

APPENDIX 6

**ANALYSIS OF WATER QUANTITY AND QUALITY
IN
MANYAME CATCHMENT AREA**

6.1 Water Quantity and Quality in Manyame Catchment Area

6.1.1 Water Use in the Study Area

(1) Water Use in the Entire Study Basin

In the upper Manyame river basin, the major impoundments are Lake Manyame, Lake Chivero, Seke Dam and Harava Dam. Several rivers flow into these water bodies. Their general dimensions and water use are shown in Table A6.1.1.

Table A6.1.1 Water Use in the Entire Study Basin

Water Body	Catchment Area (km ²)	Rated Capacity (x1000 m ³)	Flow Rate (x 1000 m ³ /day)	Water Use
1. L. Manyame	590	480,236		Water Supply, Recreation and Fishery
Gwebi R.	770		282,540	Irrigation
Muzururu R.	310		113,900	Irrigation
2. L. Chivero	421	247,181		Water Supply, Recreation and Fishery
Marimba R.	215		131,000	Irrigation
Mukuvisi R.	230		214,000	Irrigation
Nyatsime R.	280		163,200	Irrigation
3. Seke & Harava Dam	115	12,406		Water Supply, Recreation and Fishery
Ruwa R.	195		72,846	Irrigation
Manyame R.	474		174,000	Irrigation

Source: JICA Project Team

The direct use of river water is minimal due to limited availability during dry season. As for irrigation, about 200 private dams are scattered in the Gwebi and Muzururu catchment area, while the reuse of treated effluent is dominant in the entire Study Area. On the other hand, lakes and dams are utilised for water supply, recreation and commercial fishery purposes. Four impoundments are the most valuable water sources for water supply of metropolitan Harare where presently 467,000 m³/day are availed of.

As for recreational usage, Lake Manyame and Lake Chivero are designated as national recreational parks with a variety of interests including fishing, boating, swimming and game viewing. Commercial fishery is also allowed in both lakes. Since these impoundments are situated at a lower elevation than the urban area and farm land, generated wastewater reach the lakes.

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As of September in 2012, there is no future plan on water use in the study basin, thus the present manner of water use will continue to be practised

(2) Domestic and Industrial Water Supply

1) Existing Water Supply System

The Harare water supply system covers Harare City (350 km^2) and its adjoining urban areas; Chitungwiza, Norton, Epworth, and Ruwa. The water supply service for the satellite areas of the city is provided by means of bulk water supply. The present water demand for Harare and Chitungwiza is projected to be $382,900 \text{ m}^3/\text{day}$. The industrial water consumption is about 23% of the domestic consumption, while that of commercial/institutional is 5%.

2) Raw Water Sources

The raw water sources of the Harare water supply system depend on four impounding dams with a yield of $586,000 \text{ m}^3/\text{day}$. The total intake amount at present is approximately $640,000 \text{ m}^3/\text{day}$. Water quality of the lakes/dams has deteriorated due to grey water and industrial wastewater discharge from urban areas into the Manyame river basin.

3) Water Treatment Plant

Two existing WTPs, Prince Edward and Morton Jaffray, adopt conventional water treatment system provided with sludge blanket clarifiers and rapid sand filters. The design capacity of the Morton Jaffray WTP and Prince Edward WTP are $614,000 \text{ m}^3/\text{day}$ and $90,000 \text{ m}^3/\text{day}$, respectively. However, the Prince Edward WTP is operated intermittently to supplement peak demand, since its "safe yield" is limited to $23,000 \text{ m}^3/\text{day}$. Water production is $40,000$ to $550,000 \text{ m}^3/\text{day}$

Table A6.1.2 Outline of Water Treatment Works

	Morton Jaffray WTW		Prince Edward WTW	
Intake Source	Lake Manyame	Lake Chivero	Seke Dam	Harava Dam
Design Capacity	$614,000 \text{ m}^3/\text{day}$		$90,000 \text{ m}^3/\text{day}$	
Actual Production Capacity	$350,000 \text{ m}^3/\text{day}$		$23,000 \text{ m}^3/\text{day}$	

Source: Harare Water

The deterioration of raw water quality has affected the operation of the water treatment plants. The Morton Jaffray WTP, for instance, requires high chemical dosage which is beyond its full capacity for its dosing equipment to handle

4) Transmission and Distribution

Treated water is pumped from Morton Jaffray WTP to Warren Pump Station, and is again pumped to service reservoirs through four transmission mains. Water is then distributed through the respective

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network systems from the concerned service reservoirs to end users. Figure A6.1.1 shows schematic diagram of the water supply system at present.

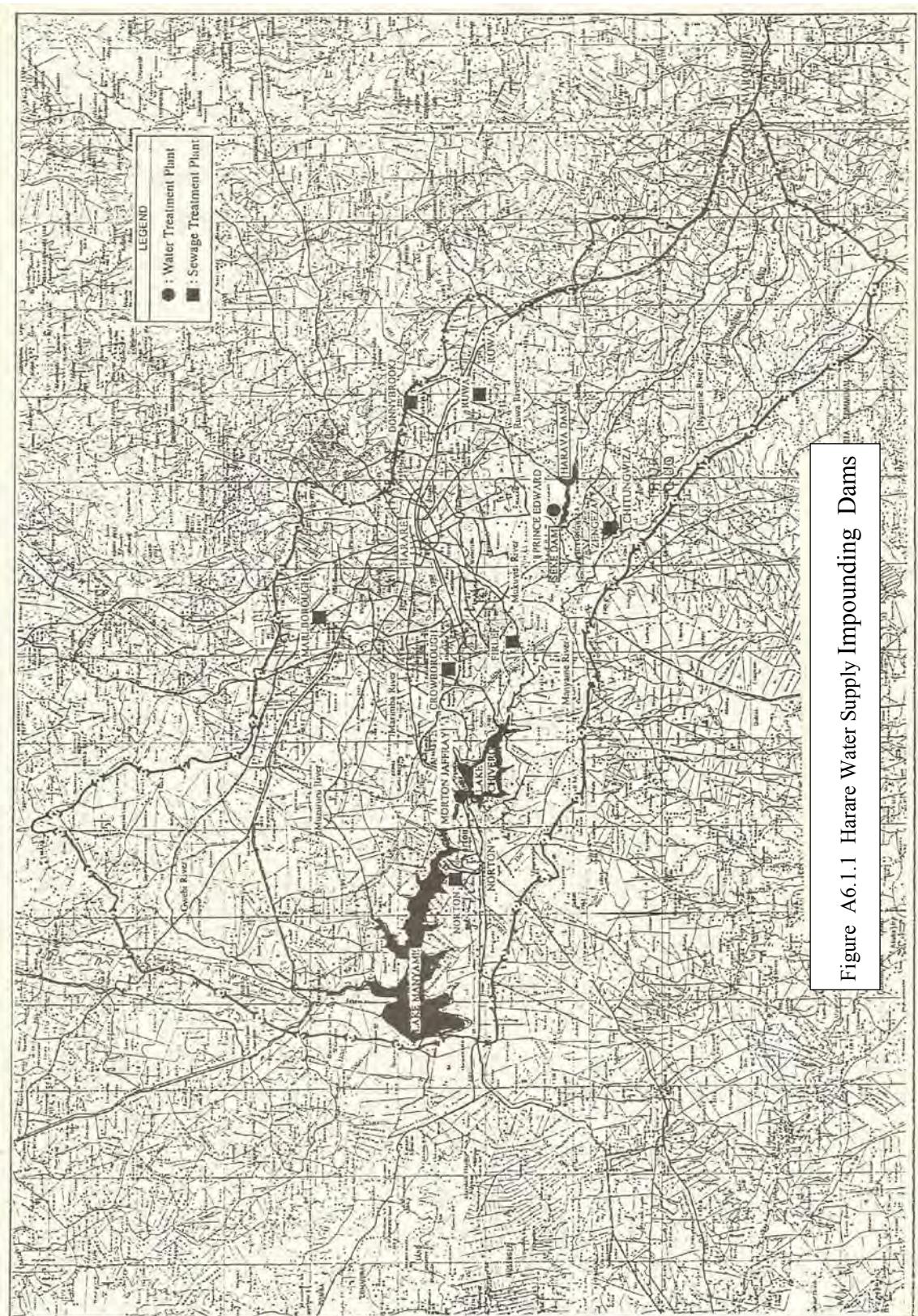


Figure A6.1.1 Harare Water Supply Impounding Dams

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(3) Ambient Water Quality Standards

1) General

In Zimbabwe, the regulation of effluent for wastewater has been enacted; however, the ambient water quality standards have yet not been established. Moreover, there is no informational base upon which to evaluate the present water quality in the water bodies of the country, since level of water quality is to be required has not yet been established for the various water uses and for water quality preservation. To prepare the water pollution control plan for the Upper Manyame Basin, the establishment of the Ambient Water Quality Standard would be primarily required. A proposal for the Ambient Water Quality Standard was made in “the Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe” (hereinafter the Study 1997), in 1997 conducted by JICA. Since the Study 1997 is considered to be sound for the catchment area, proposed standard will be followed in this study.

The subject water basins are to be classified based on water use and water preservation. Staged goals may be introduced as provisional standards due to the current water pollution status of the water bodies. Water quality checking points were established for monitoring purposes in the Study 1997.

2) Ambient Water Quality Standard

Generally, water quality items consist of two categories, i.e., the environmental items represented by BOD and COD as the general indicators of organic pollution load, and human health related items including heavy metals, volatile organic chemicals and agricultural chemicals. These items must be monitored in the water bodies throughout the year.

The ambient items for rivers as adopted in Japan comprise pH, BOD, SS, DO and a coliform group; and for the lakes Total Nitrogen (T-N) and Total Phosphorus (T-P) were added and COD was replaced by BOD. Standard qualities for these items were determined in accordance with the different purposes of the intended water uses. The ambient water quality standard is usually set considering the dilution of effluent with river water (1/10-1/100). The following table shows the effluent standards of Zimbabwe (Refer to Section 3.3 for detail) for the Class Blue, Normal. In the application of 1/10 dilution ratio to the effluent standard, the ambient water quality standards are in the same level as those in Japan. The water quality in the Table A6.1.3 is showing very strict water quality which is allowed to discharge into the river.

Table A6.1.3 Effluent Standard of Wastewater, Zimbabwe

	pH	BOD	COD	SS	DO	T-N	T-P
STP	6.0-9.0	30mg/l	60mg/l	25mg/l	60mg/l	10mg/l	0.5mg/l

Class: Blue, Normal

Source: EMA

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a) BOD and COD

Based on the above discussions, the standards for BOD and COD were proposed as shown in Table A6.1.4: Class A, "Not greater than 3 mg/l both for BOD and COD" was applied for natural environmental preservation, and for potable water supply and swimming purposes. Class B, "Not greater than 5 mg/l both for BOD and COD" was applied for fisheries only in consideration of the present guideline for irrigation water "Not greater than 70 mg/f of BOD". Class C, "Not greater than 10 mg/I for BOD and 8 mg/L for COD" was applied for irrigation water, industrial water use and flow maintenance.

Table A6.1.4 Proposed Classification

BOD for Rivers										
mg/L	Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation	Industrial	Environmental Preservation	mg/L	Proposed Class	Japanese Class
0				Class-1				0		
1				Class-2				1	AA	
2				Class-2				2	A	
3				Class-2				3	B	
4				Class-3				4		
5				Class-3		Class-1		5	B	C
6						Class-1		6		
7						Class-2		7		
8						Class-2		8		D
9						Class-3		9		
10						Class-3		10	C	E

COD for Lakes										
mg/L	Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation	Industrial	Environmental Preservation	mg/L	Proposed Class	Japanese Class
0				Class-1				0		
1				Class-1				1	AA	
2				Class-2				2		
3				Class-2				3	A	A
4				Class-3				4		
5				Class-3		Class-1		5	B	B
6						Class-1		6		
7						Class-2		7		
8						Class-2		8	C	C
9								9		
10								10		

b) Total Nitrogen and Total Phosphorus

The standards for T-N and T-P are shown in Table A6.1.5 in the same manner as the study of BOD and COD. In the classification, three nutrient grades were applied to the lakes: poor, medium and rich. Neither T-N nor T-P are hazardous substances but they cause algal growth. Under these conditions, the classified grades of T-N and T-P are applied for the respective water uses: fisheries, irrigation water, industrial water use and environmental preservation.

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Class A, "Oligotrophic Lake", for potable water supply and swimming purposes. There is no need for any treatment of the water to remove nutrients. The Standards of T-N and T-P are not greater than 0.2 mg/l and 0.01 mg/l, respectively.

Class B, "Mesotrophic Lake" for fisheries use. The standards of T-N and T-P are not greater than 0.6 mg/l and 0.05 mg/l, respectively.

Class C, "Eutrophic lake" for irrigation water, industrial water and flow maintenance. The standards of T-N and T-P are 1.0 mg/l and 0.08 mg/l respectively.

c) Other Items

The standards of pH, DO, SS and Coliform groups that are adopted in Japan are proposed. Table A6.1.5 presents the proposed standards on environmental items.

Table A6.1.5 Classification of Total Nitrogen and Total Phosphorus

T-N for Lakes		Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation Industrial	Environmental Preservation	Eutrophic Class	mg/L	Proposed Class	Japanese Class
mg/L											
0								Oligotrophic	0		1
0.1								Mesotrophic	0.1	A	2
0.2								Eutrophic	0.2		
0.3									0.3		
0.4									0.4		
0.5									0.5	B	3
0.6									0.6		4
0.7									0.7		
0.8									0.8		
0.9									0.9	C	5
1.0									1.0		

T-P for Lakes		Natural Environmental Preservation	Potable Water	Swimming Recreation	Fishery	Irrigation Industrial	Environmental Preservation	Eutrophic Class	mg/L	Proposed Class	Japanese Class
mg/L											
0								Oligotrophic	0	A	1,2
0.01								Mesotrophic	0.01		
0.02								Eutrophic	0.02		
0.03									0.03		
0.04									0.04	B	3
0.05									0.05		
0.06									0.06		
0.07									0.07	C	4
0.08									0.08		
0.09									0.09		
0.1									0.1		

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Table A6.1.6 Proposed Ambient Standard

Rivers

Class	Water Use	BOD	pH	SS	DO	Coliforms Group	Remarks
A	Natural Environmental Preservation	L.E. 3mg/L	6.5-8.5	L.E. 25mg/L	G.E. 5mg/L	L.E. 1000MPN/100ml	
	Potable Water						
	Swimming and Recreation						
	As in "B,C"						
B	Fishery	L.E. 5mg/L	6.5-8.6	L.E. 50mg/L	G.E. 5mg/L	-	
C	Irrigation Water	L.E. 10mg/L	6.0-8.6	No Suspend Dusts	G.E. 2mg/L	-	
	Industrial Water						
	Environmental Preservation						

Lakes

Class	Water Use	COD _{Mn}	T-N	T-P	pH	SS	DO	Coliforms Group	Remarks
A	Natural Environmental Preservation	L.E. 3mg/L	L.E. 0.2mg/L	L.E. 0.01mg/L	6.5-8.5	L.E. 25mg/L	G.E. 5mg/L	L.E. 1000MPN/100ml	Oligotrophic Lake
	Potable Water								
	Swimming and Recreation								
	As in "B,C"								
B	Fishery	L.E. 5mg/L	L.E. 0.6mg/L	L.E. 0.05mg/L	6.5-8.5	L.E. 50mg/L	G.E. 5mg/L	-	Mesotrophic Lake
C	Irrigation Water	L.E. 8mg/L	L.E. 1mg/L	L.E. 0.1mg/L	6.5-8.5	No Suspend Dusts	G.E. 2mg/L	-	Eutrophic Lake
	Industrial Water								
	Environmental Preservation								

Note: L.E.: Less than or Equal to

G.E.: Greater than or Equal to

d) Health Related Items

There are many hazardous substances that pose potential health risks, like heavy metals and agricultural chemicals. These are discharged mainly from specific sources such as industries and farms. Effluent standards for industrial wastewater have been established by the government to control unnecessary influence to the aquatic environment as well as various water uses. In view of assuring the safety of drinking water sources, it is deemed indispensable to monitor the presence of such hazardous substances in the public water body, especially lakes/dams in the Study Area. In this connection, the government has adopted the "Guideline for Drinking Water" of WHO as the national standard.

