width, are inferior in alignment and poorly paved so that access by automobile is often difficult.

At present, however, the level of automobile ownership in this town is low, reflecting the income level of this country. Especially, the number of owner driven cars and taxi cabs are countable with the fingers. Most of the automobile population is accounted for by buses and trucks, but as the buses and trucks use the arterial roads and the roads of adjacent areas, traffic congestion on the small roads due to entry of automobiles is not as frequent as one would assume.

The major mode of urban transport is the rikshaw which accounts for most of the traffic on the roads within the city.

(2) Electric Power Situation

Power lines ramify through the length and breadth of Narayanganj Town. High tension lines of 11,000 V (11 kV) are laid along major roads and electricity to ordinary houses (one-storied) is supplied at 220 V and to multi-story buildings at 440 V. Generally speaking, power failure is said to occur at the rate of around one hour every day.

(3) Gas

Gas is distributed within the town through gas pipes laid underneath the roads.

(4) Telephone Line

Telephone lines are also laid beneath the roads within the town.

(5) Public Facilities

Various facilities of every sort of public organs are found within Narayanganj Town. As for primary schools, there are a total of 42 schools, 28 on the west side and 14 on the east side; as for middle schools, there are 17 schools, 12 on the west side and five on the east side. All of its four colleges are located on the west side. There are also 12 Muslim schools (Madrashs) and 12 kindergartens.

As for hospital, there is only one on the west side now but another one is being constructed as a grants-in-aid program of the Japanese Government.

There are two police stations, one each for the west side and east side. There are also 35 government office buildings and 13 semi-government facilities most of which are distributed on the west side of the town.

As public facilities consume little water, it was assumed ignorable. Large scale factories have their own wells, and cottage industries consume about the same amount of water as public facilities.

(6) Current Status of the Development Project

Two urban residence development projects are currently being contemplated for Narayanganj Town in the outer periphery of the existing urban area of the Poroushaova on the West Bank.

The timing, scale, target population and other details of these development schemes are undecided yet. Accompanying the growth of population within the town, it is anticipated that the existing town area will have to be expanded by about 25% in the future. However, the area to be expanded, location, timing, scale and future population have yet to be studied.

CHAPTER 4 WATER SOURCE PLAN

4-1 Types of Water Source

At the present time the water sources of the water supply facilities of Narayanganj Town are the purification plants and deep wells. The purification plants use water of the Sitalakhya River and the deep wells use groundwater.

The present water utilization from all source is shown in the following table.

Table 4-1-1 Water Utilization by Source (per day)

Water Source \ Area	Facility	West Bank	East Bank	Total
Surface flow water	Purification plant	1 place 3,640 m³/day	1 place 796 m³/day	2 places 4,436 m³/day
Groundwater	Deep well	7 wells 5,737 m³/day	2 wells 819 m³/day	9 wells 6,556 m³/day
	Hand pump			720 pumps
Total		9,377 m³/day	1,615 m³day	10,992 m³/day

As can be seen, at the present time groundwater dominates surface flowing water with a ratio of 6:4.

As stated in Par. 5-4, Chapter 5, this project is aimed at securing the supply of 34,176 m³/day in the western district and 10,944 m³/day in the eastern district, totaling 45,120 m³/day. Of the said quantities, the existing facilities such as purification plants, deep wells, etc., that will be available for use also in the future, are expected to supply 8,554 m³/day in the western district, while in the eastern district there is no available facility at all. Therefore, the quantity of water to be developed anew in this project will be 25,622 m³/day in the western district and 10,944 m³/day in the eastern district, totaling 36,566 m³/day.

Two types of water source are available at the vicinity of Narayanganj Town, which are groundwater and surface flowing water of the Sitalakhya River. The alternatives of using groundwater and surface flowing water as water source were examined comparatively.

4-2 Groundwater

(1) Outline of the Hydrogeology

Generally speaking, deltaic areas have complicated geological structure both on the plan and three-dimensionally due to their formation process and the effect of the river, but on the other hand they are areas object of groundwater development because gravel strata and sand strata, which are good acquifiers of groundwater, are widely distributed therein.

The geological structure of the project area is shown in Figs. 3-4 to 3-8 obtained by sorting data of the existing deep wells and results of electrical prospecting. As can be seen, there are conspicuous changes in the bed thickness and soil texture, and there are local peculiarities such as predominance of clayey soil strata, predominance of sandy soil strata, alternation of strata, and the geological structure is by no means simple. Generally speaking however, at depths down to GL -200 m from the surface of the ground there are clay/silt stratum, fine to medium sand, clay/silt stratum, fine to medium sand stratum and clay/silt stratum distributed in this order. Strata of fine to medium sand, which are objects of groundwater development, tend to be distributed at depth ranges of GL -10 m to -60 m and GL -100 m to -200 m.

The first sand stratum sedimented in the depth range of GL -10 m to -60 m has maximum bed thickness of the order of 40 m, but in reality it does not have so good continuity because it pinches out in some areas. On the other hand, the second sand layer sedimented in the depth range of GL -100 m to -200 m has bed thickness of 50 m or more with good stratum continuity and it is regarded as a promising acquifier for development of groundwater because in addition to the said favorable characteristics it contains artesian groundwater.

According to contour line of second sand layer shown in Fig. 4-2-1, the distribution conditions of this sand bend presents two valley topographies in the western district located on the right bank of the Sitalakhya River and in the eastern district located on the left bank. The direction of this valley topography is approximately parallel to the actual river course, but its center is located on the outskirts of the town. In this hydroptopographical structure groundwater is supplied from the upper course of the river and concentrates in the project area.

Comparing the eastern district with the western district, the valley topography of the western district has large scale and groundwater is supplied from a wide area and therefore from the hydrogeological standpoint the western district is regarded as more advantageous than the eastern district.

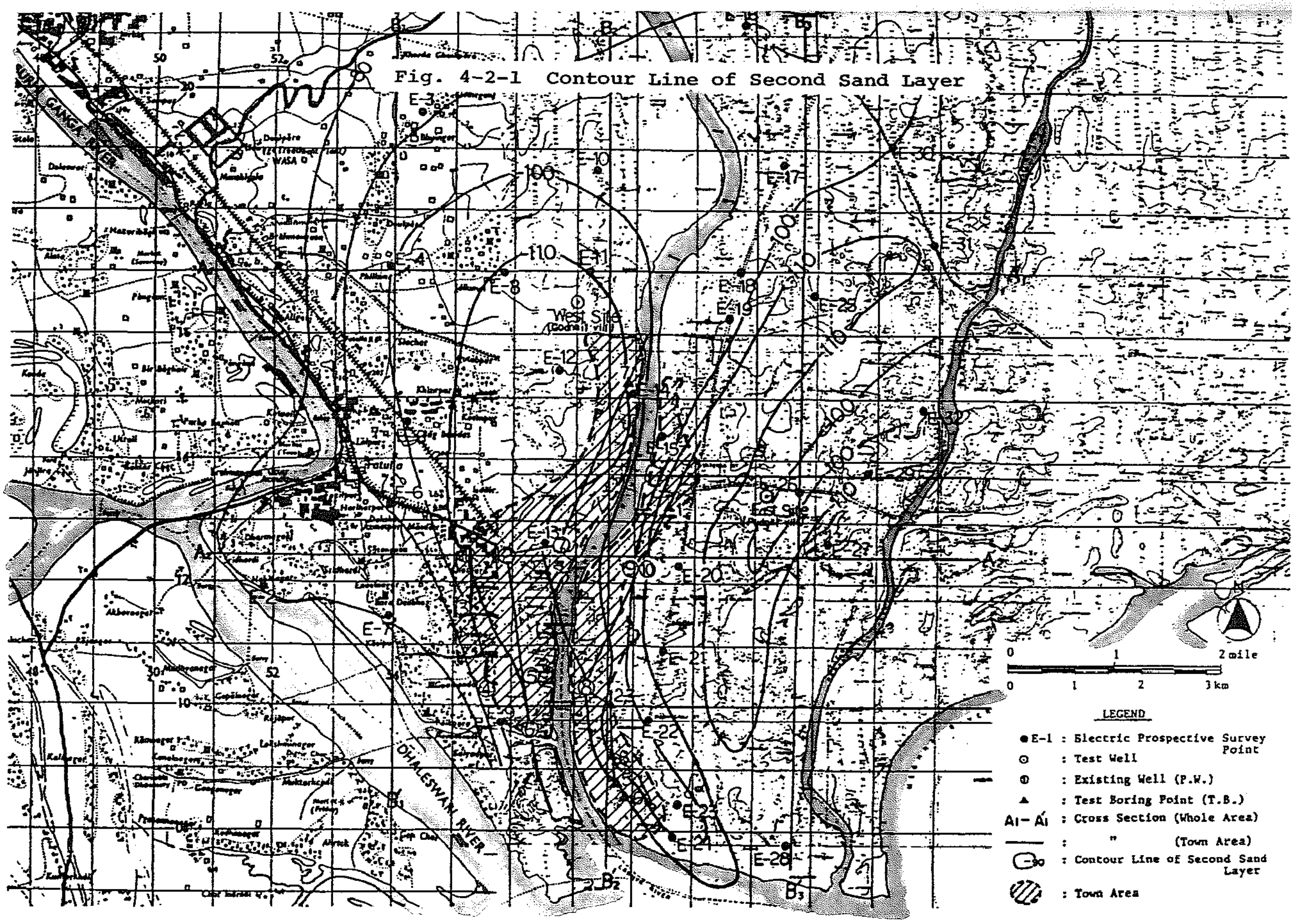


Fig. 4-2-1 Contour Line of Second Sand Layer

(2) Possibility of Groundwater Development

(a) Current state of things

The groundwater development state in the project area is restricted to deep wells and hand pump wells located in the street area and its vicinity.

The second sand stratum sedimented at depths larger than GL -100 m is the water collecting stratum of the deep wells. At the present time the DPHE has 14 wells of this kind, with 5 of them out of order.

The water collecting stratum of the hand pump wells is the first sand stratum sedimented in the depth range of GL -10 m to -60 m. There are 900 wells of this kind including public and private ones, and 180 of them are out of order. The causes of malfunction of the deep wells and hand pump wells are not known in details.

The said state of things of groundwater development indicates that the development of groundwater resources of the first sand stratum, where well digging is relatively easy in view of the acquifier distribution depth, is advanced up to a certain extent. On the other hand, it may safely be said that groundwater development of the second sand layer which requires well digging down to 100 m depth or more is practically untouched.

(b) Strata object of groundwater development

Water consumption of this project is 45,120 m^3 /day, and a large-scale groundwater development plan will be required in order to cope with the said consumption. Therefore, the second sand layer sedimented at depths of GL -100 m or more is selected as object of groundwater development within the project area in view of the aforementioned hydrogeologic conditions and by taking into consideration its future potentiality.

(c) Water quality

The desirable quality of water for drinking is without turbidity or color; contains neither escherichia coli and other pathogenic bacteria nor cyanogen, mercury, organic phosphorus and other toxic chemical substances; and contents of iron and manganese are below stipulated standards.

Since the object here is groundwater from deep strata, a study will be made on iron (F_e) and manganese (M_n) which are particularly problematic in the quality of drinking water.

According to the water quality standards adopted by Japan and the WHO the content of Fe should be less than 0.3 mg/liter and the content of Mn should be less than 0.3 mg/liter, and particularly in connection with Mn these standards consider it recommendable to have contents of less than 0.05 mg/liter in potable water.

