sources, not to meet the agricultural demands.

Recently, additional land for effluent irrigation is not available, especially in urban centres, where the land is needed for urban facilities/housing. A cost-effective Biological Nutrient Removal (BNR) sewage treatment process has been partially employed in Harare City, which demonstrated, for about last 15 years, the public heath safety of the system and that high-quality effluent suitable for discharge to water courses can be used for potable water supply. In application of this sewage treatment process, the local authorities concerned will increase the effluent discharge from sewage treatment plants, while effluents to be used for irrigation will be assumed to meet agricultural needs.

4.3 Potential Projects

There are seven existing public sewerage systems in the study area. Of the seven sewage treatment plants, about 95% of the total sewage inflow in the study area is treated at three sewage treatment plants: Crowborough and Firle in Harare City and Zengeza in Chitungwiza Municipality, while a total of only 2.5% is treated at Marlborough (0.5%) and Donnybrook (2%). Aside from the small-capacity Marlborough and Donnybrook STWs, these plants are located at the northern periphery of the study basin; they are 83 km and 24 km from the confluence of the main river/lake, respectively. It is considered that the influence to the water pollution of study rivers/lakes by these two STWs is well discounted in comparison with other sewage works.

Thus, the potential projects are, selected as follows:

1) Crowborough Sewerage System
2) Firle Sewerage System
3) Zengeza Sewerage System
4) Norton Sewerage System
5) Ruwa Sewerage System

5. Comparative Study on Potential Projects

5.1 General

An synthetic evaluation of the five existing sewage works was made in terms of technical/service level, environmental improvement, and economical and financial aspects as well

as the implementation capacity of the concerned authorities/works and the sustainability of the projects.

When comparing the relative priority of the potential projects, an emphasis was placed on the areas which are experiencing significant supply/demand discrepancies and furthermore lack of funding access/arrangements for future improvement projects. Therefore, those areas with little or no prospect of obtaining project funding but with clear need for such improvement projects received a higher relative priority ranking.

The study entailed recommendations on immediate-medium term development project/s for water pollution control and environmental improvements.

5.2 Technical Aspects

(1) Present sewerage services and problem areas

The service coverage by the respective existing sewerage systems is almost 100%, except for the Norton Sewage Works (80%). The existing sewer systems in Harare City and Chitungwiza municipality are reported to have some sections with damage resulting in rising offensive odour problems and health hazards. With regard to sewage treatment, the File and Zengeza STWs are considerably overloaded, while the Norton and Ruwa STWs have room at their treatment capacities. Of the larger three STWs, only the Zengeza STW does not have facilities to discharge treated effluent to the water course. Most of the treated effluent is used for irrigation, which is common to all STWs. Environmental problems in terms of offensive odour at the treatment site and its surroundings are reported at the Zengeza STW. Table 3.1 summarises the present conditions in both the sewers and the sewage treatment plants.

(2) Sewage treatment methods/processes

Table 3.2 presents the sewage treatment methods used for direct discharge of effluent into the river and for irrigation. The Crowborough and File STWs use BNR treatment processes to meet the effluent quality for discharge into the river. The secondary treatment process, by means of trickling filters, is employed for the use of effluent for irrigation except for Ruwa STW. The possible overflow of treated effluent from the STWs is

Table 3.1 Present Sewerage Services and Problem Areas

Sewage Treatment Works	Served Population *1 / Coverage (%)	Service Area: Sewer Conditions	Service Area: Environmental Problems	Sewage Treatment: Inflow to STW Flow (m^3/d) / Influent Quality (mg/l)	Sewage Treatment: Treatment Capacity (m^3/d) / Overloaded Flow (m^3/d)	Sewage Treatment: Discharge to River Flow (m^3/d) / Effluent Quality (mg/l)	Sewage Treatment: Irrigation Use Flow (m^3/d) / Effluent Quality (mg/l)	Environmental problems at STW / Environs of STW
Crowborough STW	506,200	- damage of manhole & sewers - build manhole cover - rain water intrusion to manhole	- common offensive odor	55,300	54,000	16,000	39,300	- no special problem
	100			COD 1,108.9 TN 53.0 TP 7.2	1,300	COD 80.6 TN 12.6 TP 0.6	COD 371.0 TN 39.0 TP 5.2	- no special reports on problems with sufficient distance from STW to housing
Firle STW	600,800	- raw sewage spill along 6 routes of lateral sewers (14 km) *2	- health hazard - offensive odor along problem sewers	132,300	72,000	27,700	104,600	- trickling filter is overloaded with offensive odor
	100			COD 943.0 TN 54.0 TP 6.9	60,300	COD 27.9 TN 0.8 TP 0.7-12.0	COD 232.5 TN 39.6 TP 3.4	- no special reports on problems with sufficient distance from STW to housing
Zengeza STW	420,000	- identified 30 problem points along sewer lines	- health hazard - stream pollution by raw sewage	36,400	21,750	None	36,400	- offensive odor pollution of nearby river upon overflow of effluent
	100			BOD 810.0 TN 38.0 TP N.A.	14,700	None	BOD 275.0 TN 57.0 TP N.A.	- pollution of streams in Beatrice down-stream of Imbgwa farm
Norton STW	21,000	- no special reports	- no special reports	2,700	3,400	None	2,700	- unsanitary w/odor problem at storage pond before pump station
	95			BOD 660.0 TN 83.3 TP 7.6	(700)	None	BOD 520.0 TN 65.8 TP 7.6	- no special reports on problems
Ruwa STW	1,600	- intrusion of groundwater and storm water	- no special reports	2,900	5,300	None	2,900	- during rainy season overflow of effluent to nearby river
	80			BOD 510.0 TN 31.0 TP 3.6	(2,400)	None	BOD 47.5 TN N.A. TP trace	- no special reports

Note: N.A. Not Available

*1; The term "Coverage" means the percentage of population served by respective STW

*2; Report on Subsidiary Sewers in the Firle Catchment Area, Harare Sewerage Firle V Project, Department of Works, City of Harare

Table 3.2 Sewage Treatment Methods/Processes and Effluent Reuse

Sewage Treatment Works	Treatment Process to Discharge Effluent into River	Treatment Process to Use Effluent for Irrigation	Problems Areas Operation of Facilities and Environmental Problems
Crowborough STW	Screen & Grit removal - Primary Sedi. Tank - BNR - Final Sedi. Tank : Marimba River	Screen & Grit removal - Primary Sedi. Tank - Trickling Filter - Final Sedi. Tank - Storage Pond - Pump Station	- routine work is done for operation of STP (effluent quality of secondary treatment needs to be improved) - no special reports on environmental problems
Firle STW	Screen & Grit removal - Primary Sedi. Tank - BNR - Final Sedi. Tank : Mukuvisi River	Screen & Grit removal - Primary Sedi. Tank - Trickling Filter - Final Sedi. Tank - Storage Pond - Pump Station	- routine work is done for operation of STP (effluent quality of secondary treatment needs to be improved) - secondary treatment needs to be improved)
Zengeza STW	None	Screen & Grit removal - Anaerobic Pond - Trickling Filter - Pump Station	- no primary and final sedimentation tank is installed - offensive odour at STP site and its influence to residential area as reported by residents - possible overflow of treated effluent into Naytsime River during rainy season
Norton STW	None	Screen & Grit removal - Primary Sedi. Tank - Pump Facility - Trickling Filter - Final Sedi. Tank - Storage Pond - Pump Station	- no special reports on operation of facilities - unsanitary condition at storage pond (anaerobic condition covered by scum on the pond surface)
Ruwa STW	None	Pump Facility - Anaerobic Pond - Facultative Pond - Matulation Pond	- overflow of effluent into nearby river during rainy season

pointed out at the Zengeza and Ruwa STWs either by the shortage of treatment capacity or the excess inflow of rainwater. Unsanitary conditions at the storage pond of Norton STW is also identified.

(3) Immediate- to medium-term rehabilitation/expansion projects

Improvement projects for the sewers were planned within a limited scope of work in the File and Ruwa STWs, while there is no on-going construction work for sewers in the five STWs. Plans and designs were prepared for expansion of the sewage treatment facilities at the Crowborough, Zengeza, Norton and Ruwa STWs. The tertiary treatment facilities at the Firle STW are under construction, while limited rehabilitation/construction work is being undertaken at the Zengeza and Norton STWs.

Recommendations on the expansion and rehabilitation of existing treatment facilities were made for the Zengeza and Norton STWs based on the previous studies in view of environmental measures including water quality preservation and replenishment of water for the water bodies.

The recommended projects for the rehabilitation of sewers are common to all STWs. Urgent improvement of the sewage treatment facilities for the Zengeza STW was emphasised in comparison with the other STWs in consideration of the present countermeasures provided and prepared plans/designs. Table 3.3 presents the summary of above mentioned.

5.3 Environmental Improvements

(1) Contribution to water pollution control

The treated effluent with a total of 46,800m3/d is presently discharged at the Crowborough and Firle STWs after the provision of tertiary treatment. About 75% of the sewage collected by the STWs in the study area is used for irrigation to avoid direct inflow of effluent into the water bodies. However, there is the possibility of effluent overflow at the Zengeza and Ruwa STWs during the rainy season, due to the lack of existing treatment capacity.

Table 3.3 (1) Planned/On-going Sewerage Projects for Immediate-Medium Term Improvement

Sewage Works	Sewer or S.Ws	Item	Planned/Designed	On-going Construction	Recommended by Study Team	Adequacy between Present Needs and Countermeasure
Crowborough S.Ws	Sewer System	SS1 SS2 SS3	N/A	None	N.A	-needs of continuous rehabilitation and expansion
	Sewage Works	ST1 ST2 ST3 ST4 ST5 ST6	60,000 tertiary treatment thickening-digestion-reuse discharge to the river BNR and sludge treatment	None	N.A	-The plan will cater for the need for the year 2000. -Tertiary treatment is adequate.
Firle S.Ws	Sewer System	SS1 SS2 SS3	N/A -do- lateral sewer:225-600 mm dia 14km	None	N.A	-needs of continuous rehabilitation and expansion
	Sewage Works	ST1 ST2 ST3 ST4 ST5 ST6	None	72,000 tertiary treatment thickening-digestion-reuse discharge to the river BNR and sludge treatment Z$ 322 million	N.A	-Current shortage of treatment capacity will be solved by on-going project.
Zengeza S.Ws	Sewer System	SS1 SS2 SS3	No plan/design -do- -do-	None	N.A	-needs of continuous rehabilitation and expansion
	Sewage Works	ST1 ST2 ST3 ST4 ST5 ST6	34,600 (total 55,000) secondary treatment drying bed irrigation anaerobic pond and trickling filter Z$ 106 million	6,900 primary treatment None irrigation anaerobic pond Z$ 7 million	20,000 tertiary treatment thickening-digestion-reuse discharge to the river BNR and sludge treatment	-Partial discharge of treated effluent may be necessary applying an adequate treatment process -Improvement of existing secondary treatment facilities is required to ensure water quality level for irrigation use.

Note :
SS1 : Trunk Sewer
SS2 : Pump Station
SS3 : Lateral & Service Connection

ST1 : Design Flow (m3/day)
ST2 : Sewage Treatment Level
ST3 : Sludge Treatment & Disposal
ST4 : Effluent Reuse/Disposal
ST5 : Major Facilities & Equipment
ST6 : Estimated Cost (million Z$)

N.A : Not applicable
N/A : No information Available

Table 3.3 (2) Planned/On-going Sewerage Projects for Immediate-Medium Term Improvement (cont'd)

Sewage Works	Sewer or S.Ws	Item	Planned/Designed	On-going Construction	Recommended by Study Team	Adequacy between Present Needs and Countermeasure
Norton S.Ws	Sewer System	SS1 SS2 SS3	None	None	N.A	-needs of continuous rehabilitation and expansion
	Sewage Works	ST1	1,300	3,400 (rehabilitation of existing facilities)	-rehabilitation of existing storage pond (unsanitary)	-Rehabilitation of existing secondary treatment facilities meets the present needs.
		ST2	secondary treatment	secondary treatment		
		ST3	drying bed	None		
		ST4	irrigation	irrigation		
		ST5	trickling filter	trickling filter		
		ST6	Z$ 21 million	Z$ 1.4 million		
Ruwa S.Ws	Sewer System	SS1	None	None	N.A	-needs of continuous rehabilitation and expansion
		SS2	installation of additional pump units			
		SS3	None			
	Sewage Works	ST1	5300 (existing capacity)	None	N.A	-Treatment capacity is well exceed present sewage inflows.
		ST2				
		ST3				
		ST4				
		ST5	expansion of grit chamber			
		ST6	Z$ 0.12 million			

Note :
SS1 : Trunk Sewer
SS2 : Pump Station
SS3 : Lateral & Service Connection

ST1 : Design Flow (m3/day)
ST2 : Sewage Treatment Level
ST3 : Sludge Treatment & Disposal
ST4 : Effluent Reuse/Disposal
ST5 : Major Facilities & Equipment
ST6 : Estimated Cost (million Z$)

N.A : Not applicable
N/A : No information Available

The tertiary treatment facilities are planned/designed for the Crowborough STW with a capacity of 60,000 m3/d and the facilities at the Firle STW with a capacity of 72,000 m3/d are under construction. In addition, provision of tertiary treatment at Zengeza STW for a capacity of 20,000 m3/d is recommended. A total effluent of 152,000 m3/d to discharge into the rivers would contribute to the increase of the available water sources, which is about 80% of present sewage volume flowing into STWs.

(2) Environmental improvements at STW sites and service areas

Strategic and staged improvements of sewer systems are required particularly in Harare City and Chitungwiza municipality. Environmental problems at the STW site and its surroundings are found at the Zengeza STW. A storage pond for irrigation at Norton STW is also identified.

5.4 Economic and Financial Aspects

(1) Financial arrangements on planned/on-going projects

There are no identified financial sources common to the five existing STWs for the improvement of existing sewers. The planned/on-going projects for the Crowborough and Firle STWs are financed by the World Bank. The on-going project for the Norton STW is being done with financing from the MLGRUD. There are no arrangements for the Zengeza and Ruwa STWs. Table 3.4 summarises the related information by STW.

(2) Project benefits by planned/on-going/recommended projects

About 1.5 million people in the study area will benefit from the realisation of additional tertiary treatment facilities for the Crowborough, Firle and Zengeza STWs with reference to water replenishment of the water bodies without causing water pollution problems.

(3) Cost-effectiveness on planned/on-going/recommended projects

With regard to the rehabilitation/expansion of the STWs, the planned/on-going projects at the two STWs in Harare City are adjusted in the Sewerage Master Plan and arranged to use the existing treatment facilities fully. The existing treatment facilities at the Zengeza

Table 3.4 Financial and Economical Evaluation

Sewage Works	Type	Item	Financial Arrangement	Project Benefit		Cost-Effectiveness		
				No. of Beneficiaries	Environmental Improvement	Size of Project	Full Use of Existing Facilities / Unity with Future Expansion	Land Availability / Acquisition Status
Crowborough S.Ws	A	SS	N/A	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	World Bank	- Water supply 1.5 M people - Supplement water source	- Water quality of rivers/lakes - Sanitation in service area	large	- Continuous use of existing facilities - Adjusted in the M/P	- Sufficient land available owned by the city
	B	SS						
		ST	None	N.A.	N.A.	N.A.	N.A.	N.A.
Firle S.Ws	A	SS	N/A	- about 4,200	- Sanitation in service area	small	- Existing sewers are used	- Land is secured.
		ST	None	N.A.	N.A.	N.A.	N.A.	N.A.
	B	SS	None	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	World Bank	- Water supply 1.5M people - Supplement water source	- Water quality of rivers/lakes - Sanitation in service area	large	- Continuous use of existing facilities - Adjusted in the M/P	- Sufficient land available owned by the city
Zengeza S.Ws	A	SS	N/A	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	No Source	- Present served pop.	- Mitigate existing treatment on secondary treatment level	medium	- Continuous use of existing facilities - Considered existing facilities	- Sufficient land available owned by the municipality
	Ar	SS	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	No Source	- Present served pop. - Supplement water source - Water supply 1.5 M people	- Water pollution control - Sanitation at STP site and its environs	medium	- Continuous use of existing facilities To - be adjusted in preparation of M/P	- Sufficient land available owned by the municipality
Norton S.Ws	A	SS	None	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	No Source	- 9,700 people	- Sanitation in service area	small	- Continuous use of existing facilities To - be adjusted in preparation of M/P	- Available land at existing STP
	B	SS	N/A	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	MLGRUD	- Present served pop.	- At STP site (odor) - Effluent quality	small	- Continuous use of existing facilities To - be adjusted in preparation of M/P	N.A.
Ruwa S.Ws	A	SS	-	- Present served pop.	- Sanitation in service area	small	- Existing sewers are used	- Land is secured
		ST	None	N.A.	N.A.	N.A.	N.A.	N.A.
	B	SS	None	N.A.	N.A.	N.A.	N.A.	N.A.
		ST	None	N.A.	N.A.	N.A.	N.A.	N.A.

