Table 7.2.16 Flow Rate to be Adopted in Analysis

Unit: m^3/day

	River	Annual Flow for Lake Analysis				Dry Season Flow for River Analysis				Natural Flow Rate		Derived from STW				
												1995				
		1995	2000	2005	2015	1995	2000	2005	2015	Annual	Dry	Annual	Dry	2000	2005	2015
Scenario -1	Manyame Origin	102,000	102,000	102,000	102,000	31,000	31,000	31,000	31,000	102,000	31,000	0	0	0	0	0
	Ruwa R.	42,600	43,700	44,200	47,500	13,600	14,700	15,200	18,500	42,000	13,000	600	600	1,700	2,200	5,500
	Seke D/S	170,000	170,000	170,000	170,000	40,000	40,000	40,000	40,000	170,000	40,000	0	0	0	0	0
	Nyatsime R.	96,000	94,700	95,900	127,400	33,900	51,000	52,200	83,700	77,600	33,900	18,400	0	17,100	18,300	49,800
	Manyame R.	266,000	265,800	271,000	304,800	73,900	92,100	97,300	131,100	247,600	73,900	18,400	0	18,200	23,400	57,200
	Mukuvisi R.	114,000	230,500	298,400	360,000	54,000	170,100	238,000	299,600	86,300	25,900	27,700	28,100	144,200	212,100	273,700
	Marimba R.	63,000	96,200	158,800	189,600	21,000	55,100	117,700	148,500	43,800	2,700	19,200	18,300	52,400	115,000	145,800
	L.Chivero	6,700	2,900	2,900	2,900	6,500	2,900	2,900	2,900			6,700	6,500	2,900	2,900	2,900
	L.Chivero D/S	45,000	45,000	45,000	45,000	16,000	16,000	16,000	16,000	45,000	16,000	0	0	0	0	0
	Muzururu R.	67,000	67,000	67,000	67,000	20,000	20,000	20,000	20,000	67,000	20,000	0	0	0	0	0
	Gwebi R.	166,200	166,200	166,200	166,400	50,200	50,200	50,200	50,400	166,000	50,000	200	200	200	200	400
	L.Manyame	200	500	1,000	3,300	200	500	1,000	3,300			200	200	500	1,000	3,300
	L.Manyame D/S	154,000	154,000	154,000	254,500	211,000	211,000	211,000	254,500	154,000	211,000	0	0	0	0	0
Scenario -2	Manyame Origin	102,000	102,000	102,000	102,000	31,000	31,000	31,000	31,000	102,000	31,000	0	0	0	0	0
	Ruwa R.	42,600	43,300	43,500	46,400	13,600	14,300	14,500	17,400	42,000	13,000	600	600	1,300	1,500	4,400
	Seke D/S	170,000	170,000	170,000	170,000	40,000	40,000	40,000	40,000	170,000	40,000	0	0	0	0	0
	Nyatsime R.	96,000	102,700	115,300	164,900	33,900	59,000	71,600	121,200	77,600	33,900	18,400	0	25,100	37,700	87,300
	Manyame R.	266,000	273,000	289,100	338,700	73,900	99,300	115,400	165,000	247,600	73,900	18,400	0	25,400	41,500	91,100
	Mukuvisi R.	114,000	234,000	255,600	328,200	54,000	173,600	195,200	267,800	86,300	25,900	27,700	28,100	147,700	169,300	241,900
	Marimba R.	63,000	95,500	103,400	134,900	21,000	54,400	62,300	93,800	43,800	2,700	19,200	18,300	51,700	59,600	91,100
	L.Chivero	6,700	2,900	2,900	2,900	6,500	2,900	2,900	2,900			6,700	6,500	2,900	2,900	2,900
	L.Chivero D/S	45,000	45,000	45,000	45,000	16,000	16,000	16,000	16,000	45,000	16,000	0	0	0	0	0
	Muzururu R.	67,000	67,000	67,000	67,000	20,000	20,000	20,000	20,000	67,000	20,000	0	0	0	0	0
	Gwebi R.	166,200	166,200	166,200	166,200	50,200	50,200	50,200	50,200	166,000	50,000	200	200	200	200	200
	L.Manyame	200	300	600	2,100	200	300	600	2,100			200	200	300	600	2,100
	L.Manyame D/S	154,000	154,000	154,000	200,500	211,000	211,000	211,000	211,000	154,000	211,000	0	0	0	0	0

Note: Treated effluent discharged from Zengeza STW in 1995 is arranged for the analyses of lake and river:
18,400 m^3/day before provision of measures to reuse all effluent for lake and 0 m^3/day after measures for the river analysis.

Table 7.2.17(1) Estimated Water Balance (scenario-1)

Unit: x1000m^3/day

Name	1995		2000		2005		2015	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Seke And Harava Dam								
Manyame River	102.0		102.0		102.0		102.0	
Ruwa River	42.6		43.7		44.2		47.5	
Direct Rainfall	7.4		7.4		7.4		7.4	
Direct Area Run-off	25.0		25.0		25.0		25.0	
Evaporation & others		-13.5		-13.5		-13.5		-13.5
Prince Edward		20.5		21.6		22.1		25.4
Discharge		170.0		170.0		170.0		170.0
Subtotal	177.0	177.0	178.1	178.1	178.6	178.6	181.9	181.9
Lake Chivero								
Manyame River	266.0		265.8		271.0		304.8	
Mukuvisi River	114.0		230.5		298.4		360.0	
Marimba River	63.0		96.2		158.8		189.6	
Direct Rainfall	58.9		58.9		58.9		58.9	
Direct Area Run-off	55.7		51.9		51.9		51.9	
Evaporation & others		318.3		318.3		318.3		318.3
Morton Jaffray		164.3		340.0		475.7		601.9
Discharge		45.0		45.0		45.0		45.0
Subtotal	557.6	527.6	703.3	703.3	839.0	839.0	965.2	965.2
Change of Storage Volume	30.0							
Lake Manyame								
Lake Chivero	45.0		45.0		45.0		45.0	
Muzururu River	67.0		67.0		67.0		67.0	
Gwebi River	166.2		166.2		166.2		166.4	
Direct Rainfall	182.0		182.0		182.0		182.0	
Direct Area Run-off	109.2		109.5		110.0		112.3	
Evaporation & others		306.1		306.1		306.1		306.1
Morton Jaffray	97.6	225.9	0.0	109.6		110.1		12.1
Discharge		154.0		154.0		154.0		254.5
Subtotal	667.0	686.0	569.7	569.7	570.2	570.2	572.7	572.7
Change of Storage Volume	-19.0							
Total WTW Intake		313.1		471.2		607.9		639.4

Table 7.2.17(2) Estimated Water Balance (scenario-2)

Unit: x1000m³/day

Name	1995		2000		2005		2015	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Seke And Harava Dam								
Manyame River	102.0		102.0		102.0		102.0	
Ruwa River	42.6		43.3		43.5		46.4	
Direct Rainfall	7.4		7.4		7.4		7.4	
Direct Area Run-off	25.0		25.0		25.0		25.0	
Evaporation & others		-13.5		-13.5		-13.5		-13.5
Prince Edward		20.5		21.2		21.4		24.3
Discharge		170.0		170.0		170.0		170.0
Subtotal	177.0	177.0	177.7	177.7	177.9	177.9	180.8	180.8
Lake Chivero								
Manyame River	266.0		273.0		289.1		338.7	
Mukuvisi River	114.0		234.0		255.6		328.2	
Marimba River	63.0		95.5		103.4		134.9	
Direct Rainfall	58.9		58.9		58.9		58.9	
Direct Area Run-off	55.7		51.9		51.9		51.9	
Evaporation & others		318.3		318.3		318.3		318.3
Morton Jaffray		164.3		350.0		395.6		549.3
Discharge		45.0		45.0		45.0		45.0
Subtotal	557.6	527.6	713.3	713.3	758.9	758.9	912.6	912.6
Change of Storage Volume	30.0							
Lake Manyame								
Lake Chivero	45.0		45.0		45.0		45.0	
Muzururu River	67.0		67.0		67.0		67.0	
Gwebi River	166.2		166.2		166.2		166.2	
Direct Rainfall	182.0		182.0		182.0		182.0	
Direct Area Run-off	109.2		109.3		109.6		111.1	
Evaporation & others		306.1		306.1		306.1		306.1
Morton Jaffray	97.6	225.9	0.0	109.4		109.7		64.7
Discharge		154.0		154.0		154.0		200.5
Subtotal	667.0	686.0	569.5	569.5	569.8	569.8	571.3	571.3
Change of Storage Volume	-19.0							
Total WTW Intake		313.1		480.6		526.7		638.3

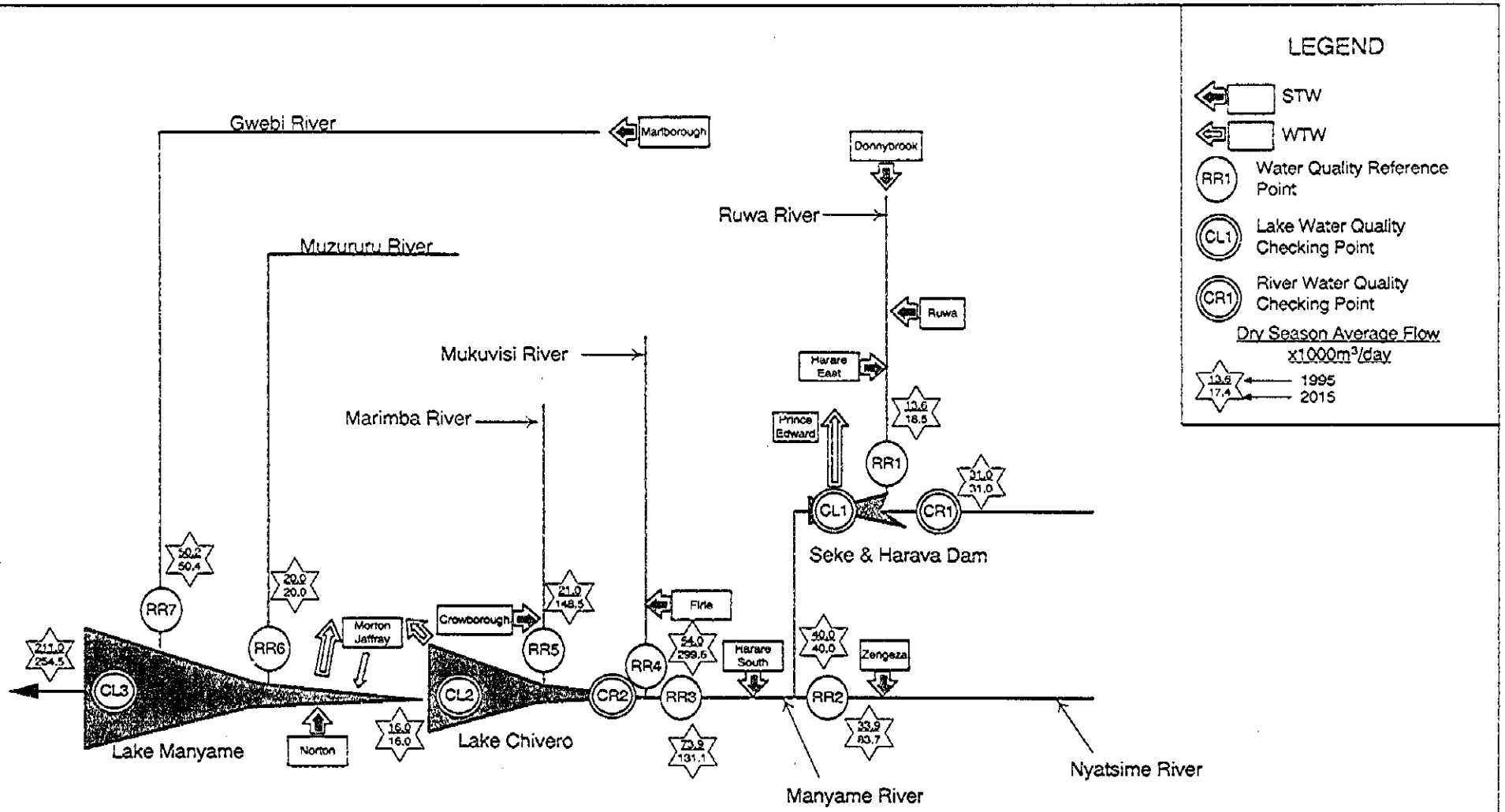

Figure 7.2.17(1) Flow Model to be Adopted in Analysis of Rivers (Scenario-1)

