The adopted formula for the analysis were as follows:

$$N = L(N) / ((\rho w + \sigma N) \times V)$$

$$P = L(P) / ((\rho w + \sigma P) \times V)$$

$$COD = L(COD) / ((\rho w + \sigma COD) \times V) + \Delta COD$$

where;
- N: Concentration of Nitrogen of lake (g/m^3)
- P: Concentration of Phosphate of lake (g/m^3)
- COD: Concentration of COD of lake (g/m^3)
- L(N): Quantity of inflow-Nitrogen to lake (g/day)
- L(P): Quantity of inflow-Phosphate to lake (g/day)
- L(COD): Quantity of inflow-COD to lake (g/day)
- ρw: Rate of change of water (annual inflow/lake volume or 1/retention time)
- σN: Self-purification (reduction) or production coefficient of Nitrogen
- σP: Self-purification (reduction) or production coefficient of Phosphate
- σCOD: Self-purification (reduction) or production coefficient of inflow-COD
- V: Volume of lake
- ΔCOD: Secondary produced COD

The run-off pollution load obtained through the pollution analysis for the river was adopted as the inflow loads into the lake. The parameters used in the model were verified through the present water pollution analysis and the simulation model was established for the future pollution analysis.

3. Frame Values and Unit Pollution Load

3.1 Projection of Frame Values

Frame values by local authority in relation to major pollution sources were projected for study base year 1995 and the year 2005.

(1) Population Projection

The 1992 population census data are the base of the projection. Projection results were as follows:

Table 3.1.1 Projected Population

(unit: person)

Scenario	Year 1995		Year 2005	
	UMRB	Chitungwiza	UMRB	Chitungwiza
Scenario - 1	1,957,877	-	3,145,767	439,475
Scenario - 2	1,961,755	419,797	2,707,120	668,304

Note: Scenario - 1 : Projection by the factors of residential density of the "Master Plan for Water Distribution, The City of Harare, 1995"
Scenario - 2 : Projection by the population growth rate of the "Harare combination Master Plan, 1992".

(2) Industrial Development

With reference to the projection of industrial wastewater quantity and quality, the number of employees was selected as a parameter. The present number of employees in the industrial sector was obtained from the Census of Industrial Projection for Harare and the survey results by the Study Team for other 3 local authorities. Number of employees in the future by local authority was estimated in proportion to the increase of industrial areas (future land use plan) to the present areas.

(3) Livestock

Present number of livestock was quoted from the estimates by the Department of Veterinary Services, Ministry of Agriculture, 1996. Future number of livestock was assumed to be unchanged.

(4) Farmland and Natural Land

No categorisation of farm land and natural land was made based on the study results of unit pollution load (organic substances) without much difference between the two land use. The total study area is regarded as the potential pollution source in terms of natural pollution.

(5) Solid Waste Dumping Site

Present dumping area of respective local authorities was investigated, while future disposal area was estimated in proportion to the increase of population against present population.

3.2 Unit Wastewater Quantity and Pollution Load

The unit wastewater pollution load and quantity for the target year by major pollution source was decided based on the data in previous studies for water supply and sewerage systems in the study area, data obtained through the Study, and experiences in Japan. Except for the unit quantity of domestic sewage and commercial/institutional wastewater, adopted figures was assumed to be constant through the future..

(1) Domestic Sewage

a. Sewage Quantity

Table 3.2.1 Unit Sewage Quantity

Density	Present	2005
High	60 lpcd	65 lpcd
Medium	210 lpcd	unchanged
Low	315 lpcd	unchanged
Rural Area	Same to High density area	

Based on the study report of "Master Plan for Water Distribution, Harare" and "Crowborough Sewage Treatment Works", study on actual inflow sewage at Donnybrook STW.

b. Pollution Load

Table 3.2.2 Unit Domestic Pollution Load

(unit: g/capita/day)

Unit P.L.	High-density	Medium-density	Low-density
BOD	44	47	50
COD	88	94	100
T-N	11	12	13
T-P	1.2	1.3	1.4

Based on the Sanitation manual, study on actual inflow sewage at Donnybrook STW by the JICA Team and reference data in Japan. These load will be assumed to be constant in the future.

Five percent (5%) of above pollution load was assumed to be concentrated at high density area in unsewered area (septic tanks, etc.) as follows:

Table 3.2.3 Unit Domestic Pollution Load (Unsewered)

(unit: g/capita/day)

Indices	High-density
BOD	2.2
COD	4.4
T-N	0.55
T-P	0.06

Concentration ratio of effluent of sewage treatment works was assumed as follows:

Direct discharge to rivers: 100%

Irrigation reuse: 8%

(2) Commercial and Institutional Wastewater

a. Sewage Quantity

Table 3.2.4 Unit Wastewater Quantity (Commercial/Institutional)

(Against Domestic Sewage)	Present	2005
Harare City*	75%	78%
Chitungwiza Municipality.	5%	unchanged
Norton Town, Ruwa and Epworth	Same to Chitungwiza	
Rural Area	nil (negligible)	

Based on actual water supply record. Figures for Harare City includes industrial wastewater.

The commercial/institutional wastewater calculated for Harare City was allocated to Mukuvisi and Marimba sub-basins with a share of 80% and 20%, respectively.

b. Pollution Load

Assumed to be same as those of average domestic sewage.

(3) Industrial Wastewater

Unit values per employee of factory by type of industry were decided based on the results of survey on 45 factories. These figures were assumed to be constant through the future.

a. Unit Wastewater Quantity

Table 3.2.5 Unit Wastewater Quantity (Industrial)

Type of Industry	Unit WW Quantity (m^3/employee/day)
Processed Foodstuffs	0.677
Pulp, Paper & Related Products	4.308
Chemicals	0.288
Plastic Products	0.083
Chemicals, Stone & Clay products	0.833
Metal Products	0.218
Transportation Equipment	0.137
Other Industry Products	0.315

b. Unit Pollution Load

Table 3.2.6 Unit Pollution Load (Industrial)

Type of Industry	Unit Pollution Load (g/employee/day)				
	BOD	COD	SS	T-N	T-P
Processed Foodstuffs	966	2,002	301	25.06	9.61
Pulp, Paper & Related Products	9,800	41,871	2,145	163.69	26.71
Chemicals	106	840	306	6.3	1.73
Plastic Products	23	242	1,954	0.27	0.08
Chemicals, Stone & Clay products	91	66	682	13.89	2.26
Metal Products	61	208	93	6.92	0.66
Transportation Equipment	70	392	81	3.54	4.90
Other Industry Products	230	887	397	56.04	6.51

(4) Other Pollution Source

a. Livestock

The standard figures used in Japan was adopted for generated pollution load. Concentration ratio of pastured livestock was assumed to be 8% as presented in following table. Pollution load of poultry was ignored because of minimal emission of wastewater to water bodies.

Table 3.2.7 Unit Pollution Load (Livestock)

(unit: g/head/day)

	Cattle	Sheep/Goats	Pigs	Horses
BOD	51.2	5.12	16.0	17.6
COD	102.4	10.24	32.0	35.2
T-N	30.24	3.04	3.2	13.6
T-P	4.48	0.48	2.0	3.2

b. Natural Land / Farmland

Following values investigated in Japan were adopted as concentrated pollution load.

Table 3.2.8 Unit Pollution Load (Natural/Farmland)

PL Index	UPL ($kg/km^2/d$)
BOD	0.795
COD	11.781
T-N	0.986
T-P	0.082

Pollution load from farmland was assumed to be same as those of natural land.

c. Solid Waste

Pollution load of leachate caused at solid waste dumping site was assumed based on size of existing dumping site and investigated results in Japan. Quantity of leachate was calculated using evaporation amount by Thornthwait's method and average monthly rainfall. Following figures were adopted.

Table 3.2.9 Unit Pollution Load (Solid Waste Leachate)

Quantity (m^3/ha/year)	
on-going	3,300
completed	2,000
Quality (mg/l)	
BOD	500
COD	900
T-N	250

Taking account of location of dumping sites, 80% was adopted as the concentration ratio.

d. Water Treatment Works

Total amount of pollution load of wastewater discharged from water treatment works was assumed as same as those of intake water. Concentrated load of them was assumed taking account of present condition of wastewater treatment at WTWs. The expected improvement by the introduction of the backwashing wastewater treatment plant at the Morton Jaffray WTW was also considered in the future analysis.

4. Present Water Pollution Analysis

4.1 Pollution Load

4.1.1 Domestic/Commercial/Institutional Sewage

The estimated population in 1995 was broken down to those in sewered and unsewered area as shown in Table 4.1.1. Generated and discharged pollution load were calculated by sewered/unsewered area applying unit pollution load of domestic sewage.

The pollution load collected from the sewered area is discharged at sewage treatment works. The pollution load is calculated using present effluent water quality and quantity. Calculation results are presented in Table 4.1.2. As presented in the table, about 172,900 m^3/day or 80% of

Table 4.1.1 Population by Sewered/Unsewered by Sub-basin (Present)

Sub-basin/District	Total Population		Estimated	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B											
Goromonzi Rural	-	25,825	0%	-	-	-	-	-	-	25,825	25,825
Harare Rural	-	118	0%	-	-	-	-	-	-	118	118
Manyame Rural	-	2,339	0%	-	-	-	-	-	-	2,339	2,339
Total	-	28,282		-	-	-	-	-	-	28,282	28,282
2. Ruwa River S/B											
Harare City	84,165	-	100%	-	-	84,165	84,165	-	-	-	-
Ruwa Local Board	1,568	15	99%	128	32	1,407	1,568	15	-	-	15
Epworth Local Board	-	45,660	0%	-	-	-	-	-	-	45,660	45,660
Goromonzi Rural	-	6,127	0%	-	-	-	-	-	-	6,127	6,127
Harare Rural	-	4,069	0%	-	-	-	-	-	-	4,069	4,069
Total	85,733	55,871		128	32	85,572	85,733	15	-	55,856	55,871
3. Seke & Harava Dams S/B											
Epworth Local Board	-	4,936	0%	-	-	-	-	-	-	4,936	4,936
Goromonzi Rural	-	117	0%	-	-	-	-	-	-	117	117
Harare Rural	-	7,464	0%	-	-	-	-	-	-	7,464	7,464
Manyame Rural	-	972	0%	-	-	-	-	-	-	972	972
Total	-	13,489		-	-	-	-	-	-	13,489	13,489
4. Nyatsime River S/B											
Chitungwiza Municipality	**330,840**	-	**100%**	-	**13,455**	**317,385**	**330,840**	-	-	-	-
Manyame Rural	-	10,179	0%	-	-	-	-	-	-	10,179	10,179
Marondera Rural	-	7,467	0%	-	-	-	-	-	-	7,467	7,467
Total	330,840	17,646		-	13,455	317,385	330,840	-	-	17,646	17,646
5. Mukuvisi River S/B											
Harare City	600,791	27,138	96%	37,804	61,025	501,962	600,791	27,138	-	-	27,138
Epworth Local Board	-	17,894	0%	-	-	-	-	-	-	17,894	17,894
Harare Rural	-	1,843	0%	-	-	-	-	-	-	1,843	1,843
Zvimba Rural	-	421	0%	-	-	-	-	-	-	421	421
Total	600,791	47,296		37,804	61,025	501,962	600,791	27,138	-	20,158	47,296

Table 4.1.1 Population by Sewered/Unsewered by Sub-basin (Present)

Sub-basin/District	Total Population		Estimated	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
6. Manyame River (D.stream) S/B											
Chitungwiza Municipality	**88,957**	-	**100%**	-	-	**88,957**	**88,957**	-	-	-	-
Harare Rural	-	10,128	0%	-	-	-	-	-	-	10,128	10,128
Manyame Rural	-	1,466	0%	-	-	-	-	-	-	1,466	1,466
Total	88,957	11,594		-	-	88,957	88,957	-	-	11,594	11,594
7. Marimba River S/B											
Harare City	506,221	-	100%	57,378	27,620	421,223	506,221	-	-	-	-
Zvimba Rural	-	2,624	0%	-	-	-	-	-	-	2,624	2,624
Total	506,221	2,624		57,378	27,620	421,223	506,221	-	-	2,624	2,624
8. Lake Chivero S/B											
Harare City	-	-	-	-	-	-	-	-	-	-	-
Chegutu Rural	-	1,384	0%	-	-	-	-	-	-	1,384	1,384
Manyame Rural	-	2,017	0%	-	-	-	-	-	-	2,017	2,017
Zvimba Rural	-	4,649	0%	-	-	-	-	-	-	4,649	4,649
Total	-	8,050		-	-	-	-	-	-	8,050	8,050
9. Muzururu River S/B											
Zvimba Rural	-	13,699	0%	-	-	-	-	-	-	13,699	13,699
Total	-	13,699		-	-	-	-	-	-	13,699	13,699
10. Gwebi River S/B											
Harare City	9,757	68,002	13%	9,757	-	-	9,757	68,002	-	-	68,002
Mazowe Rural	-	12,423	0%	-	-	-	-	-	-	12,423	12,423
Zvimba Rural	-	19,887	0%	-	-	-	-	-	-	19,887	19,887
Total	9,757	100,312		9,757	-	-	9,757	68,002	-	32,310	100,312
11. Lake Manyame S/B											
Norton Town	21,021	1,293	94%	265	283	20,473	21,021	1,293	-	-	1,293
Chegutu Rural	-	6,026	0%	-	-	-	-	-	-	6,026	6,026
Zvimba Rural	-	12,250	0%	-	-	-	-	-	-	12,250	12,250
Total	21,021	19,569		265	283	20,473	21,021	1,293	-	18,276	19,569
Grand Total	1,643,320	318,432	84%	105,332	102,416	1,435,572	1,643,320	96,448	-	221,984	318,432

Note: 1. Estimated population for year 1995 is based on Scenario - 2.

2. Land use categorization is based on those shown in the Study.

3. Population in rural districts is categorised to high-density area.

Table 4.1.2 Discharged Pollution Load at Sewage Treatment Works (Present)

Sub-basin	Sewage Treatment Works	Eff. Flow (m3/day)		Irrigation	Average Effluent Water Quality (mg/l)				Pollution Load of Effluent (kg/day)				Concentrated Pollution Load [f] (kg/day)			
		Annual	Dry	Reuse (%)	BOD	COD	T-N	T-P [a]	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	39,400	32,300	100%	98.1	282.0	37.9	8.4	3,169	11,111	1,493	331	253	889	119	26
do	Crowborough (ENR)	16,000	15,700	0%	18.9	91.3	9.3	2.7	297	1,461	149	43	297	1,461	149	43
	Crowborough Total	55,400	48,000						3,465	12,572	1,642	374	550	2,350	268	70
L. Chivero	Firle Units 1&2 (TF)	83,900	81,300	100% [c]	137.8	268.0	38.7	7.2	11,203	22,485	3,247	604	896	1,799	260	48
Mukuvisi R.	Firle Unit 3 (BNR)	12,400	12,700	0%	13.8	107.6	13.7	4.7	175	1,334	170	58	175	1,334	170	58
do	Firle Unit 4 (BNR)	15,300	15,400	0%	18.2	94.7	13.0	3.7	280	1,449	199	57	280	1,449	199	57
	Firle Total (Mukuvisi)	27,700	28,100						456	2,783	369	115	456	2,783	369	115
Gwebi R.	Marlborough (WSP) [b]	2,000	2,000	100%	51.4	161.9	36.4	6.5	103	324	73	13	8	26	6	1
Ruwa R.	Donnybrook-1 (WSP) [b]	400	400	-	-	-	-	-	-	-	-	-	-	-	-	-
do	Donnybrook-2 (WSP) [b]	1,400	1,400	100%	40.6	162.1	99.6	17.3	73	292	179	20	6	23	14	2
do	Donnybrook-3 (WSP) [b]	1,400	1,400	100%	89.6	264.3	69.3	15.2	340	1,004	263	37	27	80	21	3
do	Donnybrook-4 (WSP) [b]	2,400	2,400	-	-	-	-	-	-	-	-	-	-	-	-	-
	Donnybrook Total [h]	5,600	5,600						414	1,296	443	56	33	104	35	5
Nyatsime R.	**Zengeza (TF) [b]**	**36,400**	**33,100**	**100, 50% [d]**	**130.0**	**540.0**	**119.0**	**16.6**	**4,303**	**19,656**	**4,332**	**266**	**-**	**9,828**	**2,166**	**133**
	% to Total	**17%**	**16%**						**20%**	**31%**	**42%**	**18%**	**0%**	**57%**	**69%**	**35%**
L. Manyame	Norton (TF)	2,700	2,700	100%	520.0	1,191.9	65.8	12.0	1,404	3,218	178	32	112	257	14	3
Ruwa R.	Ruwa (WSP) [b]	2,900	2,000	100%	123.0	278.0	6.1	4.0	246	806	18	12	20	64	1	1
Total		216,600	202,800						21,593	63,140	10,300	1,472	2,075	17,211	3,119	375

Note: a) T-P is calculated from P-P values using following correlation formula which is derived from measurement results by the Study Team.
T-P = P-P x 1.5482 + 0.2682 P-P; Phosphate Phosphorus

b) COD values of STWs with " [b] " are calculated from BOD values using following correlation formula which is derived from measurement results of other STWs with trickling filter method.
COD = BOD (annual average) x 2.08

c) The irrigation farm of the Firle STW is located in the Lake Chivero sub-basin.

d) The irrigation farm of the Zengeza STW is located outside of the Upper Manyame river basin. 100% of effluent is reused at present. Previously, 50% of it was discharged to Nyatsime River (conditions for calculation of COD, T-N and T-P).

e) Water quality of Zengeza STW is from measurement results surveyed by JICA team.

f) Concentration ratios of pollution loads are; for direct discharge; 100% for irrigation reuse; 8% (for BOD during dry season ; 8%)

g) Values for dry season are adopted for calculation regarding BOD.

h) Treated effluent of Donnybrook Nos. 1 and 4 are flowing into Nos. 2 and 3 respectively.

i) T-N for Ruwa STW is calculated from Ammonia-N values using following correlation formula which is derived from measurement results of same WSP effluent of Donnybrook STW.
T-N = A-N x 1.58

total effluent flow was assumed to be used for irrigation. The percentage of irrigation reuse was the result of the Zengeza STW arrangement in August 1995 (before the arrangement; 71%).

The current condition (100% of effluent from the Zengeza STW has been sent to irrigation farm) was adopted for present water pollution analysis of rivers (for BOD load). For pollution analysis of lakes, COD, T-N and T-P load were calculated in the condition before the arrangement because capacities of Lake Chivero and Lake Manyame is large enough to consider that influence of the Zengeza arrangement has not affected sufficiently on entire lake water after the arrangement.

It is also assumed that 8% of the pollution load for irrigation reuse reaches to the subject water bodies as concentrated load.

Calculation results of domestic/commercial/institutional sewage pollution load are presented in Tables 4.1.3 to 4.1.6 in terms of BOD, COD, T-N and T-P, respectively.

