CHAPTER 7

SEWAGE COLLECTION SYSTEM

CHAPTER 7 SEWAGE COLLECTION SYSTEM

7.1 General

In this Section, the rehabilitation/modification plan of the existing pump stations (St.Mary's No.1, No.2 and Tilcor) for the year 2000 is prepared and the rehabilitation methods for the existing sewer system are examined. Due to the capacity limitation of the existing sewer and the geographical conditions, the new trunk sewer and pump station are designed to cope with the sewage from the planned residential development area in St.Mary's.

7.2 Fundamentals and Criteria for Sewer Reticulation Design

7.2.1 Design Population and Sewage Collection Area

The design population for the year 2000 was calculated at 489,000 in Sub-section 4.2 and the population by Ward are distributed based on the population of the 1992 Census.

Table 7.2.1 shows the sewage collection area (residential and others) measured by the Study Team and the population by Ward. Figure 7.2.1 shows the Ward boundary and development area in St.Mary's.

7.2.2 Design Sewage Quantity

(1) Peak factor

In the sewer reticulation design, the peak factor, the ratio between the ADWF and PWWF, follows the "Sanitation Manual Design Procedure", which is as follows:

$$PWWF = ADWF \times 3.0$$

(2) Design sewage quantity

ADWF is calculated as shown in Sub-section 5.4. PWWF is calculated by ADWF and peak factor. Results are shown in Table 7.2.2.

Table 7.2.1 Residential Area and Population by Ward

Ward No.	Residential Area by Ward in 1995			Residential Area by Ward in 2000			1992	1995	2000	Name of Sub-treatment Area
	Residential Area (km^2)	Open and Other Areas (km^2)	Total Area (km^2)	Residential Area (km^2)	Open and Other Areas (km^2)	Total Area (km^2)	Census Population (persons)	Present Population (persons)	Future Population (persons)	
1	0.21	0.72	0.93	0.48	0.45	0.93	4,701	6,948	8,389	St.Mary's & Zengeza
2	0.37	0.50	0.87	0.61	0.26	0.87	10,325	15,259	18,424	St.Mary's & Zengeza
3	0.24	0.72	0.96	0.65	0.31	0.96	8,062	11,915	14,386	St.Mary's & Zengeza
4	0.43	0.97	1.40	1.26	0.14	1.40	13,450	19,878	24,001	St.Mary's & Zengeza
5	0.50	0.02	0.52	0.50	0.02	0.52	10,965	16,205	19,566	St.Mary's & Zengeza
6	1.79	2.34	4.13	1.79	2.34	4.13	9,062	13,393	16,171	St.Mary's & Zengeza
7	0.33	0.00	0.33	0.33	0.00	0.33	8,475	12,525	15,123	St.Mary's & Zengeza
8	0.63	0.09	0.72	0.63	0.09	0.72	10,935	16,161	19,513	St.Mary's & Zengeza
9	0.89	0.00	0.89	0.89	0.00	0.89	7,239	10,699	12,918	St.Mary's & Zengeza
10	0.49	1.06	1.55	0.49	1.06	1.55	8,108	11,983	14,468	St.Mary's & Zengeza
11	1.03	0.00	1.03	1.03	0.00	1.03	6,877	10,164	12,272	St.Mary's & Zengeza
12	0.49	3.53	4.02	0.49	3.53	4.02	8,064	11,918	14,390	St.Mary's & Zengeza
13	0.65	0.83	1.48	0.65	0.83	1.48	6,897	10,193	12,307	St.Mary's & Zengeza
14	1.29	0.51	1.80	1.29	0.51	1.80	10,043	14,843	17,921	St.Mary's & Zengeza
15	1.06	1.04	2.10	1.06	1.04	2.10	16,967	25,076	30,277	Seke
16	0.53	0.23	0.76	0.53	0.23	0.76	4,848	7,165	8,651	St.Mary's & Zengeza
	0.91	0.24	1.15	0.91	0.24	1.15	8,324	12,302	14,854	Seke
17	1.08	0.43	1.51	1.08	0.43	1.51	16,781	24,801	29,945	Seke
18	0.86	2.99	3.85	0.86	2.99	3.85	7,412	10,954	13,226	Seke
19	0.97	0.64	1.61	0.97	0.64	1.61	12,083	17,858	21,561	Seke
20	0.65	0.10	0.75	0.65	0.10	0.75	12,595	18,614	22,475	Seke
21	3.74	0.76	4.50	3.74	0.76	4.50	21,129	31,227	37,704	Seke
22	1.32	0.28	1.60	1.32	0.28	1.60	16,600	24,533	29,622	Seke
23	1.16	0.76	1.92	1.16	0.76	1.92	18,584	27,466	33,162	Seke
24	1.20	0.42	1.62	1.20	0.42	1.62	15,509	22,921	27,675	Seke
Total	22.82	19.18	42.00	24.57	17.43	42.00	274,035	405,000	489,000	

Note: Total Population in 1995 : **405,000**
Total Population in 2000 : **489,000**

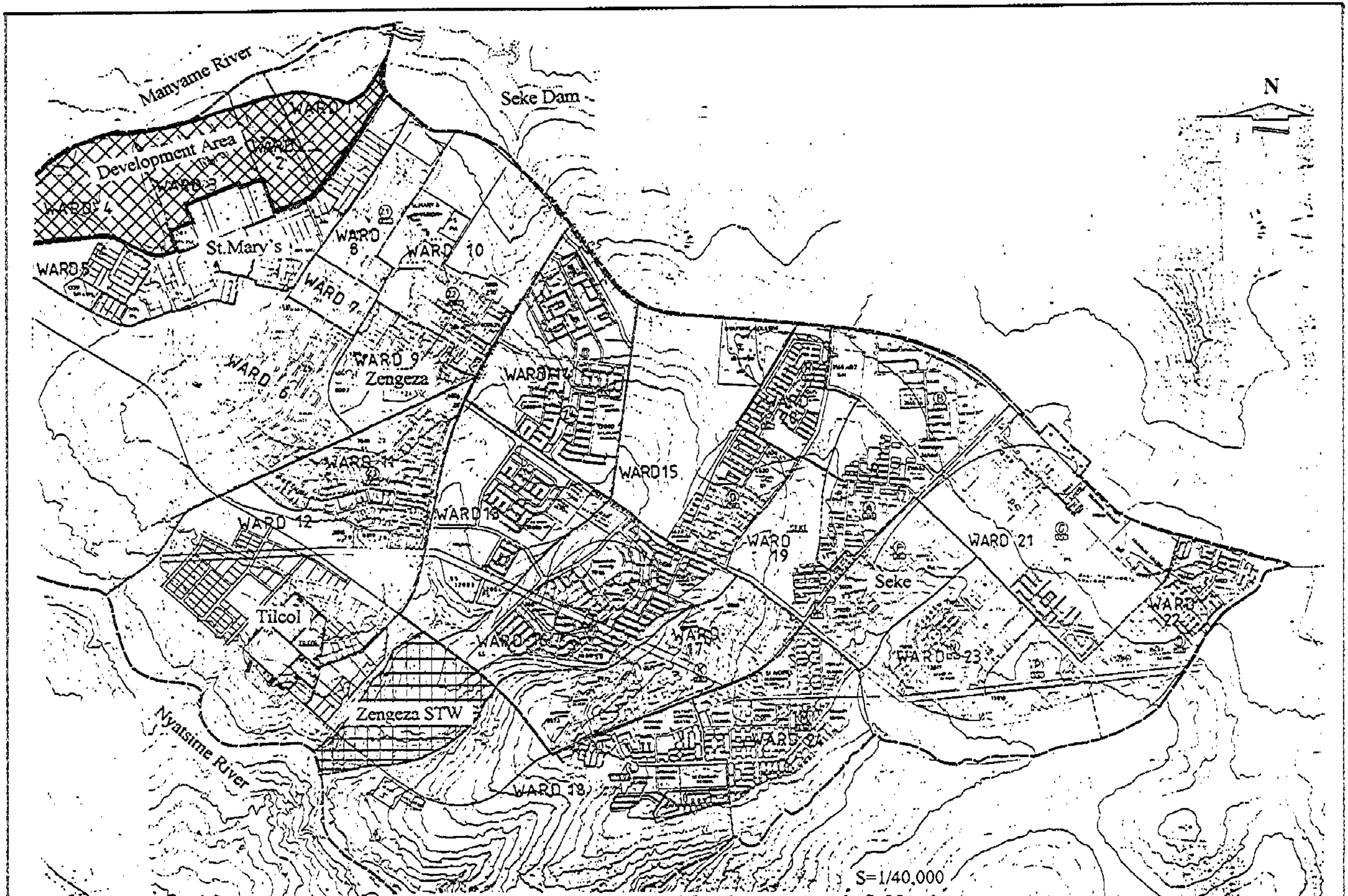


Figure 7.2.1 Ward Boundary and Development Area in St.Mary's

Table 7.2.2 Design Sewage Quantity

Type	ADWF	PWWF
	(m^3/day)	(m^3/day)
Domestic	38,240	114,720
Institutional/Commercial	1,912	5,736
Sub total	40,152	120,456
Industrial	1,387	4,161
Total	41,539	124,617

(3) Design sewage quantity for sewer reticulation

The design sewage quantity for sewer reticulation is calculated by the unit sewage quantity per km^2, dividing the design sewage quantity by sewage collection area as shown below. Figure 7.2.2 shows the sewage collection area for the existing pump stations and the proposed new pump station and major trunk sewer in St.Mary's.

1) Unit sewage quantity per km^2 (q)

Total residential area = 24.57 km^2

$q = 120{,}456 / (24.57 \times 86{,}400) = 0.0567$ m^3/sec/km^2

2) St.Mary's No.1 Pump Station

Collection area = 1.52 km^2

$Q_1 = 1.52 \times 0.0567 = 0.086$ m^3/sec = 5.17 m^3/min. = 7,446 m^3/day

3) St.Mary's No.2 Pump Station

Collection area = 0.33 km^2

$Q_2 = 0.33 \times 0.0567 = 0.019$ m^3/sec = 1.12 m^3/min. = 1,617 m^3/day

4) Tilcor Pump Station

Q_3 = 4,161 m^3/day = 2.89 m^3/min. = 0.048 m^3/sec

5) St.Mary's New Pump Station

Collection area = 24.57 - 22.82 = 1.75 km^2

$Q_4 = 1.75 \times 0.0567 = 0.099$ m^3/sec = 5.95 m^3/min. = 8,573 m^3/day

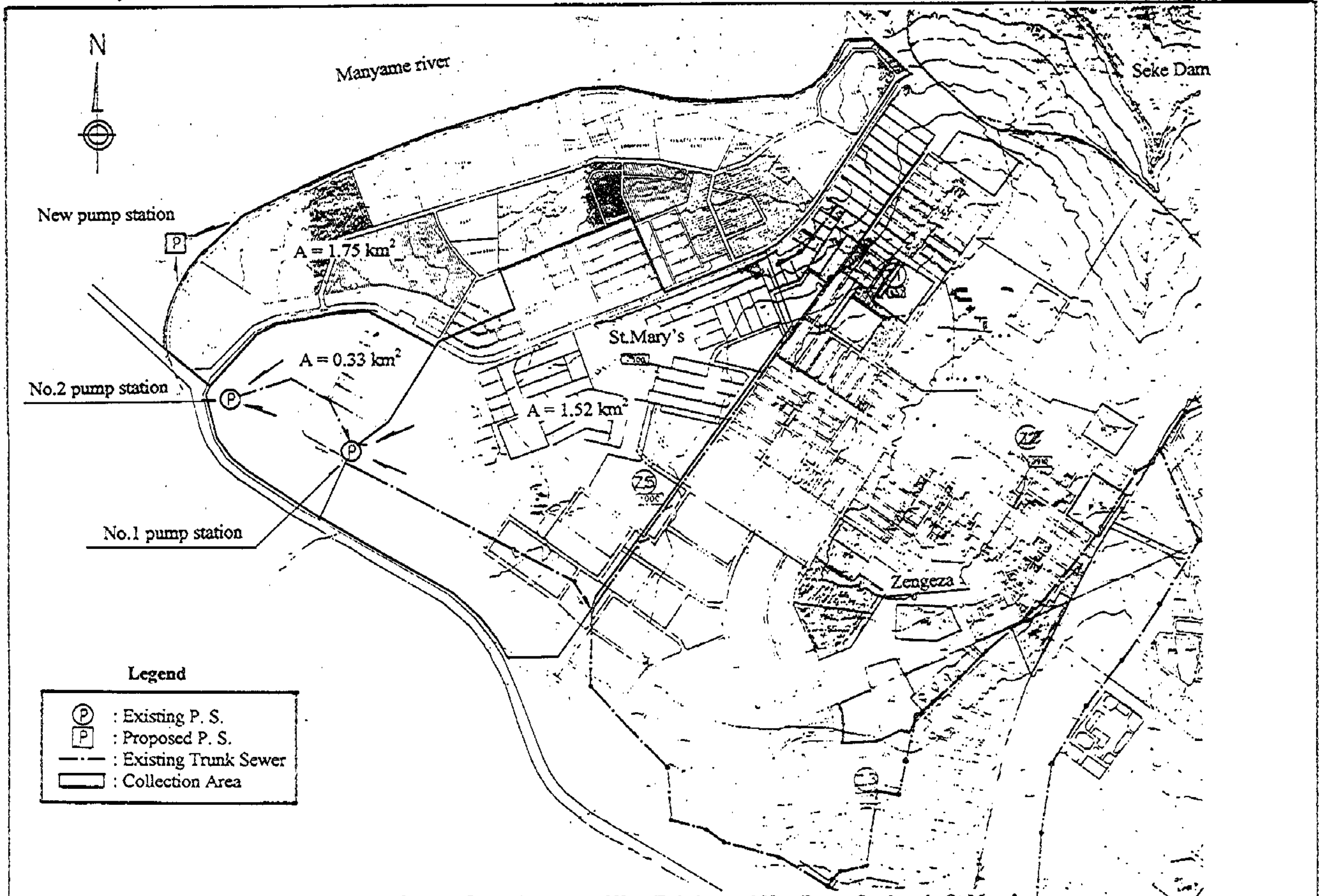


Figure 7.2.2 Sewage Collection Area of Two Existing and New Pump Stations in St.Mary's
(Scale = No scale)

6) St.Mary's New Major Trunk Sewer

Collection area = 24.57 - 22.82 = 1.75 km^2

Q_5 = 1.75 x 0.0567 = 0.099 m^3/sec = 5.95 m^3/min. = 8,573 m^3/day

7.2.3 Design Criteria

The design criteria for the new sewer reticulation is quoted from "Sanitation Manual Design Procedure" as same as the Master Plan designing. The summarized design criteria are as follows.

(1) Design criteria for sewer

Collection system	: Separate system
In-pipe velocity	: Minimum velocity = 0.60 - 0.75 m/sec
	: Maximum velocity = 3.0 m/sec
Pipe material	: Gravity Pipe (150-825 mm) = AC Pipe
Minimum earth cover	: 600 - 900 mm
Minimum diameter	: 150 mm
Manhole spacing	: Maximum spacing = 100 m

(2) Design criteria for pump station

Pump station type	: More than 5 m^3/min. = Conventional type
	: Less than 5 m^3/min. = Manhole type
Screen type	: Manual rake type
Number of channels for grit chamber	: More than 2 channels
Number of pumps	: More than 2 sets (including 1 standby)

(3) Design criteria for force main

Pipe material	: Pressure Pipe (100-750 mm) = AC Pipe
In-pipe velocity	: 1.0 -3.0 m/sec
Minimum diameter of force main	: 100 mm

(4) Formula for sewer reticulation design

1) Formula for flow calculation: Manning formula

$V = (1/n) \times R^{(2/3)} \times I^{(1/2)}$

$Q = A \times V$

Where, V : flow velocity (m/sec)

n : roughness coefficient (n=0.013, AC Pipe)

R : hydraulic radius (m)

I : gradient in decimal

A : section area (m^2)

2) Formula for pump diameter calculation

$D = 146 \times (q / v)^{(1/2)}$

Where, D : pump diameter (mm)

q : discharge volume (m^3/min.)

v : velocity at suction mouth

3) Formula for pump power calculation

$P = (0.163 \times q \times H) / \eta) \times (1+0.15)$

Where, P : pump power (kw)

q : discharge volume (m^3/min.)

H : total pump head (m)

η : pump coefficient

7.3 Rehabilitation/Modification Plan of Existing Sewer Reticulation

7.3.1 Rehabilitation/Modification Plan of Existing Pump Station

The three pump stations of St.Mary's No.1, No.2 and Tilcor have been operating since the middle of 1970's and about 20 years have passed already. The life expectancy of a concrete structure can be about 50 years if appropriate construction and repair has been done. Actually, as a result of the site investigation at their pump stations, the pump station structures are still seemed to be firm. Therefore, the rehabilitation/modification plan was limited to mechanical and electrical facilities.

At the pump stations, the inflow sewage volume should be measured at the inlet/outlet points for maintenance purpose. However, considering the layout of the existing facilities, it is difficult to set measurement equipment at the inlet point due to insufficient space. Accordingly, an electrical flow meter was selected as the measuring equipment to be used and it will be installed at the outlet point.

(1) St.Mary's No.1 Pump Station

The capacity calculation for the St.Mary's No.1 pump station was carried out based on the design inflow volume (0.086 m^3/sec =5.17 m^3/min.) as shown in Table 7.3.1, Section 7.3, Chapter 2, Supporting Report. The rehabilitation plan is shown in Figure 7.3.1. Table 7.3.1 shows the list of mechanical and electrical equipment required.

Table 7.3.1 List of Mechanical and Electrical Equipment Required for St.Mary's No.1 P. S.

Item	Specification
Pump Type	Horizontal Shaft Type
Pump Diameter	150 mm
Pump Discharge per Unit	2.60 m^3/min.
Pump Total Head	34.5 m
Pump Power (Motor Power)	25.0 kw
Number of Pump	3 units (including 1 standby)
In-plant Pipe	1 set (including valves and flow meter, refer to Figure 7.3.1)
Electrical Panel	1 set (including house wiring)
Valve Box	1 set (rehabilitation, refer to Figure 7.3.1)

(2) St.Mary's No.2 Pump Station

The capacity calculation for the St.Mary's No.2 pump station was performed based on the design inflow volume (0.019 m^3/sec =1.12 m^3/min.) as shown in Table 7.3.2, Section 7.3, Chapter 2, Supporting Report. The rehabilitation plan is shown in Figure 7.3.2. Table 7.3.2 shows the list of mechanical and electrical equipment required.

Table 7.3.2 List of Mechanical and Electrical Equipment Required for St.Mary's No.2 P.S.

Item	Specification
Pump Type	Submersible Type
Pump Diameter	100 mm
Pump Discharge per Unit	1.20 m^3/min.
Pump Total Head	12.5 m
Pump Power (Motor Power)	5.0 kw
Number of Pump	2 units (including 1 standby)
In-plant Pipe	1 set (including valves and flow meter, refer to Figure 7.3.2)
Electrical Panel	1 set (including house wiring)
Valve Box	1 set (rehabilitation, refer to Figure 7.3.2)

