CHAPTER 8

FACILITY PLANNING FOR NORTH DHAKA

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8.1 General

Facility planning at this stage will be focused on the selection of the optimum configuration of sewerage systems in North Dhaka for the long-term development. In this respect, the alternatives of sewerage systems were developed from various technical options. An in-depth evaluation on these alternatives was carried out during the Stage 1 Domestic Work not only from the viewpoint of cost requirements, but also from the viewpoint of appropriateness to the prevailing localities. Sustainability and stability are prerequisites to determine the optimum configuration.

A study on sanitation facilities was conducted including the questionnaire survey to the residents on their sanitary knowledge and awareness, requests/expectations regarding the sewerage system and their willingness to pay.

8.2 Design Sewage Flow

The design sewage flow by sewerage zone namely, Tongi, Uttara, North Dhaka East and North Dhaka West, of the target year 2020 is shown in Table 8.2.1 and Figure 8.2.1.

Sewage generated from residential areas within the Cantonment Security Zone will be received by the proposed sewerage system. Accordingly, any sewerage system development in the Cantonment Area should be carried out by the Cantonment Authority, not by DWASA, and the outlet sewer should be connected to the trunk sewer of the planned public sewerage in at a certain connection point(s).

Table 8.2.1 Design Sewage Flow by Sewerage Zone (Year 2020)

Sewerage Zone	Item	Unit	Core Area	Transitional Area	Sub-Total	Cantonment Security Zone	Total
Tongi	Area	ha	151	892	1,043	0	1,043
	Population	person	39,000	265,000	304,000	0	304,000
	Q1	cu.m/day	3,900	26,500	30,400	0	30,400
	Q2	cu.m/day	4,875	33,125	38,000	0	38,000
	Q3	cu.m/day	6,240	42,400	48,640	0	48,640
Uttara	Area	ha	504	512	1,016	0	1,016
	Population	person	86,000	75,000	161,000	0	161,000
	Q1	cu.m/day	8,600	7,500	16,100	0	16,100
	Q2	cu.m/day	10,750	9,375	20,125	0	20,125
	Q3	cu.m/day	13,760	12,000	25,760	0	25,760
North Dhaka East	Area	ha	868	1,371	2,239	1,090	3,329
	Population	person	487,000	314,000	801,000	83,000	884,000
	Q1	cu.m/day	48,700	31,400	80,100	8,300	88,400
	Q2	cu.m/day	60,875	39,250	100,125	10,375	110,500
	Q3	cu.m/day	77,920	50,240	128,160	13,280	141,440
North Dhaka West	Area	ha	789	1,677	2,466	130	2,596
	Population	person	438,000	1,184,000	1,622,000	10,000	1,632,000
	Q1	cu.m/day	43,800	118,400	162,200	1,000	163,200
	Q2	cu.m/day	54,750	148,000	202,750	1,250	204,000
	Q3	cu.m/day	70,080	189,440	259,520	1,600	261,120
Total	Area	ha	2,312	4,452	6,764	1,220	7,984
	Population	person	1,050,000	1,838,000	2,888,000	93,000	2,981,000
	Q1	cu.m/day	105,000	183,800	288,800	9,300	298,100
	Q2	cu.m/day	131,250	229,750	361,000	11,625	372,625
	Q3	cu.m/day	168,000	294,080	462,080	14,880	476,960

Note: 1) Q1: Design Average Daily Flow
2) Q2: Design Maximum Daily Flow
3) Q3: Design Maximum Hourly Daily Flow

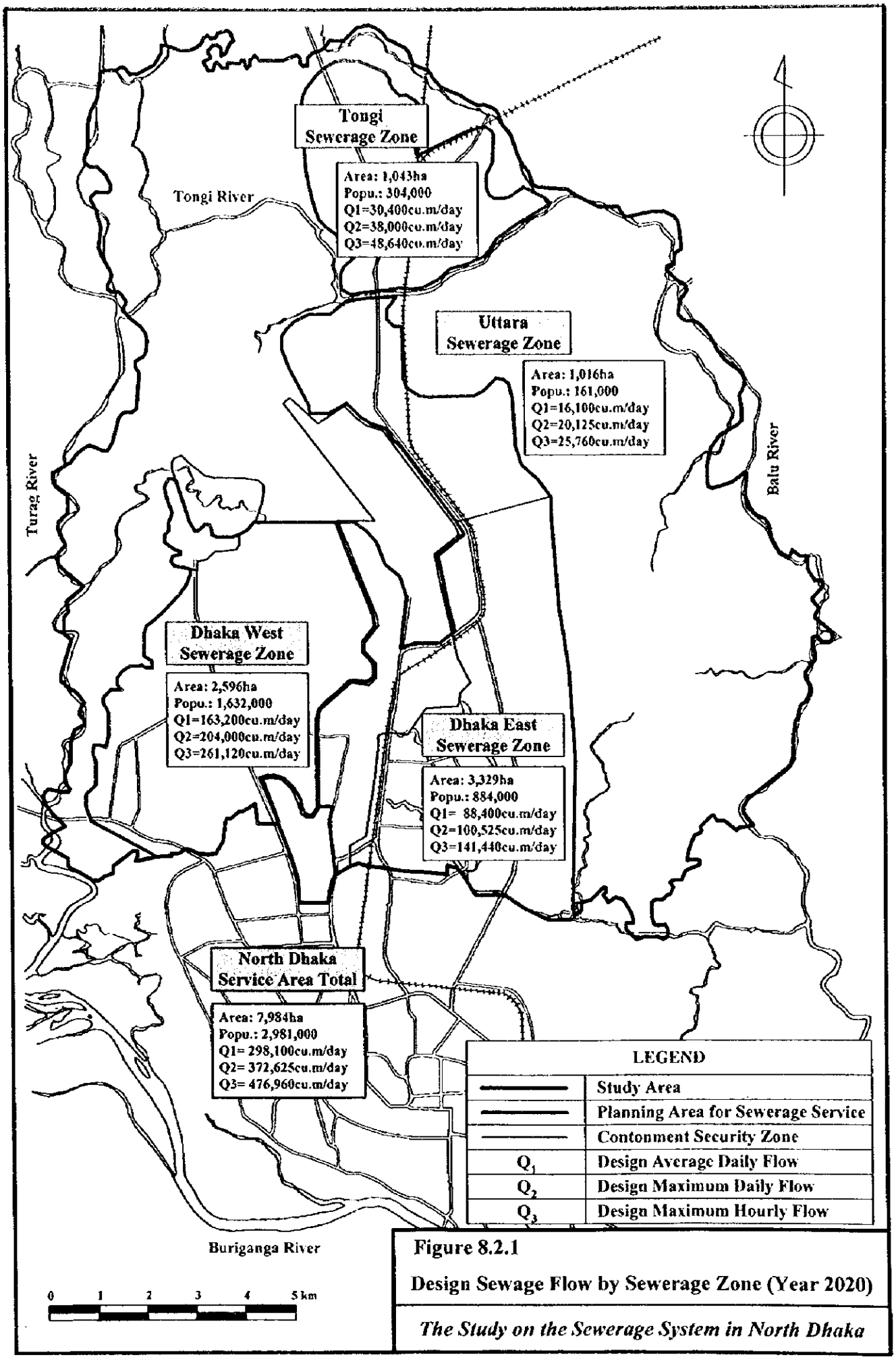


Figure 8.2.1

Design Sewage Flow by Sewerage Zone (Year 2020)

The Study on the Sewerage System in North Dhaka

8.3 Conditions and Design Criteria

8.3.1 Conditions for Facility Planning

The conditions in formulating the master plan for the North Dhaka Sewerage System are as follows:

- The target area for the above-mentioned sewerage master plan is limited to North Dhaka only and the existing sewerage service area in South Dhaka is excluded.

- The sewerage facility plan will be examined per every sewerage zone.

- The facility plan will be prepared targeting gravity sewers with diameters of more than 500 mm, which is defined as the trunk sewers in the master plan, and smaller sewers will be eliminated from facility planning since the construction cost to install such pipes is almost identical to any sewerage system that would be finally selected.

- Only the pumping stations to be constructed on the trunk sewers mentioned above will be included in the master plan.

8.3.2 Design Criteria

(1) Sanitary Sewer

1) Design capacity of sewer

Design maximum hourly sewage flow is applied to designing sanitary sewers.

2) Allowance for sewer capacity

An allowance is made for sanitary sewer capacity as shown below.

Table 8.3.1 Allowance for Sewer Capacity

Diameter of Sewer	Allowance for Sewer Capacity
200 - 600 mm	100%
700 - 1,500 mm	50 – 100%
1,650 - 3,000 mm	25 - 50%

3) Determination of size and slope of sewer

Manning's formula is adopted for gravity sewers and Hazen Williams' formula for pressure sewers.

❒ **Manning's Formula (for Gravity Pipe)**

$$Q = A \cdot V$$

$$V = \frac{1}{n} \cdot R^{\frac{2}{3}} \cdot I^{\frac{1}{2}}$$

where, Q : flow rate (m^3 / sec)
A : cross - sectional area of flow (m^2)
V : flow velocity (m / sec)
n : roughness coefficient
R : hydraulic mean depth (m) = A / P
P : wetted perimeter (m)
I : gradient

Regarding the roughness coefficient, the values of "n" shall be 0.013 for clay pipe, reinforced concrete pipe and cast-in-place reinforced concrete pipe, and 0.010 for polyvinyl chloride pipe and fibre reinforced plastic mortar pipe.

❒ **Hazen Williams' Formula (for Pressure Pipe)**

$$Q = A \cdot V$$

$$V = 084935 \cdot C \cdot R^{0.63} \cdot I^{0.54}$$

where, Q : flow rate (m^3 / sec)
A : cross - sectional area of flow (m^2)
V : flow velocity (m / sec)
C : flow velocity coefficient (C = 110)
R : hydraulic mean depth (m) = A / P
P : wetted perimeter (m)
I : hydraulic gradient (h / L)
h : friction head loss

4) Restrictions on flow velocity and gradient

The design velocity in sewers shall gradually increase downstream.

Design velocity of sanitary sewer: 0.6 to 3.0 m/sec

5) Kinds of sewers

Sewers are required to be of materials and structure strong enough to withstand continuous external pressure, although they not required to have such great strength against internal pressure except for specific cases. The kinds of sewers are summarised below.

- For gravity pipe

  Reinforced concrete pipes: more than 500 mm

  Polyvinyl chloride pipes: 200 mm – 450 mm

- For pressure pipe

  Steel Pipe

6) Minimum pipe diameter

The minimum pipe diameter shall be 200 mm for sanitary sewers.

7) Minimum earth cover

The minimum earth cover shall be 1.0 m for sanitary sewers.

8) Manhole

The manhole should be installed at the end of each pipeline and at any place of change in pipe diameter, junction of pipes and change in vertical or horizontal alignment. Conditions for the installation of the standard circular manhole are summarised below.

Table 8.3.2 Standard Circular Manhole

Type	Manhole Size	Pipe Diameter to Be Connected with the Manhole		
		at Starting Point	at Intermediate Point	at Junction Point
I	φ 900 mm	less than φ 600 mm	less than φ 600 mm	less than φ 450 mm
II	φ 1,200 mm	N.A.	less than φ 900 mm	less than φ 600 mm
III	φ 1,500 mm	N.A.	less than φ 1,200 mm	less than φ 800 mm
IV	φ 1,800 mm	N.A.	less than φ 1,500 mm	less than φ 900 mm

Table 8.3.3 Interval of Manhole Placement

Pipe Diameter	Less than φ 300 mm	Less than φ 600 mm	Less than φ 1,000 mm	Less than φ 1,500mm	More than φ 1,650 mm
Maximum Interval	50 m	75 m	100 m	150 m	200 m

9) Connection of sewers at manholes

The connection of sewers at the manhole where the sewer pipe diameter changes or where two or more sewers join; in other words, the adjustment of a step between upstream and downstream pipes, is basically made so as to fit two pipe crests.

10) Side-pipe at manholes

A side-pipe should be installed inside the manhole to protect the bottom and sidewall from erosion, when the difference in level between the inlet and outlet pipes is more than 0.60 m. The manhole structure with a side-pipe inside is shown below.

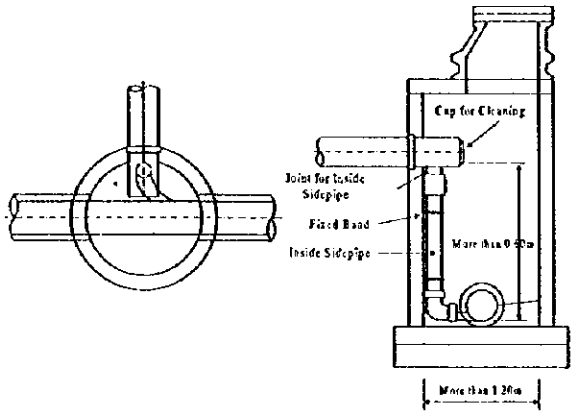


Figure 8.3.1 Manhole Structure with a Side-pipe Inside

(2) Pumping facilities

1) Basic type of pumping station

The type of a pumping station depends on the design sewage flow, of which the relationship is shown in Figure 8.3.4 in general.

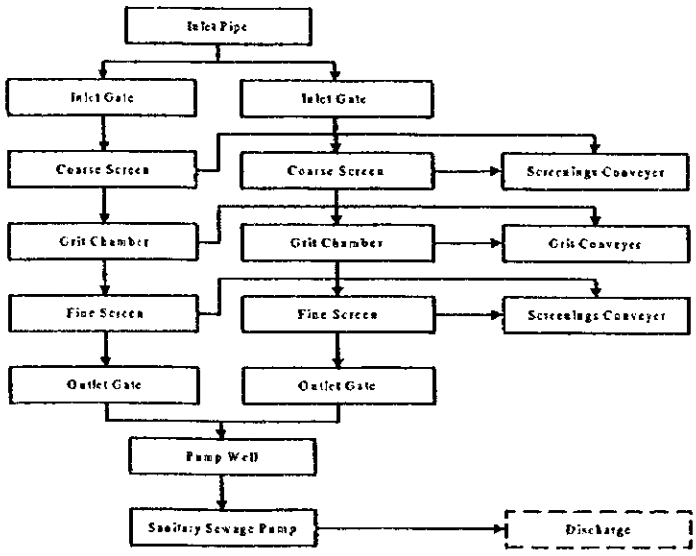
Table 8.3.4 Chart for Selection of Pumping Station Type by Design Flow

Item \ Design Flow (m³/min)		0.6	1.5	3.0	6.0	20.0	30.0
Type of Pumping Station		Manhole Type					
			Simplified Type				
					Standard Type		
Grit Chamber		None		Sand Pit	Sand Pit	Standard Grit Chamber	
Grit Removal		None		Sand Pump	Sand Pump	Bucket Conveyor	
Screenings Removal		None		Manual	Automati		
Conveyor		None		Cage	Container		Hopper
Standby Generator		None		None	Yes		Yes
Deodorization		None		None	None		Yes
Pumping	Dia.(mm)	65	80	100	100	150	150	200	250	300	350	400
	Nos. (standby)	2(1)	2(1)	2(1)	3(1)	3(1)	4(1)	4(1)	4(1)	4(1)	4(1)	4(1)

Standard Type I Pumping Station

a. Design Flow: More than 20.0 m³/min

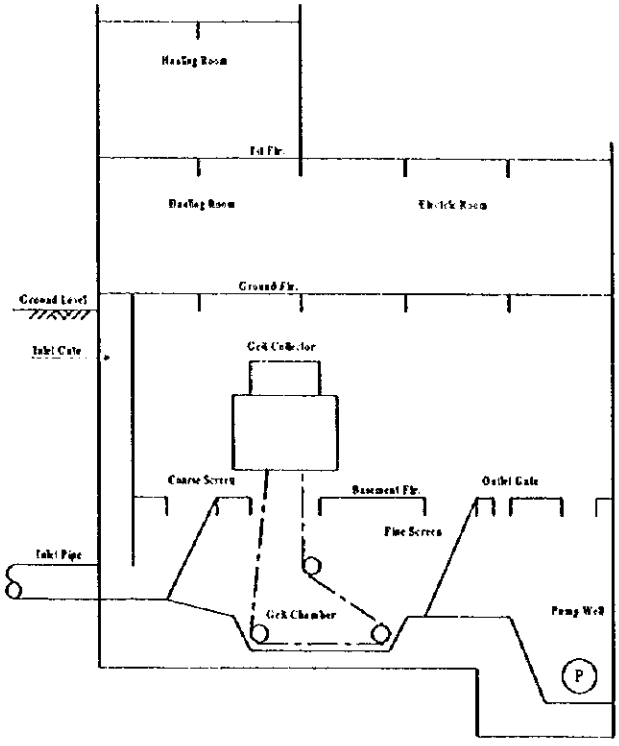
b. Standard Flow-Sheet



c. Condition

Generally more than two grit chambers should be installed and the overflow rate thereof is around 1,800 $m^3/m^2 \cdot day$ to remove the non-putrefactive inorganic matter with diameters of more than 0.2 mm.

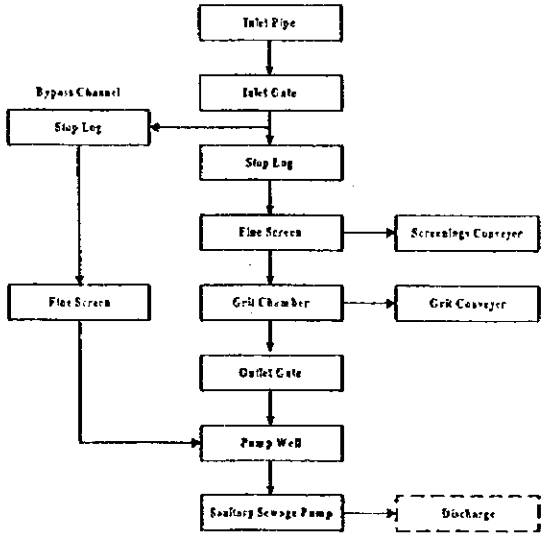
d. Schematic Diagram



Standard Type II Pumping Station

a. Design Flow: 6.0 - 20.0 m^3/min

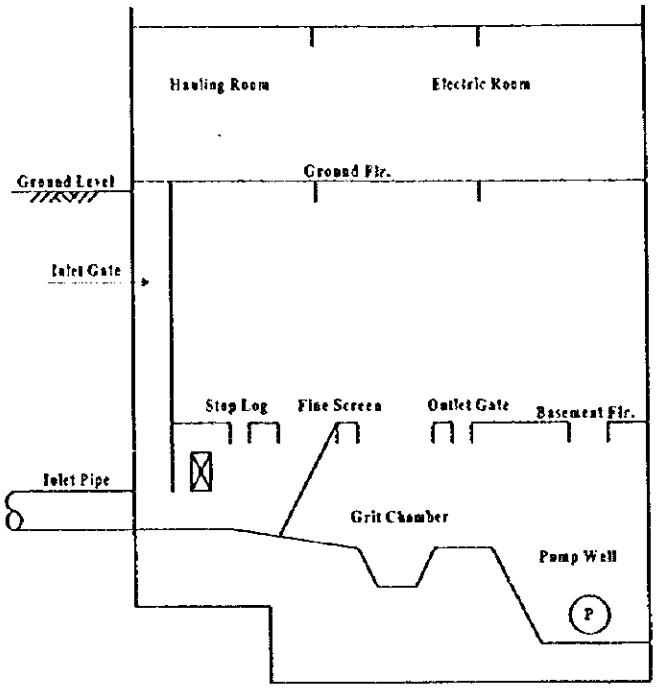
b. Standard Flow-Sheet



c. Condition

Generally one grit chamber with a grit conveyor and one bypass channel should be installed. The overflow rate of a grit chamber is 1,800 $m^3/m^2 \cdot day$ to remove the non-putrefactive inorganic matter with diameters of more than 0.2 mm.