Table 4.1.3 Estimated Domestic/Commercial/Institutional Pollution Load by Sewered/Unsewered Area by Sub-basin - BOD (Present)

Sub-basin/District	Generated BOD (kg/day)										Concentrated BOD (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
1. Manyame River (Upstream) S/B																				
Goromonzi Rural	-	-	-	-	-	-	-	1,136	-	1,136	-	-	-	-	-	-	-	91	-	91
Harare Rural	-	-	-	-	-	-	-	5	-	5	-	-	-	-	-	-	-	0	-	0
Manyame Rural	-	-	-	-	-	-	-	103	-	103	-	-	-	-	-	-	-	8	-	8
Total	-	-	-	-	-	-	-	1,244	-	1,244	-	-	-	-	-	-	-	100	-	100
2. Ruwa River S/B																				
Harare City	-	-	3,703	-	3,703	-	-	-	-	-	Donnybrook STW				33	-	-	-	-	-
Ruwa Local Board	6	2	62	4	73	1	-	-	-	1	Ruwa STW				20	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	2,009	100	2,109	-	-	-	-	-	-	-	161	8	169
Goromonzi Rural	-	-	-	-	-	-	-	270	-	270	-	-	-	-	-	-	-	22	-	22
Harare Rural	-	-	-	-	-	-	-	179	-	179	-	-	-	-	-	-	-	14	-	14
Total	6	2	3,765	4	3,777	1	-	2,458	100	2,559	-	-	-	-	53	-	-	197	8	205
3. Seke & Harava Dams S/B																				
Epworth Local Board	-	-	-	-	-	-	-	217	11	228	-	-	-	-	-	-	-	17	1	18
Goromonzi Rural	-	-	-	-	-	-	-	5	-	5	-	-	-	-	-	-	-	0	-	0
Harare Rural	-	-	-	-	-	-	-	328	-	328	-	-	-	-	-	-	-	26	-	26
Manyame Rural	-	-	-	-	-	-	-	43	-	43	-	-	-	-	-	-	-	3	-	3
Total	-	-	-	-	-	-	-	594	11	604	-	-	-	-	-	-	-	47	1	48
4. Nyatsime River S/B																				
Chitungwiza Municipality	-	632	13,965	926	15,523	-	-	-	-	-	Zengeza STW				-	-	-	-	-	-
Manyame Rural	-	-	-	-	-	-	-	448	-	448	-	-	-	-	-	-	-	36	-	36
Marondera Rural	-	-	-	-	-	-	-	329	-	329	-	-	-	-	-	-	-	26	-	26
Total	-	632	13,965	926	15,523	-	-	776	-	776	-	-	-	-	-	-	-	62	-	62
5. Mukuvisi River S/B																				
Harare City	1,890	2,868	22,086	20,629	47,473	1,357	-	-	-	1,357	Firle STW				456	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	787	39	827	-	-	-	-	-	-	-	63	3	66
Harare Rural	-	-	-	-	-	-	-	81	-	81	-	-	-	-	-	-	-	6	-	6
Zvimba Rural	-	-	-	-	-	-	-	19	-	19	-	-	-	-	-	-	-	1	-	1
Total	1,890	2,868	22,086	20,629	47,473	1,357	-	887	39	2,283	-	-	-	-	456	-	-	71	3	74
6. Manyame River (D.stream) S/B																				
Chitungwiza Municipality	-	-	3,914	-	3,914	-	-	-	-	-	to Zengeza STW				-	-	-	-	-	-
Harare Rural	-	-	-	-	-	-	-	446	-	446	-	-	-	-	-	-	-	36	-	36
Manyame Rural	-	-	-	-	-	-	-	65	-	65	-	-	-	-	-	-	-	5	-	5
Total	-	-	3,914	-	3,914	-	-	510	-	510	-	-	-	-	-	-	-	41	-	41

Table 4.1.3 Estimated Domestic/Commercial/Institutional Pollution Load by Sewered/Unsewered Area by Sub-basin - BOD (Present)

Sub-basin/District	Generated BOD (kg/day)										Concentrated BOD (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
7. Marimba River S/B																				
Harare City	2,869	1,298	18,534	5,157	27,858	-	-	-	-	-	Crowborough STW				550	-	-	-	-	-
Zvimba Rural	-	-	-	-	-	-	-	115	-	115	-	-	-	-	-	-	-	9	-	9
Total	2,869	1,298	18,534	5,157	27,858	-	-	115	-	115	-	-	-	-	550	-	-	9	-	9
8. Lake Chivero S/B																				
Harare City	-	-	-	-	-	-	-	-	-	-	Firle STW (Irrigation farm)				896	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	61	-	61	-	-	-	-	-	-	-	5	-	5
Manyame Rural	-	-	-	-	-	-	-	89	-	89	-	-	-	-	-	-	-	7	-	7
Zvimba Rural	-	-	-	-	-	-	-	205	-	205	-	-	-	-	-	-	-	16	-	16
Total	-	-	-	-	-	-	-	354	-	354	-	-	-	-	896	-	-	28	-	28
9. Muzururu River S/B																				
Zvimba Rural	-	-	-	-	-	-	-	603	-	603	-	-	-	-	-	-	-	48	-	48
Total	-	-	-	-	-	-	-	603	-	603	-	-	-	-	-	-	-	48	-	48
10. Gwebi River S/B																				
Harare City	488	-	-	-	488	3,400	-	-	-	3,400	Marlborough STW				8	-	-	-	-	-
Mazowe Rural	-	-	-	-	-	-	-	547	-	547	-	-	-	-	-	-	-	44	-	44
Zvimba Rural	-	-	-	-	-	-	-	875	-	875	-	-	-	-	-	-	-	70	-	70
Total	488	-	-	-	488	3,400	-	1,422	-	4,822	-	-	-	-	8	-	-	114	-	114
11. Lake Manyame S/B																				
Norton Town	13	13	901	50	977	65	-	-	-	65	Norton STW				112	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	265	-	265	-	-	-	-	-	-	-	21	-	21
Zvimba Rural	-	-	-	-	-	-	-	539	-	539	-	-	-	-	-	-	-	43	-	43
Total	13	13	901	50	977	65	-	804	-	869	-	-	-	-	112	-	-	64	-	64
Grand Total	5,267	4,814	63,165	26,765	100,010	4,822	-	9,767	151	14,740	-	-	-	-	2,075	-	-	781	12	793

Note: 1. Estimated population for year 1995 is based on Scenario - 2.

2. Residential density is based on those shown in the Study.

3. Population in rural districts is categorised to high-density area.

4. Concentration ratios are; for direct discharge (STW): 100% for irrigation reuse (STW): 8% for unsewered area: High; 8% Low & Medium; 0%

Table 4.1.4 Estimated Domestic Pollution Load by Sewered/Unsewered Area by Sub-basin - COD (Present)

Sub-basin/District	Generated COD (kg/day)										Concentrated COD (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
1. Manyame River (Upstream) S/B																				
Goromonzi Rural	-	-	-	-	-	-	-	2,273	-	2,273	-	-	-	-	-	-	-	182	-	182
Harare Rural	-	-	-	-	-	-	-	10	-	10	-	-	-	-	-	-	-	1	-	1
Manyame Rural	-	-	-	-	-	-	-	206	-	206	-	-	-	-	-	-	-	16	-	16
Total	-	-	-	-	-	-	-	2,489	-	2,489	-	-	-	-	-	-	-	199	-	199
2. Ruwa River S/B																				
Harare City	-	-	7,407	-	7,407	-	-	-	-	-	Donnybrook STW				104	-	-	-	-	-
Ruwa Local Board	13	3	124	7	147	2	-	-	-	2	Ruwa STW				64	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	4,018	201	4,219	-	-	-	-	-	-	-	321	16	338
Goromonzi Rural	-	-	-	-	-	-	-	539	-	539	-	-	-	-	-	-	-	43	-	43
Harare Rural	-	-	-	-	-	-	-	358	-	358	-	-	-	-	-	-	-	29	-	29
Total	13	3	7,530	7	7,553	2	-	4,915	201	5,118	-	-	-	-	168	-	-	393	16	409
3. Seke & Harava Dams S/B																				
Epworth Local Board	-	-	-	-	-	-	-	434	22	456	-	-	-	-	-	-	-	35	2	36
Goromonzi Rural	-	-	-	-	-	-	-	10	-	10	-	-	-	-	-	-	-	1	-	1
Harare Rural	-	-	-	-	-	-	-	657	-	657	-	-	-	-	-	-	-	53	-	53
Manyame Rural	-	-	-	-	-	-	-	86	-	86	-	-	-	-	-	-	-	7	-	7
Total	-	-	-	-	-	-	-	1,187	22	1,209	-	-	-	-	-	-	-	95	2	97
4. Nyatsime River S/B																				
Chitungwiza Municipality	-	1,265	27,930	1,851	31,046	-	-	-	-	-	Zengeza STW				9,828	-	-	-	-	-
Manyame Rural	-	-	-	-	-	-	-	896	-	896	-	-	-	-	-	-	-	72	-	72
Marondera Rural	-	-	-	-	-	-	-	657	-	657	-	-	-	-	-	-	-	53	-	53
Total	-	1,265	27,930	1,851	31,046	-	-	1,553	-	1,553	-	-	-	-	9,828	-	-	124	-	124
5. Mukuvisi River S/B																				
Harare City	3,780	5,736	44,173	41,257	94,947	2,714	-	-	-	2,714	Firle STW				2,783	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	1,575	79	1,653	-	-	-	-	-	-	-	126	6	132
Harare Rural	-	-	-	-	-	-	-	162	-	162	-	-	-	-	-	-	-	13	-	13
Zvimba Rural	-	-	-	-	-	-	-	37	-	37	-	-	-	-	-	-	-	3	-	3
Total	3,780	5,736	44,173	41,257	94,947	2,714	-	1,774	79	4,566	-	-	-	-	2,783	-	-	142	6	148
6. Manyame River (D.stream) S/B																				
Chitungwiza Municipality	-	-	7,828	-	7,828	-	-	-	-	-	to Zengeza STW				-	-	-	-	-	-
Harare Rural	-	-	-	-	-	-	-	891	-	891	-	-	-	-	-	-	-	71	-	71
Manyame Rural	-	-	-	-	-	-	-	129	-	129	-	-	-	-	-	-	-	10	-	10
Total	-	-	7,828	-	7,828	-	-	1,020	-	1,020	-	-	-	-	-	-	-	82	-	82

Table 4.1.4 Estimated Domestic Pollution Load by Sewered/Unsewered Area by Sub-basin - COD (Present)

Sub-basin/District	Generated COD (kg/day)										Concentrated COD (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
7. Marimba River S/B																				
Harare City	5,738	2,596	37,068	10,314	55,716	-	-	-	-	-			Crowborough STW		2,350	-	-	-	-	-
Zvimba Rural	-	-	-	-	-	-	-	231	-	231	-	-	-	-	-	-	-	18	-	18
Total	5,738	2,596	37,068	10,314	55,716	-	-	231	-	231	-	-	-	-	2,350	-	-	18	-	18
8. Lake Chivero S/B	-	-	-			-	-	-												
Harare City	-	-	-	-	-	-	-	-	-	-			Firle STW (Irrigation farm)		1,799	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	122	-	122	-	-	-	-	-	-	-	10	-	10
Manyame Rural	-	-	-	-	-	-	-	177	-	177	-	-	-	-	-	-	-	14	-	14
Zvimba Rural	-	-	-	-	-	-	-	409	-	409	-	-	-	-	-	-	-	33	-	33
Total	-	-	-	-	-	-	-	708	-	708	-	-	-	-	1,799	-	-	57	-	57
9. Muzururu River S/B																				
Zvimba Rural	-	-	-	-	-	-	-	1,206	-	1,206	-	-	-	-	-	-	-	96	-	96
Total	-	-	-	-	-	-	-	1,206	-	1,206	-	-	-	-	-	-	-	96	-	96
10. Gwebi River S/B																				
Harare City	976	-	-	-	976	6,800	-	-	-	6,800			Marlborough STW		26	-	-	-	-	-
Mazowe Rural	-	-	-	-	-	-	-	1,093	-	1,093	-	-	-	-	-	-	-	87	-	87
Zvimba Rural	-	-	-	-	-	-	-	1,750	-	1,750	-	-	-	-	-	-	-	140	-	140
Total	976	-	-	-	976	6,800	-	2,843	-	9,643	-	-	-	-	26	-	-	227	-	227
11. Lake Manyame S/B																				
Norton Town	26	27	1,802	99	1,954	129	-	-	-	129			Norton STW		257	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	530	-	530	-	-	-	-	-	-	-	42	-	42
Zvimba Rural	-	-	-	-	-	-	-	1,078	-	1,078	-	-	-	-	-	-	-	86	-	86
Total	26	27	1,802	99	1,954	129	-	1,608	-	1,738	-	-	-	-	257	-	-	129	-	129
Grand Total	10,533	9,627	126,330	53,529	200,020	9,645	-	19,535	301	29,481	-	-	-	-	17,211	-	-	1,563	24	1,587

Note: 1. Estimated population for year 1995 is based on Scenario - 2.

2. Residential density is based on those shown in the Study.

3. Population in rural districts is categorised to high-density area.

4. Concentration ratios are; for direct discharge (STW): 100% for irrigation reuse (STW): 8% for unsewered area: High; 8% Low & Medium; 0%

Table 4.1.5 Estimated Domestic Pollution Load by Sewered/Unsewered Area by Sub-basin - T-N (Present)

Sub-basin/District	Generated T-N (kg/day)										Concentrated T-N (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
1. Manyame River (Upstream) S/B																				
Goromonzi Rural	-	-	-	-	-	-	-	284	-	284	-	-	-	-	-	-	-	23	-	23
Harare Rural	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	0	-	0
Manyame Rural	-	-	-	-	-	-	-	26	-	26	-	-	-	-	-	-	-	2	-	2
Total	-	-	-	-	-	-	-	311	-	311	-	-	-	-	-	-	-	25	-	25
2. Ruwa River S/B																				
Harare City	-	-	926	-	926	-	-	-	-	-	Donnybrook STW				35	-	-	-	-	-
Ruwa Local Board	2	0	15	1	18	0	-	-	-	0	Ruwa STW				1	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	502	25	527	-	-	-	-	-	-	-	40	2	42
Goromonzi Rural	-	-	-	-	-	-	-	67	-	67	-	-	-	-	-	-	-	5	-	5
Harare Rural	-	-	-	-	-	-	-	45	-	45	-	-	-	-	-	-	-	4	-	4
Total	2	0	941	1	944	0	-	614	25	640	-	-	-	-	37	-	-	49	2	51
3. Seke & Harava Dams S/B																				
Epworth Local Board	-	-	-	-	-	-	-	54	3	57	-	-	-	-	-	-	-	4	0	5
Goromonzi Rural	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	0	-	0
Harare Rural	-	-	-	-	-	-	-	82	-	82	-	-	-	-	-	-	-	7	-	7
Manyame Rural	-	-	-	-	-	-	-	11	-	11	-	-	-	-	-	-	-	1	-	1
Total	-	-	-	-	-	-	-	148	3	151	-	-	-	-	-	-	-	12	0	12
4. Nyatsime River S/B																				
Chitungwiza Municipality	-	161	3,491	232	3,884	-	-	-	-	-	Zengeza STW				2,166	-	-	-	-	-
Manyame Rural	-	-	-	-	-	-	-	112	-	112	-	-	-	-	-	-	-	9	-	9
Marondera Rural	-	-	-	-	-	-	-	82	-	82	-	-	-	-	-	-	-	7	-	7
Total	-	161	3,491	232	3,884	-	-	194	-	194	-	-	-	-	2,166	-	-	16	-	16
5. Mukuvisi River S/B																				
Harare City	491	732	5,522	5,200	11,946	353	-	-	-	353	Firle STW				369	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	197	10	207	-	-	-	-	-	-	-	16	1	17
Harare Rural	-	-	-	-	-	-	-	20	-	20	-	-	-	-	-	-	-	2	-	2
Zvimba Rural	-	-	-	-	-	-	-	5	-	5	-	-	-	-	-	-	-	0	-	0
Total	491	732	5,522	5,200	11,946	353	-	222	10	584	-	-	-	-	369	-	-	18	1	19
6. Manyame River (D.stream) S/B																				
Chitungwiza Municipality	-	-	979	-	979	-	-	-	-	-	to Zengeza STW				-	-	-	-	-	-
Harare Rural	-	-	-	-	-	-	-	111	-	111	-	-	-	-	-	-	-	9	-	9
Manyame Rural	-	-	-	-	-	-	-	16	-	16	-	-	-	-	-	-	-	1	-	1
Total	-	-	979	-	979	-	-	128	-	128	-	-	-	-	-	-	-	10	-	10

Table 4.1.5 Estimated Domestic Pollution Load by Sewered/Unsewered Area by Sub-basin - T-N (Present)

Sub-basin/District	Generated T-N (kg/day)										Concentrated T-N (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
7. Marimba River S/B																				
Harare City	746	331	4,633	1,300	7,011	-	-	-	-	-			Crowborough STW		268	-	-	-	-	-
Zvimba Rural	-	-	-	-	-	-	-	29	-	29	-	-	-	-	-	-	-	2	-	2
Total	746	331	4,633	1,300	7,011	-	-	29	-	29	-	-	-	-	268	-	-	2	-	2
8. Lake Chivero S/B	-	-	-			-	-	-												
Harare City	-	-	-	-	-	-	-	-	-	-			Firle STW (Irrigation farm)		260	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	15	-	15	-	-	-	-	-	-	-	1	-	1
Manyame Rural	-	-	-	-	-	-	-	22	-	22	-	-	-	-	-	-	-	2	-	2
Zvimba Rural	-	-	-	-	-	-	-	51	-	51	-	-	-	-	-	-	-	4	-	4
Total	-	-	-	-	-	-	-	89	-	89	-	-	-	-	260	-	-	7	-	7
9. Muzururu River S/B																				
Zvimba Rural	-	-	-	-	-	-	-	151	-	151	-	-	-	-	-	-	-	12	-	12
Total	-	-	-	-	-	-	-	151	-	151	-	-	-	-	-	-	-	12	-	12
10. Gwebi River S/B																				
Harare City	127	-	-	-	127	884	-	-	-	884			Marlborough STW		6	-	-	-	-	-
Mazowe Rural	-	-	-	-	-	-	-	137	-	137	-	-	-	-	-	-	-	11	-	11
Zvimba Rural	-	-	-	-	-	-	-	219	-	219	-	-	-	-	-	-	-	18	-	18
Total	127	-	-	-	127	884	-	355	-	1,239	-	-	-	-	6	-	-	28	-	28
11. Lake Manyame S/B																				
Norton Town	3	3	225	12	244	17	-	-	-	17			Norton STW		14	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	66	-	66	-	-	-	-	-	-	-	5	-	5
Zvimba Rural	-	-	-	-	-	-	-	135	-	135	-	-	-	-	-	-	-	11	-	11
Total	3	3	225	12	244	17	-	201	-	218	-	-	-	-	14	-	-	16	-	16
Grand Total	1,369	1,229	15,791	6,745	25,135	1,254	-	2,442	38	3,733	-	-	-	-	3,119	-	-	195	3	198

Note: 1. Estimated population for year 1995 is based on Scenario - 2.