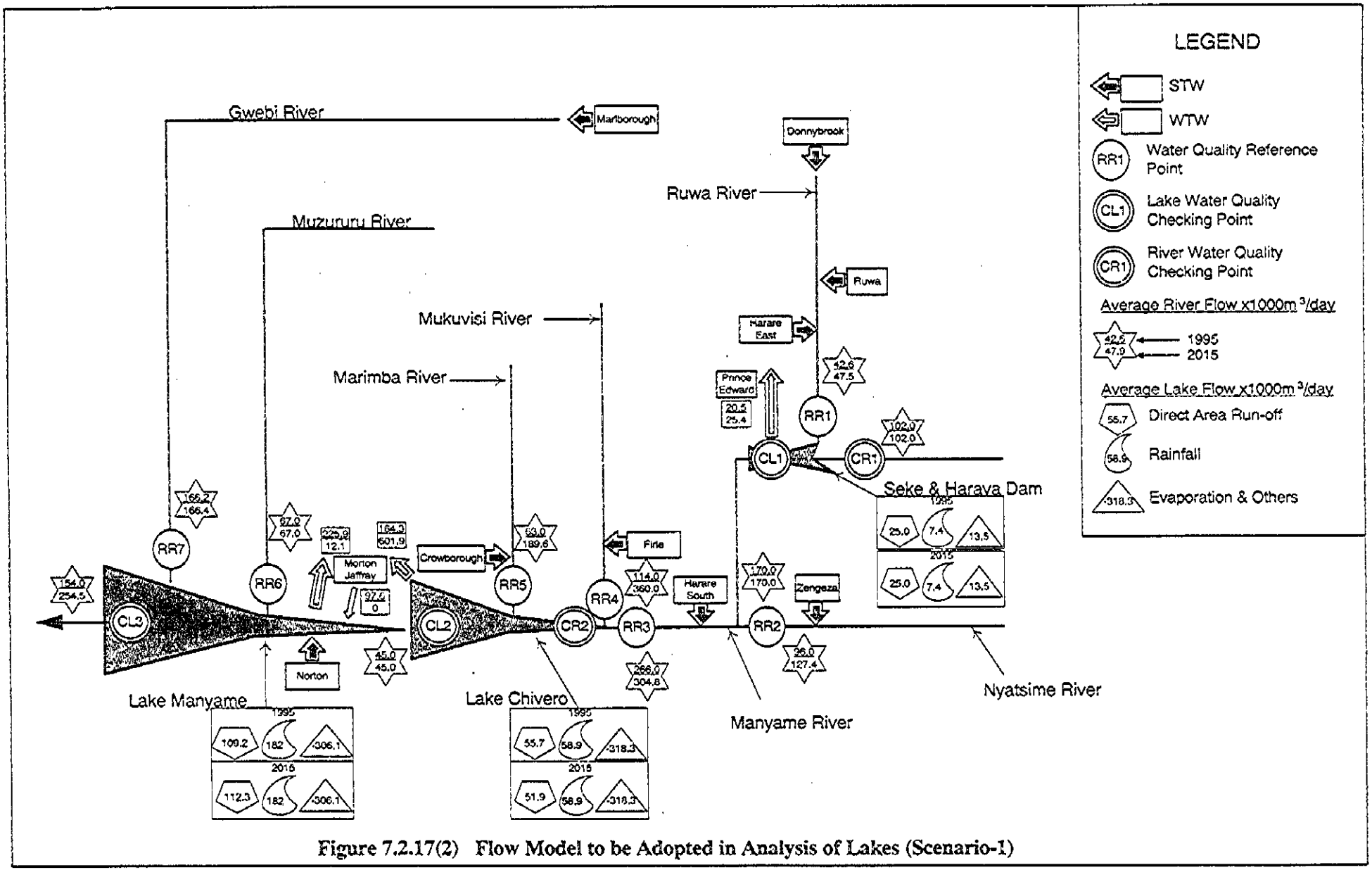

Figure 7.2.17(2) Flow Model to be Adopted in Analysis of Lakes (Scenario-1)

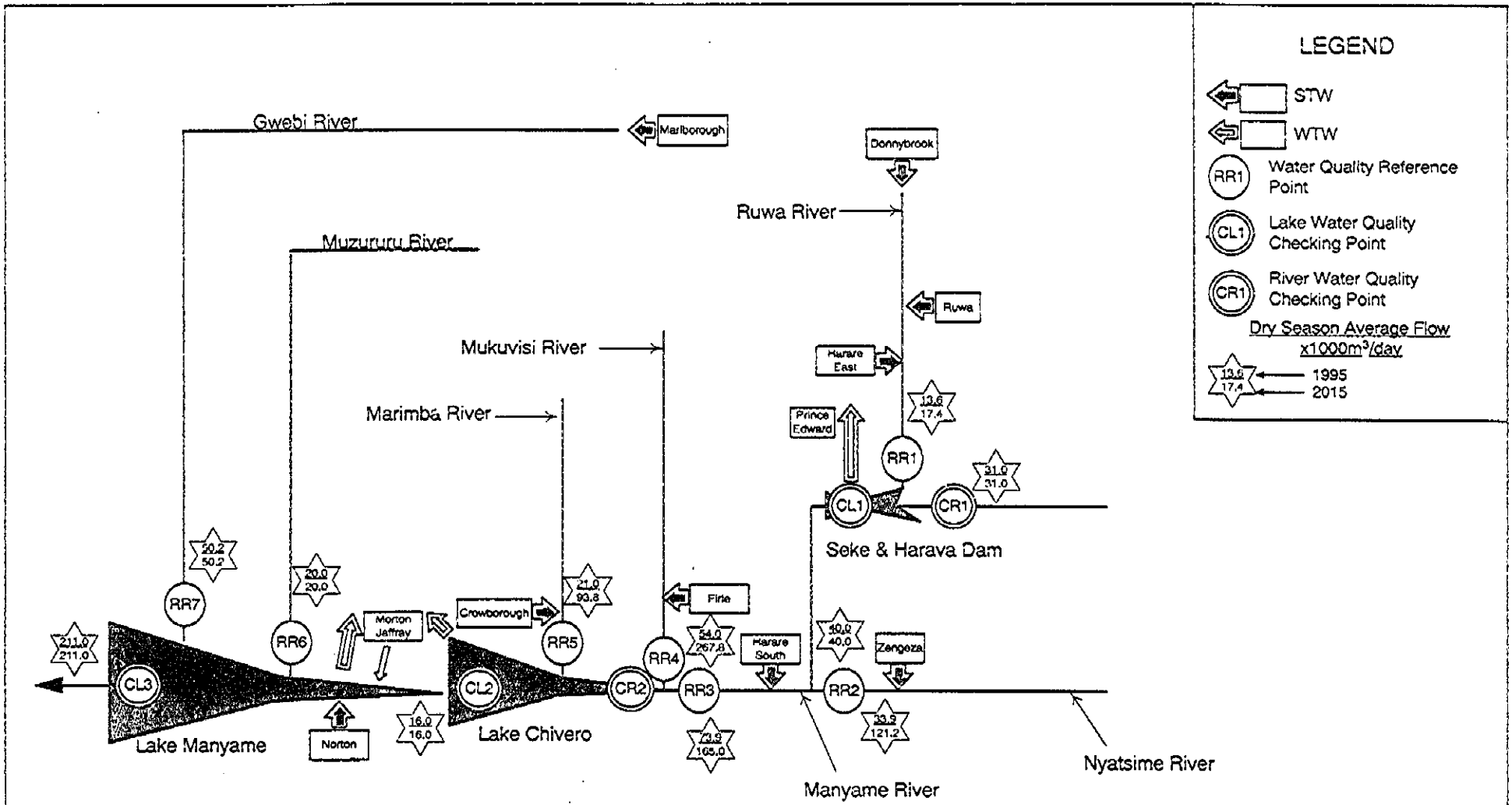

Figure 7.2.18(1) Flow Model to be Adopted in Analysis of Rivers (Scenario-2)

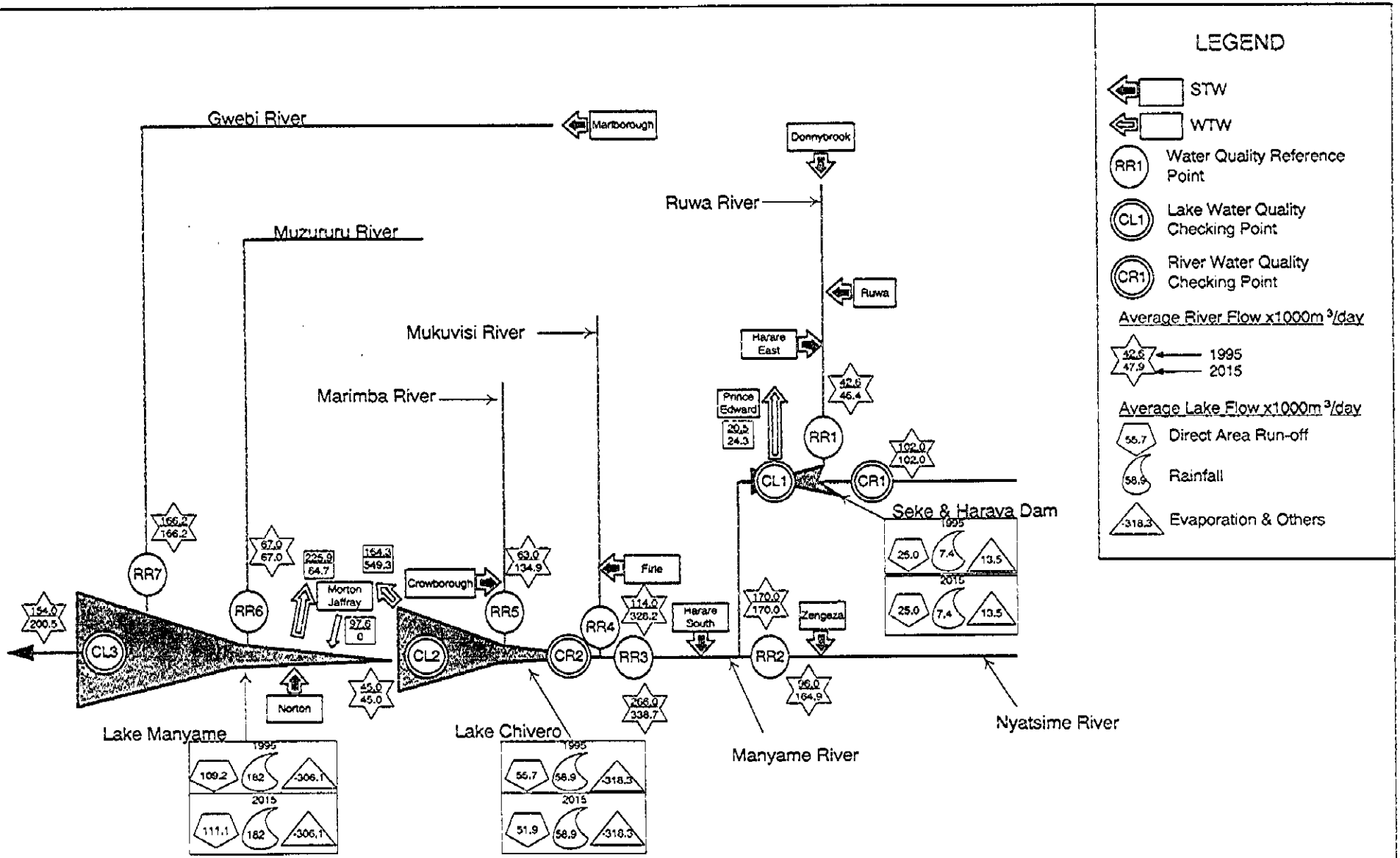

Figure 7.2.18(2) Flow Model to be Adopted in Analysis of Lakes (Scenario-2)

CHAPTER 8

UNIT WASTEWATER QUANTITY AND QUALITY

CHAPTER 8 UNIT WASTEWATER QUANTITY AND QUALITY

8.1 General

Pollution sources are categorised into those related to human related activities and natural origin, which are either point or non-point (distributed) pollution sources. The former category includes human population, business/institutional establishments, factories, livestock, farmland (fertiliser, agricultural chemicals), and rainwater run-off from urbanised area. Undeveloped areas including grassland and rainfall on water body.have a potential to discharge pollution load

Unit wastewater quantity and quality of major pollution sources are studied for the target years both for water pollution analysis and planning of countermeasures.

References were made to the previous studies conducted in Zimbabwe for water supply and sewerage expansion/development. The investigation results on the water quality of major pollution sources through this study were also utilised. Furthermore, the experiences in Japan and other countries were referred to for some pollution sources.

Unit wastewater quantity for various pollution sources through the future was projected based on the study of present water consumption and effluent amount. With regard to water quality indices, Biochemical Oxygen Demand (BOD) is used for water pollution analysis of rivers and sewage treatment plan.

Water pollution analysis of lake is made using Total Nitrogen (T-N) and Total Phosphorus (T-P), which are usually applied to analyse eutrophication problem. Chemical Oxygen Demand (COD) is also used with reference to water pollution caused by organic substances. In this regard, interrelationship between BOD and COD was analysed using available data of the water body.

8.2 Domestic/Commercial/Institutional Sewage

8.2.1 Unit Sewage Quantity

(1) Water consumption per capita per day

Per capita water consumption at present and in the future is discussed referring to existing

plans by urban local authority as follows:

- Harare City

  Harare City provides water supply service for its metropolitan area including Chitungwiza Municipality, Norton Town, Epworth Local Board and Ruwa Local Board. Investigated actual water supply and consumption amount were reported in the Master Plan for Water Distribution[1/] in 1995. The data bases of water supply and water consumption are consumer's meters records (water sales) and pumping plant records (from bulk watermeters on transmission mains). These records in the last 5 years (1986-1991) are summarised in Table 8.2.1.

Table 8.2.1 Water Supply and Consumption Records (1986-1991)

Year	Pumped		Sales	
	Total Ml/annum	ADA (Ml/d)	Total Ml/annum	ADA (Ml/d)
1986/87	91,282	250	73,495	203
1987/88	102,785	279	89,516	243
1988/89	100,095	274	86,647	237
1989/90	113,742	319	96,806	265
1990/91	128,698	352	90,884	302

Note: ADA; Annual Daily Average

Annual daily average consumption (sales) grew at a rate of 8.3% p.a. between 1986 and 1991. The mean difference between pumped volume and consumption amount was 18% mainly caused by losses in the transmission mains and reticulation system, and by under-measurement at consumers' meters.

Water consumption during 1986 to 1991 was further broken down by consumer category as shown in Table 8.2.2.

1/ Master Plan for Water Distribution, Vol. 3 - Existing Supply Area, Oct. 1995, Dept. of Works, City of Harare, Sec. 4

Table 8.2.2 Water Consumption by Category (1986-1991)

Unit: $1000m^3$

Year	Consumption (Annual Daily Average)						
	Residential (a)		Ind./Com. /Inst. (b)*	B/A (%)	Chitung-wiza	Minor Supplies	Total
	High	Low/Med.					
86/87	35	66	72	71	27	3	203
87/88	53	71	87	70	28	4	243
88/89	44	73	88	75	27	5	237
89/90	50	83	99	74	28	5	265
90/91	53	97	115	77	28	9	302
Growth Rate (% p.a.)	8.7	8.0	9.8	-	-	-	8.3

*: Ind./Com./Inst.; Industrial, Commercial and Institutional

Water consumption rates by different density residential area were analysed as follows:

High-density 800 l/stand/day (≈ 80* l/capita/day)

Medium-density 1,800 l/stand/day (≈ 300* l/capita/day)

Low-density 2,500 l/stand/day (≈ 625* l/capita/day)

*: The number of persons per stand of each category is assumed;
High-density 10 p/s, Medium- 6 p/s, Low- 4 p/s
However, following figures are presented later in the same report;
High-density 11 p/s, Medium- 9 p/s, Low- 7 p/s
Applying above figures, per capita consumption is;
High-78 l/cap/d, Medium- 200 l/cap./d, Low- 357 l/cap./d

The high consumption rates of medium- and low-density were also reviewed in the study considering possible change of social conditions in the future. The following are proposed consumption rates for the year 2012 as one of alternatives:

High-density 80 l/capita/day

Medium-density 250 l/capita/day

Low-density 350 l/capita/day

Finally, the plan adopted those calculated in use of past records without any reduction of consumption rates among three proposed alternatives for medium term target. The following is the adopted water demand in the year 2012:

High-density	(3,787,911 x 80 l/p/d)	=	303.0 Ml/d
Medium-density	(501,375 x 300 l/p/d)	=	150.4 Ml/d
Low-density	(486,545 x 625 l/p/d)	=	303.8 Ml/d
Sub Total Domestic			*757.2 Ml/d*
Institutions/Commercial/Industrial (70% of Domestic)		=	530.0 Ml/d
Chitungwiza (4.5% annual growth)		=	70.5 Ml/d
Norton & Ruwa (6.4% annual growth)		=	31.1 Ml/d
Total Estimated 2012 Demand		=	*1,388.8 Ml/d*

This projected water consumption may be regarded as a maximum figures.