In Bangladesh however, where this project is to be implemented, the limit is set at 2 mg/liter for Fe and 0.5 mg/liter in view of the various conditions related to the matter. In this connection the following results are obtained by examining the water quality test data of two classes of wells, those of digging depth not exceeding 100 m (first sand layer) and those with 100 m or more digging depth (second sand layer), in correspondence to the said standards.

1) Western district

Water quality test data of the western district consist of 52 samples, 33 of them of the first sand layer and 19 of the second sand layer.

Three out of the 33 samples of the first sand layer meet the water quality standards stipulating contents of Fe not exceeding 2 mg/liter and Mn 0.5 mg/liter. Of the remaining 29 samples, 9 meet the requirement of Fe 2 mg/liter but exceed the Mn content limit. On the other hand, 5 out of the 19 samples of the second sand layer meet the requirement referring to both elements and 4 out of 7 samples meet the requirement of Fe not exceeding 2 mg/liter although not submitted to Mn analysis.

In connection of the requirement of Fe content not exceeding 2 mg/liter, 36.4% of the samples of the first sand layer and 47.4% of the samples of the second sand layer are within this limit.

2) Eastern district

Water quality test data of the eastern district refer to 14 samples, all of the second sand layer, and they were tested in connection with Fe, Mn and other items as well.

Of the 14 samples submitted to water quality test, two have Fe content not exceeding 0.5 mg/liter and 7 meet the requirement referring to Mn not exceeding 0.5 mg/liter, but only one of the samples collected by the pumping test carried out this time meet the requirement referring to the contents of both elements.

In connection with the WHO water quality standard stipulating Cl content not exceeding 200 mg/liter and total hardness not exceeding 300 mg/liter, only 5 samples of the western district and one sample of the eastern district meet all water quality requirements, and the two samples of the two districts tested this time are included among the good ones.

The two samples of the two districts tested this time are practically in conformity with the WHO water quality standards. Of the existing water quality test data referring to 64 samples (1968-1977) contain Fe content measurement data but Mn, Cl, hardness, pH, alkalinity, etc., are measured only partially. The numerical values of the various data present fluctuations and no conspicuous tendency is observed therein. Therefore, it is doubtful if a conclusive judgement can be made in connection with the water quality of the project area on the basis of the said data. Such being the case, it seems necessary to examine the appropriateness of the groundwater of the project area for potable use by carrying out a systematic water quality test, particularly in connection with deep wells.

(d) Water balance

Groundwater is supplied incessantly by rain, but if the pumped volume surpasses the supplied volume the available volume of groundwater will run dry gradually. Therefore, when drawing up the plan for utilization of groundwater it is indispensable to know in the first place the volume of water available for pumping.

From the standpoint of hydrogeological structure the larger the basin area the more advantageous in terms of groundwater availability, but in deltaic areas it is difficult to identify the drainage divide. Such being the case, the plateau bordered by the Megna River and the Burigan River ((5+22) x 12.5 x 0.5 = 168.75 km^2), where the project area is located, is regarded as the basin area for the time being, and the water balance is calculated attemptively by using meteorological data of Dhaka. The volume of groundwater changes with the rainfall, but the total volume of water brought by the rain is partially evaporated from the surface of the ground, partially drained by surface water flow and partially infiltrated under the ground to become groundwater. The said process is repeated cyclically throughout the year, and the following mathematical expression is obtained by taking the average value of the hydrological basin over a long period.

$$R = E + S + I_G$$

where; R : Rainfall

E : Evaporation

S : Surface runoff

I_G: Increment in the groundwater volume

The average values obtained at the Dhaka Observatory in the last 10 years are annual rainfall R = 2,049 mm and annual evaporation E = 1,273 mm. In damp areas the ground evaporation is 0.6 times the water surface evaporation, and the surface runoff is approximately 50% on the basis of the coefficient of runoff on the flat cultivated land in Japan used as a reference.

Thus, we have:

$$E = 1,273 \text{ mm} \times 0.6 = 764 \text{ mm}$$

$$S = 2,049 \text{ mm} \times 0.5 = 1,025 \text{ mm}$$

$$I_G = 2,049 - 764 - 1,025 = 256 \text{ mm}$$

The groundwater replenishment volume is obtained by multiplying I_G with the basin area.

$$168.75 \text{ km}^2 \times 0.256 \text{ m/year} = 43.2\text{x}10^6 \text{ m}^3\text{/year}$$

$$43.2\text{x}10^6 \text{ m}^3\text{/year} \div 365 \text{ days} = 118.4 \times 10^3 \text{ m}^3\text{/day}$$

Judging from the foregoing results of trial estimates, it seems that the groundwater reserves are large enough and do not pose any particular problem in terms of water balance since the combined discharge from currently operating wells is 6,556 m³/day and the estimated quantity of water supply is 45,120 m³/day.

(e) Judgement on the possibility of groundwater development

Judging from the foregoing, the groundwater development plan in the project area is considered fairly promising in terms of current use of groundwater, hydrogeologic structure, and water balance with the exception of problems in water quality. The possibility of groundwater development is therefore likely to be great.

The problem of water quality is an important item in the judgement criteria, but the existing water quality test data are inadequate, so that the final judgement ought to be rendered on the basis of the water quality test data to be conducted in future.

Table 4-2-1 Existing test boring water quality test results

NARAYANGANJ MUNICIPALITY (WEST BANK)

Sl. No.	Location of tube wells	Care taker	Depth of tubewell	Water quality pH	Iron	Chloride	L.C.	Mang.	Alka.	Hardness
1.	P.H.E. Office compound	P.H.Office	111'-0"	6.9	2.2	33	-	0.4	254	59
2.	Deobhog pacca Mosque	Mosque	111'-0"	-	0.1	-	-	-	-	-
3.	Bar Academy khanpur	Bar Academy	-	-	2.8	-	-	-	-	-
4.	Khanpur	Amir Mohajan	-	-	1.5	-	-	-	-	-
5.	Khanpur	Post Office	300'-0"	-	5.0	-	-	-	-	-
6.	57,Giasuddin Road	Gobar Dair	132'-0"	-	3.5	-	-	-	-	-
7.	71,Giasuddin Road	-	120'-0"	-	4.0	-	-	-	-	-
8.	Giasuddin Near Jute Godown	-	-	-	3.1	-	-	-	-	-
9.	Baktiar Khizi Road	Badiur Rahman	130'-0"	-	3.8	-	-	-	-	-
10.	Goadnail	I.C.I. Factory	862'-0"	6.85	0.1	229	1,060	2.0	184	388
11.	"	High School	Deep	-	4.6	-	-	-	-	-
12.	Worken site	C.R. Mill	420'-0"	6.4	0.7	4.5	370	-	170	130
13.	Near R.C. Cotton Mill.	Nur Mohammed Molla	350'-0"	-	3.5	-	-	-	-	-
14.	Labour Coloney	C.R. Cotton mill	500'-0"	-	1.7	-	-	-	-	-
15.	Staff quarter	"	-	-	1.7	-	-	-	-	-
16.	Atpara	Laxmi narayan mill	400'-0"	-	6.8	-	-	-	-	-
17.	G.M.O. quarter	C.M.C.	300'-0"	-	3.2	-	-	-	-	-
18.	" Mosque	"	360'-0"	-	more than 5	-	-	-	-	-
19.	Pacca Road Deobhog	-	111'-0"	7.3	0.1	69	-	0.45	284	185

NARAYANGANJ MUNICIPALITY (WEST BANK)

Sl. No.	Location of tube wells	Care taker	Depth of tubewell	Water quality pH	Iron	Chloride	L.C.	Mang.	Alka.	Hardness
1.	Madangonj Rly. Station	Railway	66'-0"	-	7.5	-	-	-	-	-
2.	Madangonj P.S.	Police Station	-	-	2.2	-	-	-	-	-
3.	Farazi kanda	Zame Mosque	112'-0"	-	5.0	-	-	-	-	-
4.	Farazi kanda	Abed Ali	82'-0"	-	3.0	-	-	-	-	-
5.	-do-	Badruzdoza	72'-0"	-	4.0	-	-	-	-	-
6.	-do-	Murul Islam	117'-0"	-	3.0	-	-	-	-	-
7.	Katpatti Near Rice Mill	Alauddin Miah	71'-0"	-	6.3	-	-	-	-	-
8.	Sona Kanda Bapari para	Younus miah	100'-0"	-	2.2	-	-	-	-	-
9.	Islampur	A. Hoque	92'-0"	-	4.5	-	-	-	-	-
10.	-do-	F.P. School	118'-0"	-	3.0	-	-	-	-	-
11.	-do-	Anwar Ali Commissioner	120'-0"	-	9.0	-	-	-	-	-
12.	Ecrampur Sweeper Goloney	-	150'-0"	-	1.2	-	-	-	-	-
13.	Playground Mabigonj	-	112'-0"	7.1	0.2	672	2,500	0	404	282
14.	Pacharbog Ekrampur	Golam Hakim	350'-0"	-	1.7	-	-	-	-	-
15.	Ekrampur	Shabuddin	100'-0"	-	0.5	-	-	-	-	-
16.	Bangla bari Ekrampur	Mohiuddin	70'-0"	-	1.5	-	-	-	-	-
17.	Chowrapara	-	363'-0"	6.8	9.2	118	710	0.2	185	240
18.	Chowrapara	-	361'-0"	6.9	9.4	107	700	0.14	191	241
19.	S.I. Road	-	382'-0"	6.8	2.2	131	725	0.4	176	233
20.	Mabigonj	Kadam resul Darga	122'-0"	-	5.5	-	-	-	-	-
21.	"	A.Khair Dargabari	127'-0"	-	1.5	-	-	-	-	-
22.	"	A.Roug(Darga)	112'-0"	-	0.2	-	-	-	-	-
23.	"	Jalaluddin	112'-0"	-	0.6	-	-	-	-	-
24.	"	Tajuddin	112'-0"	7.0	0.4	-	-	0.3	360	200
25.	"	Muslauddin	112'-0"	-	0.5	-	-	-	-	-

NARAYANGANJ (WEST BANK)

Sl. No.	T.B. Sl. No.	Location	Depth of boring.	Depth of water sampled	Water quality pH	L.C.	T.ALK mg/L	T.Hard-ness mg/L	Chglri mg/L	Fe mg/L	Mn mg/L	Year ins-talled.	Remarks
1.	1 CDM	Deobhog (R.C.C.over head Tank) W.B.	650'	610'-8" to 62'8-5"	6.85	-	159	112	2.0	0.5	0.04	1970	T/W. No.3
2.	2 CDM	-do-	700'	642' to 666'	7.40	320	334	128	2.0	0.1	0	1973	
3.	3 CDM	T.B. Hospital, Narayangonj, P.S.	270'	208' to 244'	6.8	1,300	252	127	295	0.5	0.24	1970	
4.	4 Dacca Divn.	Nitaigonj, Kumudini Wel fare Trust, W.B.	800'	767'-6" to 785'-6"	7.0	410	184	121	22	3.6	0.58	1974	T/W No.6
5.	1 G.W.	-do-	600'	488' to 512'	6.35	300	154	104	4.25	2.2	0.1	1976	
6.	2 G.W.	Children park, Khanpur W.B.	700'	801'-6" to 601'-6"	6.8	900	280	255	40	1.7	0.5	1977	T/W No.7
7.	3 G.W.	Godnail (Near H.N. School & Chittaranjan cotton Mills)	650'	510' to 520' 546' to 556'	6.6	460	200	178	32	1.5	1.04	1977	