2. Residential density is based on those shown in the Study.

3. Population in rural districts is categorised to high-density area.

4. Concentration ratios are; for direct discharge (STW): 100% for irrigation reuse (STW): 8% for unsewered area: High; 8% Low & Medium; 0%

Table 4.1.6 Estimated Domestic Pollution Load by Sewered/Unsewered Area by Sub-basin - T-P (Present)

Sub-basin/District	Generated T-P (kg/day)										Concentrated T-P (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
1. Manyame River (Upstream) S/B																				
Goromonzi Rural	-	-	-	-	-	-	-	31	-	31	-	-	-	-	-	-	-	2	-	2
Harare Rural	-	-	-	-	-	-	-	0	-	0	-	-	-	-	-	-	-	0	-	0
Manyame Rural	-	-	-	-	-	-	-	3	-	3	-	-	-	-	-	-	-	0	-	0
Total	-	-	-	-	-	-	-	34	-	34	-	-	-	-	-	-	-	3	-	3
2. Ruwa River S/B																				
Harare City	-	-	101	-	101	-	-	-	-	-	Donnybrook STW				5	-	-	-	-	-
Ruwa Local Board	0	0	2	0	2	0	-	-	-	0	Ruwa STW				1	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	55	3	58	-	-	-	-	-	-	-	4	0	5
Goromonzi Rural	-	-	-	-	-	-	-	7	-	7	-	-	-	-	-	-	-	1	-	1
Harare Rural	-	-	-	-	-	-	-	5	-	5	-	-	-	-	-	-	-	0	-	0
Total	0	0	103	0	103	0	-	67	3	70	-	-	-	-	5	-	-	5	0	6
3. Seke & Harava Dams S/B																				
Epworth Local Board	-	-	-	-	-	-	-	6	0	6	-	-	-	-	-	-	-	0	0	0
Goromonzi Rural	-	-	-	-	-	-	-	0	-	0	-	-	-	-	-	-	-	0	-	0
Harare Rural	-	-	-	-	-	-	-	9	-	9	-	-	-	-	-	-	-	1	-	1
Manyame Rural	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	0	-	0
Total	-	-	-	-	-	-	-	16	0	16	-	-	-	-	-	-	-	1	0	1
4. Nyatsime River S/B																				
Chitungwiza Municipality	-	17	381	25	424	-	-	-	-	-	Zengeza STW				133	-	-	-	-	-
Manyame Rural	-	-	-	-	-	-	-	12	-	12	-	-	-	-	-	-	-	1	-	1
Marondera Rural	-	-	-	-	-	-	-	9	-	9	-	-	-	-	-	-	-	1	-	1
Total	-	17	381	25	424	-	-	21	-	21	-	-	-	-	133	-	-	2	-	2
5. Mukuvisi River S/B																				
Harare City	53	79	602	566	1,300	38	-	-	-	38	Firle STW				115	-	-	-	-	-
Epworth Local Board	-	-	-	-	-	-	-	21	1	23	-	-	-	-	-	-	-	2	0	2
Harare Rural	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	0	-	0
Zvimba Rural	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	0	-	0
Total	53	79	602	566	1,300	38	-	24	1	63	-	-	-	-	115	-	-	2	0	2
6. Manyame River (D.stream) S/B																				
Chitungwiza Municipality	-	-	107	-	107	-	-	-	-	-	to Zengeza STW				-	-	-	-	-	-
Harare Rural	-	-	-	-	-	-	-	12	-	12	-	-	-	-	-	-	-	1	-	1
Manyame Rural	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	0	-	0
Total	-	-	107	-	107	-	-	14	-	14	-	-	-	-	-	-	-	1	-	1

Table 4.1.6 Estimated Domestic Pollution Load by Sewered/Unsewered Area by Sub-basin - T-P (Present)

Sub-basin/District	Generated T-P (kg/day)										Concentrated T-P (kg/day)									
	Sewered Area					Unsewered Area					Sewered Area					Unsewered Area				
	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total	Low	Medium	High	C & I	Total
7. Marimba River S/B																				
Harare City	80	36	505	141	763	-	-	-	-	-			Crowborough STW		70	-	-	-	-	-
Zvimba Rural	-	-	-	-	-	-	-	3	-	3	-	-	-	-	-	-	-	0	-	0
Total	80	36	505	141	763	-	-	3	-	3	-	-	-	-	70	-	-	0	-	0
8. Lake Chivero S/B	-	-	-			-	-	-												
Harare City	-	-	-	-	-	-	-	-	-	-			Firle STW (Irrigation farm)		48	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	0	-	0
Manyame Rural	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	0	-	0
Zvimba Rural	-	-	-	-	-	-	-	6	-	6	-	-	-	-	-	-	-	0	-	0
Total	-	-	-	-	-	-	-	10	-	10	-	-	-	-	48	-	-	1	-	1
9. Muzururu River S/B																				
Zvimba Rural	-	-	-	-	-	-	-	16	-	16	-	-	-	-	-	-	-	1	-	1
Total	-	-	-	-	-	-	-	16	-	16	-	-	-	-	-	-	-	1	-	1
10. Gwebi River S/B																				
Harare City	14	-	-	-	14	95	-	-	-	95			Marlborough STW		1	-	-	-	-	-
Mazowe Rural	-	-	-	-	-	-	-	15	-	15	-	-	-	-	-	-	-	1	-	1
Zvimba Rural	-	-	-	-	-	-	-	24	-	24	-	-	-	-	-	-	-	2	-	2
Total	14	-	-	-	14	95	-	39	-	134	-	-	-	-	1	-	-	3	-	3
11. Lake Manyame S/B																				
Norton Town	0	0	25	1	27	2	-	-	-	2			Norton STW		3	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	-	7	-	7	-	-	-	-	-	-	-	1	-	1
Zvimba Rural	-	-	-	-	-	-	-	15	-	15	-	-	-	-	-	-	-	1	-	1
Total	0	0	25	1	27	2	-	22	-	24	-	-	-	-	3	-	-	2	-	2
Grand Total	147	133	1,723	734	2,737	135	-	266	4	406	-	-	-	-	375	-	-	21	0	22

Note: 1. Estimated population for year 1995 is based on Scenario - 2.

2. Residential density is based on those shown in the Study.

3. Population in rural districts is categorised to high-density area.

4. Concentration ratios are; for direct discharge (STW): 100% for irrigation reuse (STW): 8% for unsewered area: High; 8% Low & Medium; 0%

4.1.2 Industrial Wastewater

(1) Wastewater Quantity

Present industrial wastewater quantity was calculated by multiplying the unit industrial wastewater quantity per employee and the number of employees at present. The result is shown in Table 4.1.7.

(2) Pollution Load

Present pollution load was calculated by multiplying the unit pollution load of industrial wastewater per employee and the number of employees at present. The result is presented in Table 4.1.8.

(3) Sewered/Unsewered Wastewater

Present wastewater quantity and pollution load were calculated by sub-basin dividing sewered/unsewered by public sewerage system, based on the present condition described below. The results are shown in Table 4.1.9.

According to the wastewater quality investigations at factories conducted by the Study Team, there are several factories discharging their wastewater to irrigation farm at present. They are;

Harare (Mukuvisi R. sub-basin): 1 Chemical factory
Chitungwiza (Nyatsime R. sub-basin): 1 Transportation equipment factory
Norton (Lake Manyame sub-basin): 1 Pulp, paper & related products factory

The transportation equipment factory in Chitungwiza cannot be served by sewerage system because of topographical reason. As to the other two factories in Harare and Norton, effluents are pre-treated and re-used for irrigation. Considering present situation stated above, unsewered ratio was set up as follows;

Mukuvisi River Sub-basin: 1.0 % of total wastewater quantity in the sub-basin
Nyatsime River Sub-basin: 5.0 % of total wastewater quantity in the sub-basin
Lake Manyame Sub-basin: 82.4 % of total wastewater quantity in the sub-basin

Table 4.1.7 Present and Future Industrial Wastewater Quality

Local Authority	Sub-Basin	Present		2000 Year		2005 Year		2015 Year	
		Number of Employees	Wastewater Quantity (m3/day)	Number of Employees	Wastewater Quantity (m3/day)	Number of Employees	Wastewater Quantity (m3/day)	Number of Employees	Wastewater Quantity (m3/day)
Harare City	Marimba River	22,300	11,392	22,300	11,392	22,300	11,392	22,300	11,392
	Mukuvisi River	63,700	32,535	74,900	38,257	74,900	38,257	82,400	42,087
	Ruwa River	0	0	0	0	0	0	50,200	25,642
	Manyame River	0	0	3,000	1,533	77,400	39,533	77,400	39,533
	Total	86,000	43,927	100,200	51,182	174,600	89,182	232,300	118,654
Chitungwiza Municipality	Nyatsime River	2,500	972	3,100	1,206	3,600	1,401	27,600	10,740
	Manyame River	0	0	0	0	0	0	5,200	2,024
	Total	2,500	972	3,100	1,206	3,600	1,401	32,800	12,764
Norton Town Council	Lake Manyame	3,000	4,186	3,300	4,605	4,900	6,837	15,400	21,493
Ruwa Local Board	Ruwa River	2,300	657	9,300	2,660	12,400	3,545	16,200	4,632

Table 4.1.8 Present and Future Industrial Wastewater Pollution Load

Local Authority	Sub-Basin	Present Industrial Wastewater Pollution Load (kg/day)						Year 2000 Industrial Wastewater Pollution Load (kg/day)					
		Number of Employees	BOD	COD	SS	T-N	T-P	Number of Employees	BOD	COD	SS	T-N	T-P
Harare City	Marimba River	22,300	12,826	35,721	8,520	389	121	22,300	12,826	35,721	8,520	389	121
	Mukuvisi River	63,700	36,638	102,023	24,340	1,116	348	74,900	43,081	119,976	28,619	1,312	407
	Ruwa River	0	0	0	0	0	0	0	0	0	0	0	0
	Manyame River	0	0	0	0	0	0	3,000	1,725	4,804	1,147	52	16
	Total	86,000	49,464	137,744	32,860	1,505	469	100,200	57,632	160,501	38,286	1,753	544
Chitungwiza Municipality	Nyatsime River	2,500	1,138	2,711	570	41	16	3,100	1,412	3,364	708	51	21
	Manyame River	0	0	0	0	0	0	0	0	0	0	0	0
	Total	2,500	1,138	2,711	570	41	16	3,100	1,412	3,364	708	51	21
Norton Town Council	Lake Manyame	3,000	8,416	35,200	2,306	196	31	3,300	9,256	38,715	2,538	214	34
Ruwa Local Board	Ruwa River	2,300	471	1,683	1,509	82	10	9,300	1,907	6,806	6,103	336	42

Table 4.1.8 Present and Future Industrial Wastewater Pollution Load (cont'd)

Local Authority	Sub-Basin	Year 2005 Industrial Wastewater Pollution Load (kg/day)						Year 2015 Industrial Wastewater Pollution Load (kg/day)					
		Number of Employees	BOD	COD	SS	T-N	T-P	Number of Employees	BOD	COD	SS	T-N	T-P
Harare City	Marimba River	22,300	12,826	35,721	8,520	389	121	22,300	12,826	35,721	8,520	389	121
	Mukuvisi River	74,900	43,081	119,976	28,619	1,312	407	82,400	47,392	131,969	31,486	1,443	448
	Ruwa River	0	0	0	0	0	0	50,200	28,877	80,420	19,182	880	274
	Manyame River	77,400	44,516	123,960	29,573	1,355	421	77,400	44,516	123,960	29,573	1,355	421
	Total	174,600	100,423	279,657	66,712	3,056	949	232,300	133,611	372,070	88,761	4,067	1,264
Chitungwiza Municipality	Nyatsime River	3,600	1,641	3,909	822	59	25	27,600	12,585	29,963	6,301	450	184
	Manyame River	0	0	0	0	0	0	5,200	2,371	5,644	1,188	85	34
	Total	3,600	1,641	3,909	822	59	25	32,800	14,956	35,607	7,489	535	218
Norton Town Council	Lake Manyame	4,900	13,741	57,479	3,767	319	52	15,400	43,199	180,697	11,841	1,003	164
Ruwa Local Board	Ruwa River	12,400	2,543	9,077	8,136	450	56	16,200	3,322	11,858	10,631	588	74

Table 4.1.9 Industrial Wastewater Quality and Pollution Load

	Sub-Basin	Industrial Wastewater Quantity			Industrial Wastewater Pollution Load (kg/day)														
		Total	Sewered	Un-sewered	Total					Sewered					Un-sewered				
		(m3/day)			BOD	COD	SS	T-N	T-N	BOD	COD	SS	T-N	T-N	BOD	COD	SS	T-N	T-N
Present	Manyame R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ruwa River	657	657	0	471	1,683	1,509	82	10	471	1,683	1,509	82	10	0	0	0	0	0
	Seke & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nyatsime River	972	923	49	1,138	2,711	570	41	16	1,081	2,575	541	39	15	57	136	29	2	1
	Manyame R. (Downstream)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mukuvisi River	32,535	32,210	325	36,638	102,023	24,340	1,116	348	36,272	101,003	24,097	1,105	345	366	1,020	243	11	3
	Marimba River	11,392	11,392	0	12,826	35,721	8,520	389	121	12,826	35,721	8,520	389	121	0	0	0	0	0
	Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lake Manyame	4,186	735	3,451	8,416	35,200	2,306	196	31	566	1,661	588	65	10	7,850	33,539	1,718	131	21
Year 2000	Manyame R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ruwa River	2,660	2,660	0	1,907	6,806	6,103	336	42	1,907	6,806	6,103	336	42	0	0	0	0	0
	Seke & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nyatsime River	1,206	1,206	0	1,412	3,364	708	51	21	1,412	3,364	708	51	21	0	0	0	0	0
	Manyame R. (Downstream)	1533	1533	0	1,725	4,804	1,147	52	16	1,725	4,804	1,147	52	16	0	0	0	0	0
	Mukuvisi River	38,257	37,932	325	43,081	119,976	28,619	1,312	407	42,715	118,956	28,376	1,301	404	366	1,020	243	11	3
	Marimba River	11,392	11,392	0	12,826	35,721	8,520	389	121	12,826	35,721	8,520	389	121	0	0	0	0	0
	Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lake Manyame	4,605	1,154	3,451	9,256	38,715	2,538	214	34	1,406	5,176	820	83	13	7,850	33,539	1,718	131	21
Year 2005	Manyame R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ruwa River	3,545	3,545	0	2,543	9,077	8,136	450	56	2,543	9,077	8,136	450	56	0	0	0	0	0
	Seke & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nyatsime River	1,401	1,401	0	1,641	3,909	822	59	25	1,641	3,909	822	59	25	0	0	0	0	0
	Manyame R. (Downstream)	39533	39533	0	44,516	123,960	29,573	1,355	421	44,516	123,960	29,573	1,355	421	0	0	0	0	0
	Mukuvisi River	38,257	37,932	325	43,081	119,976	28,619	1,312	407	42,715	118,956	28,376	1,301	404	366	1,020	243	11	3
	Marimba River	11,392	11,392	0	12,826	35,721	8,520	389	121	12,826	35,721	8,520	389	121	0	0	0	0	0
	Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lake Manyame	6,837	3,386	3,451	13,741	57,479	3,767	319	52	5,891	23,940	2,049	188	31	7,850	33,539	1,718	131	21
Year 2015	Manyame R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ruwa River	30,274	30,274	0	32,199	92,278	29,813	1,468	348	32,199	92,278	29,813	1,468	348	0	0	0	0	0
	Seke & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nyatsime River	10,740	10,740	0	12,585	29,963	6,301	450	184	12,585	29,963	6,301	450	184	0	0	0	0	0
	Manyame R. (Downstream)	41557	41557	0	46,887	129,604	30,761	1,440	455	46,887	129,604	30,761	1,440	455	0	0	0	0	0
	Mukuvisi River	42,087	41,762	325	47,392	131,969	31,486	1,443	448	47,026	130,949	31,243	1,432	445	366	1,020	243	11	3
	Marimba River	11,392	11,392	0	12,826	35,721	8,520	389	121	12,826	35,721	8,520	389	121	0	0	0	0	0
	Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lake Manyame	21,493	18,042	3,451	43,199	180,697	11,841	1,003	164	35,349	147,158	10,123	872	143	7,850	33,539	1,718	131	21

4.1.3 Other Wastewater

(1) Livestock

Number of major livestock mentioned in sub-section 3.1 was allocated to each sub-basin in proportion to each area size. Calculation results are shown in Table 4.1.10. Generated and concentrated pollution loads from major livestock, i.e. cattle, sheep/goats, pigs and horses, were calculated for each sub-basin using the number of livestock and unit pollution load. The summary of calculation is shown in Table 4.1.11.

(2) Farmland / Natural Land

The pollution loads originated from farmland and natural land were calculated for each sub-basin as shown in Table 4.1.12 using the area of each sub-basin and unit pollution load presented in sub-section 3.2. The pollution load may be defined as concentrated pollution loads.

(3) Solid Waste Dumping Sites

Location and area of dumping sites are presented in Table 4.1.13. The pollution load from dumping sites were calculated using the area of each landfill site and unit pollution load presented in Table 3.2.9. Concentration ratio is assumed to be 80% (nil for BOD_5 during dry season) in the calculation taking account of location of dumping sites. Calculation results are also presented in Table 4.1.13.

(4) Water Treatment Works

Wastewater generated at water treatment works in the study area reaches to subject water bodies after treatment as stated in sub-section 3.2. Because of unavailability of the data on quality and quantity of the wastewater, it is assumed that the total pollution load of generated wastewater is same as the pollution load contained in the intake water. Therefore, amount of pollution load was derived from water quality of lake/dam and amount of intake water. Details of calculations are presented in Tables 4.2.1 and 4.2.3 to 4.2.5.