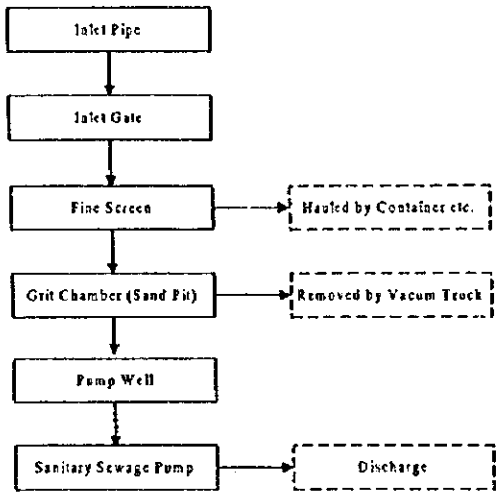
d. Schematic Diagram



Simplified Type Pumping Station

a. Design Flow: 1.5 - 6.0 m^3/min

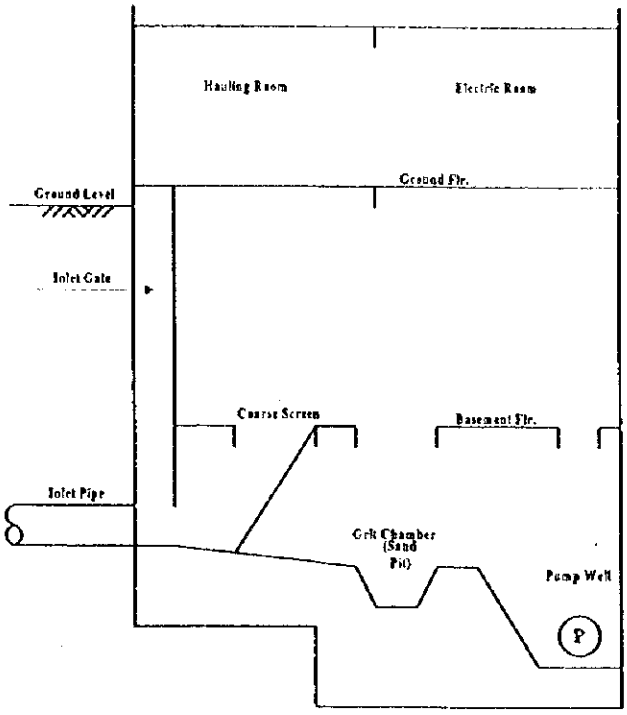
b. Standard Flow-Sheet



c. Condition

Generally, the sand pit and fine screen should be installed.

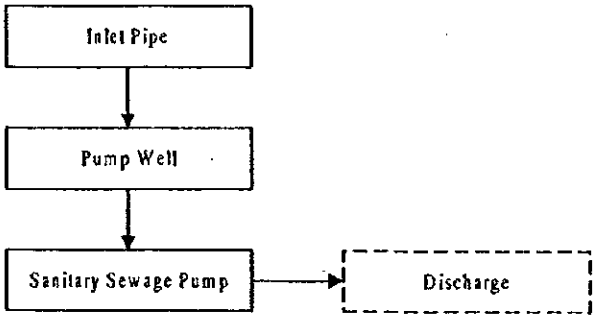
d. Schematic Diagram



Manhole Type Pumping Station

a. Design Flow: Less than 3.0 m^3/min

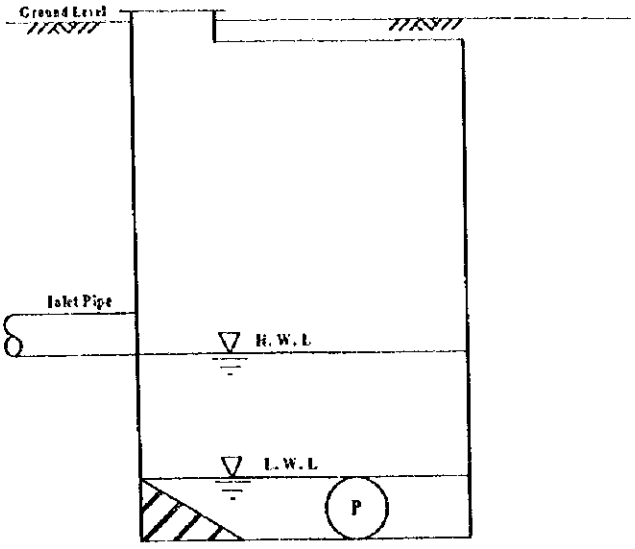
b. Standard Flow-Sheet



c. Condition

The pumps are installed inside a manhole.

d. Schematic Diagram



2) Design sewage flow

Design maximum hourly sewage flow is used for designing the pumping station.

3) Pump type

The submersible pump should be used for the pump.

4) Number of pumps

More than two pumps should be installed including the standby pump.

5) Pump size

The suction diameter of the pump is given by the following equation:

$$D = 146\sqrt{\frac{Q}{V}}$$

where, D : suction diameter (mm)

Q : discharge quantity (m^3 / min)

V : velocity at sunction (m / sec)

V value is in the range of 1.5 to 3.0 m / sec.

The minimum suction diameter of the pump is 80 mm considering the operation and maintenance.

6) Total pump head

The total pump head is calculated by the following equation:

$$H = h_a + h_f + h_o$$

where, H : total pump head

h_a: actual pump head

h_f : head loss of pressure pipe

h_o: residual velocity head of discharge pipe and head loss around pump

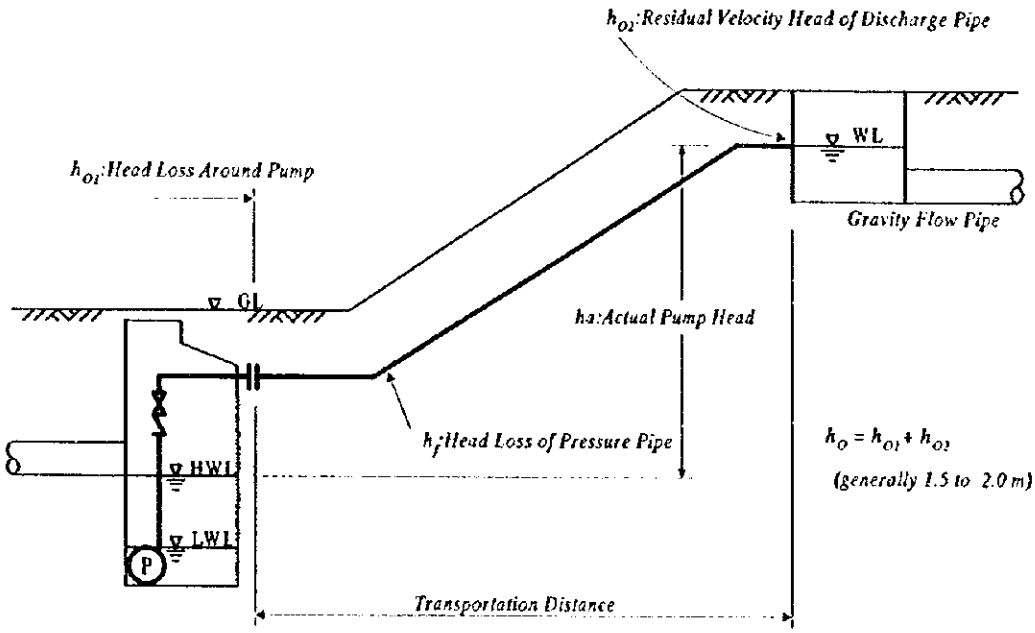


Figure 8.3.2 Total Pump Head

7) Shaft power

The shaft power of a pump is calculated by the following equation:

$$L = \frac{k \cdot \gamma \cdot Q \cdot H}{\eta}$$

where, L : shaft power of pump (kw or PS)

k : constant (0.163 for kw and 0.222 for PS)

Q : discharge quantity (m^3 / min)

H : total head of pump (m)

γ : bulk density of wastewater (γ = 1)

η : efficiency of pump

8.4 Selection of the Optimum Sewerage System

8.4.1 Alternatives of Sewerage System

(1) Considerations for Alternatives Development

The basic conditions in developing the alternatives of sewerage systems are described below.

1) Sanitary Sewer System

The sewer system is in principle designed with gravity flow. The lift pumping station is installed in consideration of difficulty in construction when the excavation depth to install trunk sewers reaches to 8 meters. The pumping station will be installed in such a case that the outgoing pipe therefrom is forced to run upward resultantly to the destination due to the topographical condition.

The pumping station is also required at the place near the zone boundary zone where all sewage from each sewerage zone will be collected since each proposed treatment plant site is isolated from the sewerage zone and will be reclaimed to protect the plant from flooding. The pressure pipes from such pumping stations will be dual in case of involvement of the traditional area taking into account the phased construction, that is to say, the pipes to pump sewage (1) from the core area where will be in service first and (2) from the transitional area where will be in service in the future. The pump equipment of the pumping station will be arranged to cope with such phased demand.

The generated sewage from the residential area in Cantonment Area, which is excluded from the planning area of sewerage service, will be connected to the proposed public sewerage system at two (2) connection points set up in North Dhaka Sewerage Zone.

2) Sewage Treatment Plant

As for the sewage treatment plant site, five sites as shown in Figure 8.4.1 were selected through the comprehensive consideration of the following matters:

- to locate the plant as near the sewerage zone as possible, to install trunk sewers with gravity flow as much as possible and to construct and maintain the plant economically.
- to locate the plant near the public water body to discharge the treated sewage.
- to assure the enough site necessary for the treatment process to be adopted.

- to have less residents near the site and to easily harmonise the surrounding environment.
- to be safe from flooding caused by rise in water level of the river during the rainy season.

As it is difficult to identify the detailed plant sites and design fundamentals at this stage, the treatment process is assumed to be the same wastewater stabilisation pond process as that of the existing Pagla Sewage Treatment Plant.

3) Sewerage District

In principle, the ground level of study area declines from north to south. Thus, upon planning the integration of sewerage service zone, sewage treatment plant shall be allocated in southern service zone to adopt the gravity sewer at maximum.

The sewerage facilities shall be implemented in order of the priority. Since there are four (4) sewerage zones in the Study Area with a vast service area, phased project implementation will be needed. According to the implementation priority of the zone, it might take long time for the sewerage development within the zone. To cope with the time lag of project implementation of each zone and the future social conditions, and also to avoid excessive capital cost investment, the trunk sewer from each zone to the sewage treatment plant shall be installed respectively.

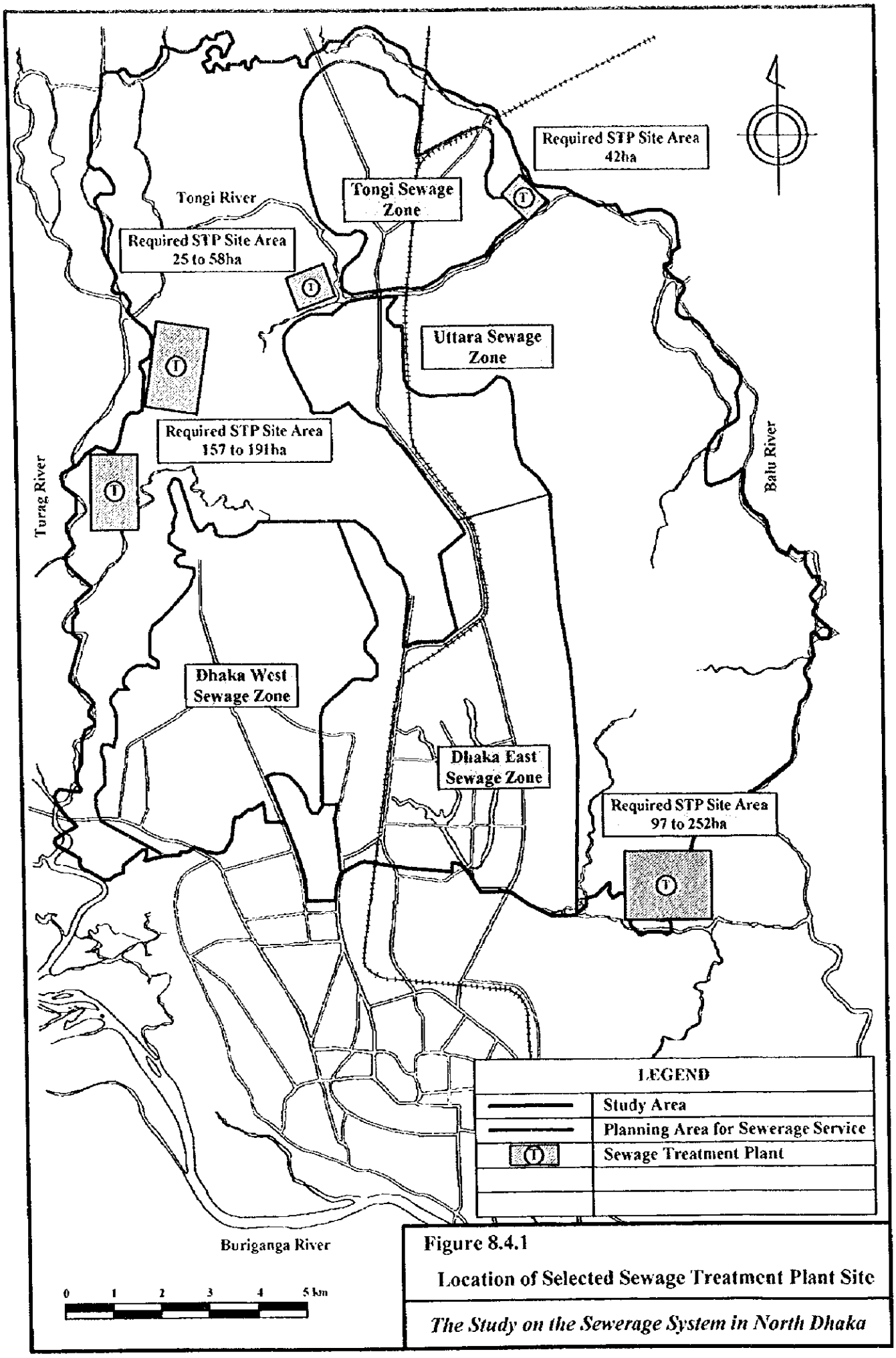


Figure 8.4.1

Location of Selected Sewage Treatment Plant Site

The Study on the Sewerage System in North Dhaka

(2) Development of Alternatives

In accordance with the basic conditions mentioned above, nine (9) alternatives of sewerage systems were developed by combination of four (4) sewerage zones. Alternatives are summarised in Table 8.4.1 and sewerage facilities by alternatives are shown in Table 8.4.3.

Table 8.4.1 Outline of Alternatives

Service Area	Alternative No.	Service Area 1	Service Area 2	Service Area 3	Service Area 4
4 Service Areas	No. 1	Tongi	Uttara	North Dhaka West	North Dhaka East
3 Service Areas	No. 2	Tongi, Uttara	North Dhaka West	North Dhaka East	-
	No. 3	Uttara, North Dhaka West	Tongi	North Dhaka East	-
	No. 4	Uttara, North Dhaka East	Tongi	North Dhaka West	-
	No. 5	North Dhaka West, North Dhaka East	Tongi	Uttara	-
2 Service Areas	No. 6	Tongi, Uttara, North Dhaka West	North Dhaka East	-	-
	No. 7	Uttara, North Dhaka West, North Dhaka East	Tongi	-	-
	No. 8	Tongi, Uttara, North Dhaka East	North Dhaka West		
1 Service Area	No. 9	Tongi, Uttara, North Dhaka West, North Dhaka East	-	-	-

Table 8.4.2 Outline of Sewerage Facilities by Alternatives(1/3)

	Alternative No.	Alternative 1	Alternative 2	Alternative 3
	No. of Service Area	4	3	3
Service Area 1	Sewerage Zone	North Dhaka West	North Dhaka West	North Dhaka West, Uttara
	Area (ha)	2,596	2,516	3,612
	Population (person)	1,632,000	1,632,000	1,793,000
	Design Sewage Flow (cu.m/day)	Q1=163,200 Q2=204,000 Q3=261,120	Q1=163,200 Q2=204,000 Q3=261,120	Q1=179,300 Q2=224,125 Q3=286,880
	Length of Trunk Sewer	14.2 km	14.2 km	25.7 km
	Number of PS	4	4	6
	Capacity of STP	163,200 cu.m/day	163,200 cu.m/day	179,300 cu.m/day
	Required STP Site	157 ha	154 ha	169 ha
Service Area 2	Sewerage Zone	North Dhaka East	North Dhaka East	North Dhaka East
	Area (ha)	3,329	3,329	3,329
	Population (person)	884,000	884,000	884,000
	Design Sewage Flow (cu.m/day)	Q1=88,400 Q2=110,500 Q3=141,440	Q1=88,400 Q2=110,500 Q3=141,440	Q1=88,400 Q2=110,500 Q3=141,4400
	Length of Trunk Sewer	18.4 km	18.4 km	18.4 km
	Number of PS	4	4	4
	Capacity of STP	88,400 cu.m/day	88,400 cu.m/day	88,400 cu.m/day
	Required STP Site	97 ha	97 ha	97 ha
Service Area 3	Sewerage Zone	Uttara	Tongi, Uttara	Tongi
	Area (ha)	1,016	2,056	1,043
	Population (person)	161,000	465,000	304,000
	Design Sewage Flow (cu.m/day)	Q1=16,100 Q2=20,125 Q3=25,760	Q1=46,500 Q2=58,125 Q3=74,400	Q1=30,400 Q2=38,000 Q3=48,640
	Length of Trunk Sewer	6.5 km	22.5 km	4.8 km
	Number of PS	2	5	2
	Capacity of STP	16,100 cu.m/day	46,500 cu.m/day	30,400 cu.m/day
	Required STP Site	25 ha	58 ha	42 ha
Service Area 4	Sewerage Zone	Tongi	-	-
	Area (ha)	1,043	-	-
	Population (person)	304,000	-	-
	Design Sewage Flow (cu.m/day)	Q1=30,400 Q2=38,000 Q3=48,640	-	-
	Length of Trunk Sewer	4.8 km		
	Number of PS	2		
	Capacity of STP	30,400 cu.m/day	-	-
	Required STP Site	42 ha	-	-