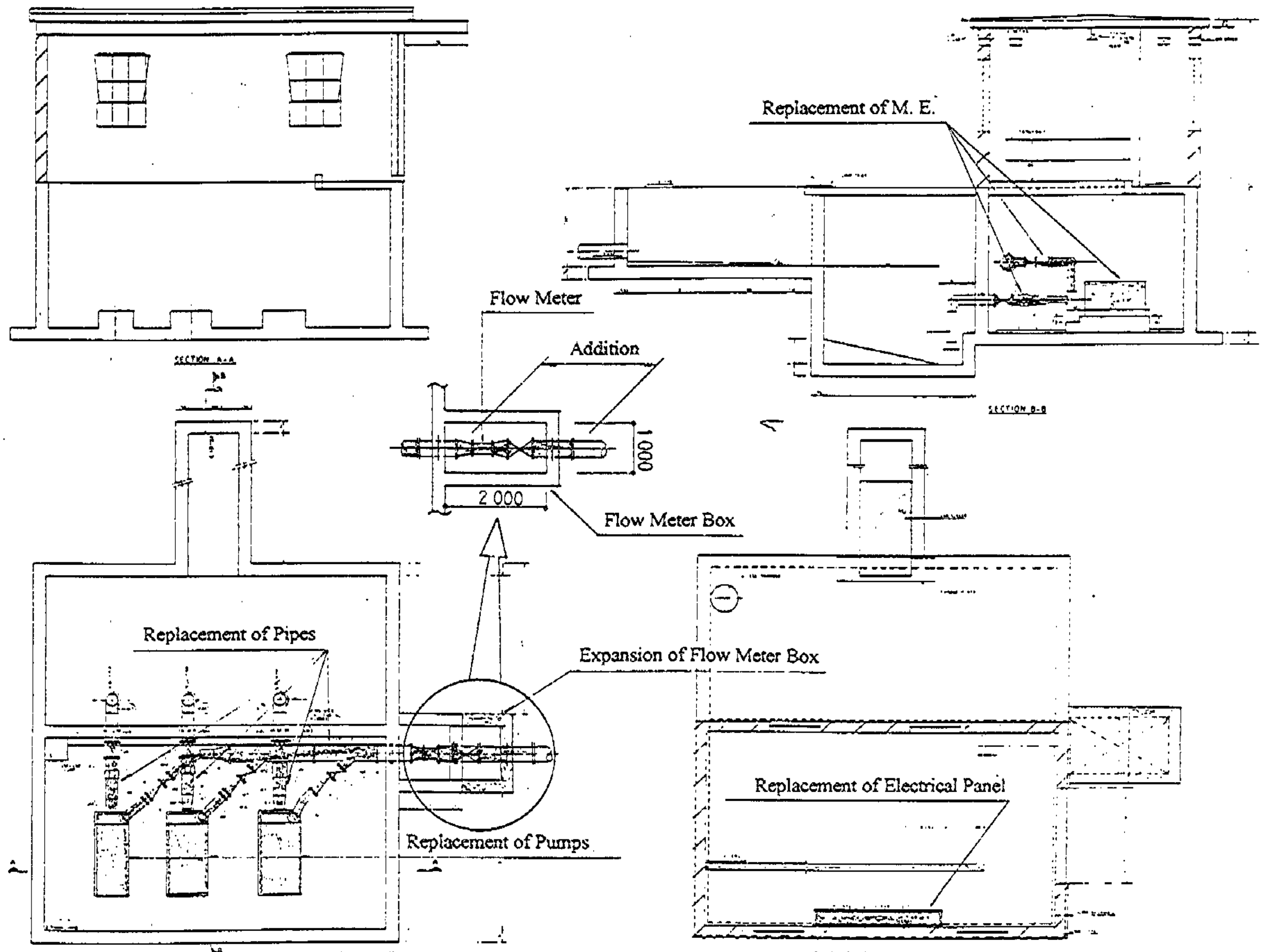


Figure 7.3.1 Rehabilitation Plan of St.Mary's No.1 Pump Station

Note: M. E.: Mechanical Equipment

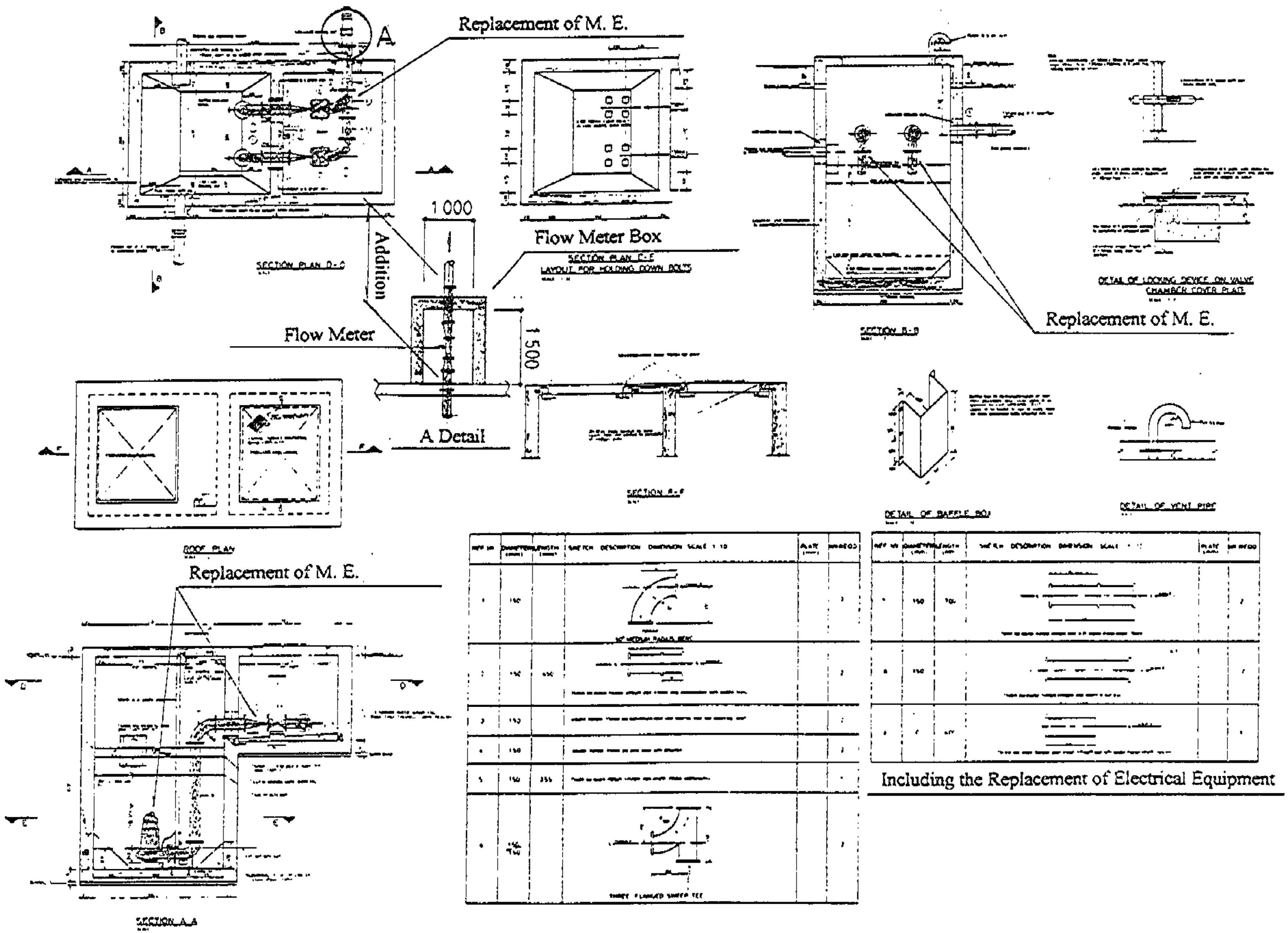


Figure 7.3.2 Rehabilitation Plan of St.Mary's No.2 Pump Station

Note: M. E.; Mechanical Equipment

(3) Tilcor Pump Station

The measurement of inflow volume at the Tilcor pump station was conducted to follow up estimated flow (4,161 m^3/day) as discussed in the previous sub-section (refer to Table 7.3.4, Section 7.3, Chapter 2, Supporting Report). The flow rate was modified in use of the result (0.073 m^3/sec = 4.34 m^3/min, refer to Table 7.3.3, Section 7.3, Chapter 2, Supporting Report). The rehabilitation plan is shown in Figure 7.3.3. Table 7.3.3 shows the list of mechanical and electrical equipment required.

Table 7.3.3 List of Mechanical and Electrical Equipment Required for Tilcor P. S.

Item	Specification
Pump Type	Horizontal Shaft Type
Pump Diameter	150 mm
Pump Discharge per Unit	2.30 m^3/min.
Pump Total Head	28.0 m
Pump Power (Motor Power)	18.0 kw
Number of Pump	3 units (including 1 standby)
In-plant Pipe	1 set (including valves and flow meter, refer to Figure 7.3.3)
Electrical Panel	1 set (including house wiring)
Valve Box	1 set (rehabilitation, refer to Figure 7.3.3)

7.3.2 Rehabilitation/Modification Plan of Existing Sewer

As shown in Sub-section 3.2, 30 problem spots were identified by the Municipality Report. The problems, such as damage and blockages, are expected to occur at not only the above-mentioned 30 spots but also throughout the existing sewer, excepting the newly constructed sewer.

At present, the municipality can only deal with the reported problems due to their lack of budget and manpower. However, the preventive maintenance is recommendable to ensure a design capacity of the sewers through the future. The rehabilitation/modification plan including annual maintenance cost is presented in Sub-section 9.2 and 10.2.

- The annual rehabilitation plan should be prepared by Ward, and should be started from priority areas. (e.g. overflowing manholes or downstream of the sewer reticulation)

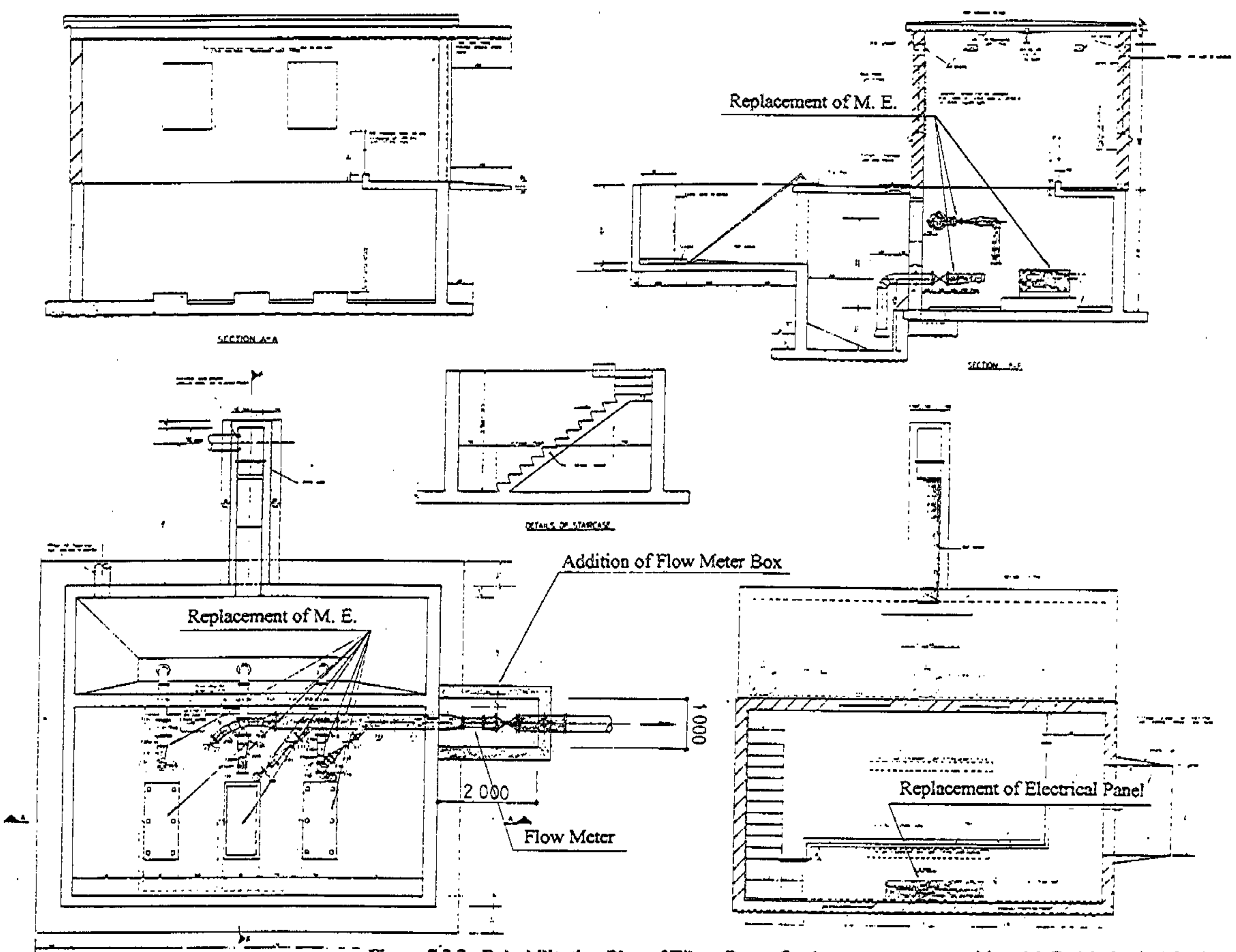


Figure 7.3.3 Rehabilitation Plan of Tilcor Pump Station

Note: M. E.; Mechanical Equipment

- Budget and supplemental manpower should be secured for the above-mentioned plan.
- The inhabitants should be instructed to refrain from the dumping of domestic refuse into the sewers through the manholes.

The rehabilitation/modification plan of the existing sewer includes the following two major works.

- Replacement/repair depending on the magnitude of damage of the sewerage facilities
- Removal of sediments and cleaning of sewers

7.4 Expansion Plan for Residential Development Area in St. Mary's

7.4.1 Expansion Plan of New Trunk Sewer

The sewage (0.099 m^3/sec : PWWF) from the residential development area is collected by gravity towards the western pump station, and lifted about 30 m up to the start point of gravity flow. Then, the new trunk sewer for the additional sewage is planned to be connected to the proposed distribution chamber at the Zengeza STW in parallel with the existing major trunk sewer of St.Mary's and Zengeza as shown in Figure 7.4.1.

The diameter with gradient for new trunk sewer is determined by Manning formula as follows:

Conditions

- Design sewage quantity : $Q_1 = 0.099$ m^3/sec
- Pipe flow allowance : R = 50% to design flow
- Sewer design: 525 mm diameter and 2.5/1,000 gradient :

  Flow velocity ; V = 0.99 m/sec

  Flow rate ; $Q_2 = 0.215$ m^3/sec

$Q_2 > Q_1 \times (50/100) = 0.198$ m^3/sec O.K

The profile of the new trunk sewer is presented in Figure 7.4.2 and the length, excavation depth and the number of manholes are shown in Table 7.4.1.

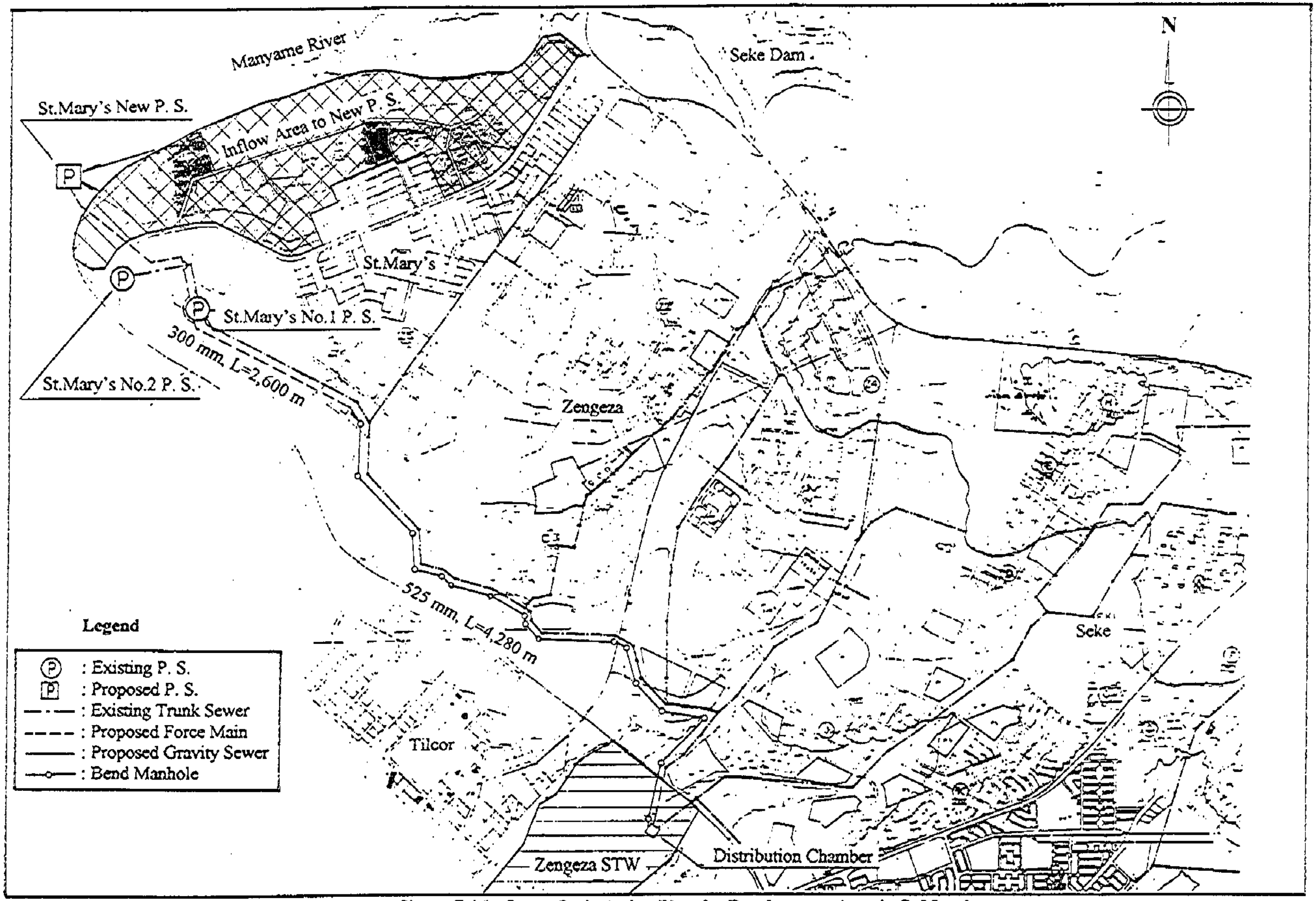
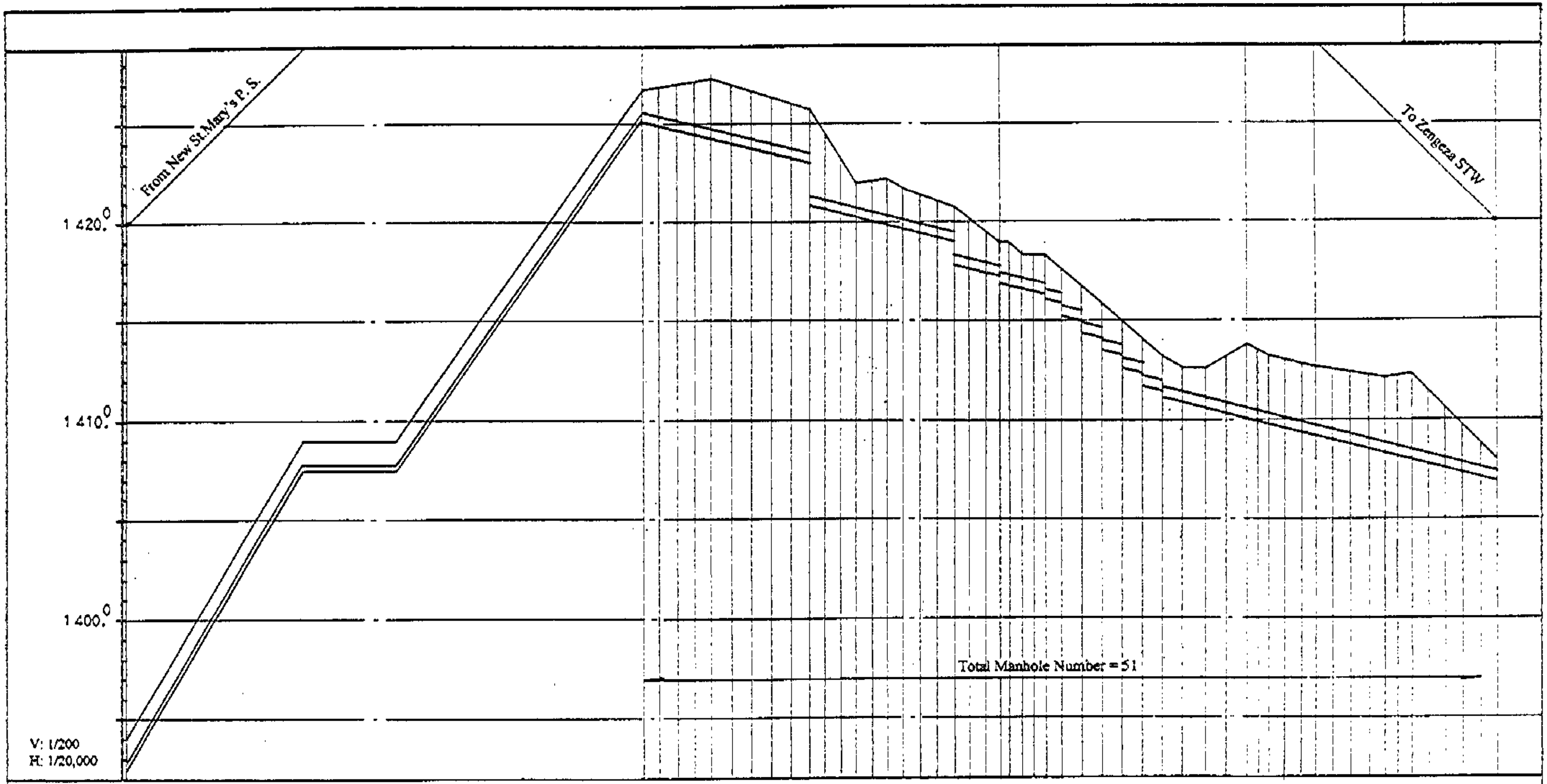


Figure 7.4.1 Sewer Reticulation Plan for Development Area in St.Mary's



Diameter Gradient	300 mm . AC FORCE MAIN	525 mm AC 2.5/1000				
Earth Cover	1.20	1.20	1.20 1.68	3.18	2.98	0.58
Invert Level	1392.5	1425.3 1425.1	1417.3 1416.8	1410.1	1409.2	1406.9
Ground Level	1394.0	1426.6	1419.0	1413.8	1412.7	1408.0
Accumulated Distance	0	2600.0	4390.0	5620.0	5960.0	6880.0
Distance	0	2600.0	1790.0	1230.0	340.0	920.0
No.						

Figure 7.4.2 Profile of New Trunk Sewr

Table 7.4.1 List of Length of New Sewer and Manhole by Excavation Depth

Excavation Depth	Sewer Length (m)	Number of Manhole
less than 2.0m	1,135	9
from 2.0 m to 3.0 m	1,930	26
from 3.0 m to 4.0 m	1,030	13
more than 4.0 m	185	3
Total	4,280	51

7.4.2 Expansion Plan of New Pump Station

The new pump station is planned to lift the collected sewage up to the starting point of gravity flow and the length of the force main is about 2,600 m. The quantity of collected sewage from the new development area is almost the same volume as the existing St.Mary's No.1 pump station. The same type of pump station is adopted.

The capacity calculation of the new St.Mary's pump station and the force main, is included in Table 7.4.1, Section 7.4, Chapter 2, Supporting Report, and the plan and section are shown in Figure 7.4.3. and 7.4.4. The list of required pump facilities is summarized in Table 7.4.2.