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On the other hand, it is not appropriate to apply all of the prescribed items of the said guideline since some chemicals are not presently used or being used in very limited amounts in Zimbabwe. Human health-related items adopted in the Japanese Standards are less than that of WHO, however these items are designated mainly considering health damage which have been caused by ambient pollution in the past. A similar situation may likely occur in Zimbabwe, if appropriate guidelines and monitoring are not applied in the subject water body when types of industries presently operated in the Study Area are taken into account.

In view of practicability to the present situation in Zimbabwe, it is deemed appropriate to adopt at least the same items and apply respective values based on WHO standards, as presented in Table A6.1.7, while such items, other than the Japanese Standards, shall be subject to be added when they are detected in the subject water body through monitoring and/or being introduced in economic activities.

Table A6.1.7 Ambient Standard for Health Related Items (Unit: mg/l)

Item	Proposed Value	Reference Value		
		Guideline for Drinking Water (WHO)	Japanese Standard	Effluent Standard of Waste Water (Zimbabwe)
Arsenic	0.01	0.01	0.01	0.05
Cadmium	0.003	0.003	0.01	0.01
Chromium	0.05	0.05	0.05	0.05
Cyanide	0.07	0.07	ND	0.2
Lead	0.01	0.01	0.01	0.05
Mercury	0.001	0.001	0.001	0.05
Selenium	0.01	0.01	0.01	*
Carbon tetrachloride	0.002	0.002	0.002	*
1,2-dichloroethane	0.03	0.03	0.004	*
1,1-dichloroethylene	0.03	0.03	0.02	*
dichloromethane	0.02	0.02	0.02	*
cis-1,2-dichloroethylene	0.05	0.05	0.04	*
tetrachloroethylene	0.04	0.04	0.01	*
trichloroethylene	0.07	0.07	0.03	*
benzene	0.01	0.01	0.01	*
1,3-dichloropropene	0.02	0.02	0.002	*

*:Items not considered in the effluent standard

3) Water Quality Classification and Checking Points

Water quality standards are to be determined for the main river and lakes/dams. In this regard, the study basin comprises three lakes/dams: the Seke and Harava dams, Lake Chivero and Lake Manyame, and two sections of the main river connected to the lakes/dams; Manyame River Origin (upstream from the Harava Dam) and the section between Seke dam and Lake Chivero. Figure 6.1.2 shows the subject sub-water bodies. The water quality checking points are to be established for the above-mentioned respectively water bodies.

- Water Quality Classification

Water quality classification shall be done taking into account of present and future water use of the subject sub-basins. The following are proposed classifications by lake/dam or river.

- Lake/Dams

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Since the lakes/dams in the study basin are used for drinking water supply and recreational purpose, Class A is required.

- Rivers

The water quality of the river is possible to adopt Class C only to ensure maintenance flow. However, the water is the source of the lakes/dams. In this connection, Class B for fishery use is recommended. Under the current status of river water quality, the classification is practical, while, Class A may be adopted for the upstream section from Harava Dam in light of the minimal inflow of pollution load in the sub-basin.

Water Quality Checking Points

In setting up water quality checking points, two categories will be utilized, i.e., "Checking Points" wherein water quality will be legislatively controlled, and "Reference Points" wherein water quality will be monitored basin-wide as reference for "Checking Point". Table A6.1.8 and Figure A6.1.2 present the checking/ reference points both for lakes/ dams and the rivers.

4) Provisional Standards

In the above study, the water quality classifications were introduced according to the water uses. However, the standards of some items are considered difficult to comply with under the present situation. The provisional standards as shown in Table A6.1.9 and Table A6.1.10 would be applied under the following conditions:

- The provisional standards are to be applied to the items which the proposed standards are not likely to be achieved. At this stage, the items involved are BOD, COD, T-N, and T-P.
- The provisional standards are required to comply with the present effluent standards of wastewater.
- Finally, the water quality standards should be followed by the year 2030.

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Table A6.1.8 Water Quality Checking /reference Points

Water Body	Water Quality Checking/Reference Point				Water Quality Classification
	No.	River/Lake	Lake/dam basin	Location	
River	CR1	Manyame R.	Harava Dam	Before inflow to Harava Dam	A
	RR1	Ruwa R.	Harava Dam	- do -	
	RR2	Nyatsime R.	Lake Chivero	Before the Confluence to Manyame River	
	RR3	Manyame R.	- do -	Before joining with Mukuvisi river	
	RR4	Mukuvisi R.	- do -	Before the confluence to main river	
	CR2	Manyame R.	- do -	Before inflow to Lake Chivero	B
	RR5	Marimba R.	Lake Chivero	Before the confluence to main river.	
	RR6	Muzururu R.	Lake Manyame	Before inflow to Lake Manyame	
	RR7	Gwebi R.	- do -	- do -	
Lake/Dam	CL1	Seke Dam	N.A.	Center of the lake	A
	CL2	Lake Chivero	N.A.	Water intake tower	A
	CL3	Lake Manyame	N.A.	Water intake point for Harare Water Supply	A

Note: CR1 - 2 ; Checking Point (River)
 CL1 - 3 ; - do - (Lake)
 RR1 - 7 ; Reference Point
 N.A.; Not applicable

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Table A6.1.9 Provisional Water Quality Standard

Water Body	Name	Period	COD _{Mn}	T-N	T-P
Lake	Seke & Harava	1997	9.4	0.65	0.07
		2015	<5	<0.4	<0.05
		2030	<3	<0.2	<0.01
	Lake Chivero	1997	14.9	0.51	0.27
		2015	<8	<0.4	<0.1
		2030	<3	<0.2	<0.01
	Lake Manyame	1997	18.9	0.75	0.044
		2015	<8	<1	<0.03
		2030	<3	<0.2	<0.01
River				BOD	
	Manyame Origin	1997		1.1	
		2015		<5	
		2030		<3	
	Manyame River	1997		1.0	
		2015		<5	
		2030		<3	

Source:JICA Project Team

Table A6.1.10 Water Quality Standard / Provisional Value

Lakes			Unit: mg/l					
No.	Name	Class	Standard			Provisional (2000/2005)		
			COD	T-N	T-P	COD	T-N	T-P
CL1	Seke & Harava Dam	A	< 3	< 0.2	<0.01	< 5	< 0.4	< 0.05
CL2	Lake Chivero	A	< 3	< 0.2	<0.01	< 8	< 0.4	< 0.1
CL3	Lake Manyame	A	< 3	< 0.2	<0.01	< 8	< 1.0	< 0.03

Rivers			BOD			
No.	Name	Class	Standard		Provisional (2000/2005)	
			< 3 mg/L	< 5 mg/L	(< 5 mg/L)	(< 5 mg/L)
CR1	Manyame R.Origin	A				
CR2	Manyame R.	B				

Source:JICA Project Team

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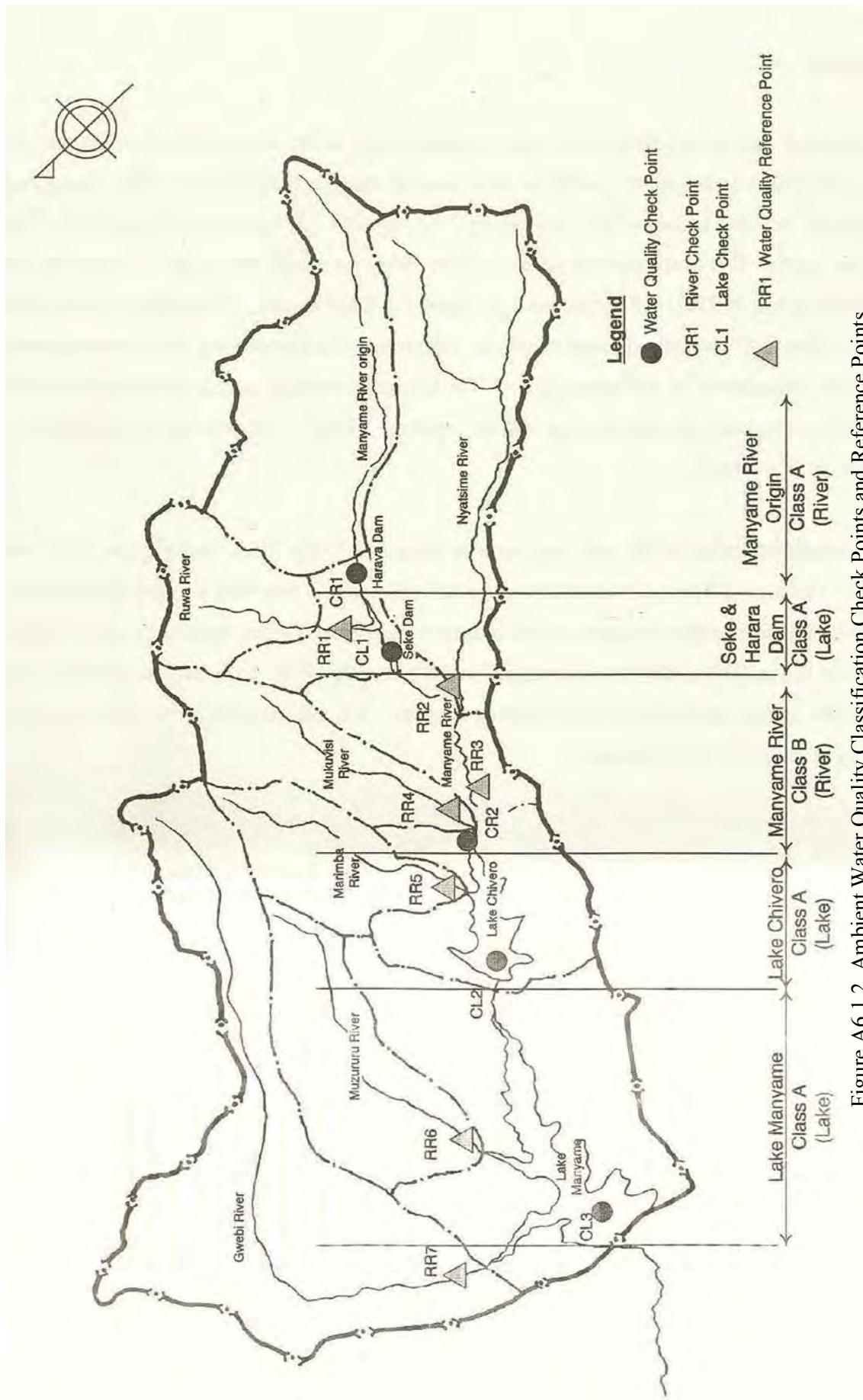


Figure A6.1.2 Ambient Water Quality Classification Check Points and Reference Points

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6.1.2 Sanitary Condition

(1) Septic Tank

Sanitation measures are categorised into on-site treatment (septic tanks) and off-site treatment (public sewerage system). Septic tank has soak way for discharging supernatant of the tank to underground. Sullage in the tank is removed periodically after the sludge becomes full and is treated in the sewage treatment plant. Population served by the septic tank will be dealt separately in the pollution analysis. In the Study Area, a part of the low density residential areas in the urban areas and most of the rural areas use septic tanks, and other types of toilet facilities, while many of the residents in the remaining urban areas are served by the public sewerage system. Table A6.1.11 shows the population presently served by septic tanks in the urban areas in the Study Area.

Table A6.1.11 Septic Tank Served Population in the Study Area

Urban Authority	Population
Harare	95,140
Chitungwiza *1	0
Norton	1,290
Ruwa	20
Epworth	68,490

*1: Septic tanks are being used only at 3 schools

As shown in the table, population served by septic tank is around 170,000, or one-tenth of the population in the area.

(2) Sewerage in Harare City

Some stands (lots) in the low density areas have on-site treatment facilities. The rest of the city is served by a public sewerage system. Figure A6.1.3 shows sewer network and location of STPs. the septic tank service area in Harare.



Figure A6.1.3 Sewer Network and Location of STPs in Harare

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The main STPs in Harare are Firle, Crowborough, Marlborough and Donny Brook. The city core is covered by the former two STPs. Most of the population are covered by sewerage system. Biological Nutrient Removal (BNR) process was partly employed in the STPs and effluent from the BNR has been discharged to the river directly. Rest of the effluent has been sent to the farms for irrigation. Septic tank is also possible to install, however, in the placement of septic tanks, the minimum stand size is principally regulated at more than 4,000 m² with loosened restriction of 2,000 m² when soil test results are favourable. (Harare Water) These discharged supernatant from soak way are sometimes polluting underground water. Counter measure will be needed to cope with the septic tank area with the public sewerage system including Epworth.

(3) Chitungwiza Municipality

At present, 100% of the municipal area is served by the public sewerage system without depending on septic tanks. However, three schools are utilising septic tanks. These septic tanks are emptied by contractors when they become full. Sullage is transported to and treated in the STP in Harare. All the sewage goes to the Zengeza STP however, due to the breakdown of all pump stations and Zengeza STP, the sewage flow has been discharged to the Nyatsime River and Manyame River polluting the rivers. The current sanitation problem is the overflow of sewage from manholes into the streets due to deposit of sand and sludge in sewers/manholes, as well as increased sewage. The dumping of domestic wastes into sewers/manholes has been another cause of this problem.



Figure A6.1.4 Sewer Network and Location of STPs in Chitungwiza

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(4) Norton Town Council

Approximately 95% of the total residential stands (lots) are served by gravity sewer connected to the Town Council's sewers. Sewage from 47 stands located in the low density areas is pumped to the trunk sewer as well. The rest, 271 houses/stands, rely on septic tanks. These septic tanks have been constructed in conformity with the Council's policy that the minimum size of each stand shall be larger than 2,400 m² in the application of septic tanks. All industrial wastewater is also discharged into the Council's sewerage system. Figure A6.1.5 shows the sewerage and septic tank service area in Norton.

Norton sewage treatment plant employs three units of the trickling filters, however the system has been broken down since 2001. Effluent was sent to irrigate farmlands by pump stations for transmitting the effluent. The system is broken down and raw sewage has been discharged to the Lake Manyame affecting the water quality of the Morton Jaffray WTP.

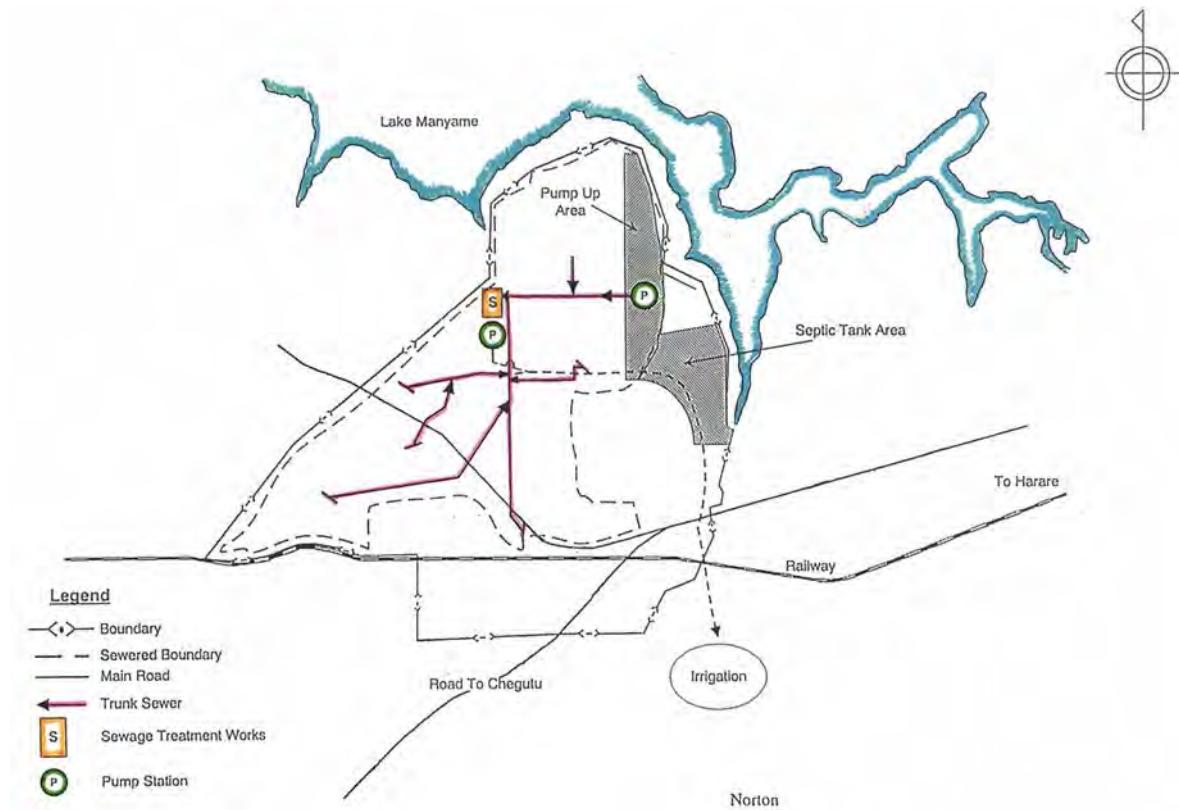


Figure A6.1.5 Sewer Network and Location of STPs in Norton

(4) Ruwa Local Board

The sanitation conditions of Ruwa have been provided with sewerage services south of the Harare-Mutare Road, excluding 22 stands located in low and high density areas. All industrial wastewater is discharged into the Local Board's sewerage system. Figure A6.1.6 shows the sewerage system in Ruwa. Ruwa has been using stabilization pond for the sewage treatment.