Table 4.1.10 Number of Major Livestock by Sub-basin

Cattle

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	12,140	-	4,768	4,029	-	3,343	-
Ruwa River	5,955	-	-	2,461	3,494	-	-
Seke & Harava D.	5,051	-	-	-	1,718	3,309	24
Nyatsime River	20,530	-	8,952	-	-	11,578	-
Mukuvisi River	1,674	-	-	-	1,674	-	-
Manyame R. (D/S)	3,994	-	-	-	1,150	2,021	823
Marimba River	1,565	-	-	-	1,565	-	-
Lake Chivero	6,507	-	-	-	4,900	-	1,608
Muzururu River	22,406	17,492	-	-	4,754	-	160
Gwebi River	44,720	43,133	-	-	1,331	-	256
Lake Manyame	10,265	4,566	-	-	1,303	-	4,395
Study Area Total	134,808	65,191	13,720	6,490	21,890	20,250	7,267

Pigs

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	1,280	-	366	844	-	69	-
Ruwa River	915	-	-	516	399	-	-
Seke & Harava D.	265	-	-	-	196	69	0
Nyatsime River	928	-	688	-	-	240	-
Mukuvisi River	191	-	-	-	191	-	-
Manyame R. (D/S)	189	-	-	-	131	42	16
Marimba River	179	-	-	-	179	-	-
Lake Chivero	591	-	-	-	560	-	31
Muzururu River	4,678	4,132	-	-	543	-	3
Gwebi River	10,346	10,189	-	-	152	-	5
Lake Manyame	1,313	1,079	-	-	149	-	86
Study Area Total	20,876	15,400	1,054	1,360	2,500	420	142

Sheep / Goats

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	3,106	-	1,886	782	-	438	-
Ruwa River	1,036	-	-	478	559	-	-
Seke & Harava D.	709	-	-	-	275	433	1
Nyatsime River	5,057	-	3,542	-	-	1,516	-
Mukuvisi River	268	-	-	-	268	-	-
Manyame R. (D/S)	472	-	-	-	184	265	23
Marimba River	250	-	-	-	250	-	-
Lake Chivero	829	-	-	-	783	-	46
Muzururu River	1,876	1,111	-	-	760	-	5
Gwebi River	2,961	2,741	-	-	213	-	7
Lake Manyame	624	290	-	-	208	-	125
Study Area Total	17,188	4,142	5,428	1,260	3,500	2,651	207

Horses

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	91	-	17	75	-	-	-
Ruwa River	237	-	-	45	192	-	-
Seke & Harava D.	94	-	-	-	94	-	0
Nyatsime River	31	-	31	-	-	-	-
Mukuvisi River	92	-	-	-	92	-	-
Manyame R. (D/S)	67	-	-	-	63	-	4
Marimba River	86	-	-	-	86	-	-
Lake Chivero	277	-	-	-	269	-	8
Muzururu River	472	211	-	-	261	-	1
Gwebi River	594	519	-	-	73	-	1
Lake Manyame	149	55	-	-	71	-	22
Study Area Total	2,190	785	48	120	1,200	-	37

Note: Area for livestock raising in Gwebi, Marimba and Mukuvisi of Harare Central is assumed to be 10% of each area because of urbanization.

Table 4.1.11 Pollution Load of Livestock (Present)

(unit: kg/day)

Sub-basin	BOD			COD		T-N		T-P	
	Generated	Concent'd	Cnc'd (dry)	Generated	Concent'd	Generated	Concent'd	Generated	Concent'd
Manyame R. (U/S)	8,244	660	53	16,489	1,319	4,774	382	734	59
Ruwa River	4,113	329	26	8,226	658	2,367	189	372	30
Seke & Harava D.	3,352	268	21	6,704	536	1,963	157	298	24
Nyatsime River	13,655	1,092	87	27,311	2,185	7,995	640	1,204	96
Mukuvisi River	1,147	92	7	2,294	184	666	53	104	8
Manyame R. (D/S)	2,639	211	17	5,278	422	1,547	124	234	19
Marimba River	1,072	86	7	2,145	172	623	50	97	8
Lake Chivero	4,397	352	28	8,794	704	2,562	205	395	32
Muzururu River	15,499	1,240	99	30,998	2,480	8,808	705	1,402	112
Gwebi River	31,010	2,481	198	62,020	4,962	17,531	1,403	2,804	224
Lake Manyame	6,905	552	44	13,810	1,105	3,982	319	617	49
Study Area Total	92,034	7,363	589	184,068	14,725	52,818	4,225	8,262	661

Table 4.1.12 Pollution Load of Farmland / Natural Land

(unit: kg/km2/day, kg/day)

Sub-basin	Area (km2)	BOD 0.795	BOD (dry) 0.0636	COD 11.781	T-N 0.986	T-P 0.082
Manyame R. (U/S)	474.0	377	30	5,584	467	39
Ruwa River	195.0	155	12	2,297	192	16
Seke & Harava D.	115.0	91	7	1,355	113	9
Nyatsime River	580.0	461	37	6,833	572	48
Mukuvisi River	230.0	183	15	2,710	227	19
Manyame R. (D/S)	166.0	132	11	1,956	164	14
Marimba River	215.0	171	14	2,533	212	18
Lake Chivero	255.0	203	16	3,004	251	21
Muzururu River	310.0	246	20	3,652	306	25
Gwebi River	770.0	612	49	9,071	759	63
Lake Manyame	590.0	469	38	6,951	582	48
Study Area Total	3,900.0	3,101	248	45,946	3,845	320

Table 4.1.13 Pollution Load of Solid Waste Dumping Site

Local Authorities	Location	Sub-basin	Area (ha)			Leachate Q (m3/ha/year)		Discharged Pollution Load (mg/l)				Concentrated Pollution Load*** (annual daily average, kg/day)			
						on-going	completed	BOD	COD*	T-N	T-P**				
			Total	on-going	comp-leted	3,300 (m3/year)	2,000 (m3/year)	500	900	250	-				
								Pollution Load Quantity (kg/year)				BOD	COD	T-N	T-P
City of Harare	Warren Park	Marimba R.	12	4	6	13,200	12,000	12,611	22,680	6,300	-	28	50	14	-
City of Harare	Pomona	Gwebi R.	80	1	1	3,300	2,000	2,691	4,770	1,325	-	6	10	3	-
Chitungwiza Mun.	Zengeza	Nyatsime R.	-	2	N/A	6,600	-	3,301	5,940	1,650	-	7	13	4	-
Norton Town	Norton	L. Manayame	6.8	1	N/A	3,300	-	1,654	2,970	825	-	4	7	2	-
Ruwa Local Board	Chiremba	Ruwa R.	0.5	0.5	-	1,650	-	826	1,485	413	-	2	3	1	-
Ruwa Local Board	Epworth ('96 open)	Ruwa R.	0.8	0	-	0	-	0	0	0	-	0	0	0	-

* : COD_{Cr} (= COD_{Mn} x 2.0)

** : T-P is negligible.

***: Concentration Ratio 80% (BOD during dry season: 0%)

4.1.4 Contribution of Zengeza STW

Present status of the STWs in the Study basin is as presented in Table 4.1.2. The Zengeza STW is discharging the effluent of about 33,000 m^3/day (average in dry season) or 36,000 m^3/day (annual average). These amounts are equivalent to 16 to 17 % of total sewage effluent flow of the STWs in the study basin.

Because of low treatment efficiency caused by overload, pollution load of effluent from the Zengeza STW occupies higher share in those of all STWs, i.e. 18 to 42 %.

With regard to concentrated pollution load, that of the Zengeza STW occupies 35 to 69 % of total concentrated load discharged from STWs (0 % for BOD because of no discharge during dry season). These high contribution percentage is due to irrigation disposal of low quality effluent in other STWs.

4.2 Pollution Load Run-off Model with Water Quality Checking Points

4.2.1 Rivers

(1) River Flow Run-off Model

As stated previously, the pollution analysis of rivers was conducted in terms of BOD_5 under the dry season condition. The river flow to be adopted in the analysis is those in dry season at present derived based on average figures in dry season of last 10 years. Applying those flow, river flow run-off model was established.

(2) Pollution Load Run-off Model

The concentrated BOD load calculated in the previous section is summarised in Table 4.2.1. Most of the concentrated load derives from sewage treatment works because of high sewerage service coverage ratio and little rainfall during dry season.

Pollution load presented in Table 4.2.1 was allocated to each pollution load discharging point presented in Figure 4.2.1 as shown in Table 4.2.2. Pollution load run-off model for present pollution analysis of rivers was formulated as presented in Figure 4.2.1.

Table 4.2.1 Concentrated Pollution Load by Sub-basin by Pollution Source (Present, BOD, Dry Season)

(kg/day)

Water Quality Checking Points	Sub-basin	Dom./Com./Ins. Sewage			Industrial	Livestock	Natural Pollution	Solid Waste Dumping	Water Treatment Works***	Total
		Sewered	Unsewered	Total	Unsewered**					
C_{R1}	1. Manyame R. (Upstream)	-	100	100	-	53	30	-	-	183
R_{R1}	2. Ruwa River	53	205	258	-	26	12	-	-	297
C_{L1}	3. Seke & Harava Dams	-	48	48	-	21	7	-	-	77
R_{R2}	4. Nyatsime River	-	62	62	57	87	37	-	-	243
R_{R4}	5. Mukuvisi River	456	74	530	29	7	15	-	-	581
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	-	41	41	-	17	11	-	3	71
R_{R5}	7. Marimba River	550	9	559	-	7	14	-	-	580
C_{L2}	8. Lake Chivero	896	28	924	-	28	16	-	-	968
R_{R6}	9. Muzururu River	-	48	48	-	99	20	-	-	167
R_{R7}	10. Gwebi River	8	114	122	-	198	49	-	-	369
C_{L3}	11. Lake Manyame	112	64	176	628	44	38	-	260	1,146
	Grand Total	2,075	793	2,868	714	589	248	-	263	4,682

*: Before confluence of Mukuvisi River.

**: Pollution load of industries in sewered area is counted as a part of domestic pollution load of sewered area.

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;	20,500	m3/day		
BOD concentration of intake water;	1.6	mg/l	(Seke Dam, Avg. COD=	20.63
Concentrated BOD load;	3	kg/day	(to Manyame river (downstream))	

Morton Jaffray WTW;

Amount of water intake;	164,300	m3/day	(Lake Chivero)	
BOD concentration of intake water;	2.4	mg/l	(Lake Chivero, Avg. COD=	25.30
Amount of water intake;	225,900	m3/day	(Lake Manyame)	
BOD concentration of intake water;	2.0	mg/l	(Lake Manyame, Avg. COD=	22.70
Intake BOD load;	839	kg/day		
from Lake Chivero;	397	kg/day		
from Lake Manyame;	443	kg/day		
Concentrated BOD load;	260	kg/day	(to Lake Manyame)	

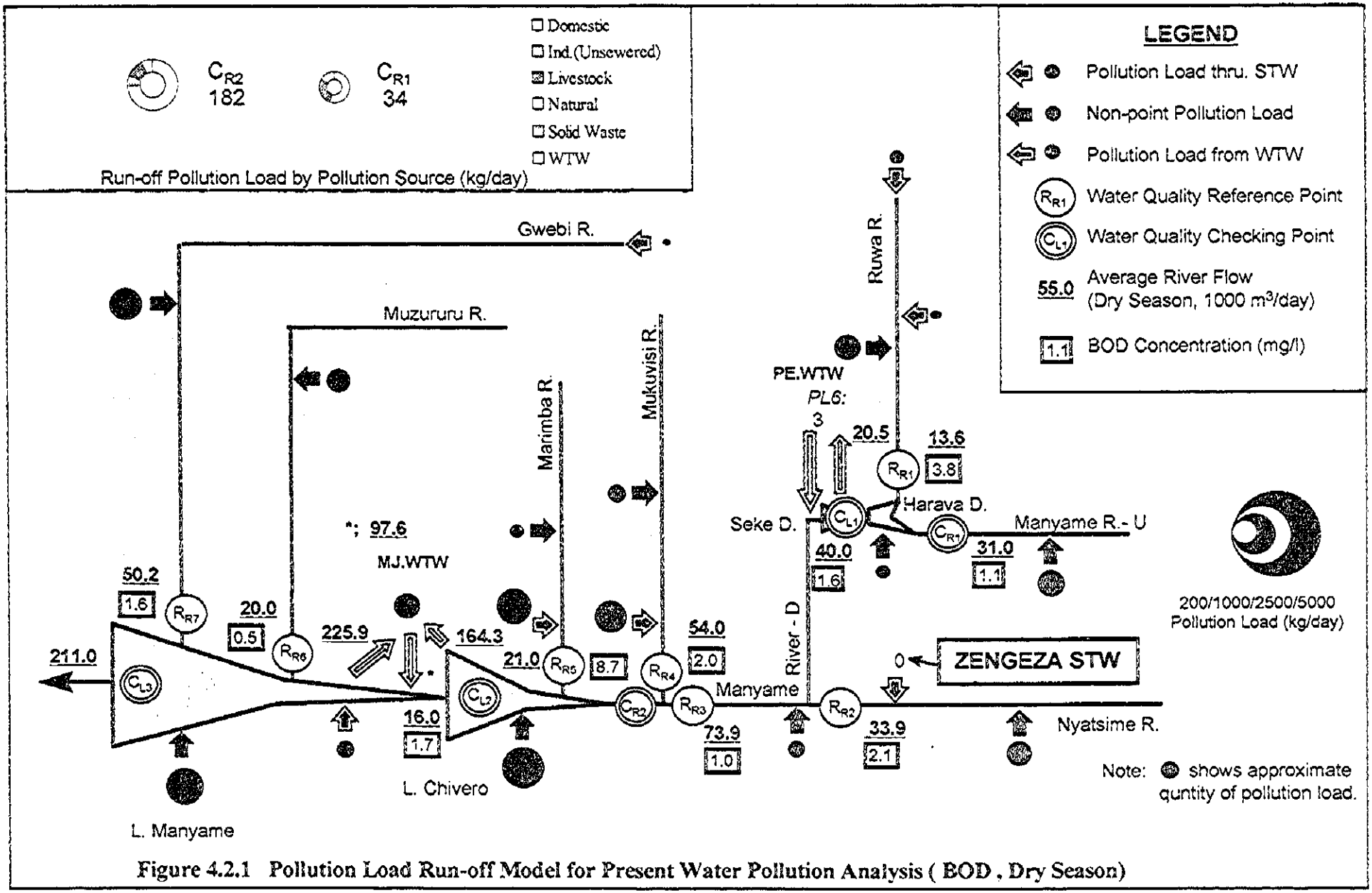

Figure 4.2.1 Pollution Load Run-off Model for Present Water Pollution Analysis (BOD , Dry Season)

Table 4.2.2 Concentrated Pollution Load by Sub-basin (Present, BOD, Dry Season)

(kg/day, km)

Water Quality Checking Points	Sub-basin	PL No.	Quantity	Flow Length	PL No.	Quantity	Flow Length	PL No.	Quantity	Flow Length	Total
C_{R1}	1. Manyame R. (Upstream)	PL1	183	23							183
R_{R1}	2. Ruwa River	PL2	33	24	PL3	20	14	PL4	244	12	297
C_{L1}	3. Seke & Harava Dams	PL5	77	-							77
R_{R2}	4. Nyatsime River	PL7	243	28	PL8	-	8				243
R_{R4}	5. Mukuvisi River	PL10	125	18	PL11	456	5				581
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	PL6**	3	24	PL9	68	12				71
R_{R5}	7. Marimba River	PL12	30	12	PL13	550	8				580
C_{L2}	8. Lake Chivero	PL14	968	-							968
R_{R6}	9. Muzururu River	PL16	167	17							167
R_{R7}	10. Gwebi River	PL17	8	83	PL18	361	41				369
C_{L3}	11. Lake Manyame	PL15***	260	-	PL19	112	-	PL20	774	-	1,146
Grand Total											4,682

*: Before confluence of Mukuvisi River.

**: Pollution load from Prince Edward WTW

***: Pollution load from Morton Jaffray WTW

4.2.2 Lakes/Dams

(1) Water Balance of Lakes/Dams

The pollution analysis of lakes was conducted under the annual average condition. The water balance of lakes to be adopted in the analysis is those derived based on annual average figures in last 10 years. Applying those water balance, run-off model was established.

(2) Pollution Load Run-off Model

The concentrated pollution calculated in the previous section are summarised in Tables 4.2.3 to 4.2.5 for COD, T-N and T-P, respectively. The concentrated loads caused by livestock and natural pollution occupies large share of the total load. These pollution loads were assumed to reach to the subject lakes without reduction (purification) during flow in main river because of following reasons:

a. Purification function of rivers identified in the pollution analysis is derived for dry season condition. River flows used in the pollution analysis of lakes are values in annual average condition which are almost three times of those in dry season. Therefore, sedimentation which is expected as a main function of purification in dry season is not expectable.
b. Pollution load substances settled during dry season is flushed out during rainy season.
c. Some extent of pollution load reduction ratio is assumed in the calculation before reaching to rivers. It may be regarded that inaccuracy of assumption of those reduction ratio is adjusted in the calculation of self-purification coefficients of lakes.

Using these pollution load and the water balance, pollution load run-off models for present pollution analysis of lakes are formulated as presented in Figures 4.2.2 to 4.2.4 for COD, T-N and T-P, respectively.

4.2.3 Contribution of Zengeza STW

Tables 4.2.6 and 4.2.7 present degree of contribution of the pollution load (PL) discharged from the Zengeza STW. At the reference point R_{R2} of the Nyatsime River, PL from the Zengeza STW occupies more than a half of the run-off PL in terms of COD, T-N and T-P at present. Even in the total inflow PL of the Lake Chivero, it contributes more than 20 %

Table 4.2.3 Concentrated Pollution Load by Sub-basin by Pollution Source (Present, COD)

(kg/day)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial	Livestock	Natural Pollution	Solid Waste Dumping	Water Treatment Works***	Total
		Sewered	Unsewered	Total	Unsewered**					
C_{R1}	1. Manyame R. (Upstream)	-	199	199	-	1,319	5,584	-	-	7,102
R_{R1}	2. Ruwa River	168	409	577	-	658	2,297	3	-	3,536
C_{L1}	3. Seke & Harava Dams	-	97	97	-	536	1,355	-	-	1,988
R_{R2}	4. Nyatsime River	9,828	124	9,952	136	2,185	6,833	13	-	19,119
R_{R4}	5. Mukuvisi River	2,783	148	2,931	82	184	2,710	-	-	5,906
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	-	82	82	-	422	1,956	-	34	2,494
R_{R5}	7. Marimba River	2,350	18	2,368	-	172	2,533	50	-	5,122
C_{L2}	8. Lake Chivero	1,799	57	1,856	-	704	3,004	-	-	5,564
R_{R6}	9. Muzururu River	-	96	96	-	2,480	3,652	-	-	6,228
R_{R7}	10. Gwebi River	26	227	253	-	4,962	9,071	10	-	14,296
C_{L3}	11. Lake Manyame	257	129	386	2,669	1,105	6,951	7	9,285	20,402
	Grand Total	17,211	1,586	18,797	2,886	14,725	45,946	83	9,319	91,756

*: Before confluence of Mukuvisi River.

