Chapter 3 Implementation Plan

3-1 Implementation Plan

3-1-1 Implementation Concept

The executing agency of the Project is the Chitungwiza Municipal Council under the direction of the Ministry of Local Government, Urban and Rural Development. The implementation system is shown below in Figure 3.1.

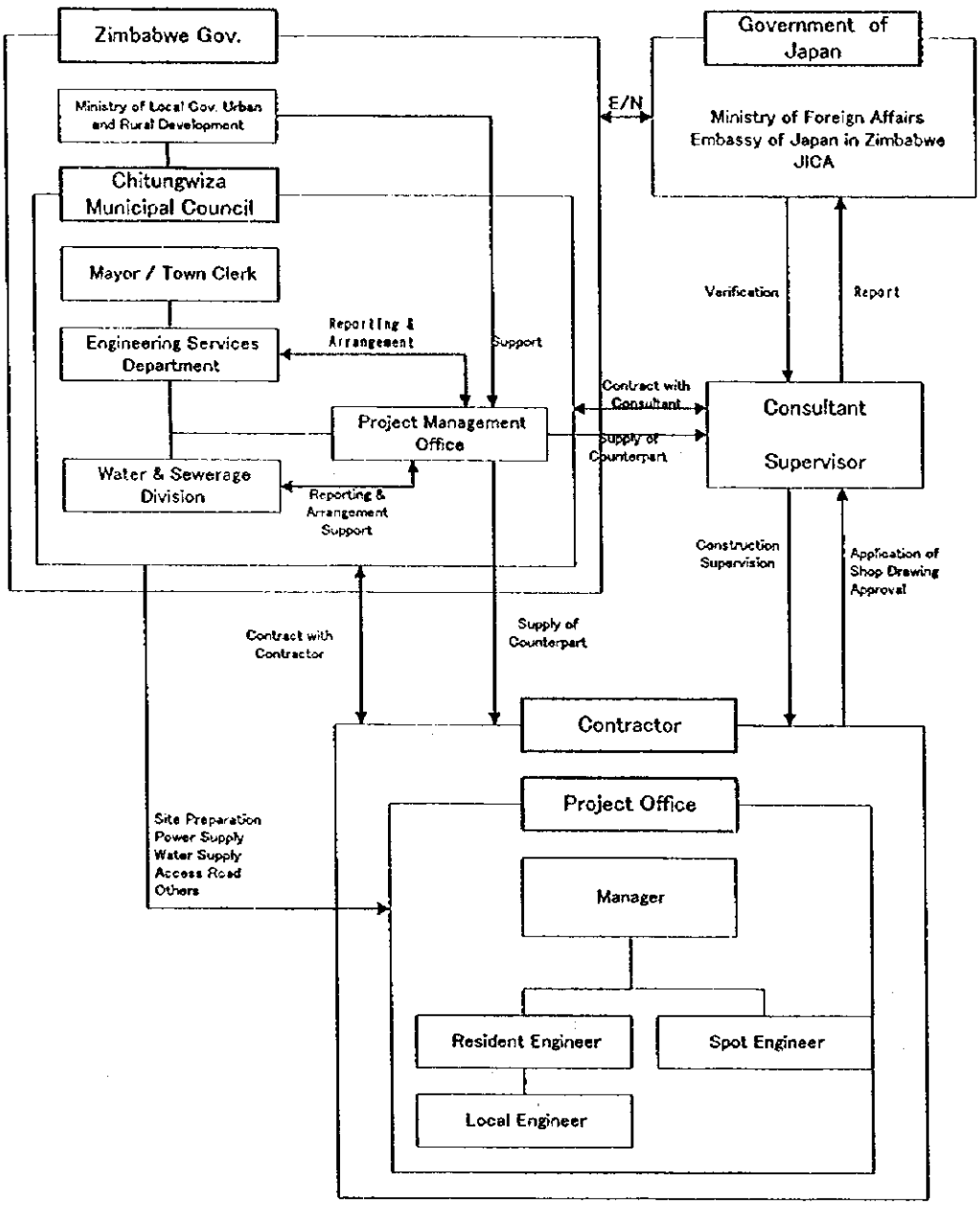


Figure 3.1 Project Implementation Diagram

The project team, which will be organized in the City Engineer's Department of the City Council, shall be consistently in charge of the Project implementation from the detailed design stage. The project team shall be responsible for the following work:

①Reception of the City Council for the Project
②Liaison and adjustment with the divisions concerned in the City Council
③Liaison and cooperation with the external agencies concerned with the Project
④Collection of designing and bidding works as the counterparts of the Japanese consultant
⑤Assurance of staff required for an additional survey and test, if any

The Japanese consultant will undertake the detailed design, bidding and construction supervision in order to proceed with the construction work smoothly and to complete it within the given construction period. The consultant will send a civil engineer, who will be stationed in the city, to supervise the whole of the construction work as an agent of the City Council, and other engineers as required; for example, at the time of the completion of the major facilities and at the end of the fiscal year.

The main part of the Project is to construct the sewage treatment plant, and it is considered appropriate that the Japanese civil engineering contractor who has experience in the construction of a sewage treatment plant will undertake the work. In selecting the contractor, the open bid system will be adopted and the qualification and selection criteria for bidders will be defined during the preparatory work for bidding through negotiation with and confirmation from the City Council.

During the construction work the Japanese contractor will send engineers to direct and supervise the work. The local contractors in Zimbabwe have sufficient experience for the Project and it will be no problem to use a local contractor as a subcontractor, contract with special subcontractor for each field because of a Zimbabwean rule prohibiting a blanket contract.

Upon completion of the Project, the contractor will provide technical guidance during the test run for three (3) months.

3-1-2 Implementation Condition

The construction of sewage treatment plant consists not only of large earth works, reinforced concrete works but also real mechanical and electrical works. At the proposed site for plant, there is enough space for a site office, storage and so on. The contractor is required to

negotiate with the municipality council for the expected location and manner.

Labor, construction material and construction machinery are available in Zimbabwe. It will be no problem for the Project to use a local contractor as a subcontractor in each field.

The items to be considered for the construction work are as follows:

1) Zimbabwe has a rainy season but the days with more than 10 mm of rainfall amount to only 30. The rainy season will not pose any trouble relating to construction efficiency.
2) The treatment site is on a gentle slope hill. The design ground level should be decided in consideration of the balance of excavation and banking.
3) A direct foundation and open-cut excavation are adopted in the civil works according to the soil investigation.
4) A rock excavation is necessary because a granite layer and boulder layer are expected in a portion of the site.
5) Pumping is necessary during the rainy season (December to March) and underground water level construction.
6) Since there is no concrete pump in Zimbabwe, cranes will be used in concrete works and it should be considered in the construction schedule.
7) According to the construction schedule for mechanical equipment, manufacture, transportation, installation should be considered.

3-1-3 Scope of Work

In the Project, the Japanese side shall undertake the detailed design and construction supervision by the consultant on the construction of the sewage treatment plant, incidental work for the existing treatment facilities and rehabilitation work for the existing pumping station and those civil, architectural, mechanical, electrical equipment installation works by the contractor.

The Zimbabwe side shall undertake the provision of the infrastructures concerned and shall be responsible of the operation and maintenance of the sewerage system after the completion of the Project.

The outline of the work assignment to be undertaken by each side is described below.

1) Scope of Work to be Undertaken by the Japanese Side

① Construction work of the proposed to construct sewage and sludge treatment facilities

with a capacity of 20,000 m^3/day.

The major facilities are as follows:

Grit Chamber
Primary Sedimentation Tank
Equalization Tank
BNR Reactor
Final Sedimentation Tank
Maturation Pond
Outlet Channel & Bypass Pipe
Sludge Thickening Tank A (For primary settled sludge)
Sludge Thickening Tank B (For final settled sludge)
Sludge Digestion Tank
Sludge Drying Bed
Sludge Storage Yard
Electrical Building
Water Examination and Supervisory Building

②Incidental work for the existing treatment facilities

a) To reconnect the existing inlet sewer to the proposed sewage treatment facilities

b) To reconstruct the effluent facility of the existing anaerobic ponds

c) To install the treated water distribution pipe to avoid the scum accumulation in the anaerobic pond of Tilcor pre-treatment plant

③Rehabilitation work for the existing three (3) pumping station

a) To renovate pumps, pipes, electrical panels, electric cables and float switches

b) To renovate electromagnetic flow-meter and valve-box in the existing

④ Equipment procurement

a) The vehicles for O&M

b) Water quality analysis equipment.

2) Scope of Work to be Undertaken by the Zimbabwean Side

a) Sewage Treatment Plant

① fencing around the proposed site:	approx. 1,240 m
② power supply to the proposed site:	primary side
③ water supply to the proposed site :	dia. 75 mm
④ telephone line to the proposed site:	extension

3-1-4 Consultant Supervision

(1) Detailed Design

In case the Government of Japan decides to implement the Project based on the result of the basic design study, then the E/N will be concluded between the Government of Japan and the Government of the Republic of Zimbabwe. The Government of the Republic of Zimbabwe will make a contract with the Japanese consultant, the Government of Japan will verify the contract, and the consultant will start the detailed design.

Upon commencement of the work, the consultant will conduct topographical, soil and detailed field surveys in the field, make a detailed design and prepare design drawings and documents.

(2) Bidding

After the approval of all bidding documents by the City Council, the consultant will enter into the bidding stage. As an agent of the City Council, the consultant will undertake a series of works.

The preparation period will be one week for the pre-qualification documents and about one month for bidding documents from the distribution. The bidding will be done in the presence of the consultant will assist in the contract negotiations and contract conclusion between the successful bidder and the City Council.

(3) Construction Supervision

The construction work consists of civil, architectural, mechanical, and electrical works. The resident engineer to be sent by the consultant will be a civil engineer and architects, mechanical and electrical engineers will be sent for a short time (at the completion of the major facilities for example). Additionally, local engineers will be hired to assist the consultant's resident engineer.

The consultant's resident engineer will hold close meetings with the City Council, other agencies concerned and with the Japanese contractor in order to implement the Project and to strictly adhere to the submission of regular reports to the JICA Zimbabwe office.

(4) Technical Guidance for Plant Operation

An advantage of the BNR method is that it can realize a high nutrient removal rate for items other than organic matter. On the other hand, there are a lot of monitoring/control items. The BNR method needs at least three (3) months for activated sludge growth in the initial operation stage. In this period, training and guidance program will be held to the operation and maintenance staff parallel to the test operation.

1) Basic treatment principle
- Outline of the treatment plant
- Water treatment Method (Biological Nutrient Removal)
- Sludge treatment method

2) Plant operation based on the analytical result
- grasp the sewage quantity and distribution
- Monitoring items and operation manners
- water examination items, frequency, sampling point and manner
- Analysis of water quality and feed-back to operation
- making manual about the reactor tank operation and maintenance
- trouble and countermeasures

3-1-5 Procurement Plan

The construction materials necessary for the Project shall be procured in-country to the greatest extent possible; however, those items which are not obtainable in-country or of which the quality or specifications do not meet the requirements, cannot be reliably procured with regard to distribution volume or cost shall be procured from Japan or third countries (i.e. South Africa).

The materials obtainable in Zimbabwe are sand, gravel, cement, concrete aggregate, ready-mixed concrete, reinforcing bar, framing wood, gasoline, etc., based on the information from related agent, i.e. the Construction Industry Federation of Zimbabwe. The quality of these materials is based on the British Standard and are considered sufficient for the Project.

There are no water treatment machinery/equipment manufacturer that could work with the Project in Zimbabwe (a South African agent exists but without factory). On the other hand, there are three (3) general water treatment machinery/equipment manufacturer in South Africa, one is local and the others are of European extraction. These three (3) manufacturers have sufficient experience. They can be used throughout the project, from installation to test

operation.

According to above reasons, it is no need to procure from machinery from Japan. Actually, for the previous work at the Zengeza treatment plant, the construction of pumping station for irrigation and anaerobic ponds for sewage treatment, all construction material are procured in Zimbabwe except stainless steel pipes and pumps which are imported from South Africa.

a) Materials to be procured in Zimbabwe

①Material

cement, sand, gravel, gasoline, brick, ready-mixed concrete, reinforcing bar, framing wood, etc.

②Construction Machinery

truck crane, backhoe, dump truck, bulldozer, truck, etc.

③Maintenance Equipment

laboratory instrument and vehicle for plant maintenance

b) Materials to be procured from Japan

-non-

c) Materials to Be Procured from Third Countries (South Africa)

①Mechanical/Electrical equipment for treatment facilities:

pumps, scrapers, electric equipment, etc.

3-1-6 Implementation Schedule

Taking into account the construction time needed to carry out the construction work economically and efficiently, the implementation schedule is defined as shown in Figure 3.2.

Eight (8) months for detailed design, 19 months for construction include with three (3) months for test operation and training, and some time for bidding etc., 31 months is required for the whole project.

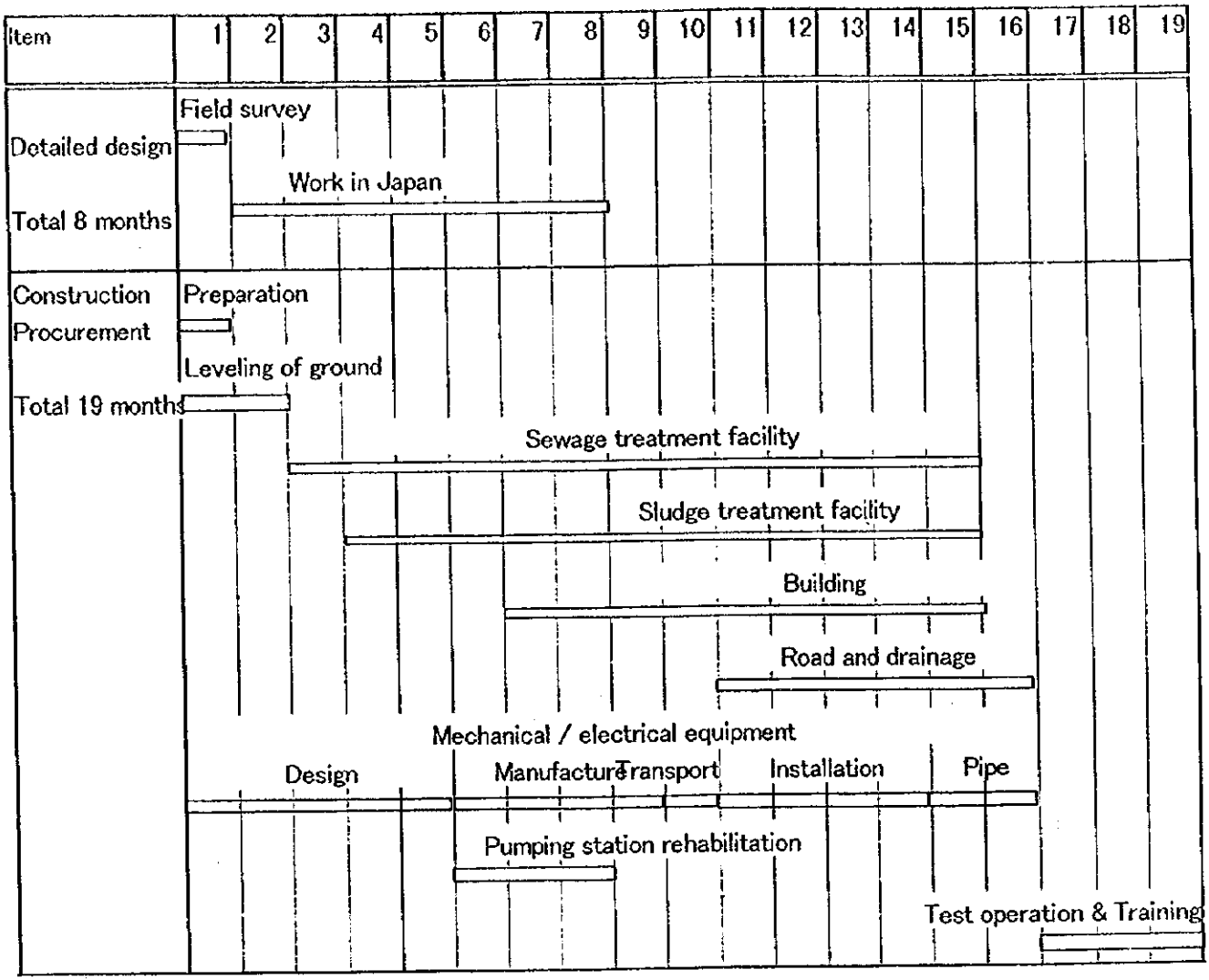


Figure 3.2 Implementation Schedule

3-1-7 Obligations of recipient country

Following items are written in the minutes of discussions July 21,1997.

1. To secure the site for the Project.
2. To clear, Level and reclaim the site prior to commencement of the construction/rehabilitation.
3. To undertake incidental outdoor works such as gardening, fencing, gates and exterior lighting in and around the site.
4. To construct the access road to the site prior to commencement of the construction/rehabilitation.
5. To provide facilities for distribution of electricity, water supply, telephone, drainage,

sewage and incidental facilities to the project site.

1) Electricity distribution line to the site.
2) City water distribution main to the site.
3) Drainage city main to the site.
4) Telephone trunk line and the main distribution panel of building.
5) General furniture such as carpets, curtains, tables, chairs and others.

6. To bear commissions to the Japanese foreign exchange bank for the banking services based upon Banking Arrangement.
7. To exempt taxes and to take necessary measures for customs clearance of the materials and equipment brought for the Project at the port of disembarkation.
8. To accord Japanese Nationals whose services under the verified contract such facilities as may be necessary for their entry into Zimbabwe and stay therein for the performance of their work.
9. To maintain and use property and effectively that the facilities constructed and equipment purchased under the Grant.
10. To bear all the expenses other than those to be borne by the Grant necessary for construction of the facilities well as for the transportation and the installation of the equipment.

3-2 Project Cost Estimation

(1) Expenses to be Borne by the Zimbabwe Side

The expenses to be borne by the Zimbabwe side are approximately MK2.80 million. The breakdown is shown in Table 4.22 and the further details are shown in Appendix 8. As for the expropriation of sites for the sewage treatment plant and sewers, there is no expense due to the sites being on public land. However, as for the compensation for private lands the Zimbabwe side shall estimate the amount for budgeting.

1) fencing around the proposed site	400 x 1000 Z$
2) power supply to the proposed site	500 x 1000 Z$
3) water supply to the proposed site	(existing)
4) telephone line to the proposed site	0.1 x 1000 Z$
Total	90.1x 1000

(2) Estimation Condition

1) Time of Estimation : July 1997

2) Exchange Rate : US$ 1 = Japanese Yen 119.00
Z$ 1 = Japanese Yen 10.57

3) Project Period : The project period is shown in Figure 3.2

3-3 Operation and Maintenance Cost

O&M cost at 2000 of the target year of this Project is estimated in table 3.1. It is based on the 1997 value and 20% annual escalation for 2000.

Table 3.1 Annual O&M cost **million Z$**

	Item	1997	1998	1999	2000
Actual (1997)	Collection system	1.07	1.07	1.07	4.58
	Treatment plant	2.93	2.93	2.93	14.74
	Total	4.00	4.00	4.00	19.32
Nominal	Co-efficient	1.00	1.20	1.44	1.73
	Nominal	4.00	4.80	5.76	33.42

Note) Cost for new facility are calculated at 2000. 20% of inflation is assumed.

The breakdown is described below.

1) Collection System

The O&M cost for collection system consists of sewer investigation, sewer cleaning, and sewer rehabilitation and pumping stations' maintenance.

The sewer investigation cost consists of staff costs; the cleaning cost consists of personnel costs and fuel cost for transportation; the rehabilitation cost consists of construction and supervision. Regarding the construction cost for rehabilitation work, the renewal cost is 50% and repair cost is 50%. The cost for renewal is estimated by a cost equation and the cost for repair is a half of the construction/renewal cost.

The cost of pumping stations consists of electricity charges, staff cost and maintenance & repair cost.