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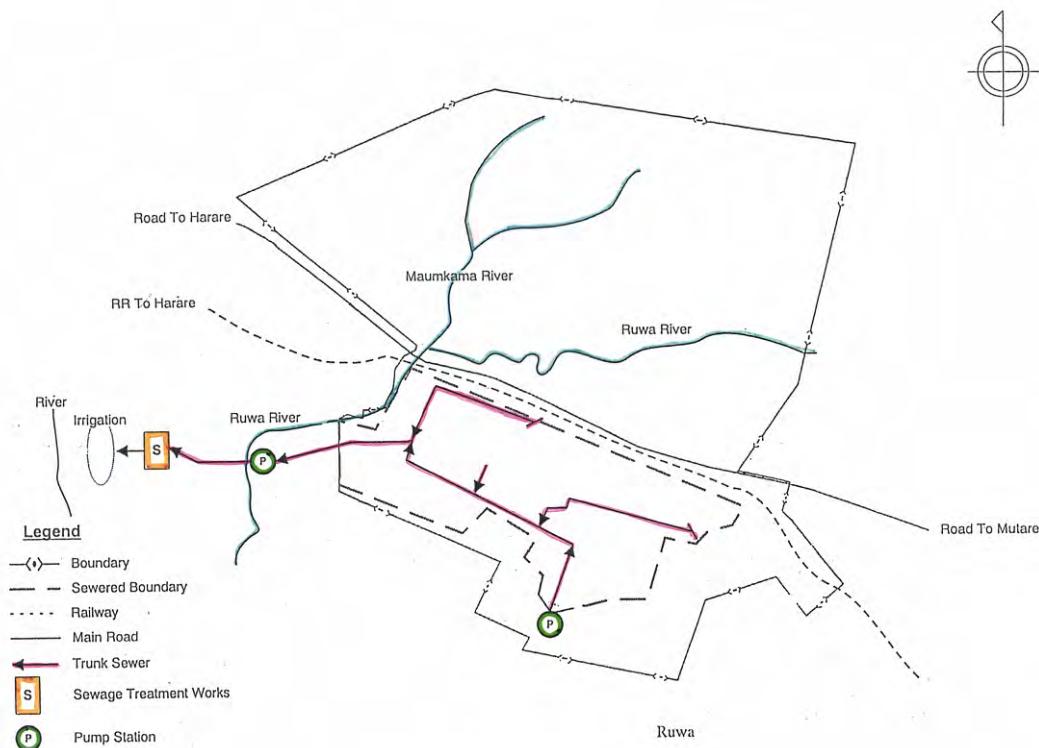


Figure A6.1.6 Sewer Network and Location of STPs in Ruwa

(6) Epworth Local Board

At present, there is no public sewerage system in Epworth. The majority of houses/stands are therefore using "ventilated improved pit (VIP)" latrines sponsored by the national government. The presence of unacceptable "drop pit latrines" is quite limited. Generally, appropriate stand spacing is maintained to locate septic tanks in order to avoid environmental hazards.

In the northern part of Epworth a series of temporary sewage ponds has been developed to serve as the overflow area for domestic sewage. However, these ponds are located too close to the existing houses. The Epworth Local Government is considering the closure of these ponds upon the construction of a new and larger treatment works south of the Epworth Local Government area on part of the Lyndhurst Farm. The Epworth Local Government also seeks to reduce the use of pit latrines and to introduce a public sewerage system.

6.1.3 Hydrological Condition of the Rivers and Lakes

(1) Rainfall

The rainfall data of the Harare City (Belvedere) located in the centre of the basin is available to analyse hydrological condition. The weather stations located in the Manyame River Basin are included in Table A6.1.14 and Figure A6.1.8. According to the Study 1997, the five-year running average fluctuates slightly, while the ten-year running average is almost constant. Thus, a ten-year cycle of

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rainfall is prevalent in the basin. The monthly rainfall of the past ten years (2000 to 2010) is shown in Table A6.1.12, Table A6.1.13, and Figures A6.1.7. The annual average rainfall in the ten years is 951 mm. The monthly average rainfall indicates a dry season from April to October. About 78 % of the annual rainfall is concentrated in the five months of the rainy season, and about 23% of the annual amount is recorded during December. The annual rainfall amount is considerably affected by that of December.

Table A6.1.12 Monyhy Rainfall (2000/2010)

Year	(mm/d)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	7.4	5.3	7.2	3.3	6.4	0.5	0.0	0.0	0.0	0.7	3.6	8.3
2001	3.8	14.7	7.1	0.0	0.0	0.0	0.2	0.0	0.0	0.4	1.7	9.1
2002	3.2	0.1	0.7	2.0	N/A	0.4	N/A	0.0	0.1	3.0	2.8	3.4
2003	1.9	6.5	N/A	N/A	0.0	0.1	N/A	N/A	3.2	1.2	2.8	7.7
2004	0.5	N/A	3.5	5.3	N/A	N/A	N/A	12.8	0.0	3.3	3.1	7.2
2005	N/A	4.7	N/A	0.2	0.7	0.0	N/A	0.0	0.0	0.5	8.0	7.3
2006	8.4	5.6	4.4	0.1	0.0	0.0	0.0	N/A	N/A	0.5	1.4	4.5
2007	4.5	1.6	4.3	11.4	N/A	0.1	0.0	N/A	N/A	N/A	5.7	18.6
2008	N/A	1.3	2.1	1.0	0.0	N/A	0.0	0.0	0.0	0.2	4.1	0.2
2009	5.1	5.3	5.4	0.0	1.6	0.0	N/A	0.0	0.0	0.0	4.4	5.0
2010	6.3	5.0	2.5	3.0	0.4	0.0	0.0	0.0	0.0	0.5	3.8	5.1
Average	4.9	4.8	4.0	2.6	1.1	0.1	0.0	1.6	0.4	1.0	3.8	6.9

Source: Meteorological Department

Table A6.1.13 Annual Rainfall from Monyhy Rainfall

Months	Num. of Days	Average	
		mm/d	mm/month
Jan	31	4.9	152.4
Feb	28	4.8	135.5
Mar	31	4.0	123.1
Apr	30	2.6	79.0
May	31	1.1	35.4
Jun	30	0.1	3.7
Jul	31	0.0	1.0
Aug	31	1.6	49.8
Sep	30	0.4	11.0
Oct	31	1.0	32.0
Nov	30	3.8	113.2
Dec	31	6.9	215.1
		Total =	951.1 mm/year

Source: Meteorological Department

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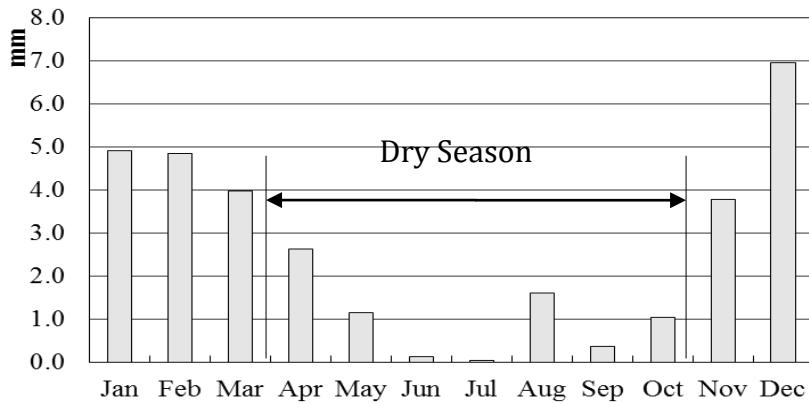


Figure A6.1.7 Monthly Rainfall (2000/2010)

Source: Meteorological Department

(2) Flow Rate of the Rivers and Discharge of the Lakes and Dams

As shown in Table A6.1.14 and Figure A6.1.8., several gauging stations are set up to measure the flow rates of the rivers and discharges from the lakes and dams. The measurement results are the base of this analysis.

1) Flow Rate

The annual average of flow rates in the Manyame River (before the confluence of Harava Dam and Lake Chivero), the Mukuvisi River, and the Marimba River in the last ten years, starting from 1992, is shown in Table A6.1.15.

In addition, the fluctuation of the last ten-year monthly average values and rates is shown in Table A6.1.17 with graph of fluctuation ratio in Figure A6.1.10.

Table A6.1.14 Data Availability on Flow Rate and Discharge

Item	No.	Name	Location	Measured Period	Date Contents
Flow Rate	C81	Manyame Origin	Before the Confluence of Harava Dam	1974 to 2001	Monthly Run-off
	C21	Manyame R.	Before the Confluence of Lake Chivero	1957 to 2001	do
	C22	Mukuvisi R.	do	1953 to 2001	do
	C24	Marimba R.	do	1953 to 2001	do
Discharge	C3	Seke & Harava Dam	Discharge Point	1951 to 1995	do
	C17	L.Chivero	Discharge Point	1953 to 1995	do
	C89	L.Manyame	Discharge Point	1976 to 1995	do

Source: ZINWA

Table A6.1.18 and Figure A6.1.11 show the relationship between rainfall and the flow rate. The average run-off ratios in the last 10 years are seven to eight percent at the two observatories respectively on the Manyame River, while 14 to 22% on the Mukuvisi and the Marimba River. The average run-off ratio of the rivers in the whole of Zimbabwe is reported at eight percent, which coincides with that of the Manyame River. The average run-off ratio of the Mukuvisi and the Marimba Rivers seems to be largely influenced by the STPs' effluent.

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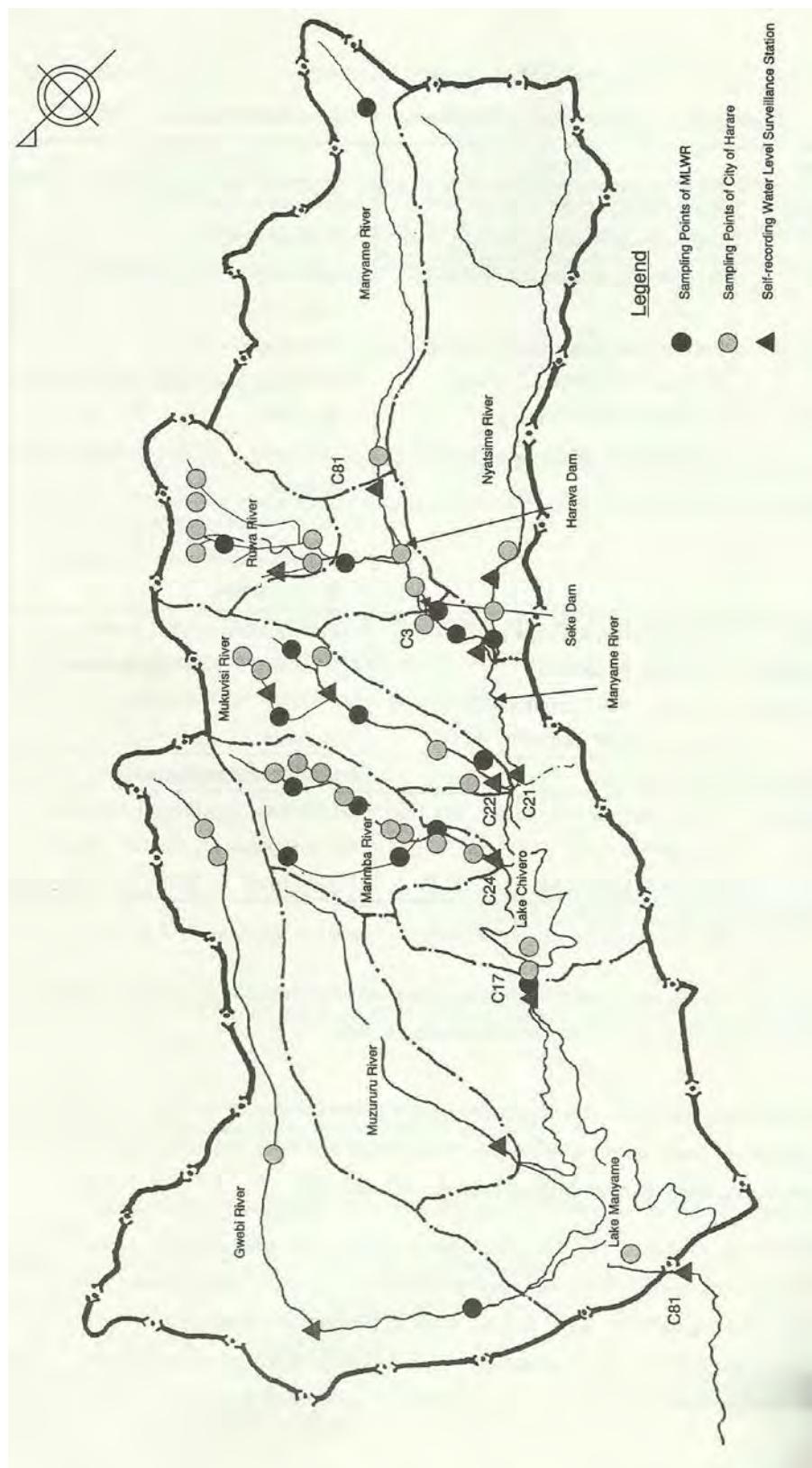


Figure A6.1.8 The Locations of Self-recording Water Level Surveillance Station and Water Sampling

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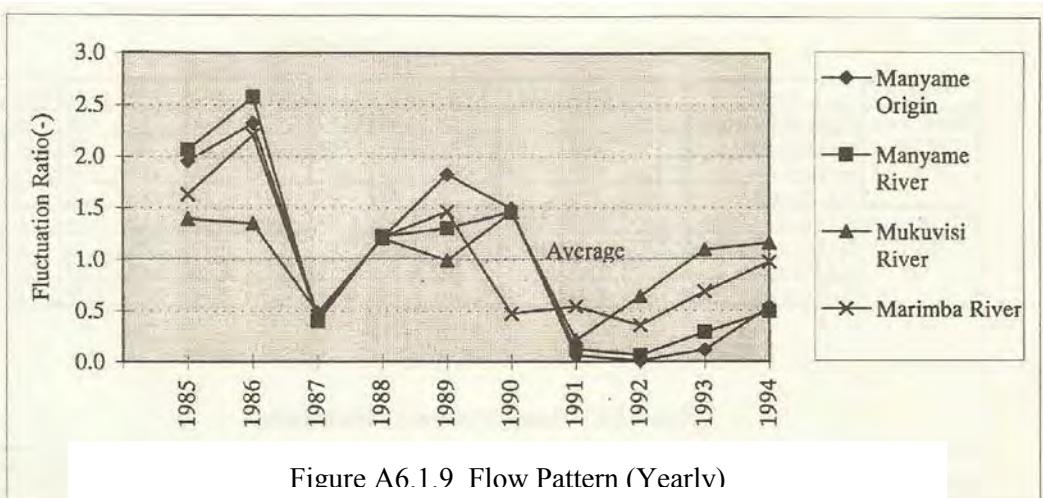