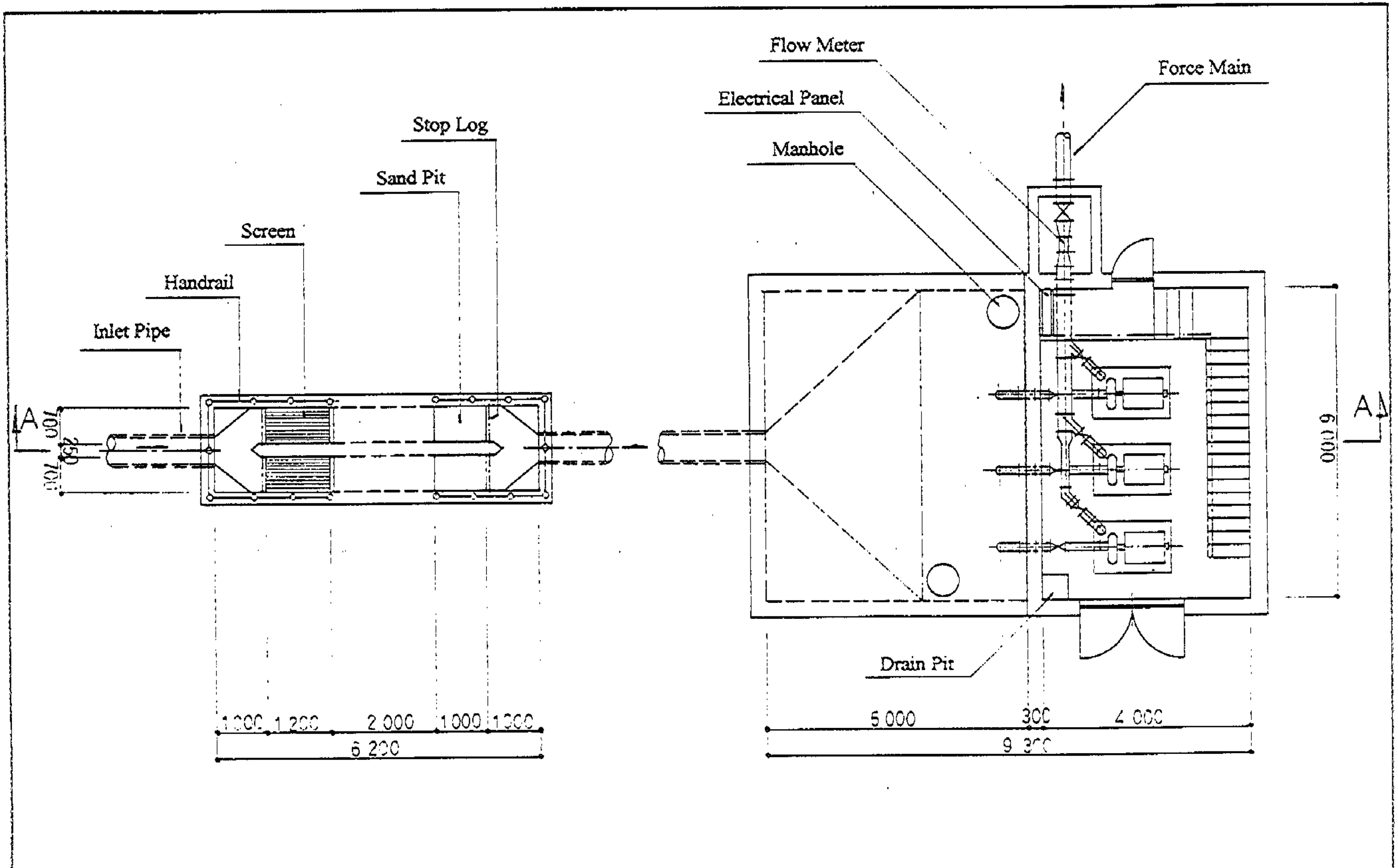


Figure 7.4.3 Plan of New Pump Station S = 1/100

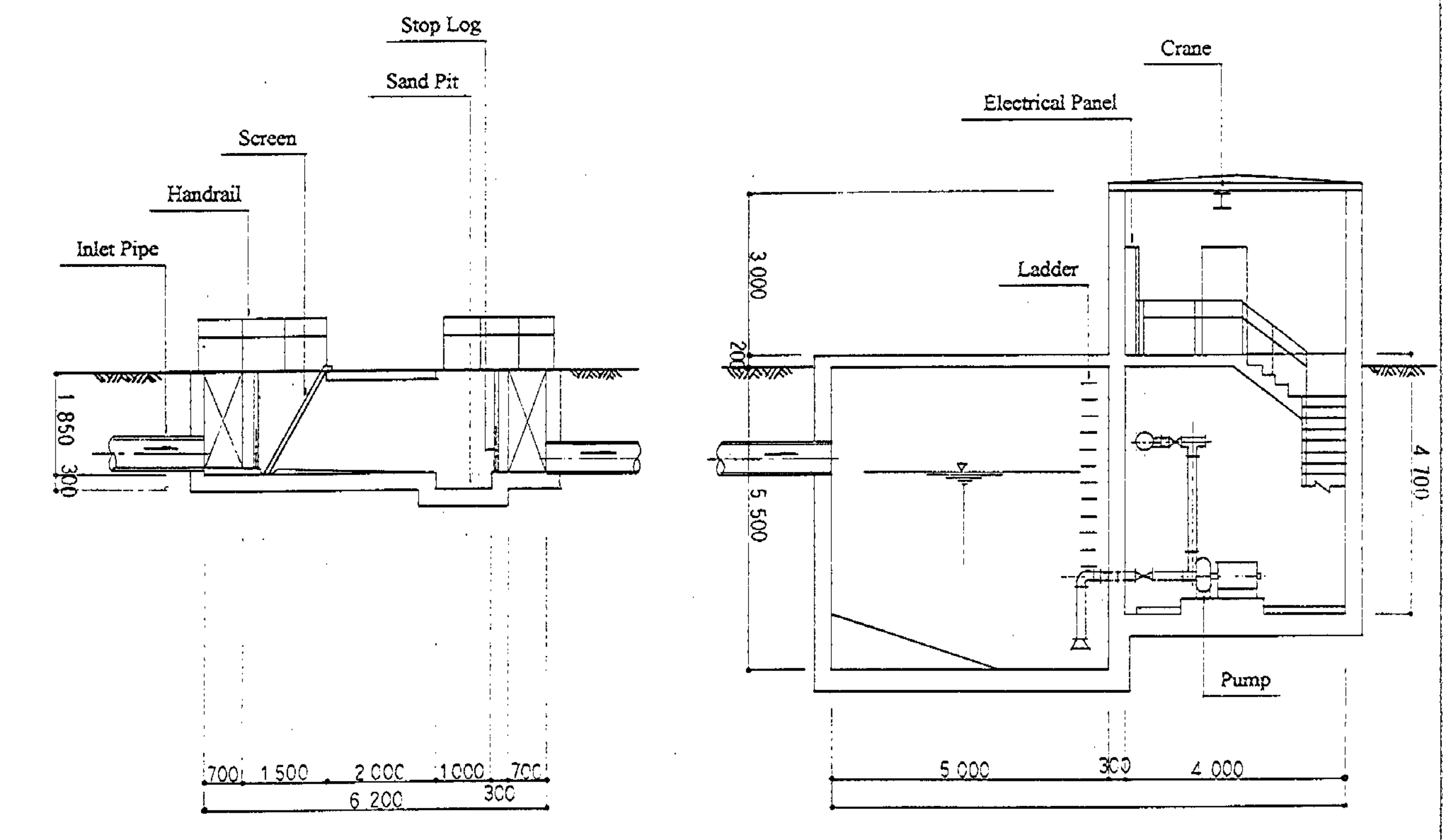


Figure 7.4.4 Section of New Pump Station (A－A) S = 1/100

Table 7.4.2 List of Required Pump Facilities

Facility	Specification
(1) Screen and Grit Chamber	
Screen Type	Manual Type
Channel Width	0.7 m
Channel Number	2 (including 1 standby)
(2) Pump Facility	
Pump Type	Horizontal Shaft Type
Pump Diameter	150 mm
Pump Discharge per Unit	3.00 m^3/min.
Pump Total Head	58.0 m
Pump Power (Motor Power)	50.0 kw
Number of Pump	3 (including 1 standby)
In plant Pipe	1 set (including valve and flow meter, refer to Figure 7.4.3 and 7.4.4)
Electrical Equipment	1 set (including float switch, house wiring etc.)
Valve Box	1 set
(3) Force Main Pipe	
Pipe Material	AC Pipe
Pipe Diameter	300 mm
Pipe Total Length	2,600 m

CHAPTER 8

SEWAGE AND SLUDGE TREATMENT AND DISPOSAL

CHAPTER 8 SEWAGE AND SLUDGE TREATMENT & DISPOSAL

8.1 Rehabilitation of Existing Facilities

8.1.1 Concept of Facility Plan

(1) Existing Sewage Treatment Works

1) Appropriate treatment

The current overload situation must be addressed and the load to be treated reduced to appropriate levels. The treatment capacity has been reevaluated to 21,750 m3/d. As a result, BOD 600 mg/l is treated to 96 mg/l, achieving a BOD removal ratio of 84%.

2) Securing emergency storage capacity

As explained in 6.2, 6.4, arrangements will be made for facilities with storage capacity to be included in the STW, to store sewage in emergencies when the facilities cease to function temporarily, in such cases as power failure or unforeseen accidents. At an additional phase II an anaerobic pond has been added, bringing the total number to four. Three of the ponds will be used on a regular basis, with one ponds to be used for O & M and to serve as a standby ponds for emergencies. The reasons for this are as follows:

- even using only three of the ponds, the projected five days retention time from the design criteria can be achieved, and
- a spare ponds is necessary for O & M. Experience at the Zengeza STW has shown that to remove the accumulated sludge from an anaerobic pond, the pond must be empty for a lengthy period of about two months.

3) Restoration of treatment capacity and replacement of broken equipment

Restoration of treatment capacity is to be achieved by removing the sludge from the anaerobic ponds and clearing the accumulated sludge from the filters. The accumulated sludge containing a large amount of nutrients will be reused, but when it is not possible to reuse, it will be appropriately disposed of in landfills so that there will be no run-off. Flow meters, which are broken, will be replaced.

(2) Facilities for the effluent pumping and final disposal

1) Ensuring treatment capacity

Treatment shall be conducted in maturation ponds to comply with effluent regulations for irrigation use. A treatment capacity sufficient to treat sewage of roughly BOD 96 mg/l to 70 mg/l will be made available in maturation ponds.

2) Securing emergency pump capacity

Measures will be taken so that, even in an emergency when the BNR facilities stop working, sewage will not be directly released into rivers. After the entire sewage influent has been treated in trickling filters, it will be sent to ponds in the farm land. The capacity of the new effluent pump station is 35,000 m^3/day, but the total amount of influent sewage is 41,500 m^3/day. Accordingly, the capacity of the old effluent pump station (potentially 18,000 m^3/day running two pumps) will also be maintained to enable the wastewater to be pumped to the Imbgwa farm. Currently, one of the two pumps is broken and has been removed.

3) Disposal of accumulated sludge in the farm land ponds

All of the trickling filter effluent is being sent to the farm land without final sedimentation tank. Consequently, the sludge produced at the trickling filters is accumulating in the farm land ponds. This sludge will be removed about once every ten years and reused or disposed of in a sludge disposal pit.

(3) Pre-treatment Facilities for the Tilcor Industrial Area

1) Ensuring treatment capacity

A treatment capacity sufficient to treat sewage of roughly BOD 6,000 mg/l to about BOD 1,000 mg/l will be made available in anaerobic ponds.

2) Ensuring pump capacity

The pumping capacity of the existing pump will be improved so that influent to the pump station can be promptly pumped up.

3) Restoration of treatment capacity

Accumulated sludge will be removed from the existing anaerobic ponds to restore the capacity of the existing facilities.

8.1.2 Design Conditions and Design Criteria

(1) Existing Sewage Treatment Works

Influent BOD	: 600 mg/l
Anaerobic pond detention time	: 5 days
Trickling filter solids loading rate	: 0.24 kg/m^3/day

(2) Facilities for the effluent pumping and final disposal

Influent BOD	: 96 mg/l
Target treated sewage BOD	: 70 mg/l

(3) Pre-treatment facilities for the Tilcor Industrial Area

Influent BOD	: 6,000 mg/l
Target treated sewage BOD	: 1,000 mg/l

8.1.3 Treatment Flow and Facility Design

(1) Existing Sewage Treatment Works

The improved treatment flow diagram is shown in Figure 8.1.1. The main facilities will continue to be used at their present scale. The contents of the rehabilitation plan are as follows:

1) Treatment capacity

As discussed in Section 8.1, Chapter 2, Supporting Report, it is possible to achieve a trickling filter effluent BOD of 96 mg/l.

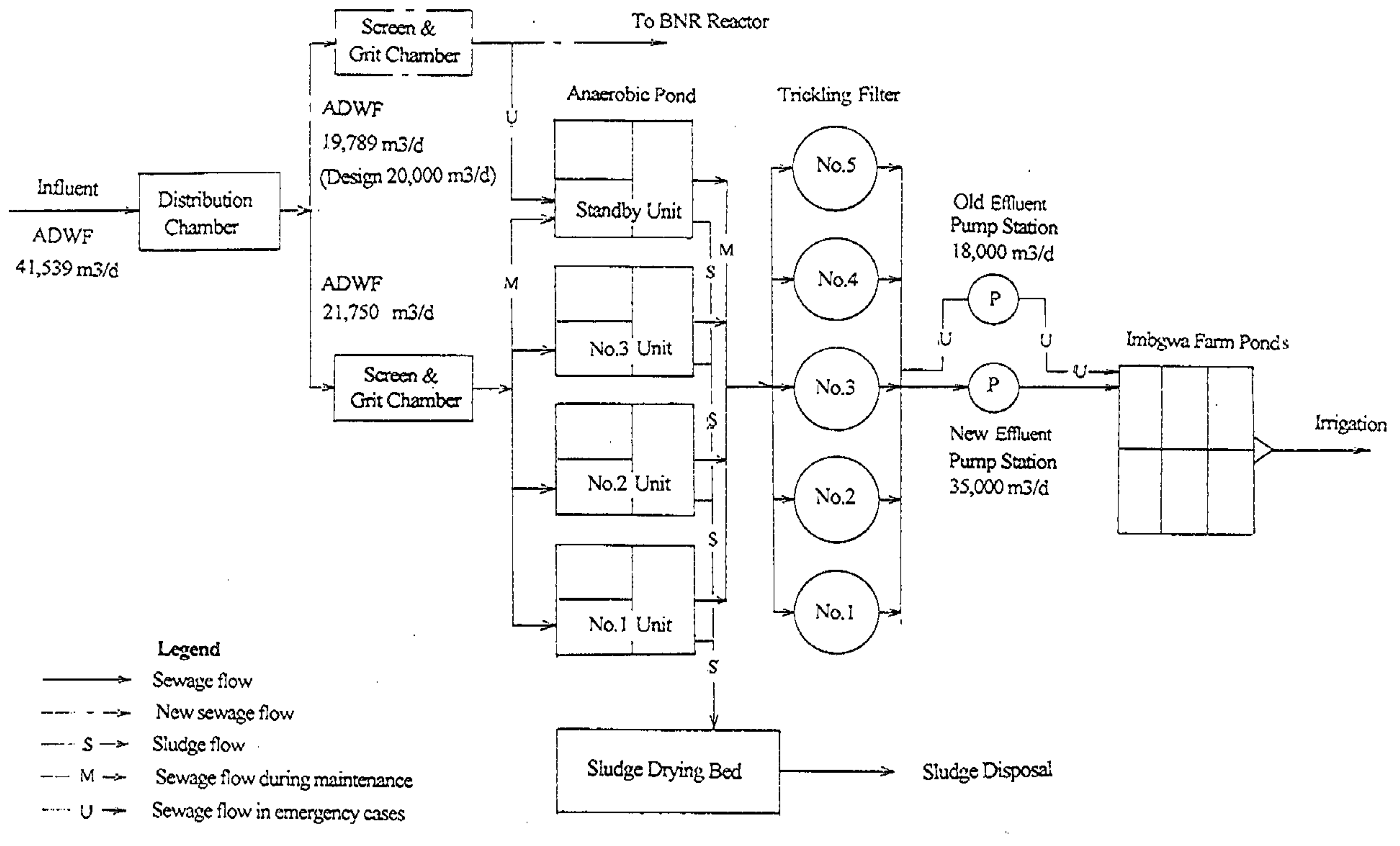


Figure 8.1.1 Flow Diagram of Zengeza Sewage Treatment Works (TF 21,750m3/d)

2) Securing emergency treatment capacity

- Installation of a connecting pipe for emergencies

  For emergencies when the BNR facility shuts down, a connecting pipe (650 mm dia. AC) will be installed from the grit chamber outlet to the old distribution chamber (to the AP).

3) Restoration of treatment capacity and replacement of broken equipment

- Removal of accumulated sludge in the anaerobic ponds (13,600 m^3 in three units)

  The wastewater will be removed from the anaerobic ponds, the accumulated sludge will be dried on the pond and then hauled away for reuse or disposal.

- Removal of accumulated sludge in the filters (1,220 m^3 in five filters)

  Removal of sludge that has accumulated in the filters involves removing the filter media from the filter, cleaning the media and returning it to the filters. The sludge will then be hauled away for disposal.

- Securing a disposal area for the accumulated sludge from existing facilities

  The accumulated sludge from the anaerobic ponds (13,600 m^3) and the trickling filters (1,220 m^3) that cannot be reused will be disposed of appropriately in a landfill. The outline of the sludge disposal is shown in Table 8.1.1.

- Replacement of the flow meters for the Parshall flumes (2 flumes)

- Construction of a fence (700 m)

4) Sludge disposal

- Securing a sludge disposal area

  For the disposal of sludge to be accumulated in the anaerobic ponds, 6,900 m^3/year.

  The sludge will be disposed of appropriately in a landfill.

The locations of the above are shown in Figure 8.1.2 Location of existing facilities rehabilitation.

(2) Facilities for the Effluent Pumping and Final Disposal

The pump that is currently out of order will be repaired. Improvements to be made are as follows:

Table 8.1.1 Accumulated Sludge Disposal

Facilities	Sludge	Place produced	Accumulated sludge volume	Sludge treatment method	Sludge characteristics	Sludge reuse	Sludge disposal method	Sludge disposal area	Remarks
Existing sewage treatment works	Sludge	Anaerobic pond	13,600m^3	Anaerobic digestion	Water content 60%. Sludge contains little organic matter and a lot of inorganic matter. It is not suitable for a soil conditioner.	No reuse	Sludge is planed to be disposed into sludge disposal pit.	Existing STW site	
	Humas sludge (accumulated sludge)	Trickling filter	1,220m^3	—	Water content 60%	No reuse	Sludge is planed to be disposed into sludge disposal pit.	Existing STW site	
Pre-treatment facilities for the Tilcor industrial area	Sludge	Anaerobic pond	2,220m^3	Anaerobic digestion	Water content 60%. Sludge contains little organic matter and a lot of inorganic matter. It is not suitable for a soil conditioner.	No reuse	Sludge is planed to be disposed into sludge disposal pit.	Existing STW site	
Facilities for the effluent pumping and final disposal	Sludge	Maturation pond	—	—	—	—	—	—	—

Note: Total accumulated sludge volume: 13,600 + 1,220 + 2,220 = 17,040m^3

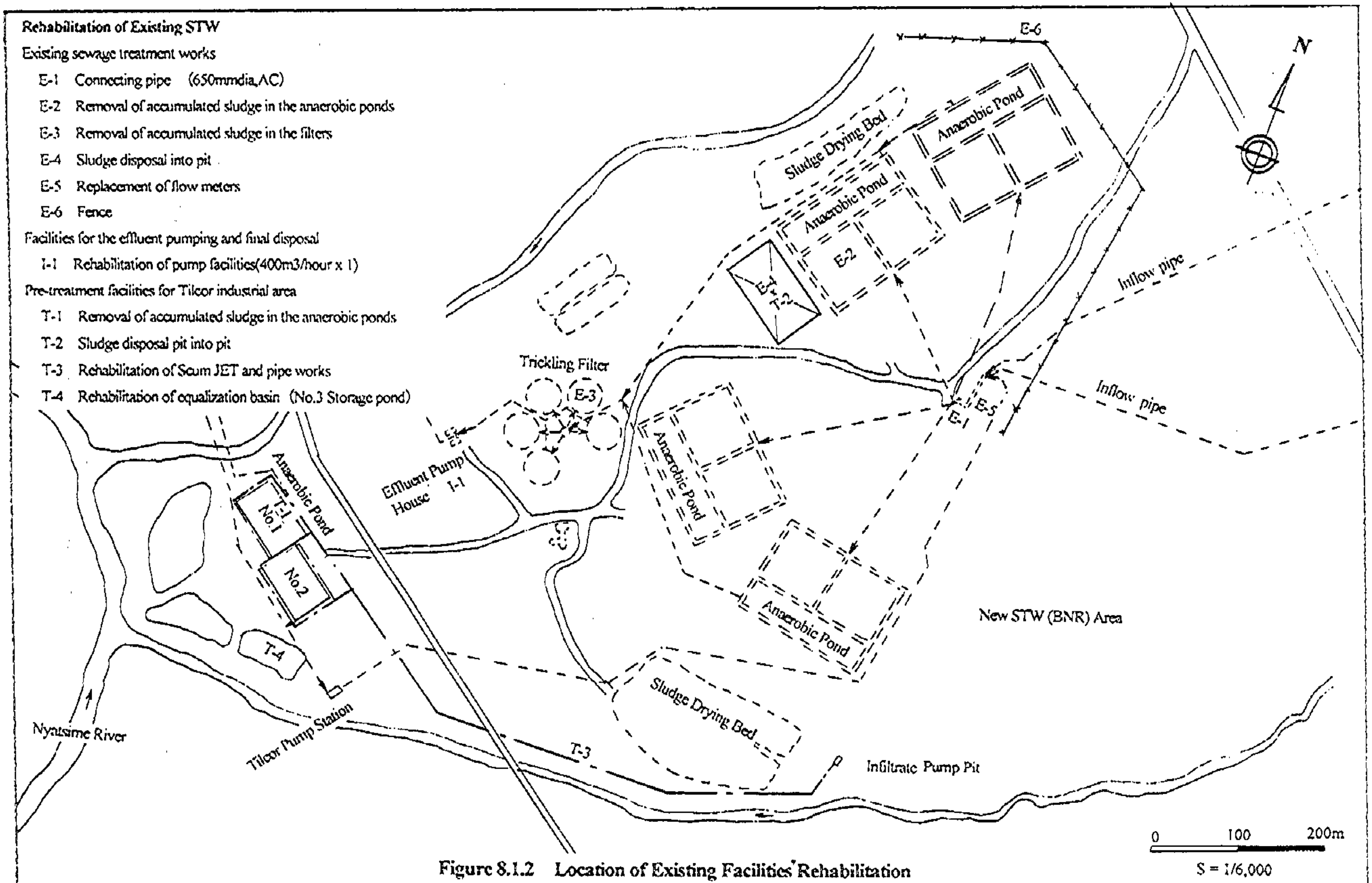


Figure 8.1.2 Location of Existing Facilities' Rehabilitation

1) Ensuring treatment capacity

As discussed in Section 8.1, Chapter 2, Supporting Report, it will be possible to achieve the target treated sewage BOD of 70 mg/l by allowing for a maturation pond retention time of three days.

2) Securing emergency effluent pumping capacity

Rehabilitation of pump facilities

Pump replacement	: 400 m^3/hour x 1 unit
Motor replacement	: 250 HP (185 kW) x 1 unit
Delivery valve replacement	: 1 unit

Improvement of electrical equipment (a new control panel)

3) Disposal of the accumulated sludge in the Imbgwa farm maturation pond

- Construction of a sludge disposal pit

  As a new maturation pond was recently completed and there is not yet much accumulated sludge, there is no need to make a sludge disposal pit in the near future.

(3) Pre-treatment Facilities for the Tilcor Industrial Area

Improvements to be made are as follows:

1) Ensuring treatment capacity

As discussed in Section 8.1, Chapter 2, Supporting Report, it will be possible to achieve roughly the target treated sewage BOD of 1000 mg/l.

2) Ensuring pump capacity

- Rehabilitation of the Tilcor pump station

  Rehabilitation will consist of replacing pumps and other works, details of which are presented in Section 7.

- Rehabilitation of the equalizing pond (No. 3 storage pond)

  The No.3 storage pond will be rehabilitated to function as an equalizing pond and it will be used only during the wet season. An access road will be constructed.

3) Restoring the treatment capacity

- Removal of sludge from the anaerobic ponds

The wastewater will be removed from the ponds, after which the sludge will be dried and removed. The sludge (2,220 m^3) will be reused or disposed of appropriately in a landfill so as to prevent the discharge of nutrients.

- Securing a disposal area for the accumulated sludge from the anaerobic ponds
  The accumulated sludge from the anaerobic ponds (2,220 m^3) will be appropriately disposed of in a landfill.
- Rehabilitation of scum JET (This jets onto the surface of the pond to break up the floating mats of scum.)
  The scum JET facility (1,800 m^3/day) will be rehabilitated. Water will be supplied from a new infiltrate pump pit within the treatment works. The pumps to be used are those built into the pump pit facility. Piping is required from the pit to the anaerobic ponds.

4) Sludge disposal

- Securing a sludge disposal area
  For the disposal of sludge to be accumulated in the anaerobic ponds, 1,400 m^3/year. The sludge will be disposed of appropriately in a landfill.

The position of these items is shown in Figure 8.1.2.

8.2 Expansion of the Zengeza STW

8.2.1 Concept of Facilities Plan

A 20,000 m^3/day expansion of sewage treatment facilities is being planned to supplement the existing sewage treatment capacity, which is expected to be insufficient in the year 2000. An explanation of the expansion process is provided below.

(1) Sewage treatment to comply with effluent regulations for discharge to rivers

To comply with the effluent regulations for discharge into river, nutrients such as organic matter, nitrogen and phosphorus must be removed from the sewage. Potential treatment processes with an emphasis on nutrient removal are shown in Table 8.2.1 (1).

Since conventional activated sludge treatment method is usually used to remove organic matter, a tertiary treatment process shall be added to remove nutrients.

Research has been conducted on a nutrients removal system as a secondary treatment process that is an improvement over the conventional biological treatment method. The addition of chemicals was also developed for further removal of phosphorous.

As a result of comparison among potential treatment processes (see Table 8.2.1 (2)), BNR was selected to meet the purpose, which is already used in the study area; the Firle STW, unit 3 (five-stage Bardenpho process), unit 4 (three-stage Bardenpho process) and the Crowborough STW, unit 3 (five-stage Bardenpho process).

The five-stages Bardenpho process is made up of the following processes:

anaerobic stage → anoxic stage → aerobic stage → anoxic stage → aerobic stage

While, the three-stage Bardenpho process consists of only the first three processes of the five-processes. It is reported that there is hardly any difference in the treatment efficiency between unit 3 and unit 4 of the Firle STW. However, even though their treatment capacity in annual average operation is almost the same, the five-stages Bardenpho process still has an advantage over the three-stages process because, having more elements to control, it offers more flexibility in dealing with varying sewage quality and pollution load. By altering the operating method, it can function as a three-stage process. Therefore, the five-stages process is recommended for this project.