Table 8.4.2 Outline of Sewerage Facilities by Alternatives(2/3)

	Alternative No.	Alternative 4	Alternative 5	Alternative 6
	No. of Service Area	3	3	2
Service Area 1	Sewerage Zone	North Dhaka East, Uttara	North Dhaka West, North Dhaka East	North Dhaka West, Tongi and Uttara
	Area (ha)	4,345	5,925	4,655
	Population (person)	1,045,000	2,516,000	2,097,000
	Design Sewage Flow (cu.m/day)	Q1=104,500 Q2=130,625 Q3=167,200	Q1=251,600 Q2=314,500 Q3=402,560	Q1=209,700 Q2=262,125 Q3=335,520
	Length of Trunk Sewer	20.4 km	35.1 km	43.2 km
	Number of PS	4	8	9
	Capacity of STP	104,500 cu.m/day	267,700 cu.m/day	209,700 cu.m/day
	Required STP Site	111 ha	231 ha	191 ha
Service Area 2	Sewerage Zone	North Dhaka West	Uttara	North Dhaka East
	Area (ha)	2,596	1,016	3,329
	Population (person)	1,632,000	161,000	884,000
	Design Sewage Flow (cu.m/day)	Q1=163,200 Q2=204,000 Q3=261,120	Q1=16,100 Q2=20,125 Q3=25,760	Q1=88,400 Q2=110,500 Q3=141,440
	Length of Trunk Sewer	14.2 km	6.5 km	17.4 km
	Number of PS	5	2	4
	Capacity of STP	163,200 cu.m/day	16,100 cu.m/day	88,400 cu.m/day
	Required STP Site	157 ha	25 ha	97 ha
Service Area 3	Sewerage Zone	Tongi	Tongi	-
	Area (ha)	1,043	1,043	-
	Population (person)	304,000	304,000	
	Design Sewage Flow (cu.m/day)	Q1=30,400 Q2=38,0000 Q3=48,640	Q1=30,400 Q2=38,0000 Q3=48,640	-
	Length of Trunk Sewer	4.8 km	5.0 km	
	Number of PS	2	1	
	Capacity of STP	30,400 cu.m/day	30,400 cu.m/day	-
	Required STP Site	42 ha	42 ha	-
Service Area 4	Sewerage Zone	-	-	-
	Area (ha)	-	-	-
	Population (person)	-	-	-
	Design Sewage Flow (cu.m/day)	-	-	-
	Length of Trunk Sewer			
	Number of PS			
	Capacity of STP	-	-	-
	Required STP Site		-	-

Table 8.4.2 Outline of Sewerage Facilities by Alternatives(3/3)

	Alternative No.	Alternative 7	Alternative 8	Alternative 9
	No. of Service Area	2	2	1
Service Area 1	Sewerage Zone	North Dhaka West, North Dhaka East and Uttara	North Dhaka East, Uttara and Tongi	North Dhaka West, North Dhaka East, Uttara and Tongi
	Area (ha)	5,925	5,388	7,984
	Population (person)	2,516,000	1,349,000	2,981,000
	Design Sewage Flow (cu.m/day)	Q1=251,600 Q2=314,500 Q3=402,560	Q1=134,900 Q2=168,625 Q3=215,840	Q1=298,100 Q2=372,625 Q3=476,960
	Length of Trunk Sewer	39.6 km	29.0 km	45.8 km
	Number of PS	10	8	12
	Capacity of STP	251,600 cu.m/day	134,900 cu.m/day	298,100 cu.m/day
	Required STP Site	220 ha	135 ha	252 ha
Service Area 2	Sewerage Zone	Tongi	North Dhaka West	-
	Area (ha)	1,043	2,596	-
	Population (person)	304,000	1,632,000	-
	Design Sewage Flow (cu.m/day)	Q1=30,400 Q2=38,000 Q3=48,640	Q1=163,200 Q2=204,000 Q3=261,120	- -
	Length of Trunk Sewer	5.0 km	14.2 km	-
	Number of PS	2	4	-
	Capacity of STP	30,400 cu.m/day	163,200 cu.m/day	-
	Required STP Site	42 ha	157 ha	-
Service Area 3	Sewerage Zone	-	-	-
	Area (ha)	-	-	-
	Population (person)	-	-	
	Design Sewage Flow (cu.m/day)	-	-	-
	Length of Trunk Sewer			
	Number of PS			
	Capacity of STP	-	-	-
	Required STP Site	-	-	-
Service Area 4	Sewerage Zone	-	-	-
	Area (ha)	-	-	-
	Population (person)	-	-	-
	Design Sewage Flow (cu.m/day)	-	-	-
	Length of Trunk Sewer	-	-	-
	Number of PS	-	-	-
	Capacity of STP	-	-	-
	Required STP Site		-	-

The facility planning was made for the sewerage system including sewers, pumping stations and a sewage treatment plant in each sewerage district based on the design criteria previously described. The facility plan of each alternative are presented in Figures 8.4.2 to 8.4.10.