- Chitungwiza Municipality

The proposal for sewerage project in the Chitungwiza Municipality[1/] suggests an average daily water supply rate at 900 l/household/day based on the data obtained through bulk meter readings. It is also assumed that a 20% of the total supply amount is not conveyed to the consumers due to leakage, wastage, etc. Under the conditions, water consumption rate is estimated to be 206 l/capita/day using an average household size of 4.37 (1992 Census).

- Norton Town

The following design criteria for the estimation of future sewage flow are adopted in the feasibility study report for the new Norton STW[2/]:

High density	18 m^3/unit/month	(÷ 5.6	≈ 107 l/capita/day)
Medium density	28 m^3/unit/month	(÷ 5.6	≈ 167 l/capita/day)
Low density	37 m^3/unit/month	(÷ 5.6	≈ 220 l/capita/day)

These figures were derived through the analysis of the records at water meters. Per capita consumption figures by different density are estimated assuming an average size of 5.6 persons/household[3/] common to three different density areas.

Under the assumption the per capita consumption estimated for high density area may be less than 107 l/day, vice-versa the figure of low density area larger than 220 l/day.

1/ Project Proposals for the Sewerage Augmentation Scheme, Feb. 1996, Municipality of Chitungwiza, p20
2/ Report on the Feasibility Study for New Sewage Treatment Works, May 1996, Norton Town Council, Table 4.2
3/ 20,405 (pop. Census '92) ÷ (3,220+423) (Number of unit presented in ref. 2) = 5.60

- Ruwa

The following design criteria are adopted for estimation of future water supply demand in the Water Supply Plan of Ruwa[1/]. In this plan, there is not any description on an average number of persons per stand.

Category	Water Supply
High density	900 l/stand/day
Low density	1800 l/stand/day

(2) Sewage discharge amount per capita per day

There is no study result on per capita domestic sewage amount using actual data in Zimbabwe. However, design criteria/assumptions for planning purpose are discussed in the previous reports and studied as shown below.

1) Sanitation Manual Design Procedure, Dec. 1990

This manual was prepared for infrastructure projects of local authorities in Zimbabwe by the Swedish Association of Local Authorities (SALA) under financing by the Swedish International Development Agency (SIDA) at the request of the Ministry of Local Government Rural and Urban Development.

Annual Average Daily Water Demand (AADWD) is recommended in the manual with a range from 600 l/stand/day to 2,000 l/stand/day depending on the difference of population density. It is assumed that about 85% of supply amount to a single high-density dwelling is discharged as sewage. In addition, 850 l/stand/day is suggested as a maximum figure for sewage planning because some water may be used for watering plants and others.

2) Plans of Sewerage Systems

- Harare City

The sewerage plan for Crowborough Sewage Treatment Works[2/] used following

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1/ Water Supply Report for Ruwa Local Board, Nov. 1994, Ruwa Local Board, p3
2/ Crowborough Sewage Treatment Works, Vol. 1 - Catchment Study, Final Report, Oct. 1995, Dept. of Works, City of Harare, p35

design criteria for the estimation of future sewage flow:

Category	Water Supply		Discharge Ratio		Sewage
High density	800 l/stand/day	x	0.85	=	680 l/stand/day
Medium density	1,800 l/stand/day	x	0.70	=	1,260 l/stand/day
Low density	2,800 l/stand/day	x	0.50/0.70[1/]	=	1,400 l/stand/day

Number of persons per stand (occupancy rate of single dwelling unit) is assumed to be 10 to 12.

Applying the same number of persons per stand in the water supply master plan, following unit sewage quantity by different density area (in the sewerage plan, 10 to 12 persons per single dwelling stand are assumed):

High density	680 l/stand/day	÷	10	=	68 l/capita/day
Medium density	1,260 l/stand/day	÷	6	=	210 l/capita/day
Low density	1,400 l/stand/day	÷	4	=	350 l/capita/day

- Chitungwiza Municipality

The following design criteria for the future sewage flow are used in the Proposal for Sewerage Project of Chitungwiza Municipality[2/]:

Category	Water Supply		Discharge Ratio		Sewage
High density	800 l/stand/day	x	0.85	=	680 l/stand/day

The proposed unit sewage amount for high density are is the same as that adopted in the plan of Harare City. Applying number of persons per stand (9 persons/stand), per capita water consumption and sewage amount is 89 l/capita/day and 76 l/capita/day, receptively.

This unit water consumption is quite low in comparison with those in water supply plans.

- Norton Town

The following design conditions are used for the estimation of future sewage

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1/ for 10-20 year period, Crowborough Sewage Treatment Works, Vol. 1 - Catchment Study, Final Report, Oct. 1995, Dept. of Works, City of Harare, p37

2/ Project Proposals for the Sewerage Augmentation Scheme, Feb. 1996, Municipality of Chitungwiza, Annex 4

amount in the feasibility study for the New Norton STW[1/]. Sewage discharge ratio of 0.677 is adopted based on the actual data.

Category	Water Supply	Discharge Ratio		Sewage
High density	18 m^3/unit/month	x 0.677	=	406 l/unit/day
Medium density	28 m^3/unit/month	x 0.677	=	632 l/unit/day
Low density	37 m^3/unit/month	x 0.677	=	835 l/unit/day

Assuming that the number of persons per unit is 5.6, per capita sewage quantity by different density area is calculated as follows:

High density	406 l/unit/day ÷ 5.6 =	73 l/capita/day
Medium density	632 l/unit/day ÷ 5.6 =	113 l/capita/day
Low density	855 l/unit/day ÷ 5.6 =	153 l/capita/day

3) Measurement results at the Donnybrook STW

Residential area mainly consisting of high density area is dominant in the service area of the Donnybrook STW. Per capita sewage quantity was calculated in the range between 55.3 to 63.0 l/capita/day using past records as discussed in sub-section 8.2.2.

4) Unit sewage quantity for water pollution control planning

Although unit water consumption quantity has a range by different population density, i.e. high density 70 - 110 l/capita/day, medium density 110 - 300 l/capita/day, and low density 150 - 625 l/capita/density, the figures used in the Harare Water Supply Master Plan was employed for the planning purpose.

The discharge ratios of consumed water is referred to those applied in the sewerage master plan for Crowborough Sewage Treatment Works. The following are the calculation results:

Category	Water Supply	Discharge Ratio		Sewage
High density	80 l/capita/day	x 0.85	=>	70 l/capita/day
Medium density	300 l/capita/day	x 0.70	=>	210 l/capita/day
Low density	625 l/capita/day	x 0.50	=>	315 l/capita/day

1/ Report on the Feasibility Study for New Sewage Treatment Works, May 1996, Norton Town Council, Table 4.2

Unit water consumption quantities of low and medium density areas are assumed to be constant through the future as same as in the previous studies, while increasing unit quantities are adopted for high density area. As a present figure of high density area, 60 l/capita/day is adopted based on the study results at Donnybrook STW (see sub-section 8.2.2). For the future projection following interpolated figures are applied:

Present	60 l/capita/day
2000	63 l/capita/day
2005	65 l/capita/day
2015	70 l/capita/day

These values are adopted for all urban local authorities, namely Harare, Chitungwiza, Norton, Ruwa and Epworth, because the life style in each authority is not different each other in same density category. Discharge rate of domestic sewage in rural area with no residential category is assumed to be the same as that in high-density area.

(3) Commercial Wastewater

1) Harare City

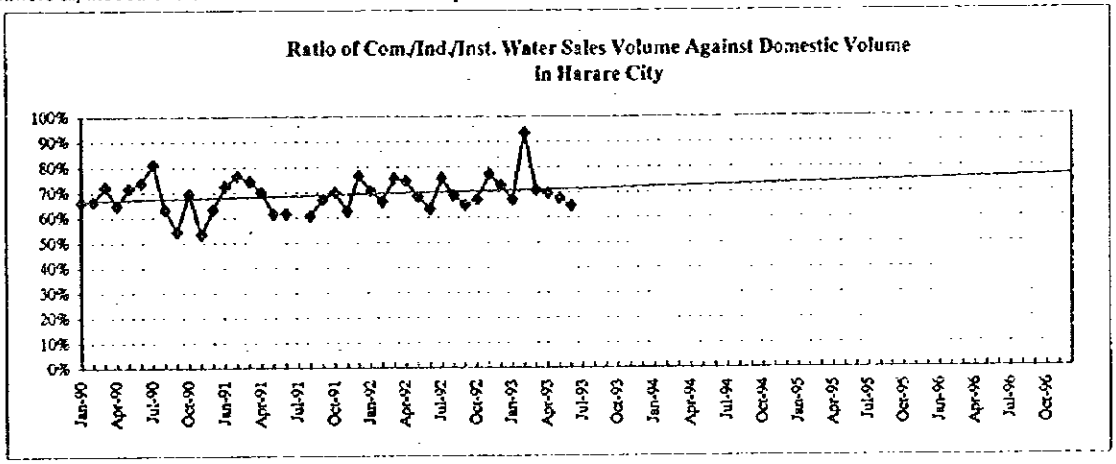
The water supply authority in the study area does not have statistics on the share of commercial/institutional water consumption. However, as presented in previous Table 8.2.2, total water consumption of commercial, institutional and industrial was computed to be about 75% of domestic water consumption in the Harare city. This assumption is also supported by the available recent data presented in Table 8.2.3. That table shows the trend line of ratio of commercial/industrial/institutional water sales volume to domestic volume in the Harare city indicating about 75% in years 1995 to 1996. Thus, the total amount of commercial, industrial and institutional water consumption at present may be assumed at 75% of domestic water consumption. Discharge ratio of them may be assumed to be equal to that of domestic sewage. Therefore, wastewater discharge quantity is also set at 75% of domestic sewage quantity. The net commercial and institutional wastewater is derived from the total amount by deducting the industrial wastewater discussed in sub-section 9.3.

The data in Tables 8.2.2 and 8.2.3 imply that the ratio of commercial and institutional consumption to domestic consumption has been increasing. The trend line showed in Table 8.2.3 indicates the percentage will be more than 100% in the year 2015.

Table 8.2.3 Water Sales Volume

Month - Year	Total Sales (m3/month)	Sales in Harare City					Sales to Chitungwiza	Sales to Norton	Sales to Others
		High-dens. Residential	Other Residential	Others* (C / I. / I)	Others/Res. %	Total			
Jan-90	6,865,275	1,416,887	2,026,572	2,273,959	66%	5,717,418	580,126	131,990	435,741
Feb-90	6,870,157	1,255,125	2,144,908	2,257,185	66%	5,657,218	744,082	90,090	378,767
Mar-90	6,684,058	1,247,952	1,928,914	2,292,405	72%	5,469,271	762,216	105,636	346,935
Apr-90	7,001,899	1,440,528	2,042,535	2,257,504	65%	5,740,567	752,670	135,720	372,942
May-90	7,104,209	1,506,601	1,796,746	2,367,513	72%	5,670,860	826,297	135,800	471,252
Jun-90	9,054,938	1,444,867	2,966,622	3,255,116	74%	7,711,246	684,785	165,984	492,923
Jul-90	9,003,703	1,287,027	3,007,597	3,476,633	81%	7,771,257	664,218	79,651	488,577
Aug-90	10,464,114	1,507,247	4,023,768	3,466,415	63%	9,017,430	941,776	79,719	425,189
Sep-90	8,685,296	1,657,672	3,442,710	2,779,368	54%	7,879,750	239,857	116,190	449,499
Oct-90	9,845,991	1,692,379	3,275,752	3,449,020	69%	8,417,151	956,147	4,000	468,693
Nov-90	10,228,822	1,760,497	3,713,892	2,927,563	53%	8,402,052	1,256,130	35,865	534,775
Dec-90	8,928,586	1,764,368	2,822,268	2,905,194	63%	7,491,830	806,821	52,018	577,917
90 Daily Avg.	275,992	49,263	90,938	92,405	66%	232,729	25,247	3,103	14,913
Jan-91	8,694,434	1,582,121	2,516,670	2,973,324	73%	7,072,115	722,919	394,100	505,300
Feb-91	8,633,746	1,486,553	2,127,135	2,763,024	76%	6,376,712	788,448	394,100	1,074,486
Mar-91	7,945,872	1,461,035	2,184,738	2,713,352	74%	6,359,125	806,162	394,100	386,485
Apr-91	8,281,005	1,755,297	2,200,829	2,766,972	70%	6,723,098	721,628	394,100	442,179
May-91	9,224,381	1,674,916	3,017,302	2,883,523	61%	7,575,741	765,009	394,100	489,531
Jun-91	9,609,357	1,712,952	3,139,943	2,986,629	62%	7,839,524	874,515	394,100	501,218
Jul-91	-	-	-	-	-	-	-	-	-
Aug-91	9,833,413	1,750,410	3,300,320	3,065,948	61%	8,189,835	1,121,907	14,923	506,748
Sep-91	9,176,004	1,797,469	2,684,203	3,006,039	67%	7,487,711	1,171,224	12,999	504,070
Oct-91	8,461,546	1,657,966	2,587,024	2,952,027	70%	7,177,017	801,414	12,999	470,116
Nov-91	8,500,070	1,842,963	2,568,561	2,760,477	63%	7,172,001	840,911	11,971	475,187
Dec-91	8,555,536	1,806,828	2,146,572	3,019,718	76%	6,973,118	1,072,169	11,770	498,479
91 Daily Avg.	265,622	50,763	77,954	87,373	68%	216,290	26,538	6,656	16,038
Jan-92	7,964,238	1,569,026	2,044,098	2,547,111	70%	6,160,235	1,316,996	8,976	478,031
Feb-92	7,721,962	1,587,010	2,195,027	2,504,384	66%	6,286,421	947,126	16,691	471,724
Mar-92	7,737,063	1,644,624	2,006,899	2,747,870	75%	6,399,393	869,464	11,538	456,668
Apr-92	7,517,527	1,568,271	2,016,766	2,669,466	74%	6,254,523	865,091	8,447	389,466
May-92	8,180,371	1,767,178	2,218,845	2,718,038	68%	6,704,061	1,133,264	16,094	326,952
Jun-92	7,840,943	1,616,864	2,411,813	2,550,581	63%	6,579,258	811,427	13,352	436,906
Jul-92	7,728,548	1,407,633	2,204,538	2,722,691	75%	6,334,862	957,041	14,077	422,568
Aug-92	8,057,252	1,753,933	2,214,570	2,725,952	69%	6,694,455	915,980	20,033	426,784
Sep-92	7,961,477	1,706,062	2,227,971	2,554,031	65%	6,488,064	878,301	24,055	571,057
Oct-92	7,211,638	1,646,740	1,905,747	2,383,107	67%	5,935,594	870,283	26,803	378,958
Nov-92	7,952,266	1,859,877	1,892,290	2,689,333	77%	6,641,500	879,826	27,864	403,076
Dec-92	7,309,890	1,658,996	1,708,961	2,446,597	73%	5,814,554	1,059,056	35,155	401,125
92 Daily Avg.	255,296	54,209	68,623	86,189	70%	209,022	31,517	611	14,146
Jan-93	6,380,212	1,650,498	1,600,246	2,175,235	67%	5,425,979	595,956	13,515	344,762
Feb-93	7,310,328	1,439,866	1,686,085	2,918,736	93%	6,044,687	943,202	20,256	302,183
Mar-93	6,724,801	1,436,671	1,840,848	2,320,597	71%	5,598,116	710,432	13,478	402,775
Apr-93	6,652,606	1,624,088	1,708,008	2,316,405	70%	5,648,501	791,263	11,316	401,526
May-93	6,889,375	1,612,291	1,727,805	2,259,406	68%	5,599,502	841,043	15,017	433,813
Jun-93	7,713,583	1,685,113	2,110,357	2,450,729	65%	6,246,199	1,002,882	23,629	440,873
93 Daily Avg.	231,331	52,202	58,969	79,785	72%	190,956	26,988	537	12,850