Table 3.2 Collection System O&M Cost (Actual value 1997)

Item		Annual O&M cost for collection system (Z$/year)			Remarks
		Additional	Present	Total	
Collection system	Investigation	0	72,000	72,000	
	Cleaning	0	570,200	570,200	
	Rehabilitation	3,140,400	0	3,140,400	
	Sub-total	3,140,400	642,200	3,782,600	
Pumping station	St. Mary No.1	0	206,200	206,200	
	St. Mary No.2	0	59,500	59,500	
	Tilcor	0	160,600	160,600	
	St. Mary's New	369,100	0	369,100	
	Sub-total	369,100	426,300	795,400	
Total		3,509,500	1,068,500	4,578,000	

2) Treatment Plant

The mjority of the O&M costs for the treatment plant are staff costs, electrical charges, and chemicals, which are estimated by multiplying the required number of units and the unit cost respectively. A simple estimation is adopted for other items. The maintenance and repair cost is estimated at 1% of the procurement cost because most of the equipment in this project have simple maintenance requirements. The fuel cost for a backhoe and dump track is estimated as a sludge disposal cost. The water examination cost is estimated as 10% of the equipment. The other costs for affairs is estimated at 20% of the staff cost.

Table3.3 Annual O&M Cost for Treatment Plant (Actual value at 1997)

Item	Annual amount (x1000Z$/year)		
	New	Existing	Total
Staff cost	1,166.4	957.6	2,124.0
Electricity charges	7,229.0	1,428.0	8,657.0
Maintenance & repairs	800.0	285.6	1,085.6
Chemicals	2,264.2	0.0	2,264.2
Sludge disposal	86.5	71.1	157.6
Water examination	30.0	0.0	30.0
Others	233.3	191.5	424.8
Total	11,809.4	2,933.8	14,743.2

Chapter 4 Project Evaluation and Recommendation

4-1 Project Effect

The objective of the Project is to improve water quality in the Upper Manyame River Basin which is being used as water source for drinking water supply and to supplement the limited source capacity in the basin through the reuse of treated effluent. The direct effect of the Project will be sought to improve the aquatic environment in terms of both water quality and quantity in the Nyatsime River. The Nyatsime River is the receiving water body of treated effluent coming from the Zengeza STW. The expected effects and benefits brought out by the implementation of the Project are described below.

The Study Area covers an area of about 3,900 sq.km including Harare City, Chitungwiza Municipality, Norton Town, Ruwa Village and Epworth Village and has population of about 2 million, of which urban population occupies 92% of the total population. Within the river basin of the Study Area are the Seke/Harava Dam, Lake Chivero and Lake Manyame. These water bodies are being utilised as water source for the Harare metropolitan area. However, water pollution has become increasingly serious problem in these water bodies due to a rapid population increse and economic development. Urgent water pollution countermeasures are required, not only for the conservation of the water environment, to source viability of the subject water bodies in terms of future water supply sources.

Through the conduct of the development study on water pollution control in the Upper Manyame River Basin. The major water pollution sources were scrutinised. A macro-view analysis was carried out to determine the present water pollution mechanism and then future water quality was projected, taking into account future land use estimates and any relevant development plans/programs. Based on these analyses and evaluations, water pollution control measures (mainly consisting of sewerage system development) were recommended.

As part of the water pollution counter measures recommended above, a feasibility study on the improvement and expansion of the Zengeza STW (in the Chitungwiza Municipality) was identified as aan emergency project to be carried. It should be noted that Chitungwiza Municipality, having present population of more than 400,000, is the second only to Harare City in terms of population density. Furthermore, Chitungwiza become an independent local government in 1996 (Previously the area was part of Harare City) and its social infrastructure is

far below the required levels-including the sanitation sector. In particular, the existing sewage treatment works are operating under heavily overloaded conditions and therefore require urgent improvement and expansion as a part of water pollution control measures for the subject river basin area.

Enumerated below are reasons for which the Zengeza STW Project was selected as an emergency project. The selection process was based on an in-depth comparative evaluations of the existing problems regarding technology, cost effectiveness, environmental issues, institutional arrangement, financial arrangements, and community participation/involvement.

Technical Aspect

- Among three major STWs being operated within the subject river basin, only the Zengeza STW does not have treatment facility which can meet the effluent water quality standards.
- The emission of offensive odour within the Zengeza STW and its surrounding area is a considerable public nuisance.

- Due to excessive inflow (170% of treatment capacity) into the Zengeza STW, there is a major potential risk of overflow of raw sewage or treated effluent into the Nyatsime River.

- For the two major STWs located in Harare City, emergency plans designs, medium term improvement and future expansion have been prepared, along with the reqired financial arrangement. In addition, at the Firle STW, the expansion of BNR facilities is on-going. The Zengeza STW, however, has no firm improvement/expansion plan as yet.

Environmental Aspect

- Through the application of the BNR treatment method at the Zengeza STW, a signficant reduction in the amount of nitrogen in the plant's effluent can be achieved. This will directly impact the eutrophication problems in the subject river basin's lakes as nitrogen is a controlling factor among the untrients responsible for algae growth.

- Approximately 20,000 cu.m/day of treated effluent can be recycled for use in supplementing the water resources in the subject river basin area. This will particularly particularly be helpful during dry season.

- Presently, treated effluent from the existing trickling filter process (which is far exceeding the design effluent quality) is transmitted to the Imbgwa Farm and partially reused for irrigation etc. after passing through the maturation pond. However, this process has causec water pollution problem in the near by water bodies due to overflows from the maturation pond. The implementation of the Project would improve both the quality and quantity of treated effluent as the trickling filter would be operated at proper design levels.

Aside from the above, the Project is expected to exhibit reasonable cost effectiveness through the maximum utilisation of the existing treatment facilities.

From the view points of technology, sanitation, environment and social aspects, the benefits to be brought by the Project can be summarized as shown below.

(1) Through the preventative measures against eutrophication in the subject basin's lakes, approximately 2 million people residing in the subject area, and in particular the roughly 400,000 people in Chitungwiza Municipality, will benefits from the Project.

(2) By preventing the incidental discharge of raw sewage into the subject river basin area, the water quality of the drinking water sources of the area will be conserved to the benefit of the entire population of the area (including those concerned in the fising industry).

(3) Conservation of the aquatic environment in the Nyatsime River from the viewpoints of water use and the supplementation of water resources. This will benefit the entire population of the area as well as the flora and fauna of the subject river basin.

(4) Recovery of the treatment efficiency of the existing trickling filter process and the recycling of treated effluent (at design effluent quality) will benefit the subject river basin. The benefits will include removal of the offensive odours, the prevention of water pollution in the downstream of the maturation pond, and the increase of agricultural reuse of effluent.

(5) Utilisation of excess sludge will enable the cost of fertilizer to be reduced.

(6) Provision of guidelines for institutional setup and O&M will help strengthen the implementation capability of the Chitungwiza Municipality.

(7) Creation of job opportunities during the project implementation and O&M subsequent activities.

A detailed explanation of the above benefits are presented hereunder.

(1) Contribution to the preventive measures against lakes eutrophication.

In the Water Pollution Control Master Plan, the magnitude of major pollution sources within the subject river basin area was estimated for both the present and in the future. The Master Plant spelled out the necessary countermeasures toward needed interm of to future water pollution control that should be taken up by cities/municipalities concerned (mainly led by Harare City). The influence of Chitungwiza Municipality, which has about one-third of the total population in the subject area, was considered large enough that the situation outlined below can be seen in the major pollution indices in relation to the total pollution load in the subject river basin area.

1) Influence of discharged pollution load from the Zengeza STW (at present and in the future).

- o Nyatsime River (RR2) downstream of the Zengeza STW (refer to Table 4.1).
  More than 50% of the total pollution load (COD, T-N, T-P) is discharged within the Nyatsime River basin area is occupied by the effluent from the Zengeza STW. Upon the completion Project in 2000, this pollution load will decrease to about 20%. Especially, T-N will be drastically reduced to about one-third (64% to 22%), though there will be increase in the population in Chitungwiza Municipality.

- o Manyame River (R_2) before entering the Lake Chivero
  At present, the discharge pollution load (COD, T-N, T-P) from the Zengeza STW contributes to 40% to 60% of the total pollution load concentrated at this monitoring point, wherein most of the pollution load from Harare City is included. This phenomenon indicates the magnitude of the water pollution from the Zengeza STW. Upon completion of the Project in 2000, the influence of the Zengeza STW will be reduced to about 10% of the total pollution load at this monitoring point. The share of T-N from the Zengeza STW will be further reduced to one-fourth (57% to 13%) from the present condition.

2) Influence of discharged pollution load (L2) from the Zengeza STW to Lake Chivero

At present, the effluent from the Zengeza STW occupies approximately 20% to 40% of the total concentrated pollution load (COD, T-N, T-P) in the subject basin area. This influence will be compressed to about one-tenth (only 2% to 4%) when the project is completed in the year 2000.

Table 4.1 Contribution of Discharged Pollution Load from the Zengeza STW to Respective Pollution Loads in River Basin at the Nyatsime River (RR2), the Manyame River (CR2) and the Lake Chivero (CL2)

Year	Item	Contribution of Discharged Pollution Loads at the Zengeza STW			Pollution Loads in Nyatsime River (RR2)			Pollution Loads in Manyame River (CR2)			Pollution Loads in Lake Chivero (CL2)		
		Inlet Pollution Load	Discharged Pollution Load	Outlet Pollution Load	Pollution Load from Zengeza STW	Total Pollution Load	Ratio (%)	Pollution Load from Zengeza STW	Total Pollution Load	Ratio (%)	Pollution Load from Zengeza STW	Total Pollution Load	Ratio (%)
Present	COD	38,874	19,656	9,828	9,828	19,119	51	9,828	25,120	39	9,828	41,711	24
	T-N	4,874	4,332	2,166	2,166	3,399	64	2,116	3,807	57	2,166	5,745	38
	T-P	531	266	133	133	280	48	133	325	41	133	667	20
2000	COD	44,611	5,941	1,502	1,502	10,686	14	1,502	30,944	5	1,502	71,335	2
	T-N	5,121	2,739	347	347	1,582	22	347	2,675	13	347	8,849	4
	T-P	580	318	49	49	195	25	49	402	12	49	1,270	4
2015	COD	88,831	11,830	2,990	2,990	12,211	24	2,990	37,022	8	2,990	83,589	3
	T-N	7,199	3,850	485	485	1,725	28	485	3,591	13	485	10,955	4
	T-P	945	518	79	79	225	35	79	540	14	79	1,578	5

As stated above, the three major water pollution indices relating on the future pollution load estimated to be discharged from the Zengeza STW exhibit the substantial effects that of the Project could bring about. It is noteworthy that massive reduction of T-N also illustrates the indispensable effect of the Project in controlling nutrients to prevent further eutrophication in the lakes in the subject area. Figures 4.1, 4.2 and 4.3 exhibit status of discharged pollution load (COD, T-N, T-P) at present and in future.

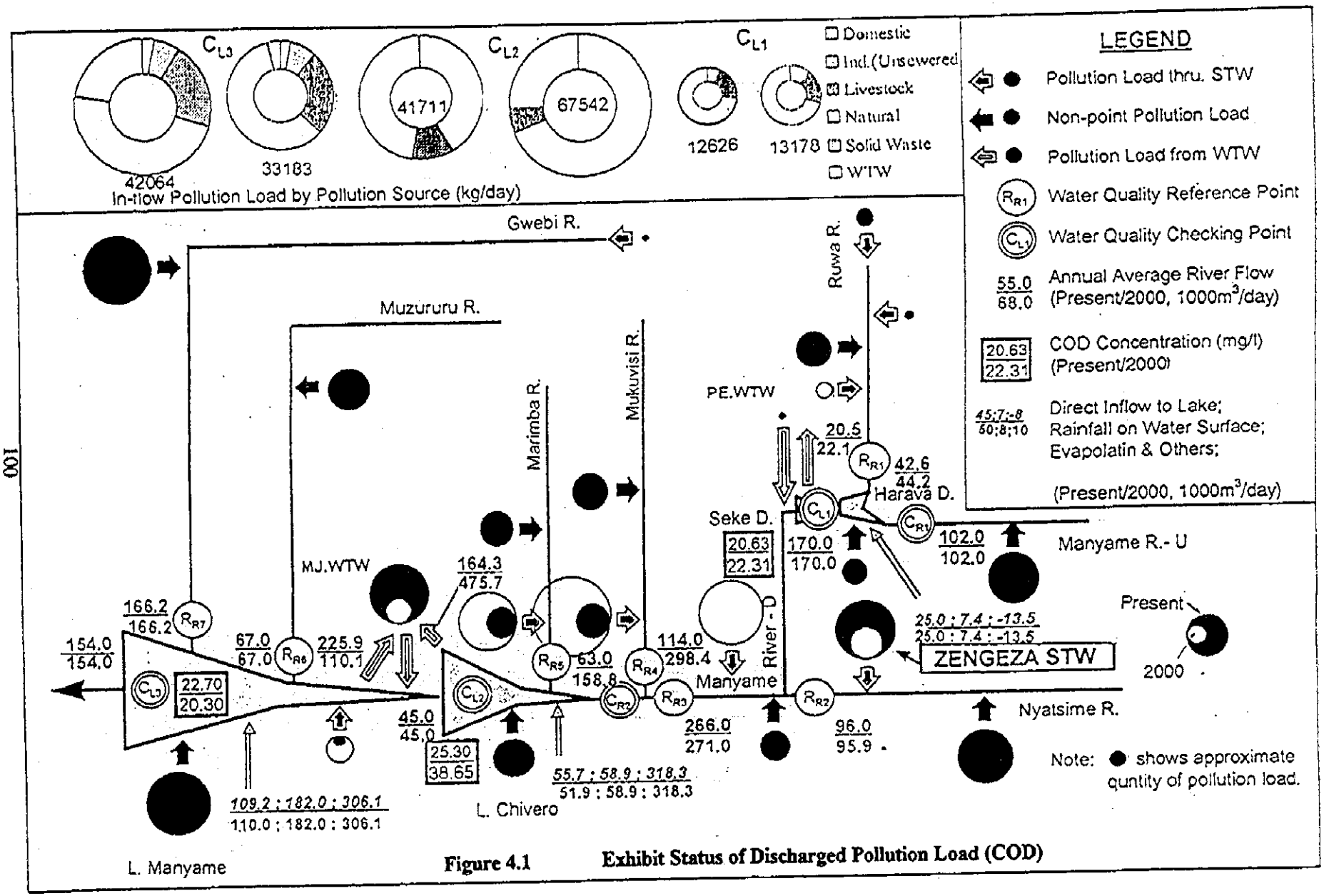


Figure 4.1 **Exhibit Status of Discharged Pollution Load (COD)**

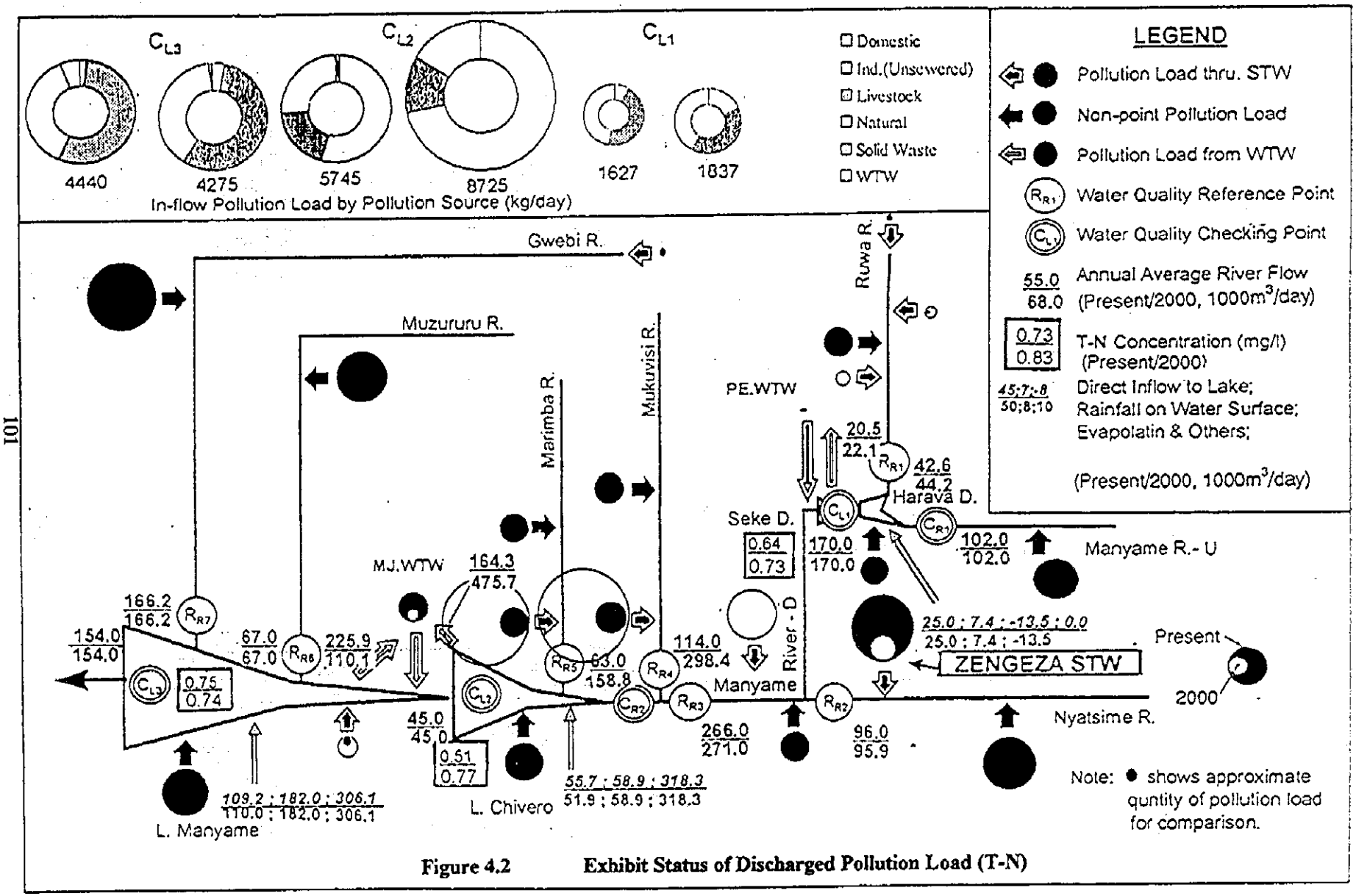


Figure 4.2 **Exhibit Status of Discharged Pollution Load (T-N)**

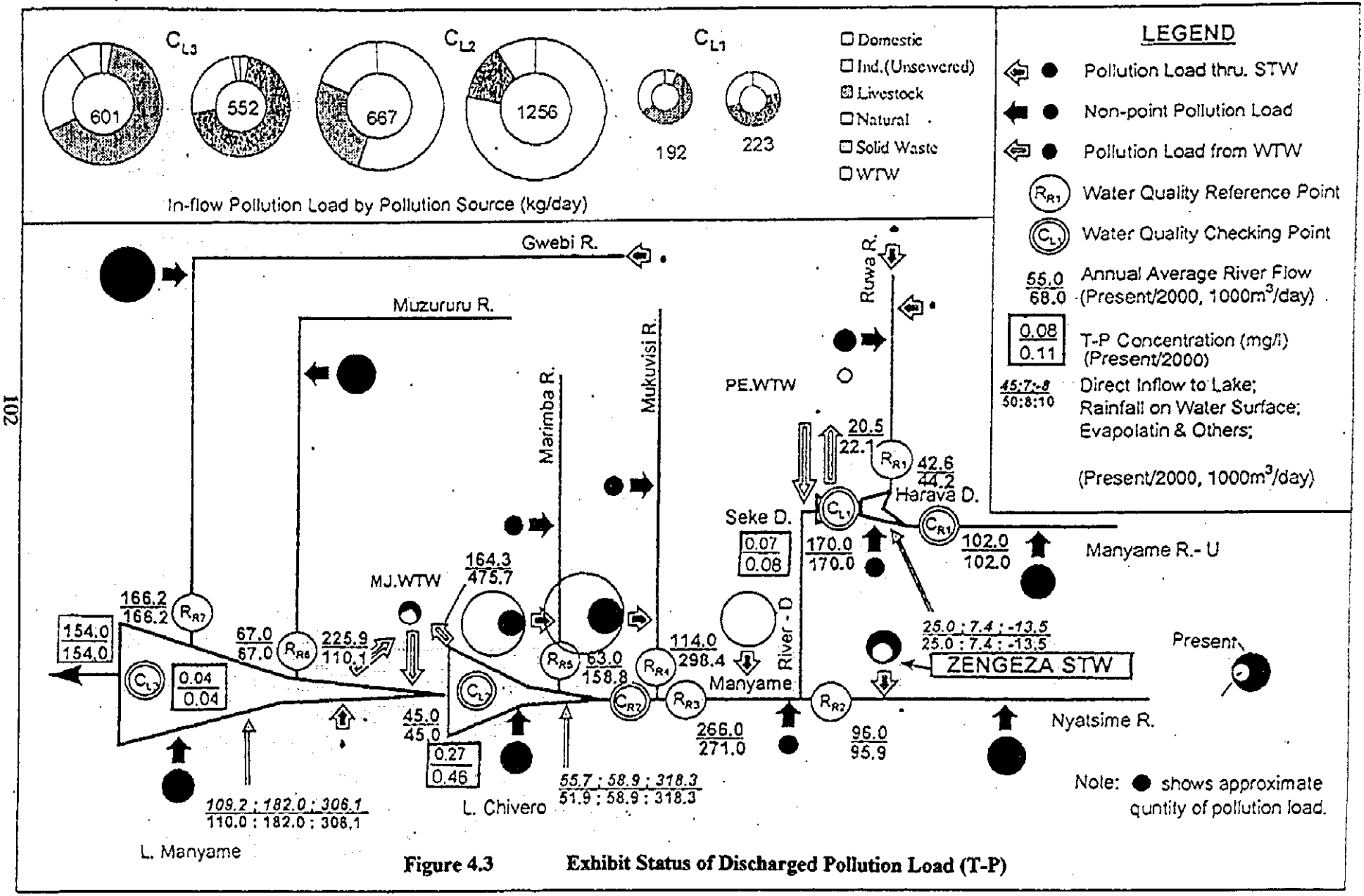


Figure 4.3 **Exhibit Status of Discharged Pollution Load (T-P)**

(2) Prevention of accidental discharge of raw sewage

Since 1996, the local newspapers have featured stories regarding the responsibility for the cases wherein large number of fishes died due to asphyxiation in Lake Manyame as well as the river mouth and inside Lake Chivero. In these stories, it was surmised that the accidental discharge of raw sewage, either from the STW or from local factories was to blame. Examples of these cases are as follows;

- that the untreated industrial wastewater discharged from a large scale factory being situated in the Lake Manyame catchment area caused death of fishes in the Lake Manyame, due to negligence to repair booster pump to transmit wastewater to farm land for about 2 weeks,
- that similar accident happened in the river mouth of the Lake Chivero by discharge of raw sewage from the Firle STW due to negligence to repair pumps.