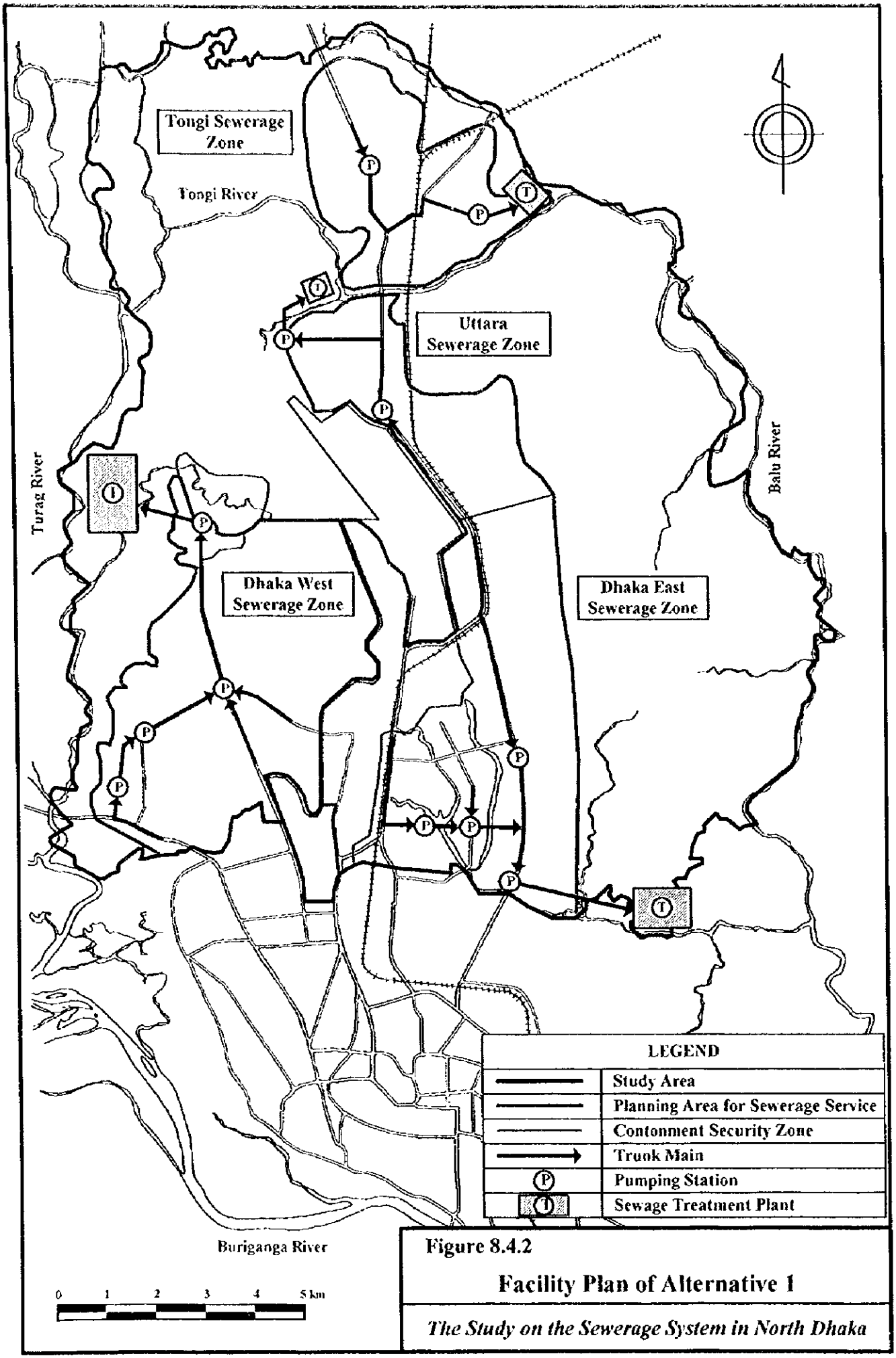


Figure 8.4.2

Facility Plan of Alternative 1

The Study on the Sewerage System in North Dhaka

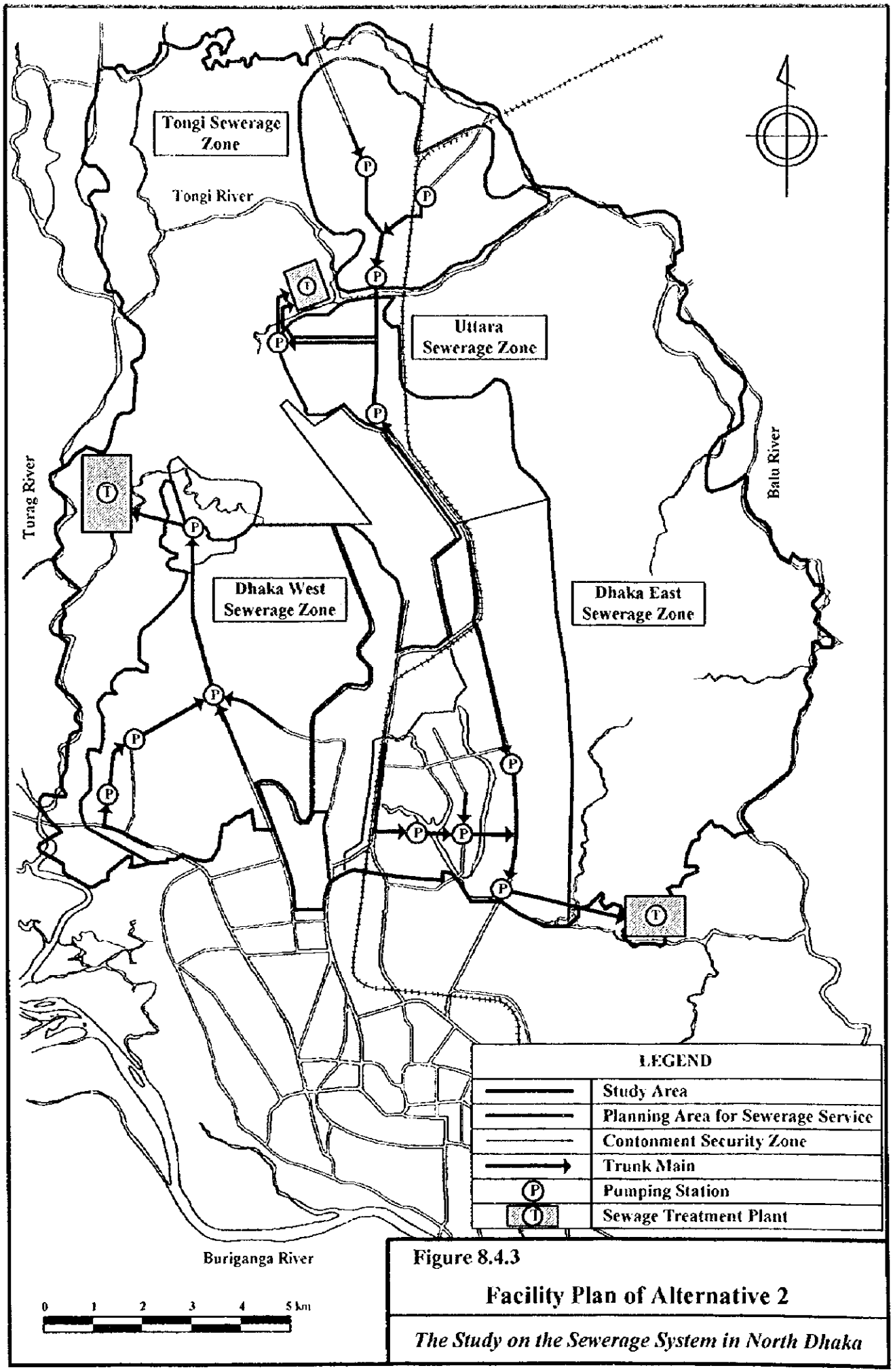


Figure 8.4.3

Facility Plan of Alternative 2

The Study on the Sewerage System in North Dhaka

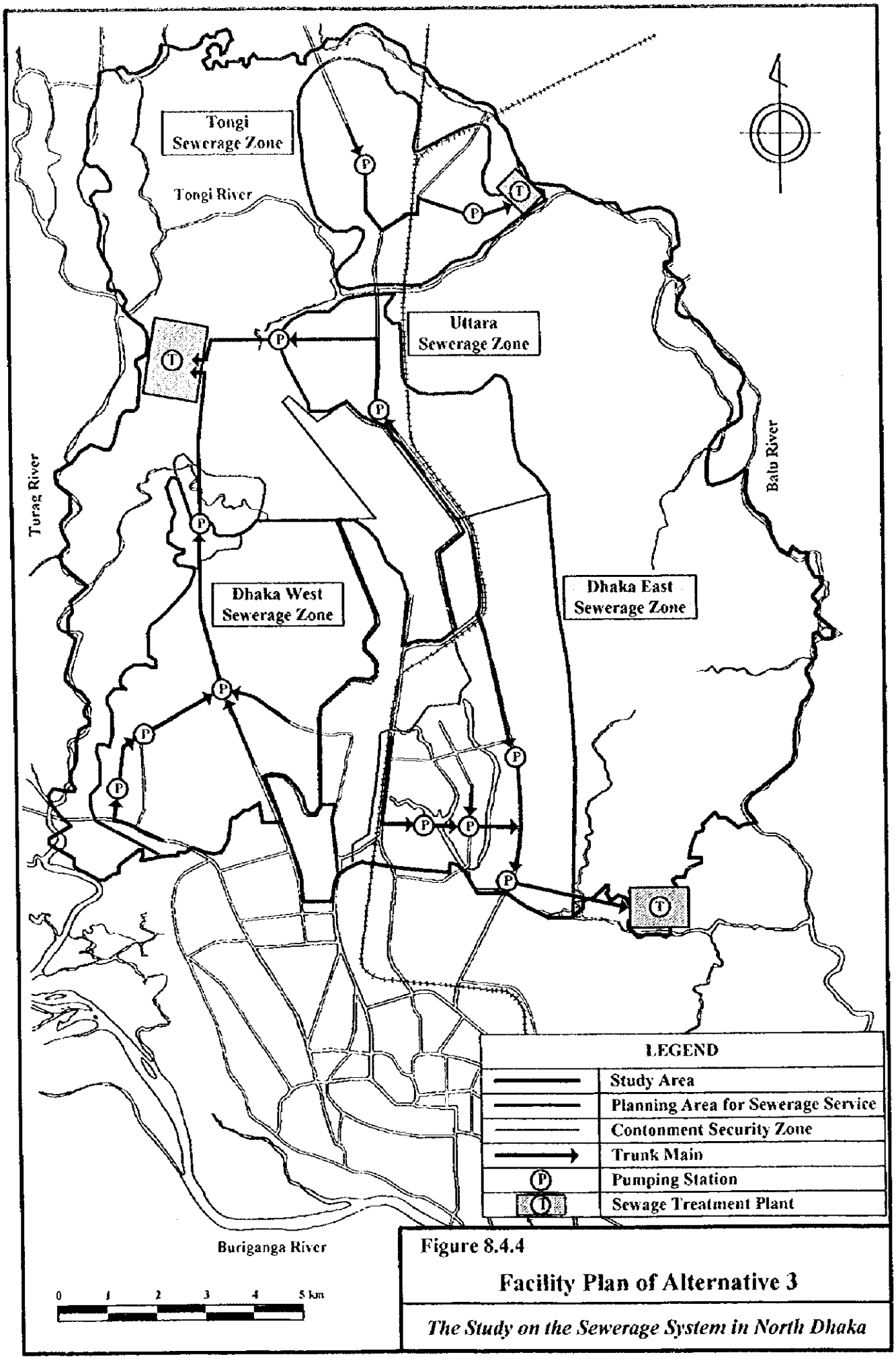


Figure 8.4.4

Facility Plan of Alternative 3

The Study on the Sewerage System in North Dhaka

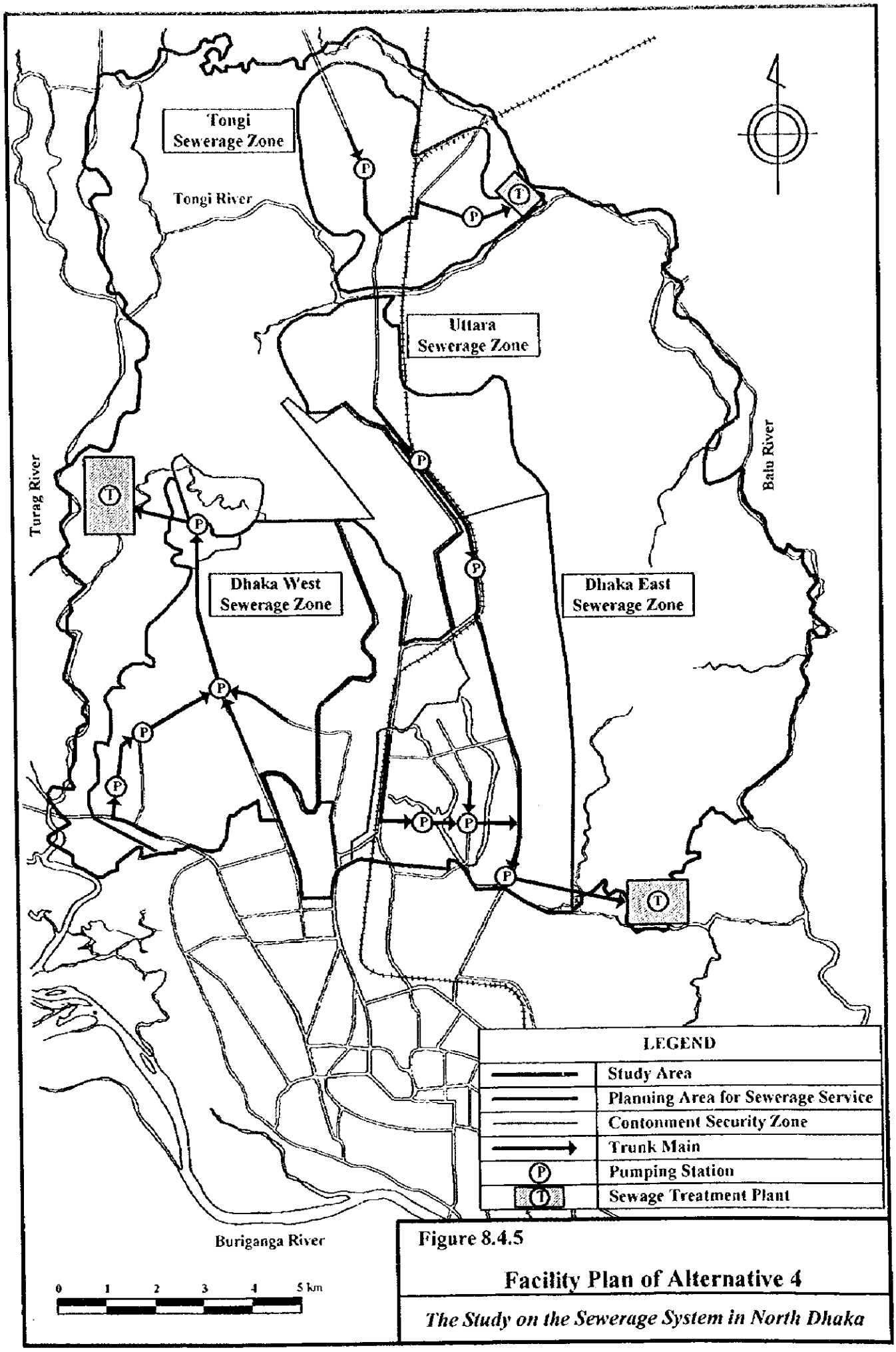


Figure 8.4.5

Facility Plan of Alternative 4

The Study on the Sewerage System in North Dhaka

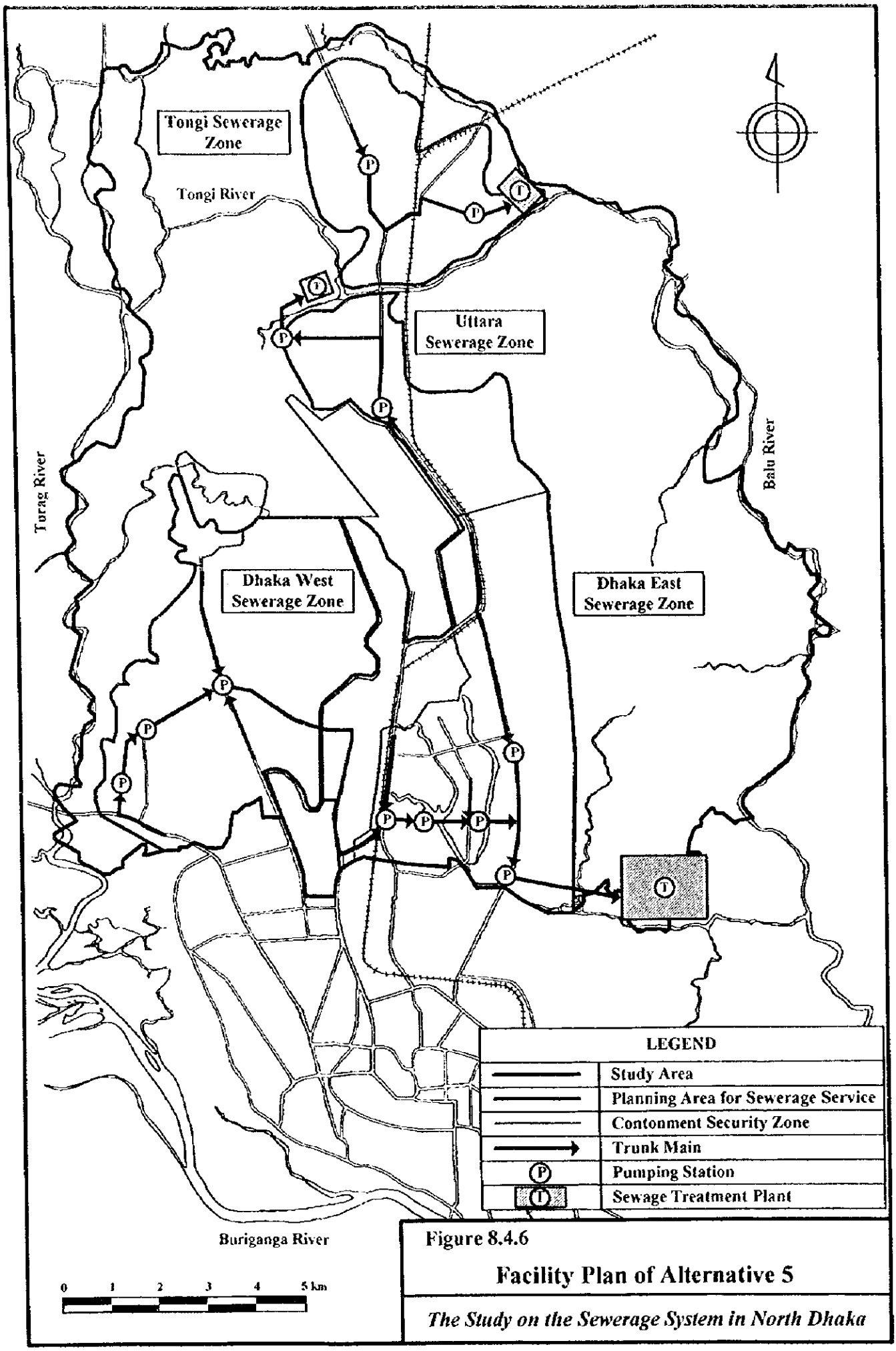


Figure 8.4.6

Facility Plan of Alternative 5

The Study on the Sewerage System in North Dhaka

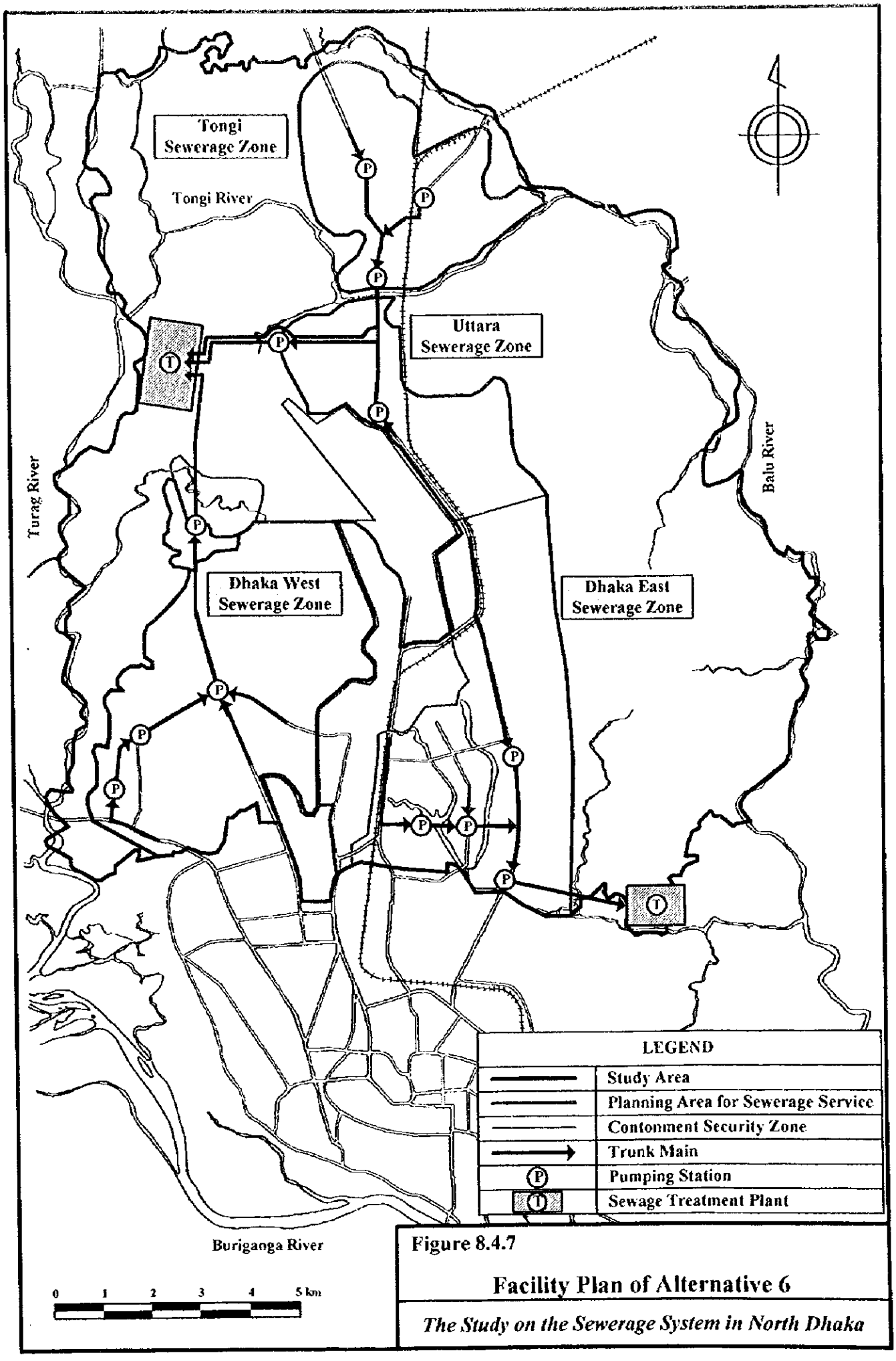


Figure 8.4.7

Facility Plan of Alternative 6

The Study on the Sewerage System in North Dhaka

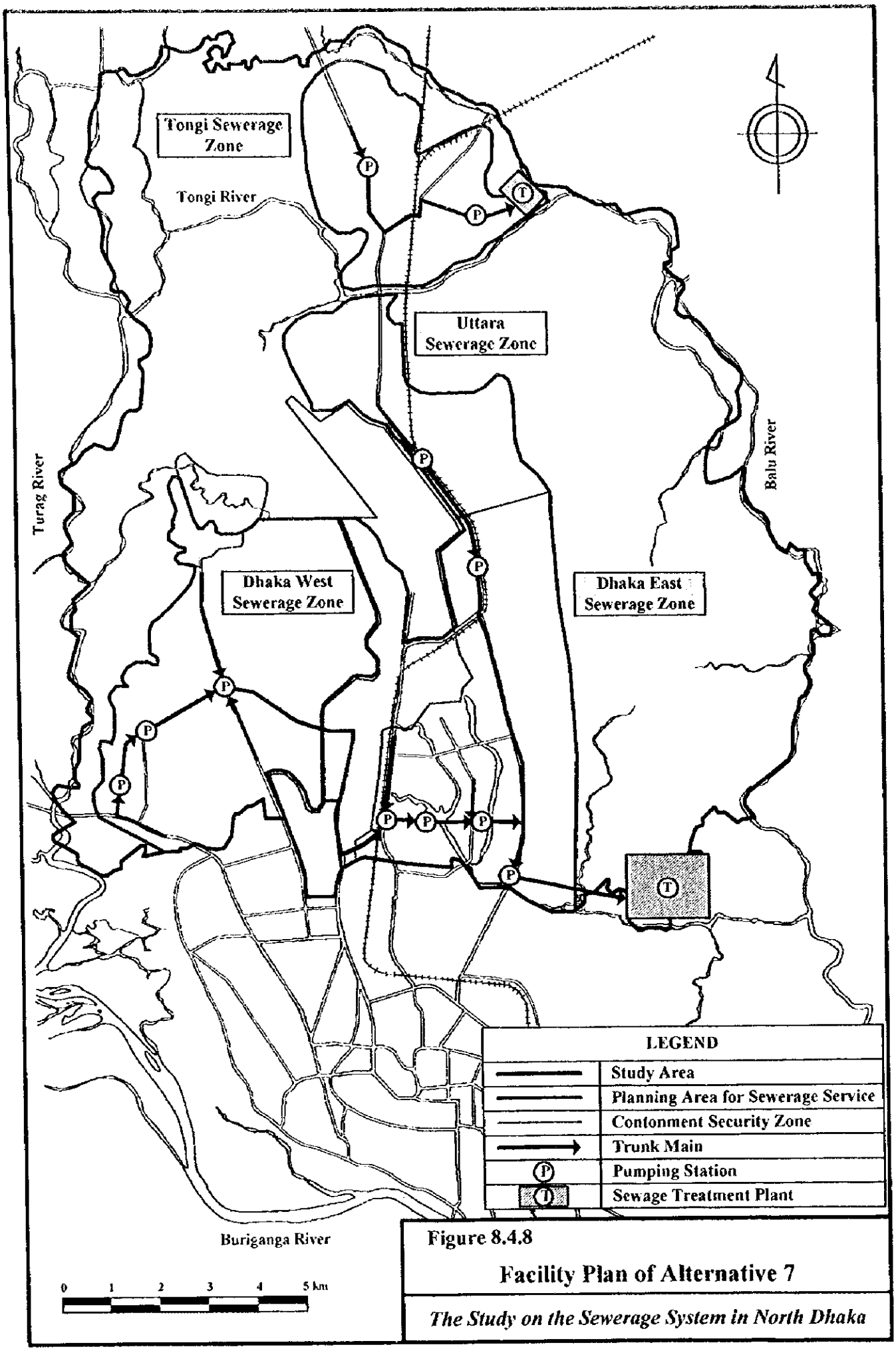


Figure 8.4.8

Facility Plan of Alternative 7

The Study on the Sewerage System in North Dhaka

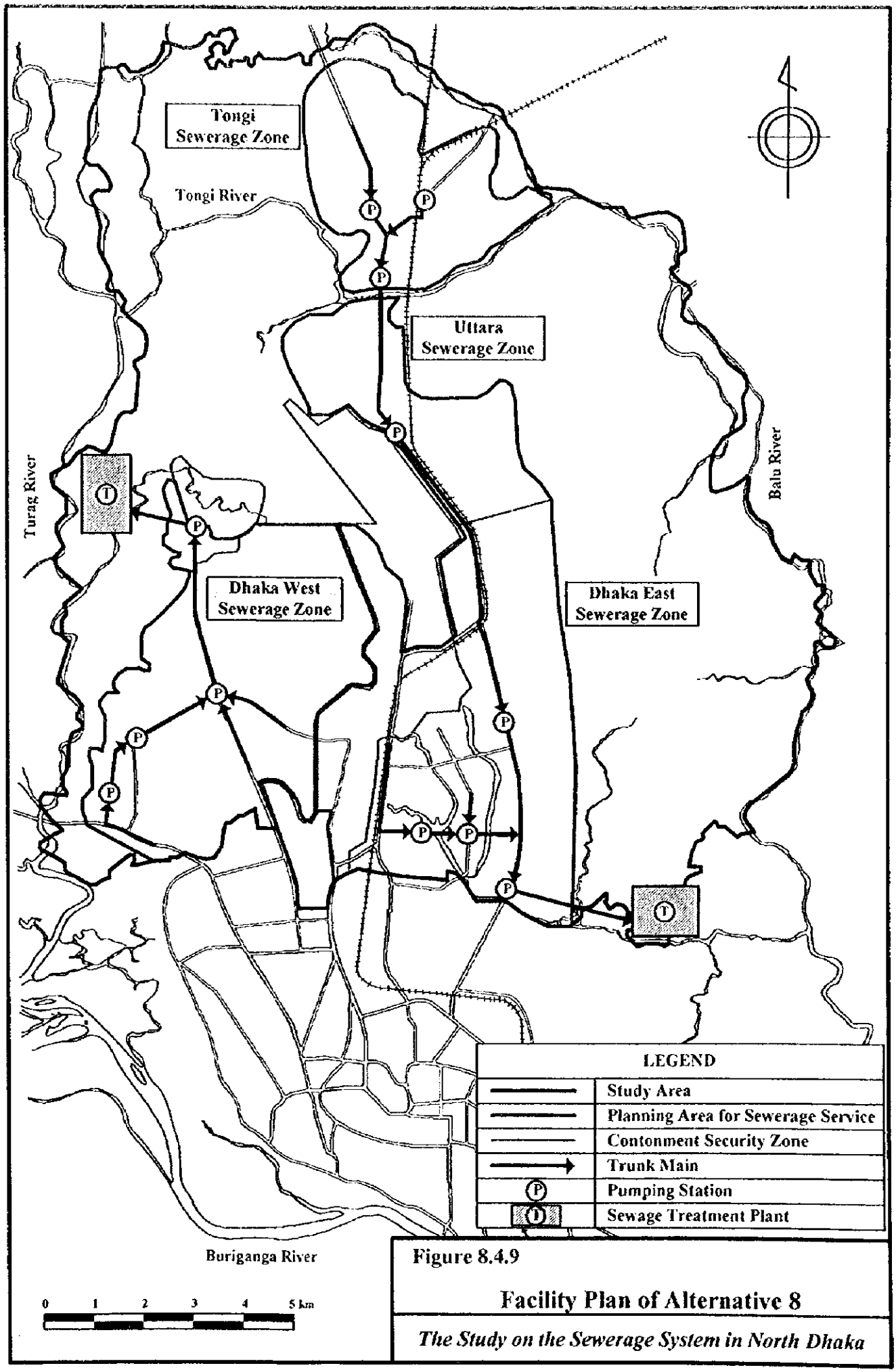


Figure 8.4.9

Facility Plan of Alternative 8

The Study on the Sewerage System in North Dhaka

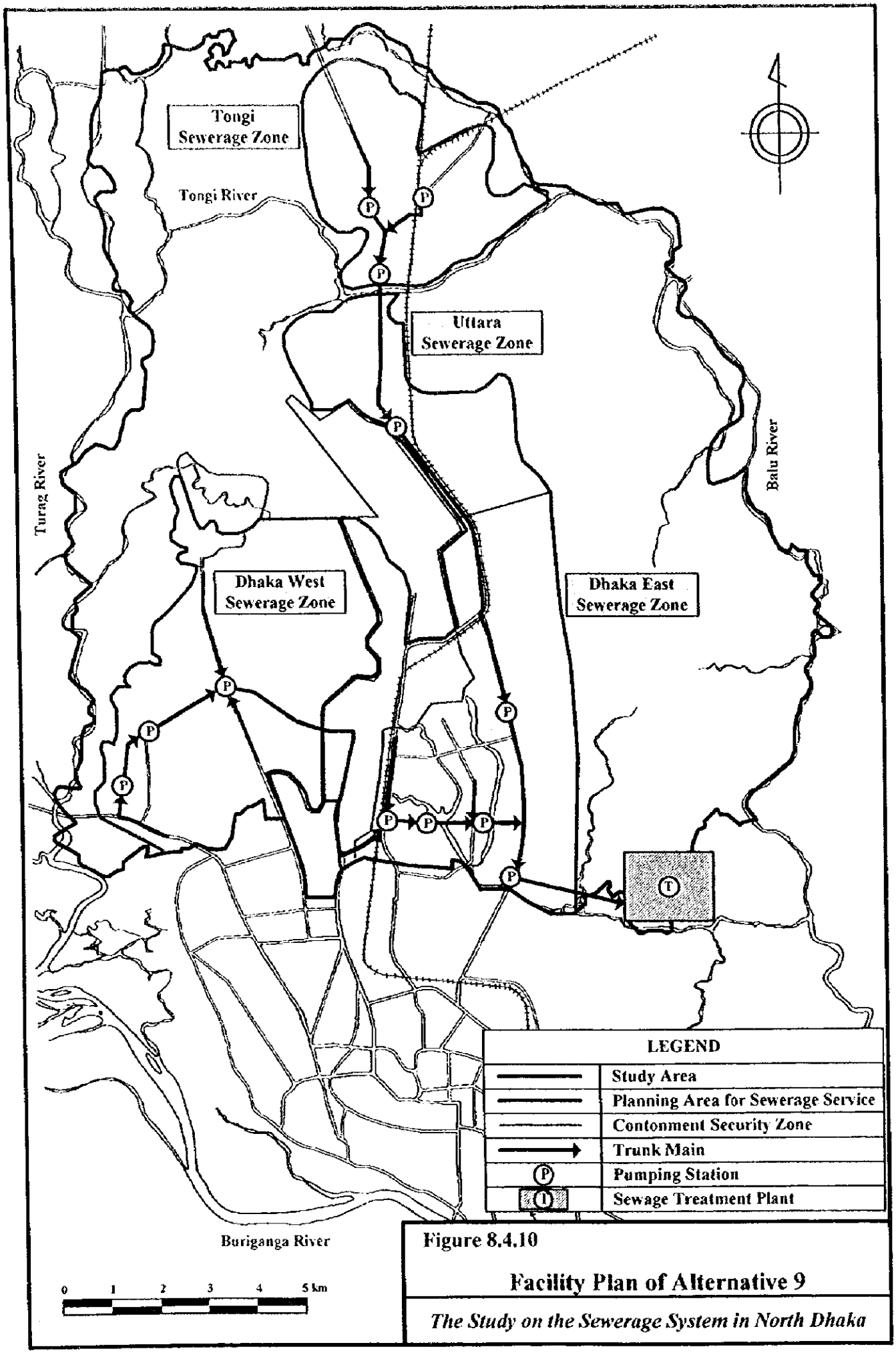


Figure 8.4.10

Facility Plan of Alternative 9

The Study on the Sewerage System in North Dhaka

8.4.2 Criteria to Select the Optimum Sewerage System

The criteria to select the optimum sewerage system from the alternatives of Sewerage Master Plan established in Chapter 8.4.1 are shown below:

(1) Cost efficiency

As the construction and O&M costs of a sewerage system are huge, cost efficiency is the most important factor. Thus, the cost efficiency of the proposed alternatives will be assessed in terms of construction cost plus power consumption (O&M) cost over 20 years.

(2) Ease of O&M

The fewer the number of sewerage service areas, i.e. the number of STPs, the easier O&M of the system will be. Further, the fewer the number of pumping stations and the shorter the total length of the trunk sewer is, the more favourable the conditions are for O&M.

(3) Project benefit

Large-scale capital investment for a sewerage system is inevitable due to the long-term construction period. However, excessive capital investment might hinder the generation of project benefits and hinder project implementation. Thus, efficient sewerage planning to allow for early benefit generation will be needed and the aspects of early benefit generation and early sewerage development will be assessed.

(4) Land availability of STP construction site

The selection of a construction site for the proposed STP is very important in regards to smooth project implementation. In the Study Area, land cost rises towards the south and consequently the southern area of the Study Area would be disadvantageous for land acquisition.

8.4.3 Selection of the Optimum Sewerage System

The construction cost of the sewerage system proposed in the nine (9) alternatives, the O&M cost and their totals are shown in Table 8.4.3 to 8.4.5. Power consumption was estimated as an O&M cost (20 year period), corresponding to the life expectancy of the mechanical/electrical equipment. A detailed estimation of the construction/O&M costs is shown in Appendix 8.4.1. Please refer to Chapter 9.4 and Chapter 9.3 for basic conditions/costs.

(TAKA'000)

Table 8.4.3 Construction cost Estimate of Sewerage System

Service Area	Sewerage Facility	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Tongi	Branch Sewer	426,764	426,764	426,764	426,764	426,764	426,764	426,764	426,764	426,764
	Trunk Main	141,357	243,028	141,357	141,357	135,157	241,793	135,157	162,773	162,773
	Pumping Station	294,520	398,826	294,520	294,520	294,520	394,268	294,520	398,833	398,833
	(Site)	3,030	4,292	3,030	3,030	3,030	4,261	3,030	4,292	4,292
	Sewage Treatment Plant	646,157	0	646,157	646,157	646,157	0	646,157	0	0
	(Site)	733,740	0	733,740	733,740	733,740		733,740		
	Sub-total	2,245,568	1,072,910	2,245,568	2,245,568	2,239,368	1,067,086	2,239,368	992,662	992,662
Uttara	Branch Sewer	415,716	415,716	415,716	415,716	415,716	415,716	415,716	415,716	415,716
	Trunk Main	205,442	218,650	205,442	149,553	205,442	218,650	128,293	218,535	218,535
	Pumping Station	213,486	213,486	213,486	81,493	213,486	213,486	104,380	227,458	227,458
	(Site)	3,052	3,052	3,052	1,320	3,052	3,052	1,515	2,340	2,340
	Sewage Treatment Plant	397,112	894,761	0	0	397,112	0	0	0	0
	(Site)	386,750	897,260	0	0	386,750	0	0	0	0
	Sub-total	1,621,558	2,642,925	837,696	648,082	1,621,558	850,904	649,904	864,049	864,049
North Dhaka East	Branch Sewer	843,306	843,306	843,306	843,306	843,306	843,306	843,306	843,306	843,306
	Trunk Main	550,286	550,286	550,286	539,120	774,520	474,074	857,007	693,932	1,003,373
	Pumping Station	896,273	896,273	896,273	898,318	2,117,262	896,273	2,210,969	1,127,714	2,790,239
	(Site)	30,500	30,500	30,500	30,325	52,600	30,500	54,225	34,300	63,925
	Sewage Treatment Plant	1,463,501	1,463,501	1,463,501	1,663,590	3,260,690	1,463,501	3,419,331	2,022,932	3,712,950
	(Site)	1,259,060	1,259,060	1,259,060	1,440,780	2,855,600	1,259,060	2,998,380	1,752,300	3,270,960
	Sub-total	5,042,926	5,042,926	5,042,926	5,415,439	9,903,978	4,966,714	10,383,218	6,474,484	11,684,753
North Dhaka West	Branch Sewer	949,520	949,520	949,520	949,520	949,520	949,520	949,520	949,520	949,520
	Trunk Main	519,893	519,893	681,880	519,893	911,762	406,746	895,683	358,322	911,762
	Pumping Station	1,171,420	1,171,420	1,171,420	1,171,420	845,917	1,171,420	845,917	1,171,420	845,917
	(Site)	6,905	6,905	6,905	6,905	5,100	6,905	5,100	6,905	5,100
	Sewage Treatment Plant	2,340,602	2,340,602	2,515,489	2,340,602	0	2,836,073	0	2,340,602	0
	(Site)	2,391,110	2,391,110	2,573,870	2,391,110		2,908,930		2,391,110	
	Sub-total	7,379,450	7,379,450	7,899,084	7,379,450	2,712,299	8,279,594	2,696,220	7,217,879	2,712,299
Total	Branch Sewer	2,635,306	2,635,306	2,635,306	2,635,306	2,635,306	2,635,306	2,635,306	2,635,306	2,635,306
	Trunk Main	1,416,978	1,531,857	1,578,965	1,349,923	2,026,881	1,341,263	2,016,140	1,433,562	2,296,443
	Pumping Station	2,575,699	2,680,005	2,575,699	2,445,751	3,471,185	2,675,447	3,455,786	2,925,425	4,262,447
	(Site)	43,487	44,749	43,487	41,580	63,782	44,718	63,870	47,837	75,657
	Sewage Treatment Plant	4,847,372	4,698,864	4,625,147	4,650,349	4,303,959	4,299,574	4,065,488	4,363,534	3,712,950
	(Site)	4,770,660	4,547,430	4,566,670	4,565,630	3,976,090	4,167,990	3,732,120	4,143,410	3,270,960
	Total	16,289,502	16,138,211	16,025,274	15,688,539	16,477,203	15,164,298	15,968,710	15,549,074	16,253,763

Table 8.4.4 Operation and Maintenance Cost Estimate of Sewrage System

(TAKA'000)

Service Area	Sewerage Facility	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Tongi	Pumping Station	79,291	52,623	79,291	79,291	79,291	102,032	79,291	103,484	103,484
	Sewage Treatment Plant	5,079	0	5,079	5,079	5,079	0	5,079	0	0
	Sub-total	84,370	52,623	84,370	84,370	84,370	102,032	84,370	103,484	103,484
Uttara	Pumping Station	50,458	50,458	50,458	17,202	50,458	50,458	24,215	71,022	71,022