**: Pollution load of industries in sewered area is counted as a part of domestic pollution load of sewered area.

***: Pollution load of Water Treatment Works

Prince Edward WTW;	Amount of water intake;	20,500	m3/day	
	COD concentration of intake water;	20.63	mg/l	(Seke Dam)
	Concentrated COD load;	34	kg/day	(to Manyame river (downstream))
Morton Jaffray WTW;	Amount of water intake;	164,300	m3/day	(Lake Chivero)
	COD concentration of intake water;	25.30	mg/l	(do)
	Amount of water intake;	225,900	m3/day	(Lake Manyame)
	COD concentration of intake water;	22.70	mg/l	(do)
	Intake COD load;	9,285	kg/day	
	from Lake Chivero;	4,157	kg/day	
	from Lake Manyame;	5,128	kg/day	
	Concentrated COD load;	2,878	kg/day	(to Lake Manyame)

Table 4.2.4 Concentrated Pollution Load by Sub-basin by Pollution Source (Present, T-N)

(kg/day)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial	Livestock	Natural Pollution	Solid Waste Dumping	Water Treatment Works***	Total
		Sewered	Unsewered	Total	Unsewered**					
C_{R1}	1. Manyame R. (Upstream)	-	25	25	-	382	467	-	-	874
R_{R1}	2. Ruwa River	37	51	88	-	189	192	1	-	471
C_{L1}	3. Seke & Harava Dams	-	12	12	-	157	113	-	-	282
R_{R2}	4. Nyatsime River	2,166	16	2,182	2	640	572	4	-	3,399
R_{R4}	5. Mukuvisi River	369	19	388	1	53	227	-	-	669
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	-	10	10	-	124	164	-	1	298
R_{R5}	7. Marimba River	268	2	270	-	50	212	14	-	546
C_{L2}	8. Lake Chivero	260	7	267	-	205	251	-	-	723
R_{R6}	9. Muzururu River	-	12	12	-	705	306	-	-	1,022
R_{R7}	10. Gwebi River	6	28	34	-	1,403	759	3	-	2,199
C_{L3}	11. Lake Manyame	14	16	30	10	319	582	2	254	1,196
Grand Total		3,120	198	3,318	13	4,225	3,845	23	255	11,680

*: Before confluence of Mukuvisi River.

**: Pollution load of industries in sewered area is counted as a part of domestic pollution load of sewered area.

***: Pollution load of Water Treatment Works

Prince Edward WTW;	Amount of water intake;	20,500	m3/day	
	T-N concentration of intake water;	0.645	mg/l	(Seke Dam)
	Concentrated T-N load;	1	kg/day	(to Manyame river (downstream))
Morton Jaffray WTW;	Amount of water intake;	164,300	m3/day	(Lake Chivero)
	T-N concentration of intake water;	0.512	mg/l	(do)
	Amount of water intake;	225,900	m3/day	(Lake Manyame)
	T-N concentration of intake water;	0.750	mg/l	(do)
	Intake T-N load;	254	kg/day	
	from Lake Chivero;	84	kg/day	
	from Lake Manyame;	169	kg/day	
	Concentrated T-N load;	79	kg/day	(to Lake Manyame)

Table 4.2.5 Concentrated Pollution Load by Sub-basin by Pollution Source (Present, T-P)

(kg/day)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial	Livestock	Natural Pollution	Solid Waste Dumping	Water Treatment Works***	Total
		Sewered	Unsewered	Total	Unsewered**					
C_{R1}	1. Manyame R. (Upstream)	-	3	3	-	59	39	-	-	101
R_{R1}	2. Ruwa River	5	6	11	-	30	16	-	-	57
C_{L1}	3. Seke & Harava Dams	-	1	1	-	24	9	-	-	34
R_{R2}	4. Nyatsime River	133	2	135	1	96	48	-	-	280
R_{R4}	5. Mukuvisi River	115	2	117	0	8	19	-	-	144
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	-	1	1	-	19	14	-	0	33
R_{R5}	7. Marimba River	70	-	70	-	8	18	-	-	95
C_{L2}	8. Lake Chivero	48	1	49	-	32	21	-	-	102
R_{R6}	9. Muzururu River	-	1	1	-	112	25	-	-	139
R_{R7}	10. Gwebi River	1	3	4	-	224	63	-	-	291
C_{L3}	11. Lake Manyame	3	2	5	2	49	48	-	54	159
	Grand Total	375	22	397	3	661	320	-	54	1,435

*: Before confluence of Mukuvisi River.

**: Pollution load of industries in sewered area is counted as a part of domestic pollution load of sewered area.

***: Pollution load of Water Treatment Works

Prince Edward WTW;	Amount of water intake;	20,500	m3/day	
	T-P concentration of intake water;	0.070	mg/l	(Seke Dam)
	Concentrated T-P load;	0	kg/day	(to Manyame river (downstream))
Morton Jaffray WTW;	Amount of water intake;	164,300	m3/day	(Lake Chivero)
	T-P concentration of intake water;	0.270	mg/l	(do)
	Amount of water intake;	225,900	m3/day	(Lake Manyame)
	T-P concentration of intake water;	0.044	mg/l	(do)
	Intake T-P load;	54	kg/day	
	from Lake Chivero;	44	kg/day	
	from Lake Manyame;	10	kg/day	
	Concentrated T-P load;	17	kg/day	(to Lake Manyame)

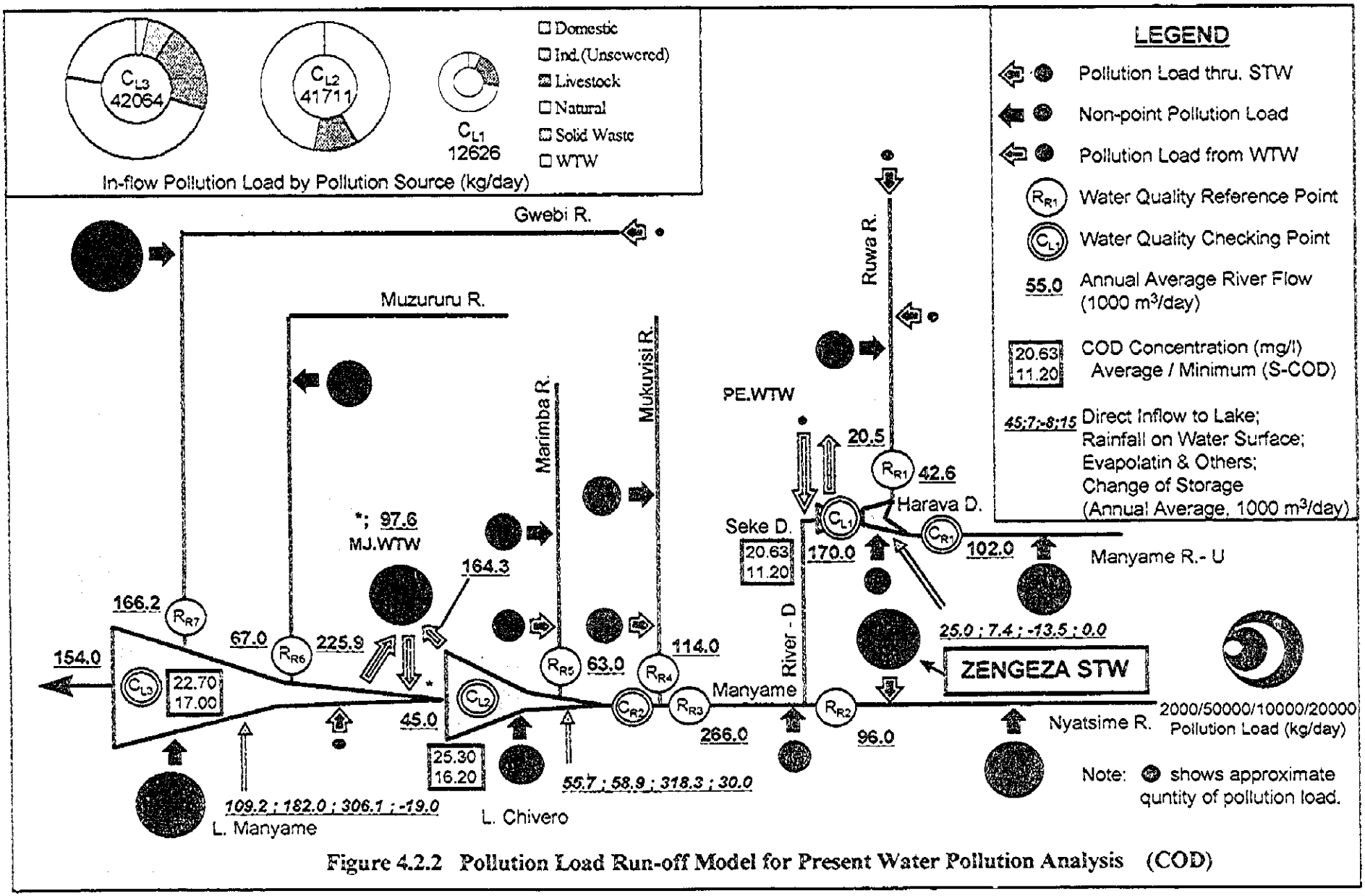

Figure 4.2.2 Pollution Load Run-off Model for Present Water Pollution Analysis (COD)

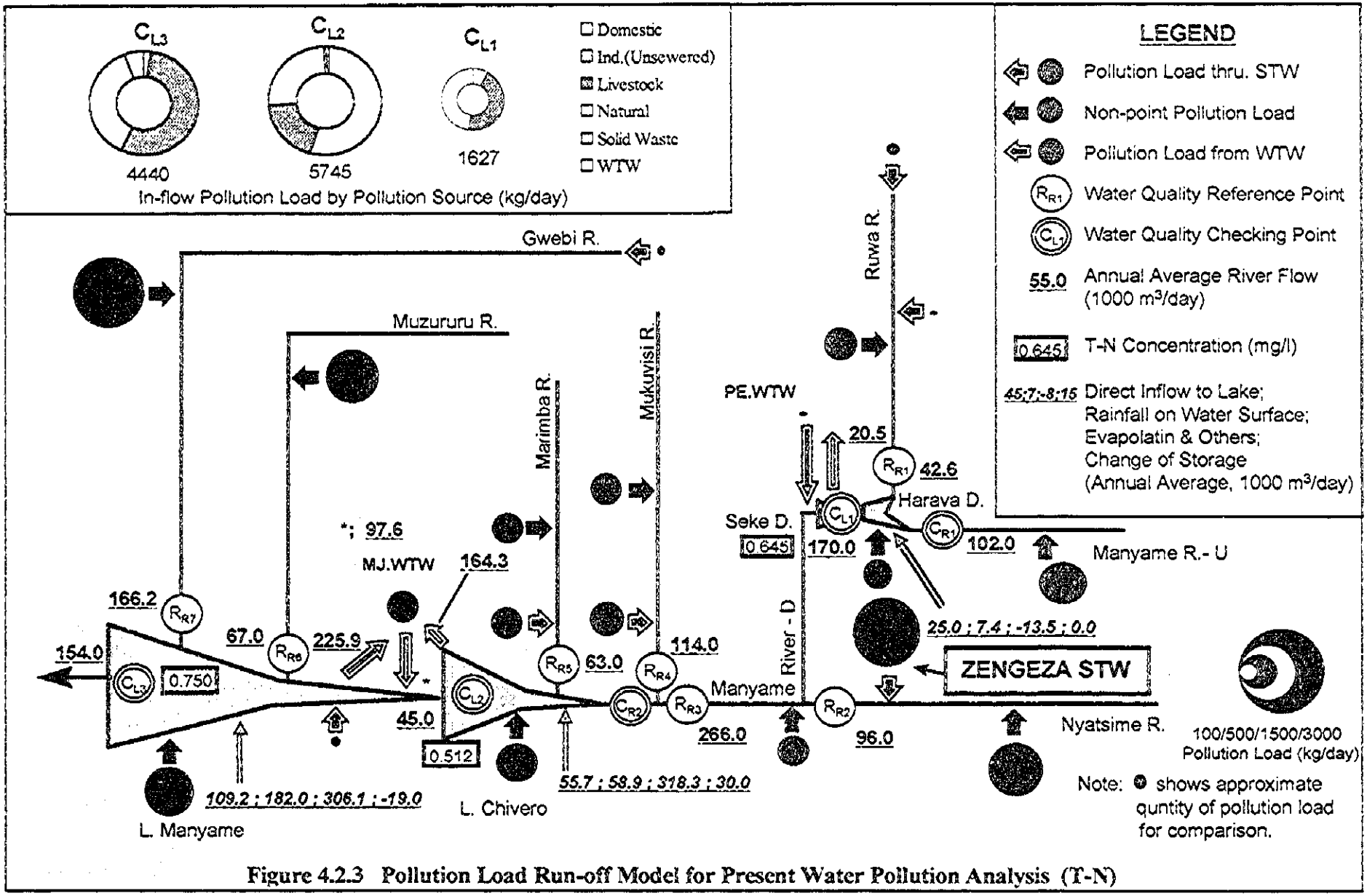

Figure 4.2.3 Pollution Load Run-off Model for Present Water Pollution Analysis (T-N)

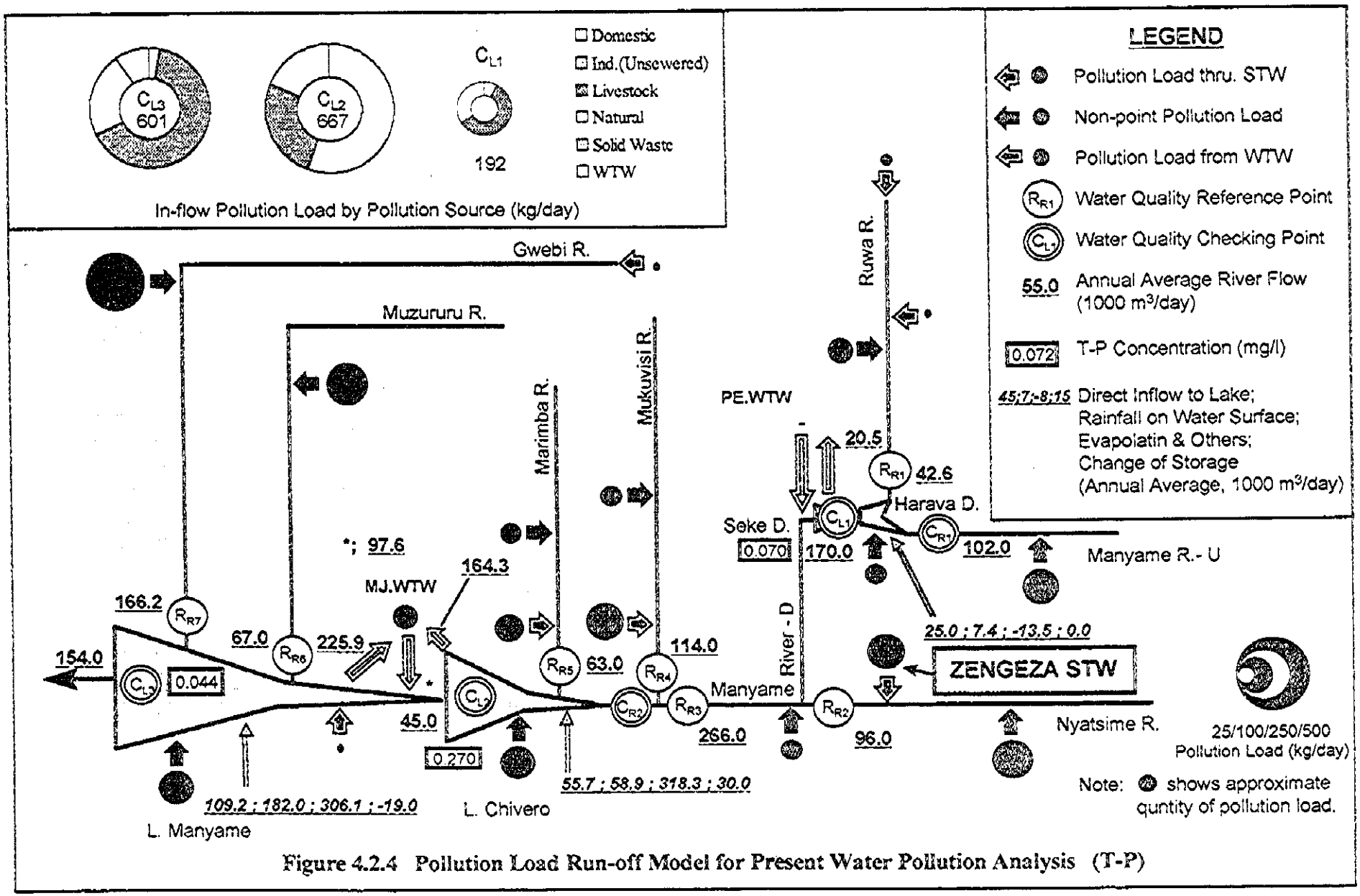

Figure 4.2.4 Pollution Load Run-off Model for Present Water Pollution Analysis (T-P)

Table 4.2.6 Contribution of Zengeza Sewage Treatment Works (Scenario 1)

Present Pollution Load (kg/day)

	PL of Zengeza STW			Nyatsime River Run-off PL (RR2)			Manyame River D/S Run-off PL (CR2)			Lake Chivero Inflow PL (CL2)		
	Inflow PL.	Effluent PL.	Concent.PL	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%
BOD	19,437	4,303	0	0	71	0%	0	74	0%	0	1,333	0%
COD	38,874	19,656	9,828	9,828	19,119	51%	9,828	25,120	39%	9,828	41,711	24%
T-N	4,863	4,332	2,166	2,166	3,399	64%	2,166	3,807	57%	2,166	5,745	38%
T-P	531	266	133	133	280	48%	133	325	41%	133	667	20%

Pollution Load in 2005 (kg/day)

	PL of Zengeza STW			Nyatsime River Run-off PL (RR2)			Manyame River D/S Run-off PL (CR2)			Lake Chivero Inflow PL (CL2)		
	Inflow PL.	Effluent PL.	Concent.PL	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%
BOD	21,992	1,829	370	111	171	65%	39	1,909	2%	39	2,891	1%
COD	44,611	5,941	1,502	1,502	10,686	14%	1,502	30,944	5%	1,502	71,335	2%
T-N	5,151	2,739	347	347	1,582	22%	347	2,675	13%	347	8,849	4%
T-P	580	318	49	49	195	25%	49	402	12%	49	1,270	4%

Table 4.2.7 Contribution of Zengeza Sewage Treatment Works (Scenario 2)

Present Pollution Load (kg/day)

	PL of Zengeza STW			Nyatsime River Run-off PL (RR2)			Manyame River D/S Run-off PL (CR2)			Lake Chivero Inflow PL (CL2)		
	Inflow PL.	Effluent PL.	Concent.PL	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%
BOD	19,437	4,303	0	0	71	0%	0	74	0%	0	1,333	0%
COD	38,874	19,656	9,828	9,828	19,119	51%	9,828	25,120	39%	9,828	41,711	24%
T-N	4,863	4,332	2,166	2,166	3,399	64%	2,166	3,807	57%	2,166	5,745	38%
T-P	531	266	133	133	280	48%	133	325	41%	133	667	20%

Pollution Load in 2005 (kg/day)

	PL of Zengeza STW			Nyatsime River Run-off PL (RR2)			Manyame River D/S Run-off PL (CR2)			Lake Chivero Inflow PL (CL2)		
	Inflow PL.	Effluent PL.	Concent.PL	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%	Zengeza Orig.	Total PL	%
BOD	32,593	2,343	915	275	326	84%	96	1,703	6%	96	2,891	3%
COD	65,814	8,024	3,697	3,697	12,831	29%	3,697	31,531	12%	3,697	65,852	6%
T-N	7,803	3,271	877	877	2,106	42%	877	2,827	31%	877	7,577	12%
T-P	869	389	122	122	267	46%	122	424	29%	122	1,097	11%

As mentioned above, contribution of pollution load from the Zengeza STW is quite large and this fact implies necessity of improvement of the Zengeza STW and its potentiality for water pollution improvement.