Note: N/A; No information available
N.A.: Not Applicable

A; Planed/Designed Project
Ar; Recommended Project
B; On-going Construction Project
SS; Sewer System
ST; Sewage Treatment

Size of Project; small (less than 10,000 m^3/d)
medium (between 10,000 and 50,000 m^3/d)
large (more than 50,000 m^3/d)

STW will be effectively used with reference to the recommended tertiary treatment facilities; however, a review of the sewerage master plan shall be done to consider the recommended expansion project, as required. The planned/on-going projects of the Norton STW are adjusted with the sewerage master plan in full use of the existing treatment facilities. The land availability for the expansion of the sewage treatment plants was confirmed to be sufficient for all STWs.

5.5 Implementing Capacity of Concerned Authorities and Sustainability of the Project

(1) Institutional set-up of concerned authorities

The concerned local governments established institutions for planning/design of sewerage systems, and operation and maintenance of the existing sewerage facilities. The sewage works are under operation by the respective engineering departments. Table 3.5 presents concerned department and division by local authority.

(2) Experience on the similar projects by concerned authority

The five existing STWs have experience with regards to the implementation of sewerage projects in the provision of secondary treatment processes. Furthermore, there STWs: Crowborough, Firle and Zengeza undertook improvements with more than 20,000 m3/d treatment capacity.

(3) Operation & Maintenance practices in operation of sewerage systems and user's participation

Operation and maintenance of the sewerage facilities and accounting work are conducted at the STWs, ensuring some engineers and caretakers. Preventive maintenance of the sewerage systems is practised, even if not sufficient, at all STWs. However, staff training is commonly insufficient and the communications with the beneficiaries to improve the sector performance are future themes. Even if so, the majority of beneficiaries are aware of the sewerage provision and the efficiency of the sewerage charge collection at present is comparatively good, commonly more than 80% using a flat rate base.

Table 3.5 (1) Implementing Capacity of Concerned Authority and Sustainability of the Project

Sewage Works	Present Institutional Set-up		Experience on Similar Projects by Concerned Authority	O&M Practices at STP	User's Participation	
	Concerned Authority	Sewage Works		Management a)Preventive Maintenance b)Staff Training c)Social Activity to Users Organization with No. of Staff	Awareness on Sewage Works Need	Charge Collection Efficiency (%)
Crowborough S.Ws	Department of Works, Harare City	Engineering Services Division, Dep., of Works, Harare City	-tertiary treatment (18,000 m3/day) -secondary treatment (36,000 m3/day) -sewer system (200-1,350mm dia.)	a) : Completely Conducted b) : No Program c) : Partially Practiced Key personnel : 6 persons Caretaker : SS 155 persons ST 67 persons	L.D : majority M.D : majority H.D : about half	HH : Flat rate charge approx. 70 ID : Flat rate charge approx. 95
Firle S.Ws	Department of Works, Harare City	Engineering Services Division, Dep., of Works, Harare City	-tertiary treatment (36,000 m3/day) -secondary treatment (36,000 m3/day) -sewer system (200-1,350mm dia.)	a) : Completely Conducted b) : No Program c) : Partially Practiced Key personnel : 6 persons Caretaker : SS 155 persons ST 100 persons	L.D : majority M.D : majority H.D : about half	HH : Flat rate charge approx. 70 ID : Flat rate charge approx. 95
Zengeza S.Ws	Department of Engineering Services, Chitungwiza Municipality	Water & Sewerage Division, Dep. of Engineerig Services, Chitungwiza Muni.	-secondary treatment (21,750 m3/day) -sewer system (200-675mm dia)	a) : Partially conducted b) : Technician Training c)Communication with users is on the way Key personnel : 3 persons Caretaker : SS 14 persons ST 37 persons	M.D : majority H.D : about half	HH : Flat rate charge approx. 80 ID : Flat rate charge approx. 95

Note : SS : Sewer System
ST : Sewage Treatment

I.D : Industry
H.H : Household
L.D : Low Population Density
M.D: Medium Population Density
H.D : High Population Density

Table 3.5 (2) Implementing Capacity of Concerned Authority and Sustainability of the Project (cont'd)

Sewage Works	Present Institutional Set-up		Experience on Similar Projects by Concerned Authority	O&M Practices at STP	User's Participation	
	Concerned Authority	Sewage Works		Management a)Preventive Maintenance b)Staff Training c)Social Activity to Users Organization with No. of Staff	Awareness on Sewage Works Need	Charge Collection Efficiency (%)
Norton S.Ws	Town Engineering Department, Norton Town Council	Electrical/superintendant Division, Town Engineering Dep., Norton Town Council	-secondary treatment (3,400 m3/day) -sewer system	a) : Completely Conducted b) : No Program c) : Partially Practiced Key personnel : 3 persons Caretaker : SS 5 persons ST 11 persons	L.D : majority M.D : majority H.D : about half	HH : Flat rate charge approx. 70 ID : Flat rate charge approx. 95
Ruwa S.Ws	Works/Engineering Department, Ruwa Local Board	Sewerage Works Division, Works/Engineering Dep., Ruwa Local Board	-secondary treatment (5,300 m3/day) -sewer system	a) : Completely Conducted b) : No Program c) : Partially Practiced Key personnel : 2 persons Caretaker : SS 3 persons ST 7 persons	L.D : majority M.D : majority H.D : about half	HH : Flat rate charge approx. 70 ID : Flat rate charge approx. 95

Note : SS : Sewer System
ST : Sewage Treatment

I.D : Industry
H.H : Household
L.D : Low Population Density
M.D: Medium Population Density
H.D : High Population Density

6 Selection of the Priority Project and its Scope of Work

The Zengeza STW in Chitungwiza municipality, where the population increase has been considerable recent years, was recommended as the result of the comparative study discussed in the previous sub-sections. The major reasons for the selection of the Zengeza STW are:

- Supplemental water replenishment can be achieved for the conservation of water environment and water sources together with the arranged tertiary treatment by Harare city.
- The overflow of treated effluent from the Zengeza STW during rainy season can be handled.
- Environmental problems, especially with reference to offensive odour at the STW site and service area can be mitigated to an acceptable level.
- Cost-effectiveness can be ensured through the full use of existing treatment facilities

In addition, the implementation capacity was confirmed through experience with similar projects. However, the financial arrangements are an urgent subject for Chitungwiza municipality.

The Scope of Work for the expansion of the Zengeza STW was proposed under the following conditions and assumptions:

About 36,400 m^3/day of raw sewage inflows into the Zengeza STW at present, although existing sewage treatment capacity is limited to 21,750 m^3/day. The BOD removal ratio is reported at approximately 80% with an average effluent BOD concentration of 140 mg/l (raw sewage: 800 mg/l BOD).

A pump station, to transmit treated effluent to the farm land, was constructed in the Zengeza STW site recently. However, no upgrades of the treatment process for the existing treatment facilities was provided.

In application of the BNR method (tertiary treatment) adopted at the Crowborough and Firle STWs, the construction of sewage treatment facilities with a capacity of 20,000 m^3/day is necessary to cope with the projected sewage inflow of about 40,000 m^3/day in the year 2000, while the existing facilities (21,750 m^3/day) will be used for irrigation.

For the year 2015, approximately 70,000 m^3/day of sewage inflow is projected. The municipal council has an expansion plan for the existing facilities in application of secondary treat-

ment processes to handle 55,000 m^3/day. It is regarded that the recommended facilities be constructed and the future plan of the municipality will meet the need of sewage treatment in 2015.

(1) Design conditions

Design flow - 20,000 m^3/day
Inflow BOD and SS concentration - 800 mg/l and 600 mg/l

Present inflow of sewage to the STW from Tilcor industrial area (BOD 2,000 mg/l) is used for designing of facilities.

(2) Major treatment facilities

1) Anaerobic Pond: retention time - 5 days, BOD removal ratio - 70%
2) Aeration Tank (BNR): retention time - 16 days, capacity - 32,000 m^3
3) Final Sedimentation Tank:
   water surface loading - 26.6 m^3/day for peak dry weather flow,
   water surface area - 2,100 m^2
4) Sludge Thickener
5) Sludge Digestion Tank
6) Sludge drying bed: 40% reduction in a week - 1 ha

Figure 3.1 shows flow diagram of proposed works.

With regard to the institutional aspect, it also constitutes a very important element in the implementation of the water pollution control projects. To ensure the long-term success of the priority project, it is important to strengthen the institutional capability of the authorities concerned.

To satisfy such requirements, the Zimbabwe Institute of Public Administration and Management (ZIPAM) was established in 1984 and this Institute has contributed, to a large extent, to enhance the institutional building of the country.

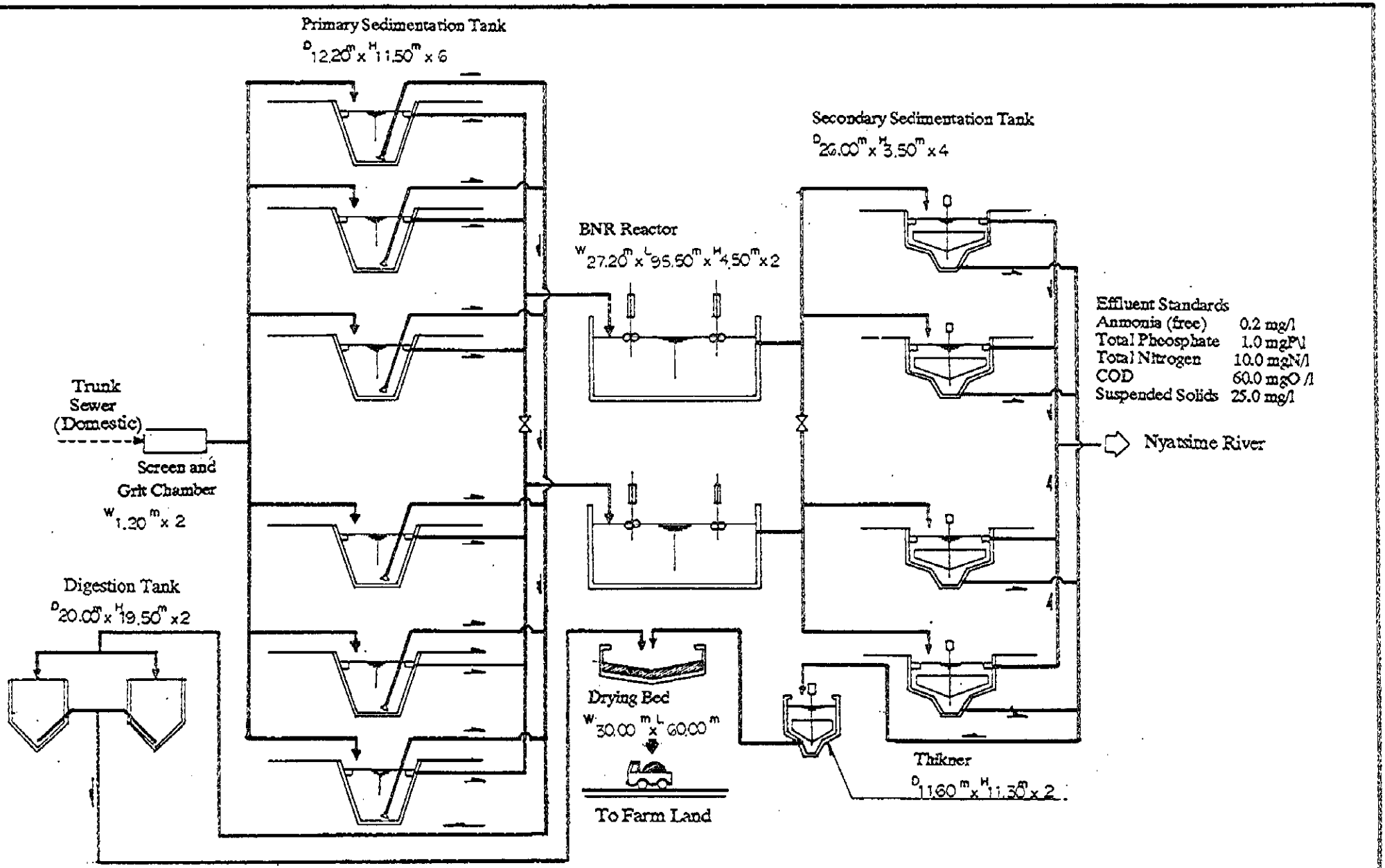

Figure 3.1 Flow Diagram of Proposed Zengeza STW

Since the capability of the local authority (Chitungwiza Municipal Council) to undertake the sewerage project is still limited in every aspects, most of activities for project implementation will necessarily be carried out through interagency co-ordination.

To ensure the smooth implementation of the priority project, the following training programme should be carried out for both the administrative and technical personnel, particularly for the staff undertaking the operations & maintenance of the sewage treatment works and water quality monitoring. At all levels, it is essential to have highly-skilled professional capability, plus a comprehensive grasp of the water pollution control field.

For the officers in charge of the project management, it is advised to strengthen their managerial and administrative capabilities through:

1) Management training in ZIPAM and/or utilising the other available training programmes;
2) Seminars for the personnel concerned, by inviting the consultants and experts specialised in each field; and
3) Training in foreign countries (ex. under the project type technical assistance).

The training programme will include, but not be limited to:

- Financial and budget management for implementation of the sewerage project,
- Environmental health management,
- Environmental impact assessment appreciation,
- General strategies for water pollution control;
    - Legal and institutional framework for water pollution control and environmental management,
    - preventive measures against water pollution including direct regulation and economic incentives,
    - measures to be taken for pollution control enforcement (ex. procedure to set and enforce the regulatory standards and sanctions/ penalties),
- General guidance on the sewerage project to be implemented prior to its construction (i.e. responsibilities, authorities, levels of activities of the local authority),
- Charge structure and sewerage tariff system,
- Charge collection system,
- Accounting, and budgeting systems and their standardisation,
- Need to consider the recurrent costs in planning and budgeting,

- Manpower development to assure the smooth operations and maintenance of the sewage treatment works, and
- Others.

To the staff directly engaging in the operations and maintenance of the sewage treatment works, the following training programmes will be provided.

1) Seminars on the expansion project (for all staff concerned);
2) Workshops for improvement of the operations and maintenance;
3) Intensive training course on water quality monitoring.

The principal training courses which must be provided for the technical staff will include, but no be limited to:

- Cost-effective management of the sewage treatment works,
- Operations and maintenance of the sewage treatment facilities,
- Procurement system of the materials and supplies necessary to maintain and repair the treatment facilities and equipment,
- Routine capital purchases: office machines, computers, major machinery, and similar items,
- Preventive measures and cost-effective means to reduce water pollution,
- Monitoring system for water pollution control,
- Others.

The approach to determining, the training needs will vary according to the educational background and occupational skills of each staff concerned, regulatory requirements and local circumstances. The manpower development programmes mentioned above are suitable for general guidance purposes, but decisions on final programmes and courses should be made on an individual case-by-case basis.

As problems become more complex, multidisciplinary approaches utilising several disciplines are more often being required, i.e.: engineering, biological sciences, in chemistry, physical sciences, operational research, system analysis, computer technology and its' applications, and others.

Consideration should be given to contracting with outside groups, such as local consulting or special services firms, to carry out specialised tasks of short duration and of a non-repetitive

nature, especially at the initial stage. This may eliminate the need for acquiring costly specialised personnel on the staff for which there is no long-term use.

In addition to the above, it is vital to provide training seminars and workshops with a view to disseminate all water pollution related information to the interested people and communities.

Finally, in the case that the project is to be implemented with the external source, it is advised to initiate communications with that source as early as possible, so as to gain not only technical assistance from the agency staffs, but also financial support in the form of grants or loans through a series of stages in the project cycle.

CHAPTER 4

Initial Environmental Examination of the Priority Project

CHAPTER 4 INITIAL ENVIRONMENTAL EXMINATION OF THE PRIORITY PROJECT

1. GENERAL

An Initial Environmental Examination (IEE) was conducted on the priority project identified above, which is the expansion/ rehabilitation of the Zengeza Sewage Treatment Works (STW) serving the Chitungwiza Municipal area.

An IEE report has been prepared in accordance with the guidelines of JICA as well as that of the Zimbabwe Government. The report covers all the requirements of a Prospectus, as specified by the Environmental Impact Assessment (EIA) Policy of Zimbabwe (Ministry of Environment and Tourism, 1994). The report scopes the most significant impacts expected to arise from the project and therefore begins to address some of the issues that would be considered in a Preliminary Environmental Impact Assessment (PEIA) as specified by the EIA Policy.

2. PROJECT DESCRIPTION

2.1 PROJECT DESCRIPTION / STATUS QUO AT ZENGEZA STW

The aim of the project is to construct additions to the Zengeza STW, which would treat sewage to a high standard and produce an effluent that could be discharged to the Nyatsime River (i.e. the effluent from the extensions would comply with the effluent standards as specified in the Government Notice No. 687 of 1977). The existing Zengeza STW are heavily overloaded, being sized for about 23Ml/d but treating an estimated flow of 36-40 Ml/d. At present a new set of anaerobic ponds is being constructed with a treatment capacity of 7Ml/d. The effect of these ponds on the treatment efficiency of the Zengeza STW is unclear as the total flow will still be fed through the existing biological filters.