Figure A6.1.9 Flow Pattern (Yearly)

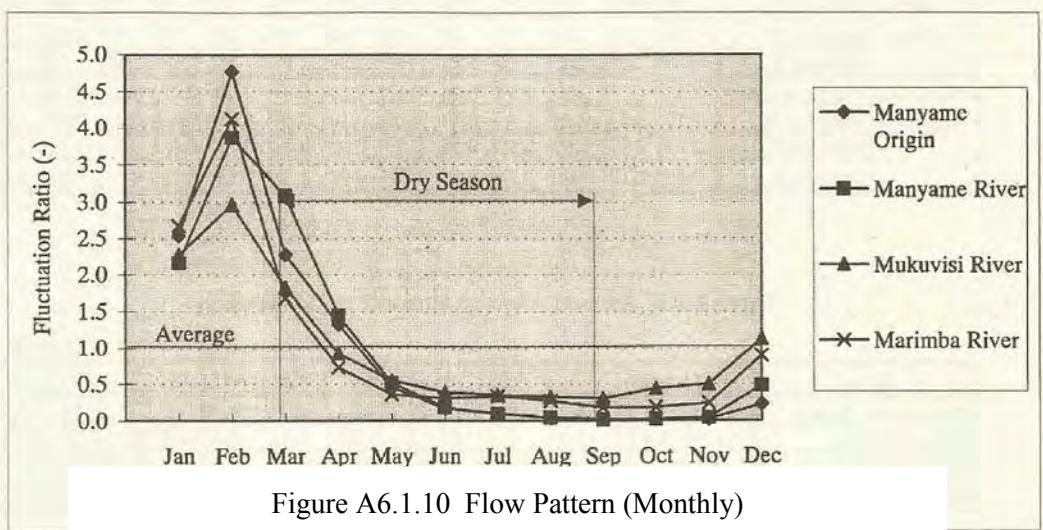


Figure A6.1.10 Flow Pattern (Monthly)

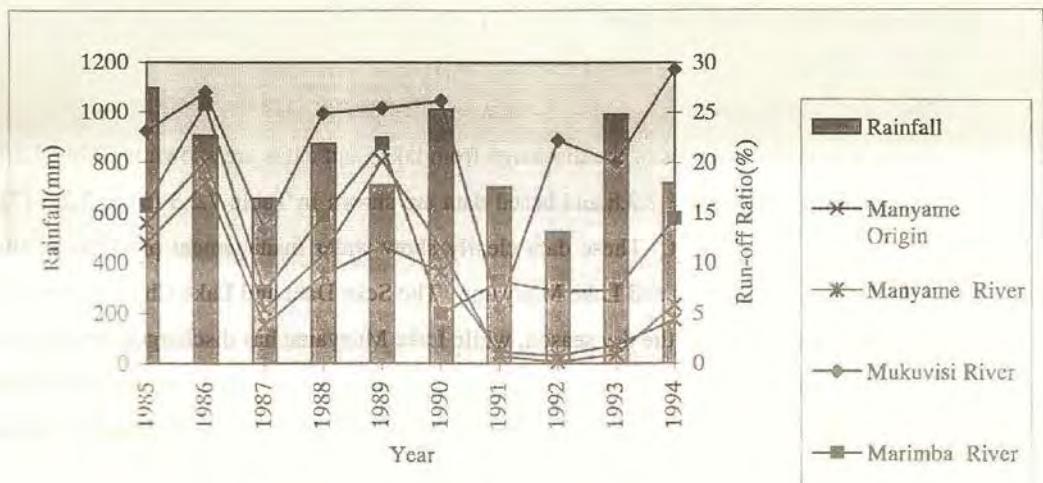


Figure A6.1.11 Rainfall and Run-off Ratio (Rivers)

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe", Volume 2 Main Report

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Table A6.1.15 Annual Average Flow Rate

	River	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Ave.
Flow Rate x1000 m ³ /day	Manyame Origin	1	12	54	3	112	279	111	454	331	388	174
	Manyame R.	17	76	128	46	317	700	367	1399	799	1310	516
	Mukuvisi R.	72	123	130	91	164	209	197	507	329	313	214
	Marimba R.	22	43	60	43	81	149	136	309	188	284	131

Table A6.1.16 Annual Fluctuation Ratio

	River	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.
Fluctuation Ratio (-)	Manyame Origin	1.95	2.33	0.46	1.21	1.83	1.5	0.06	0.01	0.12	0.54	1.00
	Manyame R.	2.07	2.57	0.4	1.22	1.3	1.46	0.13	0.07	0.29	0.49	1.00
	Mukuvisi R.	1.39	1.35	0.48	1.2	0.99	1.46	0.21	0.64	1.1	1.16	1.00
	Marimba R.	1.63	2.21	0.44	1.22	1.46	0.47	0.54	0.36	0.69	0.98	1.00

Table A6.1.17 Monthly Average Flow Rate (1952-2001)

	River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Flow Rate x1000 m ³ /day	Manyame Origin	440	687	542	258	106	48	22	13	7	5	7	90	185
	Manyame R.	1197	1704	1356	601	261	121	63	35	17	13	209	351	494
	Mukuvisi R.	285	325	274	121	79	47	36	36	29	33	51	160	123
	Marimba R.	228	278	212	58	34	23	21	19	14	13	29	131	88
Fluctuation Ratio (-)	Manyame Origin	2.54	4.77	2.28	1.33	0.46	0.17	0.10	0.04	0.03	0.02	0.02	0.23	1.00
	Manyame R.	2.17	3.87	3.09	1.45	0.52	0.19	0.10	0.04	0.02	0.03	0.05	0.48	1.00
	Mukuvisi R.	2.27	2.97	1.83	0.92	0.55	0.39	0.36	0.32	0.31	0.44	0.50	1.13	1.00
	Marimba R.	2.68	4.12	1.68	0.73	0.36	0.31	0.34	0.28	0.18	0.19	0.24	0.90	1.00

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe", Volume 2 Main Report

Table A6.1.18 Annual Average Run-off Ratio (Rivera)

River	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.	Unit: %
Manyame Origin	14.0	20.1	5.5	10.8	20.2	11.6	0.7	0.2	0.9	5.8	9.0	
Manyame R.	11.9	18.0	3.8	8.8	11.6	9.1	1.2	0.8	1.9	4.3	7.1	
Mukuvisi R.	23.1	27.0	13.3	24.9	25.4	26.2	5.5	22.2	20.0	29.3	21.7	
Marimba R.	15.8	25.8	7.1	14.7	21.9	5.0	8.2	7.2	7.3	14.4	12.7	

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe", Volume 2 Main Report

2) Discharge from Lakes and Dam

The annual averages of discharge are shown in Table A6.1.19 and Figure A6.1.12. The last ten-year monthly averages of the discharge from lakes and dams are shown in Table A6.1.20 and graphically in Figure A6.1.13, and base data are shown in The Study on Water Pollution Control in The Upper Manyame River Basin in the Republic of Zimbabwe (1997). These data clearly show water management practices of the Seke Dam Lake Chivero and Lake Manyame. The Seke Dam and Lake

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Chivero were not discharging water during the dry season, while Lake Manyame was discharging throughout the year. The purpose of constant discharge at Lake Manyame is to ensure maintenance flow for the lower reach. The relation between rainfall and discharge is shown in Table A6.1.21 and Figure A6.1.14.

Table A6.1.19 Annual Average of Discharge*

	Lake/Dam	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.
Discharge Flow x1000 m ³ /day	Seke Dam	434	482	92	193	278	139	5	0	0	54	168
	L.Chivero	39	92	4	181	56	79	0	0	0	0	45
	L.Manyame	134	483	226	171	27	225	80	72	56	76	155
Fluctuation Ratio (-)	Seke Dam	2.59	2.87	0.55	1.15	1.66	0.83	0.03	0.00	0.00	0.32	1.00
	L.Chivero	0.87	2.04	0.09	4.01	1.24	1.75	0.00	0.00	0.00	0.00	1.00
	L.Manyame	0.87	3.11	1.46	1.10	0.17	1.45	0.52	0.46	0.36	0.49	1.00

Table A6.1.20 Monthly Average of Discharge*

	Lake/Dam	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Discharge Flow x1000 m ³ /day	Seke Dam	351	918	487	202	56	10	5	1	6	2	1	5	170
	L.Chivero	28	191	211	102	12	1	0	0	0	0	0	0	45
	L.Manyame	55	19	40	453	183	155	155	202	191	138	143	109	154
Fluctuation Ratio (-)	Seke Dam	2.06	5.39	2.86	1.19	0.33	0.06	0.03	0.00	0.03	0.01	0.01	0.03	1.00
	L.Chivero	0.62	4.20	4.64	2.24	0.28	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	L.Manyame	0.36	0.13	0.26	2.95	1.19	1.01	1.01	1.32	1.24	0.90	0.93	0.71	1.00

Table A6.1.21 Annual Average Run-off Ratio (lake and Dams)*

Lake/Dam	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Ave.	Unit: %
Seke Dam	18.3	24.5	6.5	10.2	18.1	6.3	0.3	0.0	0.0	3.5	8.8	
L.Chivero	0.6	1.7	0.1	3.4	1.3	1.3	0.0	0.0	0.0	0.0	0.8	
L.Manyame	1.2	5.1	3.3	1.9	0.4	2.1	1.1	1.3	0.5	1.0	1.8	

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe", Volume 2 Main Report

3) Relationship between Water Level and Storage

The annual average of the water level compared to the full capacity level of lakes and dams is shown in Table A6.1.22 and Figure A6.1.15, and the storage volume in lakes is shown in Table A6.1.23. In applying these water levels to the storage volume, the H-V curve is obtained, as shown in Table A6.1.24 and Figure A6.1.17. The relationship between level and storage volume is explained by the following equation.

$$Y = (x/100)^{1.88} \times 100$$

x: Water level (%), y: Available Volume (%)

The results of the equation with regards to the measured level, and the storage volume of the lakes and dams are shown in Figure A6.1.18 and Figure A6.1.19.

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Table A6.1.22 Annual Average Water Level of Lakes/Dams*

Lake/Dam	1989	1990	1991	1992	1993	1994	1995	Ave.	1990/94
Harava Dam	83.7	82.2	16.3	0.0	66.9	86.2	14.9	50.0	50.3
Seke Dam	85.5	75.5	22.0	3.1	50.6	49.8	9.5	42.3	40.2
L.Chivero	96.0	97.8	93.4	78.6	73.0	89.7	68.2	85.2	86.5
L.Manyame	95.4	95.6	80.4	61.2	55.4	37.7	28.0	64.8	66.1

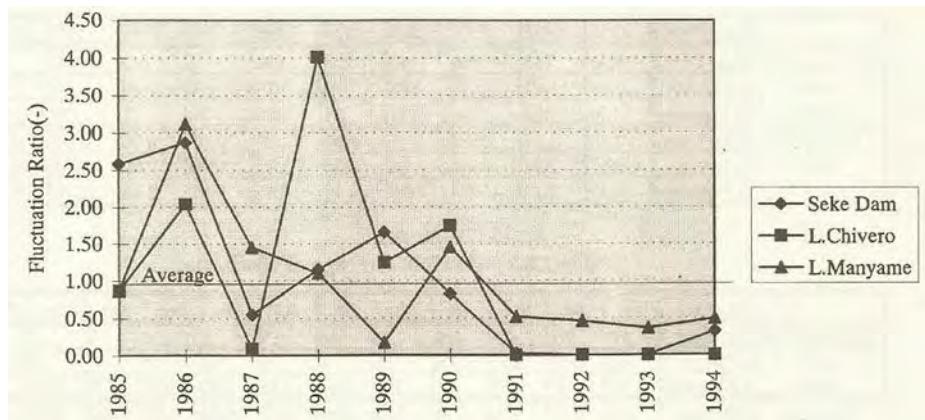


Figure A6.1.12 Discharge Pattern (Yearly)*

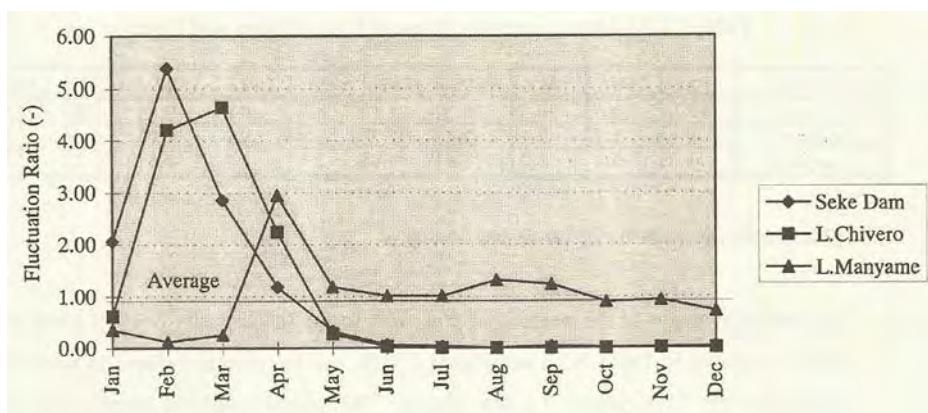


Figure A6.1.13 Discharge Pattern (Monthly)*

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the republic of Zimbabwe", Volume 2 Main Report

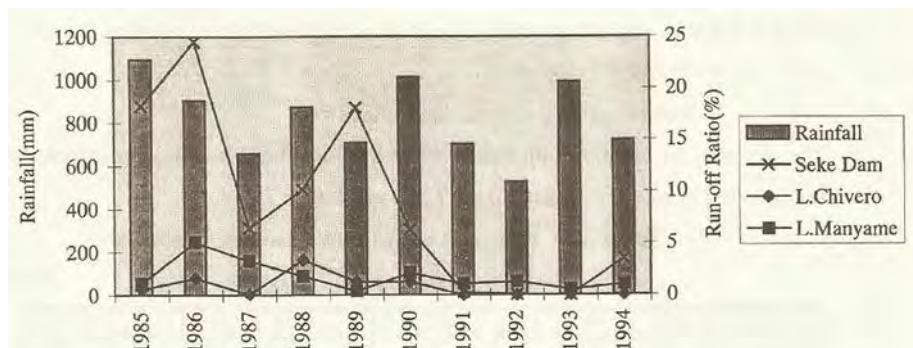


Figure A6.1.14 Rainfall and Run-off Ratio (Lakes and Dam)*

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Table A6.1.23 Monthly Average Water Level of Lakes/Dams*

	Unit; %												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Harava Dam	58.7	65.1	65.5	60.1	59.4	54.7	52.6	50.2	44.1	35.2	30.3	24.4	50.0
Seke Dam	45.1	61.0	57.9	61.3	49.3	35.6	38.8	32.2	33.9	30.9	35.5	25.7	42.3
L.Chivero	87.7	91.8	91.5	90.8	89.5	87.7	85.8	83.7	81.4	78.6	76.7	77.4	85.2
L.Manyame	67.0	71.0	70.9	69.9	68.2	66.8	65.2	63.2	61.6	59.1	57.5	57.7	64.8