*: commercial, industrial and institutional water consumption



The water supply master plan, however, proposes 70% even in the year 2012. Taking account of these figures, 80% is adopted for the year 2015. For the years before 2015, following interpolated figures were adopted;

Present	75%
2000	76%
2005	78%
2015	80%

Note: These figures include industrial wastewater discharge.

The commercial water consumers in the Harare city are distributed unevenly. Though many shopping centres are scattered in entire area, their water consumption and discharge may be regarded negligible in comparison with total domestic consumption and discharge. Most of the commercial water consumers is located in the central business district which is located in the service area of Firle STW (Mukuvisi sub-basin), while many institutional water consumers are distributed in the service area of Crowborough STW (Marimba sub-basin). Taking account of influent quantities at both STWs, it is assumed that 80% of total commercial/institutional wastewater is discharged in the Mukuvisi sub-basin, and 20% in the Marimba sub-basin.

2) Chitungwiza Municipality

According to the investigation results of bulk meter reading in Chitungwiza in 1992, water consumption in Chitungwiza is categorised as shown in Table 8.2.4;

Table 8.2.4 Water Consumption in Chitungwiza

Area	Monthly Consump. (m^3)	Daily Consumption (m^3/day)	Share in Total
TILCOR Industrial Area	603,759	2,537	8.9%
Shopping Centre	107,095	450	1.6%
Hospital	234,552	986	3.5%
Others	5,844,651	24,557	86.1%
Total	6,790,057	28,530	-

Based on the figures in Table 8.2.4, the ratio of water consumption of the shopping

centre and the hospital to others is calculated at 5.0%. Other commercial and institutional water consumption may be regarded as minimal in comparison with total water consumption. Discharge rate to supplied water may be regarded as same to that of domestic water consumption. Thus, the present ratio of commercial/institutional wastewater to domestic sewage is planned at 5%. This ratio is set at constant in the future.

3) Norton Town, Ruwa, Epworth

Since no data is available for commercial and institutional water consumption in these areas, it is assumed at 5% based on the figure for Chitungwiza and field observation.

4) Other area (rural area)

It is assumed that wastewater discharge of commercial/ institutional establishments are included in that of domestic sewage.

8.2.2 Unit Pollution Load

(1) Domestic Sewage

Quality of the sewage is a requisite for water pollution analysis and designing of sewage treatment works. Generally, water quality indices to be used for those purpose are BOD, COD, T-N, T-P and Suspended Solid (SS). Unit pollution load in terms of such indices was studied in this chapter, except SS which is discussed in Chapter 12 for planning of sewage treatment facilities.

There is no precious studies on per capita pollution load, while the following are relevant information on sewage quality:

1) Sewage quality at present is used for future sewerage development in the new Norton STW plan.

2) Chitungwiza sewerage project proposals presented the BOD load at 50 g/capita/day.

3) Sanitation manual

Sanitation manual recommend only following design values of BOD load:

High-density areas 40 g-BOD/head/day

Low-density areas 50 g-BOD/head/day

The manual also presented following reference data reported by D. D. Mara[1/] :

Daily Per Capita BOD_5:	Zambia	36g
	Kenya	23g
	S.E. Asia	43g
	India	30-45g
	Rural France	24-34g
	UK	50-59g
	USA	45-78g

Average Breakdown of BOD_5 (g/head/day):

	USA	Tropics
Personal Washing	9	5
Dish-washing	6	8
Garbage Disposal	31	0
Laundry	9	5
Toilet - faeces	11	11
urine	10	10
paper	2	1
TOTAL	78	40

4) Raw sewage quantity and quality at Donnybrook STW

Table 8.2.5 summarises obtained data at the Donnybrook STW, which is dominated mainly by high density residential area, from May 1994 to April 1995.

Table 8.2.5 Raw Sewage Quantity and Quality at Donnybrook STW

STW	Avg. Flow (m3/d)		BOD_5		T-N		T-P**	
No.	Annual	Dry*	mg/l	kg/d	mg/l	kg/d	mg/l	kg/d
DB1	400	391	854.7	342	194.9	78	26.3	11
DB2	1,350	1,357	777.0	1,049	218.8	295	20.9	28
DB3	1,396	1,364	845.8	1,181	188.4	263	24.3	34
DB4	2,351	2,400	775.6	1,823	186.2	438	22.9	54
Total	5,497	5,512		4,395		1,074		126

* : Dry Season (May to Sept. '94, Apr. to Sept. '95, Apr. '96)

**: Converted from Phosphate -P values (T-P = P-P x 1.5482 + 0.2682, refer to Chapter 9)

1/ Sewage Treatment in Hot Climate, D. D. Mara, John Wiley & Sons, 1976

Present population in the service area may be estimated at in the range between 87,538 and 99,688[1/] based on the 1992 census population and annual population increase rate (2.65% p.a. and 6.04% p.a.) as discussed in Chapter 6. Therefore unit pollution load by quality index was estimated as shown in Table 8.2.6.

Table 8.2.6 Estimated Unit Pollution Load and Comparison with Experience in Japan

Unit Load	Calc. Results (a)	Exp. in Japan (b)	(a/b) %
Sewage (Dry Season)	55.3- 63.0 lpcd	-	-
BOD_5	44.1 - 50.2 gpcd	57 gpcd	77-88%
COD_{Mn}	-	28 gpcd	-
T-N	10.8 - 12.3 gpcd	12 gpcd	90-103%
T-P	1.3 - 1.4 gpcd	1.2 gpcd	108-117%

Note: lpcd; litre per capita per day, gpcd; gram per capita per day

Estimated unit pollution load is lower than that in Japan[2/] except for T-P which is higher than that of Japan. This high T-P value may be due to use of detergent containing phosphate.

Giving consideration to above discussions, following figures are used for planing purposes as the unit generated pollution loads of domestic sewage:

Table 8.2.7 Unit Generated Pollution Load of Domestic Sewage

Unit Pollution Load	High-density	Medium-density	Low-density
BOD_5	44 gpcd	47 gpcd	50 gpcd
COD_{Cr}*	88 gpcd	94 gpcd	100 gpcd
T-N	11 gpcd	12 gpcd	13 gpcd
T-P	1.2 gpcd	1.3 gpcd	1.4 gpcd

Note: gpcd; gram per capita per day
*: COD values are assumed to be two times of BOD values.

Unit discharged pollution loads are also calculated both for sewered and unsewered areas in assumption of removal ratio at respective treatment facilities. For the sewerage service

1/ Increased population adopted natural increase rate in Harare; $78,843 \times (1.0265)^4 = 87,538$
Increased population adopted annual increase rate in Harare; $78,843 \times (1.0604)^4 = 99,688$
2/ Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1993, p29

area, treatment efficiency at STW is applied to generated pollution load for calculation of discharged pollution loads. Calculations are carried out in Chapter 9.

Generally, generated sewage consisting of night soil and grey water in unsewered area is treated by septic tanks with seepage pit. Thus, any pollution load does not flow into public water bodies in usual under good maintenance condition. However, in rural area, it may be assumed that considerable amount of pollution load is flowing out to the environment due to overflowing from septic tanks and seepage pit, direct discharge of grey water, washing at rivers, etc.

Although it is difficult to quantify such pollution loads, 8% of generated pollution loads of unsewered area in high density areas is assumed to reach to subject water bodies as the concentrated pollution loads. This ratio is assumed to be nil for low and medium density areas in unsewered area in based on field observation. The values in Table 8.2.8 are assumed to be constant through the future.

Table 8.2.8 Unit Concentrated Pollution Load of Domestic Sewage in Unsewered Area

Unit Pollution Load	High-density
BOD_5	3.52 gpcd
COD_{Cr}	7.04 gpcd
T-N	0.88 gpcd
T-P	0.096 gpcd

Note: gpcd; gram per capita per day. Nil for Low and Medium.

(2) Commercial/Institutional Wastewater

No data is available for commercial and institutional wastewater quality. They were assumed to be the same as those of domestic sewage as suggested in the guidelines in Japan. In the calculation for the pollution analysis, it is assumed that the concentration of commercial/industrial wastewater is the same as that of domestic sewage in respective rural local authorities.

8.3 Industrial Wastewater

8.3.1 Unit Wastewater Quantity

Study on unit quantity of industrial wastewater by industrial type was conducted based on the data collected through the field survey at 45 factories in the four urban local authorities.

The following eight types of industry were selected from the 15 industrial types (refer to Table 6.3.3) considering the representative industrial types in each industrial area and the types of industrial discharge relating to the organic pollution load:

- Processed Foodstuffs,
- Pulp, Paper & Related Products,
- Chemicals,
- Plastic Products,
- Ceramics, Stone & Clay Products,
- Metal Products,
- Transportation Equipment, and
- Other Manufacturing Industry Products.

Number of employees by the above mentioned industrial type and their employees ratios by industrial type by local authority was calculated and presented in Table 8.3.1. These ratios are assumed to be constant and are utilised in calculation of future industrial wastewater quantity and pollution load.

The unit quantity of industrial wastewater by industrial type was then calculated based on the result of field survey including effluent flow rate measurement and effluent water quality analysis conducted at 45 factories (25 factories in Harare, 10 factories in Chitungwiza, 5 factories in Norton and 5 factories in Ruwa). The calculation result is shown in Table 8.3.2, while details are presented in Table 8.3.1, Section 8.3, Chapter 2, Supporting Report.

Unit quantity of industrial wastewater is assumed to be common to the four urban local authorities in the study area and to be constant from present through the future, considering that no remarkable change is anticipated on the composition and operating scale of major industries.

Table 8.3.1 Composition Ratio of Employees by Industrial Type

Local Authority	STW Service Area	Type No.	Type of Industry	Number of Factories	Number of Employees	Ratio of Employees (%)
Harare City	Firle Crowborough	1	Processed Foodstuffs	-	23,676	41.6
		4	Pulp, Paper & Related Products	-	753	1.3
		6	Chemicals	-	7,668	13.4
		7	Plastic Products	-	2,839	5.0
		11	Ceramics, Stone & Clay Products	-	4,692	8.2
		14	Metal Products	-	11,425	20.0
		17	Transportation Equipment	-	4,652	8.2
		19	Other Industry Products	-	1,340	2.3
			Subtotal	-	57,045	100.0
Chitungwiza Municipality	Zengeza	1	Processed Foodstuffs	5	836	42.0
		7	Plastic Products	1	25	1.3
		11	Ceramics, Stone & Clay Products	1	30	1.5
		14	Metal Products	2	93	4.7
		17	Transportation Equipment	3	875	43.9
		19	Other Industry Products	1	131	6.6
			Subtotal	13	1,990	100.0
Norton Town Council	Norton	1	Processed Foodstuffs	3	245	10.1
		4	Pulp, Paper & Related Products	1	650	26.7
		6	Chemicals	1	30	1.2
		11	Ceramics, Stone & Clay Products	1	61	2.5
		14	Metal Products	3	545	22.4
		17	Transportation Equipment	2	178	7.3
		19	Other Industry Products	3	723	29.8
			Subtotal	14	2,432	100.0
Ruwa Local Board	Ruwa	1	Processed Foodstuffs	1	125	5.3
		6	Chemicals	1	60	2.6
		7	Plastic Products	5	448	19.1
		11	Ceramics, Stone & Clay Products	1	35	1.5
		14	Metal Products	4	267	11.4
		19	Other Industry Products	5	1,411	60.1
			Subtotal	17	2,346	100.0

Table 8.3.2 Unit Quantity of Industrial Wastewater by Industrial Type

Number of Industrial Type	Type of Industry	Number of Factories	Number of Employees	Wastewater Quantity (m3/day)	Unit Wastewater Quantity (m3/day person)
1	Processed Foodstuffs	18	8,056	5,453.8	0.677
4	Pulp, Paper & Related Products	1	650	2,800.0	4.308
6	Chemicals	6	2,495	718.9	0.288
7	Plastic Products	2	74	6.2	0.083
11	Ceramics, Stone & Clay Products	2	580	483.3	0.833
14	Metal Products	4	786	171.1	0.218
17	Transportation Equipment	6	5,049	690.0	0.137
19	Other Industry Products	5	1,584	498.2	0.315

8.3.2 Unit Pollution Load

The unit pollution load of industrial wastewater was calculated by the same manner as adopted to the unit quantity calculation. The result is shown in Table 8.3.3 and their details by factory are contained in Table 8.3.2, Section 8.3, Chapter 2, Supporting Report.