The proposed extensions, which are the subject of this IEE, will have the capacity to treat 20Ml/d which will increase the capacity of the STW to 43Ml/d. The extensions would therefore eliminate the present overloaded situation and permit the rest of the plant to operate more efficiently as well. The present operation of the Zengeza STW is discussed elsewhere in the report.

Due to the scarcity of water in the Harare area the discharge of 20Ml/d of high quality effluent from the extensions to the Nyatsime River would be an important source of water for water supply impoundments downstream (Lakes Chivero and Manyame). This would be in keeping with the Department of Water Development's policy of maximising water reuse and ensuring water supply

during times of drought. Detailed information regarding technical aspects of the project are discussed above.

The location of Zengeza STW is shown in Figure 4.1 and summary of the Project Description is given in Table 4.1 below.

Table 4.1 Tabular Summary of the Project Description

ITEM	CONTENTS
Project Name	Rehabilitation/Expansion Project for the Zengeza Sewage Treatment Works
Background	The existing influent flow rate at the Zengeza STW's in Chitungwiza Municipality is approximately 36,400 m^3/day, while its capacity is only 21,750 m^3/day. The STWs are overloaded. Treatment effectiveness is low and this causes adverse environmental impacts, such as odour problems. Thus the STWs needs to be expanded.
Objective	Construct BNR (Biological Nutrient Removal) unit to improve effluent water quality that will be allowed to be discharged to the Nyatsime River and consequently to contribute to increase incoming water volume to Lake Chivero, a valuable water source.
Location	Chitungwiza Municipality, Zimbabwe
Relevant Government Organisation	Ministry of Local Government, Rural and Urban Development, Chitungwiza Municipal Council
Beneficiaries	Approximately 400,000 Persons
Design Criteria	Not Finalised
Project Type	Construction
Service Area	Area: 4,200 ha Population Served: 400,000 persons Flow Rate: 36,400 m^3/day
Wastewater Collection System	Separate sewer system
Treatment Plant	Existing Method: Anaerobic Pond Trickling Filter Pump Station Maturation Pond Irrigation Capacity : 21,750 m^3/day
	Proposed Method: Anaerobic Pond BNR Unit Secondary Clarifier Discharge to River Capacity : 20,000 m^3/day
Sludge Treatment and Disposal	Gravity Thickener Sludge Drying Bed Landfill Disposal
Pipelines	Conduit
Water Body to Receive Treated Effluent	Nyatsime River

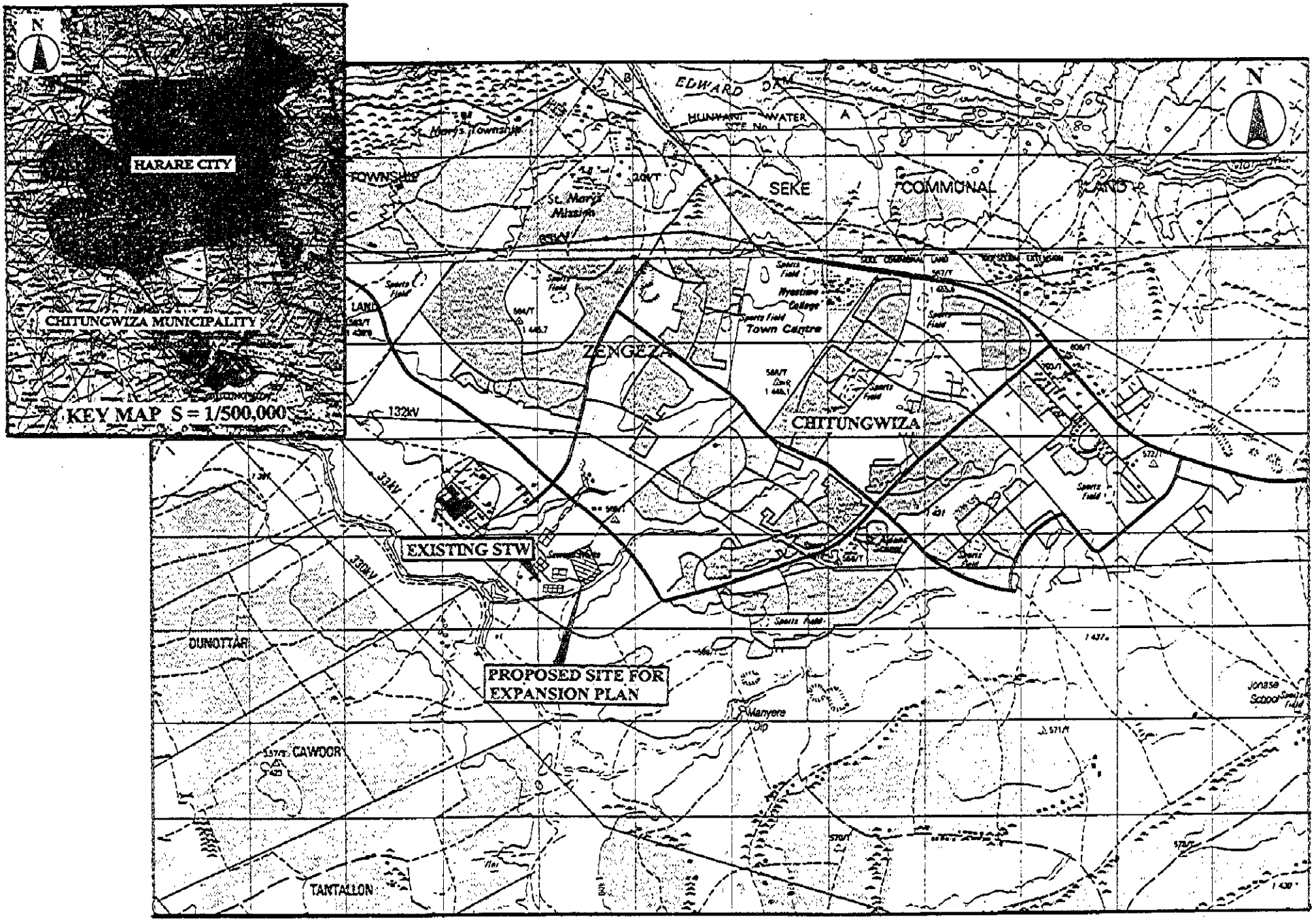

Figure 4.1 Location Map S = 1/50,000

The proposed extensions to Zengeza STW, considered for the IEE, consist of the following;

- three anaerobic ponds,
- a biological nutrient removal (BNR) activated sludge bioreactor,
- three secondary clarifiers,
- a gravity sludge thickener, and
- two concrete lined sludge drying beds.

Effluent from the BNR plant would be discharged to the Nyatsime River which drains the Seke Communal Land area to the East of Harare.

2.2 SITE DESCRIPTION

The proposed site for construction of extensions to the Zengeza STW is unutilised land on the existing sewage work's property. The land is owned by the Chitungwiza Municipality for the purpose of sewage treatment. The identified site lies to the East of existing ponds and inlet works. Part of the area was previously used as a borrow pit for road construction materials and the surface has been disrupted (see photo 4.1). The remainder of the site has a number of termitaria around which small scale agriculture of maize has previously been practised (see Photo 4.2) and domestic solid waste has been illegally dumped at random (see Photo 4.3) due to lack of fencing and no access control to the area. The natural environment of the whole site has therefore been altered to a greater or lesser degree and the site is already severely impacted. A tabular summary of the site description is given in Table 4.2.

Table 4.2 Site Description Information

ITEM		CONTENTS
Project Name		Rehabilitation/Expansion of Zengeza Sewage Treatment works
Social Environment	Inhabitants (residents attitude to Project)	Industrial housing is located near the STWs
	Land Use	Per-Urban
	Economy/Transportation	Industrial Sites / housing near the STWs
Natural Environment	Topography/ Geology	None in particular
	Coast and Ocean	No coastline
	Valuable Flora and Fauna	None
Environmental Pollution	Complaints	Offensive odours affect industries and residential areas
	Countermeasures	Rehabilitation/Expansion project for the STWs

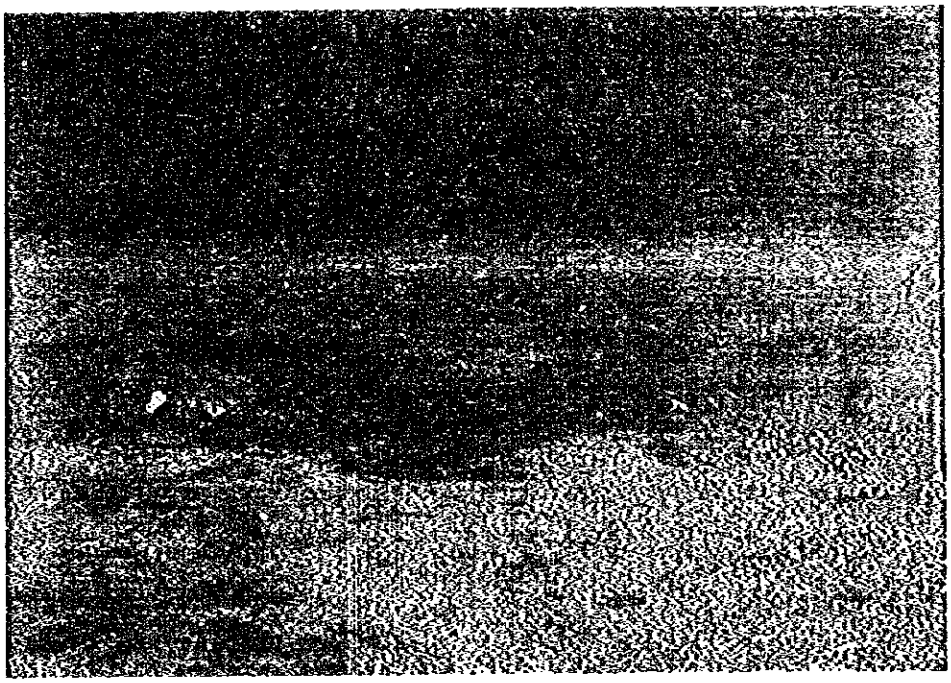

Photo 4.1 :Borrow pit on proposed site used previously for Road Construction Material

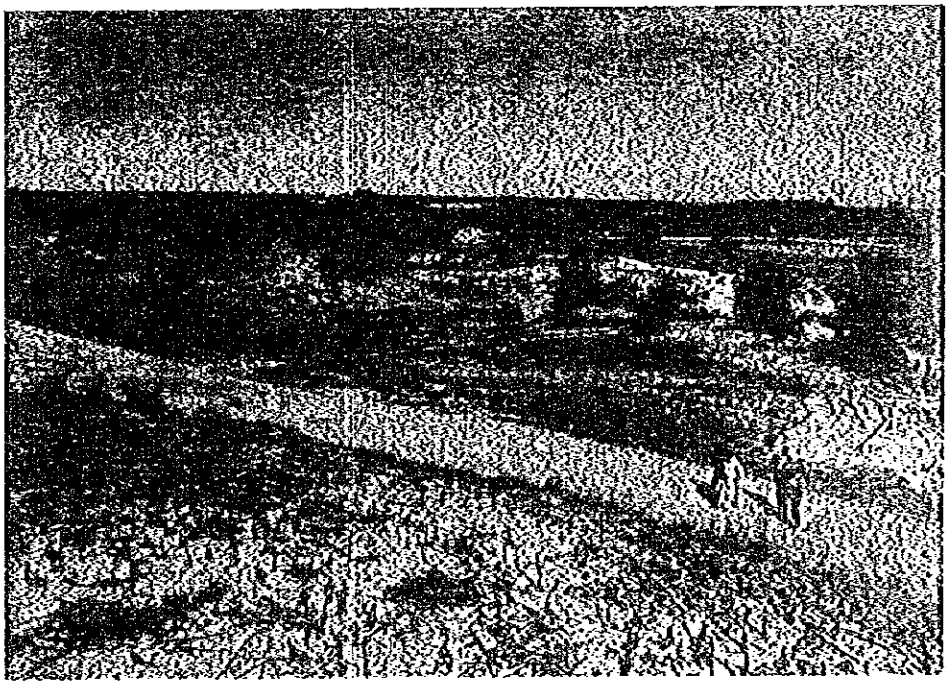

Photo 4.2 :Termitaria on the site with previous informal small scale agricultural activities.

Photo 4.3 :Illegal dumping on the proposed site.

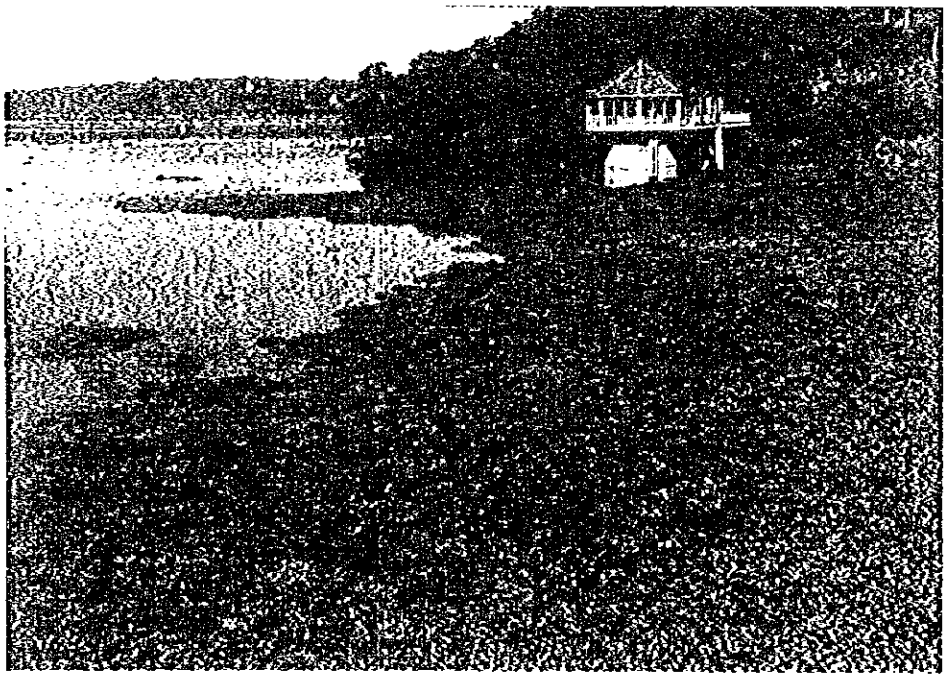

Photo 4.4 :Water hyacinth growth on Lake Chivero encouraged by eutrophication of the lake.

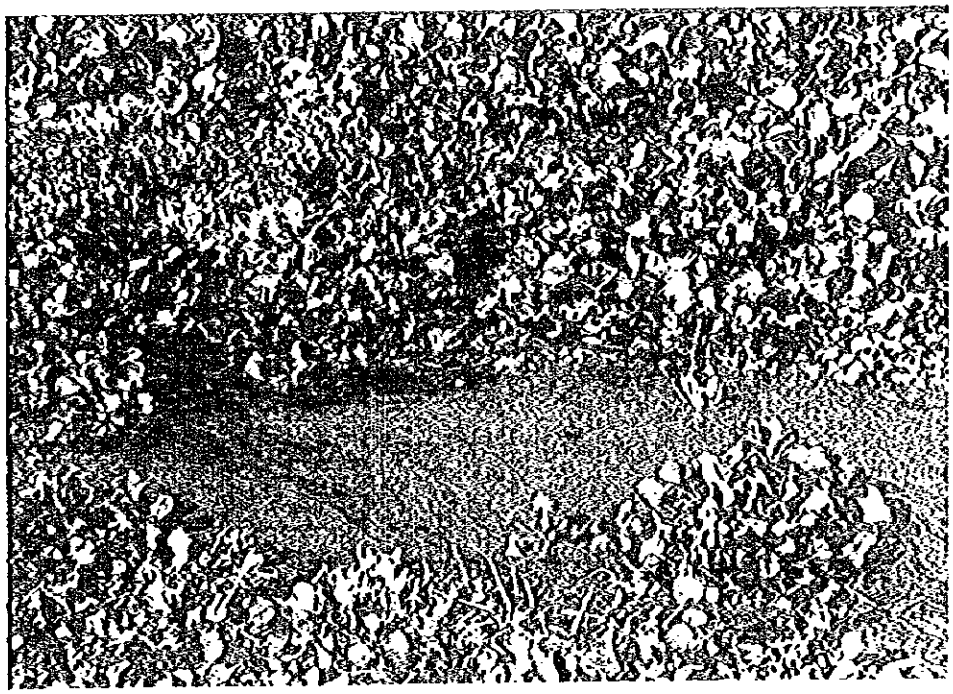

Photo 4.5 :Algal scum formation on Lake Chivero as a result of eutrophication from sewage and other nutrient discharges.

2.3 IEE METHODOLOGY

The methodology followed for the IEE was as follows:

1) The available sections of the report on the Upper Manyame River Basin Study were reviewed for relevant information.

2) Site visits were undertaken to assess the situation at relevant sites and to enable assessment of potential environmental impacts. Photos were taken on all of the site visits for information and to illustrate important points in the report. Sites visited were as follows:
   - Lake Chivero and Lake Manyame (2 July 1996)
   - Chitungwiza Municipal Offices and Zengeza Sewage Treatment Works (3 July 1996)
   - Chitungwiza Landfill Site (5 July 1996)

3) *Ad hoc* discussions with members of staff of the Chitungwiza Municipality at Zengeza STW, Mr. R. Lock of the Water Pollution Advisory Board and Mr. P. Mbira, Principle Water and Sewerage Engineer of Chitungwiza Municipality.