According to the experience in Harare city, any supernatant from the sludge treatment facilities shall not be returned. This is because the load is expected to increase 20 to 40 percent, the supernatant includes strong nutrients, and further treatment cannot be expected because the sewage passed through biological sewage treatment.

Table 8.2.1 (1) general Comparison of nutrient removal treatment methods

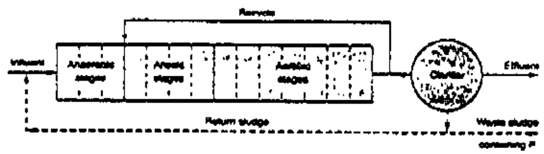
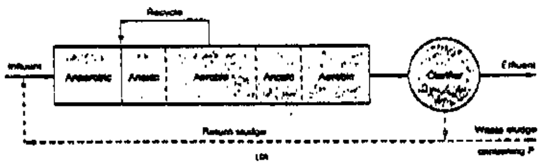
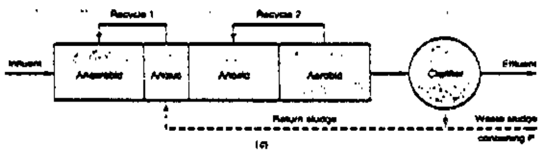
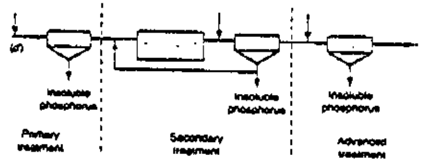
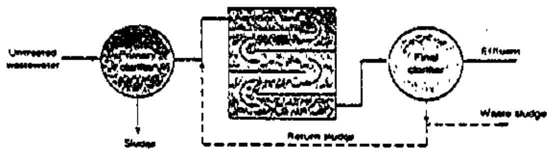
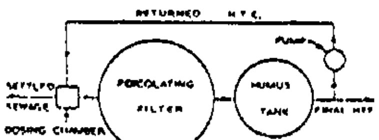
Treatment process		Flow diagram	Method explanation
BNR	A^2/O process		The proprietary A^2/O process is a modification of the A/O process and provides an anoxic zone for denitrification. The detention period in the anoxic zone is approximately one hour. The anoxic zone is deficient in dissolved oxygen, but chemically bound oxygen in the form of nitrate or nitrite is introduced by recycling nitrified mixed liquor from the aerobic section. Effluent phosphorus concentrations of less than 2 mg/L can be expected without effluent filtration.
	Bardenpho process		The proprietary Bardenpho process can be modified for combined nitrogen and phosphorus removal. The staging sequence and recycle method are different from the A^2/O process. The five-stage system provides anaerobic, anoxic, and aerobic stages for phosphorus, nitrogen, and carbon removal. Mixed liquor from the first aerobic zone is recycled to the anoxic zone. The process uses a longer θc (10 to 40 days) than the A^2/O process, which increases the carbon oxidation capability.
	UCT process		The UCT process, developed at the University of Cape Town, is similar to the A^2/O process, with two exceptions. The return activated sludge is recycled to the anoxic stage instead of the anaerobic stage, and the internal recycle is from the anoxic stage to the anaerobic stage. By returning the activated sludge to the anoxic stage, the introduction of nitrate to the anaerobic stage is eliminated, thereby improving the release of phosphorus in the anaerobic stage. The recycle of the anoxic mixed liquor provides for optimal conditions for fermentation uptake in the anaerobic stage.
	Chemical Addition BNR process		The addition of certain chemicals to wastewater produces insoluble or low-solubility salts when combined with phosphate. The principal chemicals used for this purpose are alum, sodium aluminate, ferric chloride or sulfate, and lime.
Conventional Activated Sludge (AS)			A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.
Trickling Filter (TF)			A very coarse filter used to provide secondary treatment of wastewater. A film of aerobic microorganisms on the filter media metabolizes the organic material in the wastewater trickling downward to underdrains; biofilm that sloughs off is subsequently removed by sedimentation.
Wastewater Stabilization Pond (WSP)			A relatively shallow body of wastewater contained in an earthen basin of controlled shape, in which biological oxidation of organic matter is effected by natural or artificially accelerated transfer of oxygen.

Table 8.2.1 (2) General Comparison of nutrient removal treatment methods (cont'd)

Treatment process		Advantage	Disadvantage	Removal ratio			Cost		Remarks
				COD	T-N	T-P	Const-ruction	O&M	
BNR	A^2/O process	Waste sludge has a relatively high phosphorus content (3-5%) and has fertilizer value. Provides better denitrification capability than A/O.	Performance under cold weather operating conditions uncertain. More complex than A/O.	85-95	70-95	70-90	○	○	
BNR	Bardenpho process	Produces least sludge of all biological phosphorus removal systems. Waste sludge has relatively high phosphorus content and has fertilizer value. Total nitrogen is reduced to levels lower than most processes. Alkalinity is returned to the system, thereby reducing or eliminating the need for chemical addition. Has been widely used in South Africa and substantial data are available.	Large internal cycle increases pumping energy and maintenance requirements. Limited experience in U.S. Requirements for chemical addition uncertain. Requires more reactor volume than A^2/O process. High BOD/P ratios are required. Temperature effects on process performance are not well-known.	85-95	70-95	70-90	○	○	In this region, this method has been used since the 1980's, and there are several facilities operating.
BNR	UCT process	Recycle to anoxic zone eliminates nitrate recycle and provides better phosphorus removal environment in the anaerobic zone. Has slightly less reactor volume than Bardenpho process.	No installation in U.S. Large internal cycle increases pumping energy and maintenance requirements. Requirements for chemical addition uncertain. High BOD/P ratios are required. Temperature effects on process performance are not well-known.	85-95	70-95	70-90	○	○	
BNR	Chemical Addition BNR process	Some additional nitrogen removal occurs because of better settling due to chemical addition.	The substantial increase in the mass of sludge to be handled. The O&M problems associated with the handling, storage, and feeding.	85-95	70-95	75-95	○	△	
Conventional Activated Sludge (AS)		A large area is no need.	A lot of energy and mechanical equipment is necessary.	85-90	15-40	20-45	△	△	For removal of such nutrients as nitrogen and phosphorus, tertiary treatment methods are required.
Trickling Filter (TF)		Stable to load fluctuation of sewage. Treatment method is simpler than conventional AS.	Attention shall be paid to flies/odor generation.	75-90	15-40	20-30	○	○	-ditto-
Wastewater Stabilization Pond (WSP)		Easiest in O&M due to Non-equipped process.	A large area is needed.	70-90	-50	-30	△	○	-ditto-

Note: The cost evaluation is made assuming the TF as a standard both in construction and O & M
◎: In terms of cost, it is advantageous. ○: In terms of cost, it is neither advantageous nor disadvantageous. △: In terms of cost, it is disadvantageous.

(2) Independent treatment of domestic sewage

As stated in Section 6.3, the expansion facilities shall not receive sewage mixed with industrial wastewater but treat only domestic sewage. This will ensure a standard treatment level and a supply of reusable sludge that is free of heavy metals.

(3) Sludge treatment for re-use.

To re-use the sludge for land application and to ensure a consistent supply of high-quality sludge, anaerobic digestion process (unheated) will be employed. The sludge will be dried and reduced for easy handling, after which the dried sludge will be carried out and used.

(4) Emergency measures

Facilities with BNR process have relatively small sewage storage capacity. Therefore, when the facilities stop in an emergency, the sewage shall be transferred at the inlet chamber by gravity to existing facilities that have larger storage capacity.

(5) Layout of facilities

The expansion facilities shall be constructed at the east side of the existing facilities. The facilities will be built in steps. The sewage will flow by gravity through the treatment processes utilizing the ground elevation differences between the inlet chamber and Nyatsime River. A laboratory to examine sewage quality will be located north of the facilities to ensure easy access from outside.

(6) Discharging treated sewage into the river

To discharge the treated effluent into the river, outlet facility will be built. An access road to the outlet work will be installed to facilitate the confirmation of discharge and the water sampling.

8.2.2 Design Condition and Design Criteria

(1) Design Conditions.

Design flow, design water quality, inflow pipe and receiving waters, weather conditions and soil conditions are established as follows:

1) Design flow

Average dry weather flow	: 20,000 m^3/day
Peak factor	: 1.5 (Peak dry weather flow)
Peak dry weather flow	: 30,000 m^3/day (= 20,000 x 1.5)
Peak factor	: 3.0 (Peak wet weather flow)
Peak wet weather flow	: 60,000 m^3/day (= 20,000 x 3.0)

Design flow for capacity calculation

Distribution chamber, screen & grit chamber:

Peak wet weather flow = 60,000 m^3/day

In-plant pipe: Peak dry weather flow = 30,000 m^3/day

Primary and Final sedimentation tank, BNR reactor:

Average dry weather flow = 20,000 m^3/day

2) Design Water Quality

There is a little difference between estimated values calculated based on pollutant load per unit activity of the source and measured values. The estimated BOD value is about 600 mg/l. Measured values are mostly over 600 mg/l (Measuring at the STW once every two weeks). The existing Zengeza STW paper reports strong BOD of 1000 to 1200 mg/l. However, the BOD of the 24-hour compositing sample, which was measured once by the study team as a test for the master plan, was weak, at 320 mg/l. To form the right conclusion, additional measurements for wastewater volume and quality were taken several times. The measurements were taken every one to three hours except late at night. The BOD value calculated from the weighted average of the measurements is about 660 mg/l. The value reduces to about 600 when the weak late-night wastewater is added. Both COD and SS may be similar to the BOD in their results. Based on this premise, even though the estimated value differs from the measured value, it will be reasonable to employ the estimated value calculated from pollutant load per unit activity of source.

Influent BOD	: 600 mg/l
Influent COD	: 1,200 mg/l
Influent SS	: 650 mg/l

T-N	: 140 mg/l
T-P	: 15 mg/l
Influent temperature	: 16 - 26 °C
Final effluent COD	: 60 mg/l
Final effluent SS	: 25 mg/l
Final effluent T-N	: 10 mg/l
Final effluent phosphate-P	: 1.0 mg/l

3) Inflow pipe and receiving waters

Inflow pipe diameter and invert level	: 675 mm, +1,407.622 m
Receiving waters and invert level	: Nyatsime River, +1,394.000 m

4) Weather Conditions

Mean temperature	: Hottest month: 22 °C, Coldest month: 14 °C
Annual rainfall	: 820 mm

5) Soil Conditions

Soil texture : decomposed granite exposed

Ground water level : Not obvious (considering there is no ground water recharge source near-by, it is difficult to state the existance of permanent ground water table, especially during dry season. However, there is a posibility of temporary ground water table during the rainy season)

(2) Design Criteria

The design criteria employed are basically those provided in Zimbabwe's Sanitation Manual, Design Procedures 5, hereinafter called the Z Manual. When they do not follow the Z Manual, they will be decided by referring to either South Africa's Operators Handbook, Sewage Purification, issued by the Institute of Water Pollution Control (Southern African Branch), hereinafter called the SA manual, or the Japanese Sewage Facilities Design Criteria, hereinafter called the Japan Manual. The design criteria are shown below.

1) Distribution chamber

Velocity : > 0.6 m/sec at minimum daily flow

2) Screen & grit chamber

Velocity between the bars : > 0.3 m/sec at minimum daily flow,

< 0.8 m/sec at maximum daily flow

3) Primary sedimentation tank

Type : Dortmund tank

Surface loading : 1.2 m^3/m^2/day (= 28.8 m^3/m^2/day)

Retention time : 1.5 hours

4) BNR reactor

Depth of basin : 4.5m

MLSS(Mixed Liquor Suspended Solids) : 4,000-5,000 mg/l

SRT(Solid Retention Time) : 15-25 days

Internal recycle ratio : 400%

Return activated sludge ratio : 50-100 % of influent

5) Final sedimentation tank

Surface loading rate : 8 m^3/m^2/day

6) Outlet work

Velocity : < 1.0 m/sec at peak dry weather flow

7) Sludge thickener

Type : Dortmund tank

Solids matter loading rate : 60 kg/ m^2/day (Source: Japanese Criteria)

8) Anaerobic digestion tank

Type : Unheated with recirculation

Digestion period : 60 days

9) Sludge drying bed

Drying period : 7 days

10) Sludge storage yard

Storage period : 2 months

8.2.3 Treatment Flow and Facility Design

(1) Treatment Process

The basic treatment process of the sewage is as follows:

Influent → Screen and grit chamber → PST → BNR → FST → Nyatsime River

There are two lines of sludge treatment: PST sludge and waste activated sludge (WAS). Their treatment process is as follows:

Raw Sludge(PST) → Anaerobic Digestion Tank → Sludge Drying Bed → Sludge Storage Yard → Land Application

WAS → Sludge Thickener → Sludge Drying Bed → Sludge Storage Yard → Sludge Disposal or re-use

The whole treatment flow, including sewage treatment and sludge treatment, is shown in Figure 8.2.1.

(2) Facilities Plan

The size and capacity of each facility is decided based on the calculations in Section 8.2, Chapter 2, Supporting Report. The scale and capacity for major facilities are shown in Table 8.2.2. Figures 8.2.2 to 8.2.15 presents a layout of the Zengeza sewage treatment works (capacity: 41,750 m^3/day), a layout of the Zengeza sewage treatment works (BNR 20,000 m^3/day) and outline plans for each facility.

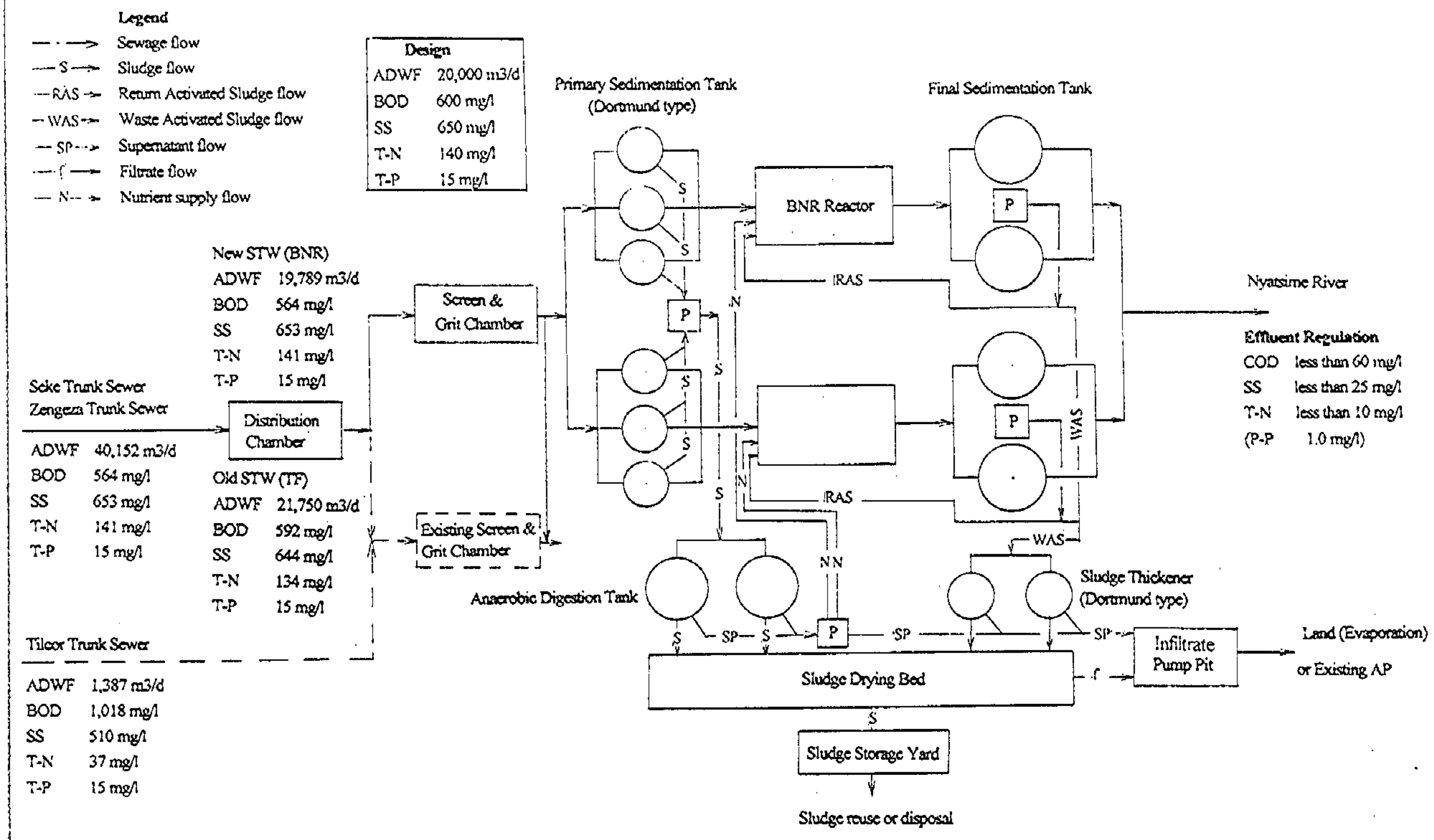
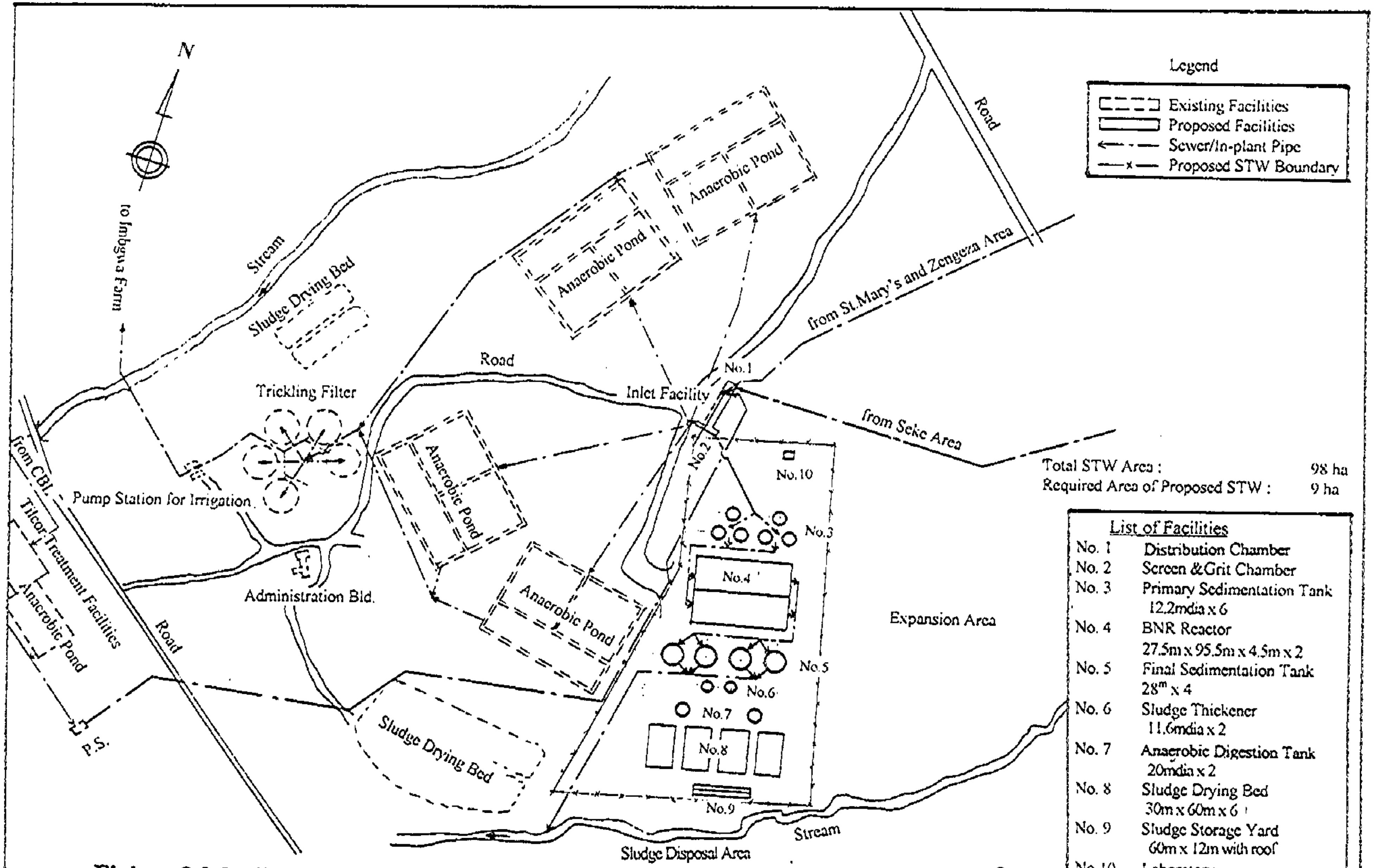


Figure 8.2.1 Flow Diagram of Zengeza Sewage Treatment Works (BNR 20,000m3/d)

Table 8.2.2 List of Zengeza Sewage Treatment Works'(BNR 20,000 m^3/day) Facilities

Facilities	Type Tank size	Tank area Tank volume	Remarks
Distribution chamber	Trunk sewer 675mm, 675mm Width 1.8m Length 4.0m Height 1.16m		
Screen & grit chamber	Coarse screen (screen gap 40mm) Width 1.2m Height 1.2m Number 2 nos. Fine screen (screen gap 14mm) Width 0.9m Height 1.24m Number 2 nos. Parshall flume Capacity 30,000m3/day Number 2 nos. Grit chamber Width 1.8m Length 6.0m Depth 7.6m Number 2 nos.		
Primary sedimentation tank	Type Dortmund tank Diameter 12.2m Depth 11.5m (1.8m + 9.7m) Number 6 nos.	A = 177 x 6 = 702 m^2	
BNR reactor	Width 27.5m Length 95.5m Depth 4.5m Number 2 nos. Aerator 45kW x 14, 22kW x 2 Mixer 3.7kW x 10	A = 2,600 x 2 = 5,200m^2 V = 11,700 x 2 = 23,400m^3	
Final sedimentation tank	Type Clarifier Diameter 28.0m Depth 3.5m Number 4 nos.	A = 531 x 4 = 2,120m^2	
Outlet work	Width 1.0 - 3.0m Length 5m Number 1 no.		
Sludge thickener	Type Dortmud tank Diameter 11.6m Depth 11.3m (1.8m + 9.5m) Number 2 nos.		
Anaerobic digestion tank	Type No - heating with recirculation Diameter 20m Depth 19.5m (10.0m + 9.5m) Number 2 nos.	V = 4,190 x 2 = 8,380m^3	
Sludge drying bed	Width 30m Length 60m Number 6 nos.	A = 1,800 x 6 = 10,800m^2	
Sludge storage yard	Yard with roof Width 12m Length 60m Number 1 no.	A = 720m^2	
Laboratory	Laboratory 6m x 12m Staff office 6m x 6m Assistant room 4.5m x 9m Storage room 6m x 9m Others Total 12m x 24m	A = 72 m^2 A = 36 m^2 A = 41 m^2 A = 54 m^2 A = 87 m^2 Total A = 290 m^2	



Figiure 8.2.2 Layout of Zengeza Sewage Treatment Works (Capacity : 41,750 m^3/day)