4.3 Water Pollution Analysis

4.3.1 General

In the pollution analysis of rivers, Pollution Load Remaining Ratios of respective rivers were identified in terms of BOD_5 under the condition of dry season. Those ratios are adopted in future pollution analysis. While, for pollution analysis of lakes, Self-purification Coefficients (Vollenweider Model) of respective lakes were computed in terms of T-N, T-P and COD under the annual average condition. Those coefficients are also adopted in future pollution analysis.

4.3.2 Rivers

The self-purification coefficient of river is usually computed in the similar pollution analysis to express the self-purification capacity of rivers referring to pollution load discharge location (refer to Figure 4.2.1). However, detailed data on time of flow, flow rate, water quality for each subject sub-section of rivers obtained through frequent surveys are essential for those analysis. Because those kind of data in the study area is not available sufficiently and allotted period for the study is limited, Pollution Load Remaining Ratios of each river were computed instead.

Pollution load remaining ratios of respective rivers are computed using pollution load run-off model as presented in Table 4.3.1. Muzururu River shows comparatively high self-purification capacity, i.e. 6% of pollution load remaining ratios, while Manyame River (downstream) and Marimba River show rather low self-purification capacity, i.e. 36% and 32%, respectively.

These remaining ratios imply not only self-purification capacity of the river, but also adjustment factor on inaccurate assumptions of concentration ratios. Pollution load remaining ratios in application to future pollution analysis are modified as presented in Table 4.3.2.

Table 4.3.1 Pollution Load Remaining Ratio of Rivers (Present, BOD, Dry Season)

Water Quality Checking Points	Sub-basin	Run-off BOD Load at Upstream (kg/day)	Concentrated BOD Load in Sub-basin (kg/day)	Total BOD Load (kg/day)	BOD Concentration at Downstream (mg/l)	Flow Rate at Downstream (m3/day)	Run-off BOD Load at Downstream (kg/day)	Pollution Load Remaining Ratio (%)
C_{R1}	1. Manyame R. (Upstream)	0	183	183	1.1	31,000	34	18.6%
R_{R1}	2. Ruwa River	0	297	297	3.8	13,600	52	17.4%
C_{L1}	3. Seke & Harava Dams	86	77	163	1.6	40,000	64	-
R_{R2}	4. Nyatsime River	0	243	243	2.1	33,900	71	29.3%
R_{R4}	5. Mukuvisi River	0	581	581	2.0	54,000	108	18.6%
C_{R2} R_{R3}*	6. Manyame R. (Downstream)	135	71	206	1.0	73,900	74	35.9%
R_{R5}	7. Marimba River	0	580	580	8.7	21,000	183	31.5%
C_{L2}	8. Lake Chivero	365	968	1,333	2.4	16,000	39	-
R_{R6}	9. Muzururu River	0	167	167	0.5	20,000	10	6.0%
R_{R7}	10. Gwebi River	0	369	369	1.6	50,200	80	21.7%
C_{L3}	11. Lake Manyame	129	1,146	1,275	2.0	211,000	413	-

Note: 1. Before confluence of Mukuvisi River.

2. Run-off BOD load at upstream for the Manyame River (downstream) is the pollution load from Prince Edward WTW.

3. Total BOD Load of Manyame River (downstream) includes Run-off Load from Nyatsime River.

Table 4.3.3 Water Pollution Analysis of Lakes (Present, Seke and Harava Dams)

Volume of Dams:		12,406,000		m3
Inflow Water Volume:		190,500		m3/day
Rivers;	Manyame;		102,000	m3/day
	Ruwa;		42,600	m3/day
Direct Inflow;			25,000	m3/day
Rainfall;			7,400	m3/day
Evaporation & Others;			13,500	m3/day
Outflow Water Volume:		190,500		m3/day
Manyame River;			170,000	m3/day
Prince Edward WTW;			20,500	m3/day

Detention Time of Dam Lake: 65.1 days

Pollution Load Inflow: (kg/day)

	T-N	T-P	COD
Manyame	874	101	7,102
Ruwa	471	57	3,536
Direct	282	34	1,988
Total	1,627	192	12,626

Present Water Quality: (mg/l)

T-N	T-P	COD	Min. COD (soluble COD)
0.645	0.070	20.63	11.20

Formula for Pollution Analysis: (Vollenweider Model)

$N = L(N) / ((rw+sN) \times V)$

$P = L(P) / ((rw+sP) \times V)$

$COD = L(COD) / ((rw+sCOD) \times V) + DCOD$

where;	N:	Concentration of Nitrogen of lake (g/m3)	=	0.645
	P:	Concentration of Phosphorus of lake (g/m3)	=	0.070
	COD:	Concentration of COD of lake (g/m3)	=	20.63
	L(N):	Quantity of inflow Nitrogen to lake (g/day)	=	1,627,000
	L(P):	Quantity of inflow Phosphorus to lake (g/day)	=	192,000
	L(COD):	Quantity of inflow COD to lake (g/day)	=	12,626,000
	rw:	Rate of change of water (1/day)	=	0.015355
	sN:	Self-purification (reduction) coefficient for Nitrogen		
	sP:	Self-purification (reduction) coefficient for Phosphorus		
	sCOD:	Self-purification (reduction) coefficient for inflow COD		
	V:	Volume of lake (m3)	=	12,406,000
	DCOD:	Secondary produced COD		

Computation of Self-purification Coefficients:

$sN = (L(N) / (N \times V)) - rw =$ **0.18797**

$sP = (L(P) / (P \times V)) - rw =$ **0.20574**

$sCOD = (L(COD) / (COD \times V)) - rw =$ **0.07551** (adopted Min.COD)

Computation of Conversion Rate for DCOD:

$DCOD = a(N) \times T\text{-}N \times 17.73$ or $a(P) \times T\text{-}P \times 128.70$

where;	a(N);	Conversion rate of Nitrogen to DCOD
	17.73;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity
	a(P);	Conversion rate of Phosphorus to DCOD
	128.70;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit phosphorus quantity
	DCOD;	Average COD - Minimum COD (COD without effect of phytoplankton)

$a(N) = ((COD - Min.COD) / (T\text{-}N \times 17.73))$

$= 82.5\%$

$a(P) = ((COD - Min.COD) / (T\text{-}P \times 128.70))$

$= 104.7\%$

$N / P = 9.2$ < 20 and $P = 0.07$ > 0.02

Nitrogen is regarded to be the Restriction Factor for secondary production of COD.

Conversion Rate of a(N) will be adopted for Future Pollution Analysis.

Table 4.3.4 Water Pollution Analysis of Lakes (Present, Lake Chivero)

Volume of Dams:		257,181,000		m3
Inflow Water Volume:		239,300		m3/day
Rivers;	Manyame;		266,000	m3/day
	Mukuvisi;		114,000	m3/day
	Marimba;		63,000	m3/day
Direct Inflow;			55,700	m3/day
Rainfall;			58,900	m3/day
Evaporation & Others;			(318,300)	m3/day
Outflow Water Volume:		239,300		m3/day
Lake Manyame;			45,000	m3/day
Morton Jaffray WTW;			164,300	m3/day
Water Level Increase:			30,000	m3/day
Detention Time of Lake:		1,075		days

Pollution Load Inflow: (kg/day)

	T-N	T-P	COD	
Manyame	3,807	325	25,120	Seke + Nyatsime + Manyame
Mukuvisi	669	144	5,906	
Marimba	546	95	5,122	
Direct;	723	102	5,564	
Total	5,745	667	41,711	

Present Water Quality: (mg/l)

T-N	T-P	COD	Min. COD (soluble COD)
0.512	0.270	25.30	16.20

Formula for Pollution Analysis: (Vollenweider Model)

N = L(N) / ((rw+sN) x V)

P = L(P) / ((rw+sP) x V)

COD = L(COD) / ((rw+sCOD) x V) + DCOD

where;	N:	Concentration of Nitrogen of lake (g/m3)	=	0.512
	P:	Concentration of Phosphorus of lake (g/m3)	=	0.270
	COD:	Concentration of COD of lake (g/m3)	=	25.30
	L(N):	Quantity of inflow Nitrogen to lake (g/day)	=	5,745,000
	L(P):	Quantity of inflow Phosphorus to lake (g/day)	=	667,000
	L(COD):	Quantity of inflow COD to lake (g/day)	=	41,711,000
	rw:	Rate of change of water (1/day)	=	0.000930
	sN:	Self-purification (reduction) coefficient for Nitrogen		
	sP:	Self-purification (reduction) coefficient for Phosphorus		
	sCOD:	Self-purification (reduction) coefficient for inflow COD		
	V:	Volume of lake (m3)	=	257,181,000
	DCOD:	Secondary production COD		

Computation of Self-purification Coefficients:

sN = (L(N) / (N x V)) - rw = 0.04270

sP = (L(P) / (P x V)) - rw = 0.00868

sCOD = (L(COD) / (COD x V)) - rw = 0.00908 (adopted Min.COD)

Computation of Conversion Rate for DCOD:

DCOD = a(N) x T-N x 17.73 or a(P) x T-P x 128.70

where;	a(N);	Conversion rate of Nitrogen to DCOD
	17.73;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity
	a(P);	Conversion rate of Phosphorus to DCOD
	128.70;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit phosphorus quantity
	DCOD;	Average COD - Minimum COD (COD without effect of phytoplankton)

a(N) = ((COD - Min.COD) / (T-N x 17.73))
= 100.2%

a(P) = ((COD - Min.COD) / (T-P x 128.70))
= 26.2%

N / P = 1.9 < 20 and P = 0.27 >0.02

Nitrogen is regarded to be the Restriction Factor for secondary production of COD.

Conversion Rate of a(N) will be adopted for Future Pollution Analysis.

Table 4.3.5 Water Pollution Analysis of Lakes (Present, Lake Manyame)

Volume of Lake:		480,236,000		m3
Inflow Water Volume:		360,900		m3/day
Rivers;	Lake Chivero;		45,000	m3/day
	Muzururu		67,000	m3/day
	Gwebi		166,200	m3/day
Direct Inflow;			109,200	m3/day
Rainfall;			182,000	m3/day
Evaporation & Others;			(306,100)	m3/day
Morton Jaffray WTW;			97,600	m3/day
Outflow Water Volume:		360,900		m3/day
Manyame River;			154,000	m3/day
Morton Jaffray WTW;			225,900	m3/day
Water Level Decrease:			(19,000)	m3/day
Detention Time of Lake:		1,331		days

Pollution Load Inflow: (kg/day)

	T-N	T-P	COD
Lake Chivero;	23	12	1,139
Muzururu	1,022	139	6,228
Gwebi	2,199	291	14,296
Direct;	1,196	159	20,402
Total	4,417	601	42,064

Present Water Quality: (mg/l)

T-N	T-P	COD	Min. COD (soluble COD)
0.750	0.044	22.70	17.00

Formula for Pollution Analysis: (Vollenweider Model)

$N = L(N) / ((rw+sN) \times V)$

$P = L(P) / ((rw+sP) \times V)$

$COD = L(COD) / ((rw+sCOD) \times V) + DCOD$

where;	N:	Concentration of Nitrogen of lake (g/m3)	=	0.750
	P:	Concentration of Phosphorus of lake (g/m3)	=	0.044
	COD:	Concentration of COD of lake (g/m3)	=	22.70
	L(N):	Quantity of inflow Nitrogen to lake (g/day)	=	4,417,000
	L(P):	Quantity of inflow Phosphorus to lake (g/day)	=	601,000
	L(COD):	Quantity of inflow COD to lake (g/day)	=	42,064,000
	rw:	Rate of change of water (1/day)	=	0.000752
	sN:	Self-purification (reduction) coefficient for Nitrogen		
	sP:	Self-purification (reduction) coefficient for Phosphorus		
	sCOD:	Self-purification (reduction) coefficient for inflow COD		
	V:	Volume of lake (m3)	=	480,236,000
	DCOD:	Secondary production COD		

Computation of Self-purification Coefficients:

$sN = (L(N) / (N \times V)) - rw =$ **0.01151**

$sP = (L(P) / (P \times V)) - rw =$ **0.02769**

$sCOD = (L(COD) / (COD \times V)) - rw =$ **0.00440** (adopted Min.COD)

Computation of Conversion Rate for DCOD:

$DCOD = a(N) \times T\text{-}N \times 17.73$ or $a(P) \times T\text{-}P \times 128.70$

where;	a(N);	Conversion rate of Nitrogen to DCOD
	17.73;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity
	a(P);	Conversion rate of Phosphorus to DCOD
	128.70;	Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit phosphorus quantity
	DCOD;	Average COD - Minimum COD (COD without effect of phytoplankton)

$a(N) = ((COD - Min.COD) / (T\text{-}N \times 17.73))$

$= 42.9\%$

$a(P) = ((COD - Min.COD) / (T\text{-}P \times 128.70))$

$= 100.7\%$

$N / P = 17.0$ < 20 and $P = 0.04$ > 0.02

Nitrogen is regarded to be the Restriction Factor for secondary production of COD.

Conversion Rate of a(N) will be adopted for Future Pollution Analysis.

Table 4.3.2 Pollution Load Remaining Ratio of Rivers

River	Calculated PLRR	Applied
Manyame R. (upstream)	18.6%	20%
Ruwa R.	17.4%	20%
Nyatsime R.	29.3%	30%
Mukuvisi R.	18.6%	20%
Manyame R. (downstream)	35.9%	35%
Marimba R.	31.5%	30%
Muzururu R.	6.0%	10%
Gwebi R.	21.7%	20%

4.3.3 Lakes/Dams

Based on the pollution load run-off models presented in Figures 4.2.3 to 4.2.5, self-purification coefficients of lakes for each pollutant were computed as presented in Tables 4.3.3 to 4.3.5. Calculation results are summarised in Table 4.3.6. These values will be adopted for future pollution analysis of lakes.

Table 4.3.6 Self-purification Coefficients of Lakes

Coefficients*	Seke & Harava Dams	Lake Chivero	Lake Manyame
σN	0.18797	0.04270	0.01151
σP	0.20574	0.00868	0.02769
σCOD	0.07551	0.00908	0.00440
α(N)	82.5%	100.2%	42.9%

*: Self-purification coefficients in Vollenweider Model formula (refer to Tables 4.3.3 to 4.3.5)

5. Future Water Pollution Analysis

5.1 Pollution Load

5.1.1 Domestic/Commercial/Institutional Sewage

The projected population for the year 2005 were arranged to those in sewered and unsewered areas for two scenarios as shown in Table 5.1.1. Wastewater quantity by sub-basin were calculated for each scenario as summarised in Table 5.1.2. Generated and discharged pollution load were calculated by sewered/unsewered area applying unit pollution load of domestic sewage.

The pollution load collected from the sewered area is discharged at sewage treatment works. The discharged pollution load is calculated using planed treatment efficiency. Calculation

Table 5.1.1 Population by Sewered/Unsewered by Sub-basin

Scenario 1, Year 2005

Sub-basin/District	Total Population		Projected	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B	-	34,679	0.0%	-	-	-	-	-	-	34,679	34,679
2. Ruwa River S/B	232,426	12,502	94.9%	11,328	810	220,288	232,426	-	-	12,502	12,502
3. Seke & Harava Dams S/B	53,813	4,085	92.9%	3,960	-	49,853	53,813	-	-	4,085	4,085
4. Nyatsime River S/B	370,675	21,638	94.5%	-	15,075	355,600	370,675	-	-	21,638	21,638
5. Mukuvisi River S/B	786,247	52,132	93.8%	42,451	98,029	645,768	786,247	49,356	-	2,776	52,132
6. Manyame River (D.stream) S/B	202,610	5,201	97.5%	-	20,610	182,000	202,610	-	-	5,201	5,201
7. Marimba River S/B	861,729	3,218	99.6%	53,923	94,807	713,000	861,729	-	-	3,218	3,218
8. Lake Chivero S/B	162,000	9,871	94.3%	-	-	162,000	162,000	-	-	9,871	9,871
9. Muzururu River S/B	150,000	16,797	89.9%	-	-	150,000	150,000	-	-	16,797	16,797
10. Gwebi River S/B	12,576	68,802	15.5%	12,576	-	-	12,576	29,184	-	39,618	68,802
11. Lake Manyame S/B	62,358	22,410	73.6%	6,468	9,540	46,350	62,358	-	-	22,410	22,410
Grand Total	2,894,434	251,335	92.0%	130,706	238,870	2,524,859	2,894,434	78,540	-	172,795	251,335

Scenario 2, Year 2005

Sub-basin/District	Total Population		Projected	Sewered Area				Unsewered Area			
	Sewered	Unsewered	Sewered %	Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B	-	34,679	0.0%	-	-	-	-	-	-	34,679	34,679
2. Ruwa River S/B	170,655	12,502	93.2%	155	11	170,489	170,655	-	-	12,502	12,502
3. Seke & Harava Dams S/B	13,047	4,085	76.2%	580	-	12,467	13,047	-	-	4,085	4,085
4. Nyatsime River S/B	526,688	21,638	96.1%	-	21,420	505,268	526,688	-	-	21,638	21,638
5. Mukuvisi River S/B	826,611	39,123	95.5%	42,446	89,664	694,502	826,611	36,347	-	2,776	39,123
6. Manyame River (D.stream) S/B	151,465	5,201	96.7%	-	1,517	149,948	151,465	-	-	5,201	5,201
7. Marimba River S/B	678,007	3,218	99.5%	40,072	79,619	558,316	678,007	-	-	3,218	3,218
8. Lake Chivero S/B	-	9,871	0.0%	-	-	-	-	-	-	9,871	9,871
9. Muzururu River S/B	-	16,797	0.0%	-	-	-	-	-	-	16,797	16,797
10. Gwebi River S/B	13,068	130,696	9.1%	13,068	-	-	13,068	91,078	-	39,618	130,696
11. Lake Manyame S/B	27,362	22,410	55.0%	1,487	2,193	23,681	27,362	-	-	22,410	22,410
Grand Total	2,406,903	300,220	88.9%	97,807	194,423	2,114,672	2,406,903	127,425	-	172,795	300,220