Death of fishes from asphyxiation easily happens since the influence accidental discharge of raw sewage rapidly appears in a day due to the limited river flow (less than 4 cu.m/day) even at the main stream of the Manyame River before flowing into the Lake Chivero during the day season.

Upon the completion of the Project, the discharge of raw sewage and the insufficiently treated effluent from the Zengeza STW will be prevented. This will be due to the fact that the overloading problem at the existing trickling filter process will be mitigated and the provision of a bypass route to the existing treatment facility from the new BNR facility will provide an emergency countermeasure.

(3) Conservation of the aquatic environment (from the view of water use) in the Nyatsime River and the supplementation to water resources

Countermeasures against the chronic water shortage that occur during the dry season has been apriority issue in Zimbabwe. Accordingly (approximately 100,000 cu.m/day) from a different river basin about 60 km outside Harare City as an immediate countermeasure, although no long-term plan has yet been prepared. It has been experienced that the reuse of effluent from the STWs has reached to about 25% of the total intake amount of water supply. The cities/municipalities concerned have deeply recognised the importance of recycling of treated effluent and are now struggling with this matter.

The river flow and discharge volume of the treated effluent from new BNR process at present and in future (2000) are exhibited in the following section and shown in detail in Tables 4.2 and 4.3 and summarised below:

Table 4.2 The River Flow and Discharge Volume of the Treated Effluent from New BNR Process in Future (2000)

River	Average Dry Season Flow			Remark
	River Flow	Discharge Volume of the STW	Ratio (%)	
Nyatuime R.	52,200 m^3/day	20,000 m^3/day	40	About 60 % of Basic Flow
Manyame R.	335,300 m^3/day	20,000 m^3/day	6	About 7 % of Basic Flow
River	Average Anual Flow			Remark
	River Flow	Discharge Volume of the STW	Ratio	
Nyatuime R.	95,500 m^3/day	20,000 m^3/day	21	About 26 % of Basic Flow
Manyame R.	569,400 m^3/day	20,000 m^3/day	4	About 4 % of Basic Flow

Table 4.2 Discharge Volume of the Treated Effluent from New BNR Process at Present and in Future (2000)

Name of STW			Present	2000	Remark
Discharge Volume of STW	Harare City	Crowborough STW	16,800 m^3/day	76,800 m^3/day	Increase 60,000 m^3/day
		Firle STW	30,000 m^3/day	102,000 m^3/day	Increase 72,000 m^3/day
		Harare South STW	-	(8,000) m^3/day	
		Harare East STW	-	(5,500) m^3/day	
	Chitungwiza City	Zengeza STW	-	20,000 m^3/day	Increase 20,000 m^3/day
	Total		46,800 m^3/day	198,800 m^3/day	Increase 152,000m^3/day

- The share of discharge volume from the Zengeza STW of river flow during dry season

  the Nyatsime River's flow downstream of the Zengeza STW: About 60% of own river flow

  Manyame River before flow into the Lake Chivero: About 10% of own river flow

- The discharge volume from the Zengeza STW at present and in the year 2000

  At present, only 46,800 cu.m/day of effluent from BNR process in the two STWs in Harare City are recycled to the river. The the rest of effluent is reused for farming or discharged. By the year 2000, upon completion of the Zengeza STW Project and other relevant projects, a total of 200,000 cu.m/day of treated effluent will supplement the water resources of the area and it will supply approximately 30% of the estimated total water demand. The Zengeza STW will contribute about 10% of the total recycled volume of treated effluent from the STWs.

As stated previously, the recycling of treated effluent from the Zengeza STW will make a significant contribution to the scarce water resources of the area. This contribution will be especially important in view of the fact that the government of Zimbabwe is considering such drastic (and expensive) measures such as utilizing distat water sources to meet the demands of Harare City.

The implementation of this Project aiming at reuse of treated effluent focusing on removal of nutrient substance to supplement supply capacity of water resources will give impact as an example for augmentation of treatment capacity to cope with increasing sewage volume toward the future in Chitungwiza Municipality and encourage/promote further increase of reusable effluent from the sewerage sector.

(4) Recovery of treatment performance of the existing STW and reuse of treated effluent.

The existing Zengeza STW is presently receiving about 36,000 cu.m/day of raw sewage. However, the design treatment capacity of the STW is 21,750 cu.m/day and this over loading result in the degradation of treatment efficiency, emission of offensive odour, etc. The water quality examination conducted on the of effluent from the STW indicated that BOD and COD were 315 m/l and 650 mg/l, respectively, which is the equivalent to raw sewage.

Through introduction of the proposed new BNR facility, the existing trickling filter process will be able to operated within its design treatment capacity and the expected treated effluent will be a BOD and COD at 60 mg/l and 180 m/l, respectively. Throug this achievement, the treated effluent from the existing trickling filter process would be able to applied for irrigation purpose in complian with the Public Hygiene Act of Zimbabwe (below 70 mg/l of BOD by GN 638/72). It should be noted that farmers near the Zengeza STW have expresses a willingness to partake in the active utilisation of treated effluent.

(5) Utilisation of excess sludge as a resource material (agricultural usage)

Anaerobic excess sludge from the treatment process is periodically removed for drying and has a low demand for reuse as fertiliser owing to its high inorganic contents (i.e. sand). The new BNR facility, which will be used exclusively for domestic sewage, with be able to produce nutritious fertiliser of stable quality.

Although local residents expressed at the public hearing their intention to actively utilize the excess sludge, the promotion of such reuse may be started from planting within the STW and public facilities, such as schools, and also requires public education efforts on the part of the government owned farms in cooperation with the Ministry of Agriculture.

(6) Provision of guidelines for institutional set-up and O&M

The organisational setup for the O&M of sewerage facilities and their management will take place along with the implementation of the Project. Human resources development, including manpower training, is also recommended. A review and updating of the regulations pertaining to sewerage service at the municipal level is also recommended.

(7) Creation of job opportunity

At present, job opportunities in the project area are quite limited. When the Project is started, the labor-intensive construction reguirement will provided the local communities with ample job the opportunities for skilled/unskilled labourers, metal smiths, plasteres, etc. The O&M of the sewerage facilities will provide opportunity for approximately five people for the positions of water quality examination, civil works, electrician, and accountant, In addition to other opportunities.

As described above, the Project is deemed feasible for implementation without any particular hindrance under the scheme of Japan's grant aid program, judging from the project benefits, the

characteristics of the Project to improve environmentally related infrastructures and the actual presence of an operating sewerage system in operation.

4-2 Recommendations

The suitability and feasibility of the Project for implementation under the grant aid scheme of the Government of Japan have been confirmed in view of the remarkable expected effects and the benefits and of contribution to the basic human needs of the local residents. In addition, a confirmation for the implementation of the recommendations provided under the foregoing development study on the Water Pollution Control Master Plan has been obtained from the Government of Zimbabwe and the acquisition of the required staff and local budget can be arranged as needed.

However, currently practised transfer of revenue from this sewerage sector to budget of another sector shall be stopped to secure appropriate budget for O&M of sewerage system to attain self-sustainable financial status of sewerage sector. If revision of sewerage tariff corresponding to inflation rate is implemented prior to the project's target year of 2000 in relation to rebuilding plan to restore financial imbalance of the Chitungwiza Municipality which is under preparation, the overall achievement of the Project's objectives will be smoothly and effectively insured.

Appendix 1 Member List of the Survey Team

No.	Name	Position	Designation
1	Mr. H. Iwahori	Senior Development Specialist, Institute for International Cooperation, JICA	Team Leader
2	Dr. K. Yoshimoto	Counselor, Japan Regional Development Corporation	Technical Advisor
3	Mr. A. Morishima	Manager, Factory Relocation Div., Dep. of Operations, Japan Environment Corporation	Technical Advisor
4	Mr. H. Hamaoka	First Project Study Div., Grant Aid Project Study Dep., JICA	Coordinator
5	Mr. M. Momose	Nippon Jogesuido Sekkei Co., Ltd	Chief Consultant / Management and O&M Planner
6	Mr. H. Sano	Nippon Jogesuido Sekkei Co., Ltd	Sewage Plant and Equipment Planner
7	Mr. M. Sano	Nippon Koei Co., Ltd	Procurement Planner
8	Mr. S. Ueno	Nippon Jogesuido Sekkei Co., Ltd	Procurement Planner

Appendix 2 Survey Schedule (Field Survey)

No.	Date		Schedule		
			Mr. Iwahori Dr. K. Yoshimoto Mr. A. Morishima Mr. H.Hamaoka	Mr. M. Momose Mr. H. Sano	Mr. T. Naka
1	July 14	Mon	Narita－Singapore		
2	15	Tue	Singapore－Johannesburg－Harare		
			Courtesy call on MLGRUD		
3	16	Wed	Explanation of contents of IC/R and tentative study schedule		
4	17	Thr	Discussions on IC/R		
5	18	Fri	Site survey & discussions		
6	19	Sat	Site survey & inner meeting		
7	20	Sun	Data review and arrangement		
8	21	Mon	Signing of the Minutes of Discussions		
9	22	Tue	Site survey		
10	23	Wed	Courtesy call to the Japanese Embassy and JICA Zimbabwe office		
			Harare－	Site survey	
11	24	Thr	－Amsterdam－	Site survey	
12	25	Fri	－Narita	Site survey	
13	26	Sat		Site survey	
14	27	Sun		Site survey	Harare –Johannesburg
15	28	Mon		Site survey	Site survey
16	29	Tue		Site survey	Site survey
17	30	Wed		Site survey	Site survey
18	31	Thr		Harare – Johannesburg	Site survey
19	August 1	Fri		Site survey	
20	2	Sat		Johannesburg - Hong Kong	
21	3	Sun		Hong Kong－Narita	

Appendix 3 List of Party Concerned in the Recipient Country

No.	Ministry/Name	Position	
	MLGRUD		
1	Mr. A. C. Mpamhanga	Depart of development, Planning and Coordination	Director
2	Mr. J. T. Mutamiri	Depart of development, Planning and Coordination	Dupty Director
3	Mrs. S. N. Musungwa	Depart of development, Planning and Coordination	Assistant Secretary
4	Mr. J. Mugabe	Depart of development, Planning and Coordination	Administrative Officer
	Chitungwiza Municipality		
5	Mr. T. N. Chiroodza	City Clerk	
6	Mr. M. Khosla	Engineering Services	Director
7	Mr. P. Mbira	Water And Sewerage	Engineer

Appendix 4 Minutes of Discussion

ミニッツ

MINUTES OF DISCUSSIONS

BASIC DESIGN STUDY
ON
THE REHABILITATON AND EXPANSION PROJECT
OF THE SEWAGE WORKS IN THE MUNICIPALITY OF CHITUNGWIZA
IN
THE REPUBLIC OF ZIMBABWE

In response to a request from the Government of the Republic of Zimbabwe, the Government of Japan decided to conduct a Basic Design Study on the Rehabilitation and Expansion Project of the Sewage Works in the Municipality of Chitungwiza in the Republic of Zimbabwe (hereinafter referred to as "the Project") and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Zimbabwe a study team which is headed by Mr. Haruo IWAHORI, Development Specialist, Institute for International Cooperation, JICA, and is scheduled to stay in the country from July 15 to 31, 1997.

The team held discussions with the officials concerned of the Central Government of the Republic of Zimbabwe and of Chitungwiza Municipality and conducted a field survey at the study area.

In the course of discussions and field survey, both parties have confirmed the main items described on the attached sheets. The team will proceed to further works and prepare the Basic Design Study Report.

July 21, 1997

岩堀春雄

Mr. Haruo IWAHORI
Leader,
Basic Design Study Team,
JICA

Mr. A. C. Mpamhanga
Director,
Development Planning and Co-ordination,
Ministry of Local Government, Rural and
Urban Development,
the Republic of Zimbabwe

Mr. T. N. Chiroodza
Town Clerk,
Chitungwiza Municipality,
the Republic of Zimbabwe

ATTACHEMENT

1. Objective

The objective of the Project is to improve the water environment and the quality of the surface water resources of the Upper Manyame River Basin by means of rehabilitation and expansion of Zengeza Sewage Works.

2. Project site

Zengeza Sewage Treatment Works (Zengeza STW), St. Mary's Pump Station(2 pump stations) and Tilcor Pump Station (Shown in ANNEX-I)

3. Executing Agency and Supervising Ministry

Executing Agency: Chitungwiza Municipality

Supervising Ministry: Ministry of Local Government, Urban and Rural Development (MLGURD)

4. Items Requested by the Government of Zimbabwe

After discussions between the Basic Design Study Team and Zimbabwe side, the following items were finally requested by the Zimbabwe side.

(1) Construction of sewage treatment facilities

1)Distribution Chamber
2)Screen and Grit Chamber
3)Equalization Tank
4)Primary Sedimentation Tank
5)Biological Reactor (BNR)
6)Final Sedimentation Tank with Return and Excess Sludge Pump Facilities
7)Sludge Thickener
8)Sludge Digestion Tank
9)Sludge Drying Bed
10)Sludge Storage Yard with Roof
11)In-Plant Piping
12)Effluent Pipe and Outfall Work
13)Plant Mechanical, Electrical Equipment and Extension of Electrical Line from Transformer of Substation

14)Laboratory Building and Electric Control House
15)Roads, Drainage, etc.
16)Maintenance Vehicles (4×4 Pick-up, Backhoe and Dump truck)

(2) Rehabilitation of existing pump stations in terms of the replacement of pump facilities and relevant electric facilities

1)Tilcor Pump Station
2)St. Mary's Pump Station: No.1 and No.2

However, the final components of the Project, both quantity and specifications, will be described after further studies.

5. Japan's Grant Aid System

(1) The Government of Zimbabwe has understood the system of Japan's Grant Aid explained by the Team, as described in Annex-II.
(2) The Government of Zimbabwe will take necessary measures, described in Annex-III for smooth implementation of the Project, on condition that the Grant Aid Assistance by the Government of Japan is extended to the Project.

6. Schedule of the Study

(1) The Consultant will proceed to further studies in Zimbabwe and the Republic of South Africa until August 1, 1997.
(2) Based upon the Minutes of Discussions and technical explanation of the study results, JICA will prepare the final report in English and send it to the Government of Zimbabwe by the end of January, 1998.

7. Other Relevant Issues and Problems to be Managed/Solved Timely by Zimbabwe Side on the condition that the Grant Aid Assistance by the Government of Japan is extended to the Project

A series of discussions were made between the both parties on issues and problems with reference to the successful implementation of the Project based on the answers prepared by Zimbabwe side to the inquiries from the Team. The following are necessary

measures agreed to be taken by Zimbabwe side.

(1) Other projects to be implemented parallel to the Project with reference to water pollution control in the Upper Manyame River Basin

With regard to the water pollution control in the subject basin, the previous Master Plan concluded that it may be possible to maintain the future water quality at present level beyond medium term target year(2005) provided with appropriate countermeasures. The rehabilitation/expansion/augmentation of the existing sewerage systems are requisites in a commensurate manner to meet socio-economic development in the respective areas through the future.

In this connection the local governments concerned in the subject river basin have been implementing sewerage projects in the short-medium term target(2000-2005). However, some of them are planning/design stage trying to find financial sources. In this regard, timely arrangements by Zimbabwe side to realize the respective projects are requisites. The followings are planned/on-going projects to be managed by the local governments with the coordination of the MLGRUD. The details by project are summarized in Table 7.1.

Under construction/completion of financial arrangement to start construction work(4 projects)

Harare City

1)Firle STW expansion project
2)Mukuvisi outfall trunk sewer construction project
3)Chisipite sewage pump station construction project

Norton Town

4)Norton Town STW rehabilitation project

Planned/designed but not yet financially arranged(5 projects)

Harare City

1)Firle catchment subsidiary sewer construction project
2)Crowborough STW expansion project
3)Harare East (Mabvuku Tafara) STW construction project

Norton Town

4)Norton Town STW expansion project

Ruwa Local Board

5)Ruwa STW expansion project

(2) Relevant project to this proposed project

Rehabilitation and augmentation of the existing sewerage system are requisites for the successful implementation of the sewerage project in the Municipality. The following works will be performed by the Municipality with financial arrangements. (Details are summarized in Table 7.2.)

1)Rehabilitation of the existing sewer system with an emphasis on the preventive maintenance on annual basis

2)Rehabilitation of existing sewage treatment facilities to recover design functions

3)Expansion of sewer system to cover new housing area in St. Mary's

(3) Implementation arrangement for the Project and institutional/legal strengthening for operation and maintenance (O&M) of the facilities

The competent capability of the municipal council is necessary to execute the Project and O&M practices. According to the recommendations in the previous Water Pollution Control Master Plan, the Municipality will prepare the followings covering legal, institutional and staff training (refer to proposed organization chart in Figure 7.1).

- Creation of Project Coordination Committee to support decision making functions
- Establishment of Project Management Office for the implementation of the Project
- Augmentation of Water and Sewerage Division both for STW and sewage reticulation properly demarcating the responsibilities/duties of the staff work between these sections
- Establishment of water quality laboratory entailing the surveillance team to monitor effluent quality of the factories
- Preparation of relevant regulations for the control of effluent discharged by major pollution sources setting up a task force
- Commencement of training program, especially for O&M of BNR process with the commitment of adequate financial resources

(4) Operation and maintenance cost for the Zengeza Sewage Works

Proper operation and maintenance of the sewerage facilities are essential covering existing and newly constructed ones. In this regard, appropriate countermeasures will be taken by the Municipality based on the "Integrated Performance Program" recently prepared by the Municipal Council to reform the financial frame work. The program exhibits the recovery of the total deficit of the municipality (accumulated up to the year 1991) by the year 2001. While, as of 1995, among 12 accounts of the municipal budget, sewerage account has sustained with surplus in the balance between expenditure and revenue and the plan shows the sound financial projection in this sub-sector. Although the surplus derived from this sub-sector had been transferred mainly to health account, the Municipality will properly manage the amount for the sewerage sector to meet the implementation of the Project. Town Clerk of Chitungwiza Municipality will submit the following Tables to the Team by July 28, 1997.

1) Income Statement (Actual data of 1995 and 1996, Forecast data of 1997 and 2000)
2) Balance Sheet (ditto)
3) Cash Flow Statement (ditto)

(5) Reuse of treated sludge

The reuse of treated sludge generated at the STW is not commonly practiced in Zimbabwe. However, the promotion of the reuse of the sludge will be arranged in cooperation with Ministry of Agriculture entailing information dissemination to farmers and other prospective users.