	Sewage Treatment Plant	3,633	6,353	0	0	4,838	0	0	0	0
	Sub-total	54,091	56,811	50,458	17,202	55,296	50,458	24,215	71,022	71,022
North Dhaka East	Pumping Station	233,490	233,490	233,490	292,898	909,553	287,433	955,430	402,584	1,246,057
	Sewage Treatment Plant	8,913	8,913	8,913	9,734	15,466	8,913	15,980	11,136	16,912
	Sub-total	242,403	242,403	242,403	302,632	925,019	296,346	971,410	413,720	1,262,969
North Dhaka West	Pumping Station	435,398	435,398	435,398	435,398	307,484	435,398	307,484	435,398	307,484
	Sewage Treatment Plant	12,312	12,312	12,938	12,312	0	14,051	0	12,312	0
	Sub-total	447,710	447,710	448,336	447,710	307,484	449,449	307,484	447,710	307,484
Total	Pumping Station	798,637	771,969	798,637	824,789	1,346,786	875,321	1,366,420	1,012,488	1,728,047
	Sewage Treatment Plant	29,937	27,578	26,930	27,125	25,383	22,964	21,059	23,448	16,912
	Total	828,574	799,547	825,567	851,914	1,372,169	898,285	1,387,479	1,035,936	1,744,959

Table 8.4.5 Total Cost Estimate of Sewerage System

(TAKA'000)

Service Area	Sewerage Facility	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Tongi	Construction Cost	2,245,568	1,072,910	2,245,568	2,245,568	2,239,368	1,067,086	2,239,368	992,662	992,662
	O & M cost	84,370	52,623	84,370	84,370	84,370	102,032	84,370	103,484	103,484
	Sub Total	2,329,938	1,125,533	2,329,938	2,329,938	2,323,738	1,169,118	2,323,738	1,096,146	1,096,146
Uttara	Construction Cost	1,621,558	2,642,925	837,696	648,082	1,621,558	850,904	649,904	864,049	864,049
	O & M cost	54,091	56,811	50,458	17,202	55,296	50,458	24,215	71,022	71,022
	Sub Total	1,675,649	2,699,736	888,154	665,284	1,676,854	901,362	674,119	935,071	935,071
North Dhaka East	Construction Cost	5,042,926	5,042,926	5,042,926	5,415,439	9,903,978	4,966,714	10,383,218	6,474,484	11,684,753
	O & M cost	242,403	242,403	242,403	302,632	925,019	296,346	971,410	413,720	1,262,969
	Sub Total	5,285,329	5,285,329	5,285,329	5,718,071	10,828,997	5,263,060	11,354,628	6,888,204	12,947,722
North Dhaka West	Construction Cost	7,379,450	7,379,450	7,899,084	7,379,450	2,712,299	8,279,594	2,696,220	7,217,879	2,712,299
	O & M cost	447,710	447,710	448,336	447,710	307,484	449,449	307,484	447,710	307,484
	Sub Total	7,827,160	7,827,160	8,347,420	7,827,160	3,019,783	8,729,043	3,003,704	7,665,589	3,019,783
Total	Construction Cost	16,289,502	16,138,211	16,025,274	15,688,539	16,477,203	15,164,298	15,968,710	15,549,074	16,253,763
	O & M cost	828,574	799,547	825,567	851,914	1,372,169	898,285	1,387,479	1,035,936	1,744,959
	Total	17,118,076	16,937,758	16,850,841	16,540,453	17,849,372	16,062,583	17,356,189	16,585,010	17,998,722

Figure 8.4.11 and 8.4.12 show the tendency of the construction cost and O&M cost per STP (sewerage service area).

In terms of the construction cost, the STP 2 plan is lowest, followed by the STP 3, STP 1 and STP 4 plans. Generally, if the number of STP decrease, the total construction cost tends to decrease, however, in this case, the STP 1 plan was in third place in terms of construction cost. This is because of the increase of the construction cost for pumping stations and trunk sewers due to the increase of their number and length.

The O&M cost will also be higher if the number of STP decreases. This is also because of the relationship between the number of pumping stations and STPs. If the number of STPs decreases, the number and scale of the pumping stations will be greater and consequently, the O&M cost will be more expensive.

Based on the selection criteria for the optimum sewerage plan, established in Chapter 8.4.2, the alternatives were ranked by cost efficiency (the most important factor). The results are shown in Table 8.4.6. Alternatives 3, 4, 6, and 8 are shown as the most attractive in terms of cost effectiveness.

Table 8.4.6 Selection of Optimum Sewerage System by Cost Efficiency

Items	Alter. 1	Alter. 2	Alter. 3	Alter. 4	Alter. 5	Alter. 6	Alter. 7	Alter. 8	Alter. 9
Ranking of Total Cost	6	5	4	2	8	1	7	3	9

Further, Alternatives 3, 4, 6 and 8, chosen by the first selection, were assessed by three (3) selection criteria, namely cost efficiency, ease of O&M and project benefits.

Another criterion, the land availability of the STP construction site was excluded from this evaluation, since there was no remarkable difference among these alternatives. The proposed sewage treatment plants in the East and West Service Areas of the optimum plan are situated in a swampy area that is designated as a flood retention pond under the DMDP. Although a considerable area will be occupied by these treatment facilities, the potential usage of these swamp areas is deemed not to be jeopardised since the occupancy ratio of treatment facilities is fairly small compared to the total area. As to ease of O&M, the number of STP, the numbers of pumping stations and the total length of the trunk sewers were evaluated as shown below.

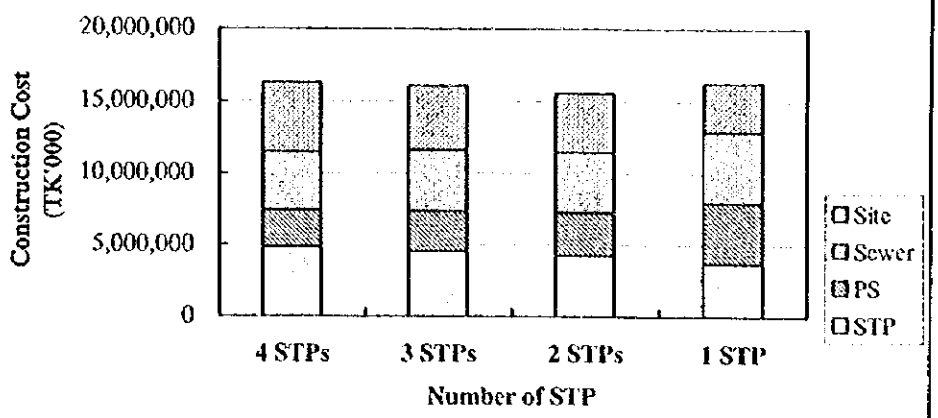


Figure 8.4.11 Comparison of Construction Cost by Number of STP

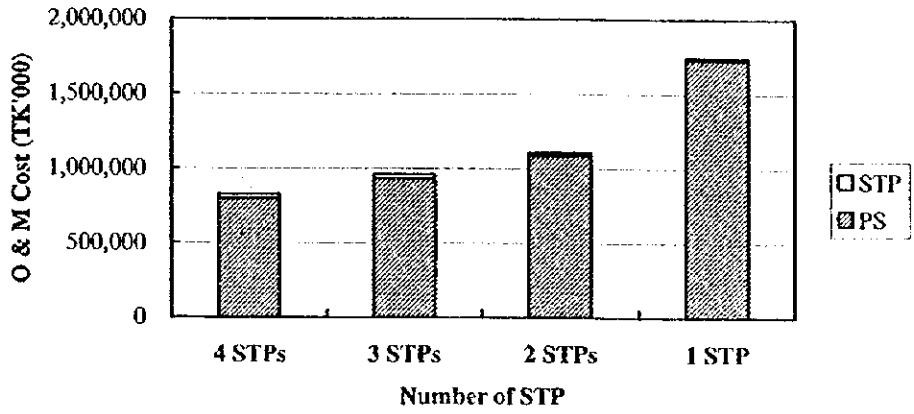


Figure 8.4.12 Comparison of O & M Cost by Number of STP

Items	Alternative 3	Alternative 4	Alternative 6	Alternative 8
No. of Sewage Treatment Plant	3	3	2	2
No. of Pumping Station	12	11	13	12
Length of Trunk Main	48.9 km	39.4 km	60.6 km	43.2 km
Evaluation	C	A	D	B

As to project benefits, early benefit generation was assessed by construction cost and construction period and alternatives were ranked in A to D.

Sewerage Zone	Alternative 3	Alternative 4	Alternative 6	Alternative 8
Tongi	A	A	B	C
Uttara	A	B	A	C
Dhaka North East	A	B	A	C
Dhaka North West	B	A	B	A
Evaluation	A	B	B	C

An assessment was carried out as follows:

- In Tongi, Alternatives 3 and 4 are independent service area plans, while Alternatives 6 and 8 are integrated plans with other sewerage service areas. In consideration of the concept of early benefit generation (early sewerage development) in this area, the independent plan(s) with the smallest scale facilities would be the optimum, followed by Alternative 6, which is an integrated plan with Uttara and North Dhaka West, and Alternative 8, in which Tongi would be served only after the completion of North Dhaka East and Uttara.
- In Uttara, Alternatives 3 and 6 would be the optimum plans since they would not be affected by the project implementation in other areas. When comparing Alternatives 4 and 8, which would be influenced by the project implementation of North Dhaka East, Alternative 8 would be inferior as the diameter of its trunk sewer would be larger due the intrusion of sewage from Tongi.
- In North Dhaka East, Alternatives 3 and 6 are independent service area plans, while Alternatives 4 and 8 are integrated plans. Alternatives 3 and 6, with the smallest facility scales, would be the optimum, followed by Alternative 4 (which is integrated with Uttara only). Last is Alternative 8, with the largest trunk sewer diameter.