8.4 Unit Pollution Load of Other Pollution Sources

Aside from domestic and industrial pollution loads, those generated by livestock, slaughter-house, farmland and natural land are studied as major pollution sources.

8.4.1 Livestock

Unit pollution load of livestock was established by species. Major livestock raising in the study area were cattle, sheep, goat, pig and poultry. However, data on pollution load of them in Zimbabwe is not available at present. The standard figures on generated and concentrated load used for pollution control plan in Japan may be employed as shown in Table 8.4.1.

Table 8.4.1 Unit Pollution Load of Livestock

Item	Generated[1]				Concentrated[2]			
	Cattle	Sheep/ Goats	Pigs	Horses	Cattle	Sheep/ Goats	Pigs	Horses
Wastewater Q (l/head/day)	90	9	13.5	N/A	-	-	-	-
BOD_5 (g/head/day)	640	64	200	220	51.2	5.12	16.0	17.6
COD_{Cr} (g/head/day)[3]	1,280	128	400	440	102.4	10.24	32.0	35.2
COD_{Mn} (g/head/day)	*530*	*53*	*130*	*700*	-	-	-	-
T-N (g/head/day)	378	38	40	170	30.24	3.04	3.2	13.6
T-P (g/head/day)	56	6	25	40	4.48	0.48	2.0	3.2

Note: 1: Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1993, p40
2: Concentrated pollution load is assumed to be 8 % of generated load according to the guidelines in Japan (less than 10%).
3: The standard COD in Japan (italics) is presented as COD_{Mn}, while COD_{Cr} is used in Zimbabwe. Thus the COD values for the study are assumed to be two times of BOD_5 values.

Further reduction of concentrated pollution load with 8% run-off is assumed in the pollution analysis of rivers for dry season based on field confirmation.

Table 8.3.3 Unit Pollution Load of Industrial Wastewater by Industrial Type

Number of Industrial Type	Type of Industry	Number of Factories	Number of Employees	Wastewater Quantity (m^3/day)	Wastewater Quality (mg/l)					Pollution Load (kg/day)					Unit Pollution Load (g/day person)				
					BOD	COD	SS	T-N	T-P	BOD	COD	SS	T-N	T-P	BOD	COD	SS	T-N	T-P
1	Processed Foodstuffs	18	8,056	5,453.8	2,262	3,916	637	66.2	23.75	12,336.5	21,357.1	3,472.0	361.15	129.51	966	2,002	301	25.06	9.61
4	Pulp, Paper & Related Products	1	650	2,800.0	2,275	9,720	498	38.0	6.20	6,370.0	27,216.0	1,394.4	106.40	17.36	9,800	41,871	2,145	163.69	26.71
6	Chemicals	6	2,495	718.9	392	2,569	795	29.8	8.19	281.6	1,846.8	571.2	21.45	5.89	106	840	306	6.30	1.73
7	Plastic Products	2	74	6.2	240	2,160	11,280	37.0	3.20	1.5	13.3	69.6	0.20	0.02	23	242	1,954	0.27	0.08
11	Ceramics, Stone & Clay Products	2	580	483.3	66	206	287	7.0	0.91	31.9	99.3	138.7	3.36	0.44	91	66	682	13.89	2.26
14	Metal Products	4	786	171.1	148	488	138	19.5	2.00	25.2	83.4	23.5	3.34	0.34	61	208	93	6.92	0.66
17	Transportation Equipment	6	5,049	718.9	262	1,802	363	16.6	20.95	180.6	1,243.3	250.1	11.45	14.44	70	392	81	3.54	4.90
19	Other Industry Products	6	1,584	498.2	213	1,324	359	53.9	5.78	106.3	659.7	178.7	26.87	2.88	230	887	397	56.04	6.51

Pollution loads of poultry were regarded to be negligible, because most of poultry is raised in pen and their excreta is not discharged. Table 8.4.2 shows unit concentrated BOD load for livestock in dry season.

Table 8.4.2 Unit Concentrated Pollution Load of Livestock (Dry Season)

Pollutant	Cattle	Sheep/ Goats	Pigs	Horses
BOD_5 (g/head/day)	4.096	0.4096	1.28	1.408

8.4.2 Slaughterhouse

Data on pollution load discharged from slaughterhouses in Zimbabwe were not available. Most of slaughtering in the study area is carried out at several abattoirs for cattle, swine, poultry and ostrich, and wastewater from those abattoirs is discharged into public sewerage system. Therefore, the wastewater from slaughterhouses was considered in the category of industrial wastewater. Table 8.4.3 shows reference values investigated in Japan[1/].

Table 8.4.3 Unit Pollution Load of Slaughterhouse (Pigs)

Item	Raw	Treated
Wastewater Q (l/head/day)	1,166	1,449
BOD_5 (g/head/day)	2,186	355
COD_{Mn} (g/head/day)	695	216
T-N (g/head/day)	304	210
T-P (g/head/day)	5	4

8.4.3 Natural Land / Farmland

(1) Natural Land

Natural pollution load is defined as that generated without effects from human activities. The land use in the study area is characterised as a combination of natural land, farmland and developed land as shown in Table 8.4.4.

1/ Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1993, p45

Table 8.4.4 Land Use in the Manyame River Basin (Upstream of Chivero Lake)

Land Use	Area	%
Woodlands (including plantations)	644	30.2
Scrubland	283	13.2
Grassland and vlei	517	24.2
Cultivation and commercial farming	231	10.8
Cultivation and rural subsistence farming	261	12.2
Residential areas	146	6.8
CBD (Central Business District) and avenues	5	0.2
Industrial area	12	0.6
Hospitals	1	0.1
Lakes, dams, sewage farms	32	1.5
Other	4	0.2
Total	2,136	100.0

Source: Lake Mcilwaine, Dr. W. Junk Publishers, 1982, p17

There is no available data on natural pollution load in Zimbabwe. References were made to the results of investigations conducted in Japan[1/] for woodlands as follows:

Table 8.4.5 Unit Pollution Load of Woodlands in Japan

Pollution Load	BOD_5	COD_{Mn}	T-N	T-P
Number of investigations	3	11	23	21
Minimum ($kg/km^2/yr$)	250	390	30	1
Maximum ($kg/km^2/yr$)	330	6,600	880	127
Average ($kg/km^2/yr$)	290	2,150	360	30

Based on these figures, the figure of 0.5~1.0 kg-BOD/km^2/day (182.5~365 kg-BOD/km^2/year) is commonly used in Japan for water pollution study of rivers. Although pollution loads fluctuate according to types of vegetation, rainfall intensity, specific flow discharge of river, etc., the average figures in the above table were used for the planning purpose as summarised in Table 8.4.6.

1/ Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1993, p53

Table 8.4.6 Unit Natural Pollution Load

Pollutant	Unit P.L.	
	(kg/km^2/year)	(kg/km^2/day)
BOD_5	290	0.795
COD_{Cr}*	4,300	11.781
T-N	360	0.986
T-P	30	0.082

*: The COD investigated in Japan (italics) are presented as COD_{Mn}, while COD_{Cr} is used in Zimbabwe. Thus the COD_{Cr} values for the study are assumed to be two times of COD_{Mn} values.

Since most of pollution loads is discharged during rainy season, 8% of BOD load, 0.064 kg/km^2/day was assumed to be discharged for the pollution analysis of river during dry season.

These pollution loads in the table were used covering all study area not only natural land but also other land use area (refer to sub-section 8.4.5).

(2) Farmland

Farmland is one of potential non-point pollution sources due to agricultural activities. Unit run-off pollution load from farmland is generally larger than that from natural land because of surface run-off ratio and provision of fertiliser. However, there is no data available on such pollution load in Zimbabwe at present. The following are the references in Japan[1/] although characteristics of cultivation and climatic condition are different from Zimbabwe:

Table 8.4.7 Unit Pollution Load of Farmland in Japan

Pollution Load	BOD_5	COD_{Mn}	T-N	T-P
Number of Investigation	2	5	24	17
Minimum (kg/km^2/yr)	29	399	820	0
Maximum (kg/km^2/yr)	471	2,190	23,800	243
Average (kg/km^2/yr)	250	1,030	7,600	68

The Department of Research and Specialists, Ministry of Agriculture investigated the quantity of fertiliser provided to farmland by seven farmers in the study area (refer to Table 8.4.1, Section 8.4, Chapter 2, Supporting Report). The results of investigation are as follows:

1/ Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1993, p51

Table 8.4.8 Investigation on Fertiliser Quantity

Pollution Load	Nitrogen Fertiliser	Phosphate Fertiliser
CROPS (including Horticulture)		
Total Area of Farmland (ha)	3,413	3,413
Total Fertilised Quantity (kg/yr)	117,411	6,520
Average Fertilised Quantity (kg/km^2/yr)	3,440	191
PASTURES		
Total Area of Farmland (ha)	1,387	1,387
Total Fertilised Quantity (kg/yr)	824	2,160
Average Fertilised Quantity (kg/km^2/yr)	59	156

Under insufficient available data, unit pollution load provided in farmland was assumed in consideration of the aforementioned information. Those for BOD and COD are based on the experience in Japan. While, T-N and T-P are referred to the investigation results in the study area. A part of those fertiliser is absorbed by crops, plants and soil, and volatilise to the air. If 10% of provided fertiliser is assumed to be potential run-off amount, unit pollution load in discharged level is calculated as shown in Table 8.4.9.

Table 8.4.9 Unit Pollution Load of Farmland

Pollutant	Unit P.L.	
	(kg/km^2/year)	(kg/km^2/day)
BOD_5	250	0.685
COD_{Cr}*	2,060	5.644
*COD_{Mn}**	*1,030*	*2.822*
T-N (Crops)	350	0.959
T-P (Crops)	20	0.055
T-N (Pastures)	6	0.016
T-P (Pastures)	16	0.044

*: The COD investigated in Japan (italics) is presented as COD_{Mn}, while COD_{Cr} is used in Zimbabwe. Thus the COD_{Cr} values for the study are assumed to be two times of COD_{Mn} values.

Farmland area by sub-basin in the study area is not available. Since the pollution loads of farmland and natural land are on the same magnitude level, pollution load discharged from farmland may be taken into account in calculation of that for natural land.

1/ Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association, 1993, p51

8.4.4 Other Pollution Sources

In addition to pollution loads discussed in the previous sub-sections those caused by rainfall (air pollution) and urban rainwater run-off are sometimes considered in the similar studies. The former may be negligible in the country, while the latter may be considered to be included in the assumed natural pollution load. Though the pollution load carried by rainwater run-off from urbanised area cannot be neglected, the amount in dry season for the analysis of river is minimal.

Pollution loads from leachate of solid waste disposal site were considered. Amount of leachate is estimated at around 3,300 m^3/year/ha for on-going landfill site, and 2,000 m^3/year/ha for completed landfill site with compacted soil cover. Details of calculation are presented in Table 8.4.2, Section 8.4, Chapter 2, Supporting Report.

Water quality of leachate from solid waste landfill varies depending on kinds of solid waste, structure of landfill site, elapsed time after landfilling, climatic condition, etc. In the absence of available data in Zimbabwe, investigation results in Japan (see Table 8.4.10) were referred to. Table 8.4.11 shows standard figures applied in the study.

Table 8.4.10 Water Quality of Leachate from Solid Waste Landfill Site in Japan

Type of Waste	Mainly Combustible Waste	Mainly Incombustible Waste	Mixed
pH	5.0 - 8.6	4.0 - 9.0	4.0 - 8.6
BOD (mg/l)	250 - 2,500 (1,000)	10 - 2,200 (500)	500 - 1,000 (500)
COD (mg/l)	200 - 800 (400)	20 - 3,600 (400)	450 - 500 (450)
SS (mg/l)	100 - 500 (200)	80 - 3,200 (200)	150 - 500 (400)
NH_4^+-N (mg/l)	200 - 400 (200)	42 - 400 (200)	250 (250)

Note: Figures in parenthesis indicate median values.
Source: Guidelines for Planning & Design of Solid Waste Disposal Site, 1989, National Urban Cleaning Conference of Japan

Table 8.4.11 Water Quality of Leachate from Solid Waste Damping Site

BOD_5 (mg/l)	COD_{Cr}* (mg/l)	T-N** (mg/l)	T-P*** (mg/l)
500	900	250	-

*: The COD investigated in Japan presented as COD_{Mn}, while COD_{Cr} is used in Zimbabwe. Thus the COD_{Cr} values for the study are assumed to be two times of COD_{Mn} values.
**: Values of NH_4-N is adopted.
***: No available data. But considerable to be negligible.

In addition to aforementioned pollution sources, the Morton Jaffray and the Prince Edward water treatment works (WTWs) are considered as pollution sources.

Presently, wastewater generated at the Morton Jaffray WTW through backwashing process is discharged to nearby river without any treatment. Sludge sedimented in a sedimentation tank is led to a sedimentation pond, and supernatant liquid is discharged to open area. Introduction of mechanical treatment plant for backwashed wastewater is scheduled at present. This project will contribute for saving water by returning treated water to the water treatment process.

At the Prince Edward WTW, sludge from sedimentation pond is discharged to open area and supernatant liquid is led to the Seke Dam, while backwashed wastewater returns to water treatment process.

Pollution loads of those wastewater is originating from intake water. Therefore, pollution load may be calculated by pollution load concentration of water sources and intake water amount. For the water pollution analysis, pollution loads from WTWs were assumed as follows:

1) Morton Jaffray WTW
   a. Sedimented sludge (assumed to be 75% of total pollution load)
      - 8% of pollution load is concentrated to Lake Manyame.
      - During dry season, 8% of BOD load is concentrated to Lake Manyame.
   b. Backwashing sludge (assumed to be 25% of total pollution load)
      - 100% of pollution load is concentrated to Lake Manyame.
      - Pollution load is not concentrated to Lake Manyame after introduction of sludge treatment plant.