Sl. No.	T.B. Sl. No.	Location	Depth of boring	Depth of water sampled	Water quality pH	L.C.	T.ALK mg/L	T.Hard-ness mg/L	Chglri mg/L	Fe mg/L	Mn mg/L	Year ins-talled.	Remarks
1.	1 CDM	Narayangonj (Near WABDA Power Station) (W.B.)	-700'	` -	-	-	-	-	-	-	-	1968	
2.	2 CDM	Sonakanda (Water works compound), E.B.	686'	a) 85' b) 58-'	7'1 6.6	550 690	324 165	306 275	3'5 245	1'8 1450	2.0 0.04	1968	
3.	3 CDM	Sonakanda (Water works compound) E.B.	1200'	a) 570'-9" to 582'-9" b) 1089' to 1101'	6.6 6.95	790 510	148 174	286 179	166 -	2.6 2.0	0 0.58	1968	
4.	4 Dacca Dvn.	Marine Diesel Training Centre, T.B.	1500'	a) 637' to 649' b) 801' to 813'	7.3 7.15	326 348	151 176	137 126	4.0 4.0	2.7 4.0	0.23 0.26	1969	T/W No.8
5.	1 G.W.	Narayangonj, (Near over hand Tank) E.B.	1000'	a) 575' to 587' b) 868' to 892'	6.80 6.60	- -	170 180	402 395	400 220	5.5 2.5	- 0	1972	T/W No.10
6.	2 G.G.	Narayangonj (Charitable Dispensory), M.B.	1000'	a) 456' to 868' b) 855' to 879'	6.30 6.9	- -	132 240	523 435	435 225	7.5 3.5	0.25 0.8	1972	
7.	3 G.E.	Nabiganj (Ekrampur Playground) E.B.	650'	a) 64'-70' 90' to 96' & 116' to 122' b) 510' to 520' 585' to 595'	6.9 6.7	1,066 2,200	344 286	140 370	130 450	1.0 13.0	0.98 2.3	1977	
8.	4 G.E.	Madangonj (Goush Darber adjacent to Railway) L.B.	1200'	845'-6" to 855'-6" 881'-6" to 891'-6"	6.8	1,375	190	670	505	2.8	1.4	1977	
9.	Lakohan Khola playgound									9'5(ipon excessive after resampling)			

Table 4-2-2 Water Quality Test Result of Test Wells
(Carried out on 4 & 12 February 1985)

Location	Water Quality				(ppm)	
	pH	Iron	Chloride	Manganese	T-Alkal.	T.Hard-ness
West site (Godhnail)	7.85 (at 25°C)	0.5	87.0	0.02	(Me-orange) 208.28	150.0
East site (Podhugar)	7.1	0.192	12.0	0.25	M-Alk 18.00 P-Alk 0.80	30.0

(3) Pumping Test Results

Pumping tests were conducted by drilling wells at sites which are satisfactory in terms of electric prospecting results and geographical conditions. Test well locations are as shown in Annex II.

(a) Test wells and observation holes

a) West side

1) One test well

Depth: 180 m Housing pipe: 350 mm x 30 m
Casing: 150 mm x 120 m
Screen: 150 mm x 30 m (20 slots, 20% opening rate)

2) Three observation holes

Depth: 150 m Diameter: 40 mm x 130 m
Screen: 40 mm x 20 m

b) East side

1) One test well

Depth: 167 m Housing pipe: 350 mm x 30 m
Casing: 150 mm x 107 m
Screen: 150 mm x 30 m (40 slots, 20% opening rate)

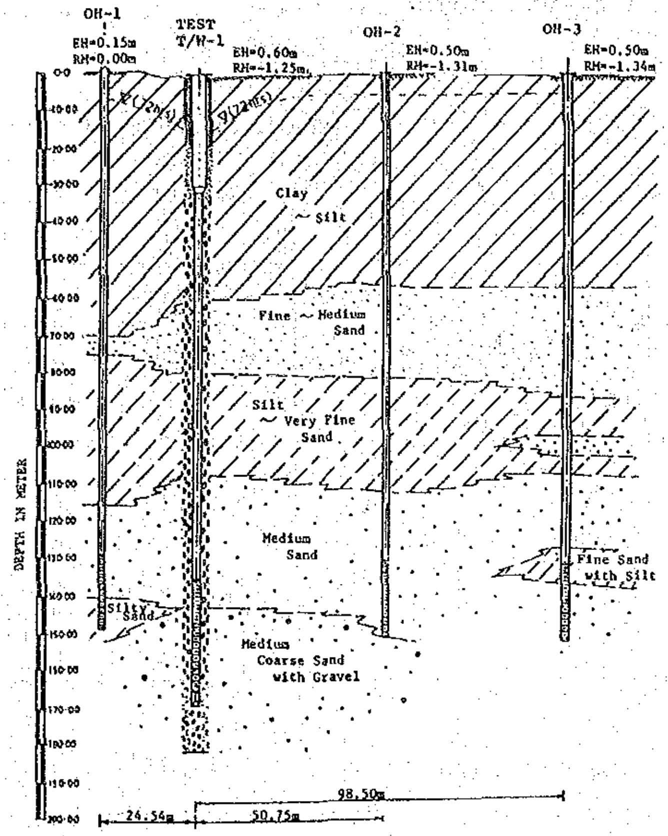
2) Three observation holes

Depth: 150 m Diameter: 40 mm x 130m
Screen: 40 mm x 20 m

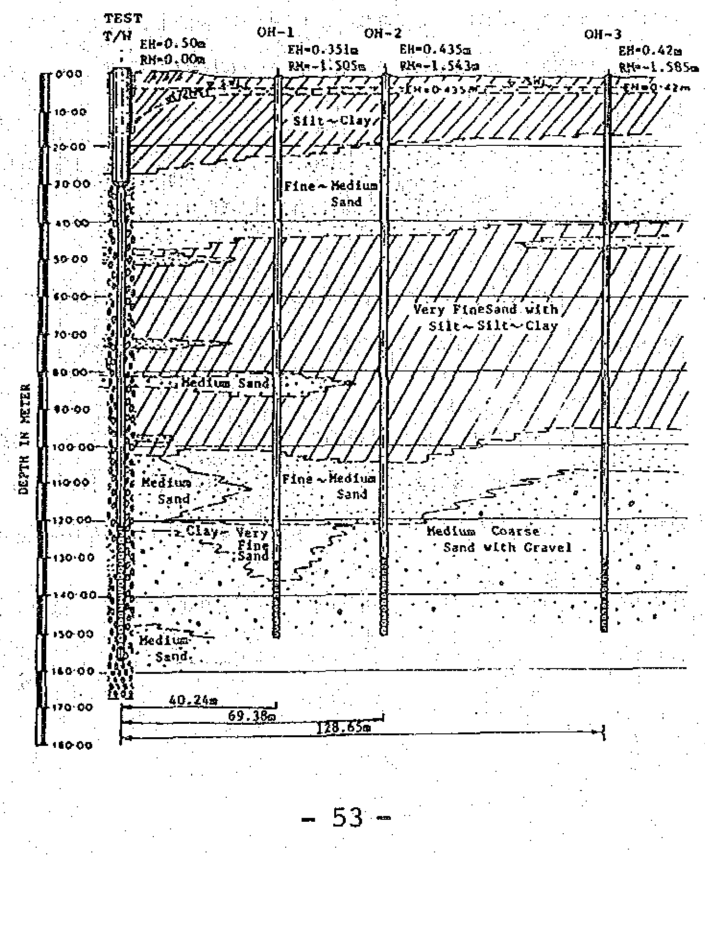
The geological profile of the test well of each site is shown in Fig. 4-2-2.

Fig. 4-2-2 Geological Section

West Site



East Site



(b) Stepped pumping test

Table 4-2-3 Staged Pumping Test

Location / Pumping Stage	West Side		West Side		Remarks
	Discharge	Drawdown	Discharge	Drawdown	
1st stage	35.9 m^3/h	4.8 m	58.7 m^3/h	4.3 m	
2nd stage	46.4	6.0	68.7	5.3	
3rd stage	58.7	7.5	80.3	6.3	
4th stage	68.7	9.2	92.1	7.5	
5th stage	80.3	10.3	103.5	8.7	
6th stage	92.1	11.9	113.8	9.8	
7th stage	103.5	13.7	123.3	10.8	

As shown in Table 4-2-3, the pumping test was carried out in 7 stages. The economic pumping volume was determined by taking into consideration the following facts.

a) The values of the discharge Q and drawdown S indicate that Q and S are related by a straight line, but S increases suddenly when Q surpasses a given limit. This point is called critical pumping point and the economical pumping discharge is 70 to 80% of this value.

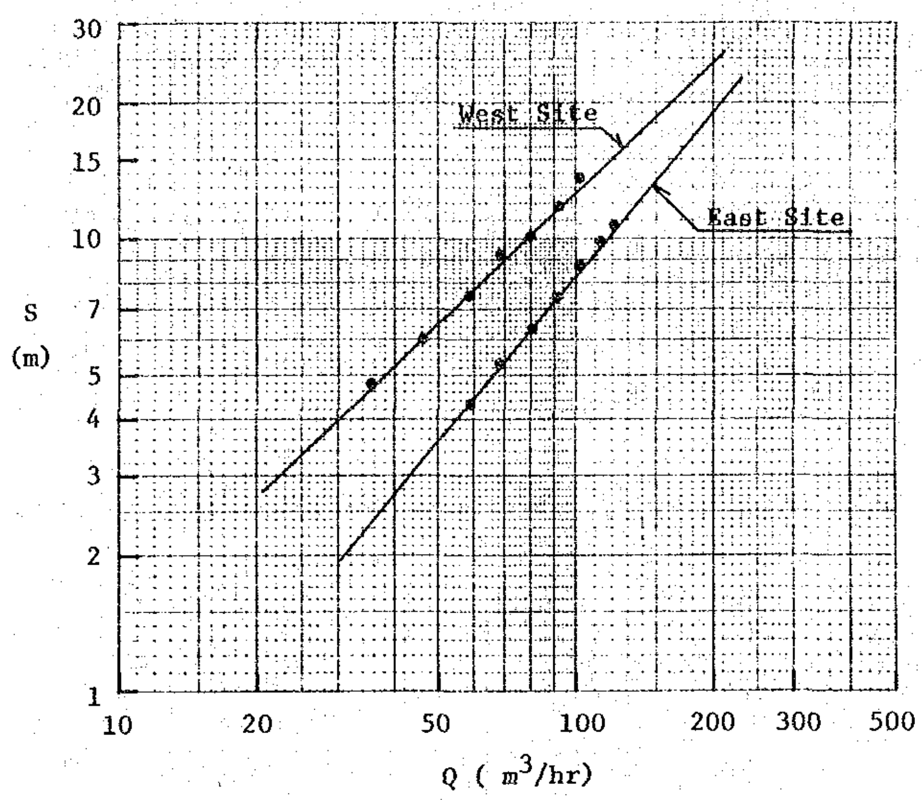
b) It is convenient to limit the drawdown at approximately 10 m to carry out a stable pumping.