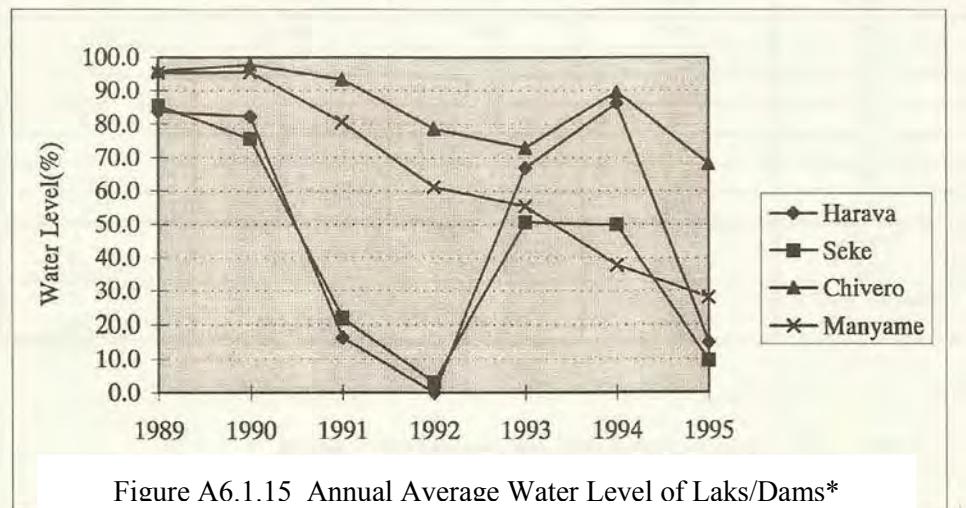


Figure A6.1.15 Annual Average Water Level of Laks/Dams*

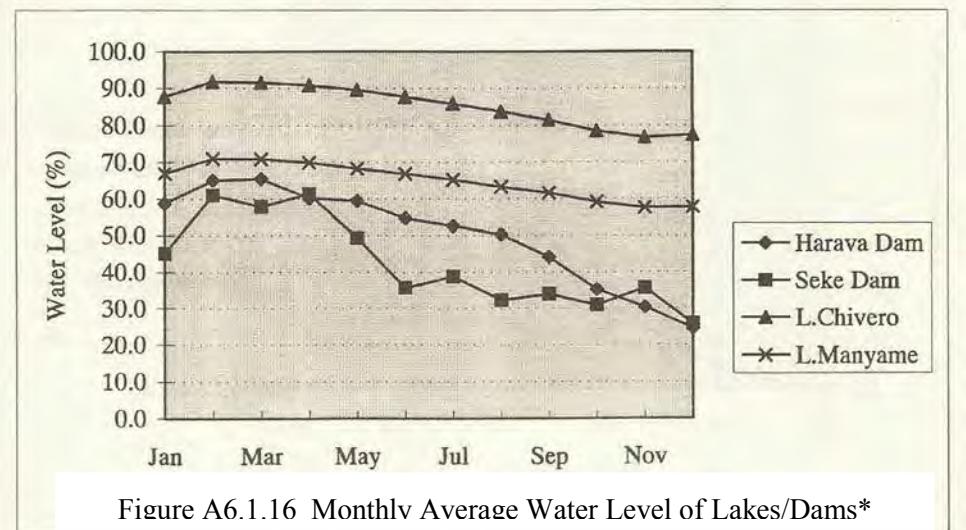


Figure A6.1.16 Monthly Average Water Level of Lakes/Dams*

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in The Republic of Zimbabwe", Volume 2 Main Report

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Table A6.1.24 H-V Curve of Lakes and Dams*

Available Level (%)	Available Capacity (%)			
	Harava Dam	Seke Dam	Lake Chivero	Lake Manyame
100	100.0	100.0	100.0	100.0
90	75.3	81.8	82.4	77.2
80	56.9	65.1	66.3	58.6
70	41.6	52.5	51.9	43.7
60	29.2	39.9	39.2	30.7
50	20.2	29.6	27.5	20.3
40	13.3	21.3	17.1	13.3
30	8.1	15.3	8.5	8.3
20	5.2	9.2	1.0	4.5
10	1.7	3.7	n.a.	n.a.
0	0.0	0.0	0.0	0.0
Depth (m)	10.65	5.795	15.3	14.25
Max Capacity (x1000m ³)	9,026	3,380	247,181	480,236

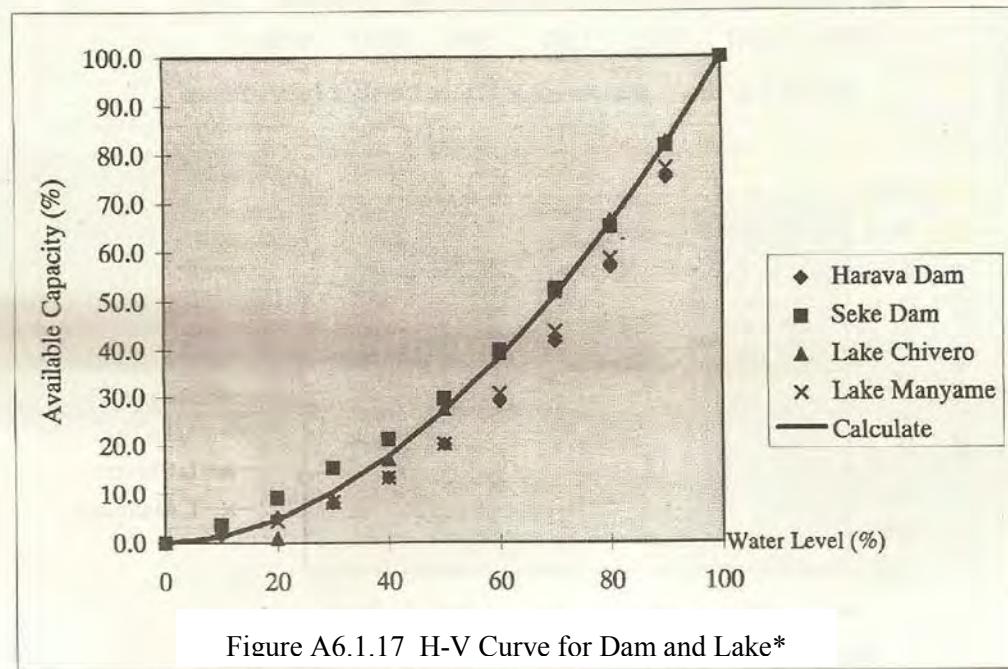
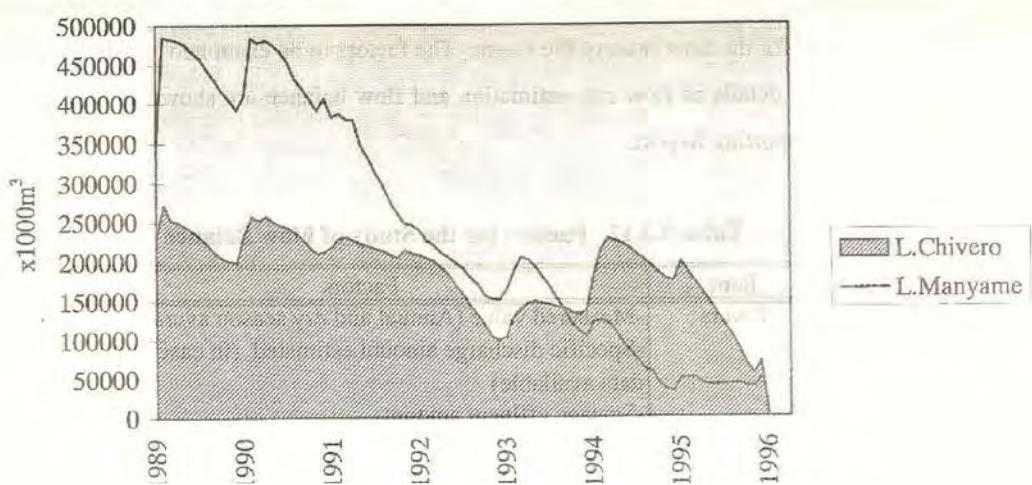
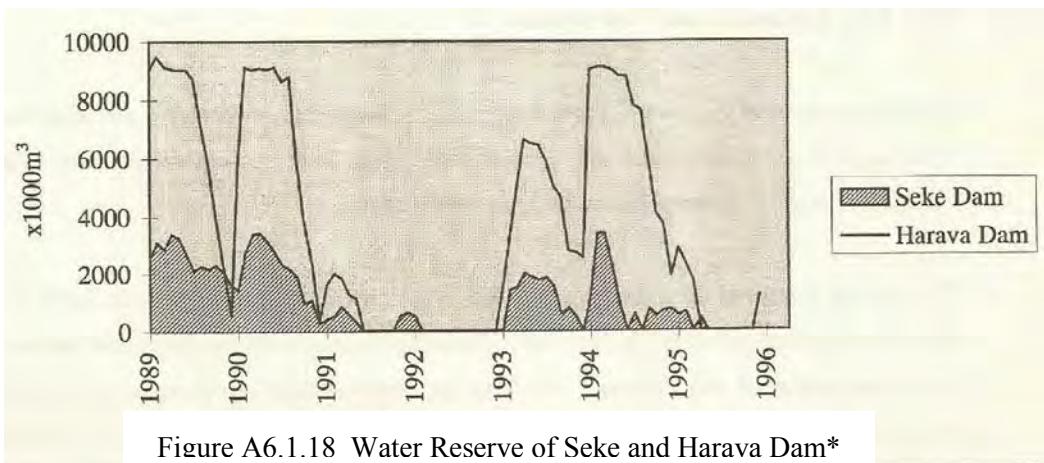


Figure A6.1.17 H-V Curve for Dam and Lake*

*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe", Volume 2 Main Report

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*Source: NIPPON JOGESUIDO SEKKEI CO., LTD. & NIPPON KOEI CO., LTD., 1997, "The Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe", Volume 2 Main Report

(3) Flow Rate Estimation and Flow Balance

The flow pattern of the rivers, water level and discharge rate of the lakes are analysed to come up with the flow balance in the entire study basin. Based on such results, the control factors which affect water pollution analysis were clarified.

The average figures of the last 10 years (1992-2001) are utilised for the analysis, since a ten-year cycle pattern of rainfall is observed. Examination points are the lakes and the confluences before and after major rivers. The Seke and Harava Dams are regarded as one water body, because they are adjoined and their rated capacities and catchment areas are comparatively small. Figure A6.1.20 shows locations of the study points. The flow balance of the lake is studied with reference to annual average of the flow rates, while the annual and dry season averages were used for the flow rates of the rivers. The factors to be examined are shown in Table A6.1.25.

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Table A6.1.25 Factors for the Study of Flow Balance

Flow	Item	Factors
inflow	Rivers	<ul style="list-style-type: none"> -Measured value Annual; 1992/2001 Dry season; 1985/94 from the Study 1996 -Specific discharge estimated (in case of no date available) -Sewage effluent amount (included in the river flow data)
	Direct Rainfall	<ul style="list-style-type: none"> -Full surface area of lake * Rainfall amount (2002/2011)
	Direct Area	<ul style="list-style-type: none"> -Specific discharge rate estimated; Runoff rate (1995)
Outflow	Evaporation	<ul style="list-style-type: none"> -Surface area of lake * Evaporation rate (2002/2011)
	Water Intake	<ul style="list-style-type: none"> -Records of Intake
	Discharge	<ul style="list-style-type: none"> -Measured value, Specific discharge rate estimated and multiplying factor estimated
Balance	Water level of the lake	<ul style="list-style-type: none"> -Measured value (1995)
	Ground water recharge and others	<ul style="list-style-type: none"> -Assumed from other data

Source: JICA Project Team

1) River Flow

The average flow rates at present were estimated using available annual data from 1992 to 2001. In this study, for the comparative result between previous and current available data, current river flow rate was estimated multiplying 1.7 times that of previous flow rate. Therefore in this study, in case no data is available 1.7 times of previous flow rate is adopted.

Influence of STP Effluent

Effluent discharged constantly from the STPs affects the flow rate of the river. Presently, the observation of simultaneous flow rates upstream and downstream of STPs is not conducted. Under these conditions, the flow rates at a certain point of the river are different between the measured date (flow implies discharged effluent) and that estimated using specific discharge rate in the subject basin. Additional flow to the rivers is calculated together with effluent discharge from the STPs. The following are condition/assumptions for the calculation of the flow rates for water pollution analysis.

- Flow rates in the river comprise base river water and effluent discharged directly from the STPs and through the irrigation area.
- The influences to river water by the discharged effluent were considered in the sub-river basin where the STPs and irrigation areas exist.
- Annual or dry season average figures are applied to the calculation.

2) Direct Rainfall into the Lake/dam

Direct inflow of rainfall into the lake/dam was assumed using the data of the Study 1997 where direct inflow of rainfall into the lake/dam was without any loss from the full surface area.

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3) Direct Area Run-off

The direct area run-off into the lake/dam through small rivers/channels was referred from the Study 1997.

4) Evaporation

According to the study on Lake McLwaine (1982), the evaporation from Lake Chivero was estimated at 1291~ 2005 mm (Average 1541 mm). The amount of evaporation was estimated using surface area of the lake/dam at the average water level and average evaporation of 1541 mm. The surface area of the lake /dam was estimated using H-V curve.

Table A6.1.26 Monthly Evaporation

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	N/A	N/A	N/A	N/A	N/A	3.07	4.06	5.24	6.51	6.03	4.24	
2002	4.77	5.48	4.57	4.26	3.69	2.83	N/A	3.87	5.28	6.07	5.61	4.71
2003	6.39	4.72	N/A	N/A	3.52	2.62	3.26	4.36	5.36	5.81	6.03	5.13
2004	0.31	N/A	4.06	3.76	N/A	N/A	3.19	4.30	5.39	5.08	5.89	4.20
2005	N/A	4.83	N/A	4.12	3.81	2.96	N/A	4.32	5.21	6.46	N/A	4.11
2006	4.13	4.21	3.37	3.56	3.08	2.92	3.48	4.26	N/A	6.63	5.93	5.17
2007	4.01	3.96	4.88	4.35	N/A	3.27	3.53	N/A	6.35	7.10	5.97	4.20
2008	N/A	4.69	4.40	4.33	N/A	3.35	3.42	4.65	6.44	7.20	5.84	7.13
2009	4.25	4.91	4.17	4.54	3.51	3.66	3.21	4.92	5.89	6.96	4.86	4.35
2010	4.28	4.26	4.13	N/A	3.62	3.04	3.26	4.58	5.99	7.14	5.48	3.71
2011	3.81	4.15	4.28	N/A								
Average	3.99	4.58	4.23	4.13	3.54	3.08	3.30	4.37	5.68	6.50	5.74	4.70

Source: Metrological Department

Table A6.1.27 Annual Evaporation

Months	Num. of Days	Average	
		mm/d	mm/month
Jan	31	3.99	123.7
Feb	28	4.58	128.2
Mar	31	4.23	131.2
Apr	30	4.13	123.9
May	31	3.54	109.7
Jun	30	3.08	92.4
Jul	31	3.30	102.4
Aug	31	4.37	135.5
Sep	30	5.68	170.5
Oct	31	6.50	201.4
Nov	30	5.74	172.1
Dec	31	4.70	145.6
		Total =	1636.7 mm/year

Source: Metrological Department

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Table A6.1.28 Evaporation

Lake/Dam	Surface Area (km ²)	Average Depth (%)	Surface Area at Ave. Depth (km ²)	Evaporation		
				(mm/y)	(×1000m ³ /y)	(m ³ /day)
Harava	2.2	50.02	1.17	1,637	1,915	5,246
Seke	1.1	42.27	0.51	1,637	835	2,287
Chivero	26.3	85.22	22.84	1,637	37,383	102,418
Manyame	81.0	64.83	55.27	1,637	90,461	247,839

Source: Metrological Department

7) WTPs Water Intake

The WTPs water intake flow at each lake/dam is estimated using the derived data in 2012.