2) Prince Edward WTW
   a. Sedimented sludge (assumed to be 100% of total pollution load)
      - 8% of pollution load is concentrated to Manyame River (downstream).

- During dry season, 8% of BOD load is concentrated to Manyame River (downstream).

b. Backwashing sludge (assumed to be 0% of total pollution load)
   - Constant pollution load is circulating in the processes.

CHAPTER 9

PRESENT WATER POLLUTION ANALYSIS

CHAPTER 9 PRESENT WATER POLLUTION ANALYSIS

9.1 General

Present water pollution analysis was undertaken to establish a simulation model and major factors to be applied for prediction of water quality at water quality checking points in the future, and to identify the degree of present contribution for water pollution by each pollution source. Flow diagrams of present water pollution analysis for rivers and lakes are presented in Figures 9.1.1 and 9.1.2, respectively.

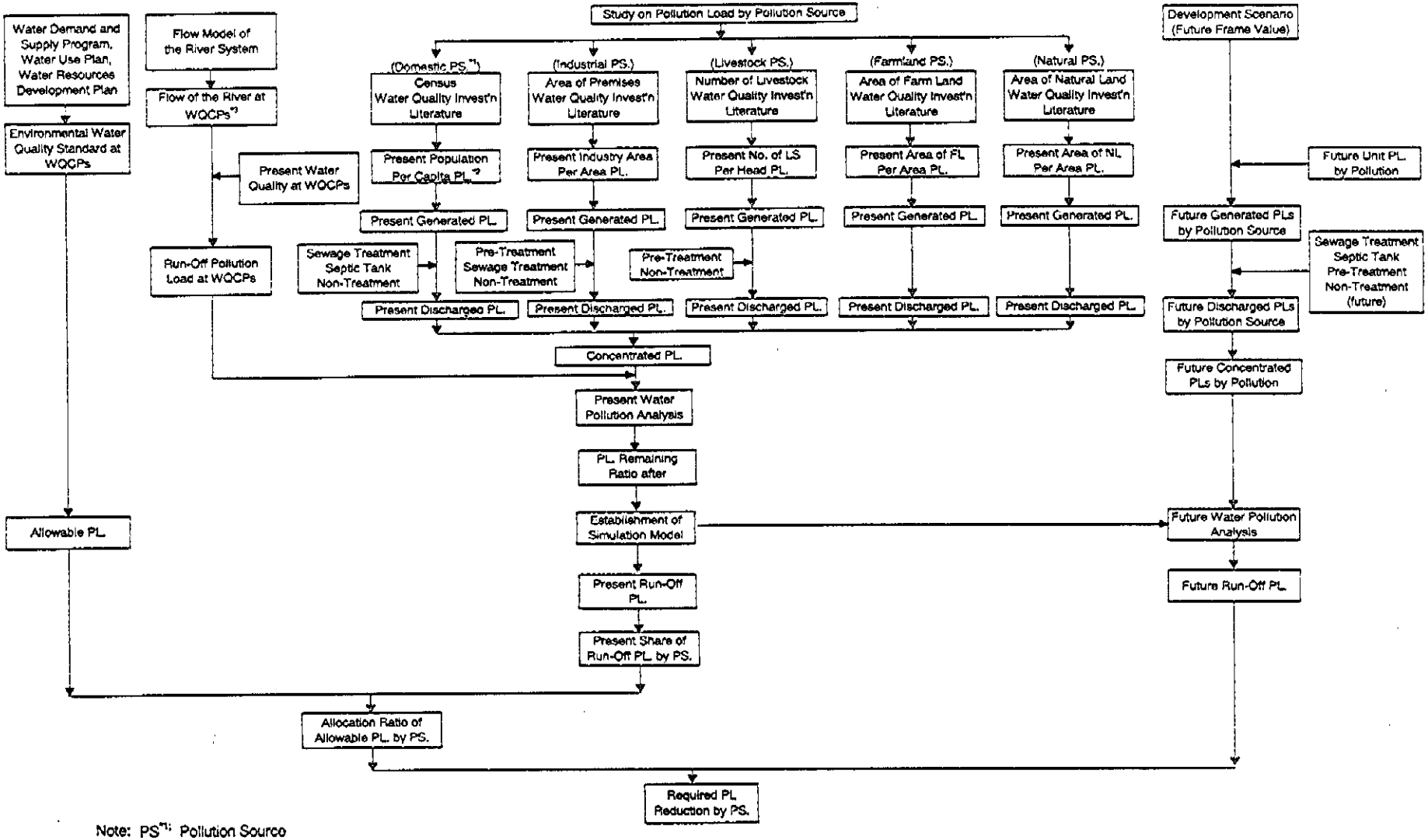
Water pollution analysis was conducted considering both of human-being related and natural pollution loads covering point and non-point sources. Flow model of entire study basin for present water pollution analysis was established using average flow rates during last 10 years as discussed in the previous sub-section 7.2.

The analysis was conducted on a simple and practical basis under constraints of available time and data. The quantitative analysis was made for Seke and Harava Dams, Lake Chivero and Lake Manyame in terms of T-N, T-P and COD, while qualitative base for rivers. The relationships between pollution loads discharged from various pollution sources and the concentrated pollution load at water quality checking points set up along the main river were derived through the analysis. Water quality indices used in the analysis for rivers was BOD representing water pollution by organic substances mainly caused by human activities. Run-off model in dry season was applied for the pollution analysis of rivers. Because of alternating location of rivers and lakes as shown in Figure 9.1.3, analysis of entire basin was conducted part by part as shown in Figure 9.1.4.

9.2 Concept of Water Pollution Analysis

9.2.1 Rivers

The water pollution study for the rivers was conducted through the analysis of existing data, water quality examination results obtained through the study, and previous pollution study reports. Water quality index used in the study was BOD. BOD is converted to COD, and vice versa, if necessary, using a conversion formula derived from the regression analysis on the results of water quality examination both for BOD and COD.



Note: PS*1: Pollution Source
PL*2: Pollution Load
WQCPs*3: Water Quality Checking Points

Figure 9.1.1 Flow Diagram of Water Pollution Study (Rivers)

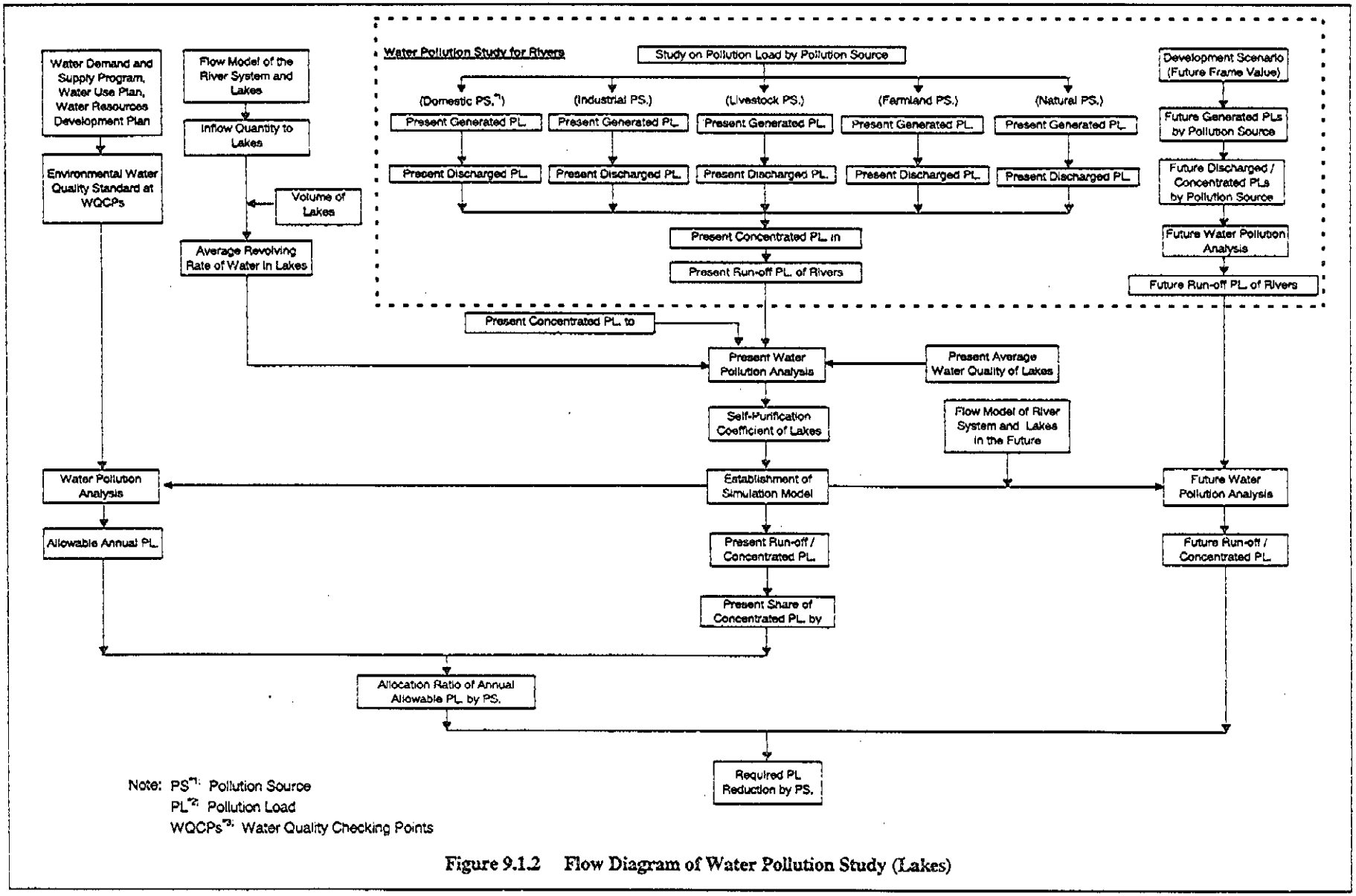


Figure 9.1.2 Flow Diagram of Water Pollution Study (Lakes)