(6) Undertaking by Zimbabwe side with reference to the construction of the proposed treatment facilities

The Municipality will make arrangement on the requirements shown below to meet the implementation of the Project.

1)Steel net fence at least along proposed treatment facilities
2)Power supply at the primary side by the Zimbabwe Electricity Supply Authority (ZESA) for the operation of proposed treatment facilities
3)Required extension of water and telephone services to the construction site

Table-7.1 Rehabilitation/Expansion/Augmentation of Existing Sewerage System

Urban Area	SWs	Project w/Scope of Work	Cost	Financial Source	Present Status
Harare City	Firle	· Firle STW Expansion project Expansion of existing treatment capacity (BNR method) from 72,000 cu.m/d to 144,000 cu.m/d to cope with the rapid increase of influent sewage	Z$322 million	European Investment Bank	Under construction to complete by the end of this year
		· Mukuvisi outfall trunk sewer construction project The trunk sewer (1,050mm-1,200mm dia. 18km) is under construction to connect to the Firle STW to be completed by early 1998	Z$200 million	European Investment Bank	The construction work was started to complete by early 1998.
		· Chisipite sewage pump station construction project Construction of a new pump station replacing existing one to connect to the Mukuvisi outfall trunk sewer (including rising main 250mm dia. 1950 m; gravity sewer 300 mm dia. 1600 m; trunk sewer 450-525 mm dia. 4900m)	N.A	World Bank	The construction work will start in August 1997 to complete by early 1998.
		· Firle catchment subsidiary sewer construction project The subsidiary sewers cover the developing area within the Firle service area	N.A	N.A	A tender for consulting services has been adjudicated, but it has not yet been awarded.
	Crowborough	· Crowborough STW expansion project Expansion of existing treatment capacity with an addition of 60,000 cu.m/d (BNR method) and construction of trunk sewer to cater for estimated sewage flow in 2005	Z$270 million	Unknown	Design of facilities was completed, but financial source/s is not yet determined.
	Harare East (Mabvuku Tafara)	· Harare East (Mabvuku Tafara) STW construction project The STW is newly constructed (BNR method) to cater for not only Harare East area but also the sewage presently treated at the existing Donnybrook STW for a total volume of about 12,000 cu.m/d. The transmission main between the STWs is also considered.	Z$100 million	Government loan (only for consulting services) ;unknown for the construction	At present a tender for consulting services has been adjudicated.

Table-7.1 Rehabilitation/Expansion/Augmentation of Existing Sewerage System (cont'd)

Urban Area	SWs	Project w/Scope of Work	Cost	Financial Source	Present Status
Norton Town	Norton	• Norton Town STW rehabilitation project Replacement and repair of existing sewage treatment facilities	N.A	N.A	The rehabilitation work was almost completed at present.
		• Norton Town STW expansion project Expansion of the STW to cope with the sewage increase in the future	N.A	Unknown	An expansion plan was prepared with alternatives in terms of secondary treatment method (trickling filter or BNR).
Ruwa Local Board	Ruwa	• Ruwa STW expansion project Expansion of the STW to cope with population increase in the future	N.A	Unknown	A plan for the expansion of the existing STW and irrigation land was prepared with two options on the treatment method (stabilization pond or BNR).

Note: N.A Data/information are not available

Table 7.2 Rehabilitation and Augmentation of Existing Sewerage System

Project/Works	Rehabilitation/Expansion Program	Cost	Financial Arrange.
Rehabilitation of the existing sewers	(1) Replacing 10 Km sewers (300-650 mm dia.), and cleaning trunk and subsidiary sewers(35 Km) The work will be completed by April 1998	23 million Z$	Gov.Loan (The total amount is available by October 1997)
	(2) The O&M of sewer systems will be conducted establishing preventive O&M program on annual base including site investigation (2-year cycle for 25.2 Km^2 service area) pipe cleaning (5-year cycle for sewer length of 487.7 Km) and rehabilitation (10-year cycle for 100.95 Km assuming 30 % rehabilitation needs to the total length of municipal sewers). The O&M for pump stations will also be done according to daily (4 persons/pump station) and periodical (overhaul of pump equipment in 5-10 year cycle) work program.	3.646 million Z$/year	Sewerage charges to be collected from users
Rehabilitation and O&M of existing sewage treatment facilities	(1) Current problems identified will be managed including repair of flow meters, removal of accumulated sludge at anaerobic ponds and trickling filter, preventive maintenance of effluent pump facilities, and sludge removal and provision of the jet nozzle for scum breaking at Tilcor pre-treatment facilities. The O&M cover continuous maintenance and repairs of the facilities, sludge transportation and disposal and water quality examination.	2.529 million Z$/year	Sewerage charges to be collected from users
	(2) Cleaning and lining of Tilcor pre-treatment ponds; The work will be completed by October 1999.	3.3 million Z$	Chitungwiza Municipality
Expansion of sewer system to cover new housing area in St. Mary's	The sewage (design flow: 8,550 cu.m /d in peak flow) discharged from new housing area in St. Mary's will be collected finally to connect to the STW. The total length of gravity type sewers is 4.28 Km. A new pump station will be constructed with a capacity of 6 m^3/min.The force main pipe with a length of 2.6 Km will also be constructed. The construction work will start in January 1998 to complete by December 1998.	25 million Z$	Chitungwiza Municipality

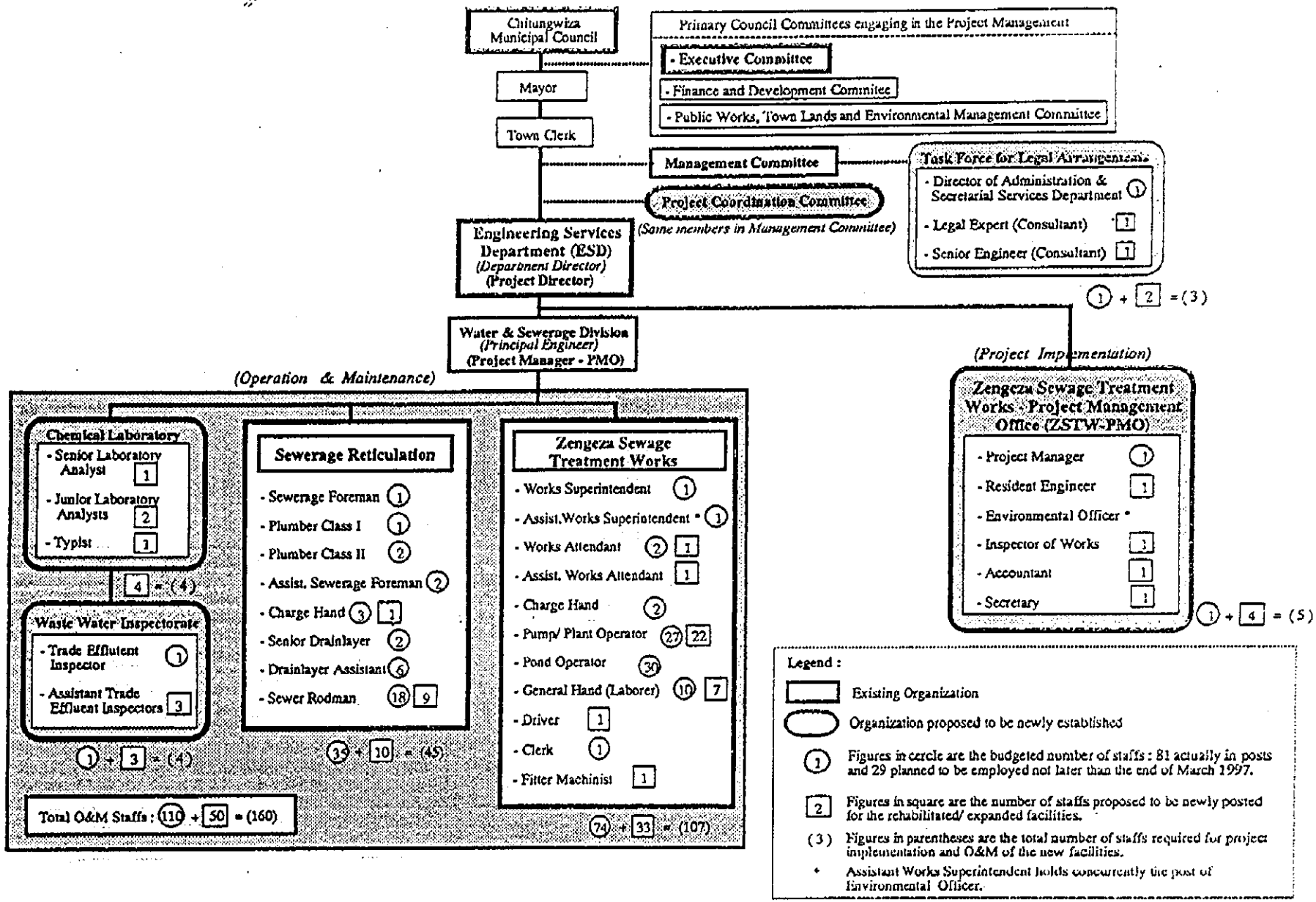
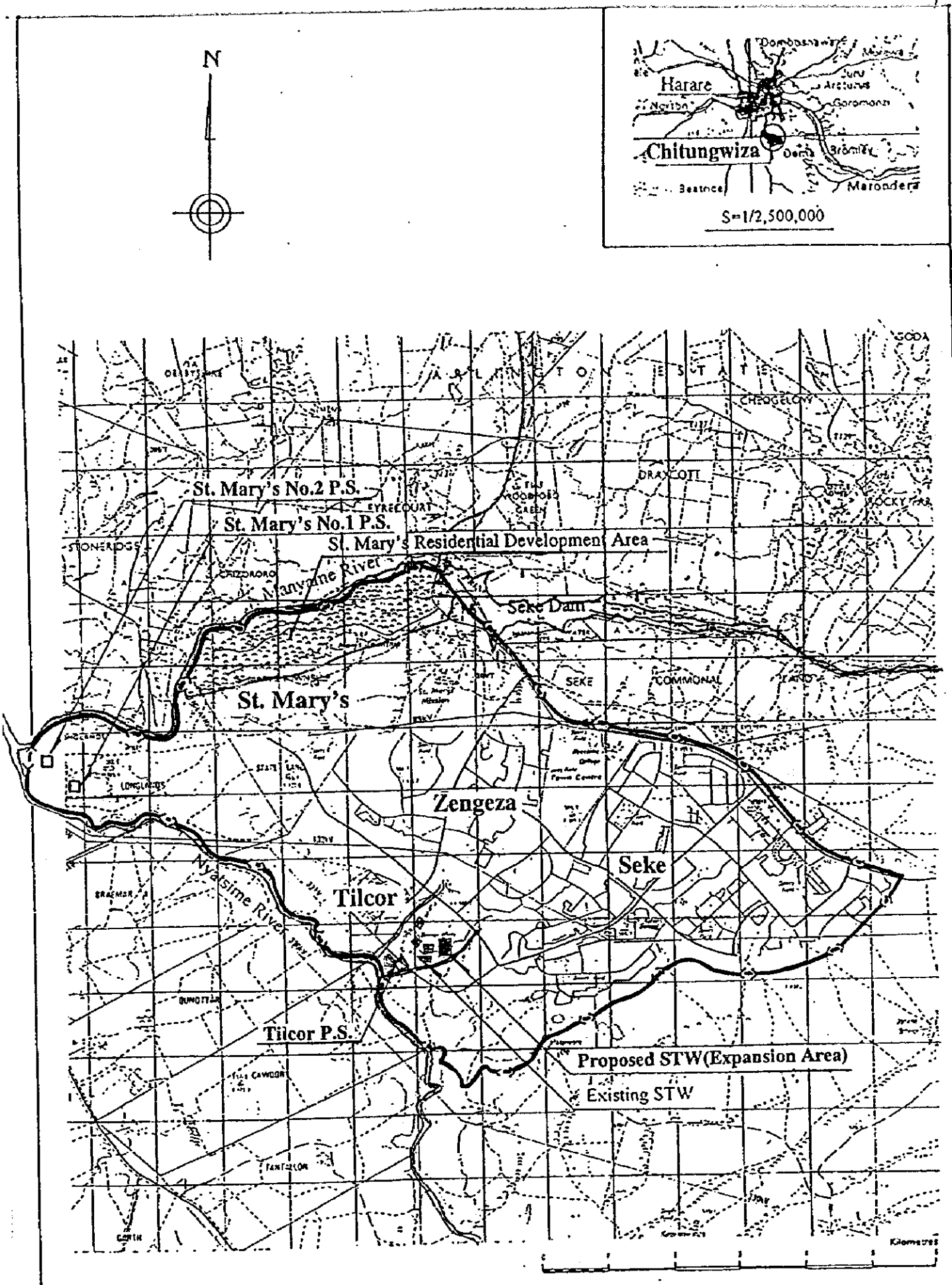


Figure 7.1 Proposed Organizational Strengthening for Project Implementation and O&M of the Municipal Sewerage System



Annex-1 Location Map

ANNEX-II

ON JAPAN'S GRANT AID PROGRAM

1. Japan's Grant Aid Procedures

(1) The Japan's Grant Aid Program is executed by the following procedures.

- **Application** (request made by a recipient country)
- **Study** (Preliminary Study / Basic Design Study conducted by JICA)
- **Appraisal & Approval** (Appraisal by the Government of Japan and Approval by the Cabinet of Japan)
- **Determination of Implementation** (Exchange of Notes between both Governments)
- **Implementation** (Implementation of the Project)

(2) Firstly, an application or a request for a project made by the recipient country is examined by the Government of Japan (the Ministry of Foreign Affairs) to see whether or not it is suitable for Japan's Grand Aid. If the request is deemed suitable, the Government of Japan entrusts a study on the request to JICA (Japan International Cooperation Agency).

Secondly, JICA conducts the Study (Basic Design Study), using a Japanese consulting firm. If the background and objective of the requested project are not clear, a Preliminary Study is conducted prior to a Basic Design Study.

Thirdly, the Government of Japan appraises to see whether or not the Project is suitable for Japan's Grant Aid Program, based on the Basic Design Study report prepared by JICA and the results are then submitted for approval by the Cabinet.

Fourthly, the Project approved by the Cabinet becomes official when pledged by the Exchange of Notes signed by both Governments.

Finally, for the implementation of the Project, JICA assists the recipient country in preparing contracts and so on.

2. Contents of the Study

(1) Contents of the Study

The purpose of the Study (Preliminary Study / Basic Design Study) conducted on a project requested by JICA is to provide a basic document necessary for appraisal of the project by the Japanese Government. The contents of the Study are as follows:

a) to confirm background, objectives, benefits of the project and also institutional capacity of agencies concerned of the recipient country necessary for project implementation,
b) to evaluate appropriateness of the Project for the Grant Aid Scheme from a technical, social and economical point of view,
c) to confirm items agreed on by both parties concerning a basic concept of the project,
d) to prepare a basic design of the project,
e) to estimate cost involved in the project.

Final project components are subject to approval by the Government of Japan and therefore may differ from an original request.

Implementing the project, the Government of Japan requests the recipient country to take necessary measures involved which are itemized on Exchange of Notes.

(2) Selecting (a) Consulting Firm(s)

For smooth implementation of the study, JICA uses (a) consulting firm(s) registered. JICA selects (a) firm(s) through proposals submitted by firms which are interested. The firm(s) selected carry(ies) out a Basic Design Study and write(s) a report, based upon terms of reference made by JICA.

The consulting firm(s) used for the study is(are) recommended by JICA to a recipient country after Exchange of Notes, in order to maintain technical consistency and also to avoid possible undue delay in implementation caused if a new selection process is repeated.

(3) Status of a Preliminary Study in the Grant Aid Program

A Preliminary Study is conducted during the second step of a project formulation & preparation as mentioned above.

A result of the study will be utilized in Japan to decide if the Project is to be suitable for a Basic Design Study.

Based on the result of the Basic Design Study, the Government would proceed to the stage of decision making process (appraisal and approval).

It is important to notice that at the stage of Preliminary Study, no commitment is made by the Japanese side concerning the realization of the Project in the scheme of Grant Aid Program.

3. Japan's Grant Aid Scheme

(1) What is Grant Aid?

The Grant Aid Program provides a recipient country with non reimbursable funds needed to procure facilities, equipment and services for economic and social development of the country under the following principles in accordance with relevant laws and regulations of Japan. The Grant Aid is not in a form of donation or such.

(2) Exchange of Notes (E/N)

The Japan's Grant Aid is extended in accordance with the Exchange of Notes by both Governments, in which the objectives of the Project, period of execution, conditions and amount of the Grant, etc. are confirmed.

(3) "The period of the Grant Aid" means one Japanese fiscal year which the Cabinet approves the Project for. Within the fiscal year, all procedure such as Exchange of Notes, concluding a contract with (a) consulting firm(s) and (a) contractor(s) and a final payment to them must be completed.

(4) Under the Grant, in principle, products and services of origins of Japan or the recipient country are to be purchased.

When the two Governments deem it necessary, the Grant may be used for the purchase of products or services of a third country origin.

However the prime contractors, namely, consulting, contractor and procurement firms, are limited to "Japanese nationals". (The term "Japanese nationals" means Japanese physical persons or Japanese juridical persons controlled by Japanese physical persons.)

(5) Necessity of the "Verification"

The Government of the recipient country or its designated authority will conclude into contracts in Japanese yen with Japanese nationals. Those contracts shall be verified by the Government of Japan. The "Verification" is deemed necessary to secure accountability to

Japanese tax payers.

(6) Undertakings required to the Government of the recipient country

In the implementation of the Grant Aid, the recipient country is required to undertake necessary measures such as the following:

a) to secure land necessary for the sites of the project and to clear and level the land prior to commencement of the construction work,

b) to provide facilities for distribution of electricity, water supply and drainage and other incidental facilities in and around the sites,

c) to secure buildings prior to the installation work in case the Project is providing equipment,

d) to ensure all the expenses and prompt execution for unloading, customs clearance at the port of disembarkation and internal transportation of the products purchased under the Grant Aid,

e) to exempt Japanese nationals from customs duties, internal taxes and other fiscal levies which will be imposed in the recipient country with respect to the supply of the products and services under the Verified Contracts,

f) to accord Japanese nationals whose services may be required in connection with the supply of the products and services under the Verified Contracts, such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work.

(7) Proper Use

The recipient country is required to maintain and use facilities constructed and equipment purchased under the Grant Aid properly and effectively and to assign staff necessary for their operation and maintenance as well as to bear all expenses other than those to be borne by the Grant Aid.

(8) Re-export

The products purchased under the Grant Aid shall not be re-exported from the recipient country.

(9) Banking Arrangement (B/A)

a) The Government of the recipient country or its designated authority shall open an account in the name of the Government of the recipient country in an authorized foreign exchange bank in Japan (hereinafter referred to as "the Bank"). The Government of Japan will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by Government of the recipient country or its designated authority under the contracts verified.

b) The payments will be made when payment requests are presented by the Bank to the Government of Japan under an Authorization to pay issued by the Government of the recipient country or its designated authority.

Necessary measures to be taken by the Government of the Republic of Zimbabwe in case Japan's Grant Aid is executed.

1. To secure the site for the Project.
2. To clear, Level and reclaim the site prior to commencement of the construction/rehabilitation.
3. To undertake incidental outdoor works such as gardening, fencing, gates and exterior lighting in and around the site.
4. To construct the access road to the site prior to commencement of the construction/rehabilitation.
5. To provide facilities for distribution of electricity, water supply, telephone, drainage, sewage and incidental facilities to the Project site.
   1) Electricity distribution line to the site.
   2) City water distribution main to the site.
   3) Drainage city main to the site.
   4) Telephone trunk line and the main distribution panel of building.
   5) General furniture such as carpets, curtains, tables, chairs and others.
6. To bear commissions to the Japanese foreign exchange bank for the banking services based upon Banking Arrangement.
7. To exempt taxes and to take necessary measures for customs clearance of the materials and equipment brought for the Project at the port of disembarkation.
8. To accord Japanese Nationals whose services under the verified contract such facilities as may be necessary for their entry into Zimbabwe and stay therein for the performance of their work.
9. To maintain and use properly and effectively that the facilities constructed and equipment purchased under the Grant.
10. To bear all the expenses other than those to be borne by the Grant necessary for construction of the facilities well as for the transportation and the installation of the equipment.