Table A6.1.29 Balance between Inflow and Reduction Amount

Division	Item/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WTP	Daily Intake(1000m ³ /d)	60	60	60	60	60	60	60	60	45	45	45	45
	Daily Distribution(1000m ³ /d)	55	55	55	55	55	55	55	55	40	40	40	40
DAM	Daily Flow(x1000m ³ /d)	485	649	959	670	131	51	8	11	4	0	2	107
	Monthly Inflow(x1000m ³ /d)	15,026	18,168	29,730	20,114	4,071	1,542	244	335	111	3	49	3,321
	Daily reduction(x1000m ³ /d)	80	80	80	80	80	80	80	80	65	65	65	65
	Monthly Balance(x1000m ³ /month)	12,546	15,928	27,250	17,714	1,591	-858	-2,236	-2,145	-1,839	-2,012	-1,901	1,264
	Storage Volume(x1000m ³)	12,500	12,500	12,500	12,500	12,500	11,642	9,406	7,261	5,422	3,410	1,509	2,773

Table A6.1.30 Specifications of PE-WTP

Item		Prince Edward
Capacity (m ³ /d)		90,000
Water Source		Seke Dam (Connecting with Harava Dam)
Process	Sedimentation	Upper flow sludge blanket type
	Filtration	Akazu Filter (Constant water level control by siphon) , Washing by air and water
	Sludge Treatment	After sedimentation, discharge to sludge lagoon
Treatment Facilities	Sedimentation Basin	Rectangular Tank 7
	Rapid Sand Filters	16 Filters
	Clear Water Tank	1 tank (under the filters)
	Sludge Treatment	Two series of sludge tanks, sludge transmission pumps and sludge lagoon
	Transmission facilities	A transmission P/S to southern east area of Harare and Chitungwiza Municipality from the clear water tank
Using Chemical		Powder activated carbon, Aluminum Sulfide, Soda ash, Chlorine (by one ton cylinder), Coagulation aid
Treated Quality		Based on WHO Standard

Source: Harare Water

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Table A6.1.31 Production amount of MJ-WTP

Production /Month	2009		2010		2011	
	Monthly	Daily	Monthly	Daily	Monthly	Daily
Jan	13,459	434	18,011	581	18,182	587
Feb	10,968	392	15,526	555	15,513	554
Mar	11,913	384	17,173	554	18,576	599
Apr	11,452	369	15,923	514	17,792	574
May	11,228	362	18,151	586	17,985	580
Jun	14,667	489	15,147	505	17,981	599
Jul	11,891	384	16,822	543	18,804	607
Aug	15,930	514	18,207	587	17,794	574
Sep	17,887	596	17,535	585	17,683	589
Oct	16,944	547	17,816	575	17,559	566
Nov	15,976	533	17,248	575	17,573	586
Dec	16,362	528	17,581	567	18,029	582
Total	168,677	462	205,140	562	213,471	585

Source: Harare Water

6) Flow Balance at the Lakes/Dams

The balance between annual average inflow and outflow at the respective lakes/dams is summarised in Table A6.1.29, and the flow model covering the basin is presented in Figure A6.1.20. The difference between inflow and outflow probably consists of groundwater influence and measurement/estimation errors. Seke and Harava receive a daily flow of around 300,000 m³/day, while that of the Study 1997 the figure was 177,000 m³/day. Lake Chivero receives a daily flow around 1,000,000m³/day and daily total discharge is 770,000 m³/day, while that of the Study 1997 was around 558,000 m³/day. Lake Manyame receives a daily flow around 930,000 m³/day and daily total discharge is 870,000 m³/day, while that of the Study 1997 was around 667,000 m³/day. The result indicates that the rainfall during the years of the Study 1997 was considerably low.

Table A6.1.32 Inflow and Outflow Water Balance at Lakes/Dams

Name	Inflow	Outflow
Seke & Harava Dam		
Manyame R.	174	
Ruwa R.	72.8	
Direct Rainfall	8.6	
Direct Area Run-off	42.8	
Evaporation & Others		7.5
Prince Edward		45
Discharge		245.7
Subtotal	298.2	298.2
Water Increase		

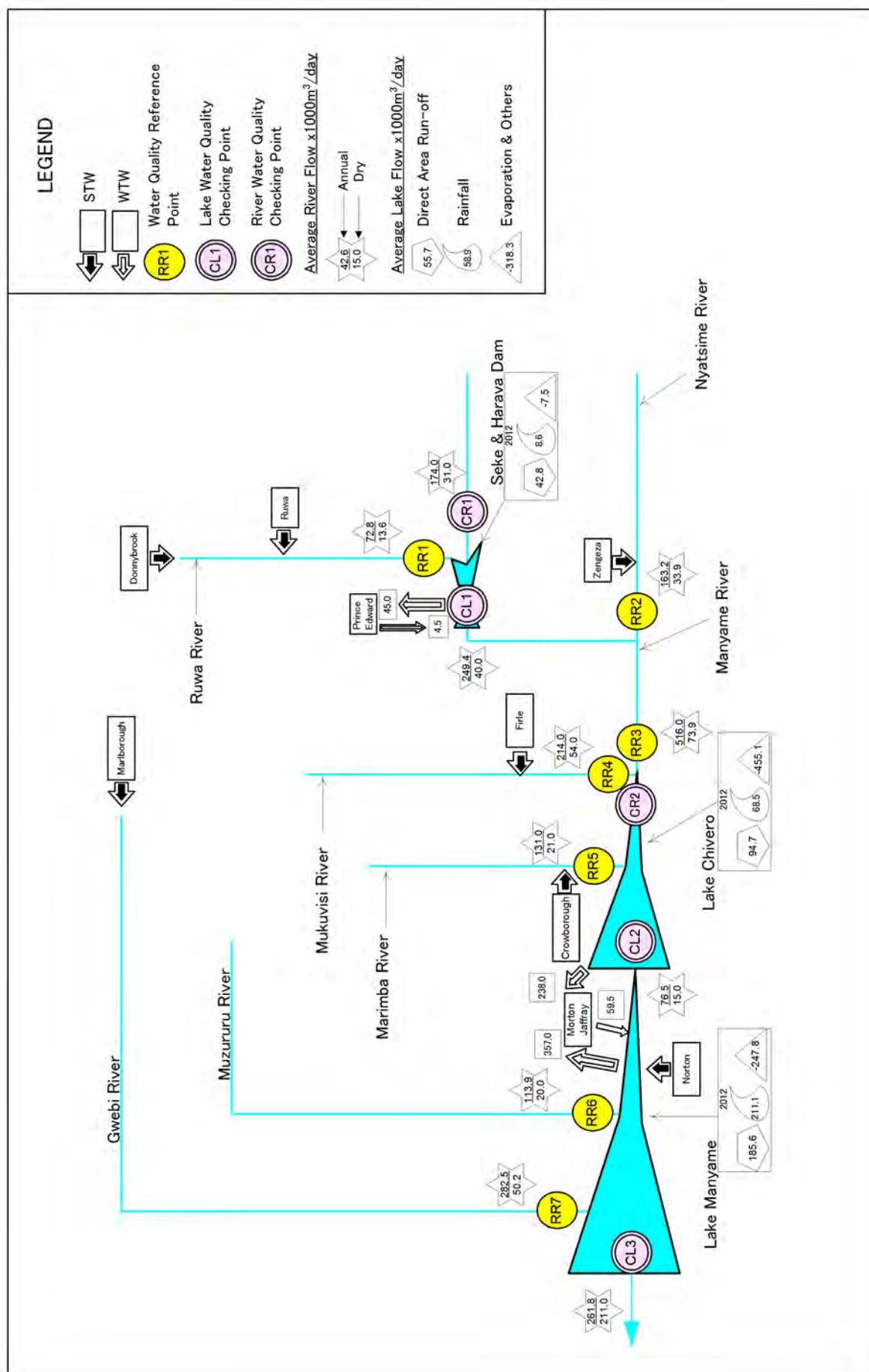
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Name	Inflow	Outflow
L.Chivero		
Manyame R.	516.0	
Mukuvisi R.	214.0	
Marimba R.	131.0	
Directi Rainfall	68.5	
Direct Area Run-off	94.7	
Evaporation & Others		455.1
Morton Jaffray		238.0
Discharge		76.5
Subtotal	1024.2	769.6
Water Increase	-254.6	
L.Manyame		
L.Chivero	76.5	
Muzururu R.	113.9	
GWEBI R.	282.5	
Directi Rainfall	211.1	
Direct Area Run-off	185.6	
Evaporation		247.8
Morton Jaffray	59.5	357.0
Discharge		261.8
Subtotal	929.1	866.6
Water Increase	-62.5	

Each catchment area is as follows:

Harava 2.2km², Seke 1.1km², Chivero 26.3km², Manyame 81.0km²
 Source: JICA Project Team

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※ Annual is flow for Lakes / Dry season is flow for Rivers

Figure A6.1.20 Flow Model of Rivers in Annual/Dry Season (Present, 2020, 2030)

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(7) Flow Balance in the Future

The natural flow rates of the rivers are largely influenced by rainfall which fluctuates year by year. The future flow rates were set based on the average rainfall in the past ten-year period. On the other hand, human activities such as intake for water supply and discharge of treated effluent etc, also affect the flow rate in the river. In this study, flow balance was set for the present and future.

Figure A6.1.20 shows the flow balance of the rivers and lakes in the Upper Manyame Catchment. All the rivers, lakes, STP and WTP are included in the diagram. Direct Area Run-off, rainfall and evaporation and others are also considered. Annual average flow and that of dry season are also expressed in the diagram. When the water balance is negative, it shows that the water level in the lake is increasing according to the area of the lake and daily increase of the balance flow. The centre of the water recirculation is Lake Chivero with most active water inflow and discharge. Approximately 1,000,000 m³/day has been inflowing to the Lake Chivero from the catchment including the effluent from the Firle STP, Crowborough STP, Zengeza STP, Ruwa STP and Norton STP. Around 640,000 m³/day has been drawn for the water supply from the PW-WTP and MJ-WTP. Water loss by evaporation and others is assumed to be 450,000 m³/day which is 60% of the total outflow from the Lake Chivero.

Since Mukuvisi and Marimba rivers do not have adequate flow and each river has Firle STP and Crowborough STP in their catchments, water quality is considered to be sensitive to pollution.

Lake Manyame has been supplying about 60% of raw water for the MJ-WTP (about 360,000 m³/day). Inflow from the Lake Chivero averages about 80,000 m³/day. Water loss by evaporation and others is assumed to be about 250,000 m³/day. Approximately 930,000 m³/day has been flowing into Lake Manyame from the catchment with less inflow from the STP. In August 2012, MJ-WTP was forced to limit water production due to the influence of raw sewage inflow from the Norton STP.

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6.2 UNIT WASTEWATER FLOW AND QUALITY

6.2.1 General

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

References were made to the Study 1997 conducted by JICA for sewerage and to the ILBM report in 2010. 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 flow investigation was also conducted in the field to get latest information regarding unit flow rate in Chitungwiza.

Future unit wastewater flow for various pollution sources 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 the 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 problems. 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.

6.2.2 Past records of Domestic/Commercial institutional sewage

(1) Water consumption per capita per day

Per capita water consumption at present and in the future is discussed in the Study 1997 referring to existing plans by urban local authority as follows:

- City of Harare

City of Harare provides water supply service to its metropolitan area including Chitungwiza Municipality, Norton Town, Epworth Local/ Board and Ruwa Local Board. Investigated actual/ water supply and consumption amounts were reported in the Master Plan for Water Distribution in 1995. The data bases of water supply and water consumption are consumers' meters records (water sales) and pumping plant records (from bulk water meters on transmission mains). The five-year records from 1986-1991 are summarised in Table A6.2.1.

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Table A6.2.1 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, Source: Harare Water

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 A6.2.2.

Table A6.2.2 Water Consumption by Category (1986-1991)

Year	Consumption (Annual Daily Average)							Unit: 1000m ³	
	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 lstand/day	($\doteq 80^*$ l/capita/day)
Medium-density	1, 800 lstand/day	($\doteq 80^*$ l/capita/day)
Low-density	2, 500 lstand/day	($\doteq 80^*$ l/capita/day)

The number of persons per stand of each category is assumed;

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

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- 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 20% of the total supply amount is not conveyed to the consumers due to leakage, wastage, etc. Under these conditions, water consumption rate is estimated to be 206 l/capita/day using an average household size of 4.37 (1992 Census).

(1) Sewage Unit Flow Rate

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^{1/} used following design criteria for the estimation of future sewage flow:

<u>Category</u>	<u>Water Supply</u>	<u>Discharge Ratio</u>	<u>Sewage</u>
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

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

High density	680l/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

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of Chitungwiza Municipality^{1/}.

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

The proposed unit sewage flow for high density is the same as Harare City. Applying number of persons per stand (nine persons/stand), unit sewage flow rate is 89l/capita/day and 761/capita/day, respectively. This unit water consumption is quite low in comparison with those in the water supply plans.

3) Unit sewage flow for water pollution control planning

Although the range of unit water consumption is different depending on 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 ratio of consumed water applied in the sewerage master plan for Crowborough Sewage Treatment Works was referred to for this study. The following are the calculation results:

<u>Category</u>	<u>Water Supply</u>	<u>Discharge Ratio</u>	<u>Sewage</u>
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

Unit water consumption quantities of low and medium density areas are assumed to be constant through the future, the same as in the previous studies, while increasing unit quantities are adopted for high density areas. The current figure of high density areas, 60 l/capita/day, is adopted based on the field study results at Zengeza STP, as shown in section 8.2.3. For the future projection, the 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 lifestyle in these authorities are similar particularly in same density category. The discharge rate of domestic sewage in the rural area with no residential/ category is assumed to be

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the same as that in high-density area.

6.2.3 Study of Sewage Unit Flow Rate in Chitungwiza

(1) Outline

As shown in the former section, there are several unit sewage flows proposed. In order to confirm the unit sewage flow and flow fluctuation in Chitungwiza Municipality, a field survey was conducted. Flow measurement and sewage sampling were conducted during 13th September to 1st October (2012) at ZSTP at the old grit chamber to get the latest sewage unit flow information. The weather during the activity was fair. Measurements were taken hourly at the sewage intake (influent). The sewage flow to the ZSTP was estimated by using the Rectangular Flume structure of the old system. In this system, only the water depth in the fixed pit is needed to calculate the water flow. A flow rate computing program was developed for the purpose after confirming the configuration of the flume. Flow rate computation was checked by the flow rate derived by the surface velocity in the channel and water depth using a float for the length of the channel. Measures of depth were taken every hour, on the hour. Fifteen minutes prior to flow measurements, screenings were cleared to prevent water damming. Sand deposits were cleared during low water in the early morning.