3. ANALYSIS OF POTENTIAL ENVIRONMENTAL IMPACTS

JICA has a prescribed checklist of 23 environmental factors to be considered when undertaking an IEE. These 23 will be discussed in the order in which they appear in the JICA Environmental Assessment Guideline.

(1) Resettlement

The extensions proposed for the project will not result in any people being resettled or moved. This is because the land to be used is already owned by the Chitungwiza Municipality and is at present an unused portion of the sewage treatment works.

(2) Economic Activity

Construction of the extensions to the STW is not expected to have any negative impacts on the economic activity or structure in the area. Positive impacts of the project on the local economy are expected to be, employment of local labour during the construction phase of the project and permanent jobs in the Municipality for operation and maintenance of the plant. The number of jobs that could be created during construction, albeit temporarily, is not known at this early stage in the planning. Similarly the number of permanent positions that might be created for operation and maintenance of the plant is unknown.

(3) Transportation/ Infrastructure

The project is not expected to have any negative impacts on existing transportation routes or public infrastructure. The roads leading to the STW (Chitungwiza Road passes the entrance to the site) are of a high standard and any additional traffic using these routes during construction is unlikely to affect the traffic flow significantly. Appropriate signage will need to be used during construction if a significant number of heavy vehicles will be entering and leaving the site. This would be to prevent possible accidents because of vehicles could be travelling at high speed on Chitungwiza Road.

(4) Isolation

The project will not cause the isolation of any rural communities due to traffic obstruction because there is no thoroughfare of any sort through the site.

(5) Ruins and Cultural Assets

There are no valuable ruins or cultural assets near the construction site. Therefore the project will not have any impact in this regard.

(6) Water Rights/ Common Rights

Construction of the Project is not expected to impact negatively on the Water or Common Law Rights of any group because the land is already owned by the Chitungwiza Municipality for the purposes of sewage treatment.

The discharge of effluent from the proposed new plant is also unlikely to negatively impact on any Water Rights of downstream users if the effluent meets the effluent standards as specified in Government Notice 687 of 1977. The standards relating to nutrients, and major chemical and physical parameters which are considered in this IEE are given in Table 4.3.

The present design philosophy is to meet these standards. The Water Act is at present under review and some of the standards might change in the foreseeable future. Therefore care should be taken during design to ensure that the effluent that will be produced by the extensions is able to comply with any new standards.

Table 4.3 Nutrient and Major Chemical and Physical Standards which the Extensions to Zengeza STW will be designed to meet

Parameter	Maximum Concentration	Units
pH	6.0-9.0	
Temperature	35	°C
COD	60	mgO/l
Suspended Solids	25	mg/l
Ammonia (free and saline)	0.5	mgN/l
Nitrogen total	10.0	mgN/l
Phosphate Total	1.0	mgP/l

(7) Hygiene

Breeding of Pests (flies)

No residents were interviewed during the IEE because the scope of the IEE did not permit a public participation programme to be undertaken. Without a public participation programme it was considered unscientific to interview only a select group of residents which might have given non representative results. It is recommended that a public participation programme would form part of an EIA.

The question of flies caused by construction of extensions at the STW will be very hard to assess because the conditions at the STW at present are conducive to fly breeding due to the overloading of the works and extensive odours being generated by the existing anaerobic ponds which attract flies and encourage breeding. The proposed extensions could possibly reduce the fly breeding problem because the process planned would generate fewer odours than the present system and would alleviate the load on the existing plant. This could lead to a reduction of the fly breeding problem in these areas. In discussions with the plant supervisor at Chitungwiza STW he reported that there had not been complaints from residents about flies.

One area of the proposed system where problems with fly breeding could be encountered is in the sludge drying beds where undigested sludge will be air dried. As the sludge dries offensive odours could arise which could encourage fly breeding. This will need to be addressed in the design and operation of the plant.

Disinfection of Effluent

From previous experience with similar systems the final effluent from the proposed BNR system can be expected to have a faecal coliform concentration of 10^4 - 10^5 units/100ml. Therefore the effluent is expected to have a significant negative effect on the bacteriological quality of the water in the Nyatsime and Manyame Rivers below the discharge point. The bacteriological levels give an indication of health risks that could be expected for people using the river water for domestic or recreational purposes. A concentration of 1000 units/100ml is unacceptable for partial contact recreation (canoeing, angling) and 150 units/100ml is the limit for full contact recreation (swimming etc.). Reliable data is not available on the present levels of faecal coliform in these rivers but the discharge of the expected levels from the proposed extensions will need to be taken into account when the water quality requirements of possible downstream users (for clothes washing, bathing) is considered in a Public Participation Programme forming part of a in an EIA.

At present there are no effluent standards for microbiological concentrations in effluents. Therefore no disinfection of the effluent has been considered up until now in the design of the proposed extensions to the STW. However in discussions with a representative of the Water Pollution Advisory Board (WPAB) the issue of bacteriological quality of effluent was raised and it was stated that the WPAB is considering proposing an faecal coliform concentration limit for inclusion in the new Water Act. Further clarification of this issue will be needed. The disinfection/ reduction of pathogens in the effluent would be considered further in an EIA.

Water Quality in Wells

Only limited data was available on the water quality of wells in the area. There are no wells close to the STW and only one near the farm where the effluent is used for irrigation at present. The only analysis available from this single well was COD of 1.4mg/l, DO of 4.5 mg/l and temperature of 24 °C. These results indicate that the ground water is unlikely to be contaminated by the effluent being used for irrigation. If contamination was occurring the COD would be expected to be higher. More thorough analyses of the ground water in the area of the STW would need to be done in order to make a better assessment of the present situation. Because of the discharge of effluent to the Nyatsime River the project is unlikely to impact on the groundwater. Analysis of nutrients, chemical and physical parameters would make the determination of impacts a lot more accurate. The relevant data obtained during the study is shown in section 3.5.3 (3) (Wells).

(8) Wastes

The sludge treatment regime is as follows:

- Waste activated sludge (WAS) from the BNR plant will be gravity thickened

- The thickened WAS and the sludge from the anaerobic ponds will be placed in the lined sludge drying beds and left until dry enough to transport

- Dried sludge will be transported to and disposed of in the municipal landfill.

The WAS will contain pathogens and therefore care must be taken in the handling of this sludge at the STW and the landfill site. Similar care should be exercised with the sludge from the anaerobic ponds. During the site visit to the STW shallow ground water was observed in the borrow pit on the proposed site and therefore disposal of sludge by burying on site would not be acceptable due to possible contamination of the ground water close to the surface.

During the site visit to the solid waste landfill near the STW it was observed that the landfill operation had not operated efficiently for about 2 months due to mechanical breakdown of the compactor. Due to this waste was lying uncovered over a large area and a number of people were scavenging on the site. If this situation arises during disposal of air dried WAS to the landfill there would be (i) a significant risk of odours being generated and (ii) the WAS would pose a serious health threat especially to scavengers at the site. Furthermore boreholes should be drilled near the landfill site and monitored for leachate generated which could be contaminated by the disposal of sludge.

Therefore there is a risk of a significant impact caused by the disposal of sludge from the extensions. This matter should be addressed in an EIA by developing an integrated sludge disposal strategy for all sludge generated by the proposed extensions. This study could also consider the sludge generated by the other sections of the Zengeza STW.

Waste materials generated during construction could also impact on the local environment and must be managed accordingly.

(9) Risk of Calamity

From the slope of the land on the site there is no anticipated risk of landslides or cave-ins on the site. This aspect need not be considered further.

(10) Topography/ Geology

There are no valuable or important topographic or geological features that will be affected by construction of the extensions. Most of the site is already disturbed due to the use of the site as a borrow pit for road construction.

(11) Land Erosion

Due to the site already being highly impacted because of the excavation activities for road construction materials the surface runoff is already severely impacted. The drainage of the site must be considered during design and construction to ensure that erosion is prevented. This would form part of the Environmental Management Plan to be formulated during an EIA. Eroded areas could be rehabilitated.

(12) Groundwater

Groundwater was observed at the surface in the borrow pit during the site visit (see Photo 4.1). This raises concerns that spillages or overflows at the proposed new plant could cause ground water contamination. The ground water is very high this year due to exceptional rains and might not normally be this close to the surface. This issue would need to be addressed in an EIA - boreholes would need to be drilled and monitored on a regular basis to ensure that no pollution was taking place from the new works.

The ground water observed on the surface in the borrow pit should be monitored for any contamination from the existing works at Zengeza.

(13) Lakes/ Rivers

Rivers

In the initial layout provided by the engineers the intention was to discharge the effluent to a small stream adjacent to the secondary clarifiers. However the flow of this stream is very low and it stops flowing in the dry season. Therefore a continuous flow of 20M /d into this stream would totally disrupt the ecology in the stream. Due to this it is thought that the effluent from the extensions should be discharged directly into the Nyatsime River. This would require a pipeline or channel about 1km long. The alignment of the pipeline would need to be reviewed for environmental impacts, if this disposal route is selected.

The effect of discharging 20 M /d of effluent to the Nyatsime river will fluctuate according to the season. During the wet season when the river flows strongly the effect of the discharge would be expected to be minimal. However during the dry season and especially during drought periods the effluent will be in excess of 90% of the flow in the river. In the recent

drought the Nyatsime River stopped flowing and therefore under these conditions the effluent would form 100% of the flow in the river.

Therefore the extensions would ensure that there is always flow in the rivers downstream and would be an important source of water for potable supply during drought conditions. The impact on the aquatic life/ riverine vegetation of the discharge of a high quality effluent forming up to 100% of the flow is unknown due to lack of information of the present situation. The main impact of the effluent discharge is expected to be in the nutrient levels in the water supply impoundments downstream. This would need to be addressed in a EIA.

The management of peak sewage flows due to excessive rain needs to be considered especially if this results in overflows into the river. The impact of these flows on the river needs to be addressed in a PEIA.

Lakes

The main water supply lake for the Harare/Chitungwiza area is Lake Chivero which lies downstream of the discharge point from the Zengeza STW, on the Manyame River. This lake already has a eutrophication problem resulting in a water hyacinth problem and algal blooms (see photos 4.4 and 4.5). Fish kills have also taken place. The exact cause for the fish kills are unknown but were probably a combination of pollution levels in the water, a change in temperature and a drop in dissolved oxygen levels due to a turnover in Lake Chivero.

Due to the eutrophication problems in Lake Chivero the discharge of poor quality effluent from the existing Zengeza works to the river was stopped and all the effluent is now irrigated to land at Imbgwa farm. The effect of discharging high quality effluent to Lake Chivero from the proposed extensions to Zengeza STW into the Nyatsime River is at present unknown and a regular monitoring programme would need to be undertaken. However it is unclear to what extent this discharge would affect the lake as there are a lot of other point and diffuse sources of pollution into the lake. A holistic approach is being developed by the Ministry of Water Development to address this problem in the upper Manyame River catchment.

As far as the effluent from the new extensions is concerned, if the effluent complies with the present (or future) effluent standards then discharge to the Nyatsime River will be permissible. However if the proposed extensions are not operated properly then there is a large risk of the effluent not meeting the effluent standards. In this case the effluent would be expected to cause a significant impact on the river and downstream impoundments. This

problem needs to be addressed on the management level and money budgeted for training of the staff to operate the plant properly.

If the proposed extensions are constructed and operated efficiently then in times of water scarcity or drought a high quality effluent will be a valuable source of water for Lake Chivero to be used for potable water supply. This is in keeping with the Ministry of Water Development's aim of maximising water conservation and reuse.

(14) Coast/ Ocean

Zimbabwe is a landlocked country and therefore the project is not going to have any effect an any coastline or ocean.

(15) Flora and Fauna

Terrestrial

The site for the proposed extensions has already been highly impacted by use of the site for growing of crops on and around the termitaria (termite hills), informal/uncontrolled dumping, and as a borrow pit for roads construction. Therefore the natural habitat has been destroyed and the construction of the extensions will not cause the loss of any unimpacted natural habitat. The construction of the proposed extensions will therefore not affect any endangered/listed natural fauna or flora.

Aquatic

At present the STW is not discharging any effluent to the river due to the poor quality of the effluent from the existing process. The aquatic environment would probably have been heavily impacted by the discharge of low quality effluent in the past but there is no available data to verify this, apart from the eutrophication problems experienced in Lake Chivero downstream and the associated fish kills.

If the effluent from the proposed extensions meets the effluent standards then the impact of the effluent on the aquatic environment will be less than was previously the case. The impact of a higher quality effluent on the river/s and impoundments downstream would need to be assessed as part of the water quality monitoring project at present being undertaken by the Ministry of Water Development. However the impact of the effluent from the extensions to Zengeza STW on the water quality of the Nyatsime and Manyame Rivers prior to other effluent discharges could be assessed by instituting a more comprehensive monitoring programme and carrying out a modelling exercise as part of an EIA.

Another impact on the aquatic environment would be the impact of continuous flow in the river on the ecological functioning of the river. The aquatic species might require periods of low flows or drought to complete their life cycles or maintain a balance. Therefore this issue should be addressed in an EIA.

(16) Climate

The project is not expected to have any impact on the local climate.

(17) Landscape

The construction of the extensions is likely to have a limited , temporary impact on the aesthetics in the area. These considerations need to be taken into account during construction to minimise any negative effects on the local community. Once constructed the plant is expected to only have a limited negative appearance but will not disrupt the skyline or any existing landscape features. The possible slight negative impact can be further limited by a landscaping plan which would be developed as part of an Environmental Management Plan (EMP).

(18) Air Pollution

Possible air pollution could be caused during construction and operation. During construction dust pollution could be caused by construction activities. Steps should be taken to keep this to a minimum by using appropriate construction techniques for dust control, e.g. wetting the surface. During operation some contaminated aerosols could be generated from the BNR unit, depending on the aeration technique used. This should be addressed during design of the BNR unit. Other minor air pollution due to fires made by construction teams could occur, which should be considered in the EMP.

Odours could also be caused but these are discussed separately below.

(19) Water Contamination

These issues have been discussed above under Lakes/Rivers and, Fauna and Flora.

(20) Soil Contamination

At present no regular monitoring of heavy metals in the raw sewage or in sludge has been carried out and therefore very limited information is available. This issue would have to be addressed as part of an EIA. The proposed sludge disposal method, to landfill, would prevent soil contamination on the STW site but could cause soil contamination at the landfill if the landfill generates leachate and is inadequately lined. Operational problems at the landfill

which were observed during the site visit will need to be resolved before sludge can be disposed of on the landfill on a regular basis.

(21) Noise and Vibration

The proposed project is expected to have minimal impact on the surrounding communities due to vibration and noise during the construction phase, if construction activities are carried out during normal working hours. If work is conducted at night and over weekends some impact might occur. The scheduling of activities will therefore have to be done with due consideration for residents in the area.

(22) Land Subsidence

The land moving activities anticipated for this project are not expected to cause any possibility of land subsidence.

(23) Odours

There are 2 areas of the proposed extensions that could be sources of odours, the anaerobic ponds and the sludge drying beds. If these 2 areas are managed and operated efficiently then odour generation should be minimised. At present a lot of odours are generated from the others areas of the STW and the construction of the proposed extensions are expected to reduce the overall level of odours by eliminating the present overloaded conditions at the STW.

The generation of odours from the disposal of sludge to the landfill is considered unlikely if the landfill operation is managed efficiently. However the observations made at the landfill during the site visit are of concern, if the sludge is not disposed of efficiently and covered on a daily basis then it could cause odours and will present a health hazard, especially because it will be undigested and due to the number of scavengers present at the landfill site.

The land use around the Zengeza STW falls into three categories; industrial, residential and open space.

The industrial area is the closest with a number of factories about 150 m from the western boundary of the existing sewage works' anaerobic ponds and sludge drying beds. Figure 4.2 shows a diagrammatic representation of the present land use surrounding the Zengeza STW and the Chitungwiza Landfill site.