S = 1/6,000

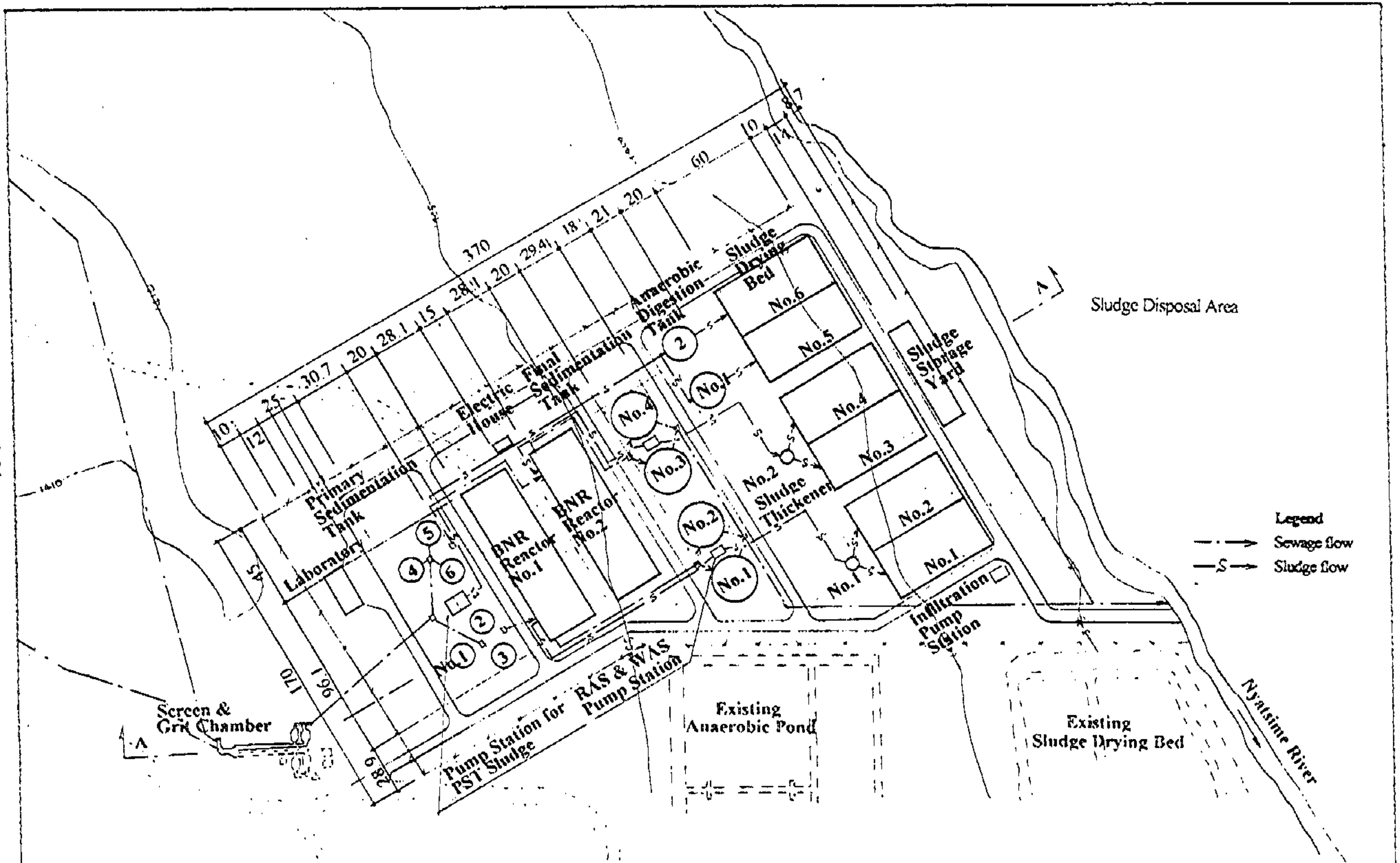


Figure 8.2.3 Layout of Zengeza Sewage Treatment Works (BNR, 20,000 m^3/day) S = 1/3,000

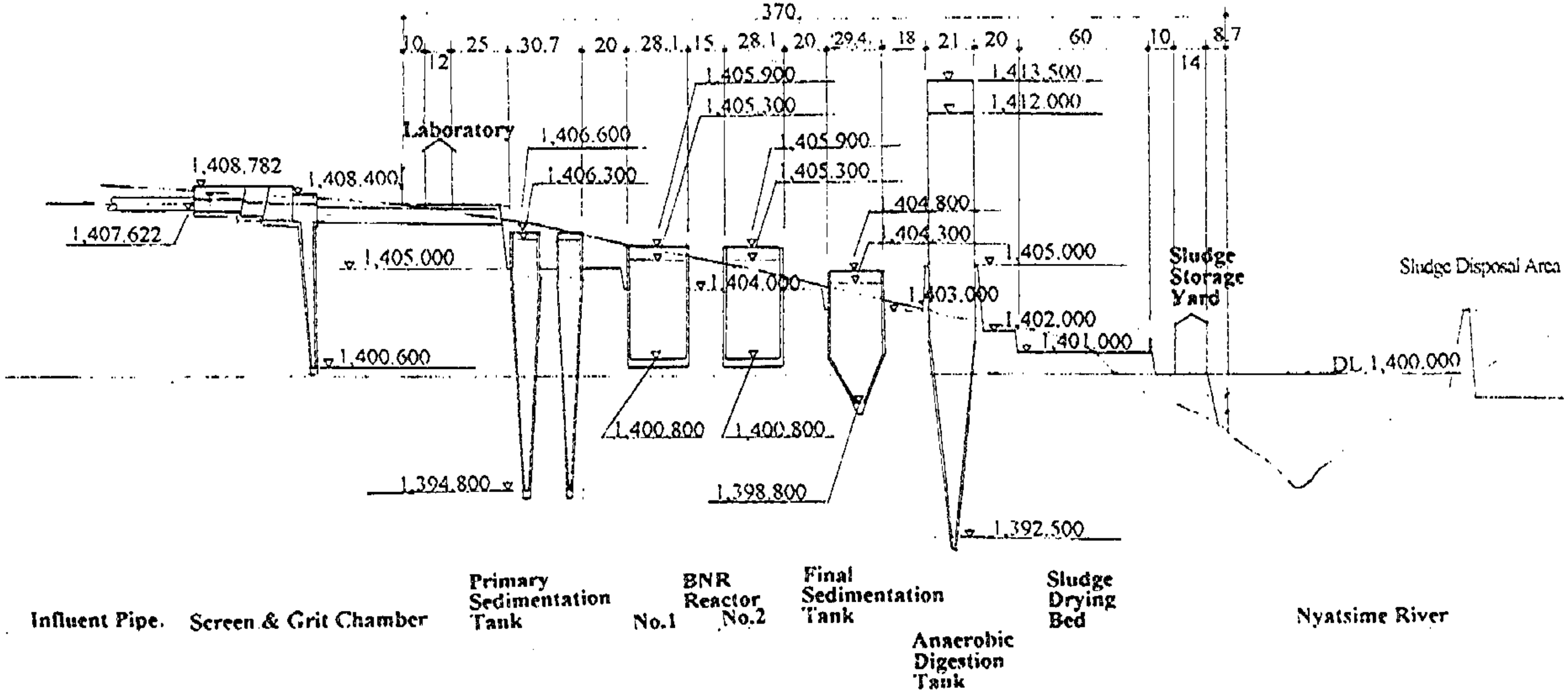


Figure 8.2.4 Section A - A of Zengeza Sewage Treatment Works (BNR, 20,000 m^3/day) H : S = 1/3,000 V : S = 1/300

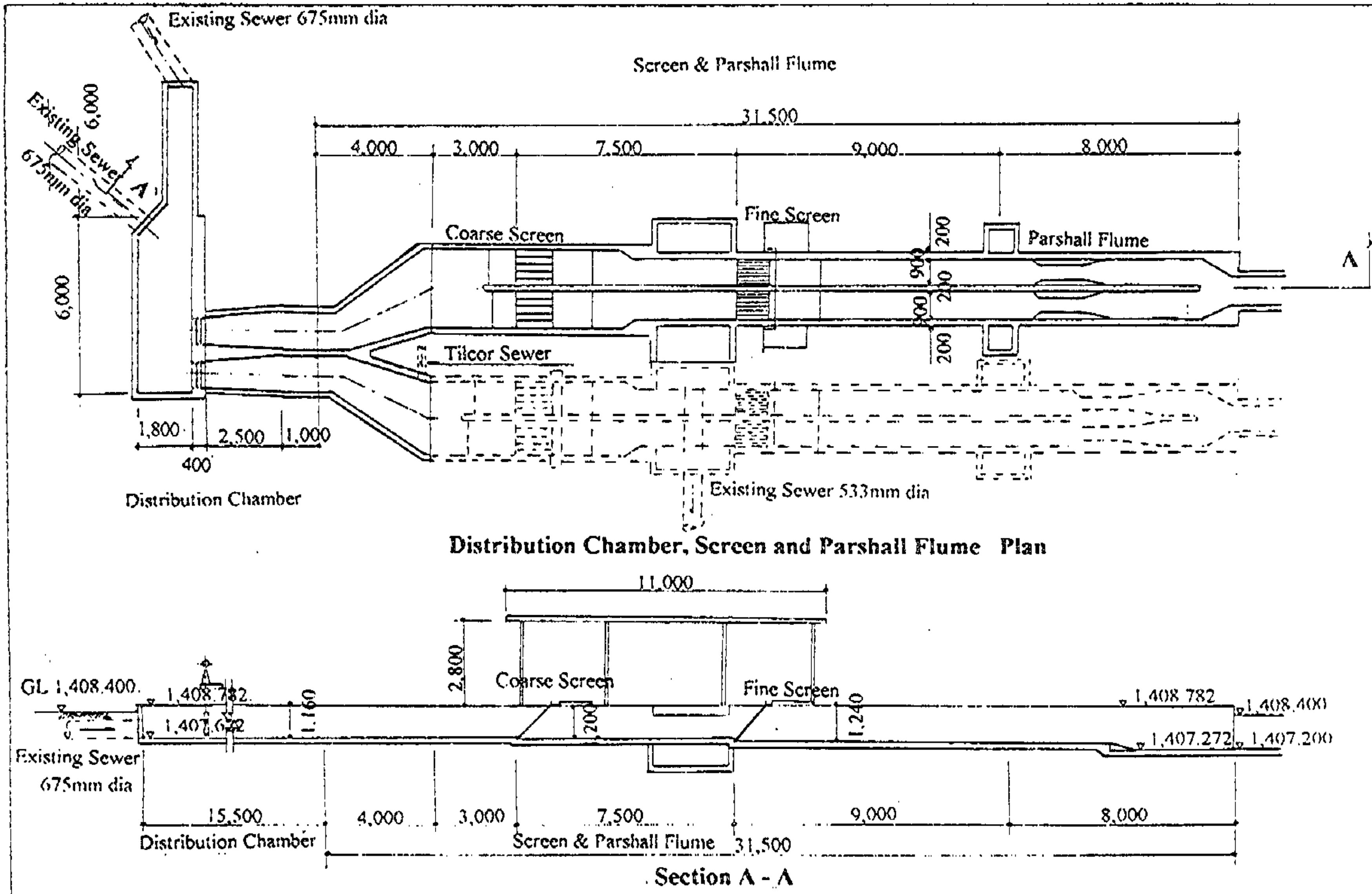


Figure 8.2.5 Distribution Chamber, Screen and Parshall Flume Plan & Section S = 1/200

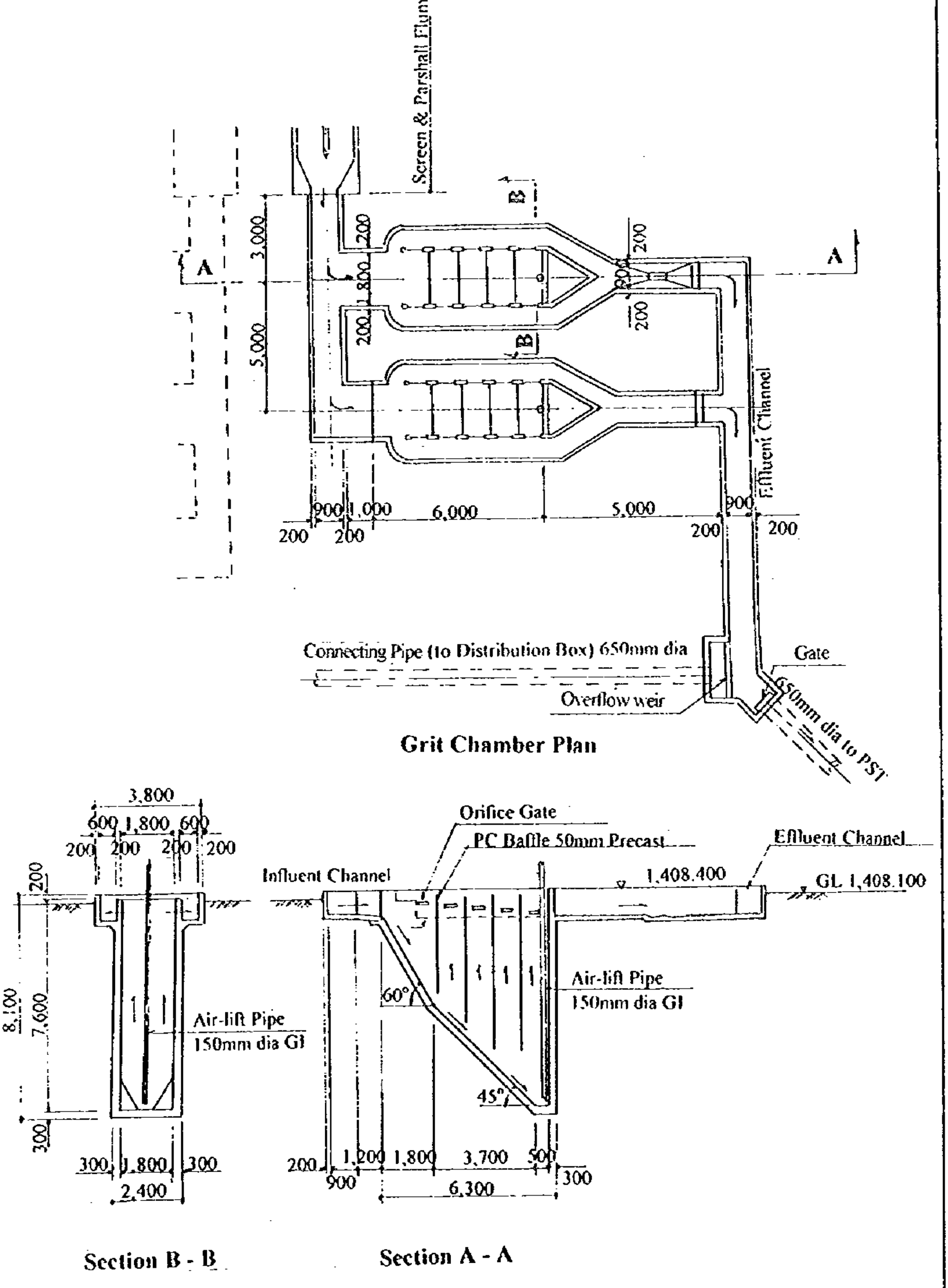
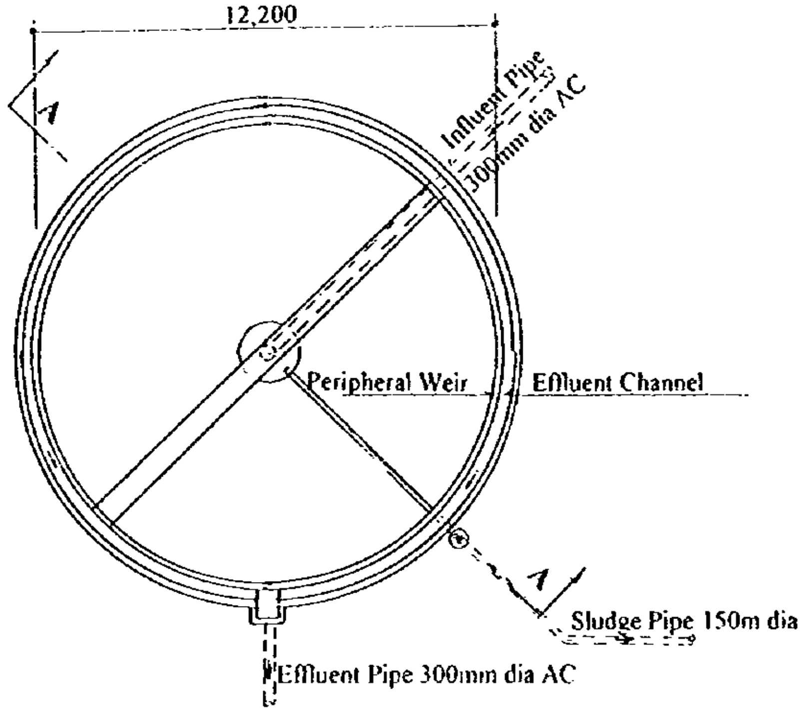
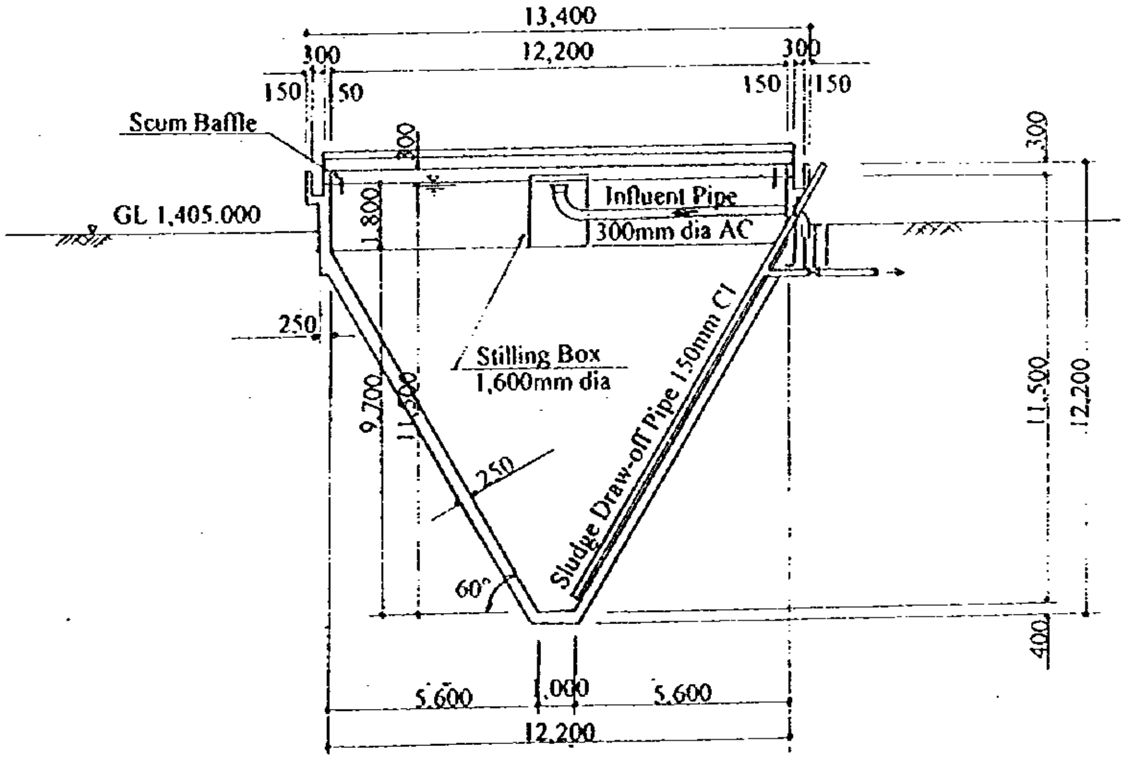