Since a clear turning point was not observed this time, the drawdown is set at 10 m and the following values are regarded as the economical pumping discharges.

West side: Q = 80.3 m^3/h Drawdown 10.3 m

East side: Q = 113.8 m^3/h Drawdown 9.8 m

Fig. 4-2-3 Relationship between Q and S



(c) Continuous pumping test

Continuous pumping test with 72-hour duration was carried out by using the value of Q determined in the staged pumping test. Furthermore, also the simultaneous observation of water level was carried out in this test by providing observation wells.

The results of the continuous pumping test are shown in Table 4-2-4.

Table 4-2-4 (1) Draw Down due to Continuous Pumping (West Side)

Pumping Time (h)	Discharge (m^3/h)	Test Well (m)	OH-1 24.5 m from T/W (m)	OH-2 50.8 m from T/W (m)	OH-3 98.5 m from T/SW (m)	Remarks
8	80	10.84	2.01	1.16	0.74	
12	"	10.87	2.03	1.21	0.83	
24	"	10.95	2.17	1.33	0.93	
48	"	11.03	2.26	1.42	1.04	
72	"	11.04	2.31	1.48	1.11	

Table 4-2-4 (2) Draw Down due to Continuous Pumping (East Side)

Pumping Time (h)	Discharge (m^3/h)	Test Well (m)	OH-1 40.2 m from T/W (m)	OH-2 69.4 m from T/W (m)	OH-3 128.7 m from T/SW (m)	Remarks
8	114	9.66	1.45	1.05	0.83	
12	"	9.76	1.56	1.17	0.85	
24	"	9.84	1.66	1.21	1.04	
48	"	9.87	1.74	1.25	1.10	
72	"	9.95	1.89	1.27	1.14	

The values of the hydraulic constants, permeability coefficients and storage coefficients calculated by using the results of Table 4-2-4 are shown in Table 4-2-5.

Table 4-2-5 Comparison of the Aquifier Constant Analysis Results

(1) West Site

Method of Analysis, etc.			Aquifier Constant: Coefficient of Permeability T (m^2/sec)	Aquifier Constant: Storage Coefficient S	Remarks
Team's Method (Equilibrium formula)			6.23×10^{-3}	7.41×10^{-3}	Sphere of influence r_o: r_o = 700m (72 hrs)
Theim' Standard Curve Method	t-s curve *1	OH-1 (r = 24.54)	9.70×10^{-3}	2.02×10^{-4}	
		OH-2 (r = 50.75)	1.17×10^{-2}	2.14×10^{-4}	
		OH-3 (r = 98.50)	1.03×10^{-2}	9.42×10^{-4}	
	r-s curve *2	6 hrs.	4.68×10^{-3}	4.72×10^{-3}	OH-2 was used as the matching point.
		12 hrs.	6.02×10^{-3}	3.84×10^{-3}	
		24 hrs.	5.99×10^{-3}	5.61×10^{-3}	
		72 hrs.	5.13×10^{-3}	6.20×10^{-3}	
Yacob's Continuous Analysis	OH-1		7.41×10^{-3}	1.32×10^{-4}	
	OH-2		7.99×10^{-3}	6.63×10^{-4}	
	OH-3		9.06×10^{-3}	9.80×10^{-4}	
Recovery Method	T.W.		4.79×10^{-3}		
	OH-1		8.63×10^{-3}		
	OH-2		8.49×10^{-3}		
	OH-3		1.23×10^{-2}		
Mean Value			7.89×10^{-3}	2.81×10^{-3}	

(2) East Site

Method of Analysis, etc.			Aquifier Constant: Coefficient of Permeability T (m^2/sec)	Aquifier Constant: Storage Coefficient S	Remarks
Team's Method (Equilibrium formula)			1.21×10^{-2}	1.76×10^{-3}	Sphere of influence r_o: r_o = 2,000m (72 hrs)
Theim' Standard Curve Method	t-s curve	OH-1 (r = 40.24)	1.39×10^{-2}	1.51×10^{-4}	
		OH-2 (r = 69.38)	1.68×10^{-2}	1.90×10^{-4}	
		OH-2 (r = 128.65)	1.62×10^{-2}	2.96×10^{-4}	
	r-s curve	6 hrs.	1.30×10^{-2}	6.99×10^{-4}	
		12 hrs.	1.01×10^{-2}	4.90×10^{-4}	
		24 hrs.	1.64×10^{-2}	2.36×10^{-4}	
		72 hrs.	2.13×10^{-2}	4.60×10^{-4}	
Yacob's Continuous Analysis	OH-1		1.44×10^{-2}	1.73×10^{-4}	
	OH-2		1.31×10^{-2}	3.97×10^{-4}	
	OH-3		1.41×10^{-2}	3.64×10^{-4}	
Recovery Method	T.W.		1.13×10^{-2}		
	OH-1		1.33×10^{-2}		
	OH-2		1.46×10^{-2}		
	OH-3		1.37×10^{-2}		
Mean Value			1.43×10^{-2}	4.74×10^{-4}	

*1 : For t-s curve, coefficient was obtained from the relationship between r^2/t and drawdown S of one observation hole (distance r from the pumped well is constant).

*2 : For r-s curve, coefficient was obtained from the relationship between r and s after a predetermined time (t).

(4) Estimation of the Production

(a) West side

The following conclusions are drawn on the basis of the existing data and the results of the study carried out this time.

a) The hydraulic constants of the wells digged in the street area are estimated as follows, on the basis of the existing data shown in Table 4-2-6.

   In the street area there are 7 deep wells, with depth ranging from 70 m to 195 m (mainly about 180 m), screen ranging from 18 to 30 m and diameters from 6 to 8 inches. The pumping discharge is of the order of 23 to 127 m^3/h and the drawdown is 5.8 to 14.5 m. Therefore, the specific springing rate is estimated to be of the order of 1.6 to 20.2 $m^3/h/m$ (mostly 10 $m^3/h/m$).

b) Pumping discharge of 80 m^3/h and draw down of 10.9 m were obtained in the test carried out this time (December 1984 to February 1985) in a test well with 180 m depth, 30 m screen and 6 inch diameter, as shown in Table 4-2-6. From these results it is estimated that the coefficient of permeability T is $7x10^{-3}$ m^2/sec, the storage coefficient S = $5x10^{-3}$ and the specific springing 7.4 $m^3/h/m$.

Estimating the production of each well on the basis of the considerations of a) and b) above, it is presumed that in a well with 180 m depth, 30 m screen with 20 to 30% opening rate, 6-inch diameter and 10 m drawdown it will be possible to pump water at approximately 80 m^3/h rate because in the west side the hydrogeologic characteristics are regarded as practically uniform.

(b) East side

a) Judging from the existing data (Table 4-2-6), in deep wells with 153 to 186 m depth, 30 m screen and 6-inch diameter the pumping discharge is 46 m^3/h and the drawdown is of the order of 4.8 to 4.9 m. These hydraulic constants indicate that T is $1.4x10^{-2}$ m^2/sec and that the specific springing is 9 $m^3/h/m$.

b) Pumping discharge of 110 m^3/h and drawdown of 9.8 m were obtained in the test carried out this time in a deep well with 167 m depth, 30 m screen and 6-inch diameter, as shown in Table 4-2-6. Based on these results, it is estimated that coefficient of permeability T is $1x10^{-2}$ m^2/sec and that the specific springing is 11 $m^3/h/m$.

Making the judgement on the basis of the considerations of a) and c) above, the well located in the vicinity of the street area mentioned in a) has hydrogeologic characteristics similar to those of the West Side, and it is presumed that in a well with 180 m depth, 30 m screen, 6-inch diameter and 10 m drawdown it will be possible to pump water at approximately 90 m^3/h rate. On the other hand, in the suburban area it was confirmed that water can be pumped at larger rates because the stratum composing the aquifier contains large quantity of gravel. Therefore, taking into consideration the relevant numerical values, it is presumably possible to pump water at 100 m^3/h rate in a well with 180 m depth, 30 m screen, 6-inch diameter and 10 m drawdown.

Table 4-2-6 Pumping Conditions in the Existing Wells and Test Wells

Location		T/W No.	Total depth	Soil of aquifier	Screen		Pumpage		Static water level	Pumping water level	Draw down	Trans-activity	Coefficient of storage	Specific capacity	Remark
					Length	dia.	Plan	Present							
			m		m	inch	t/w	t/w	m	m	m	m^3/s	t/w/m		
West side	Existing	1	174	MS	24	8	91	127	7.50	15.75	8.25			11.0	W.S street area
West side	Existing	2	180	FMS & MS	30	6	45	45	6.90	12.69	5.79	$4.7x10^{-3}$		7.9	" "
West side	Existing	3	70	-	18	6	91	82	4.17	14.97	10.80			8.4	" "
West side	Existing	4	174	FM	30	6	91	68	5.70	15.42	9.72			9.3	" "
West side	Existing	5	180	FMS	24	6	136	91	6.72	13.50	6.78			20.2	" "
West side	Existing	6	180	MCS	30	6	91	91	5.79	11.43	5.64			16.0	" "
West side	Existing	7	195	FM	18	6	23	23	6.51	21.00	14.49			1.6	" "
West side	New	Test well	180	MCS	30	6	-	80	4.65	15.60	10.95	$7x10^{-3}$	$5x10^{-3}$	7.4	W.S suburban area
East side	Existing	8	186	MS	30	6	91	45	5.46	12.33	6.87			12.8	E.S street area
East side	Existing	9	154	-	30	6	45	45	6.30	11.10	4.80	$9.7x10^{-3}$		9.5	" "
East side	Existing	10	-	-	15	6	23	-	6.30	13.11	6.81			3.4	" "
East side	New	Test well	167	CS & G	30	6	-	110	4.44	14.28	9.84	$1x10^{-2}$	$3x10^{-4}$	11.2	" suburban area
		Hand pump	39	SCl & FMS	-	1.5		180 out of 900 deep wells are out of order (in urban areas)							

W.S: West Side
E.S: East side

(5) Distance between Wells

The distance between wells is determined as follows, in such a way as to prevent mutual interference between adjacent wells and by taking into consideration the sphere of influence of each well.

The study was made by using the results of tests carried out this time and also the existing data.

(a) West side

a) When the pumping test results are organized by the Thiem's method, the sphere of influence becomes as follows. (Pumpage Q = 80 m^3/h, drawdown 10 m)

. In the case of 8-hour pumping
Sphere of influence: R = 330 m

. In the case of 12-hour pumping
Sphere of influence: R = 400 m

. In the case of 72-hour pumping
Sphere of influence: R = 700 m

Based on the aforestated results and pumping duration (12 ha), the distance between adjacent wells of 2 times R or 800 m is considered satisfactory.

(b) East side

a) When the sphere of influence is calculated in the same manner as a) above, following results. (Pumpage Q = 100 m^3/h, drawdown 10 m)

- In the case of 8-hour pumping
  Sphere of influence: R = 950 m
- In the case of 12-hour pumping
  Sphere of influence: R = 1,100 m
- In the case of 72-hour pumping
  Sphere of influence: R = 2,000 m

When R for 12-hour pumping duration is adopted as with a) above, the distance between adjacent wells becomes 2,200 m.