Figure 4.2 also gives the recorded annual wind directions recorded at the airport which is the closest weather monitoring station to the Zengeza STW. From the wind rose given in Figure

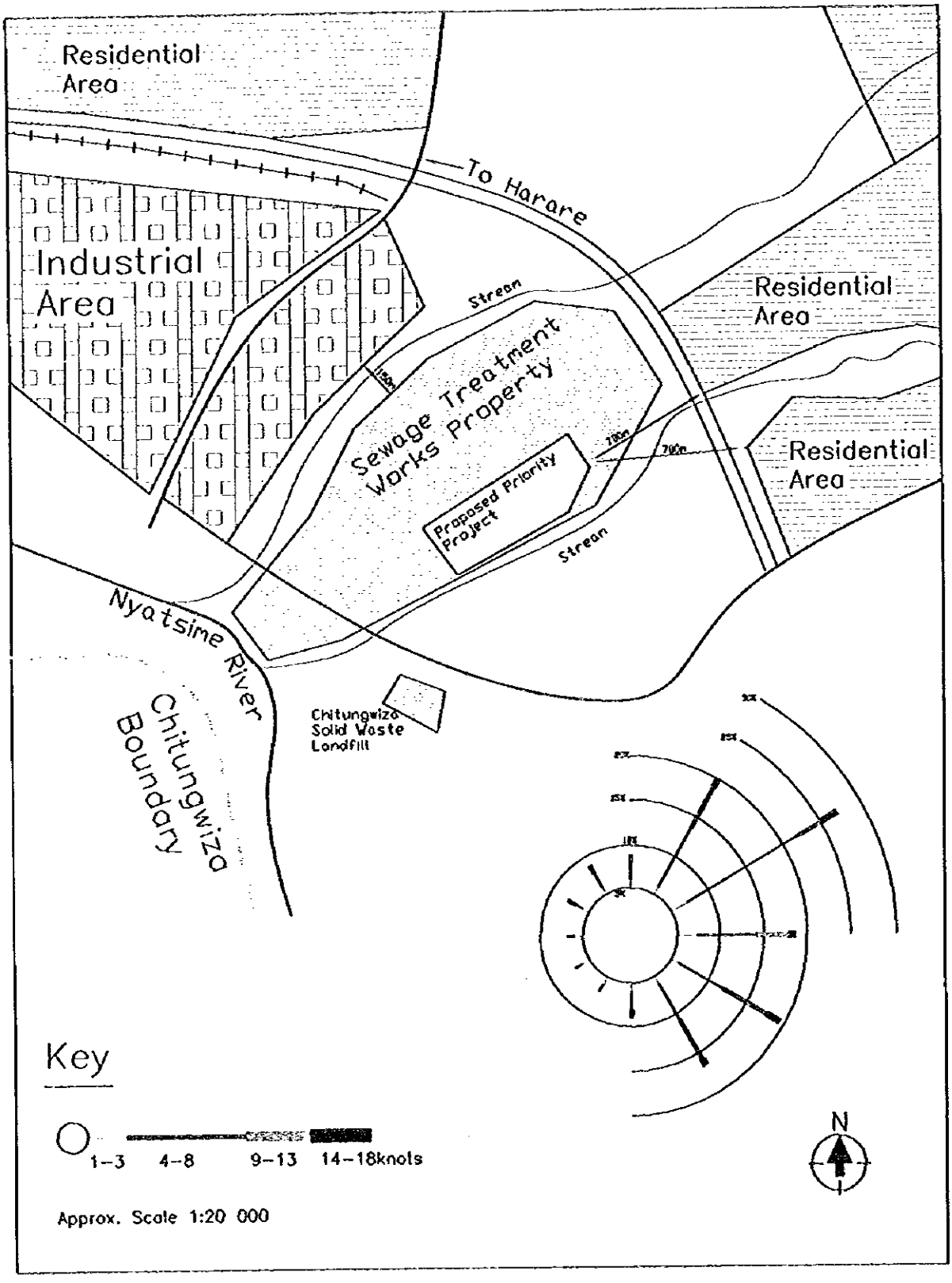

Figure 4.2 The Annual Wind Direction at Zengeza STW

4.2 it can be seen that the prevailing wind direction from the East to North East away from the Seke South residential areas and the open space to the South East. Therefore the industrial areas are likely to be affected mostly by odours generated at the STW and these are situated close to the treatment works. This must be addressed in an EIA to identify methods of reducing the odours generated.

4. TABULATION OF IEE FINDINGS

The JICA IEE requirements stipulate that the findings of the IEE be presented in tabular form indicating the rating of the impacts expected under the 23 environmental factors discussed in section 3 above. The Table is presented below in Table 4.4. The expected impacts under each factor are ranked as follows:

A; Serious environmental impact is anticipated.
B; Some Environmental impact is anticipated.
C; The environmental impact unknown from available information, and
D; Slight or no environmental impact is anticipated.

These rankings are in accordance with the JICA IEE procedure. A ranking of A, B or C indicates that further work is required to fully assess the environmental impact of the proposed project on this environmental factor. Factors having these rankings will be included in a "Scope of Work" for an EIA.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

An Initial Environmental Evaluation (IEE) was carried out on the proposed project , The Extension/ Rehabilitation of Zengeza Sewage Treatment Works (STW). These works serve the Chitungwiza municipal area, receiving between 36 and 40 M /d of domestic and industrial wastewater. The IEE was conducted according to the requirements of JICA for an IEE and fulfils all the requirements of a Prospectus as specified by the Zimbabwe Environmental Impact Assessment Policy of 1994.

In conducting the IEE the impact of the proposed extensions to Zengeza STW on 23 environmental factors was assessed. Where data availability was insufficient for the purposes of assessing an impact a negative impact was assumed.

Table 4.4 Tabulation of the findings of the Initial Environmental Examination (IEE)

No	ITEM	Anticipated Impact of Item Considered	Rank
1	Resettlement	No people will be moved by the proposed project	D
2	Economic Activity	The project will impact positively on the local economy by creating employment (temporary and permanent)	D
3	Transportation/Infrastructure	No negative impact is anticipated. Road safety at STW entrance must be managed.	D
4	Isolation	No negative impact is anticipated	D
5	Ruins and Cultural assets	No negative impact is anticipated	D
6	Water Rights / Common Rights	A potential impact exists if the effluent does not meet required standards. Backup disposal route should be investigated.	B
7	Hygiene	A public participation programme is required to address status quo and future potential problems.	B
8	Wastes	A potential negative impact exists. Disposal must be managed properly/ according to safety regulations. Sludge could pose a health risk at the landfill - needs to be addressed in the EMP.	A/B
9	Risk of Calamity	No negative impact is anticipated	D
10	Topography /Geology	No negative impact is anticipated	D
11	Land Erosion	Erosion must be considered during construction and operation. Drainage of the site must be addressed in the design and construction techniques.	B
12	Ground water	Disposal of sludge to the landfill could cause Ground water contamination. A monitoring programme needs to be instituted to monitor this. This must be included in the EMP.	A/B
13	Lakes/ Rivers	A serious negative impact could result if effluent standards are exceededIf effluent standards are met a small impact is anticipated	AB
14	Coast/Ocean	N/A	
15	Flora and Fauna	No negative impact is anticipated on the construction siteSome negative impact on the aquatic environment is anticipated - needs to be evaluated in EIA	DB
16	Climate	No negative impact is anticipated	D
17	Landscape	No significant changes to the landscape are expected. Any possible change to the landscape must be considered during design.	C
18	Air Pollution	Dust could be caused during construction and affect the residential areas nearby. Some aerosols could be generated by the aeration equipment used on the BNR reactor - must be considered in EIA.Odours could have an impact	B
19	Water contamination.	Discussed in 13 above	A / B
20	Soil Contamination	Sludge disposal could have a negative impact on the soil. Data is limited and a monitoring programme is required to address this. To be considered in EIA.	B
21	Noise and Vibration	Minimal negative impact is anticipated but needs to be considered in the Public Participation Programme and EMP.	B
22	Land Subsidence	No negative impact is anticipated	D
23	Odours	The proposed extensions are expected to improve the present situation. Some odours will be generated by the proposed plant. These odours and the impact on industries/ communities will need to be kept to a minimum by appropriate operation and management	B

From the discussions in the IEE above a number of overall conclusions were drawn, as follows:

1) The proposed extensions to the Zengeza Sewage Treatment Works (STW) will have a number of positive and negative environmental impacts.

Potential negative environmental impacts of the proposed project are as follows :

- *Effluent discharge to the Nyatsime River*: the discharge of 20M /d of effluent to the river will have an impact on the ecology of the river and the downstream impoundments, even if the effluent meets the present effluent standards. Areas of concern are : Water Rights/ Common Rights of downstream users, point 6; Hygiene/ disinfection related issues, point 7; The effect on Lakes/ Rivers and the aquatic and riverine ecosystems, point 13, 15 and 19.

- *Disposal of Wastes*: the disposal of sludge could have significant impacts and must be managed properly. Areas of concern are: The management of sludge disposal, point 8; Generation of odours, point 23; Hygiene related health risks, point 7; Contamination of ground and/or surface water, points 12 and 20.

- *Public Response*: the public are unaware of the proposed project at present and could object to the project if uninformed. A Public Participation Programme would reduce the risk and include the public in the decision making process.

- *Erosion* : there is a risk of land erosion during construction and after commissioning, which should be prevented. Refer to point 11.

- *Air Pollution* : there is a risk of air pollution during construction (dust and smoke) and a slight risk during operation (airborne pathogens). Refer to point 18.

- *Noise and Vibration* : some impacts are expected to be caused by construction activities (except if blasting takes place, in which case the impacts could be significant). Refer to point 21.

Potential positive impacts of the extensions to the plant are expected to be:

- *Effluent Quality* : the extensions will alleviate the present overloading of the STW. 20Ml/d (of a total of 40Ml/d) will be treated to a quality that meets the effluent

standards. The quality of the rest of the effluent is expected to improve because the system will be operating within design conditions.

- *Odours* : the overall level of odours on the STW is expected to be reduced due to the reduction in loading on the existing system and the efficient treatment in the proposed extensions.

- *Water Reuse* : the discharge of high quality effluent to the river will contribute towards the reuse of water, a priority of the Department of Water Resources.

- *Employment Opportunities*: the project will create temporary (construction) and permanent (operation of the plant) employment opportunities.

2) None of the negative impacts are fatal flaws and can be eliminated or mitigation measures developed, to reduce their impact to acceptable levels, by appropriate design and management. These considerations need to be addressed in more depth.

3) The construction of the proposed extensions to the STW is expected to improve the treatment of sewage at the STW leading to an overall reduction of the environmental impacts caused by the plant at present. The extensions will enable the discharge of effluent to the Nyatsime River which has been discontinued because of the low quality of effluent.

5.2 RECOMMENDATIONS

From the findings of this Initial Environmental Evaluation (IEE) of the proposed Extensions to the Zengeza Sewage Treatment Works it is recommended that a Preliminary Environmental Impact Assessment (PEIA), as defined in the Zimbabwe Environmental Impact Assessment Policy of 1994, be carried out. The PEIA should evaluate and quantify the potential negative environmental impacts of the proposed project, identified and scoped in the IEE, and formulate mitigating measures to reduce or eliminate these impacts. The PEIA should also develop a comprehensive Environmental Management Plan (EMP) for the life cycle of the project. This EMP would ensure that sound environmental management is implemented from the early design stages right through to final decommissioning of the plant and rehabilitation of the site. An essential part of the EMP would be an Environmental Review of the Final Design and all tender documents issued for the project. The EMP should be monitored by an Environmental Officer/ Specialist, appointed by the client for this purpose, who will ensure compliance to the EMP.

Proposed Terms of Reference for the PEIA are also attached to this IEE report

This IEE has been compiled to comply with the requirements of JICA for an IEE and fulfils all the requirements of a Prospectus in the Zimbabwe Environmental Impact Assessment Policy of 1994. It is believed that the recommended PEIA, as set out in Zimbabwe's Environmental Impact Assessment Policy of 1994, will fulfil the JICA requirements of an EIA. Thus the Draft Terms of Reference were developed according to the specified format given in the EIA policy of 1994.

DRAFT TERMS OF REFERENCE
FOR A
PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT
FOR THE PROJECT:
EXTENSIONS TO THE ZENGEZA SEWAGE TREATMENT WORKS

1. INTRODUCTION

The need of a Preliminary Environmental Impact Assessment (PEIA) study was identified through Initial Environmental Examination (IEE) for the Extension/Rehabilitation of the Zengeza Sewage Treatment Works (hereafter referred to as the Project) in accordance with the requirements of Zimbabwe's EIA Policy of September 1994.

The PEIA study should identify significant positive and negative environmental impacts relating to the Project and propose practical, cost-effective mitigating measures for avoiding or minimising negative environmental impacts. Methods of enhancing positive impacts should be developed and strategies for ensuring sound environmental management for the duration of the Project's life cycle must be proposed.

Therefore the purpose of the PEIA study is two-fold:

1) To provide a PEIA report to the Ministry of Environment and Tourism (MoET) which will satisfy the Ministry's requirements under their EIA Policy; and

2) To develop, as part of the PEIA, a comprehensive Environmental Management Plan (EMP). The EMP would take into consideration the findings of the PEIA. An essential part of the EMP would be an Environmental Review of the Preliminary Design. The EMP should be monitored by an Environmental Officer/ Specialist, appointed by the client for this purpose, who will ensure compliance to the EMP.

The Project is at present in the Feasibility Stage of the project cycle. The site has been identified, a treatment process proposed and a layout of the proposed extensions prepared.

2. PROJECT DESCRIPTION

The aim of the project is to construct additions to the Zengeza STW, which would treat sewage to a high standard and produce an effluent that could be discharged to the Nyatsime River (i.e. the effluent from the extensions would comply with the effluent standards as specified in the

Government Notice No. 687 of 1977). The existing Zengeza STW are heavily overloaded, being sized for about 23Ml/d but treating an estimated flow of 36-40 Ml/d. The proposed extensions, which are the subject of this PEIA, will have the capacity to treat 20Ml/d. The extensions would therefore eliminate the present overloaded situation and permit the rest of the plant to operate more efficiently as well. The present operation of the Zengeza STW is discussed in detail in the report on the Water Pollution Control Master Plan for the Upper Manyame River Basin of which this document forms a part.

Due to the scarcity of water in the Harare area a high quality effluent from the extensions to Zengeza STW would be an important source of water for impoundments downstream (Lakes Chivero and Manyame) during times of drought.

The proposed extensions to Zengeza STW, considered for the PEIA, consist of the following;

- three anaerobic ponds,
- a biological nutrient removal activated sludge bioreactor,
- three secondary clarifiers,
- a gravity sludge thickener, and
- two concrete lined sludge drying beds.

Effluent from the BNR plant will be discharged to the Nyatsime River which drains the Seke Communal Land area to the East of Harare.

3. ENVIRONMENTAL CONCERNS TO BE ADDRESSED IN PEIA

An Initial Environmental Evaluation (IEE) of the Project was conducted as part of the Upper Manyame River Basin Study. This IEE identified potential positive and negative environmental impacts of the project which are to be addressed in detail in the PEIA study.

The potential negative impacts identified in the IEE were:

- *Effluent discharge to the Nyatsime River*: the discharge of 20Ml/d of effluent to the river will have an impact on the ecology of the river and the downstream impoundments, even if the effluent meets the present effluent standards. Areas of concern are: The effect of the discharge on the Water Rights/Common Rights of downstream users; Possible Hygiene/disinfection related issues caused by the faecal coliform concentration in the effluent; The effect of discharging the effluent on Lakes and Rivers downstream of the discharge, and the effect on the aquatic and riverine ecosystems.

- *Disposal of Wastes*: the disposal of sludge from the Project could have significant impacts and must be managed properly. Areas of concern are: The management of sludge disposal; Generation of odours by the sludge, both on site and at the disposal site; Hygiene related health risks of sludge handling and disposal; Contamination of ground and/or surface water by the sludge both short term and long term.

- *Public Response*: the public are unaware of the proposed project at present and could object to the project if uninformed. A Public Participation Programme (PPP) must be carried out as part of the PEIA. This PPP must involve Interested and Affected Parties (I&APs) potentially affected by the project and include them in the decision making process.

- *Erosion*: there is a risk of land erosion during construction and after commissioning, which should be addressed in the PEIA.

- *Air Pollution*: there is a risk of air pollution during construction (dust and smoke) and a slight risk during operation (airborne pathogens).

- *Noise and Vibration*: some impacts are expected to be caused by construction activities (except if blasting takes place, in which case the impacts could be significant). The exact nature of these impacts will only become evident during detailed design.

Potential positive impacts of the Project identified in the IEE were expected to be:

- *Effluent Quality*: the extensions will alleviate the present overloading of the STW. 20Ml/d (of a total of 40Ml/d) will be treated to a quality that meets the effluent standards. The quality of the rest of the effluent is expected to improve because the system will be operating within design conditions.

- *Odours*: the overall level of odours on the STW is expected to be reduced due to the reduction in loading on the existing system and the efficient treatment in the proposed extensions.

- *Water Reuse*: the discharge of high quality effluent to the river will contribute towards the reuse of water, a priority of the Department of Water Resources.

- *Employment Opportunities*: the project will create temporary (construction) and permanent (operation of the plant) employment opportunities.

While the study is to concentrate on the above issues, if, in the course of conducting the PEIA, further environmental issues are identified then these must be raised as well.

4. ENVIRONMENTAL MANAGEMENT

An Environmental Management Plan (EMP) will be developed in accordance with in principles of Integrated Environmental Management for the project. The scope of the EMP is given below.

4.1 Scope of the Environmental Management Plan (EMP)

The EMP will aim to manage and control environmental impacts of the proposed project. The EMP must deal with the following components of the life cycle of the proposed extensions to the Zengeza STW:

- *Design*: the design of the extensions to the STW is still in a very preliminary stage. The EMP will specify an Environmental Review of preliminary and final design. The review could modify the design to incorporate the mitigation of identified environmental impacts. The detailed design could also be altered to ensure compliance with environmental standards, as required.

- *Construction and Commissioning*: An Environmental Specification must be compiled for the construction and commissioning phases of the project. The environmental specifications will form part of the tender documentation and must be complied with by the contractor/s. A system of bonuses and fines to encourage compliance with the environmental specifications shall be developed.