Figure 8.2.6 Grit Chamber Plan & Section S = 1/200

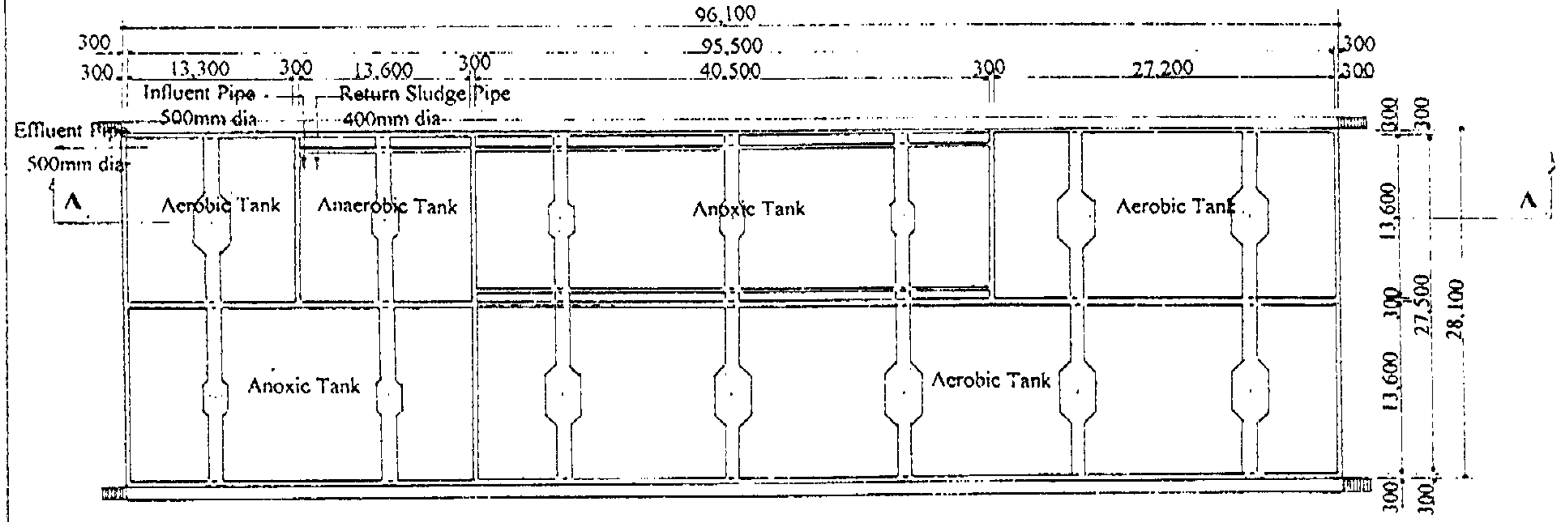


Primary Sedimentation Tank Plan

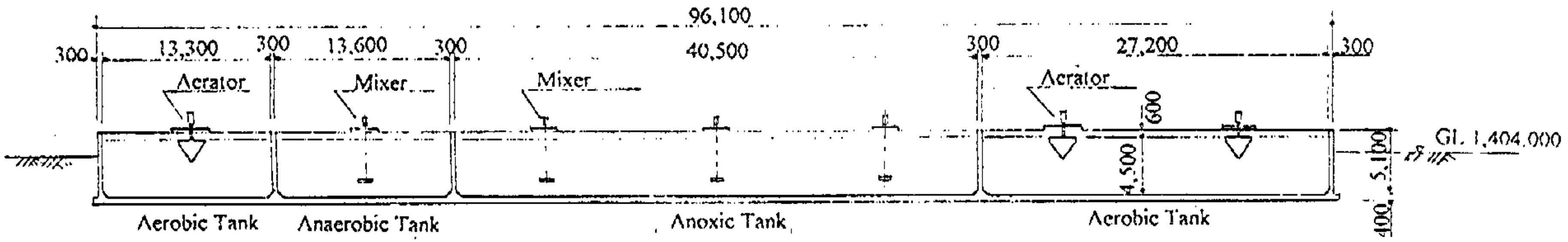


Section A - A

Figure 8.2.7 Primary Sedimentation Tank Plan & Section S = 1/200

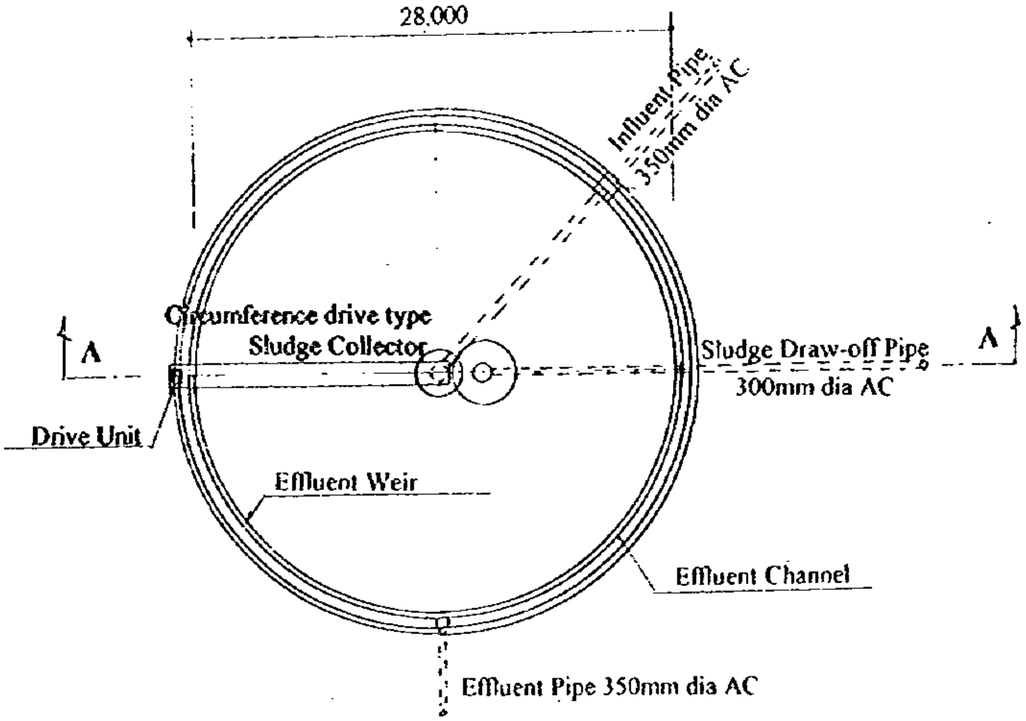


BNR Reactor Plan

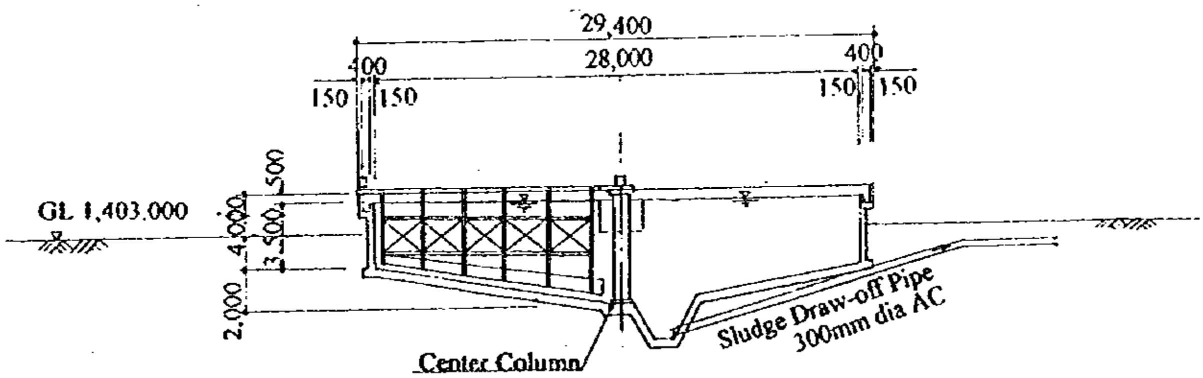


Section A - A

Figure 8.2.8 BNR Reactor Plan & Section S = 1/500

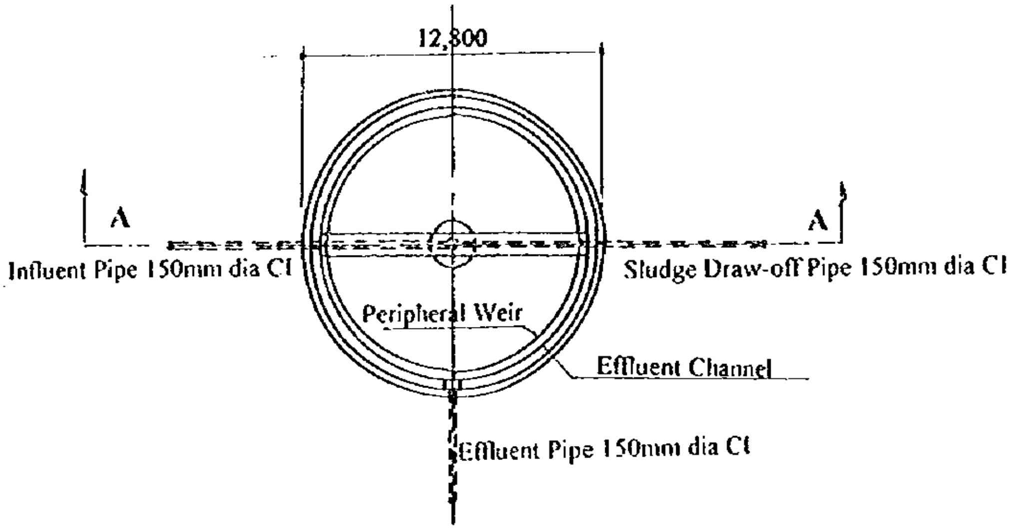


Final Sedimentation Tank Plan

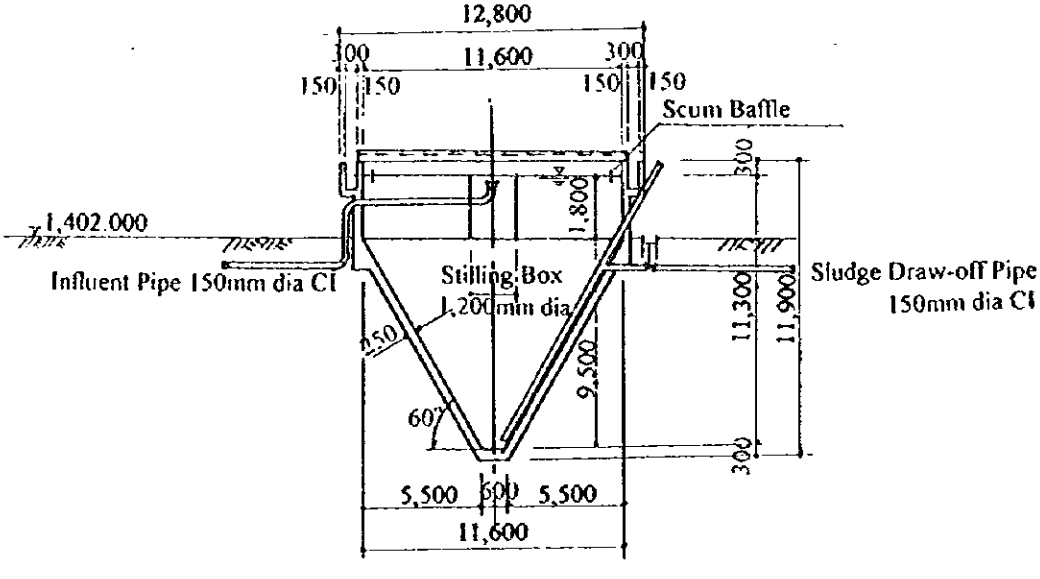


Section A - A

Figure 8.2.9 Final Sedimentation Tank Plan & Section S = 1/400

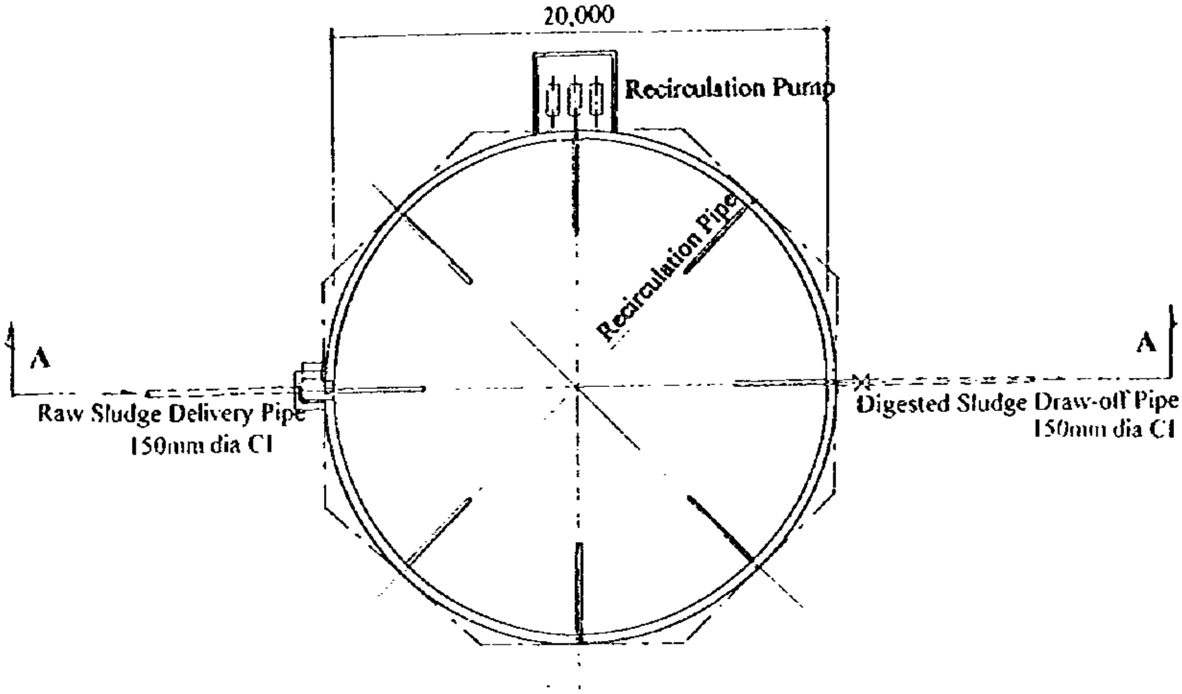


Sludge Thickener Plan

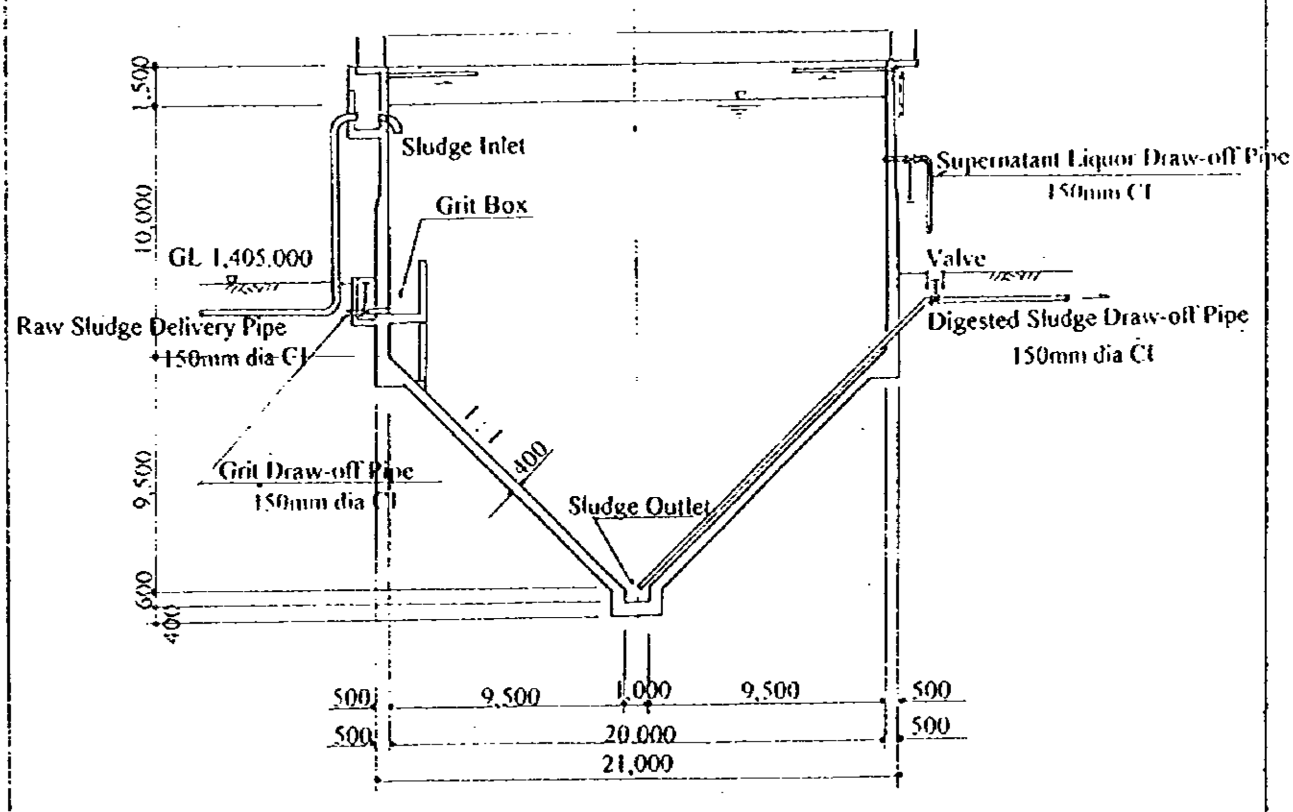


Section A - A

Figure 8.2.10 Sludge Thickener Plan & Section S = 1/200

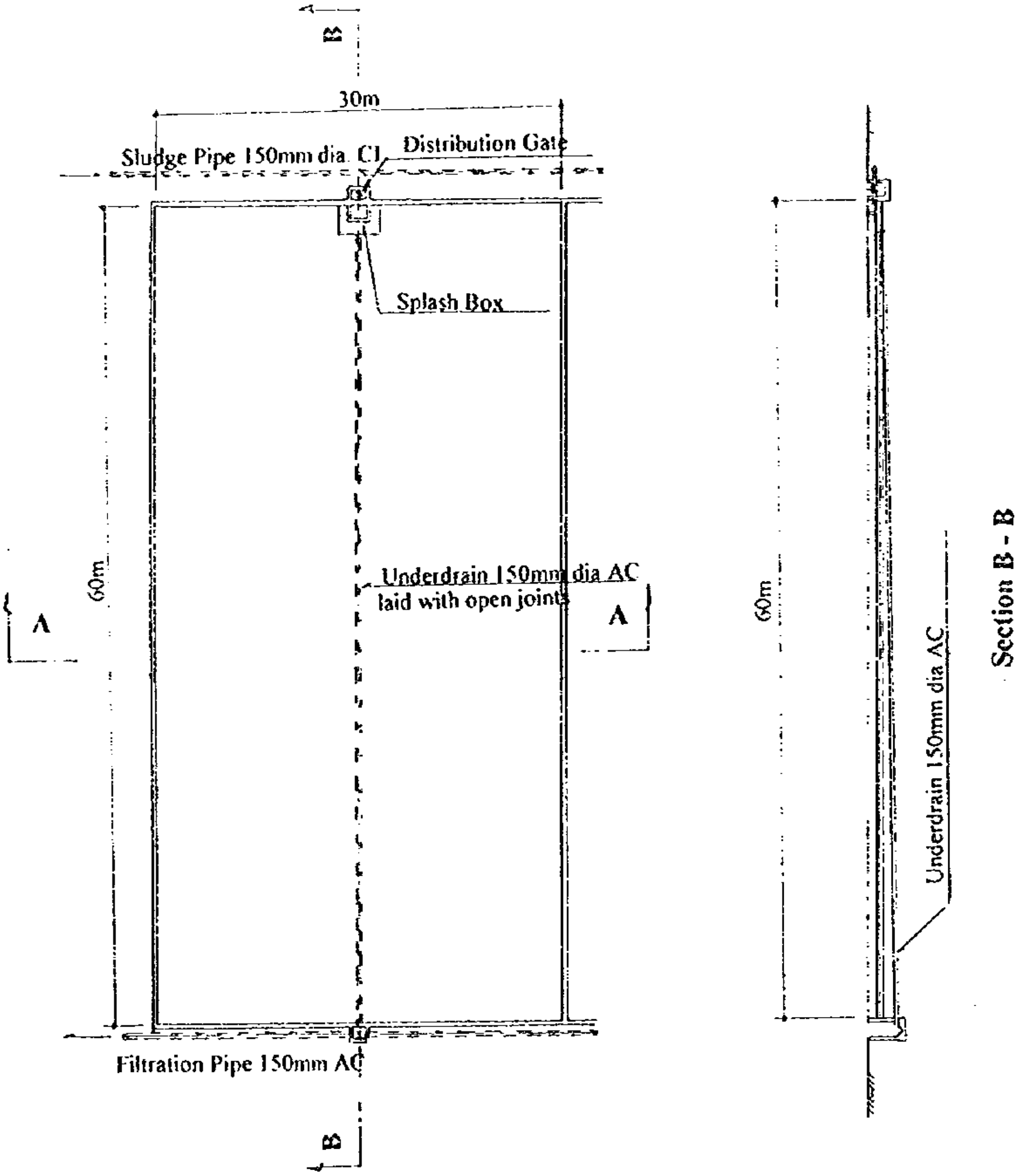


Anaerobic Digestion Tank Plan

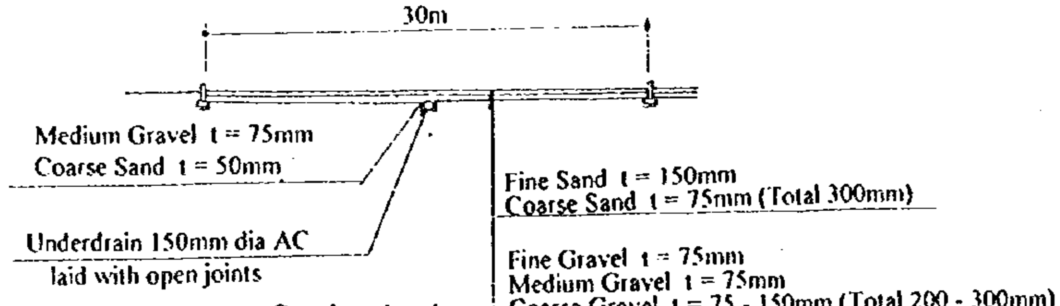


Section A - A

Figure 8.2.11 Anaerobic Digestion Tank Plan & Section S = 1/300



Sludge Drying Bed Plan



Section A - A

Figure 8.2.12 Sludge Drying Bed Plan & Section S = 1/500

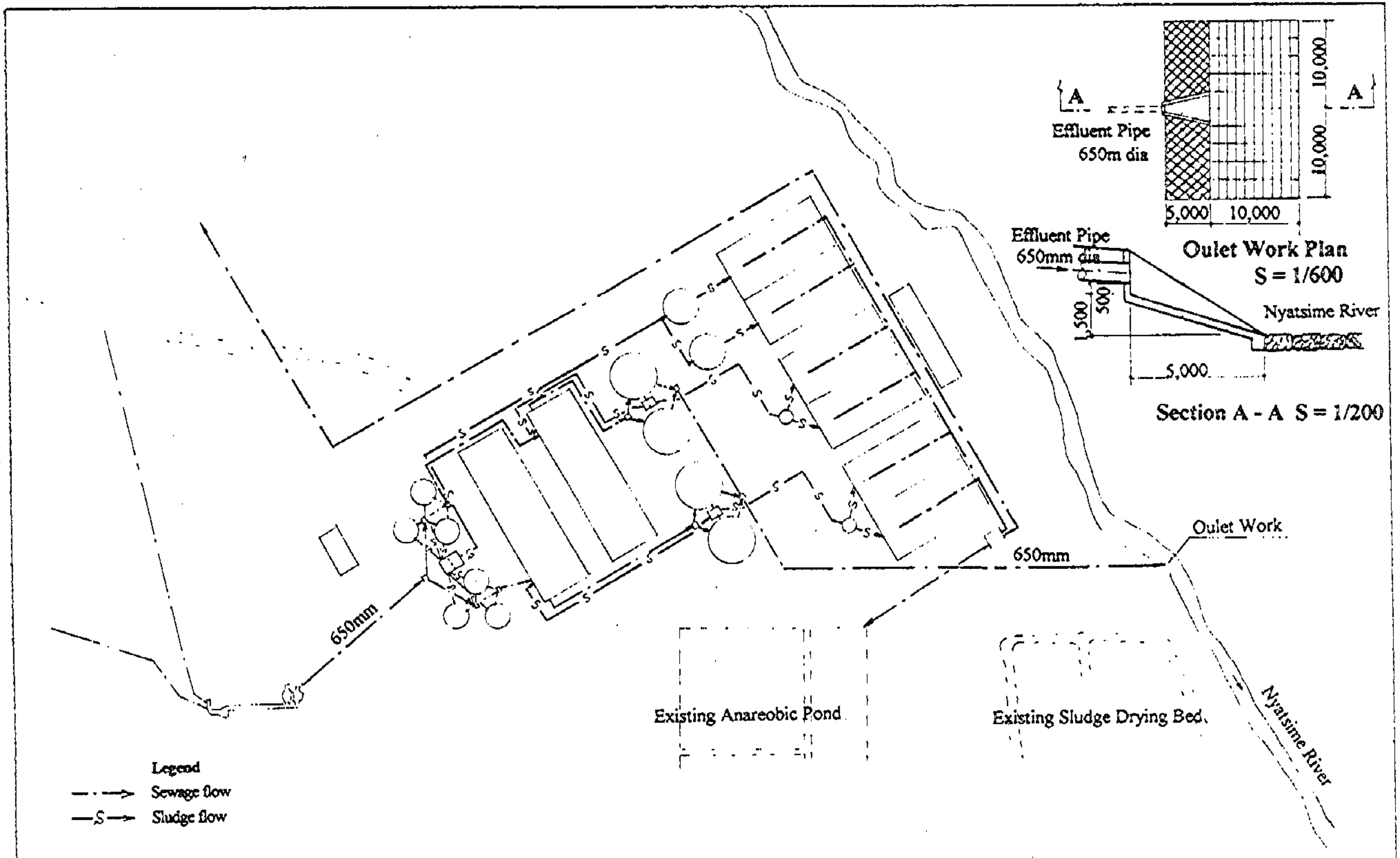
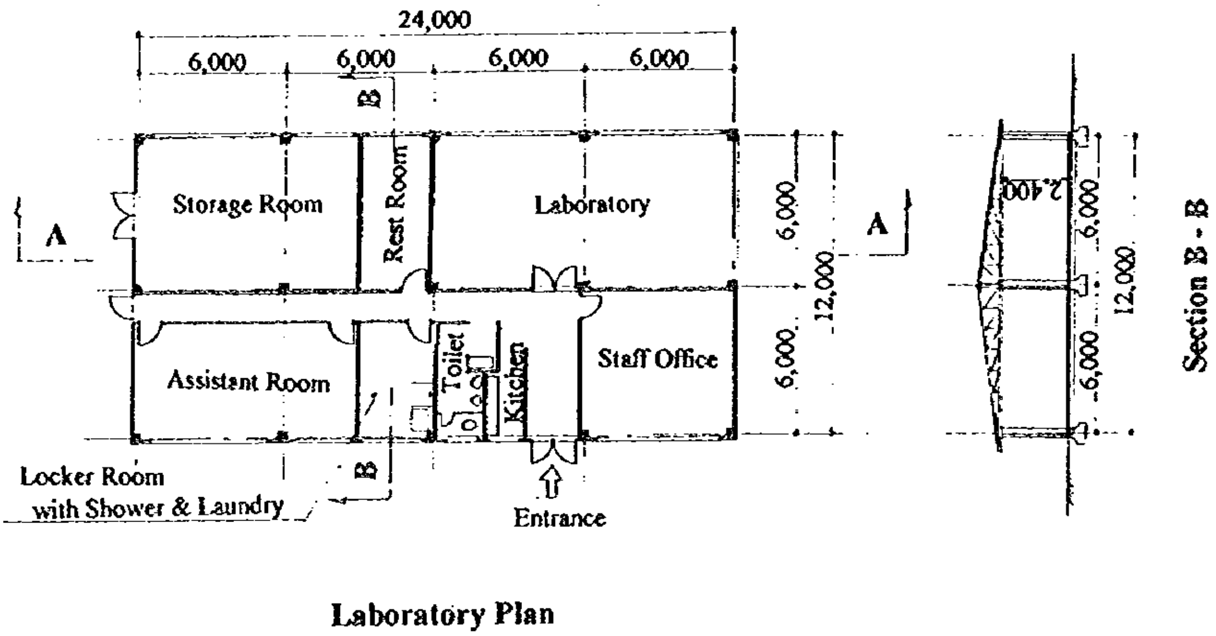