4-3 Surface Water (Sitalakhya River)

(1) Discharge

The discharge of the Sitalakhya River is not observed at Narayanganj Town but at Demra about 5 km up-stream from Narayanganj Town. But as Demra is within the tidal compartment of the Sitalakhya River, the discharge data observed there during the dry season are not very reliable. The discharge is being measured during the flood period between June and October. Table 4-3-1 shows usable data observed for six years.

According to present plans, the volume of water that has to be developed anew for the eastern and western parts of the town is 36,566 m^3/day as stated in Par. 5-4, Chapter 5. When the operating hours of the facilities and the capacity of purification plants are taken into consideration, the required volume of water to be developed is 0.74 m^3/sec.

Even though river discharge during the dry season has not been recorded, the following can be inferred from the discharge data at Demra shown in Table 4-3-1 and the water level data shown in Table 4-3-3. The water level of the river ranges between EL 1.5 to 2.0 m during May and June which is the transitional period from the dry season to the rainy season and also in November which is the transitional period from the rainy (flood) season to the dry season. The lowest water level, which occurs in January to February during the dry season, is around EL 0.67 m which is about 1.0 - 1.5 m lower than during the transition periods. Assuming the water depth to be around three meters even in the dry season, and the river cross section to be a natural parabola, the water level during the dry season will be about 2/3 of the level during the transition periods and the

Table 4-3-1 Flow of the Sitalakhya River

(Demra locality)

(unit: m^3/sec)

Year	River Flow	Annual	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
1965/66	Max. Mean Min.	2,210 - -			1,670 1,552 1,370	2,210 1,954 1,680	2,200 1,909 1,750	1,700 1,046 580	
1966/67	Max. Mean Min.	2,540 - -	459 303.9 232	1,450 1,044 470	1,880 1,655 1,250	2,320 1,912 1,720	2,540 2,251 1,680	1,720 1,106 599	574 376.2 241
1967/68	Max. Mean Min.	1,780 - -			1,750 1,470 1,110	1,780 1,457 1,130	1,260 1,103 1,010	1,400 1,093 552	
1968/69	Max. Mean Min.	2,160 - -		1,380 907.5 518	2,150 1,784 1,420	2,160 1,934 1,720	1,770 1,513 1,280	1,570 1,272 665	637 362.2 220
1975/76	Max. Mean Min.	1,950 - -		974 750.5 597	1,780 1,324 959	1,950 1,747 1,550	1,700 1,642 1,480	1,460 1,204 739	
1976/77	Max. Mean Min.	2,030 - -		1,560 1,360 838	2,030 1,811 1,470	1,680 1,499 1,350	1,670 1,290 1,040	1,100 707.5 258	

cross sectional area of flow become almost halved. Besides the above, because of the tide level, the flow velocity becomes slower (and occasionally flows upstream), and the discharge is believed to be considerably smaller compared to that of the transitional periods.

(2) Water Level

The water level of the Sitalakhya River is as shown in Table 4-3-3. The highest levels are almost always recorded in August and fluctuates between EL 5 m and 6 m. The lowest level recorded mostly in February to March is around EL 0.65 - 0.80. Very little change is noted year to year in the highest water level and the lowest water level.

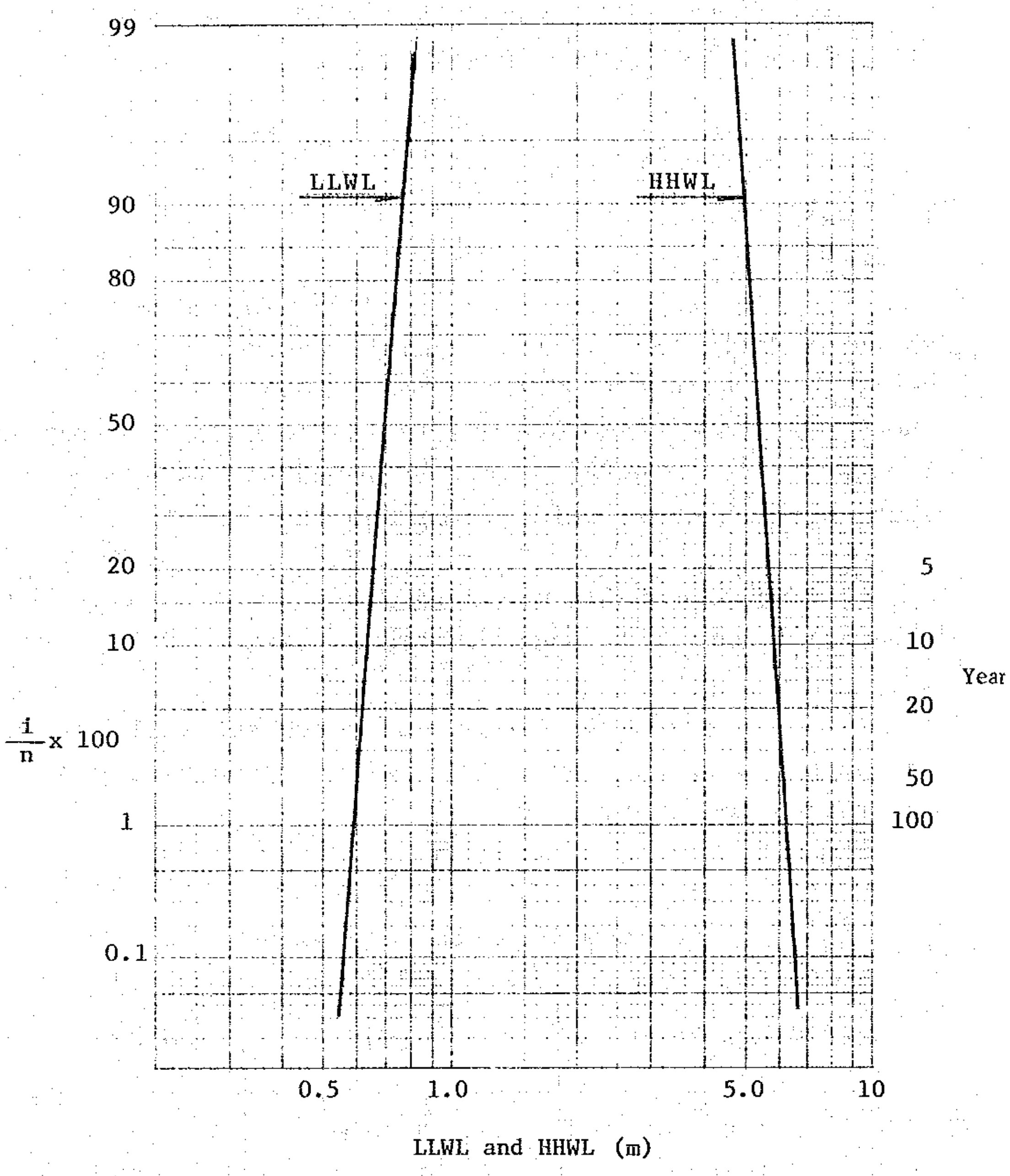
The probable water level obtained by means of the Hazen Plot method is shown in Table 4-3-2.

Intake facilities in this project will be designed on the basis of the water level with a probability of occurring once every 50 years.

Table 4-3-2 Probable Water Level

Probable Year	L.LWL	H.HWL
1/5	0.66 m	5.70 m
1/10	0.64	5.85
1/20	0.62	6.00
1/50	0.60	6.10
1/100	0.59	6.25

Fig. 4-3-1 Hazen Plot

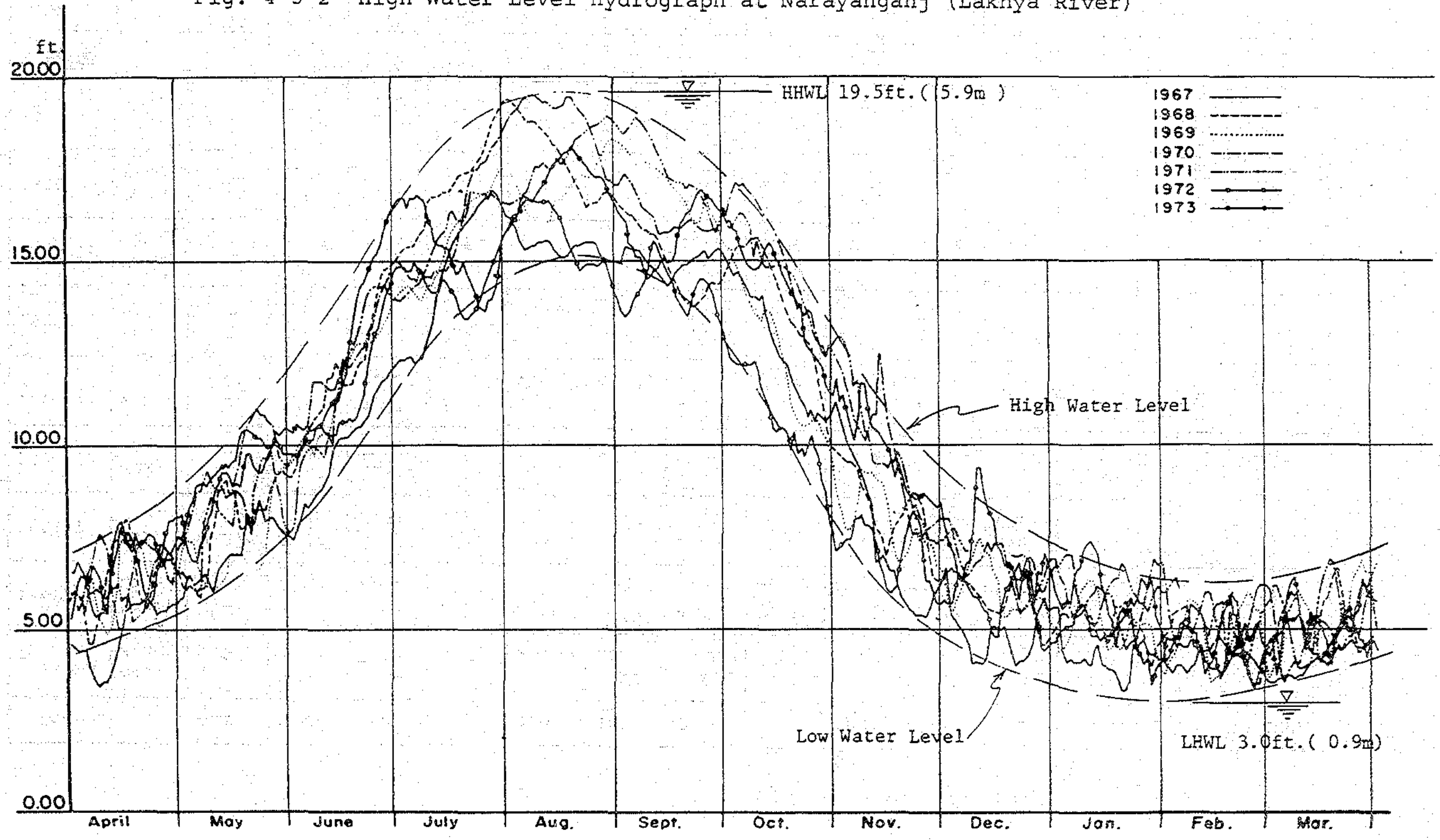


(Narayanganj Town locality)

(unit: m)