Appendix 5 Cost Estimation Borne by the Recipient Country

Sewage Treatment Plant

1.	① fencing around the proposed site:	applox.1,240m	400 x 1000 Z$
2.	② power supply to the proposed site:	primary side	500 x 1000 Z$
3.	③ water supply to the proposed site :	dia.75mm	(existing)
4.	④ telephone line to the proposed site:	extension	0.1 x 1000 Z$
	Total		900.1x1000

Appendix 6 Other Relevant Data

Appendix A Capacity Calculation

1. Design Criteria

(1) Basic Items

Name:	Zengeza sewage treatment works
Location:	Municipality of Chitungwiza
Elevation:	+1,408.2～1,402.5M
Land use:	Crop field, uncultivated land
Type of sewer:	Separate type
Treatment method:	Biological nutrient removal (BNR) method + maturation pond
Sludge treatment method:	Primary settled sludge: Thickening, digestion, drying
	Final settled sludge: Thickening, drying
Sludge disposal:	Reuse of the sludge for land application (fertilizer)
Effluent point and water level:	Nyatsime river, +1399.0M
Target year:	2000
Lowest monthly temperature:	14℃ (average)

(2) Design sewage flow (m^3/day)

Item	Total	Existing Facilities	Proposed facilities	
			Flow	Target facilities
ADWF (Q_1)	41,500	21,500	20,000	Sewage treatment facilities and Sludge treatment facilities
PDWF (Q_2)	62,250	42,250		
PWWF (Q_3)	124,500	104,500		
Hourly maximum (Q_4)			32,000	Grit chamber to equalization tank

(3) Design water quality (mg/L)

Item	Influent	Grit Chamber Influent	Primary treatment		Secondary treatment		Total Removal ratio (%)
			Removal ratio (%)	Effluent	Removal ratio (%)	Effluent	
BOD (mg/L)	700	620	35	403	93	30	95.7
COD (mg/L)	1,350	1,200	35	780	92	60	95.6
S S (mg/L)	550	490	50	245	90	25	95.5
T－N (mg/L)	115	102	20	82	88	10	91.3
T－P (mg/L)	12.4	11.0	30	7.7	87	1.0	91.9

(4) Moisture content of the sludge (%)

Item	Raw	Thickened	Digested	Dried
Primary settled	96.5	95.0	94.0	60.0
Final settled	99.2	96.0	-	60.0

(5) Design sludge volume

1) Primary settled sludge

Item	Generated	Thickened	Digested	Dried
Sludge weight	20,000x(490-245) x 1/1,000 =4,900kg/day	4,900kg/day	4,900 x (1-0.7x0.50) =3,185kg/day	3,185kg/day
Sludge volume	4,900 x 1/1,000 x 100/(100-96.5) =140m^3/day	4,900 x 1/1,000 x 100/(100-95) =98m^3/day	3,185 x 1/1,000 x 100/(100-94) =53.1 m^3/day	3,185 x 1/1,000 x 100/(100-60) =8.0 m^3/day
Supernatant liquid		140-98 =42m^3/day	98-53.1 =44.9 m^3/day	-

2) Final settled sludge

Item	Generated	Thickened	Digested	Dried
Sludge weight	6,981kg/day	6,981kg/day	—	6,981kg/day
Sludge volume	6,981 x 1/1,000 x 100/(100-99.2) =873m^3/day	6,981 x 1/1,000 x 100/(100-96) =175m^3/day	—	6,981 x 1/1,000 x 100/(100-60) =17.5m^3/day
Supernatant liquid	—	873-175 =698m^3/day	—	—

Final settled sludge (waste sludge) volume is calculated as below:

$$W_{SI} = (a \times S_{CS} + b \times S_{SS} - c \times \theta \times X_A) \times Q$$

Where,

Q = 20,000 m^3/day
a = 0.5 gMLSS/gBOD
b = 0.95 gMLSS/gSS
c = 0.03 1/d
S_{CS} = 403 x 50% = 202 mg/L
S_{SS} = 245 mg/L
X_A = 4,500 mg/L
θ = 12,000m^3 / 20,000m^3/day = 0.6 day

Accordingly,

W_{S1} = (0.5 x 202 + 0.95 x 245 - 0.03 x 0.6 x 4,500) x 20,000

= 252.8 x 20,000 = 5,056kg/day

Additional sludge weight owing to the hydrated lime dosing is estimated as below:

a. A impurity's weight of the hydrated lime

A purity of the hydrated lime product is 3.8 % in Zimbabwe.

3,485 kg/day x 0.038 = 132kg/day

b. Additional weight of the generated calcium compound

As a result of a chemical reaction between the calcium ion of the hydrated lime and free carbonic acid that is generated in the aerobic tank, calcium compound will be settled in the final sedimentation tank.

Assuming that the 80 % of the fed calcium will generate calcium carbonate ($CaCO_3$) and calcium bicarbonate ($Ca(HCO_3)_2$), and only the calcium carbonate will be settled.

2,509 kg/day x (40/56) x 80% = 1,434kg/day

$CaCO_3$ = 1,434kg/day x 50% x (100/40) = 1,793kg/day

c. Total additional weight of the sludge

W_{S2} = a. + b. = 132 + 1,793= 1,925kg/day

Therefore, the waste sludge is calculated as below:

$W_S = W_{S1} + W_{S2}$ = 5,056 + 1,925=6,981kg/day=6.981ton/day

In general, the concentration of the waste sludge in the BNR method is assumed as 4,000 to 6,000mg/L, however, it is recommended that the average concentration should be 8,000 mg/L (a range of 6,000 to 10,000mg/L) considering the effective settleability by means of the lime dosing.

2. Capacity calculation

(1) Sewage treatment facilities

Item		Calculation
1.Grit Chamber		
Type		Plug flow type
Design sewage flow	Q_4	$32,000m^3/day=0.370m^3/sec.$
No. of basin	N	2basins
Effective depth	H	0.5m
Area load	WL	$1,800m^3/m^2/day$
Required surface Area	A_1	$32,000 \div 1,800 = 17.8m^2$
Average velocity	V	0.3m/sec.
Required flow Area	A_2	$0.370 \div 0.3 = 1.23m^2$
Required width	W	$(1.23/2) \div 0.5 = 1.23m \rightarrow 1.4m$
Required length	L	$(17.8/2) \div 1.4 = 6.36m \rightarrow 6.5m$
Dimension		$1.4m^W \times 6.3m^L \times 0.5m^H \times 2basins$
Check		
Area load	WL	$32,000 \div (1.4 \times 6.5 \times 2) = 1758 < 1,800m^3/m^2/day$
Average velocity	V	$0.370 \div (1.4 \times 0.5 \times 2) = 0.264 < 0.3m/sec.$
Screen		Manual type coarse screen: bar pitch 40mm
		Manual type fine screen : bar pitch 14mm
2.Measuring Device		
Type		Venturi flume
Design sewage flow	Q_4	$32,000\ m^3/day=0.370\ m^3/sec.$
3.Primery Sedimentation Tank		
Type		Radial flow, Circular tank
Design sewage flow	Q_1	$20,000m^3/day$
Area load	WL	$1.2\ m^3/m^2/hour=28.8m^3/m^2/day$
Required surface area	A	$20,000 \div 28.8 = 694\ m^2$

Item		Calculation
No. of basin	N	2basins
Required Diameter	D	$((694/2)/0.785)^{0.5}$=21.0m
Effective depth	H	3.2m
Dimension		$21.0m^{D}\times3.2m^{H}\times$2basins
Check		
Area load	WL	$20,000\div(21.0^2\div4\times3.14\times2)=28.9m^3/m^2/day$
Retention time	T	$(21.0^2\div4\times3.14\times3.2\times2)\div(20,000/24)$=2.7hours
4.Equalization Tank		
Type		Rectangular tank, Orifice effluent
Peak factor		Influent :1.6
		Effluent: 1.2 (target level)
Required volume		4,000 m^3
No. of basin	V	1basin
Dimension	N	$40.0m^{W}\times40.0m^{L}\times2.9m^{H}\times$1basin
5.Hydrated Lime Dosing Facility		
Required alkali dosing weight		Influent T-N concentration : 82mg/L Influent alkalinity : 180mg/L Reactor effluent alkalinity : -72mg/L (calculation result) - do - : 40mg/L (target level) Design sewage flow & return activated sludge volume: 40,000m^3/day
Required hydrated lime dosing weight		Alkali ($CaCO_3$) weight: (40-(-72)) x 40,000 = 4,480kg/day Hydrated lime (CaO) weight: 4,480 x (56/100) = 2,509 kg/day Hydrated lime products (purity=72%): 2,509 / 0.72 = 3,485 kg/day Dosing slurry concentration: 5%
Storage facility		Storage period 10days, Silo type, 30m^3
6.BNR Reactor		
Design sewage flow	Q_1	20,000 m^3/day

Item		Calculation
Influent water quality		BOD_5 403 mg/L Solved BOD_5 201 mg/L (50% of BOD_5) SS 245 mg/L T-N 82 mg/L T-P 7.7 mg/L
Temperature	T	14℃
MLSS		Aerobic tank : 4,500 mg/L Return sludge: 9,000 mg/L
Return sludge ratio	Rr	9,000 x Rr / (Rr+1) = 4,500 Rr = 1.0
Circulation ratio	R	$R = \alpha \cdot C_{TN,in} / C_{NOX,A} - 1 = 0.7 \times 82 / 10 - 1 = 4.0$
Return sludge volume		$Q_1 \times Rr = 20,000 \times 1.0 = 20,000\ m^3/day$
Circulated liquid volume		$Q_1 \times R = 20,000 \times 4.0 = 80,000\ m^3/day$
A-SRT	θ_{XA}	$\theta_{XA} = \delta \times 20.6 \exp(-0.0627 \times T)$ $= 1.2 \times 20.6 \exp(-0.0627 \times 14) = 10.3$ days
Required tank capacity		
Anoxic tank	V_{AN}	$V_{AN} = Q_1 \cdot t_{AN}/24 = 20,000 \cdot (1 \text{ to } 2)/24 = 833 \text{ to } 1,666 \fallingdotseq \underline{1,500\ m^3}$
Anaerobic tank	V_{DN}	$V_{DN} = S_{CS} \cdot Q_1 / L_{BOD/X} \cdot X - V_A$ $= 403 \cdot 20,000 / 0.08 \cdot 4,500 - 12,000 = 10,389 \fallingdotseq \underline{10,500\ m^3}$
Aerobic tank	VA	$VA = Q_1 \cdot (\theta_{XA} \cdot (a \cdot S_{CS} + b \cdot S_{SS})) / ((1 + c \cdot \theta_{XA}) \cdot X)$ $= 20000 \cdot (10.3 \cdot (0.5 \cdot 201 + 0.95 \cdot 245)) / ((1 + 0.03 \cdot 10.3) \cdot 4500)$ $= 11,654 \fallingdotseq \underline{12,000\ m^3}$
Dimension		
Anoxic tank		Diameter 18.1m to 4.7m x $6.4m^H$ $= 1,578m^3 > 1,500m^3$
Anaerobic tank		Diameter 50.1m to 18.9m x $6.4m^H$ $= 10,983m^3 > 10,500m^3$
Aerobic tank		Diameter 84.9·72.9m to 50.9m x $4.45m^H$ $= 13,391m^3 > 12,000m^3$
Oxygen demand		
For BOD removal	D_B	$D_B = ((C_{BOD,in} - C_{BOD,eff}) \cdot Q_{in} \cdot 10^{-3} - L_{NOX,DN} - L_{NOX,A}) \times 2.0) \times 0.45$ $= ((403-30) \times 20,000 \times 10^{-3} - 1,150) \times 2.0) \times 4.5$ $= 2,322\ kgO_2/day$
For nitrification	D_N	$D_N = \alpha \cdot C_{TN,in} \cdot Q_{in} \times 10^{-3} \times 4.57$ $= 0.7 \times 82 \times 20,000 \times 10^{-3} \times 4.57 = 5,246\ kgO_2/day$

Item		Calculation
For endogenous respiration	D_E	$D_E = X \cdot V_A \times 0.12$ $= 4.5 \times 12{,}000 \times 0.12 = 6{,}480\ kgO_2/day$
For DO maintain	D_O	$D_O = C_{O,A} \times (Q_{in} + Q_r + Q_c) \times 10^{-3}$ $= 1.5 \times (20{,}000 + 20{,}000 + 80{,}000) \times 10^{-3} = 180\ kgO_2/day$
Total oxygen demand	TOD	$D_B+D_N+D_E+D_O = 2{,}322 + 5{,}426 + 6{,}480 + 180 = 14{,}228\ kgO_2/day$
Supply oxygen volume	SOV	$SOV = TOD \times C_{SW} / (1.024^{T2-T1} \cdot \alpha(\beta \cdot C_S \cdot \gamma - C_A)) \times (760/P)$ $= (14{,}228 \times 8.84 \times 1.05) /$ $(1.024^{14-20} \times 0.93 \times (0.97 \times 9.97 \times 1.05 - 1.5)) \times (760/640)$ $= 132{,}064 / 0.807 \times 8.654 \times 760/640 = 22{,}456\ kgO_2/day$
Aerator specification		Power efficiency for oxygen supply: 1.8 kg/kWh Required power: 22,456 / (1.8 x 24) = 520 kW Number of unit: 12 units Capacity: 40% x 4units, 25% x 3units, 20% x 3units, 10% x 2units Mechanical efficiency: $\xi = 0.60$ Affordability: $\alpha = 0.20$ No.1: (520 x 0.40 / 4) x (1/0.60) x (1+0.20) = 104 ≒ 110 kW No.2: (520 x 0.25 / 3) x (1/0.60) x (1+0.20) = 86 ≒ 90 kW No.3: (520 x 0.20 / 3) x (1/0.60) x (1+0.20) = 69 ≒ 75 kW No.4: (520 x 0.10 / 2) x (1/0.60) x (1+0.20) = 52 ≒ 55 kW
Mixer Specification for anaerobic tank		Tank capacity: 1,500 m^3 Unit required power: 5 W/m^3 Number of unit: 4units Required power per unit: 1,500 x 5 x 10^{-3} / 4 = 1.9 -> 3.0kW
Mixer Specification for anoxic tank		Tank capacity: 10,500 m^3 Unit required power: 5 W/m^3 Number of unit: 4units Required power per unit: 10,500 x 5 x 10^{-3} / 4 = 13.1 -> 15.0kW
7.Final Sedimentation Tank		
Type		Radial flow, Circular tank
Design sewage flow	Q_1	20,000m^3/day

Item		Calculation
Area load	WL	12 $m^3/m^2/day$
Required surface area	A	20,000÷12=1,667m^2
No. of basin		4basins
Required diameter	D	$((1667/4)/0.785)^{0.5}$=23.0m
Effective depth	H	3.5m
Dimension		$23.0m^D \times 3.5m^H \times 4basins$
	WL	20,000÷(23.0²÷4×3.14×4)=12.0$m^3/m^2/day$
	T	(23.0²÷4×3.14×3.5×4)÷(20,000/24)=6.98hours
8.Maturation Pond		
Design sewage flow	Q_1	20,000 m^3/day
Type		Embanked multi-cell pond
Retention time	T	3.0day
Required capacity	V	20,000×3.0=60,000m^3
No. of pond	N	4ponds
Effective depth	H	1.5m
9. Outlet channel		
Design sewage flow	Q_1	20,000 m^3/day
Type		RC Cascade type open channel
Dimension		1.0 m^W x 15m^L

(2) Sludge treatment facilities

Item		Calculation
1.Thickening tank - A (For primary settled sludge)		
Type		Circular thickener with sludge scraper
Design sludge volume	S	4,900kg/day, 140m^3/day (Water content ratio: 96.5%)
Proposed solids load	SL	90kg/m^3/day
Required tank surface area	A	4,900÷90=54.4m^2
No. of tank	N	2tanks
Required tank diameter	D	$(54.4/2/0.785)^{0.5}$=5.9 → 6.0m
Effective depth	H	4.0m
Dimension		$6.0m^D \times 4.0m^H \times 2$ tanks
Check		
Solids load	SL	4,900÷(6.0^2÷4×3.14×2)=86.7kg/m^2/day
Retention time	T	(6.0^2÷4×3.14×4.0×2)÷(140/24)=38.8hours
2.Thickening tank – B (For final settled sludge)		
Type		Circular thickener with sludge scraper
Design sludge volume	S	6,981kg/day, 873m^3/day (Water content ratio: 99.2%)
Proposed solids load	SL	70kg/m^3/day
Required tank Surface area	A	6,981÷70=99.7m^2
No. of tank	N	2tanks
Required tank diameter	D	$(99.7/2/0.785)^{0.5}$=8.0 → 8.0m
Effective depth	H	4.0m
Dimension		$8.0m^D \times 4.0m^H \times 2$ tanks

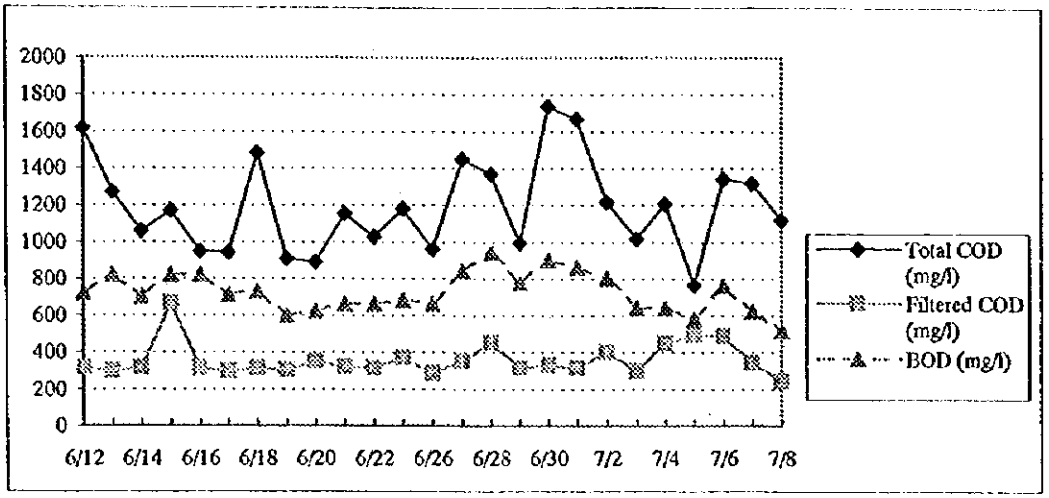
Item		Calculation
Check		
Solids load	SL	$6,981 \div (8.0^2 \div 4 \times 3.14 \times 2) = 69.5 kg/m^2/day$
Retention time	T	$(8.0^2 \div 4 \times 3.14 \times 4.0 \times 2) \div (873/24) = 11.1 hours$
3. Digestion tank (For primary settled sludge)		
Type	S	Anaerobic digestion, No-heating with recirculation
Design sludge volume		4,900kg/day, $98m^3$/day (Water content ratio: 95.0%)
Retention time	T	60days
Required tank capacity	V	$98 \times 60 = 5,880m^2$
No. of tank	N	2tanks
Effective depth	H	10.0m
Required water surface area	A	$5,880 \div (2 \times 10) = 294m^2$/tank
Required tank diameter	D	$(294/0.785)^{0.5} = 19.4 \rightarrow 20.0m$
Dimension		$20.0m^D \times 10.0m^H \times 2$ tanks
Sludge volume through digestion		
Organic matter content ratio		70%
Digestion efficiency		50%
Sludge volume	S	$4,900 \times (1-0.7 \times 0.5) = 3,185 kg/day$
		$53m^3$/day (Water content ratio: 94%)
Check		
Retention time	T	$(20.0^2 \div 4 \times 3.14 \times 10.0 \times 2) \div 98 = 64.1 days$
4.Sludge drying bed		
Type		Sand drying bed utilizing evaporation and percolation
Design sludge volume	S	Thickened : 6,981kg/day, $175m^3$/day (Water content ratio: 96%)
		Digested : 3,185kg/day, $53m^3$/day (Water content ratio: 94%)
		Total : 10,166kg/day, $228m^3$/day (Water content ratio: 95.5%)
Retention time	T	2weeks (14days)