Table 5.1.2 Projected Wastewater Quantity by Sewered/Unsewered Area by Sub-basin

Scenario 1, Year 2005

Sub-basin/District	Generated/Discharged Wastewater Quanity (m3/day)											
	Sewered Area						Unsewered Area					
	Domestic			Com. &	Indust-		Domestic			Com. &	Indust-	
	Low	Medium	High	Inst.	rial	Total	Low	Medium	High	Inst.	rial	Total
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	2,254	-	-	2,254
2. Ruwa River S/B	3,568	170	14,319	559	3,545	22,161	-	-	813	-	-	813
3. Seke & Harava Dams S/B	1,247	-	3,240	20	-	4,508	-	-	266	-	-	266
4. Nyatsime River S/B	-	3,166	23,114	1,898	1,401	26,280	-	-	1,406	-	-	1,406
5. Mukuvisi River S/B	13,372	20,586	41,975	55,931	37,932	169,796	15,547	-	180	-	325	16,053
6. Manyame River (D.stream) S/B	-	4,328	11,830	-	39,533	55,691	-	-	338	-	-	338
7. Marimba River S/B	16,986	19,909	46,345	13,965	11,392	108,597	-	-	209	-	-	209
8. Lake Chivero S/B	-	-	10,530	-	-	10,530	-	-	642	-	-	642
9. Muzururu River S/B	-	-	9,750	-	-	9,750	-	-	1,092	-	-	1,092
10. Gwebi River S/B	3,961	-	-	-	-	3,961	9,193	-	2,575	-	-	11,768
11. Lake Manyame S/B	2,037	2,003	3,013	353	3,386	10,792	-	-	1,457	-	3,451	4,908
Grand Total	41,172	50,163	164,116	72,726	97,189	422,066	24,740	-	11,232	-	3,776	39,748

Scenario 2, Year 2005

Sub-basin/District	Generated/Discharged Wastewater Quanity (m3/day)											
	Sewered Area						Unsewered Area					
	Domestic			Com. &	Indust-		Domestic			Com. &	Indust-	
	Low	Medium	High	Inst.	rial	Total	Low	Medium	High	Inst.	rial	Total
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	2,254	-	-	2,254
2. Ruwa River S/B	49	2	11,082	190	3,545	14,868	-	-	813	-	-	813
3. Seke & Harava Dams S/B	183	-	810	20	-	1,013	-	-	266	-	-	266
4. Nyatsime River S/B	-	4,498	32,842	1,910	1,401	37,341	-	-	1,406	-	-	1,406
5. Mukuvisi River S/B	13,370	18,829	45,143	49,240	37,932	164,514	11,449	-	180	-	325	11,955
6. Manyame River (D.stream) S/B	-	319	9,747	-	39,533	49,598	-	-	338	-	-	338
7. Marimba River S/B	12,623	16,720	36,291	12,292	11,392	89,317	-	-	209	-	-	209
8. Lake Chivero S/B	-	-	-	-	-	-	-	-	642	-	-	642
9. Muzururu River S/B	-	-	-	-	-	-	-	-	1,092	-	-	1,092
10. Gwebi River S/B	4,116	-	-	-	-	4,116	28,690	-	2,575	-	-	31,265
11. Lake Manyame S/B	468	461	1,539	123	3,386	5,978	-	-	1,457	-	3,451	4,908
Grand Total	30,809	40,829	137,454	63,776	97,189	366,745	40,139	-	11,232	-	3,776	55,147

Note: 1. Estimated population and land use are based on Appendix A 12.2.3.

2. Population in rural districts is categorised to high-density area.

Table 5.1.3 Pollution Load from Sewage Treatment Works

Scenario 1, Year 2005

Sub-basin	Sewage Treatment Works	Average Flow (m3/d)	Irrigation Reuse (%)	Influent Pollution Load (kg/day)				Discharged Pollution Load (kg/day)				Concentrated Pollution Load (kg/day)			
				BOD	COD	T-N	T-P	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	36,000	100%	19,549	42,160	4,048	465	1,955	6,324	2,834	325	156	506	227	26
do	Crowborough (BNR)	82,347	0%	44,716	96,437	9,260	1,063	2,236	9,644	1,852	266	2,236	9,644	1,852	266
L. Chivero	Firle (TF)	36,000	100%	21,999	50,747	3,628	448	2,200	7,612	2,540	314	176	609	203	25
Mukuvisi R.	Firle (BNR)	142,829	0%	87,279	201,336	14,395	1,777	4,364	20,134	2,879	444	4,364	20,134	2,879	444
Gwebi R.	Marlborough (WSP)	3,961	100%	629	1,258	163	18	63	189	82	12	5	15	7	1
Ruwa R.	Donnybrook (WSP)	6,877	100%	4,655	9,310	1,164	127	466	1,397	582	89	37	112	47	7
do	Harare East (BNR)	5,732	0%	3,805	7,611	951	104	190	761	190	26	190	761	190	26
Manyame R. -D	Harare South (BNR)	55,314	0%	52,591	140,109	3,381	642	2,630	14,011	676	160	2,630	14,011	676	160
Nyatsime R.	**Zengeza (TF)**	**20,400**	**100%**	**14,589**	**29,594**	**3,417**	**385**	**1,459**	**4,439**	**2,392**	**269**	**117**	**355**	**191**	**22**
do	**Zengeza (BNR)**	**10,352**	**0%**	**7,403**	**15,017**	**1,734**	**195**	**370**	**1,502**	**347**	**49**	**370**	**1,502**	**347**	**49**
	Total	**30,752**		**21,992**	**44,611**	**5,151**	**580**	**1,829**	**5,941**	**2,739**	**318**	**487**	**1,857**	**538**	**70**
	% to Total	**7%**		**8%**	**7%**	**12%**	**11%**	**11%**	**8%**	**17%**	**15%**	**5%**	**4%**	**8%**	**7%**
L. Manyame	Norton (TF)	10,792	100%	8,843	29,843	932	112	884	4,477	652	78	71	358	52	6
Ruwa R.	Ruwa (WSP)	11,463	100%	5,880	15,752	1,291	147	588	2,363	645	103	47	189	52	8
Total		422,066		271,938	639,175	44,365	5,483	17,404	72,851	15,671	2,137	10,399	48,195	6,722	1,041

Scenario 2, Year 2005

Sub-basin	Sewage Treatment Works	Average Flow (m3/d)	Irrigation Reuse (%)	Influent Pollution Load (kg/day)				Discharged Pollution Load (kg/day)				Concentrated Pollution Load (kg/day)			
				BOD	COD	T-N	T-P	BOD	COD	T-N	T-P	BOD (dry)	COD	T-N	T-P
Marimba R.	Crowborough (TF)	36,000	100%	19,093	42,244	3,657	430	1,909	6,337	2,560	301	153	507	205	24
do	Crowborough (BNR)	53,317	0%	28,277	62,565	5,416	637	1,414	6,256	1,083	159	1,414	6,256	1,083	159
L. Chivero	Firle (TF)	36,000	100%	21,106	49,615	3,222	409	2,111	7,442	2,256	286	169	595	180	23
Mukuvisi R.	Firle (BNR)	127,017	0%	74,466	175,055	11,370	1,442	3,723	17,506	2,274	361	3,723	17,506	2,274	361
Gwebi R.	Marlborough (WSP)	4,116	100%	653	1,307	170	18	65	196	85	13	5	16	7	1
Ruwa R.	Donnybrook (WSP)	7,327	100%	4,960	9,920	1,240	135	496	1,488	620	95	40	119	50	8
do	Harare East (BNR)	5,732	0%	3,805	7,611	951	104	190	761	190	26	190	761	190	26
Manyame R. -D	Harare South (BNR)	40,993	0%	45,265	125,458	1,543	441	2,263	12,546	309	110	2,263	12,546	309	110
Nyatsime R.	**Zengeza (TF)**	**20,400**	**100%**	**14,285**	**28,845**	**3,420**	**381**	**1,428**	**4,327**	**2,394**	**267**	**114**	**346**	**192**	**21**
do	**Zengeza (BNR)**	**26,146**	**0%**	**18,308**	**36,969**	**4,383**	**488**	**915**	**3,697**	**877**	**122**	**915**	**3,697**	**877**	**122**
	Total	**46,546**		**32,593**	**65,814**	**7,803**	**870**	**2,344**	**8,024**	**3,270**	**389**	**1,030**	**4,043**	**1,068**	**143**
	% to Total	**13%**		**14%**	**11%**	**21%**	**19%**	**15%**	**12%**	**25%**	**21%**	**11%**	**9%**	**20%**	**17%**
L. Manyame	Norton (TF)	5,978	100%	7,132	26,422	500	65	713	3,963	350	45	57	317	28	4
Ruwa R.	Ruwa (WSP)	3,720	100%	2,629	9,250	472	58	263	1,387	236	41	21	111	19	3
Total		366,745		239,980	575,259	36,343	4,609	15,492	65,906	13,232	1,826	9,065	42,777	5,413	862

Note: 1) Concentration ratios of pollution loads are; Direct Discharge 100% ;Irrigation reuse 8% (for BOD during dry season 8%)

2) Intruded water to sewer (groundwater, etc.) is not included in sewage flow.

3) Concentrated BOD is calculated for dry season.

4) Pollution load reduction efficiency at STWs:

	BOD	COD	T-N	T-P
BNR	95%	90%	80%	75%
TF	90%	85%	30%	30%
WSP	90%	85%	50%	30%

5) Effluent from Zengeza (TF) is transferred to outside of the study basin.

results are presented in Table 5.1.3. In the calculation, following conditions are assumed in future sewage treatment situation in the study area considering present tendency:

- Existing trickling filters of Crowborough, Firle and Zengeza STWs are maintained with its present planned capacity. Treated effluent will be discharged to irrigation farm.
- New BNR plants will be constructed for increasing raw sewage influent at Crowborough, Firle and Zengeza STWs. Treated Effluent will be discharged directly to nearby rivers.
- New STWs, namely Harare East STW and Harare South STW with BNR process, are planned to cope with increasing population in southern and eastern areas of Harare city.
- Wastewater Stabilisation Pond in Marlborough, Donnybrook and Ruwa STWs will be maintained and expanded to cope with increasing influent.
- Augmentation of Norton STW will be carried out adopting Trickling Filter method based on the existing plan.

Treatment efficiency of STWs are assumed for respective treatment methods as follows:

Table 5.1.4 Treatment Efficiency by Treatment Method

Treatment Method	Treatment Efficiency (Pollution Load Reduction Ratio)			
	BOD_5	COD	T-N	T-P
Biological Nutrient Removal	95%	90%	80%	75%
Trickling Filter	90%	85%	30%	30%
Wastewater Stabilisation Pond	90%	85%	50%	30%

It is also assumed that 8% of the pollution load transferred for irrigation reuse reaches to the subject water bodies as concentrated load.

Calculation results are presented in Table 5.1.5.

5.1.2 Industrial Wastewater

(1) Wastewater Quantity

Future industrial wastewater quantity was calculated by multiplying the unit industrial wastewater quantity per employee and the number of employees in the future as shown in Table 4.1.7.

(2) Pollution Load

Future pollution load was calculated by multiplying the unit pollution load of industrial wastewater per employee and the number of employees in the future as presented in Table 4.1.8.

(3) Sewered/Unsewered Wastewater

Future wastewater quantity and pollution load were calculated by sub-basin dividing sewered/unsewered by public sewerage system based on the present condition. The results are shown in Table 4.1.9. Pollution load of unsewered industrial wastewater is also presented in Table 5.1.5, and those of sewered industrial wastewater is considered as a part of effluent from STWs in the same table.

5.1.3 Other Pollution Load

In addition to aforementioned pollution load, those of following pollution sources were considered in the calculation as presented in Table 5.1.5.

(1) Livestock

Number of major livestock was assumed to be constant through the future. Therefore, generated and concentrated pollution calculated for present analysis presented in Table 4.1.11 was also adopted in the future analysis.

(2) Farmland / Natural Land

The pollution loads calculated for each sub-basin as shown in Table 4.1.12 using the area of each sub-basin and unit pollution load was assumed to be constant through the future. The pollution load may be defined as concentrated pollution loads.

(3) Solid Waste Dumping Sites

The leachate from dumping sites in the future was projected to increase in proportion to population of respective local authorities. Adopting the pollution load concentration of leachate presented in Table 3.2.9, calculation was made as presented in Table 5.1.6 for the

Table 5.1.5 Concentrated Pollution Load by Pollution Source

(kg/day)

Pollution Indices Scenario, Year	Dom./Com./Ins. Sewage			Industrial	Livestock	Natural Pollution	Solid Waste Dumping	Water Treatment Works	Total
	Sewered	Unsewered	Total	Unsewered*					
BOD, Dry Season									
Scenario 1, 2005	10,282	608	10,890	657	589	248	-	113	12,497
Scenario 2, 2005	8,951	380	9,331	657	589	248	-	113	10,938
COD									
Scenario 1, 2005	47,840	1,216	49,056	2,765	14,725	45,946	149	1,261	113,903
Scenario 2, 2005	42,431	760	43,191	2,765	14,725	45,946	113	998	107,738
T-N									
Scenario 1, 2005	6,531	152	6,683	11	4,225	3,845	43	29	14,837
Scenario 2, 2005	5,221	95	5,316	11	4,225	3,845	33	22	13,453
T-P									
Scenario 1, 2005	1,019	17	1,036	1	661	320	-	14	2,031
Scenario 2, 2005	841	10	851	1	661	320	-	10	1,843

*: Pollution load of industries in sewered area is counted as a part of domestic pollution load of sewered area.

Table 5.1.6 Concentrated Pollution Load from Solid Waste Dumping Site (Future)

Quantity of Leachate (m3/year)

Local Authority		Harare	Harare	Chitungwiza	Norton	Ruwa/Epworth
Sub-basin		Marimba R.*	Gwebi R.	Nyatsime R.	L. Manayame	Ruwa R.**
Present Q.	on-going	13,200	3,300	6,600	3,300	1,650
	completed	12,000	2,000	0	0	0
Population Increase Rate						
Scenario 1	2005		1.93	1.09	1.93	1.87
Scenario 2	2005		1.34	1.59	1.23	1.23
Future Leachate Quantity						
Scenario 1	2005	-	58,892	7,201	6,362	3,093
Scenario 2	2005	-	40,850	10,507	4,047	2,023

*: Existing dumping site is assumed to be closed. Same load is assumed to be transferred to Gwebi R. Sub-basin.

**: Dumping site for Epworth is assumed to be developed in Ruwa R. Sub-basin.

Concentrated Pollution Load (kg/day)

Local Authority		Harare	Harare	Chitungwiza	Norton	Ruwa/Epworth
Sub-basin		Marimba R.*	Gwebi R.	Nyatsime R.	L. Manayame	Ruwa R.**
Present	BOD***	28	6	7	4	2
Concentrated	COD	50	10	13	7	3
Pollution	T-N	14	3	4	2	1
Load	T-P	-	-	-	-	-
Population	Scenario1					
Increase	2005		1.93	1.09	1.93	1.87
against	Scenario2					
1995	2005		1.34	1.59	1.23	1.23
Future Concentrated Pollution Load						
Scenario1						
2005	BOD***	-	66	8	8	4
	COD	-	116	14	13	6
	T-N	-	33	4	4	2
	T-P	-	-	-	-	-
Scenario2						
2005	BOD***	-	46	11	5	2
	COD	-	80	21	9	4
	T-N	-	23	6	2	1
	T-P	-	-	-	-	-

*: Existing dumping site is assumed to be closed. Same load is assumed to be transferred to Gwebi R. Sub-basin.

**: Dumping site for Epworth is assumed to be developed in Ruwa R. Sub-basin.

***:Nil during dry seasom.

future analysis. Concentration ratio is assumed to be 80% (nil for BOD during dry season) in the calculation taking account of location of dumping sites.

(4) Water Treatment Works

Wastewater generated from backwashing process at the Morton Jaffray WTW in the study area is presently discharged to subject water bodies without any treatment. Introduction of backwash wastewater treatment plant is assumed in the future analysis. Water intake amount by the Morton Jaffray and the Prince Edward WTWs was decided as presented in the flow model.

5.2 Pollution Load Run-off Model

5.2.1 Rivers

(1) River Flow Run-off Model

The future pollution analysis of rivers was also conducted in terms of BOD_5 under the dry season condition. The river flow to be adopted in the analysis is those in dry season derived based on average figures in dry season of last 10 years. Applying those flow, the river flow run-off model was illustrated with pollution load discharging points and water quality checking points.

(2) Pollution Load Run-off Model

Concentrated BOD load presented in Table 5.1.5 was allocated to each pollution load discharging point. Integrating those data, the pollution load run-off model for future pollution analysis of rivers was formulated as illustrated in Figure 5.2.1.

5.2.2 Lakes/Dams

(1) Water Balance of Lakes/Dams

The pollution analysis of lakes was conducted under the annual average condition. The water balance of lakes to be adopted in the analysis is those derived based on annual average figures in last 10 years. Applying those water balance, the run-off model was illustrated with pollution load discharging points and water quality checking points.