(2) Estimate of Population in the drainage area

Population in the drainage area of the Municipality was estimated from the total population derived from the survey described section 8.1.1 and the area temporarily unsewered. Table A6.2.3 shows the population and area to be excluded from the seweraged area in Seke and Zengeza due to break down of the pipe lines. As a result of the survey, an area of 193.3 ha and a population of 64,256 shall be excluded from the seweraged area in the Seke and Zengeza. Also, the population in the drainage area in St. Mary where three pump stations are located is 54,000. This was confirmed by the site survey with counterpart and verified by the study on the map/drawings. In total, a population of 211,744 out of 330,000, or about 64 % of the area, is considered to be in the seweraged area, as shown in Table A6.2.4

Table A6.2.3 Population out of sewage inflow in Seke and Zengeza

Area	Population	Area (ha)
Seke North	21,294	78.9
Seke South	35,887	101.9
Zengeza	7,074	12.5
Total	64,256	193.3

Source: JICA Project Team

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Table A6.2.4 Sewered Area in Chitungwiza

	Area (ha)	Population	Remarks
Sewered Area	1109.7	211,744	
St Mary's PS's Drainage Area	216.5	54,000	Breakdown of Pump Stations
Seke North, South & Zengeza Area	193.3	64,256	Refer to Table 6.1
Total	1519.5	330,000	

Source: JICA Project Team

(3) Water Supply

Situation of water supply during the survey was made in parallel with the flow rate survey as shown below:

Table A6.2.5 Water Supply during 27th September and 1st October

Data of Water Supply from 27th September to 1st October							
date	flowrate(l/sec)	flowrate(m ³ /hr)	remarks	date	flowrate(l/sec)	flowrate(m ³ /hr)	remarks
2012/9/27 9:00	150	540		2012/9/30 9:00	460	1,656	
2012/9/27 10:00	150	540		2012/9/30 10:00	460	1,656	
2012/9/27 11:00	150	540		2012/9/30 11:00	460	1,656	
2012/9/27 12:00	540	1,944	↑	2012/9/30 12:00	500	1,800	
2012/9/27 13:00	520	1,872		2012/9/30 13:00	540	1,944	
2012/9/27 14:00	520	1,872		2012/9/30 14:00	540	1,944	
2012/9/27 15:00	520	1,872		2012/9/30 15:00	540	1,944	
2012/9/27 16:00	520	1,872		2012/9/30 16:00	540	1,944	
2012/9/27 17:00	520	1,872		2012/9/30 17:00	540	1,944	
2012/9/27 18:00	520	1,872		2012/9/30 18:00	540	1,944	
2012/9/27 19:00	520	1,872		2012/9/30 19:00	540	1,944	
2012/9/27 20:00	520	1,872		2012/9/30 20:00	540	1,944	
2012/9/27 21:00	530	1,908		2012/9/30 21:00	540	1,944	
2012/9/27 22:00	530	1,908		2012/9/30 22:00	540	1,944	
2012/9/27 23:00	530	1,908		2012/9/30 23:00	530	1,908	
2012/9/28 0:00	530	1,908		2012/10/1 0:00	520	1,872	
2012/9/28 1:00	520	1,872		2012/10/1 1:00	520	1,872	
2012/9/28 2:00	520	1,872		2012/10/1 2:00	520	1,872	
2012/9/28 3:00	520	1,872		2012/10/1 3:00	520	1,872	
2012/9/28 4:00	520	1,872		2012/10/1 4:00	520	1,872	
2012/9/28 5:00	520	1,872		2012/10/1 5:00	510	1,836	
2012/9/28 6:00	520	1,872		2012/10/1 6:00	520	1,872	
2012/9/28 7:00	530	1,908		2012/10/1 7:00	520	1,872	24hrs
2012/9/28 8:00	530	1,908		2012/10/1 8:00	520	1,872	↓ 44,928
2012/9/28 9:00	530	1,908					
2012/9/28 10:00	450	1,620	24hrs				
2012/9/28 11:00	460	1,656	↓ 44,784				
2012/9/28 12:00	460	1,656					
2012/9/28 13:00	460	1,656					
2012/9/28 14:00	460	1,656					
2012/9/28 15:00	440	1,584					
2012/9/28 16:00	440	1,584					
2012/9/28 17:00	450	1,620					

For three hours on the 27th of September (2012), there was low water supply in Chitungwiza and it was confirmed that all the water supply valves to the municipality were closed during that time. Approximately 45,000 m³/day was supplied fairly constantly during the daytime except for the three hours mentioned. Under the flow rate condition the entire area is supposed to be supplied with water necessitating the examination of the unit flow rate.

(4) Sewage Flow Measurement

Flumes are generally used to measure flowrate (discharge) in open channels. These typically have

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widths from a few centimetres to 15 m or so. The water depth in the approach section of flumes typically can be between a few centimetres and about 2 m. Flumes, compared to weirs, have the advantage of less head loss through the device, yet are more complicated to construct and more difficult to analyse.

Head is measured in the flume upstream of the throat - in the so-called "approach channel". For Parshall flumes, head is measured upstream from the throat at a distance of 2/3 of the length of the approach channel (x =length of approach channel in the above diagram). For the other three flumes, head is measured upstream from the throat at a distance of three to four times the maximum expected head. This location is somewhat arbitrary because the head does not vary too much with position, so the exact location of the head measurement is not as important as for a Parshall flume. Since the rectangular, trapezoidal, and U flumes can have a raised throat (a hump), it is important to note that head is measured from the top of the hump rather than from the bottom of the approach channel.

Parshall flumes are the most common; however the flume in the ZSTP is the rectangular type. They were studied extensively in the mid 1900s. Rectangular and trapezoidal flumes function by having a constriction at the throat and/or a raised invert (bottom) at the throat.

Either feature can cause critical flow at the throat in a properly operating flume.

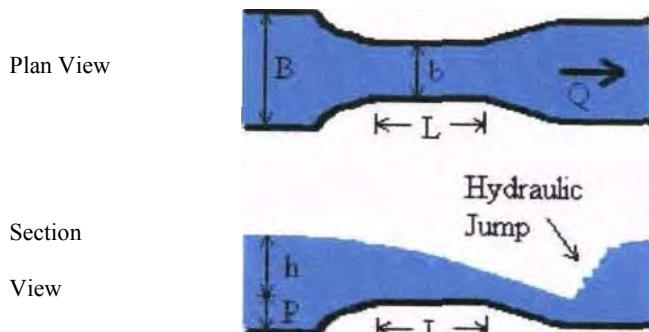


Figure A6.2.1 Flume type existing in the ZSTP-Rectangular Flume

These flumes are simpler to construct, can be more easily fit into an existing channel, and can trap less sediment than a Parshall flume. However, the methodology relating discharge to measured head is more complex. Critical flow is achieved by narrowing the throat or by raising the bottom of the flume at the throat. Analysis of U flumes is similar to that of the trapezoidal flume. All flumes must be built with their dimensions in strict accordance with specifications in published documents such as the ISO and ASTM standards. Otherwise, discharge analysis must be conducted for the specific flume beginning with theory and proceeding to experimentation to modify the theory by physical observations. The flume in the ZSTP follows the fundamental configuration.

Regarding analysis of flumes, flumes (like weirs) are designed to force a transition from sub-critical to

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super-critical flow. In the case of flumes, the transition is caused by designing flumes to have a narrowing at the throat, raising of the channel bottom, or both. Such a transition causes flow to pass through critical depth at the flume throat. At the critical depth, energy is minimized and there is a direct relationship between water depth and velocity (and flowrate). However, it is physically very difficult to measure critical depth in a flume because its exact location is difficult to determine and may vary with flowrate. Through mass conservation, the upstream depth is related to the critical depth. Therefore, flowrate can be determined by measuring the upstream depth, which is a highly reliable measurement.

(5) Equations and Methodology for Rectangular Flume

The methodology for the flume calculations follows that of ISO 4359 (1983, 1999) for the rectangular in this study. The ISO methodology for the flume was followed in this study. The calculation is most accurate when used within the ISO 4359 recommendations of $h \leq 2$ m, $0.1m \leq b \leq B$, $F \leq 0.5$, $h/b \leq 3$, $(b \times h)/[B \times (P+h)] \leq 0.7$, $h/L \leq 0.5$, and $h \geq 0.05$ or $h \geq 0.05$ L (whichever is greater). The conditions above in the ZSTP are confirmed to be within the range. The constants in the ZSTP are shown in the Table A6.2.6.

$$C_d = \left(1 - \frac{0.006L}{b}\right) \left(1 - \frac{0.003L}{h}\right)^{3/2}, \quad A = B(P+h)$$

C_v from numerical solution of

$$\sqrt{C_v^{2/3} - 1} = \frac{2}{3\sqrt{3}} \frac{bhC_v C_d}{A} \quad \text{Then,}$$

$$Q = bC_d C_v \left(\frac{2h}{3}\right)^{3/2} \sqrt{g}, \quad V = \frac{Q}{A}, \quad F = \frac{V}{\sqrt{gh}}$$

C_v can only be computed if $b \times h \times C_d / A < 0.93$.

Table A6.2.6 The value of the constant in the formula

Variables	Actual Value	Unit	Remarks
P	0	m	Hump Height
B	0.91	m	Bottom width of approach channel
h	-	m	Measured Head
L	1.15	m	Length of Flume Throat
b	0.44	m	Bottom width of flume throat
g	9.81	m/s^2	Acceleration by gravity

Source: JICA Project Team

These procedure needs iteration in the calculation using personal computer to get the required accuracy. Re-computation for this was made until there are at least four significant digits of accuracy.

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Then, V and F are computed from the final Q. Sewage flow was surveyed as shown in Table A6.2.7. For the continuous 24 hours, observed flow was 12,667 m³/day. As shown above, water supply for the days were 44,784 m³/day and 44,928 m²/day indicating loss due to leakage from water supply, usage practices such as gardening, spill-out from manholes by blocked the sewers, discharge from broken pipelines. Spill-outs from manholes and discharge from broken pipelines were actually observed in the survey as shown in (3). About a population of 120,000 was confirmed to directly discharge raw sewage to the environment.

Table A6.2.7 Result of Field Sewage Flow Measurement

Hour	Sewage Flow (m ³ /day)			
	27 th Sept, 2012	28 th Sept 2012	30 th Sept 2012	1 st Oct, 2012 Monday
0		8,563		1,0136
1		9,120		1,2366
2		11,147		1,3030
3		9,991		1,5277
4		10,925		14766
5		11,024		1,3751
6		11,598		1,5676
7	5,618	16,104		1,6114
8	5,618	22,945		1,6020
9	5,618	13,575	13,929	
10	6,162	12,632	10,319	
11	5,322	9,381	10,166	
12	9,767	7,913	9,693	
13	12,056	7,752	10,556	
14	11,287	7,297	13,943	
15	16,500	6,004	16,070	
16	11,613	5,611	14,024	
17	10,172	5,112	14,710	
18	10,498		9,516	
19	10,791		10,973	
20	9,909		8,393	
21	10,145		13,007	
22	9,598		11,536	
23	8,694		10,030	

Remarks: Flowrate is expressed as m³/day

- 1) From 9a.m. on the 30th September (2012) to 8a.m. on the 1st October (2012), total flow observed was 12,667 m³/day
- 2) For the peak flow was observed at 1500 hours the on 27th September (2012).

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- 3) Peak flow on 28th September (2012) was 800hours.
- 4) From 9 a.m. on the 30th September (2012) to 8 a.m. on 1st October (2012), there were two peaks in the morning and afternoon.
- 5) Although large fluctuations were found, there were trends of having two peaks, one in the morning and another in the afternoon.

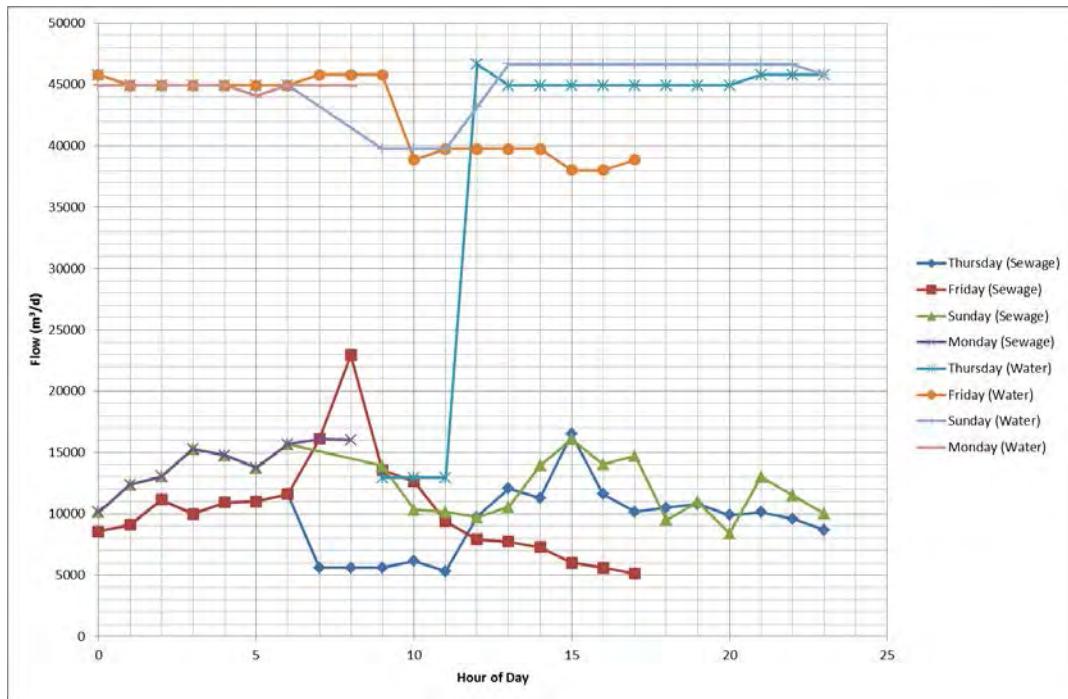


Figure A6.2.2 Flow Measurement Results (1)

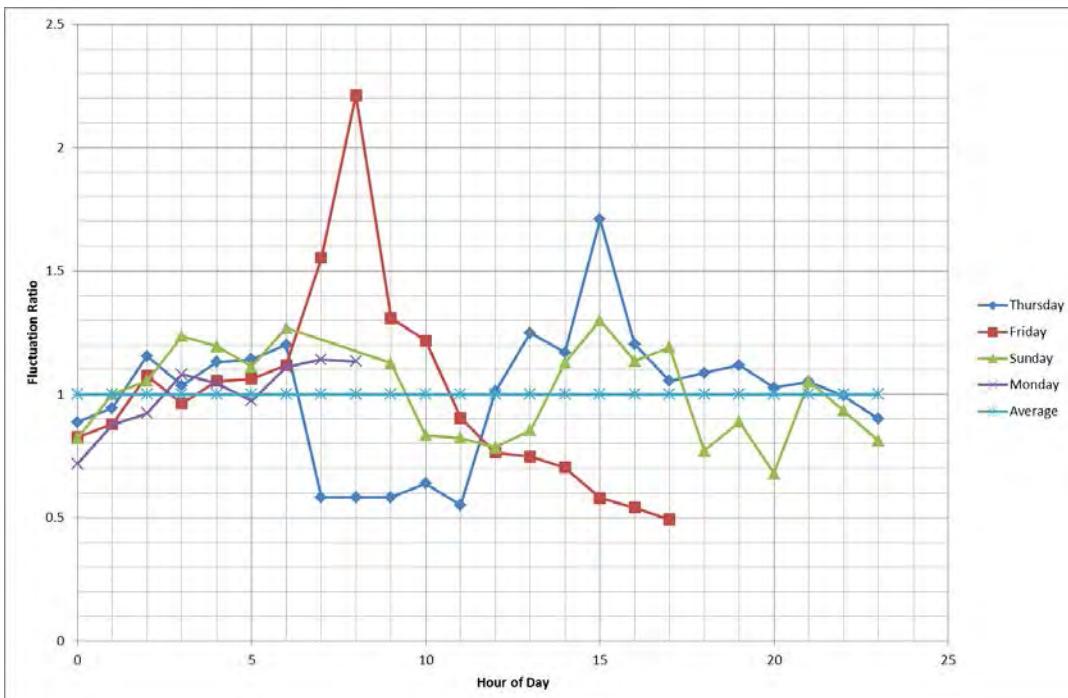


Figure A6.2.3 Flow Measurement Results (2)

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(6) Sewage Unit Flow and Peak Ratio

1) Sewage unit flow

Sewage flow of 13,000 m³/day on the 30th September (2012) was used for the examination. Population of 211,700 was confirmed in the area, excluding the pump station area and clogged/blocked area by sand deposit.

Then:

$$\text{Sewage Unit Flow Rate: } 13,000 \text{m}^3/\text{day} / 211,700 = 60 \text{l/day/capita}$$

2) Assumed unit water supply flow based on Sewage Unit Flow

Water supply unit rate was computed as 70.6 l/day/capita using the conversion rate of 0.85.

$$60/0.85 = 70.6 \text{ l/day/capita}$$

3) Peak Flow Rate

Peak rate was observed as 1.7 on the 27th September and 2.2 on the 30th September (2012).

It is evident that the entire Chitungwiza is high density area. The unit flow rate and peak factor will be used in planning of sewerage system in Chitungwiza.

6.2.3 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 Table A6.2.2, the total water consumption of commercial / institutional and industrial was computed to be about 75% of domestic water consumption in Harare city. This assumption is also supported by recent available data presented in Table A6.2.3 which shows the trend of the ratio of commercial / industrial and institutional water sales volume to domestic volume in Harare city to be about 75% in 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 may also be assumed to be equal to that of domestic sewage. Therefore, unit wastewater discharge is also set at 75% of domestic sewage flow. The net commercial and institutional wastewater is derived from the total amount by deducting the industrial wastewater, as discussed in sub-section 9.3.