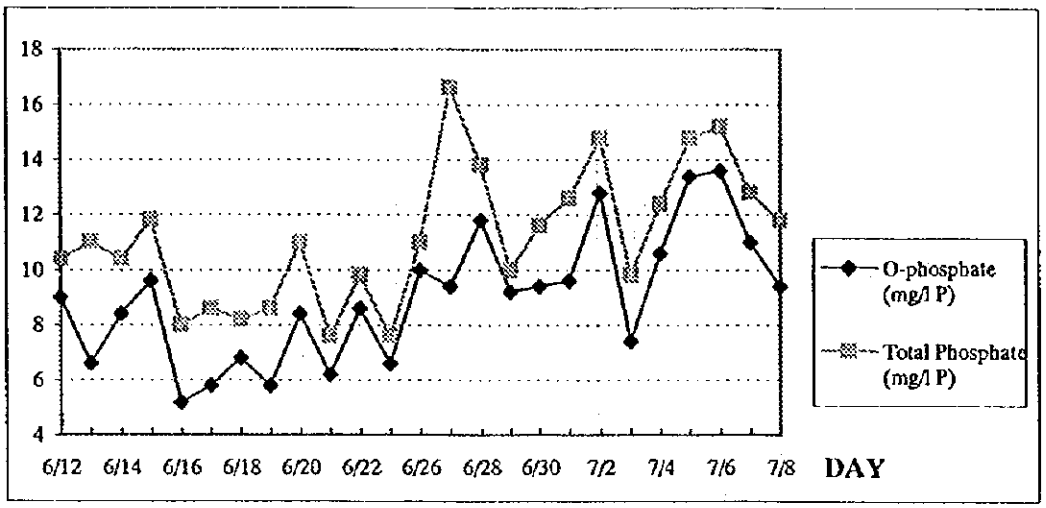
Item		Calculation
Required capacity	V	$228 \times 14 = 3,192 m^3$
Sludge thickness	H	20cm
Required bed area	A	$3,192 \div 0.20 = 15,960 m^2$
Dimension		$15.0m^W \times 20.0m^L \times 56beds\ (16,800m^2)$
Check		
Retention time	T	$(15.0 \times 20.0 \times 0.2 \times 56) \div 228 = 14.7days$
5.Sludge Stock Yard		
Type		Steel structure with roof
Sludge volume	S	$8.0 + 17.5 = 25.5 m^3/day$
Required storage period	T	60days
Required storage capacity	V	$25.5 \times 60 = 1,530 m^3$
No. of yard	N	2yards
Sludge thickness	H	2m
Width	W	12m
Length	L	$1,530 \div (2 \times 2 \times 12) = 31.9m$
Dimension		$12.0m^W \times 36.0m^L \times 2.0m^H \times 2yards$
Check		
Retention time	T	$(12.0 \times 36.0 \times 2.0 \times 2) \div 25.5 = 67.8days$

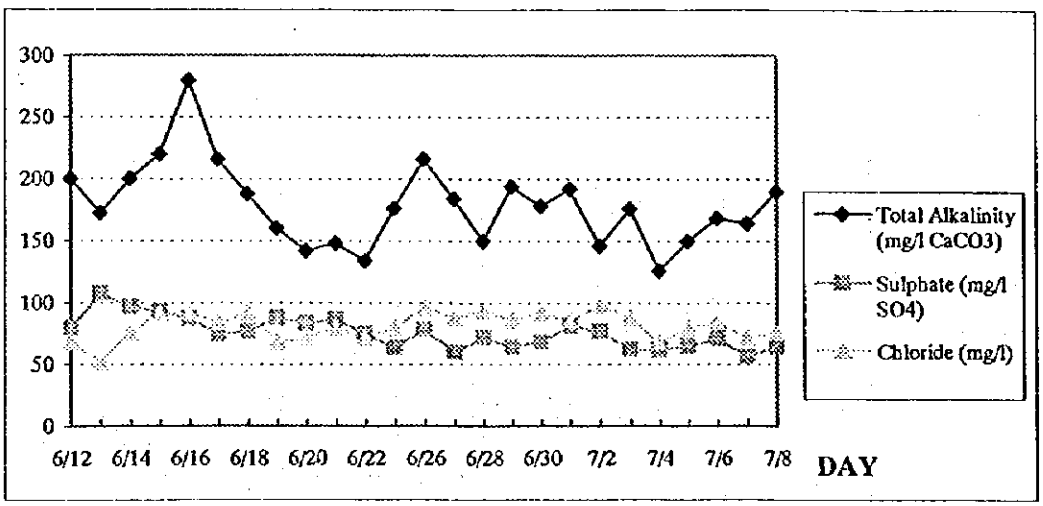
Appendix B Hydraulic Calculation

Lower Facility Upper Facility	Connecting Equipment	Specification	Flow (m^3/day)	Units	Flow (m^3/sec)	Hydraulic Loss	Lower Level Upper Level
Maturation Pond ~ Effluent Point of Final Sedimentation tank	Pipe	ϕ600 L=150m	25,200	1	0.292	$h_f = 0.339$ $h_i = 0.027$ $h_o = 0.054$ $\Sigma h = 0.420$	+1401.000 ~ +1401.420
	Pipe	ϕ450 L=77m	25,200	2	0.146	$h_f = 0.215$ $h_i = 0.023$ $h_o = 0.045$ $\Sigma h = 0.283$	+1401.420 ~ +1401.710
	Pipe	ϕ300 L=34m	25,200	4	0.073	$h_f = 0.192$ $h_i = 0.027$ $h_o = 0.054$ $\Sigma h = 0.273$	+1401.710 ~ +1401.990
Effluent Pointof Final Sedimentation tank ~ Effluent Trough of Final Sedimentation Tank	Trough	B=0.30m	25,200	4	0.073	$h_{cl} = 0.182$ $h = hcl \times 3^{1/2}$ $= 0.315$	+1401.990 ~ +1402.310
Effluent Trough of Final Sedimentation Tank ~ Final Sedimentation Tank	Weir plate		25,200	578×4	1.281×10^{-4}	$h=(q/1.42)^{2/5}$ $= 0.024$	+1401.310 ~ +1401.380
Final Sedimentation Tank ~ Aerobic Zone	Pipe	ϕ300 L=12m	25,200	4	0.073	$h_f = 0.068$ $h_i = 0.027$ $h_o = 0.054$ $\Sigma h = 0.149$	+1401.380 ~ +1402.530
	Pipe	ϕ600 L=45m	25,200	1	0.292	$h_f = 0.102$ $h_i = 0.027$ $h_o = 0.054$ $\Sigma h = 0.183$	+1402.530 ~ +1402.720
Aerobic Zone ~ Anoxic Zone	Overflow weir	B=2.00m	25,200	1	0.292	$h=(q/1.84B)^{2/3}$ $= 0.185$	+1402.720 ~ +1402.940
Anaerobic Zone ~ Eualization Tank	Pipe	ϕ600 L=48m	25,200	1	0.292	$h_f = 0.108$ $h_i = 0.027$ $h_o = 0.054$ $\Sigma h = 0.189$	+1402.940 ~ +1403.130
Equalization Tank ~ Effluent Point of Primary Sedimentation Tank	Pipe	ϕ700 L=4.5m	32,000	1	0.370	$h_f = 0.007$ $h_i = 0.024$ $h_o = 0.047$ $\Sigma h = 0.078$	+1406.000 ~ +1406.080
	Pipe	ϕ500 L=10.5m	32,000	2	0.185	$h_f = 0.025$ $h_i = 0.023$ $h_o = 0.045$ $\Sigma h = 0.093$	+1406.080 ~ +1406.180
Effluent Point of Primary Sedimentation Tank ~ Effluent Trough of Primaly sedimentation Tank	Trough	B=1.50m	32,000	2	0.185	$h_{cl} = 0.116$ $h = hcl \times 3^{1/2}$ $= 0.201$	+1406.180 ~ +1406.400
Effluent Trough of Primaly Sedimentation Tank ~ Primaly Sedimentation Tank	Weir plate		32,000	528×2	3.507×10^{-4}	$h=(q/1.42)^{2/5}$ $= 0.036$	+1406.400 ~ +1406.440

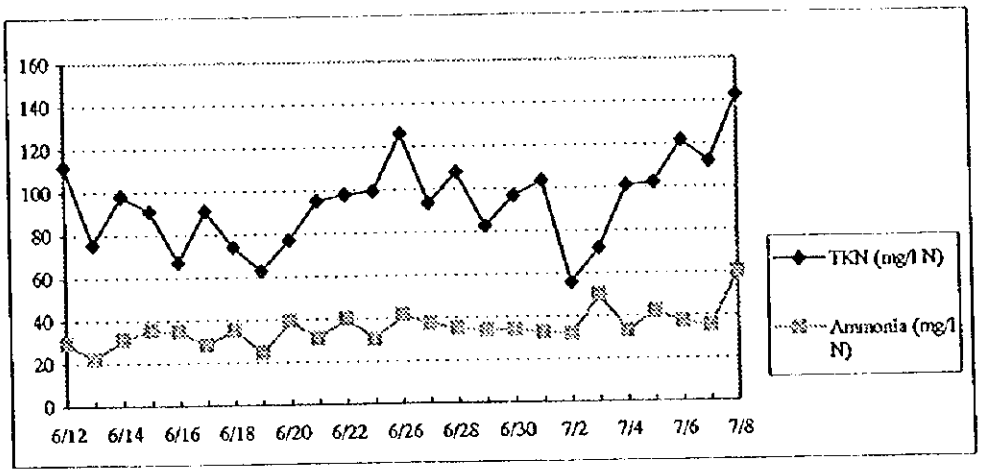
Appendix C Water Quality at Zengeza STP

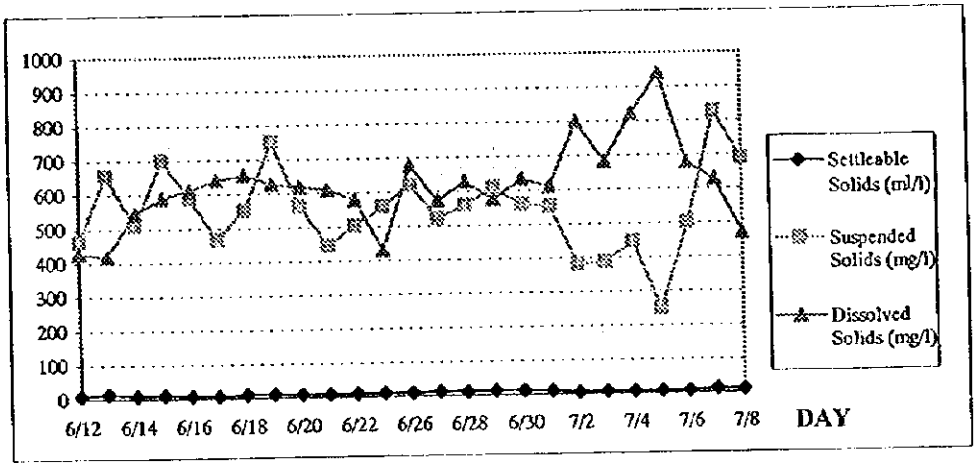


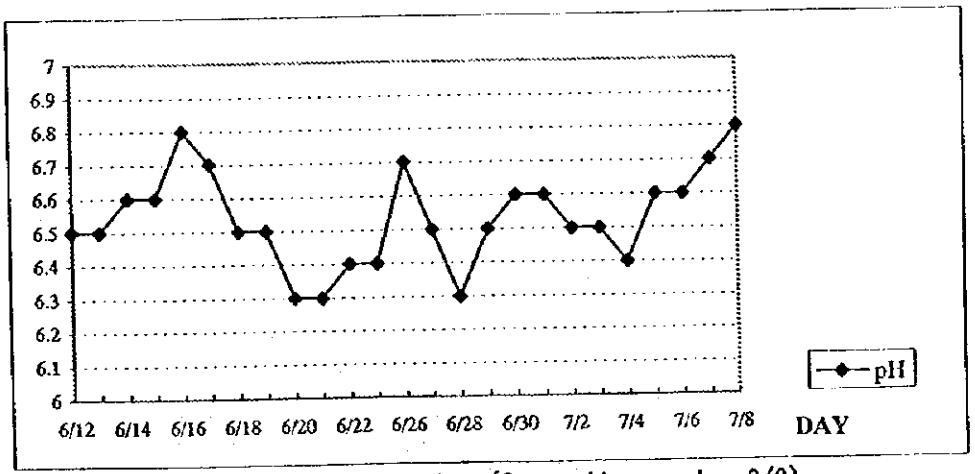




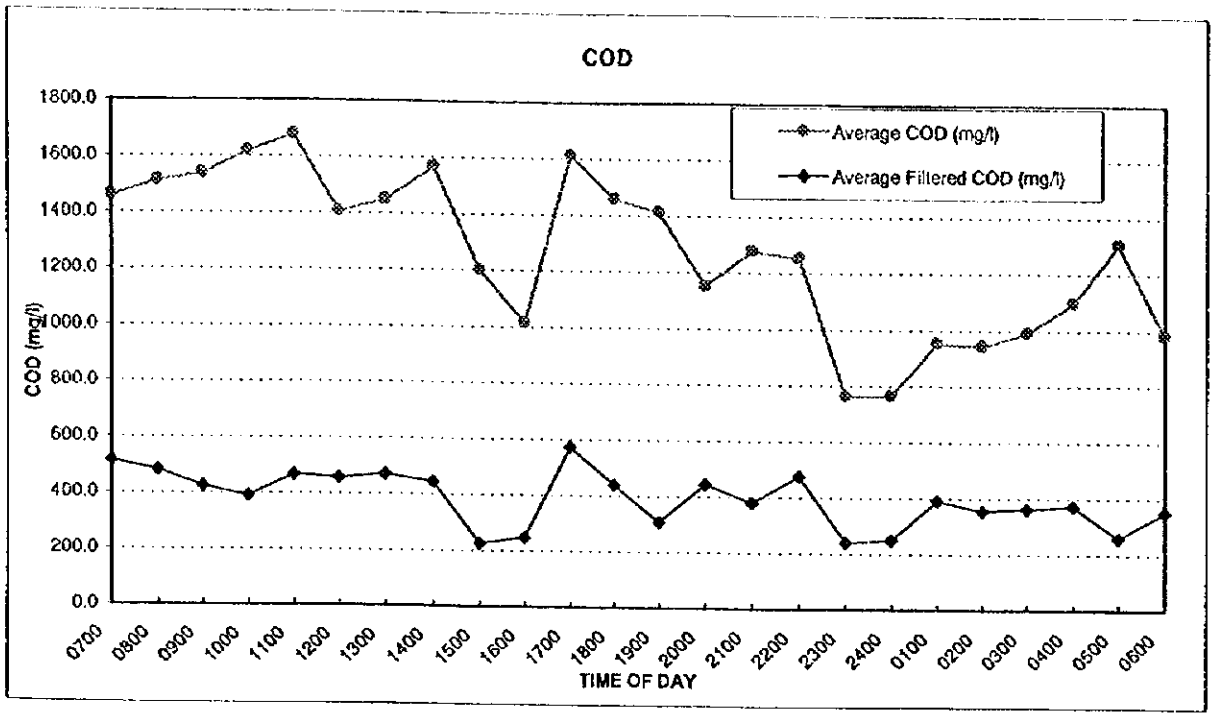
Water Quality of Zengeza STP (Composite sample 1/2)

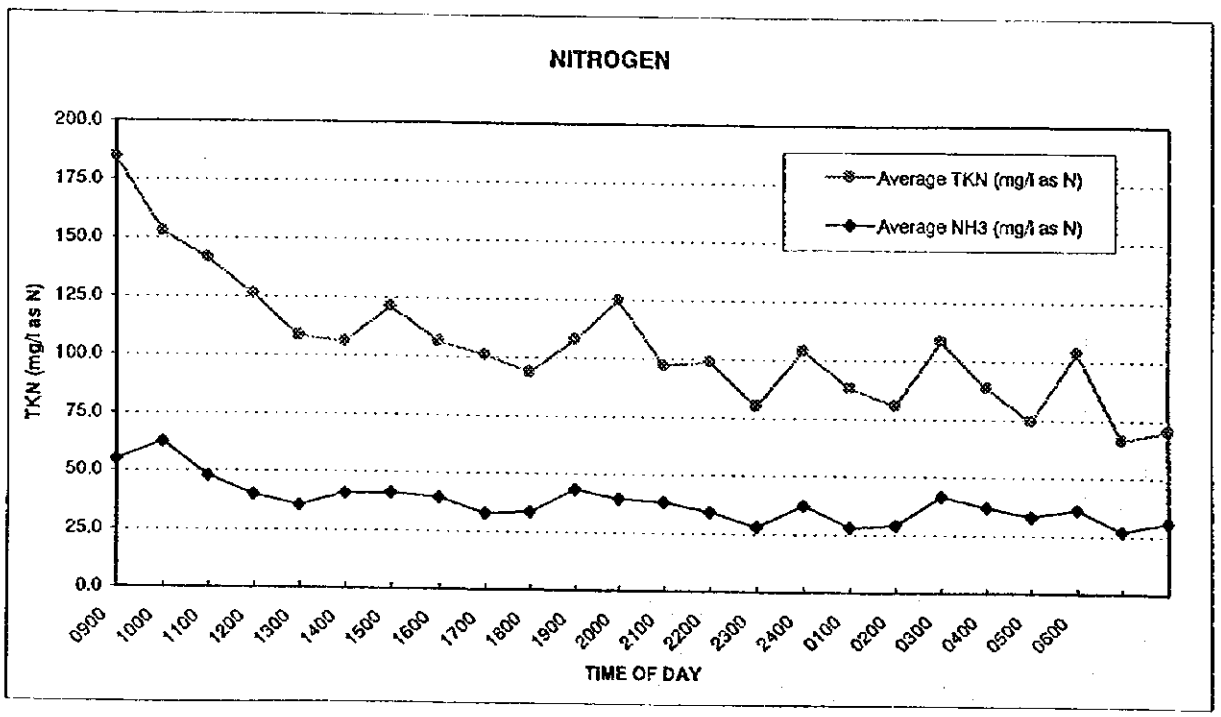




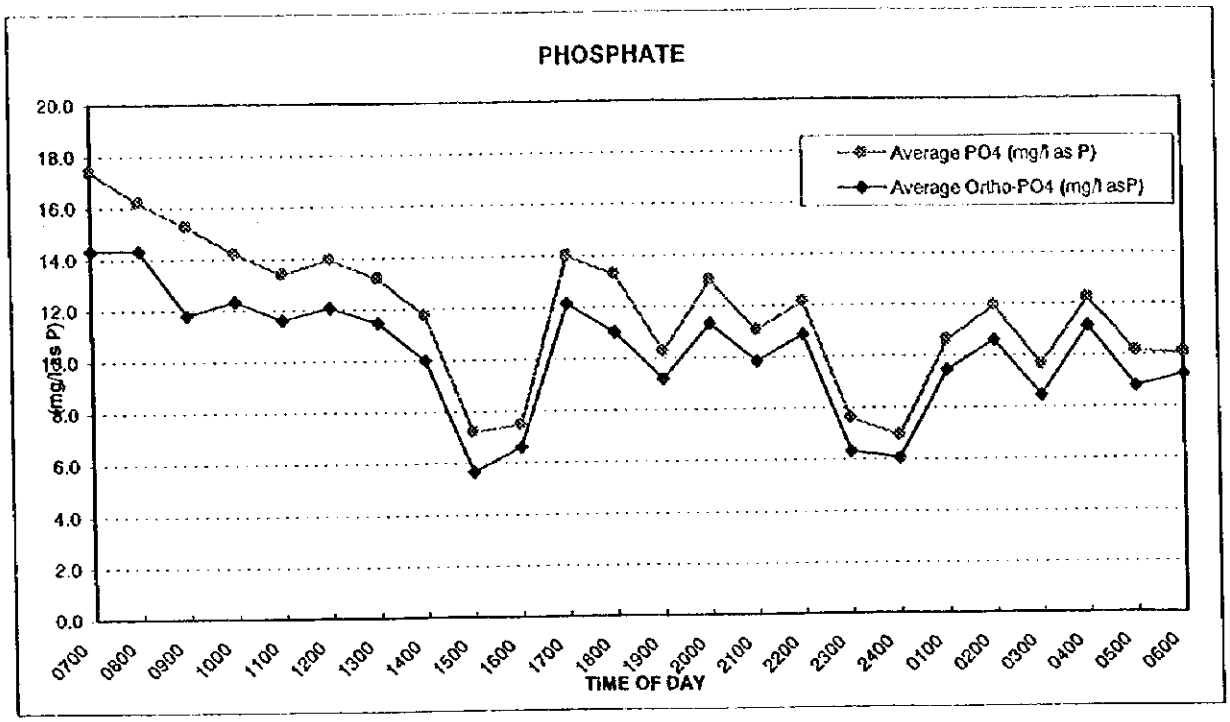


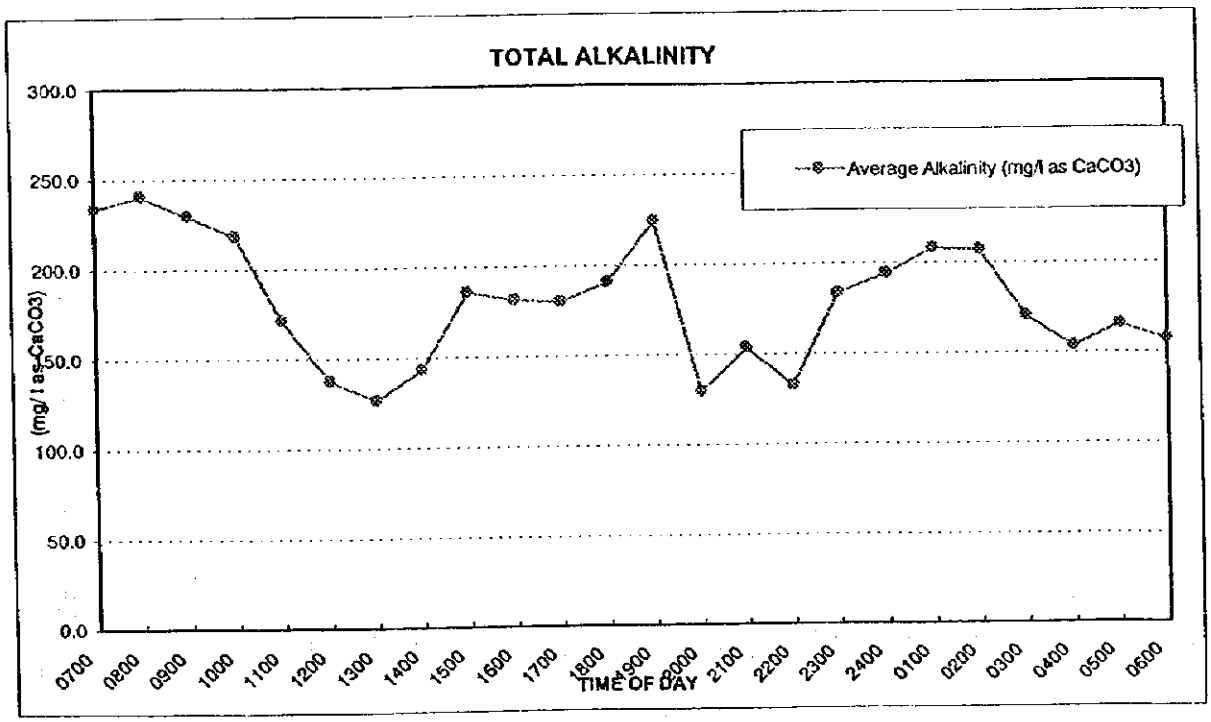
Water Quality of Zengeza STP (Composite sample 2/2)