- As to North Dhaka West, Alternatives 4 and 8 are independent service area plans, while Alternative 6 is an integrated plan. The independent plans, Alternatives 4 and 8, would be the optimum, followed by Alternatives 3 and 6, the integrated plans.

Each alternative was ranked A to D by three (3) criteria: cost efficiency, ease of O&M and project benefit; the total point was then reckoned by the given point per ranking, A=4 point, B=3 point, C=2 point and D=1 point. The optimum sewerage system was selected by the highest point total and, as shown in Table 8.4.7, Alternative 4 was assessed as the optimum plan.

Table 8.4.7 Selection of Optimum Sewerage System

Items	Alternative 3		Alternative 4		Alternative 6		Alternative 8	
	Rank	Point	Rank	Point	Rank	Point	Rank	Point
Cost Efficiency	D	1	B	3	A	4	C	2
Easiness of O&M	C	2	A	4	D	1	B	3
Project Effect	A	4	B	3	B	3	C	2
Overall Evaluation	3rd	7	1st	10	2nd	8	3rd	7

8.5 Basic Design of Sewerage System

According to Alternative 4, the design criteria for the sewerage master plan will be organised. Name of sewerage service area and served sewerage zones are as follows:

Sewerage Service Area	Sewerage Zone
Tongi	Tongi
North Dhaka East	Uttara, North Dhaka East
North Dhaka West	North Dhaka West

Area, served population and design sewage flow in the year 2020 are shown in Table 8.5.1, while that in intermediate years are contained in Appendix 8.5.1.

Table 8.5.1 Design Sewage Flow by Sewerage Service Area (Year 2020)

Sewerage Service Area	Sewerage Zone	Item	Unit	Core Area	Transitional Area	Total	Cantonment Security	Total
Tongi	Tongi	Area	ha	151	892	1,043	0	1,043
		Population	person	39,000	265,000	304,000	0	304,000
		Q1	cu.m/day	3,900	26,500	30,400	0	30,400
		Q2	cu.m/day	4,875	33,125	38,000	0	38,000
		Q3	cu.m/day	6,240	42,400	48,640	0	48,640
North Dhaka East	Uttara	Area	ha	504	512	1,016	0	1,016
		Population	person	86,000	75,000	161,000	0	161,000
		Q1	cu.m/day	8,600	7,500	16,100	0	16,100
		Q2	cu.m/day	10,750	9,375	20,125	0	20,125
		Q3	cu.m/day	13,760	12,000	25,760	0	25,760
	North Dhaka East	Area	ha	868	1,371	2,239	1,090	3,329
		Population	person	487,000	314,000	801,000	83,000	884,000
		Q1	cu.m/day	48,700	31,400	80,100	8,300	88,400
		Q2	cu.m/day	60,875	39,250	100,125	10,375	110,500
		Q3	cu.m/day	77,920	50,240	128,160	13,280	141,440
	Total	Area	ha	1,372	1,883	3,255	1,090	4,345
		Population	person	573,000	389,000	962,000	83,000	1,045,000
		Q1	cu.m/day	57,300	38,900	96,200	8,300	104,500
		Q2	cu.m/day	71,625	48,625	120,250	10,375	130,625
		Q3	cu.m/day	91,680	62,240	153,920	13,280	167,200
North Dhaka West	North Dhaka West	Area	ha	789	1,677	2,466	130	2,596
		Population	person	438,000	1,184,000	1,622,000	10,000	1,632,000
		Q1	cu.m/day	43,800	118,400	162,200	1,000	163,200
		Q2	cu.m/day	54,750	148,000	202,750	1,250	204,000
		Q3	cu.m/day	70,080	189,440	259,520	1,600	261,120
Total		Area	ha	2,312	4,452	6,764	1,220	7,984
		Population	person	1,050,000	1,838,000	2,888,000	93,000	2,981,000
		Q1	cu.m/day	105,000	183,800	288,800	9,300	298,100
		Q2	cu.m/day	131,250	229,750	361,000	11,625	372,625
		Q3	cu.m/day	168,000	294,080	462,080	14,880	476,960

Note: 1) Q1: Design Average Daily Flow
2) Q2: Design Maximum Daily Flow
3) Q3: Design Maximum Hourly Daily Flow

8.5.1 Sewer System

Figure 8.5.1 shows the general layout of sewerage system. A detailed facility plan of the collection system, sewage flow calculation and sewer profile are shown in Appendices 8.5.2, 8.5.3 and 8.5.4, respectively.

In the sewerage facility design in the master plan, the target was for trunk sewers with diameters above 500 mm; in the sewerage system development plan, the adoption of an interceptor sewerage system will be examined with the goal of rapid sanitary environmental

improvement and construction cost reduction.

An interceptor sewerage system is similar to a combined sewer system. In both systems, the sewer receives sewage and storm water. In an interceptor system, domestic grey water and septic tank effluent, which presently flow into the existing storm drainage gutters and are then discharged to the channels or rivers nearby together with storm water, will be separated from storm water by storm overflow chambers and diverted to the sewer pipe connected to the sewage treatment plant. The criteria for the adoption of an interceptor system are as follows:

- Storm drainage system, namely gutters and channels, is already completed
- There is no dry weather flow intrusion, such as spring water (which does not require treatment).
- Effluent point of the drainage system is near to the trunk sewer.
- Service area is densely populated.
- The proposed service area shall be free from the influence of backwater from the receiving water bodies.

Upon the examination of the adoption of the said system, the most important of the above-mentioned criteria is the "area shall be free from the influence of back water". The back flow of storm water from storm overflow chambers should be avoided to prevent adverse influences, such as sewage overflow, upstream of the service area.

The river water level in Buriganga River is shown in Appendix 8.5.4. Since the data shows that the highest water level in rainy season is approximately 7.0 m, an interceptor system can be adopted to the areas with ground elevation above 7.0 m. These areas correspond to the Core Area in North Dhaka West Sewerage Service Area. The remaining criteria was satisfied in the Core Area and thus, the interceptor system is applicable in this area.

However, a small-bore sewerage system that mainly collects effluent from septic tanks has already completed in this area. The existing storm drainage channels collect domestic grey water and both sewage types are discharged into the surrounding swampy area. As shown in Chapter 5.4.2, the existing small-bore system has enough capacity to receive domestic grey water in addition the septic tank waste. Therefore, a grey water connection to the existing system would be effective and less expensive than the introduction of an interceptor system. Accordingly, an interceptor sewerage system will not be adopted in the sewerage service area.

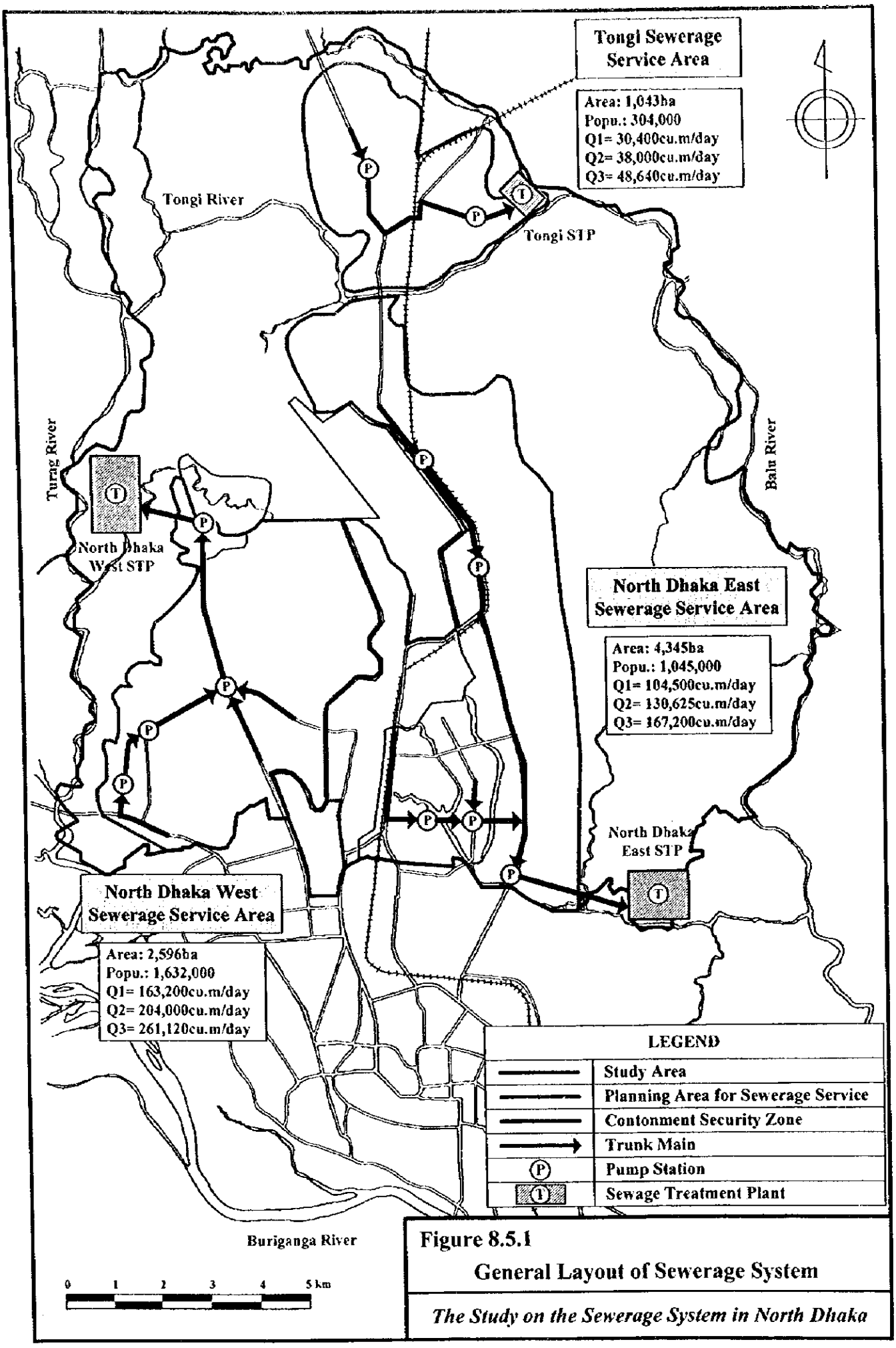


Figure 8.5.1

General Layout of Sewerage System

The Study on the Sewerage System in North Dhaka

8.5.2 Sewage Treatment Plant

(1) General

In Dhaka City, there is only one sewage treatment plant. In this respect, it is indispensable for designing sewerage system to take into account the technical level of personnel to be charged with the operation and maintenance of the sewerage system as well as the capability of operating organisation.

In some countries, it is often observed that effluent from the treatment plant is same as raw sewage, owing to several reasons, such as a lack of knowledge and experience on the part of the relevant personnel, lack of spare parts, budgetary constraints, etc.

The design of a sewage treatment plant is therefore intended to attain sustainability not only from the viewpoints of both technical design and manpower capability, but also from the view point of lower operation and maintenance costs.

(2) Preliminary Selection of Sewage Treatment Method

There are many well-developed and popular sewage treatment methods, such as:

- *Conventional Activated Sludge*
- *Extended Aeration*
- *High Rate Trickling Filter*
- *Rotating Biological Contactor*
- *Oxidation Ditch*
- *Aerated Lagoon*
- *Stabilisation Pond*

A comparison of sewage treatment methods is shown in Table 8.5.2.

Table 8.5.2 Outline of Sewage Treatment Methods

Treatment Method	Composition of Treatment Process	Theory of Reactor for Tank	Features of Treatment Process
Conventional Activated Sludge	P.S.T. → R.T. → F.S.T. → Sludge Treatment facility	Sewage flows down toghther with activated sludge and contained organic substance is absorbed and assimilated by activated sludge.	Retention time in reaction tank is relatively short and load is high. Thus, primary sedimentation tank is needed to cope with the fluctuation in sewage flow and quality and to equalize/mitigate the load. Sludge treatment facility is necessary as well.
Extended Aeration	R.T. → F.S.T. → Sludge Treatment facility	ditto	This process is flexible to the fluctuation of sewage flow and quality by its long retention time in reactor tank. Primary sedimentation tank is not necessary, however, sludge treatment facility is needed.
Oxidation Ditch	R.T. → F.S.T. → Sludge Treatment facility	Sewage is circulated together with activated sludge and contained organic substance is absorbed and assimilated by activated sludge.	ditto
Stabilization Pond	R.T.(1) → R.T.(2) → R.T.(3)	Sewage is purified by oxidation of aerobic bacteria activated by oxigen supply through algae or anaerobic bacteria.	Since oxygen supply in reactor tank is conducted by natural oxidation and photosynthesis of algae. Retention time is extremely long. Sludge treatment facility is not needed. Anaerobic pond, maturation pond and aerobic pond are allocated individually or combined.
Aerated Lagoon	R.T. → F.S.T.	Sewage is purified by oxidation of aerobic bacteria.	Since supply in reactor tank will be done by compulsive oxidation, retention time is shorter than that of flowing stabilization pond. Sludge treatment facility will not be needed.
High Rate Trickling Filter	P.S.T. → R.T. → F.S.T. → Sludge Treatment facility	Section: Sewage is sprinkled on bio-filter by rotating distributor. Contained organic substance is absorbed/assimilated by bacteria attaching on bio-filter. Enlarged bacteria membrane falls out and are removed.	Primary sedimentation tank must be installed to prevent clogging in bio filter and distributor's nozzle. Sludge treatment facility is needed as well.
Rotating Biological Contactor	P.S.T. → R.T. → F.S.T. → Sludge Treatment facility	Section: Sewage flows through rotating bio disk and contained organic substance is absorbed/assimilated by bacteria attaching on bio disk.	Primary sedimentation tank is needed to mitigate the load in reactor tank. Sludge treatment facility is needed as well.

Legend P.S.T. : Primary Sedimentation Tank, R.T. : Reactor Tank, F.S.T. : Final Sedimentation Tank

Table 8.5.2 Outline of Sewage Treatment Methods (cont'd)

Treatment Method	General Features	Operation and Maintenance
Conventional Activated Sludge	* BOD moval rate is superior, 85-95%. * Transparency of treated effluent is high. * Stability in sewage temperature flucutation is inferior in comparison with other methods. * Generated sludge volume is larger than other method.	* The system has many maintenance and inspection points. Thus, advanced/complicated operational technique is needed.
Extended Aeration	* BOD removal rate is worth than conventional method. * Transparency of treated effluent is high. * Stability in sewage temperature fluctuation is good. * Nitrification is expected. * Generated sludge volume is less than conventional method.	* Operational technique is easier than Conventional Activated Sludge Method but difficult compared with Oxidation Ditch.
Oxidation Ditch	* Same as Extended Aeration Method. * Denitrification is possible by operational condition.	* Operation and Maintenance is easy since no advanced/complicated operational technique is needed.
Stabilization pond	* Although BOD removal rate is affected by sewage temperature and retention time, approximately 70-90% can be expected. * Stability in sewage flow and temperature fluctuation is relatively good but once deteriorated, recovery takes a long time. * Odours and harmful insects are generated:	* Easiest in O&M due to "Non-equipped" process. * Algae control is important for stable treatment efficency. * Ponds should be drained periodically, once in 1 to 5 years. Sludge should be hauled/disposed after drying by sun light.
Aerated Lagoon	* BOD removal rate is affected by sewage temperature and retention time as well as stabilization pond, the rate will be 75-90% approximately. * Stability in load fluctuation is superior. * Less odour generation.	* O&M is easy since there's simple equipment like aerators.
Trickling Filter	* BOD removal rate is 65-75%. * Transparency of treated effluent is worth than Activated Sludge Method. * Less affected by sewage temperature fluctuation compared with Activated Sludge Method. * Flies and Odours are generated.	* O&M is easy since no advanced/complicated operational technique is needed. * Attention shall be paid to fly/odour generation.
Rotating Biological Contactor	* BOD removal rate is same as Conventional Activated Sludge Method. * Transparency of treated effluent is inferior. * Nitrification is expected.	* The system has little maintenance and inspection points and no advanced operational technic is needed. But, O&M is difficult compares with Oxidation Ditch and Trickling Filter.

The following criteria are applied in this Study to select the most appropriate treatment method:

- Ease of O&M (operation and maintenance)
- Low construction/O&M cost
- Less power consumption
- Applicability for target treated effluent quality
- Available land for the STP
- Environmental impact

Table 8.5.3 exhibits the general comparison of the above mentioned treatment methods.

Table 8.5.3 Comparison of Sewage Treatment Methods

Treatment Method	Operation	Maintenance	Cost	Power
Conventional Activated	difficult	difficult	high	large
Extended Aeration	difficult	difficult	high	large
Trickling Filter	fair	fair	high	fair
Rotating Biological Contactor	fair	difficult	fair	fair
Oxidation Ditch	fair	fair	fair	fair
Aerated Lagoon	easy	fair	low	less
Stabilisation Pond	easy	easy	low	none

As highlighted in the above table, the oxidation ditch, aerated lagoon and stabilisation pond methods could be selected as applicable and subject to further study.

(3) Comparative Study of Sewage Treatment Method

1) Treatment methods to be studied

The following three treatment methods are further evaluated to select the most optimum method:

- *Oxidation Ditch*
- *Aerated Lagoon*
- *Stabilisation Pond*

2) Treatment process

Sewage treatment of the said three methods consists of three processes. At first, sand/grit in sewage is settled in the grit chamber and floating substances are caught by screens.

Secondly, sewage is divided and daily average flow or flow at dry season is led to biological treatment process, such as oxidation ditch, aerated lagoon or stabilisation pond, and in this process, organic substance is removed by the activities of aerobic and anaerobic bacteria and algae. In some processes, it is required to settle these bacteria or sludge in sedimentation tanks.

Then, the excess quantity, which is considered as storm water, flows into a storm water settling tank to remove further suspended materials by sedimentation.

Thirdly, disinfection by chlorination or sun light will be done to reduce bacteria, such as coliform.

The flow diagrams of these three methods are shown in Figure 8.5.2.