- *Operation and Maintenance*: Environmental guidelines will be compiled to ensure environmentally sound, and safe operation and maintenance of the proposed extensions. The guidelines will be refined once the design of the plant has been finalised .

- *Decommissioning*: Guidelines will be developed for eventual decommissioning of the extensions. This would include dismantling of equipment and buildings, and the rehabilitation of the site.

- *Auditing*: A system for the environmental auditing of the extensions will be developed according to accepted environmental auditing practices.

A cost estimate for implementing the EMP will be prepared, including capital, operating and training costs.

5. RELATIONSHIP OF EIA TO OTHER PROJECT PLANNING AND DESIGN

To maximise the opportunity for good environmental planning and design of the project as laid out in the EMP, the study team will work in close collaboration with MLGRUD's engineering team. This will ensure that the Environmental Review of the design occurs at the correct times and that the Environmental Specification is adhered to during construction and commissioning of the Project.

6. PUBLIC CONSULTATION

All concerned I&APs affected by the Project be given the opportunity to have adequate input to its planning and execution, and that the project will be well-received by them. Thus, in addition to the usual government liaison, a thorough PPP will be proposed for consulting the public during the PEIA study. The purpose of the programme will be to both inform all I&APs about the Project and solicit their views about it. Specifically, a proposal will be prepared on an effective, comprehensive public consultation strategy which includes at least its objectives, a list of stakeholders or audiences to be consulted, methods for reaching these stakeholders/audiences, the scheduling of consultation activities, and how the consultation efforts will be analysed. In devising a public consultation programme, close attention will be paid to the guidance provided in the Ministry's General Environmental Impact Assessment Guidelines (GEIAG) (Zimbabwe EIA Policy, 1994, Section 5: Consulting the Public).

7. CONTENT OF THE PEIA REPORT

At Minimum, PEIA report will contain the information outlined in the Ministry's GEIAG (Zimbabwe EIA Policy, 1994, Section 4: Preparing EIA Reports).

PART II

FEASIBILITY STUDY
FOR
REHABILITATION/EXPANSION
OF
ZENGEZA SEWAGE WORKS

CHAPTER 2

Feasibility Study for Rehabilitation/Expansion of the ZENGEZA Sewage Works

CHAPTER 2 FEASIBILITY STUDY FOR REHABILITATION/EXPANSION OF THE ZENGEZA SEWAGE WORKS

SECTION 3 EXISTING CONDITIONS OF WATER SUPPLY AND SANITATION/SEWAGE WORKS

3.2 Sanitation/Sewerage

3.2.1 Service Coverage and Sewerage System

(2) Sewer Reticulation

At present, there are 24 wards in the municipality and their respective ares are shown in Table 3.2.1.

The plans on the existing pump stations of St.Mary's No.1, No.2 and Tilcor are shown in Figures 3.2.1 to 3.2.3, respectively.

There are 30 identified problem spots in the municipality. Treir conditions and location are shown in Table 3.2.2 and Figure 3.2.4.

(3) Sewage Treatment Works

1) Study of present sewage volume and quality

Domestic, institutional/commercial and industrial wastewater was analyzed to come up with the sewage quantity and quality at present (in 1995). The study bases are those prepared in the Master Plan.

a. Domestic and institutional/commercial sewage

a) 1995 Population

The population in 1995 was projected in assumption of a linear relationship between 1992 (354,541) and 2000 (489,000; an average figure of scenarios 1 and 2 in the Master Plan). The population arrived at about 405,000.

b) Sewage volume flowing into the STW

On the assumption that an average sewage quantity per capita on a discharged base is 68 l/d, the percentage of institutional/commercial wastewater to domestic

Table 3.2.1 Present Area by Ward

Ward	Residential Area (km^2)	Open Area (km^2)	Total Area (km^2)	Occupied Percentage (%)	Name of Sub-Treatment Area
1	0.21	0.72	0.93	23	St. Mary's and Zengeza
2	0.37	0.50	0.87	43	St. Mary's and Zengeza
3	0.24	0.72	0.96	25	St. Mary's and Zengeza
4	0.43	0.97	1.40	31	St. Mary's and Zengeza
5	0.50	0.02	0.52	96	St. Mary's and Zengeza
6	1.79	2.34	4.13	43	St. Mary's and Zengeza
7	0.33	0.00	0.33	100	St. Mary's and Zengeza
8	0.63	0.09	0.72	88	St. Mary's and Zengeza
9	0.89	0.00	0.89	100	St. Mary's and Zengeza
10	0.49	1.06	1.55	32	St. Mary's and Zengeza
11	1.03	0.00	1.03	100	St. Mary's and Zengeza
12	0.49	3.53	4.02	12	St. Mary's and Zengeza
13	0.65	0.83	1.48	44	St. Mary's and Zengeza
14	1.29	0.51	1.80	72	St. Mary's and Zengeza
15	1.06	1.04	2.10	50	Seke
16	0.53	0.23	0.76	70	St. Mary's and Zengeza
	0.91	0.24	1.15	79	Seke
17	1.08	0.43	1.51	72	Seke
18	0.86	2.99	3.85	22	Seke
19	0.97	0.64	1.61	60	Seke
20	0.65	0.10	0.75	87	Seke
21	3.74	0.76	4.50	83	Seke
22	1.32	0.28	1.60	83	Seke
23	1.16	0.76	1.92	60	Seke
24	1.20	0.42	1.62	74	Seke
-	22.82	19.18	42.00	54	

Present Residential Areas of St. Mary's and Zengeza : 9.87 km^2

Present Residential Area of Seke : 12.95 km^2

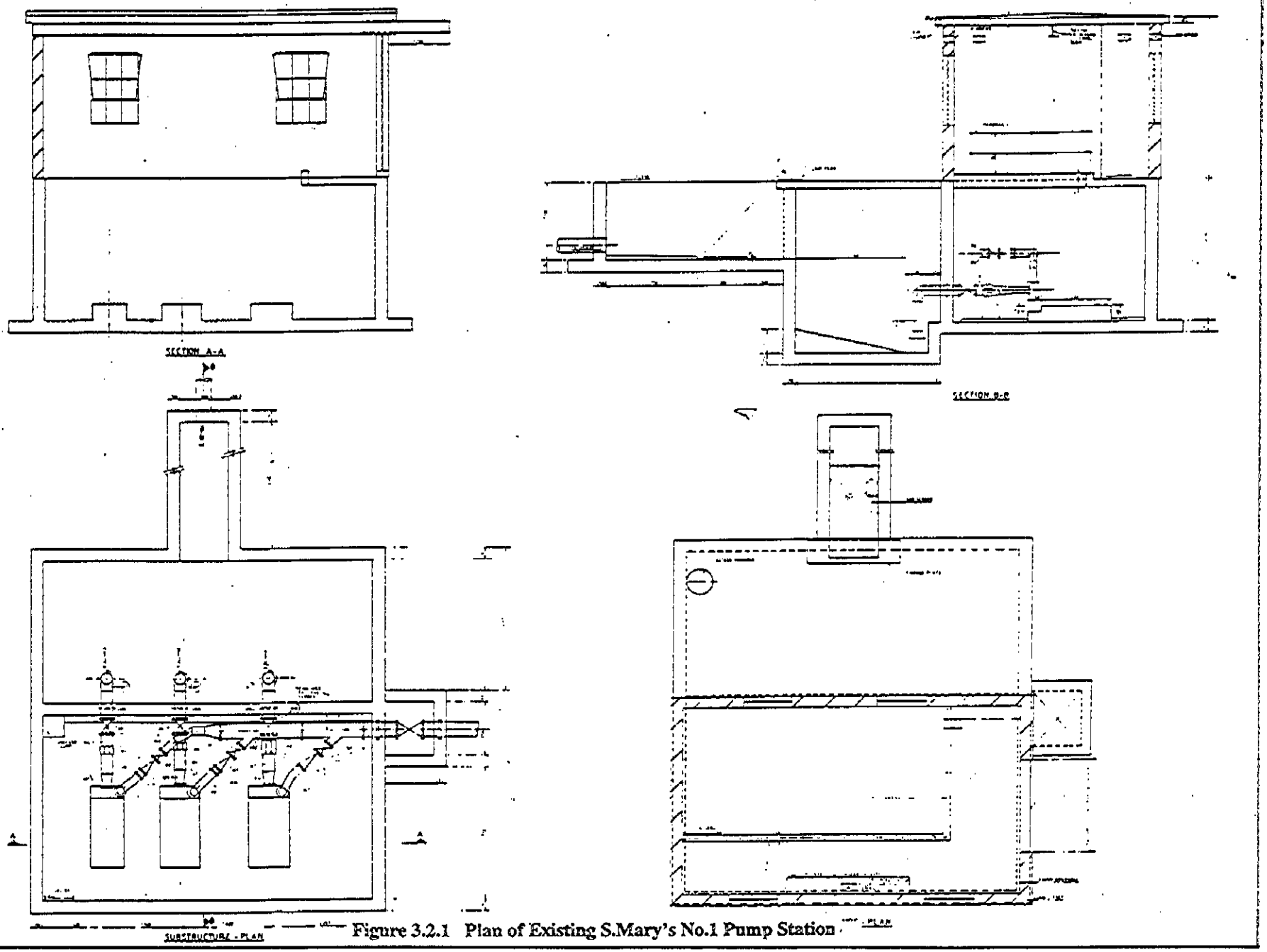

Figure 3.2.1 Plan of Existing S.Mary's No.1 Pump Station

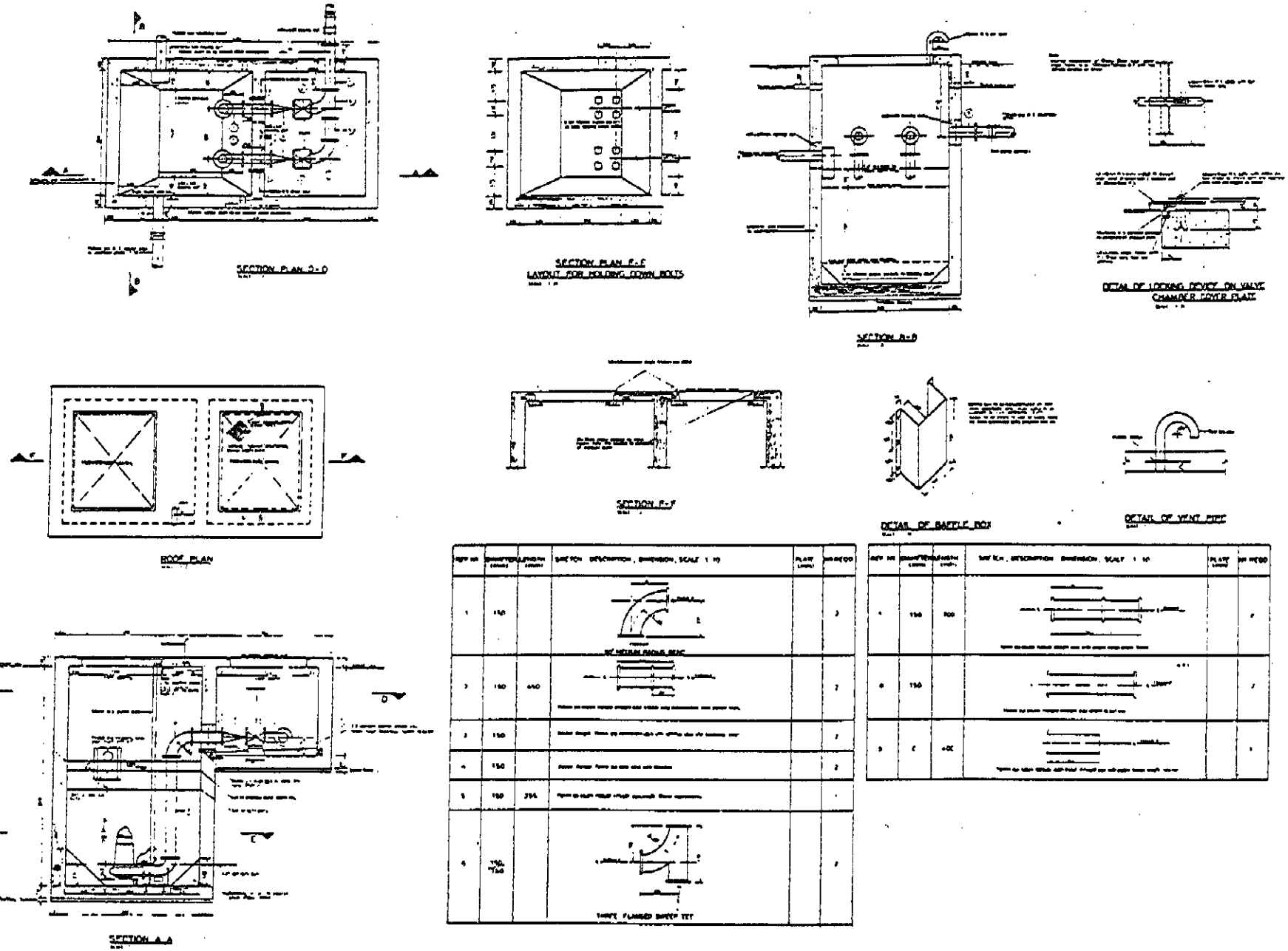

Figure 3.2.2 Plan of Existing S.Mary's No.2 Pump Station

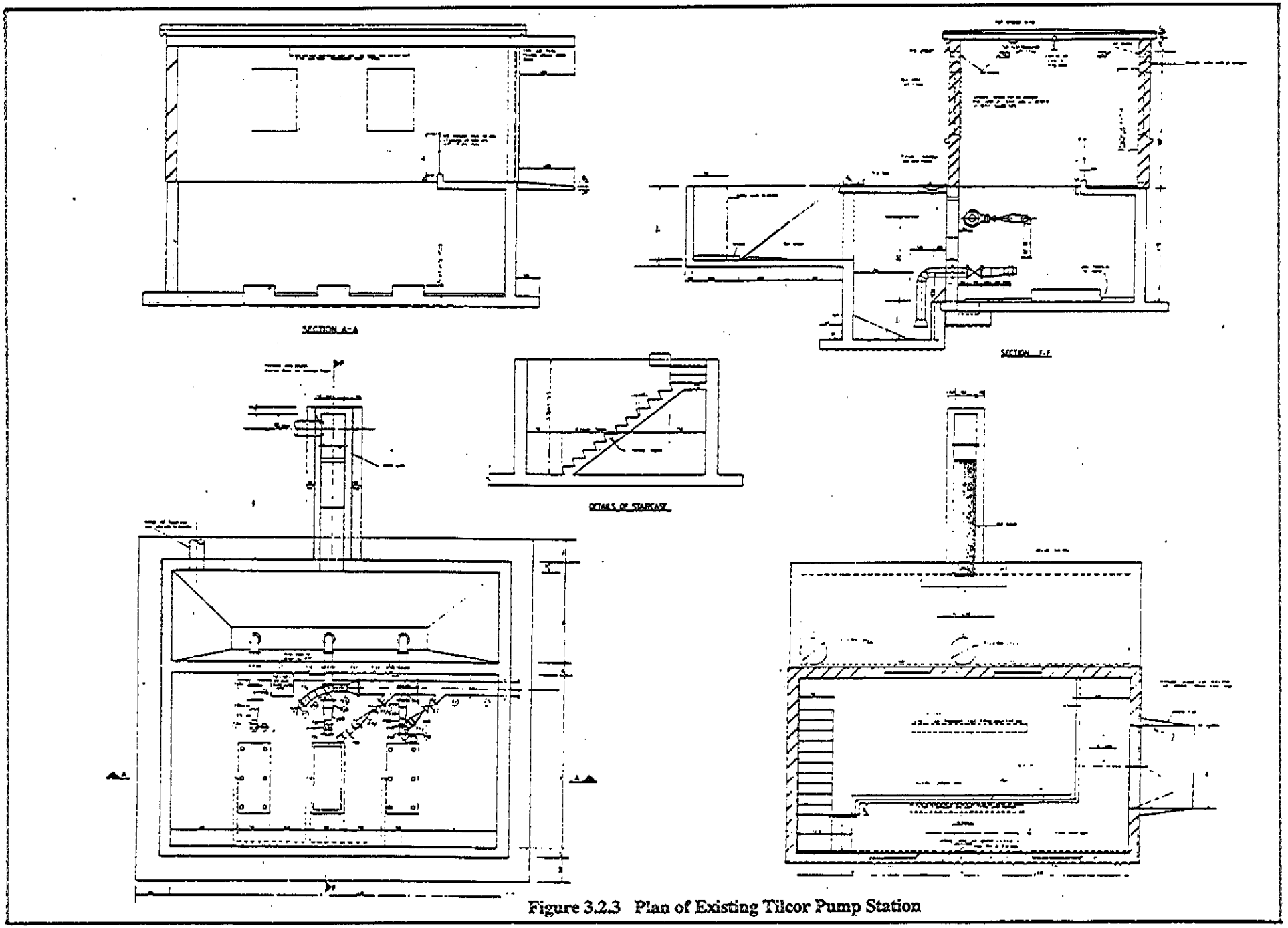

Figure 3.2.3 Plan of Existing Tilcor Pump Station

Table 3.2.2 Identified Problem Spots on Sewer Reticulation

Reference No.	Township/Area	Zone/Unit	Road of Area Name/Description	Sewer Dia. (mm)	Length Affected (m)
1	St.Mary's	-	Ndomene Road	150	200
2	St.Mary's	-	Bango Road	150	400
3	St.Mary's	-	Mhangura Road	150	300
4	St.Mary's	-	Town Centre	150	400
5	St.Mary's	-	Chitungwiza Road	150	500
6	St.Mary's	-	N of Chaminuka Dr	225	800
7	Zengeza	5	Rufaro Road	150	250
8	Zengeza	1		300	450
9	Zengeza	1	Aji/Mission P/S	225	150
10	Zengeza	4		150	150
11	Zengeza	5		150	50
12	Zengeza	5	Gadza Road	150	60
13	Zengeza	5	Mbizi Close	150	100
14	Seke	J	Trunk Sewer	675	180
15	Seke	C-D	Trunk Sewer	675	100
16	Seke	D		150	180
17	Seke	D	By Sec. School	150	400
18	Seke	B	Sewer to Unit H	150	200
19	Seke	C			50
20	Seke	C		150	70
21	Seke	O	Adi. Prim. School	150	80
22	Seke	E		150	200
23	Seke	H		150	200
24	Seke	H		225	400
25	Seke	G	Connector to 'N'	150	800
26	Seke	M		150	60
27	Seke	M		150	70
28	Seke	L		150	180
29	Seke	L	Marapara Road	225	200
30	Seke	-	to STW	225/150	200