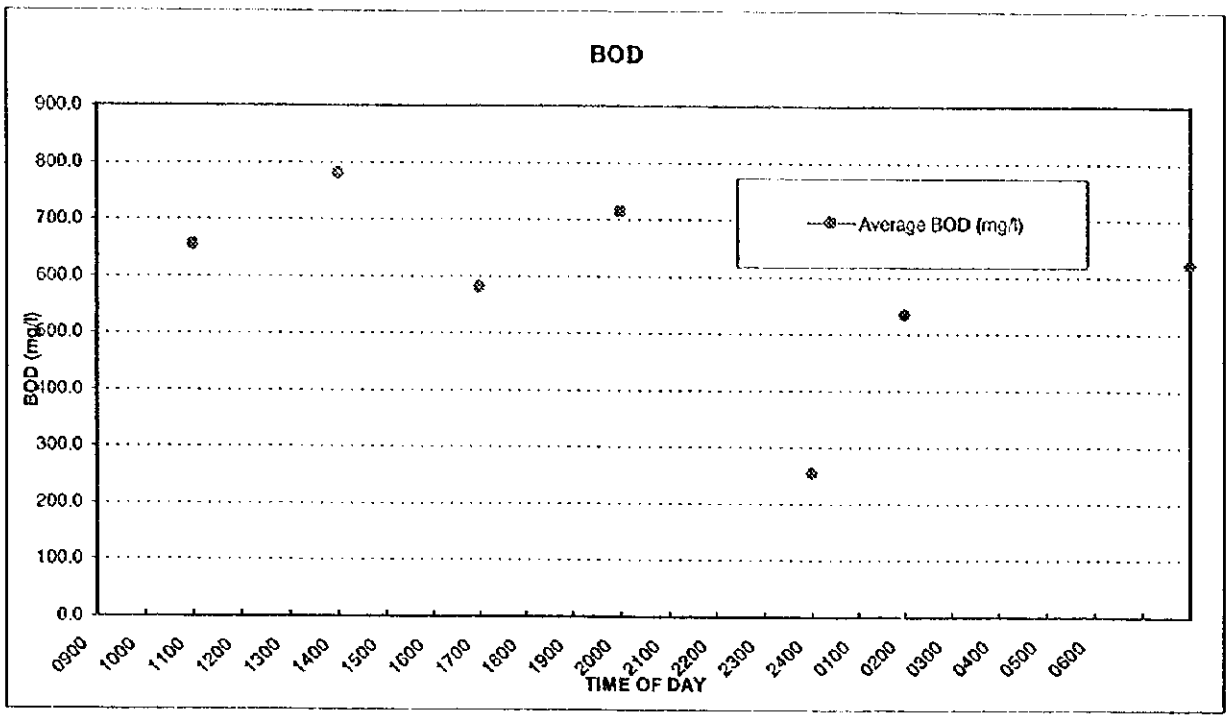


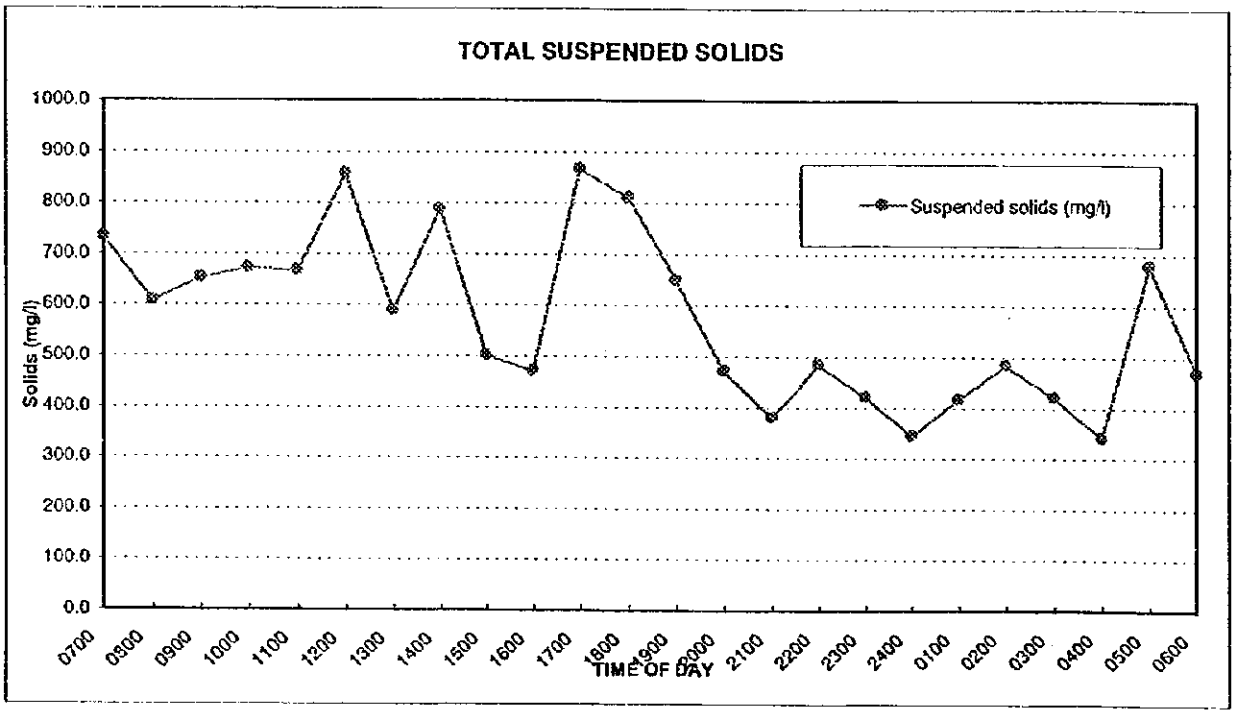
Water Quality at Zengeza STP (24hours 1/3)





Water Quality at Zengeza STP (24hours 2/3)





Water Quality at Zengeza STP (24hours 3/3)

Water Quality at Zengeza STP (Composite sample)

No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Average
Month		6																	7											
Day		12	13	14	15	16	17	18	19	20	21	22	23	24	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	
Total COD	mg/l	1620.0	1271.0	1058.0	1169.0	947.0	941.0	1483.0	906.0	889.6	1155.6	1028.0	1180.0	961.9	1451.8	1370.4	996.2	1738.4	1668.2	1217.5	1017.8	1208.4	765.6	1340.7	1319.5	1118.5	1044.7	1834.0	1578.0	1224.2
Filtered COD	mg/l	318.5	299.0	316.6	666.0	314.8	296.7	314.8	303.1	352.0	319.5	317.4	369.4	285.9	355.8	450.4	316.2	330.4	316.2	401.5	299.2	448.4	496.4	488.7	342.5	247.5	298.7	366.0	458.0	360.0
TKN	mg/l	112.0	75.6	98.0	91.0	67.2	91.0	74.2	63.0	77.0	95.2	98.0	99.4	126.0	93.6	107.8	82.6	96.6	103.6	56.0	71.8	100.8	102.2	121.8	112.0	142.8	89.6	79.8	102.2	94.0
Ammonia	mg/l	29.5	22.0	31.0	35.5	34.5	28.5	35.0	24.5	39.0	31.0	40.0	30.5	41.3	37.5	35.0	34.0	34.0	32.5	32.0	50.0	35.0	42.0	37.0	35.0	60.0	22.0	30.0	45.0	35.1
O-phosphate	mg/l	9.0	6.6	8.4	9.6	5.2	5.8	6.8	5.8	8.4	6.2	8.6	6.6	10.0	9.4	11.8	9.2	9.4	9.6	12.8	7.4	10.6	13.4	13.6	11.0	9.4	7.0	10.6	12.2	9.1
Total Phosphate	mg/l	10.4	11.0	10.4	11.8	8.0	8.6	8.2	8.6	11.0	7.6	9.8	7.6	11.0	16.6	13.8	10.0	11.6	12.6	14.8	9.8	12.4	14.8	15.2	12.8	11.8	8.6	12.2	14.0	11.3
Total Alkalinity	mg/l	200.0	172.0	200.0	220.0	280.0	216.0	188.0	160.0	142.0	148.0	134.0	176.0	216.0	184.0	150.0	194.0	178.0	192.0	146.0	176.0	726.0	150.0	168.0	164.0	190.0	168.0	206.0	204.0	180.3
pH		6.5	6.5	6.6	6.6	6.8	6.7	6.5	6.5	6.3	6.3	6.4	6.4	6.7	6.5	6.3	6.5	6.6	6.6	6.5	6.5	6.4	6.6	6.6	6.7	6.8	6.6	6.6	6.4	6.5
Sulphate	mg/l	80.0	107.5	96.4	93.1	87.3	74.4	76.9	88.0	83.6	86.5	75.0	63.9	78.4	60.0	72.0	64.4	68.2	81.4	77.1	62.5	62.1	65.0	70.9	56.6	64.6	72.7	80.2	77.2	75.9
Chloride	mg/l	68.0	52.0	76.0	92.0	92.0	84.0	92.0	68.0	72.0	80.0	72.0	80.0	96.0	88.0	94.0	86.0	92.0	86.0	98.0	88.0	68.0	80.0	84.0	72.0	76.0	84.0	96.0	96.0	82.6
Settleable Solids	mg/l	9.8	15.0	9.2	10.8	7.2	7.0	11.4	10.0	9.4	9.0	9.8	11.2	8.2	13.0	11.2	12.0	11.8	10.0	6.0	6.4	8.0	9.8	7.8	13.0	10.0	5.0	14.2	9.0	9.8
Suspended Solids	mg/l	462.0	656.0	510.0	700.0	589.0	467.0	552.0	752.0	562.0	446.0	502.0	558.0	621.0	520.0	561.0	610.0	559.0	553.0	382.0	384.0	446.0	249.0	501.0	825.0	688.0	517.0	761.0	550.0	553.0
Dissolved Solids	mg/l	428.8	418.0	543.6	590.0	612.0	640.8	654.4	627.2	618.0	609.6	579.2	429.6	676.8	573.6	628.0	575.2	633.2	610.8	800.0	682.4	822.0	939.3	676.8	628.0	469.6	526.8	783.2	786.0	627.2
BOD	mg/l	720.0	820.0	700.0	820.0	820.0	710.0	730.0	600.0	620.0	660.0	660.0	680.0	660.0	840.0	960.0	780.0	900.0	860.0	800.0	640.0	640.0	580.0	760.0	620.0	520.0	520.0	780.0	740.0	720.0

Water Quantity at Zengeza STP (Composite sample)

No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Average
Month		6																	7											
Day		12	13	14	15	16	17	18	19	20	21	22	23	24	25	27	28	29	30	1	2	3	4	5	6	7	8	9	10	
Hour	7:00	976	683	675	966	1,147	1,147	1,202	1,390	1,147	809	1,052	1,147	1,147	1,202	1,272	1,115	338	966	1,265	1,306	911	517	707	360	871	993	1,034	976	976
	8:00	1,088	840	1,539	1,186	1,052	1,147	1,005	1,202	1,257	1,414	1,225	1,084	1,084	1,052	1,288	1,225	1,241	974	1,257	1,170	1,088	585	680	551	966	1,170	993	1,088	1,088
	9:00	864	990	1,422	1,257	1,319	1,052	1,147	1,390	1,202	1,414	1,257	1,170	1,068	1,288	1,052	1,382	1,288	1,052	1,288	1,041	463	639	585	741	1,143	1,034	1,034	843	1,087
	10:00	974	856	1,162	1,288	1,296	1,296	1,115	1,351	1,115	1,319	1,052	1,225	1,202	1,210	1,288	1,492	1,100	1,225	1,319	1,143	490	741	517	639	1,170	1,143	1,088	1,088	1,104
	11:00	1,100	1,241	974	1,186	1,115	1,217	856	990	1,351	1,115	1,139	1,351	1,045	1,052	1,202	1,202	1,178	1,084	1,257	1,170	551	775	741	680	1,054	966	1,088	871	1,055
	12:00	738	715	1,037	895	1,052	1,052	778	888	1,257	1,257	1,068	1,068	1,052	966	1,257	1,115	927	1,398	1,115	741	619	292	775	707	1,088	1,054	1,115	843	960
	13:00	762	1,037	1,162	1,147	927	888	927	1,052	1,052	1,115	1,052	1,045	738	809	1,202	1,052	950	1,225	1,257	939	429	551	809	741	993	707	1,170	1,054	957
	14:00	888	1,382	966	1,257	888	778	1,147	927	1,437	1,052	1,147	1,147	809	911	1,147	1,288	1,241	785	1,052	585	360	517	741	871	939	748	1,088	911	965
	15:00	864	636	864	888	974	675	927	856	1,414	1,115	1,005	848	675	683	738	1,052	1,202	856	1,084	639	292	585	463	1,034	1,115	680	1,115	843	862
	16:00	1,162	778	1,013	1,084	738	778	778	1,288	1,461	990	1,068	738	848	903	1,052	1,005	927	1,147	1,202	911	707	680	490	1,115	707	1,034	925	429	927
	17:00	966	754	636	888	1,147	1,202	1,005	1,052	1,052	1,115	903	1,225	636	880	1,100	1,052	817	990	990	585	585	837	517	639	741	871	1,054	388	880
	18:00	565	620	306	565	1,162	927	856	707	1,115	778	738	597	809	768	950	754	613	1,202	1,241	422	292	707	401	707	911	911	1,034	843	768
	19:00	636	495	251	542	1,202	950	888	856	888	856	778	675	778	744	754	1,013	1,052	785	1,359	381	401	360	388	762	748	238	871	1,170	744
	20:00	291	518	432	550	707	1,052	1,052	990	856	738	809	903	809	1,100	1,100	675	1,178	895	1,100	401	381	333	429	551	585	218	966	592	722
	21:00	369	432	503	565	966	888	927	746	856	675	738	495	903	840	1,068	1,202	495	817	888	463	320	292	401	809	680	333	823	619	683
	22:00	306	432	432	416	565	888	448	809	746	636	597	448	495	919	888	675	864	636	723	292	490	238	388	490	490	156	741	551	563
	23:00	534	456	440	432	660	833	369	597	597	534	448	251	448	723	817	597	801	495	534	252	177	204	360	517	463	177	619	231	484
	0:00	342	157	204	448	401	401	448	778	534	448	338	228	338	778	636	361	369	534	314	204	388	177	292	490	551	102	551	265	396
	1:00	236	181	251	275	251	251	283	597	463	338	448	157	275	314	864	314	652	385	339	177	163	170	238	517	490	136	490	238	339
	2:00	416	141	275	228	495	220	228	306	283	283	338	204	251	275	534	298	377	338	291	170	204	122	204	401	429	122	517	204	291
	3:00	424	306	204	236	408	369	306	401	157	251	228	228	228	597	675	518	416	314	322	197	238	88	156	177	374	231	680	292	322
	4:00	440	346	157	369	518	361	401	534	283	228	463	251	204	581	715	652	660	565	397	238	292	122	122	204	360	204	809	646	397
	5:00	306	369	204	448	228	495	283	463	401	251	251	181	275	361	817	715	511	448	364	239	388	136	102	238	292	265	952	218	364
	6:00	330	456	338	534	534	927	565	565	738	495	565	565	534	754	581	314	762	636	520	360	517	156	156	292	639	388	1,034	292	520
Total		15,578	14,821	15,449	17,648	19,753	19,792	17,939	20,735	21,661	19,227	18,708	17,232	16,651	19,709	22,997	21,072	19,957	19,753	21,476	14,027	10,747	9,829	10,665	14,236	17,800	13,882	21,793	15,498	17,451

Water Quality at Zengeza STP (24hours)