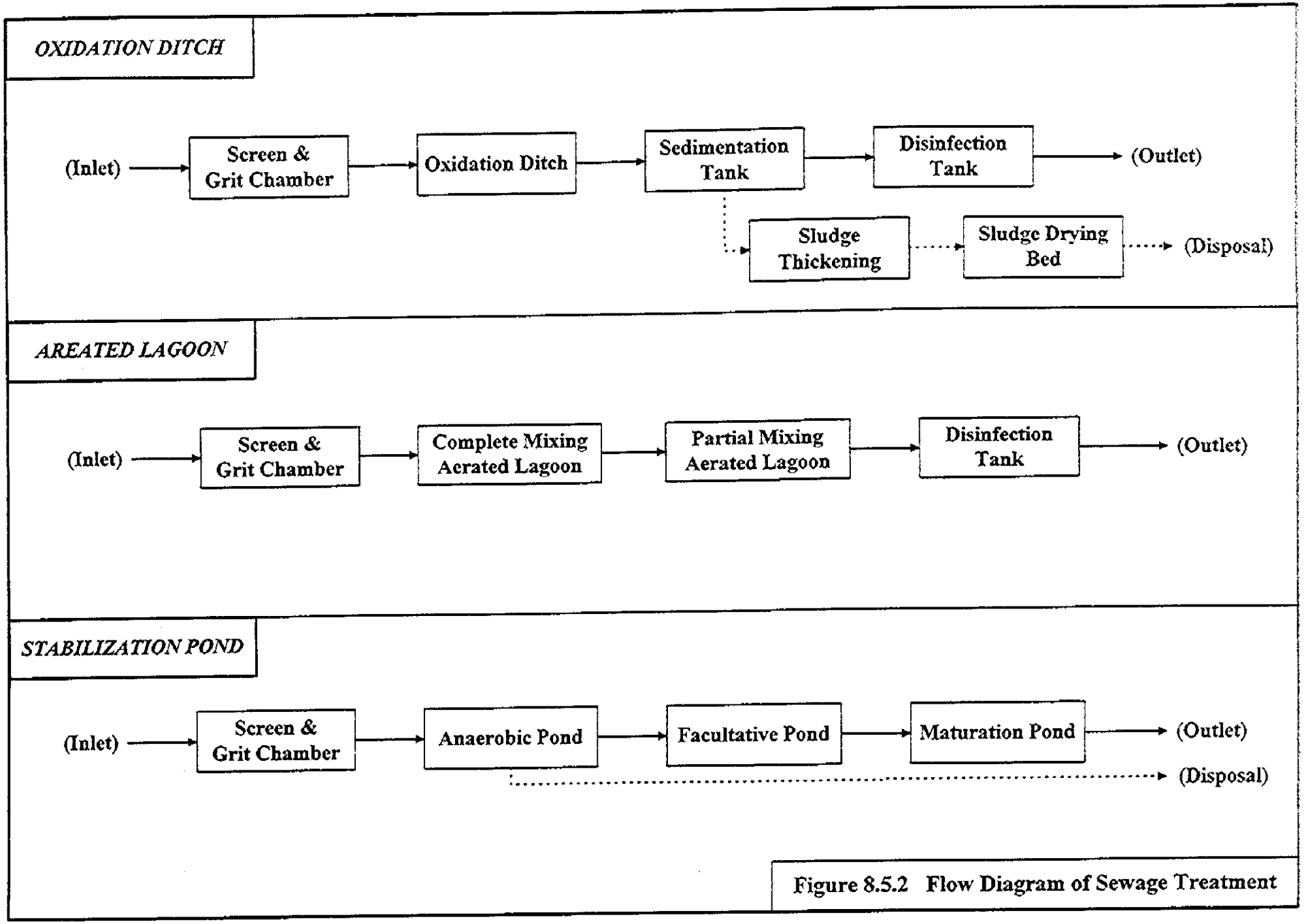


Figure 8.5.2 Flow Diagram of Sewage Treatment

3) Design calculation

The design calculations were carried out and their results are summarised in Table 8.5.4.

a. Power consumption

Among the three methods, only the stabilisation pond does not require any electric power for treatment, while the aerated lagoon method needs power for the aerators in the lagoon and chlorination in the disinfection tank, and oxidation ditch method requires power for aerators in the ditch, sludge collectors, sludge pumps and chlorinators.

The estimation of power consumption (excluding power for offices and in-plant lighting) is as follows:

-	Oxidation Ditch	approx.	3,369 kW
-	Aerated Lagoon	approx.	2,244 kW
-	Stabilisation Pond	approx.	0 kW

The stabilisation pond method does not require any power owing to absence of mechanical equipment. The oxidation ditch consumes 46% more power than the aerated lagoon.

b. Area requirement

Since the stabilisation pond method uses the natural activity of bacteria, the treatment efficiency is relatively low and a large area is required. On the other hand, the aerated lagoon and oxidation ditch methods require less area because aerators are used to accelerate the activity of the aerobic bacteria.

The area requirement of the three methods are:

-	Oxidation Ditch	approx.	22 ha
-	Aerated Lagoon	approx.	43 ha
-	Stabilisation Pond	approx.	214 ha

c. Construction cost and O&M cost

The rough construction and O&M costs of the three methods is estimated as shown below:

Table 8.5.4 Design Calculationof Tretment Facilities

Items	Oxidation Ditch	Aerated Lagoon	Stabilization Pond
Outline and Dimension of Facilities	Grit Chamber W 2.5×L 15.0×D 1.0×4Units A=0.015ha Rector Tank W 6.0×L 500.0×D 3.0×24Units A=7.2ha Final Sedimentation Tank Dia 37.0×D 3.5×16Units A=2.5ha Disinfection Tank W 15.0×L 45.0×D 2.0×2Units A=0.135ha Sludge Thickening Tank W 6.0×L 10.0×D 3.0×8Units A=0.048ha Sludge Drying Bed W 22.0×L 50.0×8Units A=0.88ha Required Area for Facilities A1=10.778ha Reqired Site Area A2=22ha	Grit Chamber W 2.5×L 15.0×D 1.0×4Units A=0.015ha Complete Mixing Tank W 80.0×L 140.0×D 3.5×8Units A=8.96ha Pertial Mixing Tank W 100.0×L 150.0×D 4.0×4Units×2Train A=12.0ha Disinfection Tank W 15.0×L 45.0×D 2.0×2Units Required Area for Facilities A=21.11ha Reqired Site Area A2=43ha	Grit Chamber W 2.5×L 15.0×D 1.0×4Units A=0.015ha Anaerobic Pond W 100.0×L 170.0×D 3.0×8Units A=13.6ha Facutatative Pond W 210.0×L 450.0×D 1.5×8Units A=75.6ha Maturation Pond W 100.0×L 220.0×D 1.5×8Units A=17.6ha Required Area for Facilities A=106.815ha Reqired Site Area A2=214ha
Required Power	3,269kw	2,244kw	0kw
Land Acquisition (700TK/m2)	TK154,000,000	TK301,000,000	TK1,498,000,000
Construction Cost	TK2,190,404,000	TK812,540,000	TK300,438,000
Total	TK2,344,404,000	TK1,113,540,000	TK1,798,438,000
Electricity (1 Year)	TK85,909,000	TK58,972,000	TK0

Unit: TK'000

Item	Oxidation Ditch	Aerated Lagoon	Stabilisation Pond
Construction Cost	2,190,404	812,540	300,438
Land Acquisition Cost	154,000	301,000	1,498,000
Sub-total	2,344,404	1,113,540	1,798,438
O&M Cost	1,718,180	1,179,440	0
Total	4,062,584 (US$ 92,897,000)	2,292,980 (US$ 52,432,000)	1,798,438 (US$ 41,124,000)

In this cost estimate, land acquisition cost is assumed at 700 Taka (16.00 US dollars) per square meter. The electricity required for the operation of the facilities was estimated as part of the O&M cost over a period of 20 years.

In a cost comparison of the construction cost, including the site acquisition cost, the aerated lagoon is the cheapest, while in terms of the total cost, including O&M cost, the stabilisation pond is the most economical.

d. Reliability of treatment

The oxidation ditch method is flexible in regards to the fluctuation of sewage flow and quality by virtue of its long reactor tank retention time (approximately 24 hours). The aerated lagoon method, meanwhile, is much more flexible due to its longer retention time in its complete and partial mixing lagoons (approximately 3.5 days). The stabilisation pond method is even more flexible due to its longer retention time in its anaerobic, facultative and maturation ponds (approximately 14 days).

The aerated lagoon method uses aerators, which entail less mechanical/electrical equipment than the oxidation ditch method, which has aerators, sludge collectors, sludge pumps. In situations where there are equipment problems, the sewage treatment in the oxidation ditch method will be affected more seriously than the aerated lagoon method.

e. Difficulty of operation and maintenance

The oxidation ditch method is inferior to the stabilisation pond method and aerated lagoon method in terms of operation and maintenance due to the following

reasons:

- The oxidation ditch method requires more mechanical/electrical equipment, which also necessitates more maintenance for proper operation.
- The oxidation ditch method requires sludge treatment in its daily operation, which consists of sludge removal, thickening and drying and requires additional manpower for the sewage treatment.

f. Conclusion

The stabilisation pond method is recommended for this particular project in view of its superiority in power consumption, construction and O&M costs, as well as its ease of O&M.

(4) Design of sewage treatment plant

1) Sewage treatment plant

The stabilisation pond method will be adopted for the proposed STP. However, this treatment method requires a large site area and this contributes to significant land acquisition costs and/or difficulty in land acquisition. Thus, an efficient design will be needed to minimise the required area for the smooth project implementation. This method was adopted, in a modified form, at the existing STP (Pagla). At the Pagla STP, they utilise a primary sedimentation tank as an anaerobic pond; they also operate a chlorination tank instead of a maturation pond. In this modification, the adoption of chlorination will not cause any inconvenience regarding sewage treatment; however the anaerobic decomposition effect belonging to an anaerobic pond can not be expected in a primary sedimentation tank. Nevertheless, in terms of BOD and SS removal rate, which are 44.7% and 56.2%, respectively, there will be no problem with the treatment system.

By adopting this modification, the site area can be considerably reduced compared with the standard stabilisation pond method. Further, in terms of O&M, there will be no difficulty since this modified method is used at Pagla. Thus, this modified method will be adopted for the proposed STP in this study.

2) Sludge treatment plant

When planning the sludge treatment method, both final disposal and reuse method should be considered. For instance, in the case of land reclamation, the disposed sludge volume shall be minimised to extend the life of the disposal site. In case of

reuse, the conditions required will be different according to the usage purpose. The applicable sludge treatment methods for reuse purposes are shown below:

Agricultural reuse:	Thickening⇒Dewatering⇒Drying
Construction material:	Thickening ⇒ (Digestion) ⇒ Dewatering ⇒ Incineration ⇒Materialise
Energy reuse:	Thickening⇒(Digestion, Dewatering)⇒Fuel
Land Reclamation:	Thickening⇒Digestion⇒Dewatering⇒Incineration

In this plan, sludge lagoon + drying (agricultural reuse) method will be adopted for the following reasons:

- High and stable temperature
- Surrounded by agriculture area
- Financial capacity of the project implementation agent is small

3) Facility design

Appendix 8.5.6 shows the capacity calculation of North Dhaka East, North Dhaka West and Tongi sewage treatment plants. The outline of major facilities for each STP is described in Table 8.5.5, 8.5.6 and 8.5.7 respectively. The layout plan of each STP is shown in Figure 8.5.3, 8.5.4 and 8.5.5.

Table 8.5.5 Outline of Tongi Sewage Treatment Plant1. General

1. General

Name:	Tongi Sewage Treatment Plant
Location:	Tongi Paurashava
Site Area:	50.0 ha
Land Use:	Swamp Area
Service Population	304,000 persons
Sewerage System:	Separate system
Treatment Method:	Sewage Treatment = Grit Chamber + Primary Sedimentation Tank + Facultative Pond+ Disinfection Chamber
	Sludge Treatment = Sludge Lagoon
Receiving Water Body:	Tongi River

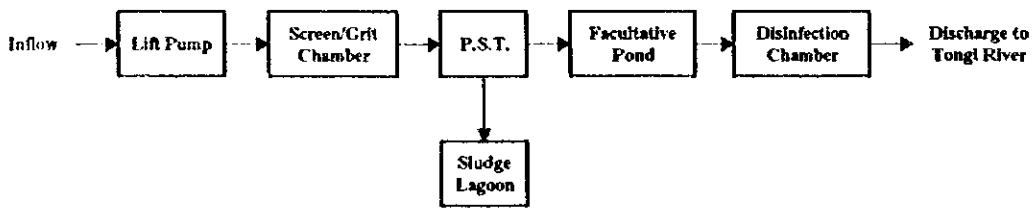
Design Sewage Flow Rate Unit: m^3/day

Item	Sewage Flow
Daily Average	30,400
Daily Maximum	38,000
Hourly Maximum	48,640

Design Sewage Effluent Quality

Water Quality Index	Influent (mg/l)	Effluent (mg/l)	Total Removal Ratio (%)
BOD	200	40	80
SS	200	100	50

2. Treatment Flow



3. Outline of Major Facilities

Facility	Dimension	No. of Facility	Capacity
Grit Chamber	Horizontal Flow Type W 1.0 m x L 7.0 m x D 0.6 m	4	Surface Load: 1,737 m^3/m^2 x day
Primary Sedimentation Tank	Centrifloc Sludge Scraper Ø16 m x D 3.5 m	4	Detention Time: 1.8 hr. Overflow Rate: 47 m^3/m^2 x day
Facultative Pond	Embanked Rectangular Pond W 100 m x L 200 m x D 1.5 m	8	Retention Days: 5.9 BOD Area Load: 238 kg BOD/ha x day
Disinfection Chamber	Embanked Rectangular Pond W 5 m x L 16 m x D 2.0 m	2	Retention Time : 15 min
Sludge Lagoon	Embanked Rectangular Pond W 50 m x L 100 m x D 1.0 m	8	Retention Days : 106 days

Table 8.5.6 Outline of North Dhaka East Sewage Treatment Plant

1. General

Name: North Dhaka East Sewage Treatment Plant

Location: Dhaka City, Baidertek District

Site Area: 120.0 ha

Land Use: Swamp Area

Service Population 1,045,000 persons

Sewerage System: Separate system

Treatment Method: Sewage Treatment = Grit Chamber + Primary Sedimentation Tank + Facultative Pond+ Disinfection Chamber

Sludge Treatment = Sludge Lagoon

Receiving Water Body: Balu River

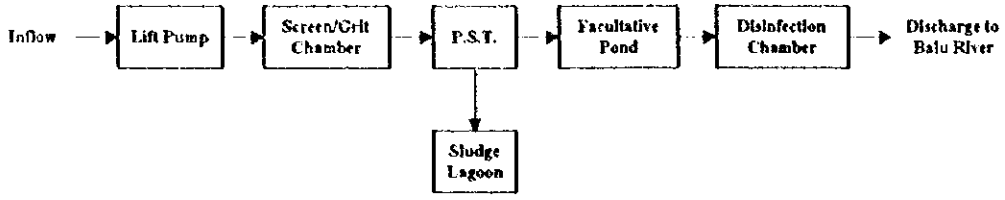
Design Sewage Flow Rate Unit: m^3/day

Item	Sewage Flow
Daily Average	104,500
Daily Maximum	130,625
Hourly Maximum	167,200

Design Sewage Effluent Quality

Water Quality Index	Influent (mg/l)	Effluent (mg/l)	Total Removal Ratio (%)
BOD	200	40	80
SS	200	100	50

2. Treatment Flow



3. Outline of Major Facilities

Facility	Dimension	No. of Facility	Capacity
Grit Chamber	Horizontal Flow Type W 2.0 m x L 12.0 m x D 0.6 m	4	Surface Load: 1,742 m^3/m^2 x day
Primary Sedimentation Tank	Centrifloc Sludge Scraper Ø21 m x D 3.5 m	8	Detention Time: 1.8 hr. Overflow Rate: 47 m^3/m^2 x day
Facultative Pond	Embanked Rectangular Pond W 200 m x L 330 m x D 1.5 m	8	Retention Days: 5.8 BOD Area Load: 238 kg BOD/ha x day
Disinfection Chamber	Embanked Rectangular Pond W 11 m x L 25 m x D 2.0 m	2	Retention Time : 15 min
Sludge Lagoon	Embanked Rectangular Pond W 100 m x L 180 m x D 1.0 m	8	Retention Days : 110 days

Table 8.5.7 Outline of North Dhaka West Sewage Treatment Plant

1. General

Name:	North Dhaka West Sewage Treatment Plant
Location:	Dhaka City, Diabari District
Site Area:	180.0 ha
Land Use:	Swamp Area
Service Population	1,632,000 persons
Sewerage System:	Separate system
Treatment Method:	Sewage Treatment = Grit Chamber + Primary Sedimentation Tank + Facultative Pond+ Disinfection Chamber
	Sludge Treatment = Sludge Lagoon
Receiving Water Body:	Turag River

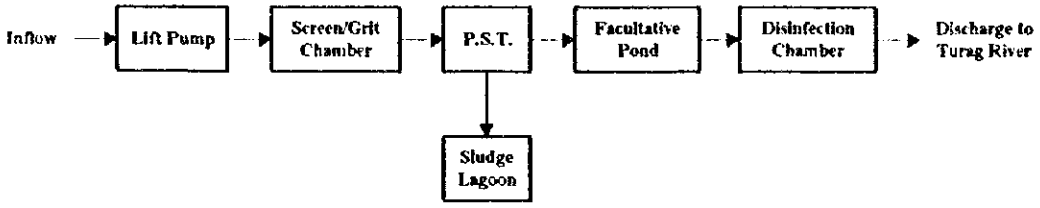
Design Sewage Flow Rate Unit: m^3/day

Item	Sewage Flow
Daily Average	163,200
Daily Maximum	204,000
Hourly Maximum	261,120

Design Sewage Effluent Quality

Water Quality Index	Influent (mg/l)	Effluent (mg/l)	Total Removal Ratio (%)
BOD	200	40	80
SS	200	100	50

2. Treatment Flow



3. Outline of Major Facilities

Facility	Dimension	No. of Facility	Capacity
Grit Chamber	Horizontal Flow Type W 2.5 m x L 14.5 m x D 0.6 m	4	Surface Load: 1,801 m^3/m^2 x day
Primary Sedimentation Tank	Centrifloc Sludge Scraper Ø26 m x D 3.5 m	8	Detention Time: 1.7 hr. Overflow Rate: 48 m^3/m^2 x day
Facultative Pond	Embanked Rectangular Pond W 260 m x L 400 m x D 1.5 m	8	Retention Days: 5.9 BOD Area Load: 235 kg BOD/ha x day
Disinfection Chamber	Embanked Rectangular Pond W 15 m x L 30 m x D 2.0 m	2	Retention Time : 16 min
Sludge Lagoon	Embanked Rectangular Pond W 100 m x L 270 m x D 1.0 m	8	Retention Days : 106 days