Source : Second Urban Development Project, Project Proposals for the Sewerage Augmentation Scheme, Chitungwiza Municipality, February 1996

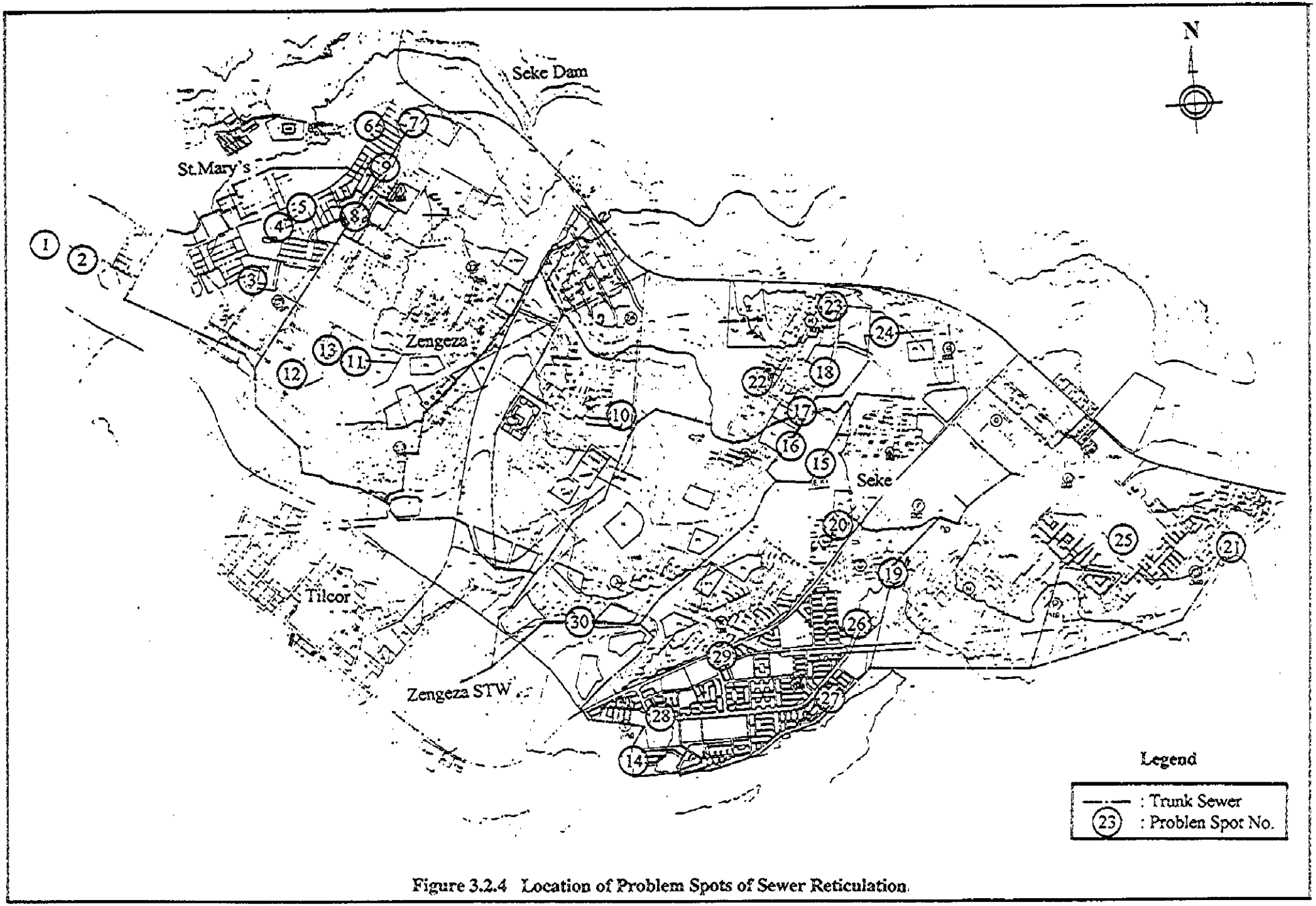

Figure 3.2.4 Location of Problem Spots of Sewer Reticulation

sewage is 5% and groundwater inflow (15% of discharged sewage), the inflow sewage into the STW arrived at 33,255 m^3/d as the ADWF .

c) Sewage quality (domestic and institutional/commercial)

BOD (44 gpcd) and SS (51 gpcd) loads of domestic sewage are estimated at 17,820 kg/d and 20,655 kg/d, respectively. The concentrations of the sewage (sewage volume: 31,671 m^3/d) are 563 mg/l BOD and 652 mg/l SS. Assuming the sewage quality discharged from institutional/commercial area is the same as domestic sewage, BOD and SS loads of institutional/commercial sewage (1584 m^3/d) are estimated at 892 kg/d and 1,032 kg/d, respectively.

b. Industrial wastewater

The quantity and quality of industrial wastewater were estimated in the Master Plan as follows:

Wastewater quantity (discharged base)	: 972 m^3/day
BOD	: 1,138 kg/day
SS	: 570 kg/day

The inflow volume into the STW is 1,118 m^3/d considering groundwater (15% of discharged W.W.). The BOD and SS concentrations are estimated at 1,018 mg/l and 510 mg/l, respectively.

c. Total inflow volume into the STW and average concentrations of BOD and SS

The total inflow sewage volume was arrived at about 35,000m^3/day (33,255 + 1,118 = 34,373 m^3/day), which almost coincides with the reported volume, 36,000 m^3/day and average BOD and SS concentrations of combined sewage are 577 mg/l and 648 mg/l, respectively.

2) Present condition of each facility

The problems (hydraulic, structural, operational, maintenance) of each facility and its present conditions are studied as follows.

a. Existing sewage treatment works

The results of an investigation of the present operating conditions of the STW are shown in Table 3.2.3.

- Current yearly sludge production of existing anaerobic ponds (estimate)

  Assuming influent of 36,000 m3/d, influent sewage SS of 650 mg/l, and an SS removal ratio of 80%, the sludge solids produced are:

  36,000 m^3/day x 650 mg/l x 0.80 x 1/1000 = 18,720 kg/day.

  The method of drawing off the sludge that is currently being used is to open the valve of the drain in the anaerobic ponds, but considering the structure of the ponds, it seems likely that only a few (assuming 10%) of the sludge can be removed in this manner.

  18,720 kg/day x 0.10 = 1,872 kg/day

  Assuming that 2/3 of the sludge solids decompose, and assuming a sludge water content of 60%, the sludge volume is:

  1,872 kg/day x 2/3 x 100/(100-60) x 1/1000 = 3.1 m^3/day (= 1,140 m^3/year).

b. Facilities for the effluent pumping and final disposal

The results of an investigation of the operating conditions of the effluent facilities are shown in Table 3.2.4. The entire influent sewage volume sent to effluent facilities. The effluent facilities are well used in the dry season, but the need for irrigation falls dramatically in the wet season. The treated water is discharged to the river, after passing through the irrigation channels and the final storage pond.

c. Pre-treatment facilities for the Tilcor industrial area

The results of an investigation of the present operating conditions of the pre-treatment facilities for the Tilcor industrial area are shown in Table 3.2.5. The wastewater from Chibuku Breweries Ltd. goes to the two anaerobic ponds. The first pond is almost completely filled in with sludge. The starchy, white wastewater is the same color coming out of the pond as it is going in. Because most of the pond is filled in with sludge, the wastewater is able to shortcut

Table 3.2.3 (1) Present Conditions at the Zengeza Sewage Treatment Works

Facilities	Hydraulic problems	Structural problems	Operational problems	Maintenance
Inflow pipe	In the wet season, the sewage flow increases but there is no overflow.	At the upper part of the SEKE LINE sewer, near the inlet works, there was a collapse due to pipe corrosion. Other than that, there are no particular problems	—	There are no particular maintenance problems.
Screen and grit chamber	In the wet season, the sewage flow increases to near the top of the channel, but does not overflow.	The external appearance of the structure is normal, and there is no particular evidence of aging. Because an aluminum gate is used, there is no problem of corrosion. There is a little corrosion on a part of the airlift pipe, but it is not a problem.	There are 2 flow meters next to the Parshall flume, and both are broken.	There are two air compressors for removing grit, but a new, larger compressor and a holding tank are needed.
Anaerobic pond	There are no particular hydraulic problems	There is serious corrosion of the iron valves and gates, but they are all undergoing repairs. There is no seepage.	There are no particular problems.	There is an offensive odor, but there are relatively few filter flies. Accumulated sludge must be removed once every 2 years or so, but it cannot be removed because there is no money for it. Sludge removed from only one pond, and that operation took two months.
Trickling filter	In the wet season, when sewage flow increases, there is some overflow of sewage from the distribution tower.	In one of the five ponds, part of the concrete wall surface has come away, leaving the iron reinforcing bar exposed. The iron lid of the distribution tower is badly corroded.	In the daytime, sewage flow is much, so all five ponds are working, but at night, when sewage flow is a few, only three ponds are working. The flow meter is broken, so the amount cannot be known exactly, but lately the sewage flow is about 28,000-30,000m3/d. Currently, recirculation pump equipment is under construction, and the work is expected to be completed by the end of October. When this work is complete, treated sewage will be introduced to the anaerobic pond at a maximum rate of 15,000m3/d in order to break the scum. This treated sewage will then be added to the trickling filter as recirculation water.	When a rotating distributor malfunctions and stops, there is an offensive odor and a large quantity of filter flies are produced, but other than that, there are no problems. Currently, all of the rotating distributors are undergoing maintenance work to correct the problem of water leaking from the distributors' bases and to correct balance problems. Ponding can be observed, to varying degrees, in all of the ponds. This gets worse as the hydraulic loading grows. It appears that the primary cause of this problem is that accumulated sludge has not been removed from the trickling filter once since its introduction in 1979. The nozzles of the rotating distributors are cleaned daily. After opening the plate at the end of the arm, a metal rod is pushed through the nozzle opening from the outside, and any debris is dropped into the inside of the arm, to be flushed away by wastewater. Paper and plastic jam many of the nozzles. A screen may be necessary in the distribution tower as well. Greasing of the pump (once a week) and the rotating distributor bearings (twice a week) are conducted according to manufacturer instructions.
Sludge drying bed	There are no drainage facilities, but water is lost through infliltration and evaporation, so there is no problem.	No particular problems.	No particular problems.	There is relatively little generation of filter flies. Dried sludge is piled up within the treatment work site. Nearby farmers take some of it, but the rest of it remains on the site, causing a disposal problem.

Table 3.2.3 (2) Present Conditions at the Zengeza Sewage Treatment Works (Cont'd)

Facilities	Hydraulic problems	Structural problems	Operational problems	Maintenance
In-plant pipe	No overflow.	There are no problems with the AC pipes and the concrete pipes. Corrossion of the smaller iron pipes is a problem.	—	Nothing in particular.
Control building, access road, others	—	—	The power supply is 380 volts. There is a 380 kvolts power line nearby.	The office is not centrally located in the STW, and should be relocated to an appropriate position. The office is currently located near the trickling filters and the anaerobic ponds, an the odor and flies make it an inappropriate environment for cooking. There is a lot of garbage scattered around the plant site, because nearby residents bring their household garbage in illegally at night.
Emergency procedure				
The STW as a whole	Currently, the operations and maintenance personnel are organized into four groups of 7-8 people each. Three groups work on any given day in three shifts (6:00-14:00, 14:00-22:00, 22:00-6:00) with one group resting. In emergencies, the resting group is also called into service to respond to the crisis. In power failure, the pumps stop, but generally the power suspensions are for routine maintenance, about twice a month, for 3-4 hours each time, and there are few long-term power failure due to natural disasters. Therefore, it is possible to store the sewage in the anaerobic pond until the pumps are reactivated.			

Table 3.2.4 The Present Conditions of the Irrigation Facilities

Facilities	The present conditions
Pump station	The new pump station has been built next to the deteriorating old pump station, and it has been in operation since last autumn. Currently, the maximum pump capacity is 35,000m3 per day. Including one spare pump, the station is equipped with three pumps, but one pump is currently undergoing repairs at the plant for faulty bearings. There was a crack in a part of the force main that caused a leak, but the pipe was replaced and the problem solved.
Force main	The old force main was of insufficient capacity, so a new force main (675-600dia) was added parallel to the old one and is now being used. Presently, there are no hydraulic or structural problems.
Maturation pond	There had been 5 maturation ponds in the irrigation land, but a new pond has been added and is being used. The connection from the force main to the maturation ponds has, for maintenance reasons, been planned for both the new and the old ponds, and the new connection openings into the old ponds are currently under construction. The six maturation ponds can be operated in series and in parallel, and the final two ponds are set up to discharge into an open channel.
Facilities in the irrigation land	An open channel, four pump stations in the irrigation land, a sprinkler system, and one storage pond at the end of channel. The water that flows through the open channel was being pumped up and distributed to pasture land by way of a portable sprinkler. There were no cattle in sight, as they are not grazing during sprinkling. A part of the pasture land had been plowed in preparation to be sprinkled. Not all of the treated water was being used, and the excess was flowing into a storage pond at the end of the open channel.
Emergency procedures	
The facility as a whole	The maturation ponds are large-scale, so they have ample storage capacity to store a certain amount excess water in an emergency. There is no generator, so if there is a power failure the pumps stop operating, but there is ample capacity to respond to the pre-determined twice monthly power suspension due to routine maintenance, and power failure due to natural disasters are rare.

Table 3.2.5 Present Conditions of Pre-treatment Facilities of the Tilcor Industrial Area

Facilities	The present conditions
Inflow pipe	a) The line from the Chibuku Breweries Ltd. This plant releases a white, cloudy wastewater that contains a lot of starch. The wastewater is fresh, and the manhole is an open type without a cover, there is no structural corrosion. b) Other lines The wastewater is lightly turbid, but the water quality is similar to household wastewater.
Anaerobic ponds	Pond No. 1 appears to be completely filled in, and wastewater is short-circuiting from the inlet work to the outlet work. Pond No. 2 is covered with scum, but it appears there is some detention period, and the white influent is changed to a blackish anaerobic condition by the time it leaves the pond. All equipment for breaking the scum with jet sprays are stopped, and are incapable of being restarted. Erosion of the pond bank is occurring around the whole of the pond.
Storage ponds	Ponds No. 1 and No. 2 are not being used and are empty. Pond No. 3 is being used as an equalizing pond for wastewater flowing into the pump station. Sludge and refuse are being left to accumulate in the pond, producing an offensive odor and providing a breeding ground for insects.
Pump Station	One pump out of three was broken and removed from the station, but the remaining two pumps were operating. Operators are on duty round-the-clock, in three shifts. However, the pump station is old and deteriorating, and when the pumps are used, water leaks from the connection between the pump and the piping. There is no operation record for the pumps. There is a lot of storm water mixed in with the wastewater during wet season, and pump capacity is gravely insufficient.
Force main	There are no particular hydraulic or structural problems.
Emergency procedures	
The facility as a whole	There is no generator, so the pumps stop when the power is stopped. Power suspensions during routine maintenance are twice a month, lasting 3-4 hours, and there are few power failure of long duration caused by natural disasters. Wastewater is stored in ponds for the brief period the pumps are not operating.

through the pond. However, by the time the wastewater leaves the second pond, the color has changed to black, so it appears that the second pond continues to function as a treatment pond to some extent. These anaerobic ponds and the site are in under the jurisdiction of the city of Chitungwiza, but there is no manager at the site, they have been neglected.