Figure 8.2.13 Layout of Inplant Pipe and Outlet Works Plan & Section S = 1/3,000



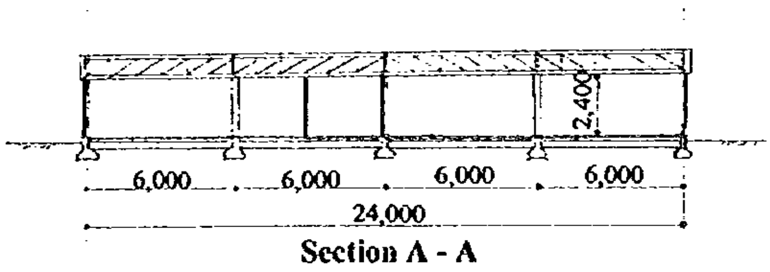
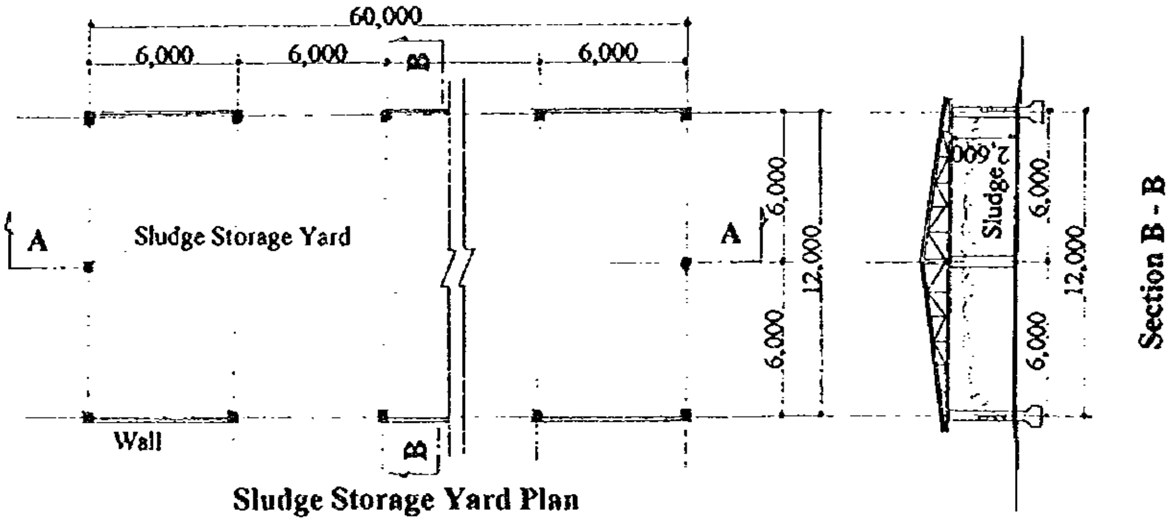


Figure 8.2.14
Laboratory
Plan & Section
S = 1/300



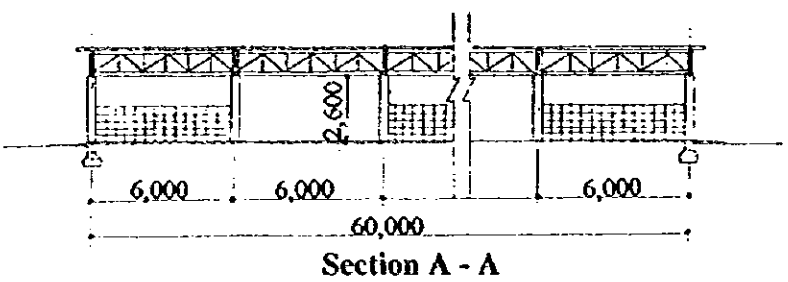


Figure 8.2.15
Sludge Storage Yard
Plan & Section
S = 1/300

CHAPTER 9

CONSTRUCTION PLAN, AND OPERATION AND MAINTENANCE

CHAPTER 9 CONSTRUCTION PLAN, AND OPERATION AND MAINTENANCE

9.1 Construction Plan

9.1.1 Conditions for Construction of Sewerage Facilities

A construction plan of the project is prepared on the basis of the preliminary design, giving an outline of possible procedures, construction sequences, methods and types of plant and equipment to implement the construction works.

The construction works will be divided into three works as follows:

- Sewer reticulation comprising of sewer pipes, new pump station at St. Marry's and rehabilitation of pump equipment.
- Expansion of sewage treatment works.
- Rehabilitation works for the existing sewage treatment works, irrigation facilities, pre-treatment facilities for Tilcor industrial area and sludge disposal pit.

(1) Project Site

The project site is situated in the Municipality of Chitungwiza and located at about 30 km from the City of Harare. The asphalt pavement road of dual carriage way is prepared and the access from Harare is Seke road - Chitungwiza road - the site. It takes approximately 30 minutes drive.

The sewer reticulation sites are located along the previous sewer pipeline and at the existing pump stations. These sites are located in the residential area.

The expansion of sewage treatment works are planned to be located adjacent to the existing sewage works.

The rehabilitation works will be made in the existing sewage work sites and/or will be considered to construct at an appropriate land which is owned by the Municipality of Chitungwiza.

All the construction site is situated on a flat land or a gentle slope area, and easy access can be made. In a view point of site conditions, the preparatory works are assumed to be easy construction.

(2) Access to the Site

Each project site is easy access from the Municipality Road and the existing residential roads. The new sewer pipeline is planned to install along the existing pipeline and situated in the open area which is located along the Chitungwiza Road. The access road from the Municipality Road will be required and also prepared along the pipeline for trench excavation and pipe installation works.

The access to the expansion of sewage treatment works is no problem and the existing access road is available.

(3) Workable Day

The construction works will be carried out considering with a wet and a dry season. From the meteorological data of Harare City monitored at Belvedere Station, "Spring" is a hot and dry from September to November, "Summer" is classified as the rainy season with hot and wet from December to April and the remaining months are called as "Winter".

The workable days are assumed to be 21 days per month in average, as a result of analysis of suspended days due to rainfall, Saturday, Sunday and holiday. The workable days are listed in Table 9.1.1, and the daily rainfall data from July 1991 to June 1996 are shown in Table 9.1.1, Section 9.1, Chapter 2, Supporting Report.

(4) Availability of Local Contractors

The sewerage works including civil works, mechanical and electrical works have been constructed by registered Zimbabwe contractors for the past projects and undergoing projects.

The registered contractors of CIFOZ (the Construction Industry Federation of Zimbabwe, 1915-1995,80 years) is shown in Table 9.1.2, Section 9.1, Chapter 2, Supporting Report. The general contractors of building of category A is 39 companies and the general contractors of civil of category A is 32 companies. Except above companies, there are

Table 9.1.1 Rainfall Data and Workable Day

1. Number of Rainfall Days

Harare Belvedere Rain Gauge Station
July 1991 - June 1996, 5 years

Rainfall(mm)	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-3mm	4.4	3.0	3.0	1.6	0.4	0.0	0.2	0.6	0.2	2.8	4.6	5.6
3-5mm	1.4	1.8	1.4	0.2	0.4	0.2	0.0	0.2	0.0	0.4	1.0	2.2
5-10mm	3.2	2.2	1.4	0.0	0.2	0.0	0.0	0.0	0.2	1.4	1.0	2.8
10-20mm	3.0	1.4	1.2	0.8	0.4	0.0	0.0	0.0	0.0	1.0	1.4	2.8
20-30mm	1.2	2.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.2	0.6	2.4
30-50mm	1.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	1.0
Over 50mm	1.4	0.4	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2. Suspended Days due to Rainfall

Rainfall(mm)	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-3mm(0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3-5mm(0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-10mm(0.5)	1.6	1.1	0.7	0.0	0.1	0.0	0.0	0.0	0.1	0.7	0.5	1.4
10-20mm(1.0)	3.0	1.4	1.2	0.8	0.4	0.0	0.0	0.0	0.0	1.0	1.4	2.8
20-30mm(1.0)	1.2	2.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.2	0.6	2.4
30-50mm(1.5)	1.5	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	1.5
Over 50mm(2.0)	0.8	0.8	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.1	6.5	3.9	1.2	1.3	0.0	0.0	0.0	0.1	2.2	2.8	8.1

3. Workable Day

	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Holiday	4.0	0.0	0.0	4.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	7.0
Saturday	2.0	2.0	3.0	2.0	3.0	2.0	2.0	3.0	2.0	2.0	3.0	2.0
Sunday	4.0	4.0	5.0	4.0	4.0	5.0	4.0	5.0	4.0	4.0	4.0	4.0
Rainfall(50%)	4.0	3.0	2.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	2.0	4.0
Total	14.0	9.0	10.0	11.0	10.0	7.0	6.0	10.0	6.0	7.0	9.0	17.0
Calender Day	31.0	28.0	31.0	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	31.0
Working day	17.0	19.0	21.0	19.0	21.0	23.0	25.0	21.0	24.0	24.0	21.0	14.0
											Total	249.0

Workable Day : 249days/12month = 21days/month

Remarks : From November to March, the rainfall days are overlapped with holidy,Saturday and Sunday.
2-Saturdays are working day.
Christmas and New Year are necessary for the continuous vacation.

Holiday in Zimbabwe

New Year's Day	Jan.1
Good Friday	Apr.5
Easter Saturday	Apr.6
Easter Monday	Apr.8
Independent day	Apr.18
Worker's day	May.1
African Day	May.25
Heroes day	Aug.11
Defense Forces Day	Aug.12
Christmas Day	Dec.25
Public Holiday	Dec.26

many subcontractors registered in CIFOZ.

As for the mechanical and electrical works for the sewerage works, the Zimbabwe general contractors, supply/installation contractors and special sewage contractors can carry out the works for pumps, valves, pipes, sewage equipment and so on. The capability of implementing the sewage works seems to be quite sufficient.

For the actual implementation of the project, the main contractor can employ and manage several subcontractors and special contractor such as earthmoving, rock blasting, pavement, ready mixed concrete, building/housing, fencing, piping, steel structure, concrete and formwork, reinforcement, roofing,etc.

(5) Hiring Construction Equipment

There are many general contractors and subcontractors in Zimbabwe, especially in Harare. These contractors are also hiring companies simultaneously. According to the construction works in Zimbabwe, the main contractor will commonly employ a special subcontractor or hire the construction equipment from the hiring companies. The construction equipment to be hired is bulldozer, excavator, loader, dump truck, roller, crane, truck, water sprinkler, and so on.

Resale market of the construction equipment and vehicles is also functioned in Zimbabwe. There are many secondhand equipment in the resale market.

The minimum number of construction equipment will be delivered to the project from foreign country, since the available equipment will be hired in Zimbabwe as much as possible.

(6) Labor Source

In case the subcontractors and special contractors are employed, the labor is supplied and managed by these contractors. Operators and skilled labors are employed through the subcontractors and special contractors, and common labor will be employed from the project area.

9.1.2 Construction Material and Equipment

Almost construction materials are produced and supplied in Zimbabwe. The imported materials are also available from the local market. There are many manufacturers, suppliers and sales agents in Harare City and Bulawayo City. The materials will be delivered from several industrial area located around Harare City. One cement company and several quarry companies are exist near Harare city and the subcontractors are also in the industrial areas. Ready mixed concrete is recently used for the building works and civil works, and the batching and mixing plant are installed in the industrial areas.

Local products and imported materials and equipment are below. However, the imported material and equipment are procured through sales agents and suppliers.

(1) Local material

Cement, stone, aggregate, sand, crusher-run, timber, plywood, ready mixed concrete, reinforcement, structural steel, AC pipe, Hume pipe, steel pipe, CI pipe, vale and fitting, gate, screen, PVC pipe(up to 250mm), manhole, road kerb, concrete block, brick, AC roof and tile, precast building wall, fence, road/pedestrian gate, wire, nail, gabion mesh, explosive, and so on.

(2) Imported material

Construction equipment, track crane, vehicle, motorcycle, computer, pump, motor, transformer, switchgear, sewage treatment equipment, gasoline, diesel, lubricant, explosive, detonator, laboratory equipment, flow meter, bit, rod, admixture, waterstop, scaffolding, metal form, guardrail, asphalt, emulsion, and so on.

9.1.3 Construction Method of Sewage Facilities

(1) Construction Schedule

The target date for the commissioning of sewage treatment works is planned to be on September 1999. After the completion of Feasibility Study on March 1997, about one year is required for the financial arrangement, detailed design, tendering and contract award. The construction works will be performed for 1.5 years (18 months) from April

1998 to September 1999.

The overall construction schedule is shown in Figure 9.1.1. The detailed construction schedule is shown in Figure 9.1.1, Section 9.1, Chapter 2, Supporting Report.

(2) Sewer Reticulation

1) Sewer

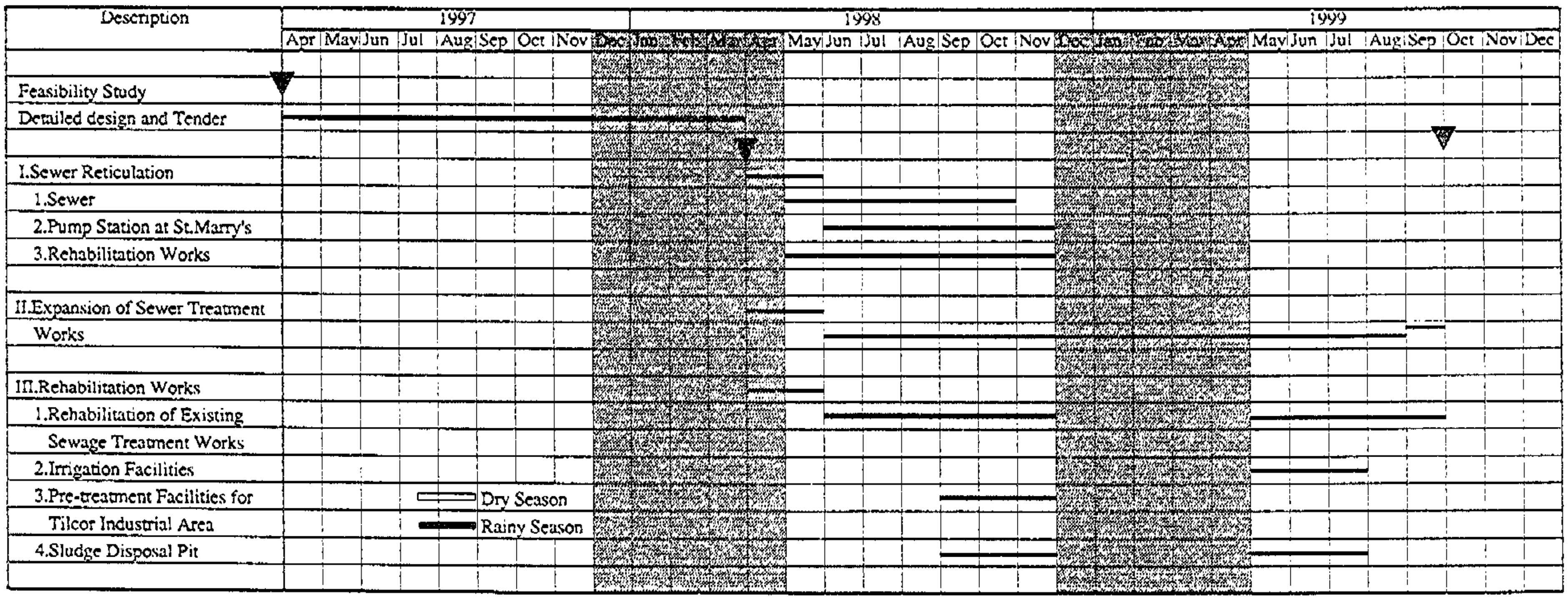
Sewer force main of 300mm dia. will be installed within a residential area and the gravity sewer pipe of 525mm dia. will be installed in the open area. The required land for the both routes is owned by the Municipality of Chitungwiza.

5m wide area along the pipe route will be stripped and graded for the construction purpose. Trench excavation will be carried out by 0.6-1.0m^3 backhoe, and the material will be stocked or spread in the open area for a disposal. AC pipes will be installed in the trench by 3-5 ton crane with manpower. Below 2 m in depth from the ground level, concrete breaker and blasting will be required for excavating intermediate and hard rock materials. And then, the trench will be backfilled with manpower and small tamper and rammer. Trench excavation, pipe laying and backfill will be made in parallel work during dry season, since the wet season construction will require additional dewatering work and difficulty of earthworks.

2) Pump Station at St. Marry's (New)

The new pump station area is also in the municipality land. The excavation of grit chamber and pumphouse will be carried out by 0.6-1.0 m^3 backhoe, concrete breaker and jackhammer, 10 ton dump truck, etc. The concrete will be delivered from a ready mixed concrete company located at the industrial area within one hour. The concrete placement will be made by 15 ton crane with bucket and manpower. The pump station construction is also scheduled to be performed during dry season.

Figure 9.1.1 Construction Schedule for Rehabilitation/Expansion of Zengeza Sewage Works



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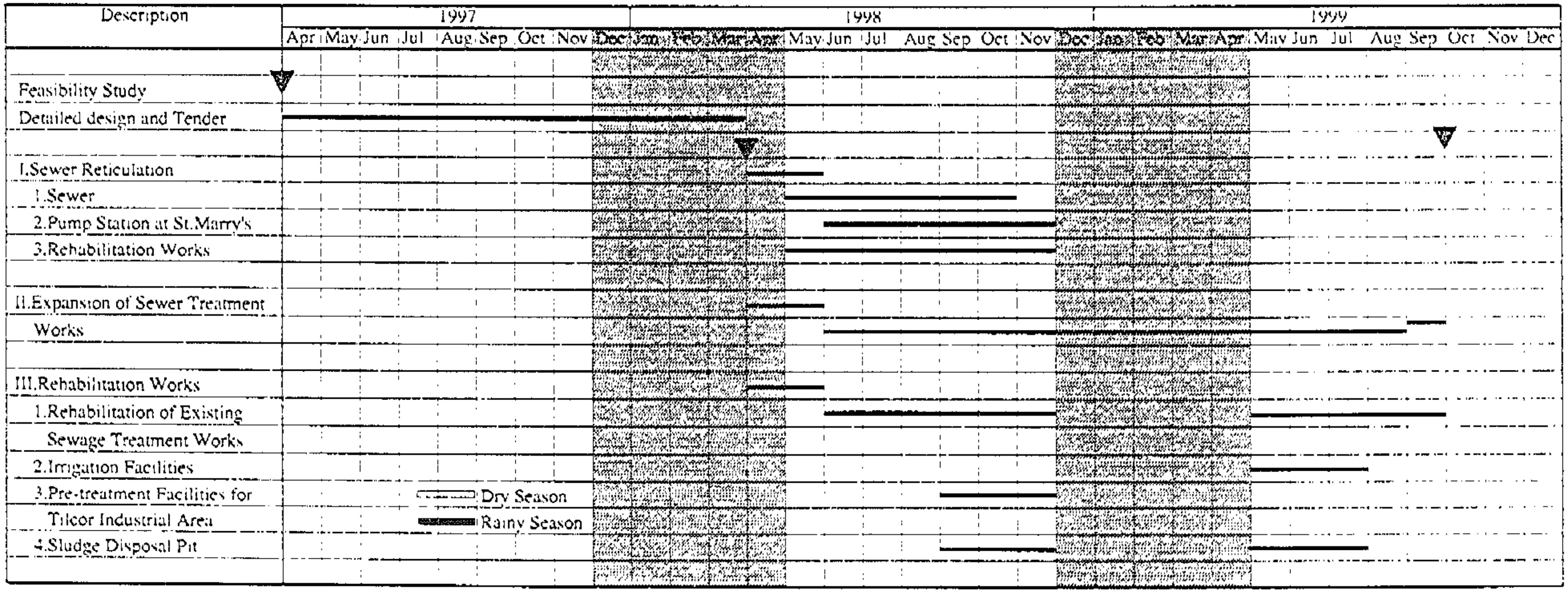

3) Pump Replacement

The existing pump station of St. Marry's No.1 and No.2 and Tilcor will require the replacement pump equipment and civil works for the extension of flow meter box. The box structure is a small and carried out by manpower for excavation and concrete works.

Before starting the removal and demolishing the existing pumps, valves and pipes, the temporary pump equipment including pipes and valves will be installed as a detour of sewer. In addition to the temporary equipment, the temporary pond of half day capacity of daily sewer volume will be prepared near the existing pump station as a safety mind.

When the sewer is detoured through the temporary pump, the removal and installation works will be made using the existing gear chain block. The replacement works will be carried out during dry season, since the sewer volume is seemed to be minimum.

(3) Expansion of Sewage Treatment Works

1) Preliminary and General (Preparatory works)

The project site is located adjacent to the existing sewage works and it takes about 30 minutes from Harare City. Access to the site is easy from the Chitungwiza Municipality road and the temporary access road is already provided. The topographic condition is to be a flat and gentle slope and the preparation of temporary facilities such as offices, labor camps, warehouses, workshop, storage yard, etc. is easy construction. These areas are free of charges and the Municipality of Chitungwiza will prepare. The construction temporary land will be necessary of 100 m x 100 m.

The construction period of mobilization is scheduled to be 2 months, taking into account of the Zimbabwe construction conditions, i.e. hiring construction equipment, employing subcontractors and special contractors, available construction material from local market.

Drinking water will be supplied from the existing water pipeline of 75mm dia. which connect to the existing control house. The water requirement for construction purpose is seems to be small quantity according to the usage of ready mixed concrete. The construction water will be stocked in water tanks and/or transported by water bowzer.

The existing 11 kV transmission line is available in the sewage treatment works for power supply. The electric power supply for the construction use will be supplied the above line. The power consumption is mainly for offices, labor camps and other buildings only. The construction use is minimum for using a diesel driven equipment.