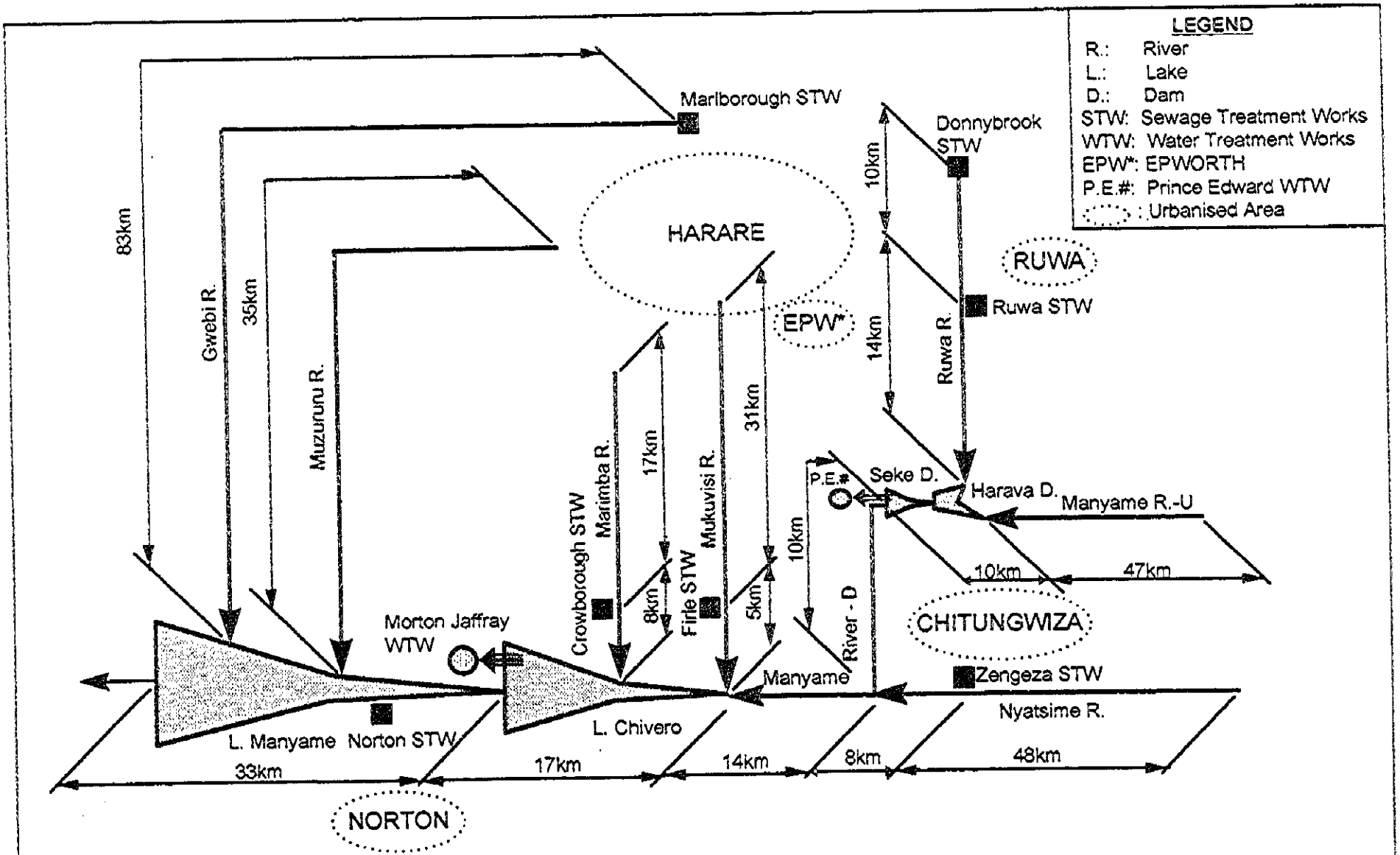


Figure 9.1.3 Location of Rivers, Lakes and STWs

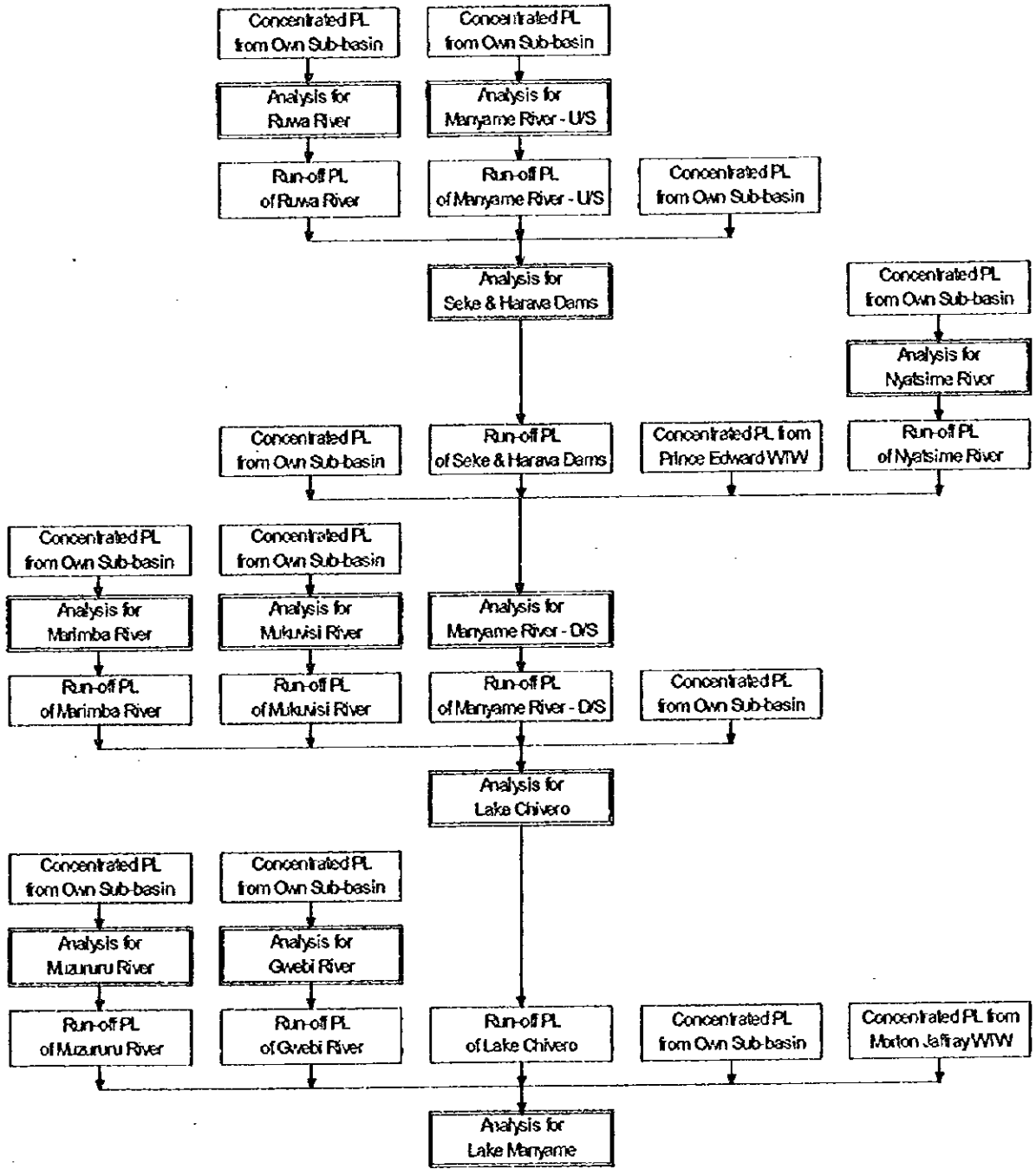


Figure 9.1.4 Flow Diagram of Analysis for Rivers and Lakes

The pollution load generated at pollution sources is discharged to the environment through treatment facilities such as sewage treatment plants, septic tanks, industrial wastewater treatment facilities, etc. Then discharged load is further reduced in conduits and streams before flowing into rivers due to infiltration, sedimentation, natural oxidation, and so on. The reduced pollution load at the inflow point is called as concentrated load, and the ratio of discharged load to concentrated load is called as the concentration ratio. The concentrated load and run-off load reached from upstream of the river is further reduced by natural self-purification phenomena due to sedimentation, absorption, biological decomposition, etc. The ratio of concentrated load to run-off load is called as the pollution load remaining ratio, and the ratio of run-off load to discharged load is called as the run-off ratio. Figure 9.2.1 shows a concept of pollution load flow system.

In the study, pollution load remaining ratios of each river were derived through the pollution analysis of rivers. Concentrated pollution load was estimated using frame values, unit pollution load and assumed concentration ratio. Run-off load was estimated based on the existing data on flow rate and water quality of rives.

9.2.2 Lakes/Dams

The water pollution study for the lakes was also conducted through the analysis of collected data and previous pollution study reports. Water quality indices used in the study were T-N, T-P and COD. COD was utilised to eliminate the influence of algae in examination of BOD. In the study, COD was referred to as a reference.

The Vollenweider Model was adopted for water pollution simulation model in terms of T-N, T-P and inflow-COD.

Pollution analysis in terms of COD was conducted for the inflow-COD to the lake and the secondary produced COD mainly produced by phytoplankton in the lake . The inflow-COD was analysed using the Vollenweider model, and the secondary produced COD by the ΔCOD method.

The ΔCOD method was introduced assuming that the difference (ΔCOD) between the lowest COD value in the year and the average COD value is equivalent to the secondary produced COD. It was also assumed that increase of COD caused by elution from sediment in the lake is considered in this concept. In this Study, the lowest COD was measured as S-COD (Soluble

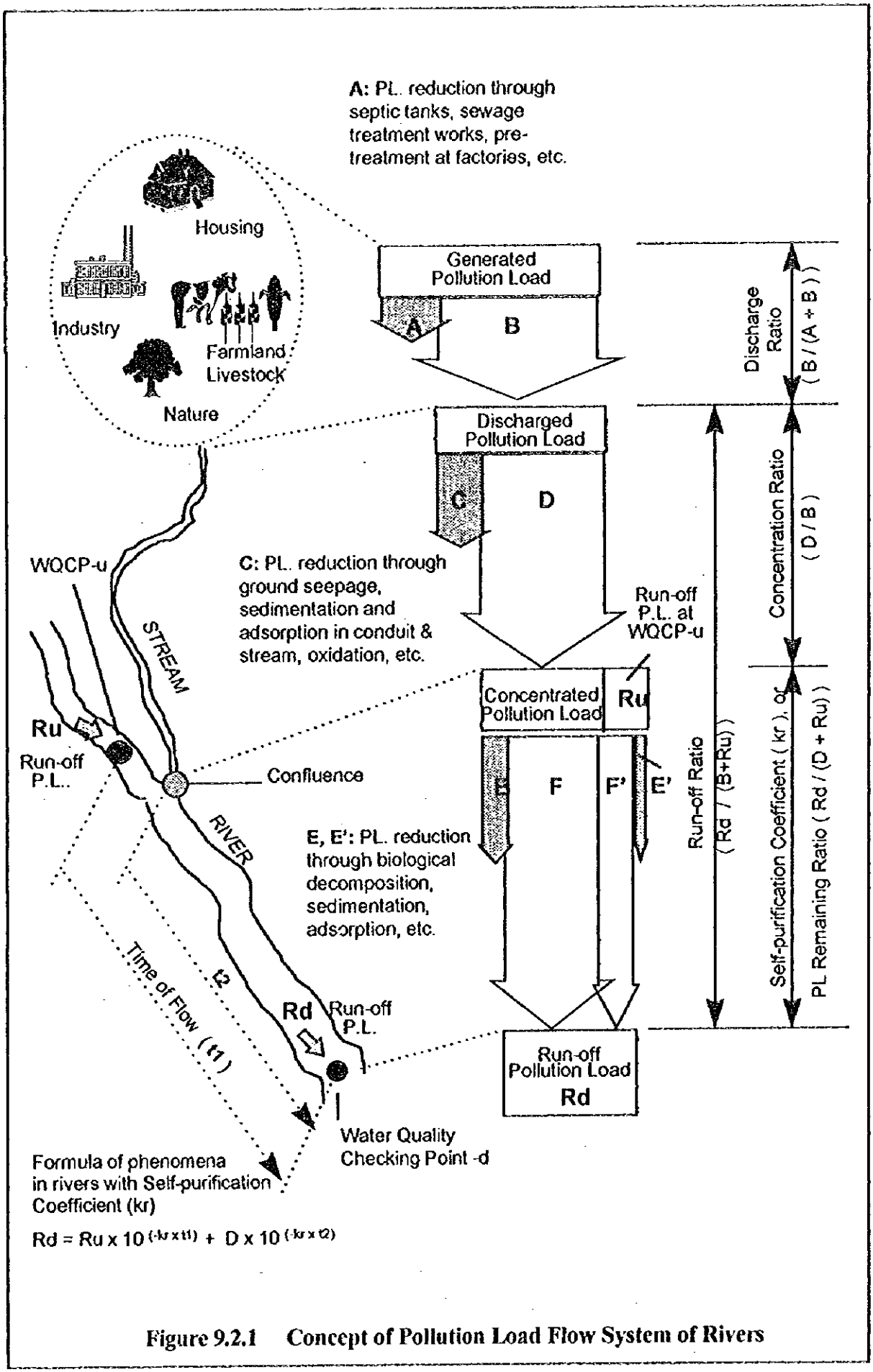


Figure 9.2.1 Concept of Pollution Load Flow System of Rivers

COD - to eliminate algae's activities). The secondary produced COD in the future was estimated using projected pollution loads in terms of T-N and T-P, and the relationship between ΔCOD, T-N and T-P in the present condition.

Average values were used as input data to this model assuming that water quality in the lake is stable and uniform. Thus, the lake was regarded as a kind of black box with a completely mixed condition and inflow nutrient load balances with the water quality of the lakes.

The adopted formula for the analysis are 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

Run-off pollution load obtained through the pollution analysis for the river was adopted as the inflow loads into the lake (refer to Figure 9.2.2). 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.

9.3 Frame Values and Pollution Load by Sub-basin

9.3.1 Domestic/Commercial/Institutional Sewage

The population in 1995 estimated in sub-section 6.2 was broken down to those in sewered and unsewered area as shown in Table 9.3.1. The projected population of Scenario-2 was used as

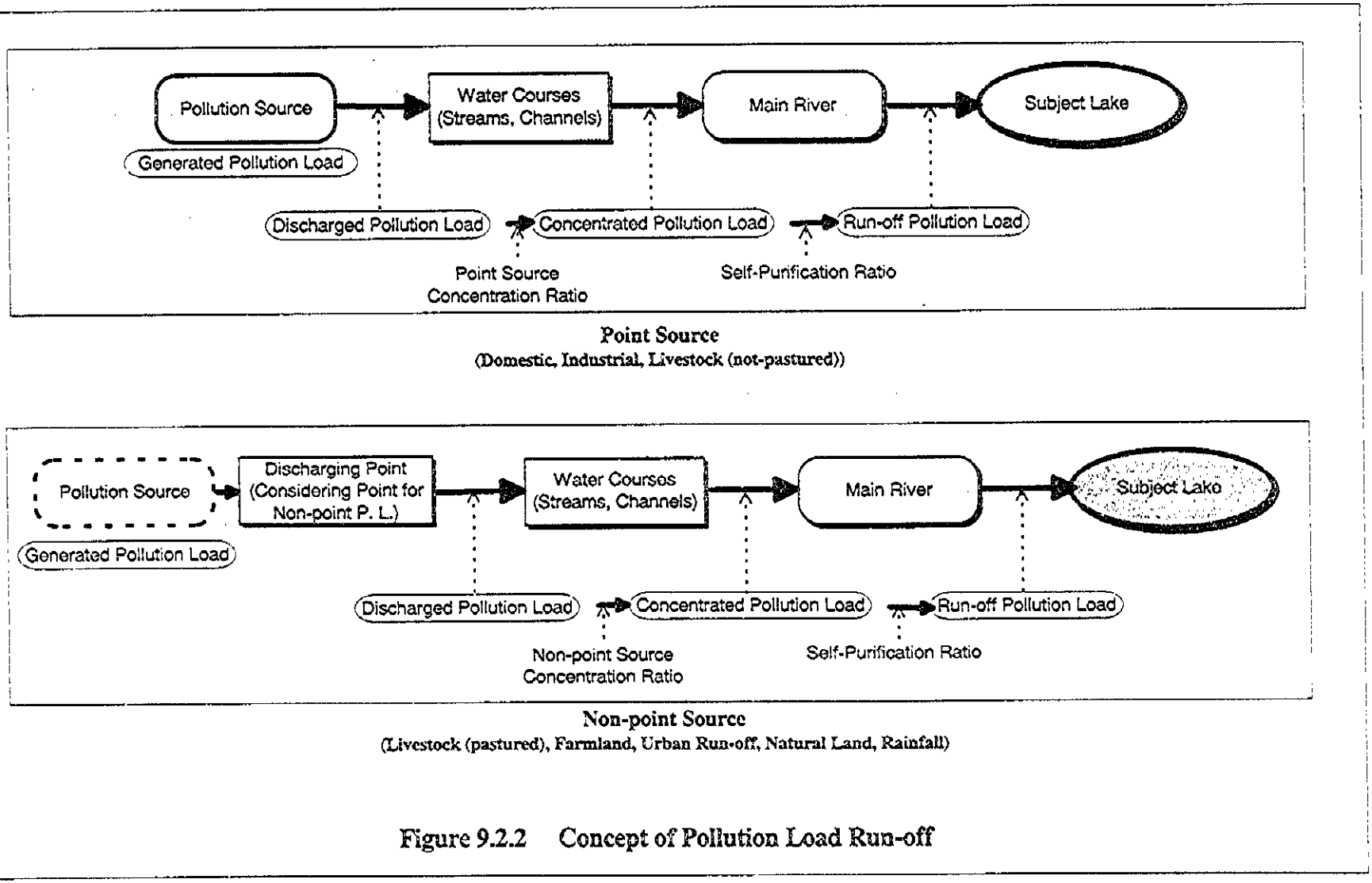


Figure 9.2.2 Concept of Pollution Load Run-off

Table 9.3.1 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 9.3.1 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 12.2.3., Section 12.3, Chapter 2, Supporting Report

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

present figure, because the differences among projected populations in two scenarios are minimal. Generated and discharged pollution load were calculated by sewered/unsewered area applying unit pollution load of domestic sewage discussed in sub-section 8.2. The estimated sewage/wastewater quantity by sewered/unsewered area by sub-basin are presented in Table 9.3.1, Section 9.3, Chapter 2, Supporting Report.