7.3 Rehabilitation/Modification Plan of Existing Sewer Reticulation

Table 7.3.1 Capacilty Calculation of St.Mary's No.1 Pump Station

(1) Design Sewage Quantity

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.086
	Q2	m3/min	Q1 x 60	5.16

(2) Capacity Calculation for New Pump Equipment

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.086
	Q2	m3/min	Q1 x 60	5.16
Pump Unit	PU	unit	(including 1 standby)	3
Pump Discharge Volumeper Unit	DV1	m3/min	Q2 / (PU - 1)	2.58
	DV2	m3/min	-	2.60
Required Pump Diameter	D1	mm	146 x (DV2 / 2.5)^0.5	149
	D2	mm	-	150
Pump Total Head	H	m	same as existing	34.5
Required Pump Power	PP1	kw	(0.163 x DV2 x H / 0.70) x 1.15	24.0
	PP2	kw	-	25.0
(Dimension)				
Pump Type	-	-	Horizontal Shaft Type	
Pump Diameter	D2	mm	-	150
Pump Discharge per Unit	DV2	m3/min	-	2.60
Pump Total Head	H	m	-	34.5
Pump Power	PP2	kw	-	25.0
Pump Unit Number	PU	unit	(including 1 standby)	3

(3) Capacity Evaluation of Existing Force Main Pipe

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.086
Diameter of Existing Force Main	R	m	-	0.30
Section Area	A	m2	(R / 2) ^2 x 3.14	0.071
Velocity	v	m/sec	Q / A	1.22

1.0 m/sec < v=1.22 m/sec < 1.5 m/sec : O.K

Table 7.3.2 Capacilty Calculation of St.Mary's No.2 Pump Station

(1) Design Sewage Quantity

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.019
	Q2	m3/min	Q1 x 60	1.14

(2) Capacity Calculation for New Pump Equipment

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.019
	Q2	m3/min	Q1 x 60	1.14
Pump Unit	PU	unit	(including 1 standby)	2
Pump Discharge Volumeper Unit	DV1	m3/min	Q2 / (PU - 1)	1.14
	DV2	m3/min	-	1.20
Required Pump Diameter	D1	mm	146 x (DV2 / 2.5)^0.5	101
	D2	mm	-	100
Pump Total Head	H	m	same as existing	12.5
Required Pump Power	PP1	kw	(0.163 x DV2 x H / 0.70) x 1.15	4.0
	PP2	kw	-	5.0
(Dimension)				
Pump Type	-	-	Submersible Type	
Pump Diameter	D2	mm	-	100
Pump Discharge per Unit	DV2	m3/min	-	1.20
Pump Total Head	H	m	-	12.5
Pump Power	PP2	kw	-	5.0
Pump Unit Number	PU	unit	(including 1 standby)	2

(3) Capacity Evaluation of Existing Force Main Pipe

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.019
Diameter of Existing Force Main	R	m	-	0.15
Section Area	A	m2	(R / 2) ^2 x 3.14	0.018
Velocity	v	m/sec	Q / A	1.08

1.0 m/sec < v=1.08 m/sec < 1.5 m/sec : O.K

Table 7.3.3 Record of Operation Time in Tilcor Pump Station

Start Date and Time : 4. Nov. 1996, 6:00 AM
End Date and Time : 5. Nov. 1996, 6:00 AM

Pump Number 2			Pump Number 3		
Start Time	Stop Time	Operation Time	Start Time	Stop Time	Operation Time
06:00	06:57	00:57			
07:15	07:40	00:25			
07:48	08:08	00:20			
08:13	08:22	00:09			
08:36	08:53	00:17			
09:05	09:20	00:15			
09:37	09:50	00:13			
10:06	10:16	00:10			
			10:16	10:25	00:09
			10:32	10:44	00:12
			10:57	11:12	00:15
			11:28	11:43	00:15
			11:59	12:13	00:14
			12:30	12:48	00:18
			13:04	13:18	00:14
			13:34	13:50	00:16
			14:05	14:17	00:12
14:33	14:43	00:10			
15:00	15:14	00:14			
15:28	15:40	00:12			
15:55	16:05	00:10			
16:20	16:33	00:13			
16:44	16:58	00:14			
17:14	17:29	00:15			
17:42	17:56	00:14			
18:06	18:20	00:14			
			19:00	19:21	00:21
			19:55	20:26	00:31
			21:05	21:35	00:30
22:10	22:38	00:28			
23:13	23:42	00:29			
00:27	00:59	00:32			
01:30	01:57	00:27			
02:29	02:59	00:30			
03:30	03:45	00:15			
04:10	04:39	00:29			
05:17	05:44	00:27			
Sub-total	-	08:19	-	-	03:27
Total	8:19 + 3:27 =		11:46		

The Study of Inflow Wastewater Volume to Tilcor Pump Station

Pump Discharge Capacity: 177 m^3/hr
Pump Number: 2 Units (including 1 Standby)
Inflow Volume (ADWF): (177 x 11) + (177 x 46/60) = 2,083 m^3/day
Inflow Volume (PWWF): 2,083 x 3.0 = 6,249 m^3/day
= 4.34 m^3/min
= 0.073 m^3/sec

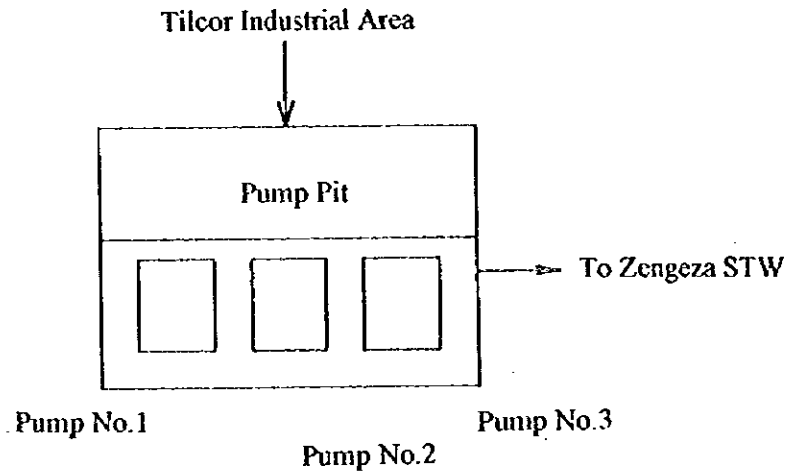

Table 7.3.4 Capacilty Calculation of Tilcor Pump Station

(1) Design Sewage Quantity

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.073
	Q2	m3/min	Q1 x 60	4.38

(2) Capacity Calculation for New Pump Equipment

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.073
	Q2	m3/min	Q1 x 60	4.38
Pump Unit	PU	unit	(including 1 standby)	3
Pump Discharge Volumeper Unit	DV1	m3/min	Q2 / (PU - 1)	2.19
	DV2	m3/min	-	2.30
Required Pump Diameter	D1	mm	146 x (DV2 / 2.5)^0.5	140
	D2	mm	-	150
Pump Total Head	H	m	refer to (4) calculation	28.0
Required Pump Power	PP1	kw	(0.163 x DV2 x H / 0.70) x 1.15	17.2
	PP2	kw	-	18.0
(Dimension)				
Pump Type	-	-	Horizontal Shaft Type	
Pump Diameter	D2	mm	-	150
Pump Discharge per Unit	DV2	m3/min	-	2.30
Pump Total Head	H	m	-	28.0
Pump Power	PP2	kw	-	18.0
Pump Unit Number	PU	unit	(including 1 standby)	3

(3) Capacity Evaluation of Existing Force Main Pipe

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.073
Diameter of Existing Force Main	R	m	-	0.30
Section Area	A	m2	(R / 2) ^2 x 3.14	0.071
Velocity	v	m/sec	Q / A	1.03

1.0 m/sec < v=1.03 m/sec < 1.5 m/sec : O.K

(4) Total Pump Head Calculation

Friction Head	10.666 x (0.073/110)^1.85 x 0.30^-4.87 x 1,040 =	5.15
Static Head	1,408 - 1,388 =	20.00
Others		2.00
Total Pump Head (m)		28.00

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

Table 7.4.1 Capacilty Calculation of New St.Mary's Pump Station

(1) Design Sewage Quantity

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.099
	Q2	m3/min	Q1 x 60	5.94

(2) Screen and Channel

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.099
Channel Number	CN	basin	(including 1 channel)	2
Average Velocity	v	m/sec	assumption	0.50
Water Depth	H	m	assumption	0.30
Required Width	W1	m	Q1 / (v x H)	0.66
	W2	m	-	0.70
(Dimension)				
Screen Type	-	-	Manual Type	
Width	W2	m	-	0.70

(3) Capacity Calculation for New Pump Equipment

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.099
	Q2	m3/min	Q1 x 60	5.94
Pump Unit	PU	unit	(including 1 standby)	3
Pump Discharge Volumeper Unit	DV1	m3/min	Q2 / (PU - 1)	2.97
	DV2	m3/min	-	3.00
Required Pump Diameter	D1	mm	146 x (DV2 / 2.5)^0.5	160
	D2	mm	-	150
Pump Total Head	H	m	refer to (5) calculation	58.0
Required Pump Power	PP1	kw	(0.163 x DV2 x H / 0.70) x 1.15	46.6
	PP2	kw	-	50.0
(Dimension)				
Pump Type	-	-	Horizontal Shaft Type	
Pump Diameter	D2	mm	-	150
Pump Discharge per Unit	DV2	m3/min	-	3.00
Pump Total Head	H	m	-	58.0
Pump Power	PP2	kw	-	50.0
Pump Unit Number	PU	unit	(including 1 standby)	3

(4) Capacity Calculation of New Force Main Pipe

Item	Symbol	Unit	Calculation	Application
Design Sewage Quantity	Q1	m3/sec	-	0.099
Velocity	v	m/sec	1.0 < v <1.5	1.30
Diameter	D1	m	(4 x Q1 / (3.14 x v))^0.5	0.311
	D2	m	-	0.30
Length	L	m	-	2,600

(5) Total Pump Head Calculation

Friction Head	10.666 x (0.099/110)^1.85 x 0.30^-4.87 x 2,600 =	22.63
Static Head	1,427 - 1,394 =	33.00
Others		2.00
Total Pump Head (m)		58.00

SECTION 8 SEWAGE AND SLUDGE TREATMENT AND DISPOSAL

8.1 Rehabilitation of Existing Facilities

8.1.3 Treatment Flow and Facilities Design

(1) Existing Sewage Treatment Works

1) Capacity calculation

Flow rate : 21,750 m^3/day

Influent BOD : 600 mg/l

Influent SS : 650 mg/l

a. Anaerobic pond

Assuming an anaerobic retention time of 5 days, 21,750 m^3/day x 5 = 108,750 m^3 (Existing AP volume of 3 Units 108,900 m^3) The anaerobic pond effluent BOD is calculated as below with an expected BOD removal rate of 60%:

600 mg/l x (100-60)/100 = 240 mg/l

b. Trickling filter

The filter volume, assuming a solids loading rate of 0.24 kg/ m^3/day, is:

21,750 m^3/day x 240 mg/l ÷ 0.24 kg/ m^3/day x 1/1000 = 21,750 m^3

(Existing TF volume of 5 filters 21,750 m^3).

2) Emergency storage capacity calculation

One anaerobic pond unit (36,300 m^3) will be set aside for use in emergencies. As the influent to the entire treatment works is 41,500 m^3/day, the retention time is:

36,300 m^3 ÷ 41,500 m^3/day = 0.9 days.

3) Sludge volume calculation

a. Anaerobic ponds

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

21,750 m^3/day x 650 mg/l x 0.80 x 1/1000 = 11,310 kg/day.

2/3 of the solids are decomposed, so the sludge volume, assuming a sludge water content of 60%, is:

11,310 kg/day x 2/3 x 100/(100-60) x 1/1000 = 18.9 m^3/day (= 6,900 m^3/year)

b. Trickling filters

Calculated below under item (2).

4) Accumulated sludge

a. Anaerobic ponds

Assuming that the sludge from all three units will be removed, the volume of accumulated sludge is estimated. Assuming an accumulation ratio in the ponds of 50%, an accumulated sludge water content of 90% and a dried sludge water content of 60%, the dried sludge volume is:

108,900 x 0.50 x (100-90)/(100-60) = 13,600 m^3

b. Trickling filters

The media volume for the trickling filters is:

4,350 m^3/filter x 5 filters = 21,750 m^3

Assuming a 45% void space, 50% accumulation ratio, a sludge water content of 90% and a dried sludge water content of 60%, the dried sludge volume is:

21,750 m^3 x 0.45 x 0.50 x (100-90) / (100-60) = 1,220 m^3

5) Sludge disposal pit

Assuming that the sludge to be accumulated in the APs will be disposed of by landfill, the volume required for the sludge disposal pit is:

6,900 m^3/year x 10 years = 69,000 m^3

the dimensions of the required sludge disposal pit are:

length 100 m, width 180 m and piled height 4 m.

The sludge disposal area is located in the land owned by the municipality, south of the site for the new STW, across the stream. The sludge disposal pit is equipped with earth bank all around to prevent the sludge and leachate from flowing into public water bodies and causing a pollution problem.

(2) Facilities for the effluent pumping and final disposal

1) Capacity calculation

Influent BOD : 96 mg/l

Target treated sewage BOD : 70 mg/l

The ponds that are currently available are the five existing ponds (with volumes ranging from 48,400 - 50,400 m^3/pond, for a total volume of 247,600 m^3), plus one new pond (61,300 m^3) for a total of six ponds with a combined volume of 308,900 m^3. A removal rate of (1 - 70 mg/l ÷ 96 mg/l) x 100 = 30% is required. According to the treatment capacity evaluation criteria (Section 4.2, Part-I, Supporting Report), that was conducted based on "Wastewater Engineering: Treatment, Disposal and Reuse, Third Edition," Metcalf & Eddy, INC, p. 644-648, the required retention time is three days. Accordingly, 21,750 x 3 = 65,250 m^3. The target treatment level can be met even if the volume of the new pond is set aside.

2) Sludge volume

The volume of the sludge that accumulates in the Imbgwa farm pond is the same volume as the sludge produced by the trickling filters. The anaerobic pond effluent SS is:

650 mg/l x (100 - 80) / 100 = 130 mg/l

With an SS removal ratio of 90%, a sludge yield ratio for removal SS of 92%, and a sludge water content of 60%, the sludge volume is:

21,750 m^3/day x 130 x 1/1,000,000 x 0.90 x 0.92 x 100/(100 - 60) = 5.85 m^3/day

(3) Pre-treatment facilities for the Tilcor industrial area

1) Calculation of the anaerobic pond volume

Influent BOD : 6,000 mg/l

The volumes of the anaerobic ponds are:

No. 1 anaerobic pond : 5,700 m^3

No. 2 anaerobic pond 5,300 m^3,

for a total volume of 11,000 m^3. The sewage volume from Chibuku Breweries Limited is calculated by dividing the plant's monthly public water consumption of 14,000 m^3 by the number of days the plant operates in a month, 20, for a daily sewage volume of 700 m^3/day. For this volume of sewage, the anaerobic ponds have

a retention time of 15.7 days. Further, the BOD of the sewage is about 6,000 mg/l. In Section 4.2, Part-I, Supporting Report, 70% is estimated as the removal ratio for a five-day retention time. Due to the long retention time and the high strength of the sewage, a treatment efficiency of 80-85% is expected. Accordingly,

6,000 mg/l x (1 - 0.80 to 0.85) = 900 to 1,200 mg/l.

The target treated sewage BOD of 1,000 mg/l will be roughly met.

2) Sludge accumulated in the anaerobic ponds

Assuming the SS concentration of the produced sludge to be equal to the BOD concentration, and assuming 1/3 solids reduction and a water content of 60%, the volume of sludge produced is:

(6,000 mg/l - 1,000 mg/l) x 14,000 m^3/month x 2/3 x 100/(100-60) x 1/1,000,000 = 117 m^3/month (= 1,400 m^3/year).

3) Accumulated sludge in the ponds

Assuming an accumulated sludge ratio of 80%, a sludge water content of 90% and a dried sludge water content of 60%, the dried sludge volume is:

No. 1 anaerobic pond : 5,730 m^3 x 0.80 x (100-90)/(100-60) = 1,150 m^3

No. 2 anaerobic pond : 5,330 m^3 x 0.80 x (100-90)/(100-60) = 1,070 m^3

Total volume : 2,220 m^3

4) JET water

Assuming 3,000 m^3/ha, JET water required is:

3,000 m^3/d/ha x (0.3+0.3) ha = 1,800 m^3/day (= 0.0208 m^3/sec)

5) Sludge disposal pit

Assuming that the sludge to be produced from the Tilcor AP will be disposed of landfill, the volume required for the sludge disposal pit is:

1,400 m^3/year x 10 years = 14,000 m^3

the dimensions of the required sludge disposal pit are:

length 100 m, width 35 m and piled height 4 m

The sludge disposal area is located in the land owned by the municipality, south of the site for the new STW, across the stream.

Because this sludge is the same in quality as that generated from the existing AP, it will be disposed of at the same place in the same manner. The sludge disposal land is equipped with earth bank all around to prevent the sludge and leachate from

flowing into public water bodies and causing a pollution problem. To prevent the leachate from infiltrating into the ground, the soil of the pit surface, about 15 cm deep, is improved in texture with soil cement.