2) Bulk Excavation

The bulk excavation of all proposed sewage site will be first carried out. The excavation of topsoil of 150mm thick will be made by 21 ton bulldozer, 2-3 m^3 wheel loader and 10 ton dump truck. The top soil will be stocked and recovered with turfing after the completion of the project.

The bulk excavation comprises common, intermediate and hard rock materials which are assumed to be 0-2 m, 2-4m, and below 4m respectively. The excavated material will be transported to the spoil bank and/or stock pipe located within 500 - 1000 m distance from the site. The land acquisition of disposal area are prepared by the Municipality of Chitungwiza.

The open cut excavation will be carried out using a conventional earthmoving equipment, such as 21 ton bulldozer, 32 ton bulldozer with ripper, 2-3 m^3 wheel loader and 10 ton dump truck. The hard rock will be blasted using crawler mounted drilling machine with 17 m^3/min air compressor. At the spoil bank, the material will be spread and compacted using 15 ton bulldozer.

3) Screen and Grit Chamber

The screen and grit chamber is planned to construct on the original ground formation of EL 1408 m and the structure is narrow in 2.5m wide. The excavation will be mainly carried out by backhoe and manpower. The intermediate and hard rocks will be excavated by concrete breaker and blasting with jackhammer.

The concrete placement will be made by manpower with one wheel buggy and concrete dumper. The concrete will be purchased from a ready mixed concrete factory. The concrete placing at the deep portion of 8 m in depth from the ground will be placed using 15ton crane with concrete bucket.

The mechanical equipment of airlift compressor, screen, gate and stoplog will be installed at the position in the screen portion, and baffle plates of concrete panel will be installed in the grit chamber.

4) Primary Sedimentation Tank

The construction of No.1 to No.6 sedimentation tanks will be made continuously one by one. The tank is to be 12 m dia. and 11 m in depth. The excavation will be carried out applying a shaft excavation with manpower using concrete breaker for intermediate material and blasting with jackhammer. The excavated fragment will be handled by a small shovel and manpower into a bucket and pulled up by crane. After the excavation, the surface will be trimmed smoothly not to shutter the ground for concrete placement.

The ready mixed concrete will be transported by 6 m^3 transit mixer from Harare City and the placing will be done by 15 ton crane with concrete bucket. The precast concrete beam will be installed on the top of tank wall and a steel stilling box will be prepared under the concrete beam.

After the completion of 6 nos. of concrete structures, the mechanical works including scum baffle, scum skimer, pipes and valves will be installed simultaneously on the last stage construction.

5) Biological Reactor

The construction of biological reactor is a main component of the expansion of sewage treatment works. Comparing with other structures, a large quantities of excavation after the bulk excavation and reinforced concrete will be necessary, and a number of surface aerators and mixers will require a long period of design, manufacturing, delivery, installing and electrical works. To minimize a construction period and to secure a target commissioning date, two numbers of biological reactor structures will be constructed in parallel work and be completed simultaneously.

Excavation works will be carried out as an open cut of 30 m x 100 m x 5m deep each. The common and intermediate materials will be dozed and ripped by 21 ton and/or 32 ton bulldozers and the hard rock material will be blasted using crawler drilling machine, and loaded by 2 -3 m^3 wheel loader into 10 ton dump truck. The final surface of bottom portion will be picked and baring to remove a loose fragment.

The concrete will be a ready mixed concrete to eliminate a batching and mixing plant and transit mixer trucks, taking into account smooth implementation and unreasonable equipment delivery from a foreign country. The concrete will be placed directly from 6 m^3 transit mixer truck on the base concrete and be placed by 15 ton crane with concrete bucket and by manpower.

After the completion of concrete works, the installation works of aerator, gear box, motor, mixer, circulation pump, wiring/cabling and electrical works will be continued. The installation period of aerator and mixer is assumed to be five months and then one month testing will be required. These equipment will be transported on the base concrete and installed in position by 15 ton crane. The temporary access or the opening space in the wall will be provided during installation period.

6) Final Sedimentation Tank

Tank diameter is 26 m and the excavation depth is 4 m. The excavation will be made as an open cut, by similar way applied for the biological reactor. The final surface will be trimmed by pick hammer with manpower. After the completion of structure concrete, four number of sludge collector with mechanical bridge will be installed one by one.

7) Sludge Thickener

The construction of sludge thickener will be made as a shaft construction, by a same method applied for the primary sedimentation tank.

8) Pump Station for RAS/WAS, Sludge, Infiltration and Nutrients

These pump station and pump pit are small structure without lifting facility and covered with roofing. The excavation will be made by backhoe and manpower and the pump installation will be made using truck crane.

9) Sludge Digestion Tank

The underground structure of 9 m in depth will be made applying a same method of other structures. The concrete wall above ground level is about 12 m high. The wall concrete will be placed using crane with concrete bucket and high scaffolding will be required around internal and external concrete wall.

10) Sludge Drying Bed

The earthwork will be made by bulldozer dozing work and the final ground will be graded and compacted. The filter layer comprising of five layers such as fine sand, coarse sand, fine gravel, medium gravel and coarse gravel. The spreading and laying material will be made by one wheel buggy and manpower, and compacted by 1 ton vibrating roller and tamper.

11) Interconnecting Pipe Work

Interconnection pipe work includes AC pipe, CI pipe, fitting and manhole. The pipes will be laid by a gravity flow conditions in principle. A pressure type AC pipe and CI pipe will be required at a part of pipeline. Trench excavation is within 1 m - 1.5 m in depth. The trench excavation and pipe laying works will be carried out by small backhoe and manpower.

12) Sludge Storage Yard

The ground will be graded and compacted by bulldozer, and the base slab concrete will be placed. The storage yard will be covered with roofing.

13) Site Works

Site works comprises of turfing, tree planting, fencing with road and pedestrian gates, pavement works including base and DBST surface, road kerb, stormwater, administration building including office, laboratory and staff room, repair shop, garage for maintenance equipment, staff house, gate house, and so on.

The site works will be carried out on the last stage construction.

14) Plant and Equipment

After the completion of construction works, the following plant and equipment will be necessary for a smooth operation and maintenance.

The plant and equipment : laboratory equipment, 2-dumper(1 m^3), 1-dump truck(6ton), 1-front end loader(1 m^3), 1- backhoe(excavator,0.35 m^3), 3-pedestrian mower, 3-pick-up car, 5-motorcycle, 2-computer and printer, 10-walky talkey, 3-VHF for vehicle and 1-VHF main.

9.2 Operation and Maintenance of Sewerage Facilities

After the completion of sewerage facilities, proper operation and maintenance (O & M) are indispensable to extend their durable years and to display their full treatment capacity.

The study on O & M in consideration with the preventive maintenance is prepared for sewer reticulation and sewage treatment works, respectively. The Ghuza pump station is excluded from the O & M study because it is located outside of administrative area of municipality

9.2.1 Sewer Reticulation

(1) Sewer

There are three types of O & M namely, site investigation, pipe cleanings and rehabilitation of damaged sewers. The working items by O & M types are presented in Table 9.2.1.

Table 9.2.1 Working Items by O & M Types on Sewer

O & M Type	Working Items
Site investigation	- Identification of damage and blockage location - Identification of the percolation point of groundwater - Investigation of the overflow point at manhole - Measurement of the volume of sedimented soil at the sewer bottom
Pipe cleaning	- Removal of sedimented soil, silt and foreign matters
Rehabilitation	- Replacement/repair of damaged sewer

The O & M for sewer should be conducted by the working program as shown below.

1) Site investigation

The investigation plan by year should be prepared covering the entire sewer in municipality, and the actual site investigation should be examined along the above-mentioned working items based on the investigation plan. During the site investigation, all staffs have to be careful about the anoxic condition in manhole, and the transportation at working area. The investigation plan is as follows.

Administrative area	: 42 km^2	
Occupied percentages for land use	: 60 %	
Sewer served area	: A_1 = 42 x 0.60 = 25.2 km^2	
Site investigation area per day	: A_2 = 5 ha	
Required site investigation day	: D = 25.2 x 100 / 5 = 504 days	
Required site investigation year	: Y = 504 / 250 = <u>2 years</u>	
Composition of site investigation team	: Attendant	; 1 person
	Worker	; 2 person

This investigation plan should be performed repeatedly every two years, and the investigation team should describe the site condition in a daily record.

2) Pipe cleaning program

The pipe cleaning program by year should be prepared for an entire sewers in municipality and be conducted from the priority spot based on the results of site investigation.

Generally, there are four types of pipe cleaning methods: high pressure jet cleaning machine, vacuum machine, bucket machine and manual type. A manual type is recommendable in consideration with the past experience and financial status. The pipe cleaning program is shown below.

At present, about 55 % (22.82 km^2) of municipal area (42.00 km^2) are used for residential purpose. The percentage of occupied area is assumed to be 60 %. The total length of the existing trunk sewers and of the reticulated lateral sewers are as follows.

Total length of trunk sewers	: 34,100 m (measured length)
Total length of lateral sewers	: 42 x 0.60 x 180m/ha x 100 = 453,600 m
Total length	: 487,700 m

Required length of pipe cleaning	: 487,700 m	
Pipe cleaning length per day	: 100 m (one manhole section)	
Pipe cleaning days per year	: 250 days	
Number of cleaning team	: 4 teams	
Composition of pipe cleaning team	: Attendant	; 1 person
	Foreman	; 1 person
	Worker	; 4 persons
	Total	; 6 persons

Required years for pipe cleaning:
487,700 / (100 x 4 x 250) = about 5 years

The pipe cleaning for an entire sewers is performed repeatedly every five years, and the pipe cleaning team should make a daily record on the removed sediments' volume and quality, cleaning method and cleaning time for future O & M.

3) Rehabilitation plan

The pipe rehabilitation plan by year should be prepared for damaged sewers in municipality and be conducted from the priority spot according to the site investigation.

Generally, there are two types of rehabilitation, namely replacement of damaged sewers and repair of a part of damaged sewers. The damages are caused by the natural or external factors. (damaged/deformed sewer resulting from ground subsidence, adjacent construction works, overweight vehicle, and corrosion by hydrogen sulfide etc.)

Among the total length, the required length to be rehabilitated is calculated by assuming that the percentage of rehabilitation length are 30 % (trunk sewers) and 20 % (lateral sewers), respectively.

Rehabilitation length for trunk sewers	: 34,100 x 0.30 = 10,230 m
Rehabilitation length for lateral sewers	: 453,600 x 0.20 = 90,720 m
Total rehabilitation length	: 100,950 m

Required length of pipe replacement: 100,950 m

Replacement length per day : 10 m (assumption)

Working days per year : 250 days

Number of working team : 4 teams (Contractor)

Composition of working team :

Attendant ; 2 persons for 4 teams (supervision for construction)

Required years for pipe replacement:

100,950 / (10 x 4 x 250) = about 10 years

The pipe rehabilitation for damaged sewers should be conducted repeatedly every ten years, and the working teams should make a record on the damaged conditions, causes of damage, countermeasures for damage and rehabilitation time for future O & M.

(2) Pump station

The O & M for pump station is classified into two items, daily and periodical working. The working items by O & M types are shown in Table 9.2.2.

Table 9.2.2 Working Items of Pump Station by O & M Types

O & M Type	Working Items
Daily work	- Measurement of inflow sewage volume - Removal of screenings and soils and silts at screen and grit chamber - Inspection by pump operation manual - Mutual operation of pump facility
Periodical work	- Removal/cleaning of scum, soil and silt at pump pit every 6 months - Overhaul of pump facility every 5 to 10 years

The O & M for pump station should be conducted by the working program as shown below.

1) Daily working program

The measurement of inflow volume is significant item for proper operation of sewerage facilities through the future. The screenings, soils, silts and other substances collected at the screen and sand pit have to be removed every day. The substances collected from 4 pump stations should be conveyed to the disposal site in the STW for the purpose of conserving a adjacent environment. The inspection and mutual operation of pump facility is also very important items for expand their durable years and proper operation through the future.

The required staff number in each pump station are shown below.

AM 8:00 to PM 4:00	Worker (Operator);	1 person
PM 4:00 to AM 0:00		1 person
AM 0:00 to AM 8:00		1 person
Standby		1 person
Total		4 persons/pump station

2) Periodical working program

The pump pit needs the periodical cleaning (every 6 months) by resident worker at pump station to remove the settled soil and silt and floating scums. The overhaul of pump equipment should be done every 5 to 10 years for expand their durable years and proper operation through the future.

(3) Organization for O & M

According to the results of the above-mentioned study, the required staff number for preventive maintenance is 45 persons as shown in Table 9.2.3, while the existing number are 35 persons for sewer reticulation. Therefore, the municipality should increase the staff number based on the proposed O & M plan.

Table 9.2.3 Required Total Staff Number for O & M of Sewer Reticulation

(unit: persons)

Type	Sewer			Pump Station	Total
	Site Investigation	Cleaning	Rehabilitation	Daily Working	
Attendant	1	4	2	0	7
Forman	0	4	0	0	4
Worker	2	16	0	16	34
Total	3	24	2	16	45

Besides the supplemental O & M staffs, the municipality should have the organization of workshop in cooperation with STW for easy repair and maintenance of sewerage facility.

9.2.2 Sewage Treatment Works

(1) Existing Sewage Treatment Works

The treatment flow of old facilities will be changed, and the required O & M for the new treatment flow will be explained below.

a. Anaerobic ponds

One of the four units will be kept empty for emergencies and maintenance, with the remaining three units in normal use. The anaerobic ponds will be desludged by emptying a pond, drying the sludge in the pond and removing the dried sludge for disposal. To determine the desludge frequency, sludge volume is calculated as below.

Assuming an SS removal ratio of 80%, sludge solids are:

$21{,}750\ m^3/day \times 650\ mg/l \times 0.80 \times 1/1{,}000 = 11{,}310\ kg/day.$

With decomposition of 2/3 of the sludge, and a 90% water content of the accumulated sludge, the accumulated sludge volume is:

11,310 kg/day x 2/3 x 100/(100-90) x 1/1,000= 75.4 m^3/day.

The accumulated sludge volume per unit is:

75.4 m3/d ÷ 3 units = 25.1 m^3/day.

One unit is comprised of ponds No. 1, No. 2 and No. 3, which are connected in series, so most of the sludge is accumulated in pond No. 1 (13,300 m^3).

25.1 m^3/day x 365 days ÷ 13,300 m^3 x 100 = 69 %

This means that pond No. 1 will become 2/3 filled in the course of a year. The sludge from pond No. 1 will need to be removed at least once a year.

b. Trickling filters

Operation and maintenance will be conducted as they have been thus far.

c. Imbgwa farm ponds

The new pond will be used as a maturation pond, and the other five ponds will be used as storage ponds. Accordingly, when there is a great demand for irrigation water, it will be all right to empty the storage ponds.

d. Sludge disposal

The sludge from the anaerobic ponds will be disposed of in a landfill, as it may contain toxic substances originating in industrial wastewater. The accumulated sludge from the Imbgwa farm pond will be disposed of in a landfill on the farm site. An overview of sludge treatment and disposal is provided in Table 9.2.4.

(2) New Sewage Treatment Works

a. Distribution chamber and screen & grit chamber

In the case of PWWF, the PDWF (1.5 x ADWF) passes through a connecting pipe into the old treatment works line. Similarly, when the BNR line stops in an emergency, its sewage will flow via a connecting pipe to the old treatment works line.

Table 9.2.4 Sludge Treatment and Disposal

Condition	Facilities	Sludge	Place to be Produced	Annual Sludge Volume	Sludge Treatment Method	Sludge Characteristics	Sludge Reuse	Sludge Disposal Method	Sludge Disposal Area	Remarks
Present conditions	Existing sewage treatment works	Sludge	Anaerobic pond	1,140m^3/year (the estimated value)	Anaerobic digestion	Sludge contains little organic matter and a lot of inorganic matter. It is not suitable for a soil conditioner	Some sludge are taken away by farmers.	The rest sludge is piling up on the site	Existing STW site	
New conditions after BNR facilities operation facilities	Existing sewage treatment works	Sludge	Anaerobic pond	6,900m^3/year	Anaerobic digestion	Water content 60% . Sludge contains little organic matter and a lot of inorganic matter. It is not suitable for soil conditioner.	In principle sludge is not scheduled to be used for land application.	In principle, landfill	New disposal site (Sludge A)	Sludge is removed from No.1 pond of each unit once a year.
	New sewage treatment works (BNR)	Waste activated sludge (WAS)	Sludge thickener + sludge drying bed.	3,180m^3/year (= 8.7m^3/day)	Aerobic digestion	Water content 60%. Sludge contains a lot of organic mater and nutrients. It is suitable for land application. But it includes a little undecomposed matter.	In principle sludge is scheduled to be used for land application.	The rest sludge is disposed into sludge disposal pit.	New disposal site (Sludge B)	
		Digested Sludge	Sludge digestion tank + sludge drying bed.	4,750m^3/year (= 13.0m^3/day)	Anaerobic digestion	Water content 60%. Sludge contains a lot of organic matter and nutrients. It is suitable for land application.	In principle sludge is scheduled to be used for land application.	The rest sludge is disposed into sludge disposal pit.	New disposal site (Sludge B)	
	Facilities for the effluent pumping and final disposal	Sludge	Maturation pond in Imbgwa farm	2,140m^3/year	Anaerobic digestion	Water content 60%	In principle sludge is not scheduled to be used for land application	In principle, landfill	Imbgwa farm site	Sludge is removed from first maturation pond every ten years.
	Pre-treatment facilities for Tilcor industrial area.	Sludge	Anaerobic pond	1,400m^3/years	Anaerobic digestion	Water content 60%.	In principle sludge is not scheduled to be used for land application	In principle, landfill	New disposal site (Sludge A)	Sludge is removed from No.1 anaerobic pond once a year.

Note: Sludge A (includes Industrial wastewater); 6,900 + 1,400 = 8,300 m^3/year.
Sludge B (contains only domestic sewage); a part of (3,180 + 4,750 = 7,930 m^3/year).

b. Primary sedimentation tank and anaerobic digestion tank

Twice a day, morning and evening, the sludge will be drawn off and pumped up to the anaerobic digestion tank.

c. BNR reactor, final sedimentation tank and sludge thickener

Operation and maintenance consists of the following:

- Commissioning of a BNR reactor
- Control of the dissolved oxygen concentration
- The control of ammonia
- The control of phosphorus
- Control of sludge retention time (SRT)
- Control of mixed liquor suspended solids (MLSS)
- Supplementing nutritious substances.

Details of the terms used above, except for the last item, are provided in the text for the Wastewater Treatment Plant Operators Course of the Institute of Water and Sanitation.

The last item "Supplementing nutritious substances" is explained as follow. In the wet season, the concentration of the sewage decreases due to the infiltration of storm water. The required nutritious substances will be supplied from the anaerobic digestion tank. The nutritious substances will be sent from the anaerobic digestion tank through a branch of the supernatant pipe to a storage pit, from which they will be pumped to the BNR by the nutritious substance supplement pump. The necessary supernatant volume is as follows:

Digested sludge volume	:	86.7 m^3/d
Digested sludge solids concentration	:	6,000 mg/l
Supernatant volume	:	108.3 m^3/d
Solids capture rate	:	85 %.

Therefore, the supernatant solids concentration is:

86.7 m^3/day x 60,000 mg/l x (100-85) / 85 x 1 / 108.3 = 8,500 mg/l

In cases where the infiltration of storm water reduces the influent concentration by half, anaerobic digestion tank supernatant will be sent to the BNR, as a supplement of nutritious substances, to ensure that the sludge volume in the reactor is not decreased.

The supply solids are calculated as follows:

$300 \text{ mg/l} \times 20{,}000 \text{ m}^3\text{/day} \times 1/1{,}000 = 6{,}000 \text{ kg/day}$.

To supply this amount of solids, the required supernatant volume is:

$6{,}000 \text{ kg/day} \times 1{,}000 \times 1/8{,}500 \text{ mg/l} = 710 \text{ m}^3\text{/day}$.

The supply will be divided into two trains, each of which will supply for two hours every morning and evening. Assuming one pump for each train,

$710 \text{ m}^3\text{/day} \times 1/2 \times 24/4 = 2{,}130 \text{ m}^3\text{/day/pump}$ (= $0.025 \text{ m}^3\text{/sec} = 1.5 \text{ m}^3\text{/min.}$)

Three pumps (including one standby) with suction pipe diameter of 125 mm will be installed. Assuming a velocity of 1 m/s in the delivery pipe, the required diameter is:

$(0.025/1.0/0.785)^{0.5} = 0.178 \rightarrow 200 \text{ mm}$.

d. Sludge drying bed and sludge storage yard

The dried sludge will be gathered manually from the sludge drying bed and will be carried every day to the sludge drying yard, employing loading and transporting machines.

e. Laboratory

The new facilities will discharge the treated water into the river, but the treated water will have to comply with strict effluent regulations. Because the quality of the treated water will need to be checked immediately as required, a laboratory will be built within the STW site, upon the addition of water quality analysts to the permanent staff. Precise water quality analysis will however be conducted by contract. Staff requirements may be met with the addition of a specialist and assistants.

The examination items and frequency are as follows:

Items	Regulations	O&M	Trade effluent	Remarks
(Sewage)				
Air temperature		●		
Water temperature	⊙	●	×	
Colour		●		
Odor		●		
Transparency by cylinder test		●		
pH	⊙	●	×	
DO	⊙	●		
BOD		○		
COD	⊙	●		
SS	⊙	●		
Settleable solids		●	×	
Chlorides	⊙	○		by contract
Total solids		○		
Fixed solids		○		
Volatile solids		○		by contract
Dissolved solids	⊙	○		by contract
Total nitrogen	⊙	●		by contract
Ammonia (Free)	⊙			by contract
Ammonia nitrogen		●		by contract
Nitrate		●		by contract
Nitrite		○		by contract
Organic nitrogen		●		by contract
Phosphorus (total as P)		●		by contract
Fats			×	by contract
Mineral oils			×	by contract
Organic solvents			×	by contract
Individual heavy metals			×	by contract
Calcium carbide			×	by contract
Bitumen			×	by contract
Cyanides			×	by contract
MLSS		○		
MLVSS		○		
SV (30 minute settleable solids)		●		
MLDO		●		
Microscopic examination		○		
(Sludge)				
Temperature		●		
pH		⊙		
Total solids		⊙		
Volatile solids		⊙		by contract
BOD		⊙		
SS		⊙		
Alkalinity		⊙		by contract
Moisture content		●		
Hazardous substance		×		by contract

Note: Examination frequency
● ; more than once a day
○ ; more than once a week
⊙ ; more than twice a month
× ; as required

f. Sludge disposal

In principle, the produced sludge will be disposed of through land application. The sludge that remains will be disposed of appropriately in landfills. An overview of sludge treatment and reuse or disposal is presented in Table 9.2.4.

(3) Tilcor

a. Scum JET

At least operate 8 hours a day.

b. Sludge disposal

In order to calculate the required desludging frequency, it is necessary to estimate the volume of sludge produced in the anaerobic ponds. SS concentration is assumed to be the same as BOD concentration. Assuming that 1/3 of the solids are reduced by decomposition, and assuming the water content of the accumulated sludge to be 90%, the produced sludge volume is:

(6,000 mg/l -1,000 mg/l) x 14,000 m^3/month x 2/3 x 100/(100-90) x 1/1,000,000

= 467 m^3/month (= 5,600 m^3/year).

The volume of the No. 1 anaerobic pond is 5,730 m^3, so it is expected to be filled in about a year. Accordingly, the sludge must be removed at least once a year. The sludge will be disposed of appropriately in the same kind of site as the sludge from the old treatment works' anaerobic pond.