Year		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	L.LWL	H.HWL.
1967/68	Max. Min.	1.77 1.04	2.68 1.77	3.69 2.26	5.17 3.72	4.94 4.56	4.69 4.36	4.57 3.26	3.41 1.62	2.04 1.22	1.71 1.01	1.40 1.16	1.43 1.07	1.01	5.17
1968/69	Max. Min.	2.43 1.16	2.84 1.53	4.53 2.51	5.87 4.50	5.90 4.95	5.07 4.19	4.77 2.94	3.00 1.60	2.03 0.99	1.77 0.88	1.83 0.69	2.03 0.81	0.69	5.90
1969/70	Max. Min.	2.27 0.99	2.87 1.49	4.22 2.56	5.35 4.16	5.58 4.84	5.56 4.68	4.68 2.55	2.85 1.60	2.27 1.17	1.91 0.87	1.81 0.66	2.09 0.72	0.66	5.58
1970/71	Max. Min.	2.27 1.23	3.37 1.81	4.54 2.64	5.64 4.31	5.93 5.18	5.30 4.74	5.23 3.63	3.76 1.89	2.44 1.34	2.10 1.04	1.89 0.85	1.89 0.70	0.70	5.93
1971/72	Max. Min.	2.23 1.01	2.99 1.40	4.37 2.01	5.18 4.13	5.76 5.00	5.76 4.79	4.97 3.69	3.95 1.89	2.35 1.40	2.13 1.16	1.95 0.94	2.10 0.73	0.73	5.76
1972/73	Max. Min.	2.45 1.20	3.09 1.87	4.45 2.79	4.75 3.99	5.12 4.22	4.75 3.89	3.90 2.10	2.50 1.40	2.07 1.04	1.74 0.73	1.83 0.73	1.71 0.70	0.70	5.12
1975/76	Max. Min.	2.08 1.20	2.88 1.56	3.06 2.30	4.99 3.59	5.36 4.54	4.84 4.35	4.41 3.13	3.74 1.90	2.54 1.38	1.90 0.89	1.81 0.78	2.10 0.97	0.78	5.36
1976/77	Max. Min.	2.51 1.07	2.82 1.71	4.05 2.30	5.17 3.99	5.15 4.36	5.12 4.28	4.19 2.38	2.56 1.71	2.41 1.19	1.89 0.67	1.80 0.82	1.83 0.72	0.67	5.17
1977/78	Max. Min.		3.47 2.07	4.53 3.08	5.18 4.16	5.47 4.93	5.52 4.27	4.36 2.82	3.14 1.98	2.68 1.49	1.98 0.93	1.84 0.69	1.86 0.67	0.67	5.52
1981/82	Max. Min.	2.51 0.93	2.88 1.66	3.26 2.55	4.81 3.17	5.19 4.67	5.01 4.27	4.44 1.97	2.55 1.75	2.75 1.23	1.65 0.80	1.88 0.93	1.88 0.86	0.80	5.19
1982/83	Max. Min.	2.56 1.22	2.79 1.82	4.35 2.02	4.84 4.14	5.20 4.53	5.04 4.59	4.86 2.08	2.56 1.18					-	5.20

Fig. 4-3-2 High Water Level Hydrograph at Narayanganj (Lakhya River)



(3) Water Quality

Results of the water quality tests and the Jar tests at the projected site of the purification plant at Narayanganj Town on the Sitalakhya River in August 1984 are shown in Table 4-3-4 through 4-3-6. The results of water quality tests which were conducted in the past near the existing purification plant at Narayanganj Town by the Environment Pollution Control Board of the Bangladesh Government are shown in Annex III.

From these data it will be seen that although there are seasonal changes, pH is between 6.5 - 8.0, and Chloride is below 40 and in most months below 20. And the present survey showed that the turbidity was between 80 - 90 degrees. The turbidity at Burhi Ganga, which is the water source of the purification plant of the Dhaka Water and Sewerage Authority was 16 degrees (Observation taken in August 1984). The changes in the turbidity of Burhi Ganga are shown in Fig. 4-3-3. Although there are differences in the flow of the Burhi Ganga and Sitalakhya River, if monthly changes in the turbidity is assumed to be similar for the two rivers, the turbidity of the Sitalakhya River around August would be between 80 and 90 degrees and when the turbidity is high, it is possible that it may even rise to 150 degrees.

Again, as a result of physical and chemical analysis of metals, results of which are shown in Table 4-3-5, it has been judged that the water of the Sitalakhya River raises no questions when considered as a source of drinking water.

Moreover, although the town of Narayanganj is located in the tidal compartment (of the Meghna River), because in the lower reaches it joins the three great rivers, the Jamuna, Ganges and Meghna, salt water does not appear to town of Narayanganj. The tidal compartment of Bangladesh is shown in Annex IV. The data from a survey on the salt content of water in the lower reaches of the Meghna River are also shown in Annex IV.

Table 4-3-4 Results of Water Quality Tests (Aug. 1984)

Name of River	Sitalakhya	Sitalakhya	Burigonga	WHO / EPCB
Point	Narayanganj (East Bank)	Narayanganj (West Bank)	WASA purification plant	
Test date	'84. 8. 10	'84. 8. 10	'84. 8. 19	
Temperature	32°C	32°C	32°C	
Water temperature	28°C	28°C	29°C	
External appearance	Light, Yellow brown colour	Light, Yellow brown colour	Light, Yellow colour	
Odour	None	None	None	
Turbidity	82 degrees	84 degrees	16 degrees	5 - 25 / 25
Degree of colour	70 degrees	72 degrees	36 degrees	5 - 20 / 30
pH	7.8	7.8	7.7	6.5 - 9.2
Alkalinity	43 ppm	43 ppm	43.5 ppm	
$KMnO_4$ consumption	7.9 ppm	7.9 ppm		
Dissolved F_e	under 0.1 ppm	under 0.1 ppm		0.1 - 1.0 / 1.5 (5 max.)
Mn Ion	under 0.05 ppm	under 0.05 ppm		0.05 - 0.5 / 0.5
NH_4	0.25 ppm	0.22 ppm		
Colon bacilli	+ (	+ (		
General bacilli				

Note: The degree of colour of the Sitalakhya River is the value (true colour) after absorption and filtering to remove turgidity.

Table 4-3-5 Results of Heavy Metal Analysis (August, 1984)

	Sitalakhaya	Quantitative limit	Standard value
Zinc (Zn)	ND	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 4-3-6 The Results of Jar Test
(Sitalakhya River, August, 1984)

Flocculant	Feeding rate (ppm)	Flock conditions	Sedimentation	pH	Turbidity	Chromaticity (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	-	-	-	-

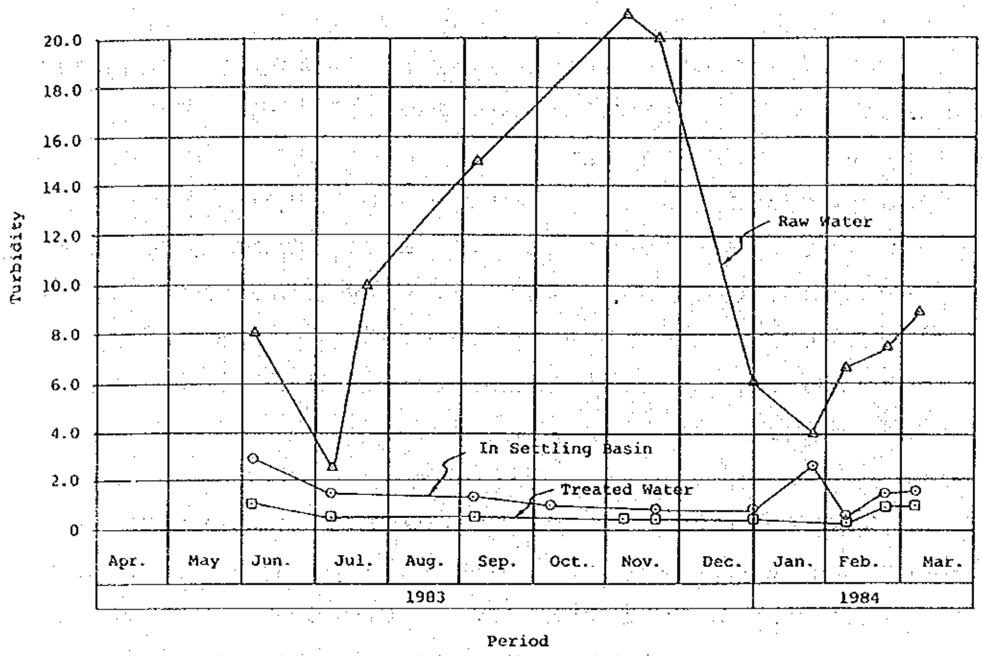
Remark: In the "sedimentation", "good" represents 40 to 60 mm/min, while "fair" represents 20 to 30 mm/min sedimentation velocity (the same also applies to the following page.)
Ferric sulfate was tested after 10 days from the sampling date, with the raw water pH being 7.4.

(Jar Test Conditions)

Rapid stirring (190 rpm) .... 3 minutes
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. As for the Sitalakhya River, different sampling points of the West Bank and the East Bank were used. It was determined, however, that the quality of water was the same. The raw water sampled from the East Bank was, therefore, used in the jar test.

Fig. 4-3-3 Monthly Changes in Turbidity at Burhi Ganga



4-4 Comparison of the Water Sources

(1) Outline

At the present time the water supply facilities of Narayanganj Town use groundwater and the Sitalakhya River as water sources. The quantities of water are 6,556.0 m^3/day of groundwater and 4,436.0 m^3/day of river water, totaling 10,992.0 m^3/day. The quantity of water to be developed anew in this project, excluding the quantity available for use from the existing facilities, is 36,566 m^3/day (25,622 m^3 /day in the western district and 10,944 m^3/day in the eastern district).

The results of the groundwater investigation carried out in the town, including the peripheral areas, indicate that the practicability of groundwater development is quite promising, although the pumpage per well is small. As for water of the Sitalakhya River, the water level becomes low in the dry season but the discharge is large enough for the volume of intake and can be utilized throughout the year. As stated before, the droughty water discharge is considered to be 5 to 11 m^3/sec, which is adequate to meet the planned intake rate (0.74 m^3/sec) Water intake is considered sufficiently even in the dry season, since there is no other plan nor factory which might intake water in large quantities as of now.

Purification plants will be required when using river water, and many production wells should be provided in the town and at its vicinity when using groundwater, and pipeline should be provided to convey potable water from the said facilities to the town. In connection with groundwater, results of water quality tests by test drilling carried out in the town indicate that some samples are not appropriate for potable use due to the high content of iron

(Fe). However, the water quality of test wells dug this time (December 1984) in the outskirts of the town present no problem at all. Such being the case, it is presumed that there will be no problem in connection with the water quality, because this comparative design study the construction of production wells in the outskirts of the town.

Schematic designs were prepared for the purification plant alternative using river water and the well alternative using groundwater, and based on the comparative study of which the water source to be adopted was determined.

The schematic designs for the well alternative and purification plant alternative are shown in Annex V and Annex VI, respectively.

(2) Comparison of the Well Alternative and Purification Plant Alternative

The well alternative and the purification plant alternative are compared in Table 4-4-1 from the standpoints of quantity of water available from each source, water quality, merits for future expansion, outline of the required facilities, construction cost, acquisition of the construction site, relative ease of construction, relative ease and cost of maintenance and administration, on the basis of the schematic designs for the two alternatives.