No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
19/20 June		0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	Average
Total COD	mg/l	1644.5	1667.0	1692.9	1791.8	1842.2	1547.0	1604.4	1769.5	1303.0	1118.7	1807.1	1634.4	1556.3	1276.2	1477.7	1428.8	879.1	872.2	1023.7	1020.3	1110.1	1205.4	1507.0	1104.4	1411.8
Filtered COD	mg/l	586.5	532.3	486.6	445.5	547.8	520.6	544.2	525.6	243.3	265.6	655.1	520.0	352.5	487.5	423.1	516.3	283.1	299.9	435.6	395.4	404.2	413.9	296.6	389.2	440.4
TKN	mg/l	203.2	168.2	157.5	141.8	120.7	118.1	134.6	119.5	108.8	102.4	115.6	139.8	103.2	106.0	86.4	113.1	97.5	88.1	115.3	95.5	77.8	114.2	72.1	75.2	115.6
Ammonia	mg/l	62.2	70.5	55.1	45.3	40.3	44.8	46.0	44.5	35.2	36.0	49.0	44.6	41.4	37.0	30.2	41.0	32.0	32.5	45.3	40.3	35.5	39.1	29.7	33.3	42.1
O-phosphate	mg/l	16.4	16.1	13.7	14.5	13.4	13.7	13.5	11.8	6.2	7.0	13.8	12.9	10.6	12.4	11.1	11.9	7.3	7.1	10.4	11.8	9.3	12.3	10.0	10.0	11.6
Total Phosphate	mg/l	22.1	25.8	25.3	18.6	16.0	16.5	16.0	14.2	9.6	9.3	17.1	16.2	12.0	14.8	13.2	14.4	9.1	8.4	12.5	13.6	11.1	13.9	12.0	11.3	14.7
Total Alkalinity	mg/l	250.7	261.1	247.9	255.0	182.9	141.9	130.9	150.3	200.6	197.5	204.0	205.5	246.4	146.1	169.7	150.5	198.9	210.0	223.2	222.9	180.0	162.5	174.5	166.5	194.2
pH	mg/l	6.8	6.8	6.8	6.7	6.5	6.3	6.5	6.5	6.9	6.8	6.4	6.6	6.7	6.3	6.4	6.4	6.9	7.0	6.8	6.7	6.6	6.5	6.7	6.6	6.6
Sulphate	mg/l	89.5	101.1	99.5	90.1	79.0	82.8	108.1	89.7	93.5	86.7	92.6	89.0	85.7	92.5	76.8	111.6	98.7	101.3	129.3	65.7	84.8	88.1	85.5	81.3	91.7
Chloride	mg/l	132.5	112.6	116.0	105.9	107.7	96.3	97.8	103.1	96.4	98.0	120.7	125.2	112.3	121.9	107.2	112.1	91.6	90.3	101.4	99.1	96.5	86.2	93.3	89.1	104.7
Settleable Solids	mg/l	16.0	15.0	12.5	15.4	13.1	11.2	10.1	17.8	12.1	13.0	15.1	16.3	9.0	7.8	9.1	10.3	9.5	7.0	7.0	12.6	9.7	11.8	15.0	12.1	12.0
Suspended Solids	mg/l	809.2	664.8	703.4	719.1	710.1	907.7	634.1	881.5	531.2	498.6	1030.7	920.0	724.2	523.8	439.5	543.2	468.7	385.5	432.7	546.1	493.0	385.6	774.1	556.1	635.9
Dissolved Solids	mg/l	783.1	808.3	785.5	807.6	873.0	806.2	1014.2	891.9	782.2	931.7	990.3	881.7	729.5	860.0	777.0	964.1	789.4	790.7	921.7	914.6	620.5	755.9	578.8	778.2	826.5
BOD	mg/l			995.3			872.0			632.0			779.3			764.7			605.3			734.0			692.0	759.3
26/27 June		0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	Average
Total COD	mg/l	1224.0	1575.2	1703.2	1801.0	1827.8	1739.8	1540.7	1421.6	1334.6	771.8	1671.6	1354.4	1369.0	1121.5	1087.6	995.8	994.8	828.7	862.5	679.4	788.8	841.3	789.3	567.0	1158.8
Filtered COD	mg/l	288.1	431.2	419.2	385.0	355.8	315.8	348.7	247.6	305.6	307.8	675.6	274.4	225.0	221.5	199.6	315.8	226.8	148.7	154.5	159.4	164.8	169.3	95.3	131.9	275.6
TKN	mg/l	259.0	187.6	139.3	128.8	109.2	116.2	148.4	116.2	107.8	106.4	158.2	100.8	99.4	96.6	112.4	106.4	96.6	93.8	86.8	99.4	84.0	95.2	51.8	79.8	115.8
Ammonia	mg/l	58.0	70.0	54.0	45.0	31.0	52.0	48.0	41.0	44.0	40.0	40.0	24.0	29.0	29.0	36.0	33.0	30.0	26.0	24.5	25.0	22.0	26.5	17.0	32.5	36.6
O-phosphate	mg/l	10.2	11.4	10.4	8.8	8.6	6.0	5.8	5.0	4.2	5.4	12.6	5.4	6.0	7.2	6.0	4.2	6.4	3.8	4.2	3.2	4.0	7.8	3.4	7.0	6.5
Total Phosphate	mg/l	16.6	34.0	32.4	14.8	10.0	8.2	7.0	5.8	9.4	9.2	16.4	7.0	6.6	8.6	8.0	7.4	7.2	4.8	6.8	4.0	5.2	9.2	4.6	8.0	10.5
Total Alkalinity	mg/l	380.0	392.0	330.0	300.0	220.0	210.0	170.0	180.0	200.0	150.0	68.0	172.0	194.0	198.0	198.0	188.0	232.0	220.0	212.0	220.0	180.0	152.0	172.0	244.0	215.9
pH	mg/l	7.4	7.5	7.2	7.0	6.6	6.4	6.6	6.6	6.6	6.6	6.0	6.6	6.5	6.5	6.5	6.8	6.8	7.0	6.9	6.9	6.9	6.5	6.9	7.1	6.8
Sulphate	mg/l	92.0	94.5	96.5	97.6	76.4	92.0	94.5	96.5	97.6	76.4	104.8	68.9	67.4	76.9	82.3	126.7	114.2	119.4	198.3	104.3	75.9	80.5	73.3	66.3	94.6
Chloride	mg/l	104.0	108.0	108.0	100.0	88.0	88.0	84.0	80.0	80.0	88.0	106.0	94.0	100.0	98.0	106.0	88.0	92.0	84.0	76.0	72.0	66.0	64.0	64.0	74.0	88.0
Settleable Solids	mg/l	17.0	24.0	15.2	20.4	18.0	20.2	18.6	15.0	10.4	15.0	11.0	13.2	10.4	10.0	9.4	10.2	12.8	3.0	7.4	7.6	2.4	19.8	1.8	8.4	12.6
Suspended Solids	mg/l	744.0	710.0	785.0	1108.0	906.0	1539.0	837.0	794.0	688.0	519.0	543.0	594.0	544.0	558.0	506.0	682.0	587.0	356.0	395.0	358.0	126.0	506.0	62.0	247.0	611.4
Dissolved Solids	mg/l	691.2	742.4	830.4	797.6	978.8	784.4	818.0	704.8	630.8	666.0	926.0	791.6	751.2	834.4	765.6	966.4	938.4	833.2	896.8	909.6	462.0	855.6	393.0	857.2	784.4
BOD	mg/l			740.0			880.0			620.0			680.0			780.0			560.0			320.0			300.0	630.0
3/4 July		0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	Average
Total COD	mg/l	1673.7	1389.2	1586.4	1562.0	1467.6	1263.0	1398.2	1814.5	925.8	941.0	1759.0	1571.4	1283.4	1118.2	1794.2	1579.0	1045.8	959.4	643.0	678.2	1078.3	976.7	1812.2	2107.1	1301.1
Filtered COD	mg/l	636.5	453.2	562.0	485.6	726.0	557.4	663.8	723.7	151.8	163.4	733.0	721.8	403.2	380.2	384.8	362.2	376.2	441.0	401.8	355.1	365.5	357.5	350.6	325.9	461.7
TKN	mg/l	170.1	139.9	146.2	142.4	112.1	109.6	123.5	117.2	73.1	78.1	71.8	136.1	55.4	66.8	56.7	86.4	86.4	66.8	63.0	61.7	31.5	94.5	52.9	42.8	90.9
Ammonia	mg/l	67.5	73.8	63.9	47.7	45.0	36.9	45.0	45.0	21.6	22.1	51.3	47.7	27.9	27.0	19.8	33.3	34.2	31.5	34.2	29.7	22.5	26.1	24.3	22.5	37.5
O-phosphate	mg/l	18.4	16.2	16.9	19.8	16.6	14.4	18.0	16.2	4.5	4.0	15.1	16.9	12.6	9.4	11.0	9.4	8.6	9.7	8.6	11.2	7.2	10.3	11.0	6.7	12.2
Total Phosphate	mg/l	22.7	18.4	24.1	21.6	19.1	16.2	22.0	19.8	6.3	5.2	16.2	21.6	14.0	11.7	15.0	10.6	11.2	10.3	9.7	12.8	9.5	11.2	12.8	8.1	14.5
Total Alkalinity	mg/l	156.6	183.6	167.4	153.0	104.4	41.4	37.8	63.0	131.4	145.8	216.0	133.2	201.6	151.2	147.6	160.2	140.4	144.0	136.8	145.8	90.0	82.8	82.8	82.8	129.2
pH	mg/l	6.2	6.1	6.0	6.0	6.0	5.8	5.8	5.9	6.8	6.8	6.1	5.8	6.4	6.5	6.3	6.4	6.4	6.3	6.4	6.3	6.0	6.1	6.0	5.9	6.2
Sulphate	mg/l	62.3	80.6	85.6	76.1	69.8	75.5	55.9	66.1	71.9	70.7	87.2	80.0	83.4	91.6	74.9	74.4	71.1	76.2	71.8	19.4	69.0	64.7	61.3	63.6	71.0
Chloride	mg/l	142.2	95.4	108.0	95.4	99.0	81.0	88.2	93.6	75.6	72.0	108.0	118.8	86.4	100.8	82.8	84.6	86.4	86.4	84.6	88.2	70.2	73.8	72.0	70.2	90.2
Settleable Solids	mg/l	11.7	8.5	3.6	4.7	4.5	6.5	3.6	18.4	7.6	7.4	14.7	14.4	8.1	8.8	11.7	13.5	10.8	10.8	0.4	13.3	10.1	9.4	16.2	12.6	9.6
Suspended Solids	mg/l	685.8	513.9	453.6	473.9	385.2	456.3	396.9	841.5	274.5	248.4	1476.0	983.7	693.1	468.9	529.2	532.8	429.3	367.2	147.6	561.6	645.3	404.1	858.6	666.9	557.3
Dissolved Solids	mg/l	652.3	740.5	666.0	838.4	769.2	725.8	1013.4	899.3	691.6	982.4	936.7	919.1	698.8	801.4	700.2	733.7	716.4	729.7	763.9	689.0	402.5	416.9	448.9	466.9	725.1
BOD	mg/l			1098.0			828.0			468.0			594.0			522.0			648.0			666.0			648.0	684.0
10/11 July		0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	Average
Total COD	mg/l	1292.0	1419.0	1373.0	1318.0	1579.0	1077.0	1253.0	1266.0	1237.0	1225.0	1209.0	1279.0	1446.0	1092.0	754.0	1010.0	132.0	402.0	1280.0	1402.0	1484.0	1364.0	1694.0	1147.0	1197.3
Filtered COD	mg/l	552.0	511.0	229.0	250.0	239.0	441.0	325.0	234.0	205.0	253.0	231.0	243.0	250.0	692.0	514.0	710.0	79.0	114.0	572.0	514.0	520.0	556.0	290.0	563.0	378.6
TKN	mg/l	105.0	115.0	122.0	91.0	91.0	79.8	77.0	73.0	113.0	88.0	85.0	122.0	130.0	125.0	65.0	111.0	74.0	74.0	168.0	98.0	104.0	111.0	88.0	84.0	99.7
Ammonia	mg/l	31.0	35.0	19.0	22.0	25.0	29.0	25.0	27.5	30.5	36.0	33.0	43.0	55.0	43.0	26.0	42.0	16.5	26.0	62.0	53.0	52.0	53.0	37.0	35.0	35.6
O-phosphate	mg/l	12.4	13.6	6.2	6.2	7.8	14.2	8.6	7.0	7.8	10.0	7.0	8.8	7.6	16.4	11.4	18.0	3.0	3.6	14.6	16.2	13.4	14.2	10.8	13.4	10.5
Total Phosphate	mg/l	16.8	16.8	8.6	9.8	10.4	17.8	9.4	8.2	10.4	11.2	11.4	10.4	9.2	18.8	12.8	20.4	4.0	5.6	16.8	18.4	14.4	16.4	12.8	14.2	12.7
Total Alkalinity	mg/l	146.0	126.0	172.0	184.0	178.0	156.0	168.0	180.0	212.0	232.0	232.0	252.0	254.0	22.0	98.0	32.0	162.0	202.0	260.0	238.0	230.0	216.0	232.0	136.0	180.0
pH	mg/l	6.4	6.2	6.6	6.7	6.5	6.3	6.5	6.6	6.7	6.6	6.7	6.8	6.7	5.4	5.8	5.4	6.9	7.1	6.6	6.4	6.4	6.4	6.7	6.3	6.4
Sulphate	mg/l	80.4	92.3	78.5	62.9	59.6	47.3	149.2	77.1	79.1	81.7	46.9	82.6	69.2	68.2	39.8	100.6	79.2	74.3	89.9	64.7	78.9	90.4	94.8	85.6	79.2
Chloride	mg/l	88.0	92.0	84.0	80.0	92.0	84.0	82.0	94.0	100.0	102.0	100.0	110.0	112.0	122.0	96.0	126.0	58.0	62.0	106.0	98.0	122.0	88.0	112.0	92.0	95.9
Settleable Solids	ml/l	14.0	8.8	17.0	19.0	14.8	4.0	6.4	12.0	15.0	13.4	13.0	15.0	5.0	0.8	1.0	1.3	0.0	2.4	13.0	11.0	12.0	2.0	19.8	9.6	9.6
Suspended Solids	mg/l	693.0	542.0	670.0	437.0	668.0	525.0	472.0	635.0	509.0	618.0	417.0	745.0	642.0	336.0	48.0	178.0	199.0	270.0	690.0	489.0	421.0	67.0	1020.0	485.0	491.5
Dissolved Solids	mg/l	716.0	613.0	564.0	414.0	529.0	586.0	760.8	672.0	717.0	710.0	692.0	526.0	428.0	588.0	554.0	866.0	395.0	485.0	764.8	839.0	818.0	810.0	695.0	803.0	647.7
BOD	mg/l			660.0			540.0			600.0			800.0			760.0			320.0			920.0			840.0	660.0

Water Quality at Zengeza STP (Average of 24hours)

	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
	時間	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	1267.3
Water quality	Total COD	mg/l	1458.6	1512.6	1538.9	1618.2	1679.2	1406.7	1449.1	1567.9	1200.1	1014.1	1611.7	1459.8	1413.7	1152.0	1278.4	1253.4	762.9	765.6	952.3	985.0	990.3	1096.8	1305.6	981.4	389.1
	Filtered COD	mg/l	515.8	481.9	424.2	391.5	462.2	458.7	470.4	445.2	226.4	247.5	573.7	439.8	307.7	445.2	380.4	476.1	241.3	250.9	391.0	356.0	365.6	374.2	257.6	352.0	105.5
	TKN	mg/l	186.3	152.7	141.2	126.0	108.3	105.9	120.9	106.5	100.7	93.7	107.7	124.7	97.0	98.6	80.1	103.7	88.1	80.7	108.3	88.7	74.3	103.7	66.2	70.5	38.0
	Ammonia	mg/l	54.7	62.3	48.0	40.0	35.3	40.7	41.0	39.5	32.8	33.5	43.3	39.3	38.3	34.0	28.0	37.3	28.2	29.0	41.5	37.0	33.0	36.2	27.0	30.8	10.2
	O-phosphate	mg/l	14.3	14.3	11.8	12.3	11.6	12.1	11.5	10.0	5.7	6.6	12.1	11.0	9.2	11.3	9.9	10.9	6.3	6.1	9.5	10.6	8.5	11.1	8.8	9.3	13.1
	Total Phosphate	mg/l	19.5	23.7	22.6	16.2	13.9	14.7	13.6	12.0	8.9	8.7	15.3	13.8	10.5	13.5	11.7	13.2	7.9	7.3	11.5	12.2	10.1	12.7	10.5	10.4	179.8
	Total Alkalinity	mg/l	233.3	240.7	229.3	218.0	171.3	137.3	126.7	143.3	186.0	181.3	189.0	190.7	224.0	129.3	153.3	132.7	183.3	194.0	208.0	206.7	170.0	153.3	165.3	157.3	6.5
	pH		6.7	6.6	6.6	6.6	6.4	6.2	6.3	6.4	6.7	6.7	6.3	6.4	6.6	6.2	6.2	6.2	6.7	6.8	6.7	6.6	6.5	6.4	6.6	6.5	83.9
	Sulphate	mg/l	81.5	92.1	90.0	81.7	71.2	74.4	101.9	82.3	85.5	78.9	82.9	80.1	76.4	82.3	68.4	103.3	90.8	92.8	121.3	63.5	77.2	80.9	78.7	76.2	94.7
	Chloride	mg/l	116.7	102.0	104.0	95.3	96.7	87.3	88.0	92.7	88.0	90.0	108.7	112.0	102.7	110.7	98.0	102.7	82.0	80.7	92.0	89.3	88.7	78.0	85.3	81.3	10.9
	Settleable Solids	mg/l	14.7	14.1	12.1	14.9	12.6	10.5	9.7	15.8	11.3	12.2	13.4	14.7	8.1	6.9	7.8	8.8	8.3	5.8	6.9	11.1	8.5	10.7	13.2	10.7	574.0
	Suspended Solids	mg/l	733.0	807.7	653.0	672.0	667.3	857.0	590.0	788.0	500.7	471.0	866.7	810.7	648.3	471.7	380.7	484.0	421.0	344.7	416.3	483.7	421.3	340.7	678.7	468.7	745.9
	Dissolved Solids	mg/l	710.7	726.1	711.5	714.4	787.5	725.6	901.6	792.0	705.4	822.5	886.3	779.6	651.9	770.9	699.2	882.5	709.8	709.7	856.8	838.1	575.7	709.6	528.9	726.3	683.2
	BOD	mg/l	873.3	873.3	873.3	780.0	780.0	780.0	580.0	540.0	580.0	713.3	713.3	713.3	706.7	706.7	706.7	533.3	533.3	533.3	660.0	660.0	660.0	620.0	620.0	620.0	Total 17451.0
Flowrate			975.7	1087.5	1086.6	1103.8	1055.4	959.7	956.9	964.6	861.6	927.1	879.5	768	743.6	721.8	682.6	562.8	484.4	395.5	339	291.3	322.3	397.3	364.5	519.7	Total 23531.0	Quality 1348.4
Load	Total COD	kg/day	1423.0	1645.0	1672.0	1786.0	1772.0	1350.0	1387.0	1512.0	1034.0	940.0	1417.0	1121.0	1051.0	831.0	873.0	705.0	370.0	303.0	323.0	275.0	319.0	436.0	476.0	510.0	9073.0	405.3
	Filtered COD	kg/day	503.0	524.0	461.0	432.0	493.0	440.0	450.0	429.0	195.0	229.0	505.0	338.0	229.0	321.0	260.0	268.0	117.0	99.0	133.0	104.0	117.0	149.0	94.0	183.0	2958.0	112.2
	TKN	kg/day	180.0	166.0	153.0	139.0	114.0	102.0	116.0	103.0	87.0	87.0	95.0	96.0	72.0	71.0	55.0	58.0	43.0	32.0	37.0	26.0	24.0	41.0	24.0	37.0	692.0	39.7
	Ammonia	kg/day	53.0	68.0	52.0	44.0	37.0	39.0	39.0	38.0	28.0	31.0	38.0	30.0	29.0	25.0	19.0	21.0	14.0	11.0	14.0	11.0	11.0	14.0	10.0	16.0	186.0	10.7
	O-phosphate	kg/day	14.0	16.0	13.0	14.0	12.0	12.0	11.0	10.0	5.0	6.0	11.0	8.0	7.0	8.0	7.0	6.0	3.0	2.0	3.0	3.0	3.0	4.0	3.0	5.0	247.0	14.2
	Total Phosphate	kg/day	19.0	26.0	25.0	18.0	15.0	14.0	13.0	12.0	8.0	8.0	13.0	11.0	8.0	10.0	8.0	7.0	4.0	3.0	4.0	4.0	3.0	5.0	4.0	5.0	3179.0	182.2
	Total Alkalinity	kg/day	228.0	262.0	249.0	241.0	181.0	132.0	121.0	138.0	160.0	168.0	156.0	146.0	167.0	93.0	105.0	75.0	89.0	77.0	71.0	60.0	55.0	61.0	60.0	82.0	1460.0	83.7
	Sulphate	kg/day	80.0	100.0	98.0	90.0	75.0	71.0	98.0	79.0	74.0	73.0	73.0	62.0	57.0	59.0	47.0	58.0	40.0	32.0	31.0	26.0	29.0	31.0	31.0	42.0	1686.0	96.6
	Chloride	kg/day	114.0	111.0	113.0	105.0	102.0	84.0	84.0	89.0	76.0	83.0	96.0	86.0	76.0	80.0	67.0	58.0	40.0	32.0	31.0	26.0	29.0	31.0	31.0	42.0	199.0	11.4
	Settleable Solids	kg/day	14.0	15.0	13.0	16.0	13.0	10.0	9.0	15.0	10.0	11.0	12.0	11.0	6.0	5.0	5.0	5.0	4.0	2.0	2.0	3.0	3.0	4.0	5.0	6.0	10670.0	611.4
	Suspended Solids	kg/day	715.0	661.0	710.0	742.0	704.0	822.0	565.0	760.0	431.0	437.0	762.0	623.0	482.0	340.0	260.0	272.0	204.0	136.0	141.0	141.0	136.0	135.0	247.0	244.0	13154.0	753.8
	Dissolved Solids	kg/day	693.0	790.0	773.0	789.0	831.0	696.0	863.0	764.0	608.0	763.0	779.0	599.0	485.0	556.0	477.0	497.0	344.0	281.0	284.0	244.0	186.0	282.0	193.0	377.0	12343.0	707.3
	BOD	kg/day	852.0	950.0	949.0	861.0	823.0	749.0	555.0	559.0	500.0	661.0	627.0	548.0	525.0	510.0	482.0	300.0	258.0	211.0	224.0	192.0	213.0	246.0	226.0	322.0		

Appendix 7 References

Collected Data

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- Labour Relations Act 1985
- Labour Relations (General) Regulations, 1985, Statutory Instrument 368 of 1985, ACT 16/85
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