The pollution load collected from the sewered area is discharged at sewage treatment works. The pollution load was calculated using present effluent water quality and quantity at the STWs. Calculation results are presented in Table 9.3.2. As presented in the table, about 172,900 m^3/day or 80% of total effluent flow was assumed to be used for irrigation. The percentage of irrigation reuse was the result of 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 the influence of the Zengeza arrangement has not affected sufficiently on entire lake water after the arrangement.

It was 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 9.3.3 to 9.3.6 in terms of BOD, COD, T-N and T-P, respectively.

9.3.2 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 9.3.7, while details are presented in Table 9.3.2, Section 9.3, Chapter 2, Supporting Report.

(2) Pollution Load

Present pollution load was calculated by multiplying the unit pollution load of industrial

Table 9.3.2 Discharged Pollution Load at Sewage Treatment Works (Present)

Sub-basin	Sewage Treatment Works	Eff. Flow (m3/day)		Irrigation Reuse (%)	Average Effluent Water Quality (mg/l)				Pollution Load of Effluent (kg/day)				Concentrated Pollution Load [f] (kg/day)			
		Annual	Dry		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 (BNR)	16,000	15,700	0%	18.9	91.3	9.3	2.7	297	1,461	149	43	297	1,461	149	43
do	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
do	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) [h]	400	400	-	-	-	-	-	-	-	-	-	-	-	-	-
do	Donnybrook-2 (WSP) [h]	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) [h]	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) [h]	2,400	2,400	-	-	-	-	-	-	-	-	-	-	-	-	-
do	Donnybrook Total [h]	5,600	5,600						474	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
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 (refer to Section 9.3, Chapter 2, Supporting Report)

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 (refer to Section 9.3, Chapter 2, Supporting Report)

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

Table 9.3.3 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 9.3.3 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 12.2.3., Section 12.2, Chapter 2, Supporting Report

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 9.3.4 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 9.3.4 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 12.2.3., Section 12.2, Chapter 2, Supporting Report

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 9.3.5 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 9.3.5 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 12.2.3., Section 12.2, Chapter 2, Supporting Report

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 9.3.6 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 9.3.6 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 12.2.3., Section 12.2, Chapter 2, Supporting Report

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 9.3.7 Present and Future Industrial Wastewater Quantity

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

wastewater per employee and the number of employees at present. The result is presented in Table 9.3.8, while details are presented in Table 9.3.3, Section 9.3, Chapter 2, Supporting Report.

(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 9.3.9.

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 reused 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

9.3.3 Other Wastewater

(1) Livestock

Number of major livestock presented in Table 6.4.1 was allocated to each sub-basin in proportion to area size presented in Table 6.4.2. Calculation results are shown in Table 9.3.10. 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 discussed in sub-section 8.4.1 (refer to Tables 9.3.4 to 9.3.7, Section 9.3, Chapter 2, Supporting Report). The summary of calculation is shown in Table 9.3.11.

Table 9.3.8 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 9.3.8 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 9.3.9 Industrial Wastewater Quantity 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

Table 9.3.10 Number of Major Livestock by Sub-basin

Cattle

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Cheguru
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	22,406	65,191	13,720	6,490	21,890	20,250	7,267

Pigs

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Cheguru
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	4,678	15,400	1,054	1,360	2,500	420	142

Sheep / Goats

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Cheguru
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	1,131	-	-	760	-	5
Gwebi River	2,961	2,741	-	-	213	-	7
Lake Manyame	624	290	-	-	208	-	125
Study Area Total	472	4,142	5,428	1,260	3,500	2,651	207

Horses

Sub-basin	Total	Nyabira	Marondera	Mel./Ruwa	Harare C.	Manyame	Cheguru
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	67	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 9.3.11 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

(2) Farmland / Natural Land

The pollution loads derived from farmland and natural land were calculated for each sub-basin as shown in Table 9.3.12 using the area of each sub-basin and unit pollution load presented in Tables 8.4.6. The pollution load may be defined as concentrated pollution loads.

(3) Solid Waste Dumping Sites

Present condition of major solid waste dumping sites of respective rural local authorities are described in sub-section 4.3. Location and area of dumping sites are presented in Table 9.3.13. The pollution load from these dumping sites were calculated using the area of each landfill site and unit pollution load presented in Table 8.4.11. Concentration ratio was 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 9.3.13.

(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 8.4.4. Because of unavailability of the data on quality and quantity of the wastewater, it was 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 9.4.1 and 9.4.3 to 9.4.5.

9.4 Establishment of Pollution Load Run-off Model with Water Quality Checking Points

9.4.1 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 was those in dry season derived based on average figures in dry season of last 10 years as discussed in sub-section 7.2. Applying those flow, river flow run-off model was established as

Table 9.3.12 Pollution Load of Farmland / Natural Land

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

Sub-basin	Area	BOD	BOD (dry)	COD	T-N	T-P
	(km2)	0.795	0.0636	11.781	0.986	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 9.3.13 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**				
						3,300	2,000	500	900	250	-				
			Total	on-going	comp-leted	(m3/year)	(m3/year)	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%)

illustrated in Figure 9.4.1 with pollution load discharging points and water quality checking points.

(2) Pollution Load Run-off Model

The concentrated BOD load calculated in the previous section is summarised in Table 9.4.1. 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 9.4.1 was allocated to each pollution load discharging point presented in Figure 9.4.1 as shown in Table 9.4.2. Pollution load run-off model for present pollution analysis of rivers was formulated as presented in Figure 9.4.2 (refer to Figure 9.4.1, Section 9.4, Chapter 2, Supporting Report).

9.4.2 Lakes/Dams

(1) Water Balance of Lakes

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 as discussed in sub-section 7.2. Applying the water balance, run-off model was established as illustrated in Figure 9.4.1 with pollution load discharging points and water quality checking points.

(2) Pollution load run-off model

The concentrated pollution loads calculated in the previous chapter are summarised in Tables 9.4.3 to 9.4.5 for COD, T-N and T-P, respectively. The concentrated loads caused by livestock and natural pollution occupy large share of the total loads. 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.

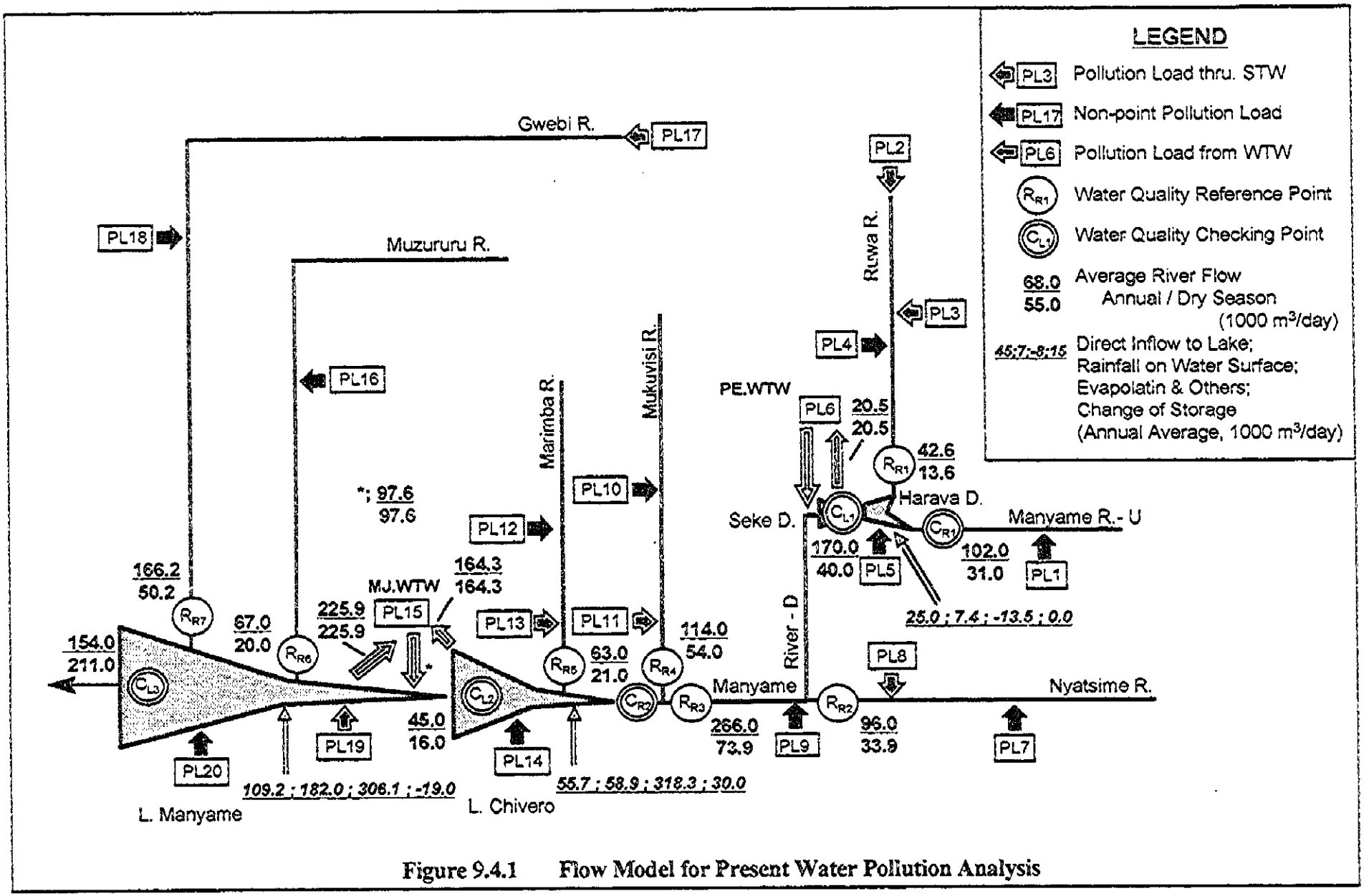


Figure 9.4.1 Flow Model for Present Water Pollution Analysis

Table 9.4.1 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)

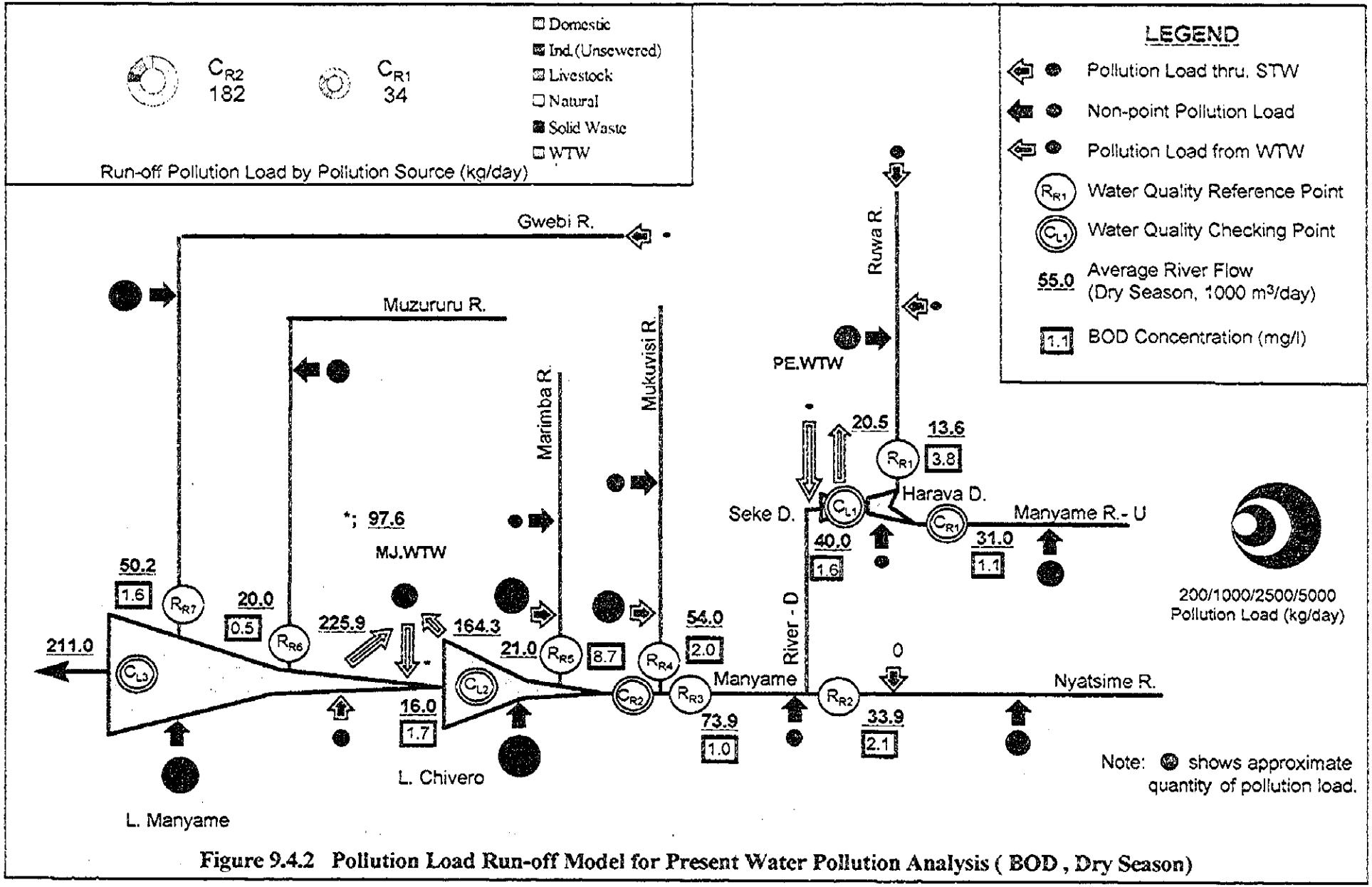


Figure 9.4.2 Pollution Load Run-off Model for Present Water Pollution Analysis (BOD , Dry Season)

Table 9.4.2 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

Table 9.4.3 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} RR_3*	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 9.4.4 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 9.4.5 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)