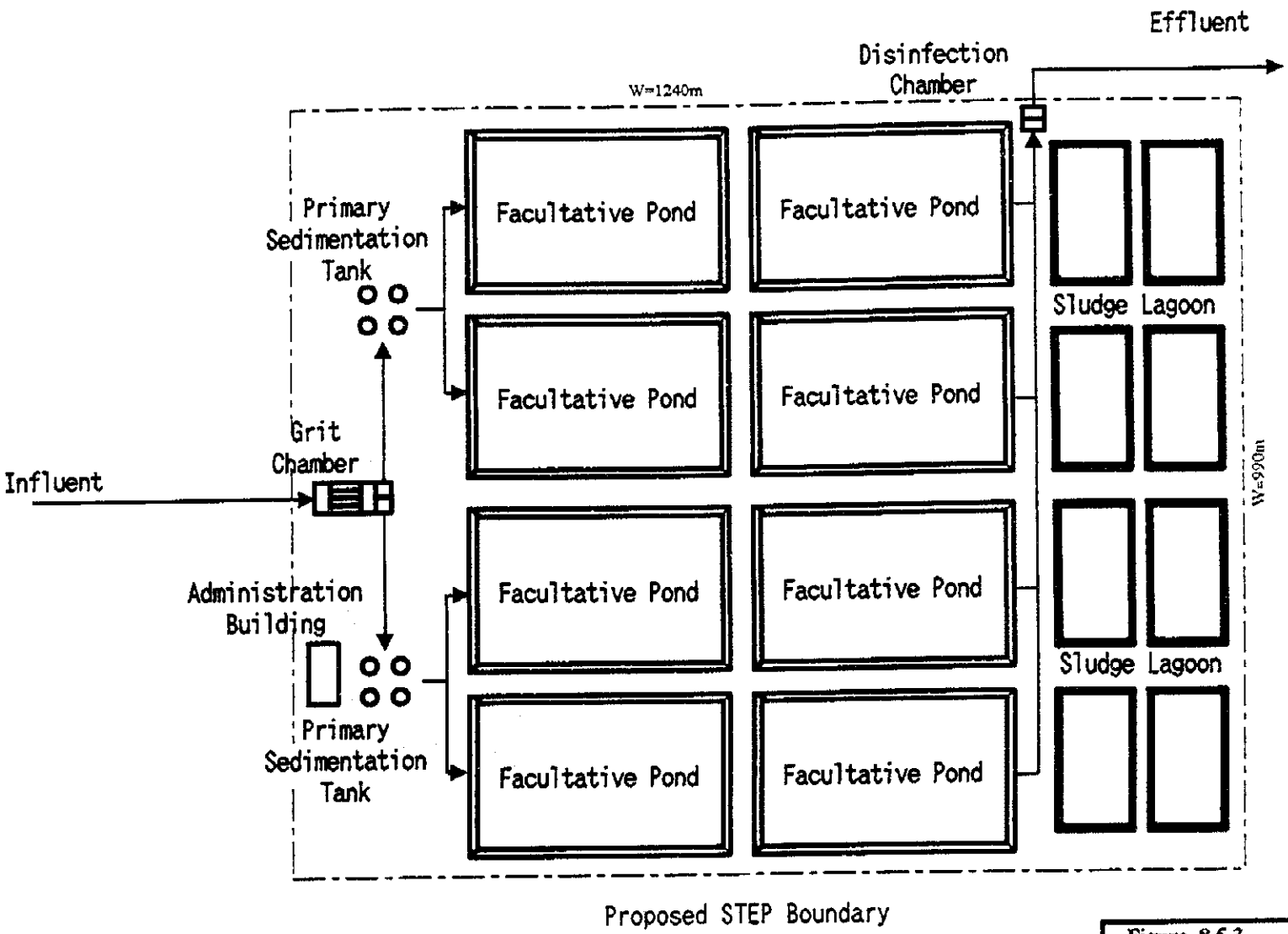


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Figure 8.5.3

Layout Plan of East STP

The Study on the Sewerage System in North Dhaka

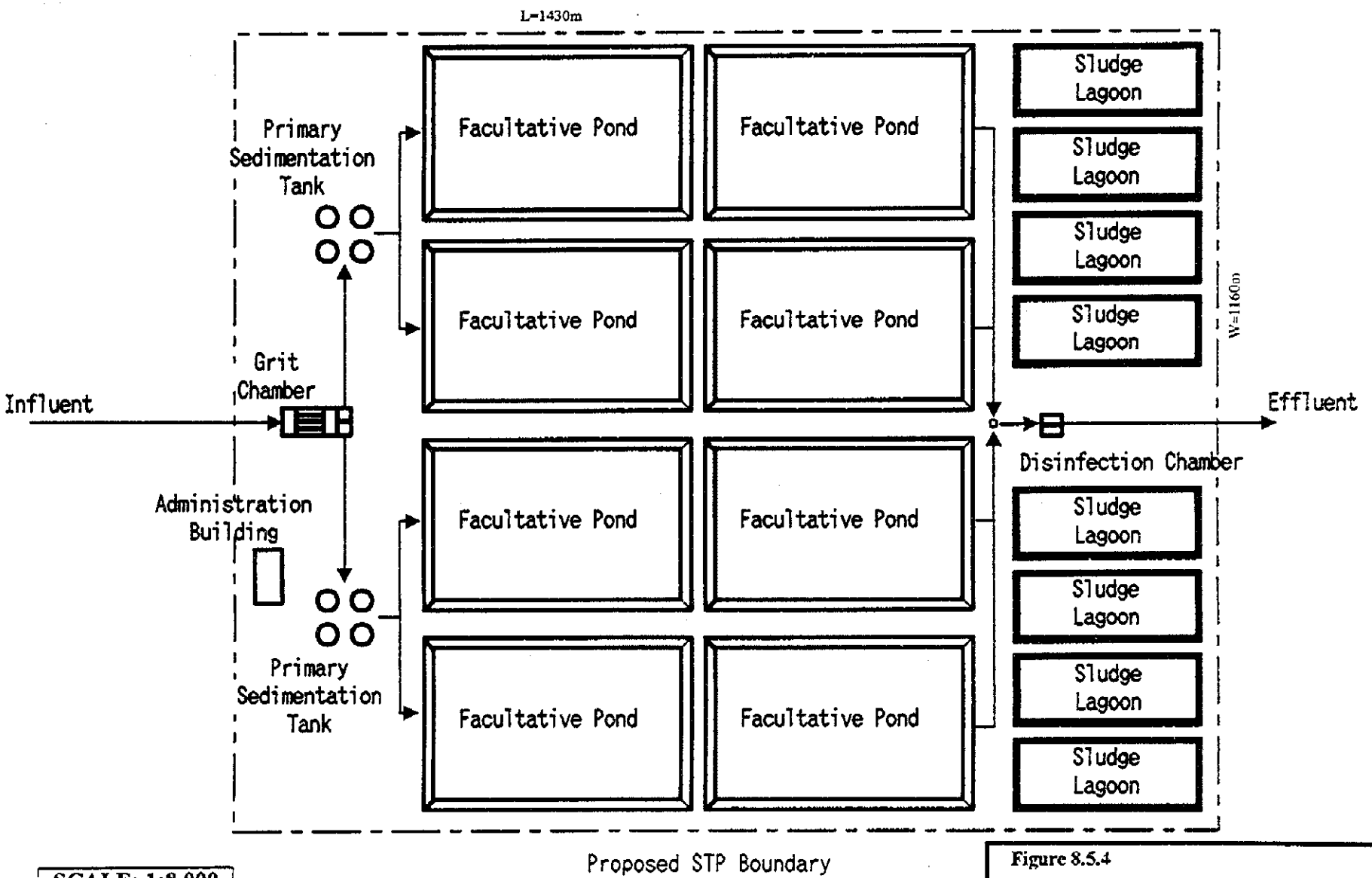

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Figure 8.5.4

Layout Plan of West STP

The Study on the Sewerage System in North Dhaka

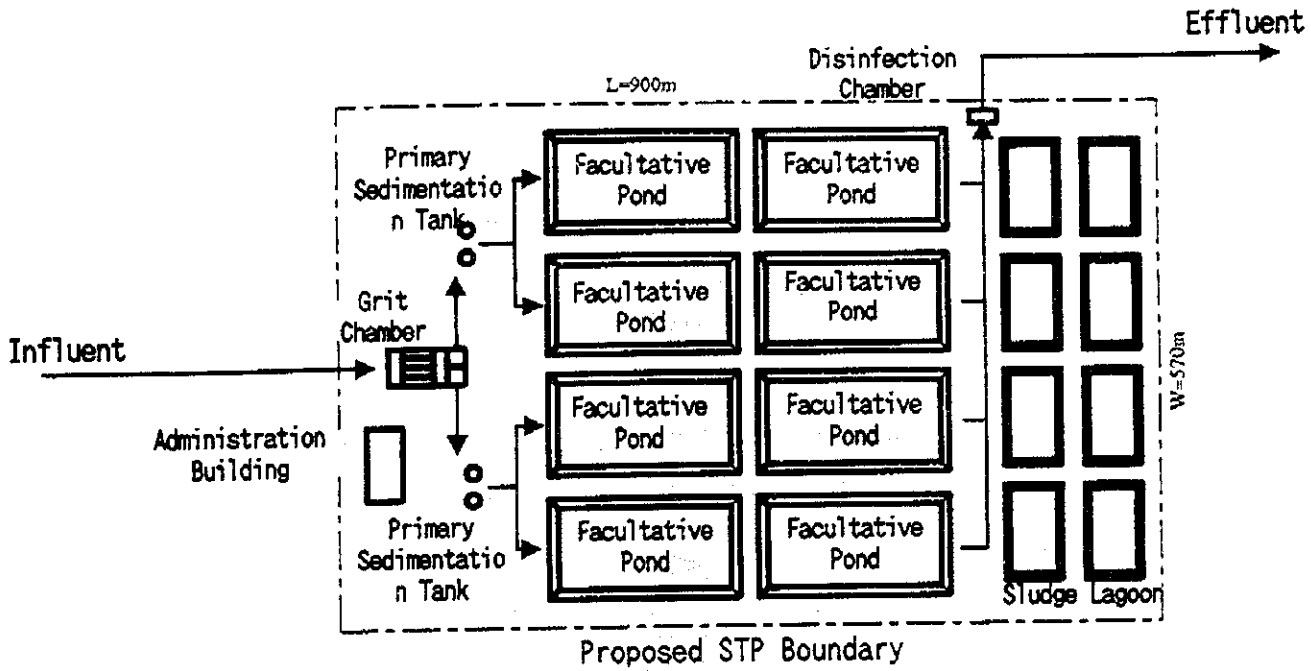

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Figure 8.5.5
Layout Plan of Tongi STP

The Study on the Sewerage System in North Dhaka

8.6 Pretreatment Facility for Wastewater with High Pollution Load

8.6.1 Need for Pretreatment Facility

In most countries wherein public sewerage systems are being operated, there are particular legislative set-up associated with certain technical standards and appropriate technologies to handle wastewater with high pollution load as well as toxic/hazardous substances. These arrangements are enforced not only to protect sewerage system from anticipated damage caused by such wastewater, but also to prevent any secondary environmental pollution caused by the effluent and excess sludge discharged from sewage treatment plants.

Damages and/or hazards to a sewerage system may be classified into the following categories:

- Corrosion of concrete pipes and structures by highly acidic wastewater,
- Deterioration of biological treatment process by the extreme biochemical characteristics of wastewater (including high organic pollution load),
- Biological concentration of toxic/hazardous substances in micro-organisms and sewerage sludge.

In this subsection, the pretreatment facilities used to remove such excessive pollutants at factories and establishments will be discussed, mainly looking into the major types of industries and commercial establishments, which are presently operated in the Study Area.

Recommendations on the pertinent legislative arrangements will also be prepared to help regulate those prospective pollution sources.

8.6.2 Major Types of Pollution Sources

The following types of industries are identified mainly in Tongi Industrial Estate:

- Textile dying,
- Synthetic detergent manufacturing,
- Pharmaceutical and chemical products manufacturing,
- Dry battery manufacturing,
- Poultry,
- Food processing, and
- Tanning.

Other major sources of high pollution load are:

- Slaughterhouse,
- Large scale restaurant, and
- Plating factory.

8.6.3 Legislative Arrangements

At present, there are no particular regulation and wastewater quality standards to handle industrial wastewater for the operation of sewerage service in Bangladesh.

In the absence of such regulation, DWASA does not posses any authority neither to prevent toxic/hazardous industrial wastewater from being discharged into the sewerage system, nor to regulate the acceptable strength of wastewater quality for the sewerage system.

The following table presents the Japanese regulation for industrial wastewater allowed to be discharged in the sewer network prescribed on Sewerage Act Enforcement Ordinance.

Table 8.6.1 Japanese Regulation on Industrial Wastewater Quality to Discharge into the Sewer Network

Items	Allowable Limit
1. Temperature	45℃
2. pH	5 - 9
3. BOD	600 mg/l
4. Suspended Solids	600 mg/l
5. Iodine Consumption	220 mg/l
6. Normal Hexane Extracts	Mineral Oil 5 mg/l Fatty Oil 30 mg/l
7. T-N	240 mg/l
8. T-P	32 mg/l
9. Phenols	5 mg/l
10. Copper and its Compounds	3 m/L
11. Zinc and its Compounds	5 mg/l
12. Iron and its Compounds (soluble)	10 m/L
13. Manganese and its Compounds (soluble)	10 mg/l
14. Chromium and its Compounds	2 mg/l
15. Fluorine and its Compounds	15 mg/l
16. Cadmium and its Compounds	0.1 mg/l
17. Cyanic Compounds	1 mg/l

Table 8.6.1 Japanese Regulation on Industrial Wastewater Quality to Discharge into the Sewer Network (Cont'd)

Items	Allowable Limit
18. Organic Phosphoric Compounds	1 mg/l
19. Lead and its Compounds	0.1 mg/l
20. Hexavalent Chromium Compounds	0.5 mg/l
21. Arsenic and its Compounds	0.1 mg/l
22. Mercury, Alkyl Mercury and other Mercurial Compounds	0.005 mg/l
23. Alkyl Mercury	Not Detected
24. PCB	0.003 mg/l
25. Trichloroethylene	0.3 mg/l
26. Tetrachloroethylene	0.1 mg/l
27. Dichloromethane	0.2 mg/l
28. Chlorine Tetraoxide	0.02 mg/l
29. 1.2-Dichloroethane	0.04 mg/l
30. 1.1-Dochloroethylene	0.2 mg/l
31. Cis-1.2-Dichloroethylene	0.4 mg/l
32. 1.1.1-Trichloroethane	3 mg/l
33. 1.1.2-Trichloroethane	0.06 mg/l
34. 1.3-Dichloropropane	0.02 mg/l
35. Thiuram	0.06 mg/l
36. Simazine	0.03 mg/l
37. Benthiocarb	0.2 mg/l
38. Benzene	0.1 mg/l
39. Selenium and its Compounds	0.1 mg/l

Under the Environmental Protection Act of 1995, effective June 1, 1995, the Department of Environment (DOE) has the legal authority to perform as per rule against any person or group if he/they do something, which will create an environmental hazard by any means or activities. Thus, the DOE shall perform the role of the relevant legislative arrangement, including establishment of the above-mentioned regulation of wastewater discharged to sewers.

8.6.4 Typical Example of Pretreatment Method for Industrial Wastewater

There are various kinds of pretreatment methods corresponding to the characteristics of industrial wastewater. The following table exhibits typical example applicable to the existing industries identified during the Stage 1 Field Work.

Table 8.6.2 Typical Pretreatment Methods of Industrial Wastewater

Type of Industry	Wastewater Quality						Major Substances Removed	Treatment Method
	pH (-)	BOD (mg/l)	SS (mg/l)	COD (mg/l)	T-N (mg/l)	T-P (mg/l)		
Textile Dying	3~11	10~350	20~250	300	25	10		SASM Chemical Clarification Oil Separation
Synthetic Detergent	2~11	200~400	200~2500	150~2000	15~25	40~80	Phenol	Neutralisation Floatation
Pharmaceutical and Chemical Products	2~11	40~2000	70~600	--	80~100	10~20	Organic Solution	
Dry Battery	1~12	300~800	30~150	--	--	--	CN20~200 Cr40~150 Cu, Cd, Zn	Chemical Treatment Neutralisation
Poultry Farming	--	2000	3500	1450	600	100	Excreta	Drying Bed (Sun-light) Drying Bed (Heating) Composting
Food Processing	6~8	300~600	100~300	200~400	50~80	10~15	Soluble Pro-tein Oils	
Tanning	7~12	500~2000	400~3000	100~2000	250~350	10~20	Cu Sulphide	Recirculating Aeration Organic
Slaughter House	6.2~7.5	800~2000	1200~1600	--	--	--		
Large-scale Restaurant	--	10~900	20~800	--	--	--		Segregation
Matting Factory	1~2	--	30~150	10~200	--	--		Electrolysis

Note: -- indicates no data available; others are standard values

8.7 Sanitation Facilities

(1) Overview of sanitation provision

As part of the implementation of sewerage system development toward the master plan target year of 2020, all households and public/private facilities are planned to have either access to the public sewerage system or on-site treatment facilities.

Households in the core area will be given the first priority to avail themselves of sewerage service in the shortest time possible, while those in the transitional area will be served by a sewerage system through the staged implementation of the project.

The rest of the households situated in the on-site treatment area will, on the other hand, remain unsewered at least up to the year 2020 under this Master Plan. Thus, these

households will be required to install individual on-site treatment facilities or to develop cluster-wise community sewerage system for combined treatment of nightsoil and grey water.

In applying on-site treatment facility, those households will be required to ascertain technical and legislative requirements to be established by respective government authorities to maintain the desirable level of living and surrounding environment.

Septage removed from respective households is planned to be accepted at the sewage treatment plant of DWASA.

(2) On-site treatment in the transitional area

The existing houses and public/private facilities generally have flush toilets and septic tanks. These existing facilities will be allowed to use these facilities until such time as the access to the sewerage service becomes available. However, any renovation of structures including toilet facilities, may be required to have provision for the preliminary arrangement of their plumbing for reconnection to the sewer network in the near future.

Any new house/building to be built in this area during the master plan period will be required to follow the provisions for building permission as described in Chapter 7 so as to connect with the sewer network when the time comes. Particularly, separate plumbing for rainwater and wastewater is prerequisite to avoid the reconnection of in-house piping afterward.

(3) On-site treatment area

Households to be situated in lower population density locations in this particular area shall have individual septic tank or similar facilities.

Households to be situated in a cluster will have an option to develop a small-scale community sewerage system for combined treatment of nightsoil and grey water to attain better living conditions.

Public/private facilities having dining and toilet facilities and apartments shall also have package-type domestic sewage treatment facilities to treat both nightsoil and grey water. In this respect, private developers for apartment housing will be obliged to have provision for such on-site treatment facilities in their application for building permission.