Table 4-4-1 Comparison of the Well Alternative and Purification Plant Alternative

Item	Well Alternative	Purification Plant Alternative
1. Water Source	The water source of the well alternative will be groundwater. The vein which water will be taken from is the sand layer located at depths of 100m to 200m. It is assumed that the production wells to be digged anew will be have 180m depth, 150mm diameter and 30m screen diameter. (West District) No. of wells to be digged anew; 27 No. of existing wells; 4 (East District) No. of wells to be digged anew; 10 The existing wells will not be used. The existing purification plant of the west district will be used, but the existing purification plant of the east district will not be used.	The water source of the purification plant alternative will be the surface flow of the Sitalakya River. The intake of the West District will be adjacent to the existing purification plant located to the north of the town. The intake of the East District will be practically at the center of the town, approximately 1.5km below the intake of the West District. The site adjacent to the existing purification plant of the West District is already possessed by the DPHE.
2. Quantity of Water	The following quantities of water will be turned out by each production well. - In the West District: 80 m^3/h - In the East District: 100 m^3/h The sphere of influence of the well is 400m in radius in the West District and 1,100m in the East District. Therefore, the distribution area of production wells will be approximately 14km^2 in the West District and approximately 25km^2 in the East District. If the water consumption should increase	The intake sites of both districts are located in the tide-sensitive area of the Sitalakhya River, and the river flows in both directions. There is no data of low-water flow because the 3 major rivers of the country, Jamuna, Ganges and Meghna join below the project area which suffers influence of the backwater of these rivers during the dry season. Estimations on the basis of data of other rivers suggest that the low-water flow of the Sitalakhya River is of the order of 5 to 11 m^3/sec.

Item	Well Alternative	Purification Plant Alternative
	in the future, the well distribution area would be expanded further. The quantity of water to be developed anew by digging production wells will be 25,622 m^3/day in the West District and 10,944 m^3/day in the East District, totaling 36,566 m^3/day.	The water consumption taken into consideration in this project is 36,566 m^3/day. Assuming that the purification plant will operate 15 h/day and that 10% of the water will be consumed in the plant itself, the intake rate will be 0.74 m^3/sec. $\frac{36{,}566 m^3/day}{15 h/day} \times \frac{1}{3{,}600} \times 1.1 = 0.74$ The discharge of the Sitalakya River is sufficient to cope with the estimated pumpage, because there is no industry and other establishments consuming large quantities of water.
3. Water Quality	The water quality of test wells examined in December 1984 indicate that there is no problem at all in this connection both in the East and West Districts. However, results of water quality test of test boring carried out in the past by the DPHE in the Town indicate that there are samples with very high contents of iron (Fe). Therefore, in areas close to the Town it is feared that the content of iron will surpass the permissible limit. When the content of iron is high, it will be necessary to provide iron removal equipment.	Water quality tests were carried out in August 1984 at the intake construction sites of the Sitalakhya River. The test results indicate 80 or more turbidity and 70 or more color, but there is not problem in connection with the water quality itself. Results of heavy metal analysis indicate no problem at all. Water quality test on monthly basis was carried out in the 1975-83 period by the EPCB of Bangladesh, and the relevant data indicate no problem in connection with the water quality. The intake site is located in the tide-sensitive area of the Sitalakhya River, but it is not influenced by the tide.
4. Merits Regarding Future Expansion	The sphere of influence required to determine the location of the production wells is calculated by assuming that the pumps will operate 12 hours a day. Therefore, it will be neces-	The facilities to be constructed anew are being designed by assuming 15 hours of operation per day. If these facilities should operate 24 hours a day, it would be possible to supply water to a population 1.6 times as large as

Item	Well Alternative	Purification Plant Alternative
	sary to construct new production wells to cope with future increases in the water demand. In the West District the new wells will be digged to the north of the town because there is no space for new wells in the west side of the town. In this case the length of the water pipeline will become longer. In the East District there are already wells digged at the vicinity of the Town and there is no space to dig new ones in the area. The areas available for digging of new wells are located at the opposite bank of the Old Bramaputra River and at the north side of the Dhaka-Chittagong Road, and are distant from the Town. It will be necessary to cross the Old Bramaputra River by means of siphon or aqueduct.	the actual one. As for the discharge of the river, it is regarded as sufficient to cope with the demand of water. From the standpoint of merits regarding future expansion, the purification plant alternative is more advantageous than the well alternative.
5. Water Diversion, Conveyance and Distribution Methods		
1) Water diversion method	Water will be pumped from the production wells by means of multi-stage turbine pumps manufactured in Bangladesh.	In the purification plant alternative water will be diverted from the river by means of centrifugal pumps.
2) Water conveyance method	In the well alternative water will be conveyed directly to the overhead towers or to the receiving wells by means of turbine pumps installed in the pro-	After the treatment at the purification plant, water will be pumped from the clear water reservoir to the overhead tank. The pipeline will be made of cast iron.

Item	Well Alternative	Purification Plant Alternative
	duction well. The pipeline will be made of cast iron. Natural flow will be impossible because the topography of the project area is flat.	
3) Purification method	In principle groundwater will be supplied as it is in the well alternative. However, if the water quality presents any problem, particularly high iron (Fe) content, it will be supplied after being treated with iron removal equipment.	In the purification plant alternative water will be treated with alum in the first place for precipitation of suspended impurities, followed by rapid filtering and disinfection with chlorine (bleaching powder).
4) Pressure adjustment method	The required pressure will be provided by the overhead tank.	The required pressure will be provided by the overhead tank.
5) Distribution method	Water will be distributed by natural flow from the overhead tank. Cast iron pipes will be used for diameters of ø250mm or more and PVC pipes will be used for ø200mm or less.	Water will be distributed by natural flow from the overhead tank. Cast iron pipes will be used for diameters of ø250mm or more and PVC pipes will be used for ø200mm or less.
6. Outline of the Facilities	(West District) Existing purification plant: 3,640 m^3/day Existing production wells (4 units): 4,914 m^3/day Production wells (27 units): 25,622 m^3/day Depth 180m, diameter 150mm strainer 20m Planned water consumption: 34,176 m^3/day Pipeline: ø150mm 250m ø200mm 21,200m ø350mm 2,000m ø450mm 5,400m Total 32,850m	(West District) Existing purification plant: 3,640 m^3/day Existing production wells (2 units): 4,914 m^3/day Purifications plant to be built anew: 25,622 m^3/day (Purification capacity 45,095 m^3/day Design daily water consumption: 34,176 m^3/day Pipeline: ø700mm 2,710m Overhead tank: 2,000 m^3 capacity x 2 units 1,000 m^3 capacity x 2 units 300 m^3 capacity x 2 units

Item	Well Alternative	Purification Plant Alternative
	Intake pump: Model B8D 6 to 8 stages, 27 units Motor output 15 kW, 27 units Conveying pump vertical shaft mixed flow pump: ø300/250mm 4 units Motor output 55 to 110kW 4 units Collecting well capacity: 1,200 m^3 x 2 locations 600 m^3 x 2 locations Overhead tank capacity: 1,500 m^3 x 2 locations 1,000 m^3 x 2 locations 600 m^3 x 1 location Maintenance road: L = 27,800m Power receiving facilities & substation: 27 locations Transmission line (11kV): L = 14,700m	Power receiving facilities & substation: 1 location
	(East District) Production wells (10 units): 10,944 m^3/day Depth 180m, diameter 150mm strainer 30m Design daily water consumption: 10,944 m^3/day Pipeline: ø200mm 15,900m ø250mm 5,300m ø350mm 2,800m Total 24,000m Intake pump: Model B8D 6 to 13 stages 10 units Motor output 15/19kW 10 units Conveying pump: Vertical shaft mixed flow pump ø250mm 1 unit Motor output 75 kW Collecting well: Capacity 600 m^3x 1 location	(East District) Purification plant to be built anew: 10,944 m^3/day (Purification capacity 19,260 m^3/day) Design daily water consumption: 10,944 m^3/day Overhead tank: 1,000 m^3 capacity x 2 units Power receiving facilities & substation: 1 location

Item	Well Alternative	Purification Plant Alternative
	Overhead tank: Capacity 1,000 m^3 x 1 unit 700 m^3 x 1 unit Maintenance road: L = 14,850 m Power receiving facilities & substation (11 - 0.4kV): 10 locations Transmission line (11kV): L = 8,300m	
7. Ease of Acquisition of Site	In the well alternative it is necessary to acquire sites for construction of 37 production wells, 5 collecting wells, 7 overhead tanks and 42.65km of maintenance road, totaling approximately 426,000m^2. The sites for construction of the production wells will be selected at the end of the villages and in the paddy zone located in the outskirts of the town, but difficulties are expected in connection with their acquisition because they are close to the town.	In the purification plant alternative it is necessary to acquire sites for construction of 2 purification plants and 7 overhead tanks totaling approximately 32,000 m^2. Of the said area, the 15,000 m^2 site adjacent to the existing purification plant of the West District has already been acquired and is possessed by the DPHE. The acquisition of the required sites is far easier than the well alternative.
8. Ease of the Construction Work	This alternative requires a considerably long term of works because there are few roads that can be used as access road for construction of the production wells and pipe laying (to be used later on as maintenance road). Immediately after the embankment these roads cannot be used as access routes for construction and furthermore the pipeline can not be laid therein.	The construction work is easy in this alternative, because it consists mainly of the construction of two plants, in the East and West districts, respectively.

Item	Well Alternative	Purification Plant Alternative
9. Comparison of the Volume of Work	This alternative requires the construction of 37 production wells, 5 collecting wells, 7 overhead tanks, 52.6km of pipeline, 42.6km of maintenance road (554,000 m^3 of embankment).	This alternative requires the construction of two purification plants (approximately 11,000 m^3 of concrete), 7 overhead tanks and 2.7km of pipeline.
10. Construction Cost	(West District) 1. Direct construction cost 200,507,000 TK 2. Expropriation cost 29,408,000 TK 3. Total 229,915,000 TK (East District) 1. Direct construction cost 91,451,000 TK 2. Expropriation cost 15,233,000 TK 3. Total 106,684,000 TK . The costs of the common temporary works and site management become very expensive because the work extends over wide area. . The site management cost increases because the term of works is long compared with the purification plant alternative. . The ocean freight for transportation of the screens for 37 production wells, cast iron pipes for 52.7km of pipeline, etc., becomes more expensive than the purification plant alternative. . The expropriation cost is proportional to the difference of 426,000 m^2 to be expropriated.	(West District) 1. Direct construction cost 199,854,000 TK 2. Expropriation cost 6,000,000 TK 3. Total 205,754,000 TK (East District) 1. Direct construction cost 95,246,000 TK 2. Expropriation cost 3,600,000 TK 3. Total 98,846,000 TK . In the purification plant the ocean freight refers to the transportation of pumps, preforated blocks for filter basin, cast iron pipes for pipelines with more than ø250mm diameter, etc. . The required site area is 32,000 m^2, of which the site for construction of the purification plant of the West District (approximately 15,000 m^2) has already been acquired.