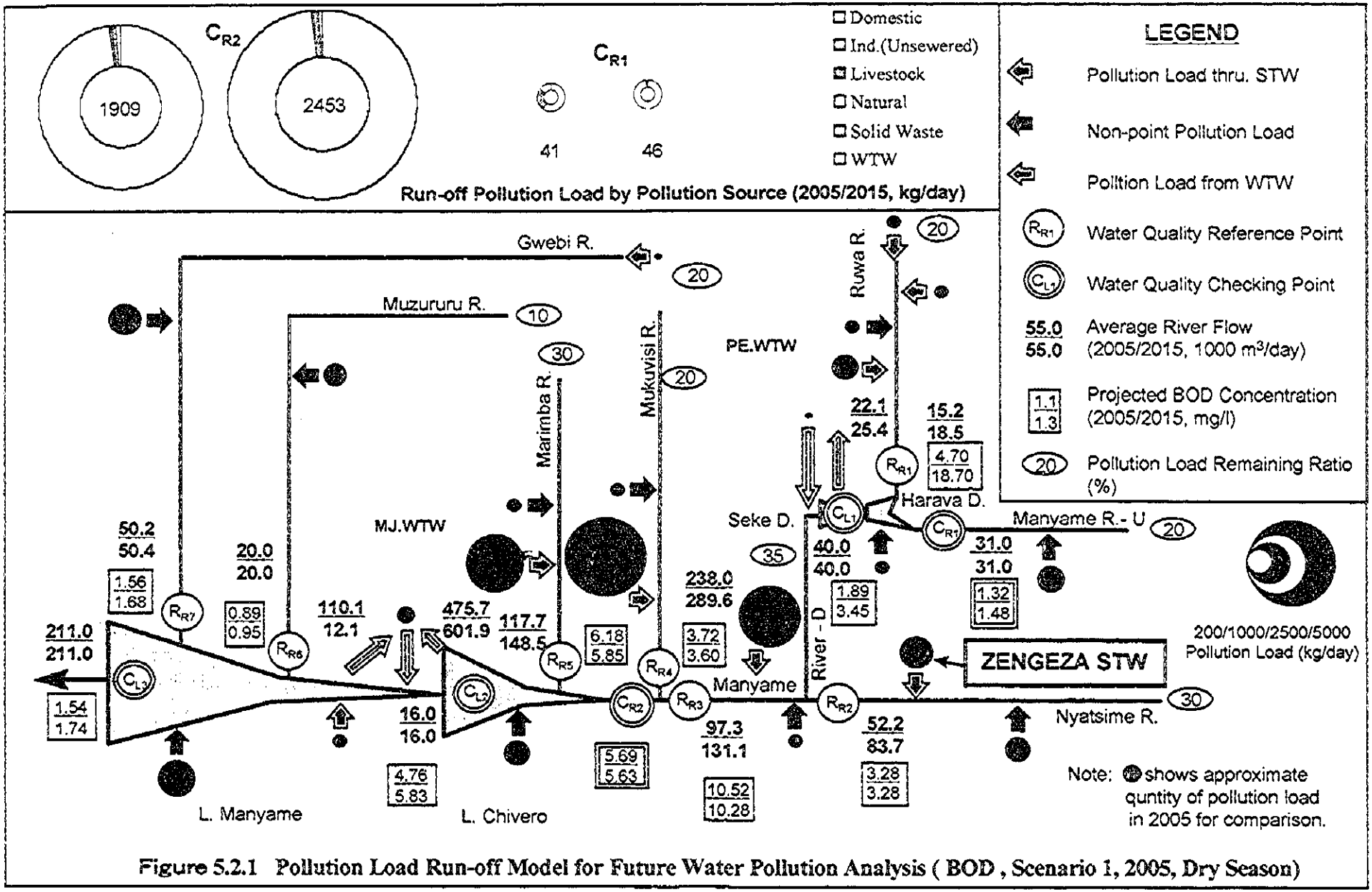

Figure 5.2.1 Pollution Load Run-off Model for Future Water Pollution Analysis (BOD , Scenario 1, 2005, Dry Season)

(2) Pollution Load Run-off Model

The concentrated pollution load was calculated in the previous section by each scenario for COD, T-N and T-P, respectively. Integrating the flow run-off model and the calculated concentrated pollution load, the pollution load run-off models in terms of COD, T-N and T-P was formulated by each scenario as illustrated in Figures 5.2.2 to 5.2.4. These pollution loads were assumed to reach to the subject lakes without reduction (purification) during flow in main river.

5.2.3 Contribution of Zengeza STW

Projected PL discharged by the STWs in the Study basin is presented in Table 5.1.3. This projection was made assuming appropriate countermeasures will be conducted for future increase of sewage in all STWs.

With regard to concentrated pollution load, that of the Zengeza STW will occupy about 4 to 8 % of total concentrated load discharged from STWs (Scenario 1). These contribution percentage is much less than the present figures.

Tables 4.2.6 and 4.2.7 also presents degree of contribution of the pollution load (PL) discharged from the Zengeza STW in the future. At the reference point R_{R2} of the Nyatsime River, PL from the Zengeza STW occupies less than a half of the run-off PL in terms of COD, T-N and T-P in the year 2005. In the total inflow PL of the Lake Chivero, it contributes less than 5 %.

As presented in the tables, not only the contribution percentage but also PL amount itself will decrease considerably.

5.3 Water Pollution Analysis

5.3.1 General

The pollution load remaining ratios of respective rivers in terms of BOD_5 identified in the present pollution analysis are adopted in the future pollution analysis. While, self-purification coefficients of respective lakes in terms of T-N, T-P and COD computed in the present analysis are also adopted in future pollution analysis of lakes.

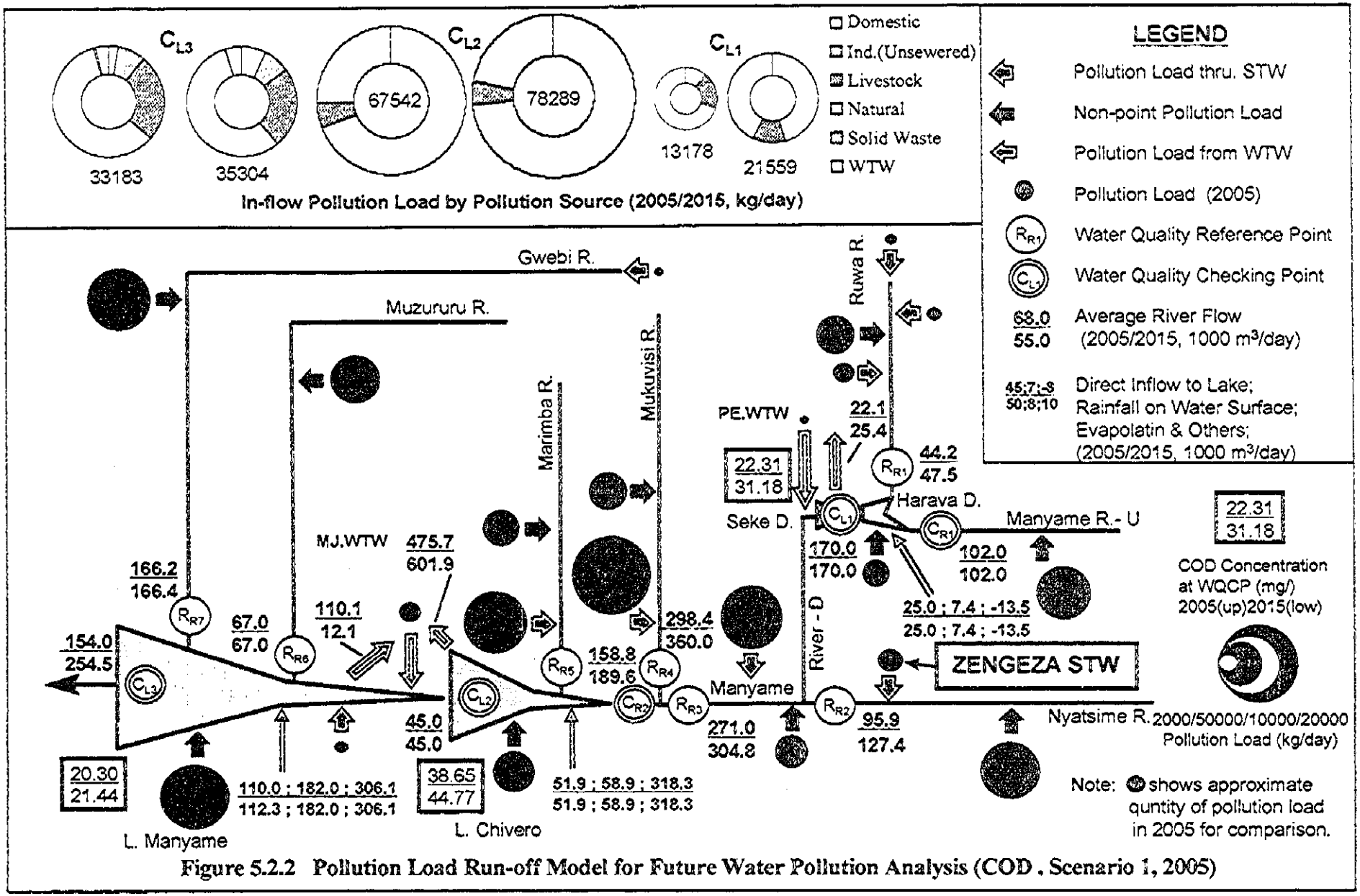

Figure 5.2.2 Pollution Load Run-off Model for Future Water Pollution Analysis (COD , Scenario 1, 2005)

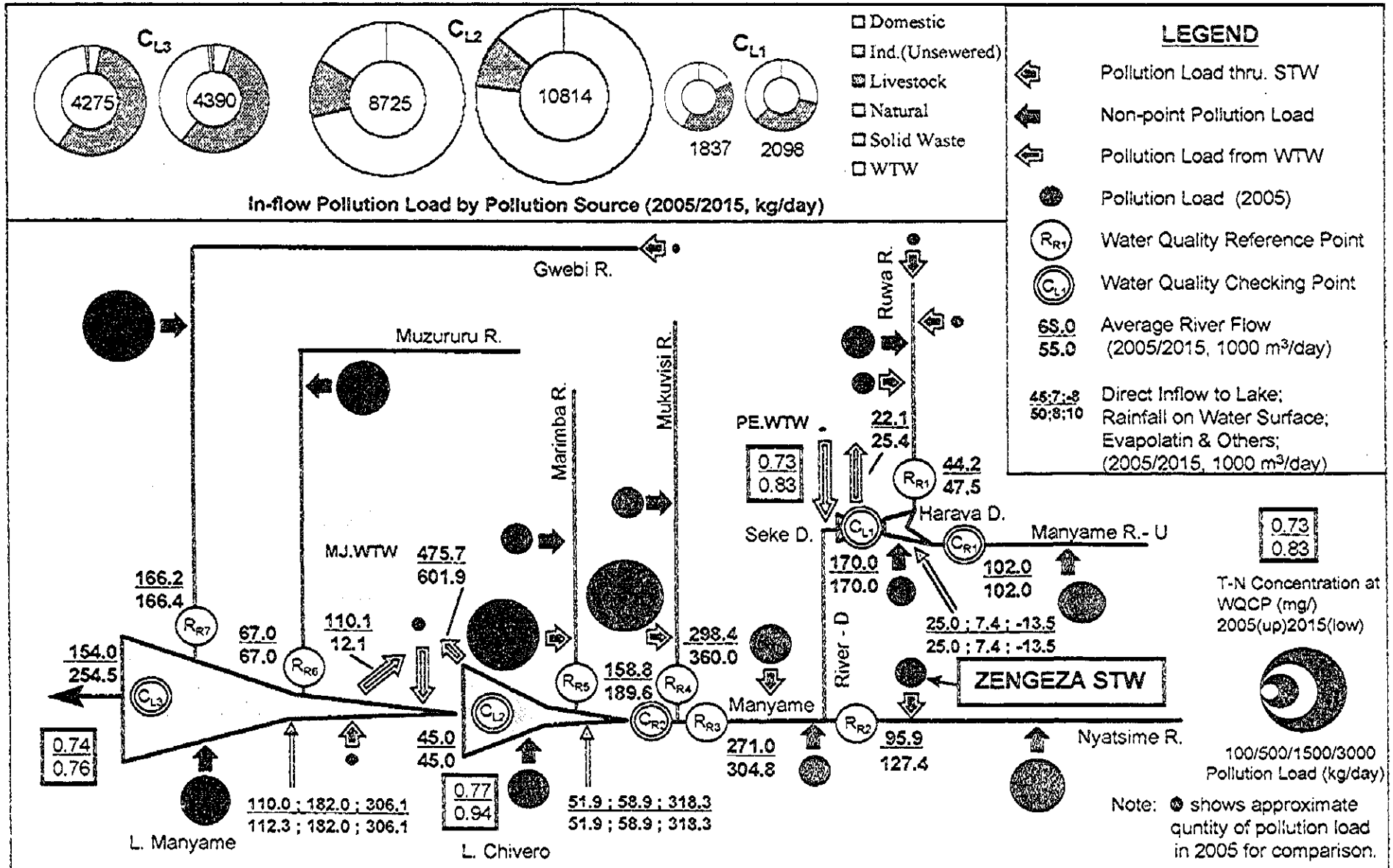

Figure 5.2.3 Pollution Load Run-off Model for Future Water Pollution Analysis (T-N , Scenario 1, 2005)

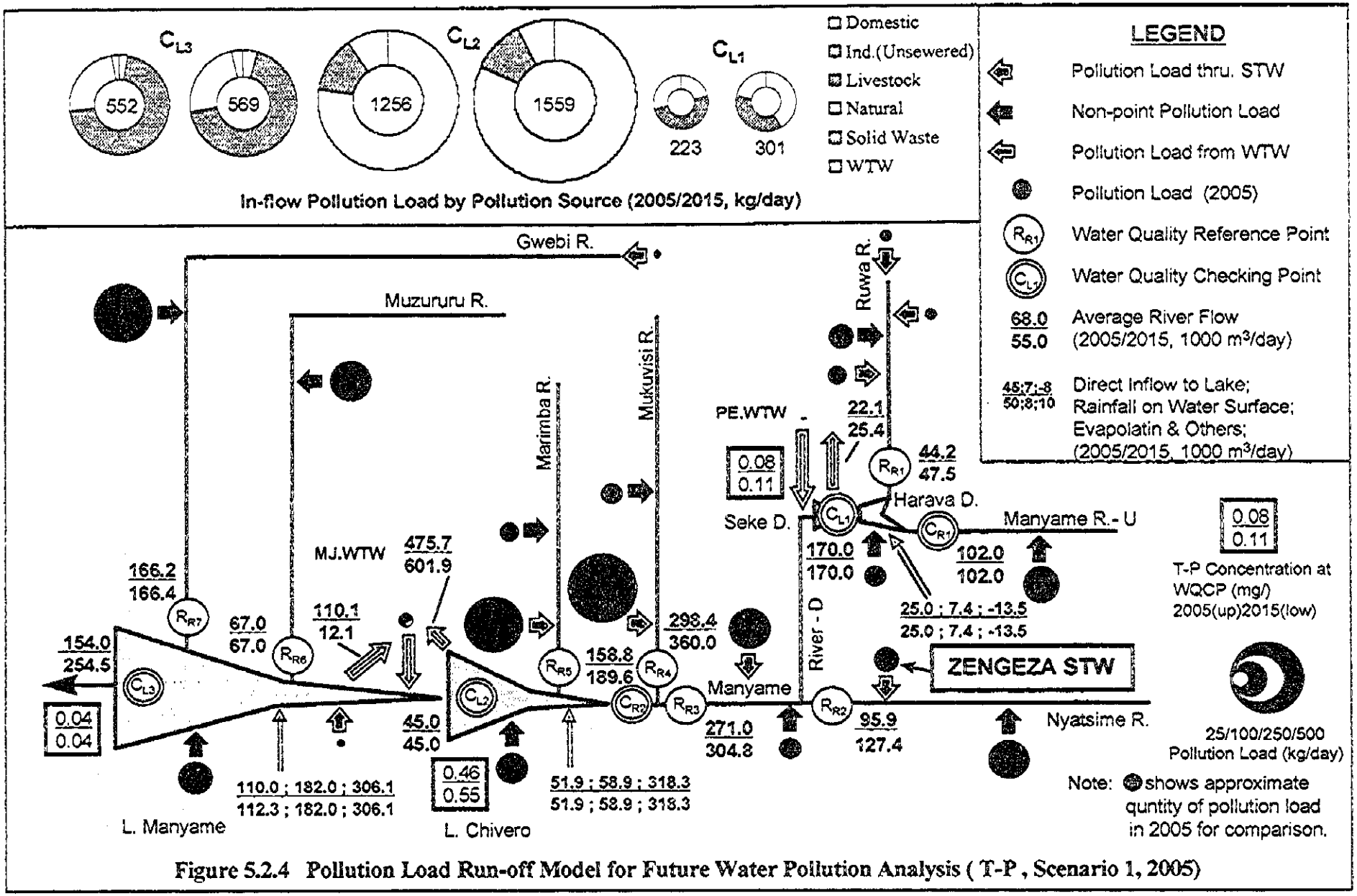

Figure 5.2.4 Pollution Load Run-off Model for Future Water Pollution Analysis (T-P , Scenario 1, 2005)

5.3.2 Rivers

Based on the BOD load run-off model established in sub-section 5.2, projection of BOD concentration at water quality checking points of rivers was conducted for each scenario as summarised in Table 5.3.1.

Table 5.3.1 Projected Future BOD Concentration at WQCPs (2005)

(unit: mg/l)

River	WQ CP	Stan-dard	Present	Scenario 1	Scenario 2
Manyame (u/s)	C_{R1}	<3	1.1	1.32	1.03
Ruwa	R_{R1}	-	3.8	4.70	4.38
Nyatsime	R_{R2}	-	**2.1**	**3.28**	**4.56**
Manyame (d/s)	R_{R3}	-	1.0	10.52	8.20
Mukuvisi	R_{R4}	-	2.0	3.72	3.87
Manyame (d/s)	C_{R2}	<5	1.4	5.69	5.48
Marimba	R_{R5}	-	8.7	6.18	7.68
Muzururu	R_{R6}	-	0.5	0.89	0.78
Gwebi	R_{R7}	-	1.6	1.56	1.35

Table 5.3.1 shows serious calculation results in Manyame (R_{R3}, C_{R2}) and Marimba (R_{R5}) rivers, i.e. more than 5 mg/l of BOD concentration, which has discharge of effluent from the STWs in the sub-basin. However, BOD concentration exceeding 5 mg/l does not be projected for other rivers including the Nyatsime river (R_{R2}) which has the Zengeza STW in its basin.

5.3.3 Lakes/Dams

Based on the pollution load run-off models, projection of water quality of lakes and dams in the future was conducted as summarised in Table 5.3.2.

Table 5.3.2 Projected Future Pollution Load Concentration at WQCPs of Lakes (2005)

River	WQ CP	Quality Standard	Present	Scenario 1	Scenario 2
T-N (mg/l)					
Seke & Harava	C_{L1}	<0.4	0.65	0.73	0.71
L. Chivero	C_{L2}	<0.4	0.51	0.77	0.66
L. Manyame	C_{L3}	<0.4	0.75	0.74	0.73
T-P (mg/l)					
Seke & Harava	C_{L1}	<0.05	0.07	0.08	0.08
L. Chivero	C_{L2}	<0.10	0.27	0.46	0.41
L. Manyame	C_{L3}	<0.03	0.04	0.04	0.04
COD* (mg/l)					
Seke & Harava	C_{L1}	<10	20.63	22.31	21.86
L. Chivero	C_{L2}	<16	25.30	38.65	35.51
L. Manyame	C_{L3}	<16	22.70	20.30	19.92

*: COD in this table is presented as COD_{Cr} assuming as two times of COD_{Mn}.

Water of lakes/dams will be in serious pollution condition in the future as presented in Table 5.3.2, even though utmost possible sewage treatment including development of new two STWs and augmentation of existing STWs was assumed in the calculation for projection. However, because of said assumption, water of Seke/Harava Dams and Lake Manyame show the stable water quality. Lake Chivero will be suffered seriously with worse water quality. Projected values in the scenario 2 (lower development) is better than those in the scenario 1. This projection implies that assumed sewage treatment, which is recognised as practical, is indispensable and depression of development in the basin shall be considered.