Item	Well Alternative	Purification Plant Alternative
	. The difference in the direct construction cost is of the order of several percent.	
11. Maintenance and Administration Cost	1. Personnel expenditure 222,900 TK/month 2. Office supplies, etc. 1,500 " 3. Vehicle and fuel cost 10,500 " 4. Building maintenance cost 1,500 " 5. Operation cost of pumps and other equipment 1,105,650 " 6. Chemicals 0 7. Expendables of pumps and other equipment (5% of 5.) 55,300 " Total 1,397,350 TK/month	1. Personnel expenditure 178,100 TK/month 2. Office supplies, etc. 1,500 " 3. Vehicle and fuel cost 5,250 " 4. Building maintenance cost 1,500 " 5. Operation cost of pumps and other equipment 918,896 " 6. Chemicals 149,085 " 7. Expendables of pumps and other equipment (5% of 5.) 46,000 " Total 1,300,331 TK/month
12. Ease of Operation, Maintenance and Management	The management of wells is apparently an easy job, but in reality this alternative requires many operation personnel and furthermore the global management of the system as a whole requires a relatively sophisticated technique because there are many wells and they are distributed throughout a wide area. Many maintenance and management personnel are required and there is much risk of trouble. Maintenance roads are indispensable for dispatch of the personnel and transportation of spare equipment in the case of trouble. The procurement of parts for repair in the case of trouble in the production	The adoption of the centralized management system is possible in this system because the facilities are centralized and furthermore the quantity of facilities is small. This system requires a small number of operation, maintenance and management personnel. The management of the injection of coagulant and disinfectant in the purification plant and the operation and management of the filter basin requires some technique. The electric equipment of the purification plant consists of pumps for water intake and conveyance and valves of the filter basin. The pumps require spare units, but the valves of the filter basin can be operated manually as well, and therefore there is no risk of water supply stoppage even in the case of malfunction of the

Item	Well Alternative	Purification Plant Alternative
	well pumps is easy because they are manufactured in Bangladesh. Spare pumps must be provided in the collector wells, because if not there is risk of water supply stoppage due to troubles in these pumps. Countermeasures to cope with power stoppage are required in each pumping station, and this is virtually impossible.	electric equipment. As for means to cope with power stoppage (motor-driven generator equipment), it is sufficient to provide them only in the purification plant, and therefore the problem is easy to solve.

(3) Consideration

The well alternative and the purification plant alternative are examined and discussed on the basis of the comparative table.

In terms of water source, the development of groundwater is regarded as very promising. On the other hand, the surface flow of the Sitalakhya River has sufficient discharge to cope with the intake demand. The water quality of the Sitalakhya River has no problem at all, and it is not influenced by brine. The turbidity in the rain season (August) is of the order of 80, and it can be treated with ease by means of alum, and there is no problem at all for use as source for waterworks. As for the quality of groundwater, there is no problem at all in the quality of samples of wells located in the outskirts of the town tested this time. However, in the town there are areas where groundwater samples have considerably high iron (Fe) content, and in wells to be constructed at the vicinity of the town the risk of problems regarding the water quality cannot be neglected at all.

As for future changes in the water demand, the purification plant alternative is being planned by assuming that its facilities will operate 15 hours a day. If the operation time should be extended to 24 hours a day, it will be possible to supply water to approximately 1.6 times the currently planned estimated population. The river discharge as the water source to meet this demand is also considered large enough. In the well alternative it is necessary to construct each well outside the sphere of influence of adjacent wells because it is necessary to prevent mutual interference between wells in order to make possible a stable intake of water also in the future. In this project the disposition of the wells is determined by calculating the sphere of influence on the premise of 12-hour operation of the pumps. For stable pumping of groundwater, the operating hours of the pumps cannot be lengthened any further. Hence, it is impossible to meet the future growth of demand for water with the currently planned facilities unless new wells are built.

In the well alternative the volume of construction works for the pipeline, collecting wells, maintenance road, transmission line, etc., not to mention the large number of required wells, become very large because the wells are scattered over a wide area. Furthermore the scope of the construction work extends over a wide area. The purification plant alternative requires only one purification plant each in the East and West Districts, which means the concentration of work and smaller volume of work.

As for the acquisition of sites, the well alternative requires the acquisition of sites totaling approximately 426,000 m^2 while the purification plant alternative requires barely 32,000 m^2, of which the site for construction of the West District purification plant has already been acquired and is possessed by the DPHE. As above, the well alternative requires land acquisition of more than 10 times that of the purification plant alternative. What is more acquisition of farmland is extremely difficult in Bangladesh. Thus, the purification plant is much more preferrable as far as land acquisition is concerned.

From the standpoint of construction cost, the difference in direct construction cost is barely 4%, and the two alternatives can be regarded almost even. If the land acquisition cost is included however, the purification plant alternative becomes slightly more advantageous. In terms of common temporary works and onsite management cost the well alternative becomes more expensive because the area in which work is to be performed becomes larger and the construction period longer. Therefore, the construction cost of the purification plant alternative is cheaper.

In terms of maintenance and administration cost, the well alternative requires 231 maintenance personnel because it comprises many production wells and collecting wells and furthermore the pumps require many operators and assistances. On the other hand, the purification plant alternative requires only 130 persons. Therefore, the personnel expenditure becomes more expensive in the well alternative. The well alternative requires twice as much vehicle and fuel cost as the purification plant alternative because the maintenance area is very wide. The electricity charge for operation of pumps becomes more expensive in the well alternative due to the difference in the number of pumps. The well alternative requires no chemicals because groundwater requires no chemical treatment. Summing up the aforementioned costs, the monthly running cost of the well alternative is 1,397,000 TK/month compared with 1,300,000 TK/month of the purification plant alternative, evidencing therefore the advantage of the latter one.

From the standpoint of operation, maintenance and administration the management of wells and pumps is apparently easier, but in reality the well alternative comprises 42 localities including production wells and collecting wells, in addition to 52.6 km of pipeline and other accessory facilities. Such being the case, a considerably sophisticated management technique is required to provide satisfactory management and maintenance. Furthermore, the volume of maintenance and repair work is expected to become larger in the well alternative because it comprises a larger number of facilities. The purification plant alternative requires a relatively sophisticated technical level for management of the purification plant, but in reality it is presumed to be simpler and easier compared with the well alternative because the facilities are concentrated at one locality. Also in terms of means to cope with power stoppage and other troubles, in the purification plant alternative it is sufficient to provide them only at the purification plants, while in the well alternative it is necessary to provide them in 37 production wells and 5 collecting wells.

In view of these considerations, it is concluded that the purification plant alternative is more advantageous, particularly from the standpoints of capability of coping with future increases in the water demand, method and cost of maintenace and mangement, acquisition of sites, ease of construction, etc.

(4) Determination of the Source

In this project it is decided that the purification plant alternative with the Sitalakhya River as the water source shall be adopted on the basis of the table of comparison and relevant discussions.

CHAPTER 5 WATER SUPPLY PLAN

5-1 Outline

This plan deals with the Narayanganj Town Water Supply Project, which is one of the three projects being implemented by the DPHE with exclusively native financial resources. As mentioned before, the Narayanganj Town Water Supply Project which is being implemented at the present time does not take into consideration future increases in the population and water demand, and therefore in this study a master plan is drawn up by examining such factors as forecast of the future population, development course of the town, change in the demand of water, etc.

The water supply plan will be drawn up under the same conditions as the design criteria for the potable water supply plan of the 7 towns, with due consideration to maintaining consistency with the water supply plans of projects which are being implemented with the aid of the Netherlands and the ADB. The purification plant is designed in conformity with the Waterworks Design Guideline of Japan because there are no official standards referring to the matter in Bangladesh, and the final details were decided after consulations with authorities of the Government of Bangladesh and DPHE.

5-2 Target Year of the Plan

According to the long-term targets of the potable water supply scheme of Bangladesh, an around the clock 100% supply rate must be attained by the year 2000 and an interim supply rate of at least 50% must be attained by 1990.

The target year of this project is 1990, and at that time 50% of the urban population will be served with house connections and the remaining 50% will be served by public posts, thus realizing the supply of safe and clean potable water for the entire the town.

5-3 Service Area and Benefited Population

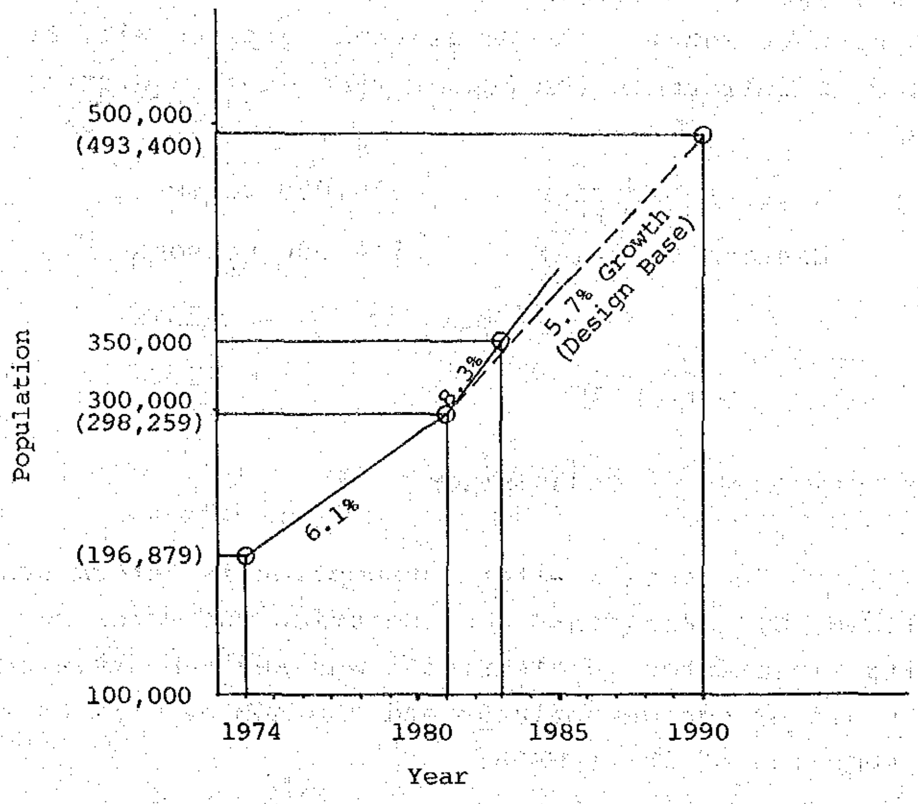
The service area consists principally of the center of the municipal area, and was demarcated by taking into consideration such factors as the current state of the existing distribution pipe network, conditions of demographic distribution, future trend of housing land development, etc. The scope of the service area is shown in Fig. 5-5-2.

The demographic evolution of the town, according to the censuses conducted in 1974 and 1981, is as follows:

Population of the 1974 census	196,879
Population of the 1981 census	298,359
Population in 1983 estimated by the authories of Bangladesh	350,000

The said population growth is shown graphically in the following figure:

Fig. 5-3-1 Population Growth of the Town



In the 1974-1981 period the annual population growth rate averaged 6.1%, but after 1981 it leaped to 8.3%. The same tendency is taking place in other local cities of the country as well.

The population in 1990, the target year of the project, was estimated on the basis of the results of the censuses and by taking into consideration the actual population and its distributions as well as the field survey findings. After consultations with authorities of the DPHE and the Narayanganj Town, the estimation was carried out by assuming the natural population growth rate of 2.4% for Bangladesh as a whole in areas with particularly high population density and 6.0% which is the growth rate for the town so far in other areas. Calculation results indicate that the average population growth rate of the town as a whole will be 5.7%, and the town population in the target year is estimated to reach 493,400.