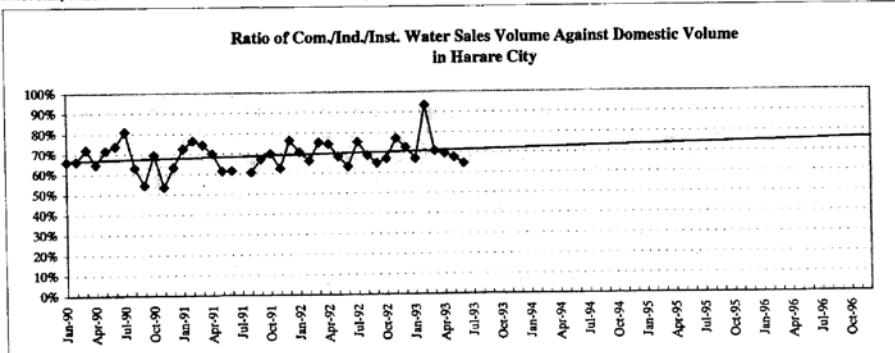
The data in Tables A6.2.2 imply that the ratio of commercial and institutional consumption to domestic consumption has been increasing. The trend indicates the percentage will be more than 100% in the year 2015, as shown in Table A6.2.2.

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Table A6.2.13 Water Sales

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	3,486,415	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	68%	8,417,151	956,147	4,000	468,693
Nov-90	10,228,822	1,760,497	3,713,992	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	2,567,024	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.	265,522	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%	6,180,235	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	2,016,786	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	2,889,333	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%	6,044,887	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	6,852,606	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 commercial water consumers in the Harare city are unevenly distributed. Many shopping centres are dispersed, but their water consumption and discharge may be regarded as negligible compared to the total domestic consumption and discharge. Most of the commercial water consumers are located in the central business district in the service area of Firle STP (Mukuvisi sub-basin), while many institutional/ water consumers are in the service area of Crowborough STP (Marimba sub-basin). Taking account the influent quantities at both STPs, it is assumed that 80% of total

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commercial/institutional wastewater is discharged in the Mukuvizi sub-basin, and 20% in the Marimba sub-basin.

(2) Chitungwiza Municipality

According to the investigation results of the bulk meter reading the Chitungwiza in 1992, water consumption is categorised as shown in Table A6.2.14;

Table A6.2.14 Water Consumption in Chitungwiza

Area	Monthly Consumption (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 A6.2.14, the ratio of water consumption of the shopping centre and the hospital to others is calculated as 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 the same with that of domestic water consumption. Thus, the present ratio of commercial/institutional wastewater to domestic sewage is planned at 5% and will be 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 is included in that of domestic sewage.

6.2.4 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 purposes are BOD, COD, T-N, T P and Suspended Solid (SS).

- 1) Sewage quality at present is used for future sewerage development in the new Norton STP plan.
- 2) Sanitation manual

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Sanitation manual recommends only following the design values of BOD load:

For high-density areas: 40 g-BOD/head/day

For low-density areas: 50 g-BOD/head/day

The manual also presented following reference data :

Daily Per Capita BOD ₅ :	Zambia	36g
	Kenya	23g
	S.E. Asia	43g
	India	30-45g
	Rural/ France	24-34g
	USA	45-78g

Average Breakdown of BOD₅ (g/head/day):

3) Raw sewage flow and quality at Donnybrook STP

Table A6.2.15 summarises data obtained from the Donnybrook STP from May 1994 to April 1995, which is mainly a high density residential area.,

Table A6.2.15 Raw Sewage Flow and Quality at Donnybrook STP

STP No.	Avg. Flow (m ³ /d)		BOD ₅		T-N		T-P**	
	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)

Therefore, unit pollution load by quality index was estimated, as shown in Table A6.2.16.

Table A6.2.16 Estimated Unit Pollution Load and Comparison with Experience in Japan

Unit Load	Cal/c. Results (a)	Exp. in Japan (b)	(a/b) %
Sewage (Dry Season)	55.3- 63.0 l/pced	-	-
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 gpd	1.2gpcd	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 except for T-P which is higher than that of Japan. This high T-P value may be due to the use of detergent containing phosphate. Giving consideration to above discussions, the following figures are used for planning purposes as the unit generated pollution loads for domestic sewage:

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Table A6.2.17 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	1.2gpcd	1.3 gpcd	1.4 gpcd

Note: gpcd; gram per capita per day

*: COD values are assumed to be two times of BOD values.

Generally, generated sewage consisting of night soil and grey water in the unsewered area is treated by septic tanks with seepage pit. Thus, any pollution load does not flow into public water bodies. Most of the septic tanks are generally maintained properly. However, in the rural area, it may be assumed that considerable amount of pollution load reaches the environment from septic tanks and seepage pit overflows, direct discharge of grey water, and 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 the water bodies. This ratio is assumed to be nil for low and medium density areas in the unsewered areas based on field observation. The values in Table A6.2.18 are assumed to be constant through the future.

Table A6.2.18 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. This is assumed to be the same as that of domestic sewage, as suggested in Japanese guidelines. 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 the respective rural local authorities.

(3) Industrial Wastewater

1) Unit Wastewater Flow

Study on unit flow of industrial wastewater by industrial type was conducted based on the data collected in the field survey at 24 factories in the four urban Local Authorities.

Six types of industries were selected from six major industrial types which consider the type of industry in each industrial area and the type of industrial discharge as it relates to the organic

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pollution load:

- Processed Foodstuffs
- Chemicals
- Plastic Products
- Ceramics, Stone and Clay Products
- Transportation Equipment
- Other Manufacturing Industry Products

The ratio of employees collected in the Study 1997 was used and is shown in Table A6.3.1. Table A6.3.2 shows current detailed data about the existing factories in the study area. According to current data, the total number of employees is 0.628 times the previous study (current is 12,096 and previous is 19,274 = 0.628). Therefore, the value of 0.628 is adopted to revise the frame. Unit wastewater flow is shown in Table A6.2.20. Current data is adopted. Unit pollution load of each industry is shown in Table A6.2.21.

In the analysis, unit flow of industrial wastewater is assumed to be constant for the four urban Local Authorities in the study area from present through the future, considering that no remarkable change is anticipated on the composition and operating scale of major industries.

Table A6.2.19 Composition Ratio of Employee by Industrial Type

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 Crownborough	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	8.3
		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

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Table A6.2.20 Unit Flow of Wastewater of Industry

Company Name	Type of Industry	Number of Employees	Waterwater Quantity	Unit Wastewater Quantity
			m ³ /day	m ³ /d·person
Chibuku Brew	Processed Foodstuffs	250	75.0	0.3
United Bottle	Processed Foodstuffs	942	1,258.1	1.336
Olivine Ind.	Processed Foodstuffs	1,500	759.1	0.506
D.M.B.	Processed Foodstuffs	600	900.0	1.5
National Foods	Processed Foodstuffs	516	256.5	0.497
Aroma Bakeries LTD	Processed Foodstuffs	145	18.7	0.129
Dairiboard	Processed Foodstuffs	70	22.0	0.314
Food & Industrial	Processed Foodstuffs	168	22.0	0.131
NBC	Processed Foodstuffs	103	3.3	0.032
Zim Freeze	Processed Foodstuffs	200	64.8	0.324
Total		4,494	3,380	0.507
Hunyani	Pulp, Paper	650	2,800	4.308
Total		650	2,800	4.308
Caps	Chemicals	400	65	0.163
Windmill(Pvt) Ltd.	Chemicals	450	12	0.027
Total		850	77	0.095
Pyramid Products	Plastics	34	6	0.176
Total		34	6	0.176
Southern Granite	Ceramics, Stone	30	417	13.889
Total		30	417	13.889
	Metal	0	0	0
W/Vale M. M. Ind.	Transportation	600	200	0.333
Zupco	Transportation	3,226	70	0.022
Zupco	Transportation	400	300	0.75
GDC Hauliers	Transportation	400	33	0.083
Total		4,626	603	0.297
Abercorn Dry Co.	Other	35	80	2.286
Norton Hospital	Other	46	17	0.362
NAT. REH. CENTRE	Other	200	115	0.576
Aurex	Other	1,000	63	0.063
Guard-Alert	Other	131	3	0.025
Total		1,412	278	0.662
Grand Total		12,096	7,561	19.934

Source: JICA Project Team

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Table A6.2.21 Unit Pollution Load of Industrial Wastewater by Industrial Type

Type of Industry	Industrial Type	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		
		Wastewater Quantity (m ³ /day)																
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	20.93	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

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2) Unit Pollution Load

The unit pollution load of industrial wastewater was calculated in the same manner as what was adopted in the unit flow calculation. The result is shown in Table A6.2.21.

6.2.5 Unit Pollution Load of Other Pollution on Sources

Aside from domestic and industrial pollution loads, the ones generated by livestock, slaughterhouse, farmland and natural land are studied as major pollution sources.

(1) Livestock

Unit pollution load of livestock was established by species. Major livestock raised in the study area are cattle, sheep, goat, pig and poultry. However, data on the pollution load from these livestock are not currently available. Thus, the standard figure for generated and reached load used in Japan for pollution control are employed as shown in Table A6.2.22.

Table A6.2.22 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 _C (g/head/day) ³	1,280	128	400	440	102.4	10.24	32.0	35.2
<i>COD_{Mn}</i> (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_C is used in Zimbabwe. Thus the COD values for the study are assumed to be two times of BOD₅ values.

Reduction of reached pollution load for open defecation of livestock is assumed to be 8% in the pollution analysis of rivers for dry season based on field confirmation. Pollution loads of poultry were regarded to be negligible, because most of poultry are raised in pens and their excreta is not discharged. Table A6.2.23 shows unit reached BOD load for livestock in dry season.

Table A6.2.23 Unit Concentrated Pollution Load of Livestock (Dry Season) Pollutant

Pollutant	Cattle	Sheep/ Goats	Pigs	Horses
BOD ₅ (g/head/day)	4.096	0.4096	1.28	1.408

(2) Slaughterhouse

Data on pollution load discharged from slaughterhouses in Zimbabwe were not available. Most of slaughtering in the study area is carried out for cattle, swine, poultry and ostrich, and wastewater from

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these are discharged into the public sewerage system.

(3) Natural Land/Farm Land

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 A6.2.24.

Table A6.2.24 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 wet land	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	2136	100.0

Source: Lake Mclwaine, 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 for woodlands as follows:

Table A6.2.25 Unit Pollution Load of Woodlands in Japan

Pollution load	BOD ₅	CODMn	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	6600	880	127
Average (kg/km ² /yr)	290	2150	360	30

Source: JICA Project Team

In Japan, the figure of 0.5-1.0 kg-BOD/km²/day (182.5-365 kg-BOD/km²/year) is commonly used 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 A6.2.26.

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Table A6.2.26 Unit Natural Pollution Load

Pollutant	Unit P.L.	
	(kg/km ² /year)	(kg/km ² /day)
BOD ₅	290	0.795
CODcr*	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 CODcr is used in Zimbabwe.
Thus CODcr Value for the study are assumed to be two times of COD_{Mn} values.

Source: JICA Project Team

Most pollution loads are discharged during the rainy season, however, for the pollution analysis of the river during the dry season, 8% of BOD load, 0.064 kg/km²/day, was assumed to be discharged. The pollution loads shown in the table were used for the entire study area, not only for natural land but also for other land use areas.

2) Farmland

Farmlands are a potential non-point pollution source due to agricultural activity. Unit run-off pollution load from farmlands are generally larger than that of natural land because of surface run-off ratio and the provision of fertiliser use. However, there is currently no data available on such pollution load in Zimbabwe. The following are the references in Japan, although characteristics of cultivation and climatic condition are different from Zimbabwe:

Table A6.2.27 Unit Pollutant Load of Farmland in Japan

Pollution load	BOD ₅	COD _{MN}	T-N	T-P
Number of Investigation	2	5	24	17
Minimum (km ² /yr)	29	399	820	0
Maximum (kg/km ² /year)	471	2,190	23,800	243
Average (kg/km ² /year)	250	1,030	7,600	68

Source: JICA Project Team

The Department of Research and Specialists, Ministry of Agriculture investigated the quantity of fertiliser provided to farmlands by seven farmers in the study area (refer to Chapter 2, Supporting Report, The Study on Water Pollution Control in The Upper Manyame River Basin in The Republic of Zimbabwe, 1997). The results of investigation are as follows:

Table A6.2.28 Investigation on Fertilizer Quantity

Pollution load	Nitrogen Fertiliser	Phosphate Fertiliser
<u>Crops (including Horticulture)</u>		
Total area of Farmland (ha)	3413	3413
Total/ Fertilised Quantity (kg/yr)	117411	6520
Average Fertilised Quantity (kg/km ² /yr)	3440	191

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Pollution load	Nitrogen Fertiliser	Phosphate Fertiliser
<u>Pastures</u>		
Total area of Farmland (ha)	1387	1387
Total/ Fertilised Quantity (kg/yr)	824	2160
Average Fertilised Quantity (kg/km ² /yr)	59	156

Source: JICA Project Team

Because of insufficient data, the pollution load provided to farmlands was assumed by taking into consideration the above-mentioned information. Those of BOD and COD are based on the experience in Japan; while T-N and T-P are based on the investigation results in the study area. Part of the fertilisers will be absorbed by crops/, plants and soil, and volatilise to the air. If 10% of the fertiliser is assumed to potentially run off, then unit pollution load in the discharged level is calculated as shown in Table A6.2.29.

Table A6.2.29 Unit Pollution Load of Farmland

Pollutant	Unit PL/.	
	(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.

Source: Guidelines for Basin-wide Water Pollution Control Master Plan, Japan Sewage Works Association

Farmland area by sub-basin in the study area is not available. Since the pollution loads of farmlands and natural land are on the same magnitude /level, the pollution load discharged from farmlands will be calculated in the same manner as that of natural land.

(4) Other Pollution Sources

In addition to the pollution loads discussed in the previous sub-sections, that caused by rainfall (air pollution) and urban rainwater run-off are sometimes considered in similar studies. The former may be negligible in the country, while the latter may have to be included in the assumed natural pollution load. Although the pollution load carried by rainwater run-off from urbanised areas cannot be neglected, the amount in dry season for river is minimal. 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 a nearby river without any treatment. Sludge in a sedimentation tank is led to a sedimentation pond, and supernatant liquid is discharged to an open area.

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

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

① Morton Jaffray

a. Sludge (assumed to be 75% of total/ pollution load)

-8% of pollution load reaches Lake Manyame

During dry season, 8% of BOD load reaches Lake Manyame

b. Backwashing sludge (assumed to be 25% of total/ pollution load)

100% of pollution load reaches Lake Manyame.

Pollution load does not reach Lake Manyame after introduction of sludge treatment plant.

② Prince Edward WTP

a. Sludge (assumed to be 100% of total/ pollution load)

8% of pollution load reaches Manyame River (downstream).

During dry season, 8% of BOD load reaches Manyame River

b. Backwashing sludge (assumed to be 0% of total/ pollution load)

Constant pollution load is circulating in the processes.

6.3 CURRENT WATER POLLUTION ANALYSIS

6.3.1 General

Current water pollution analysis was conducted to establish the simulation model and major factors to be applied to projecting water quality in the future and to identify the impact of countermeasures for water pollution. Schematic flow diagrams of present water pollution analysis for rivers and lakes are presented in Figures A6.3.1 and A6.3.2 respectively.

Water pollution analysis conducted considered human-related pollution and natural pollution loads as non-point sources. Modelling of the entire study basin for water pollution analysis was made using the result of studies made in the last 10 years as discussed in the section 6.2.

The quantitative analysis was made for Seke and Harava Dams, Lake Chivero and Lake Manyame for T-N, T-P and COD. The relationships between pollution loads discharged from pollution sources and the pollution load reached at the water quality checking points 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 modelling for the dry season was applied for the pollution analysis of rivers.

6.3.2 Methodology

(1) Rivers

The water pollution study was conducted through the analysis of existing data, water quality examination results obtained through the study, and previous pollution study reports. The major 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.

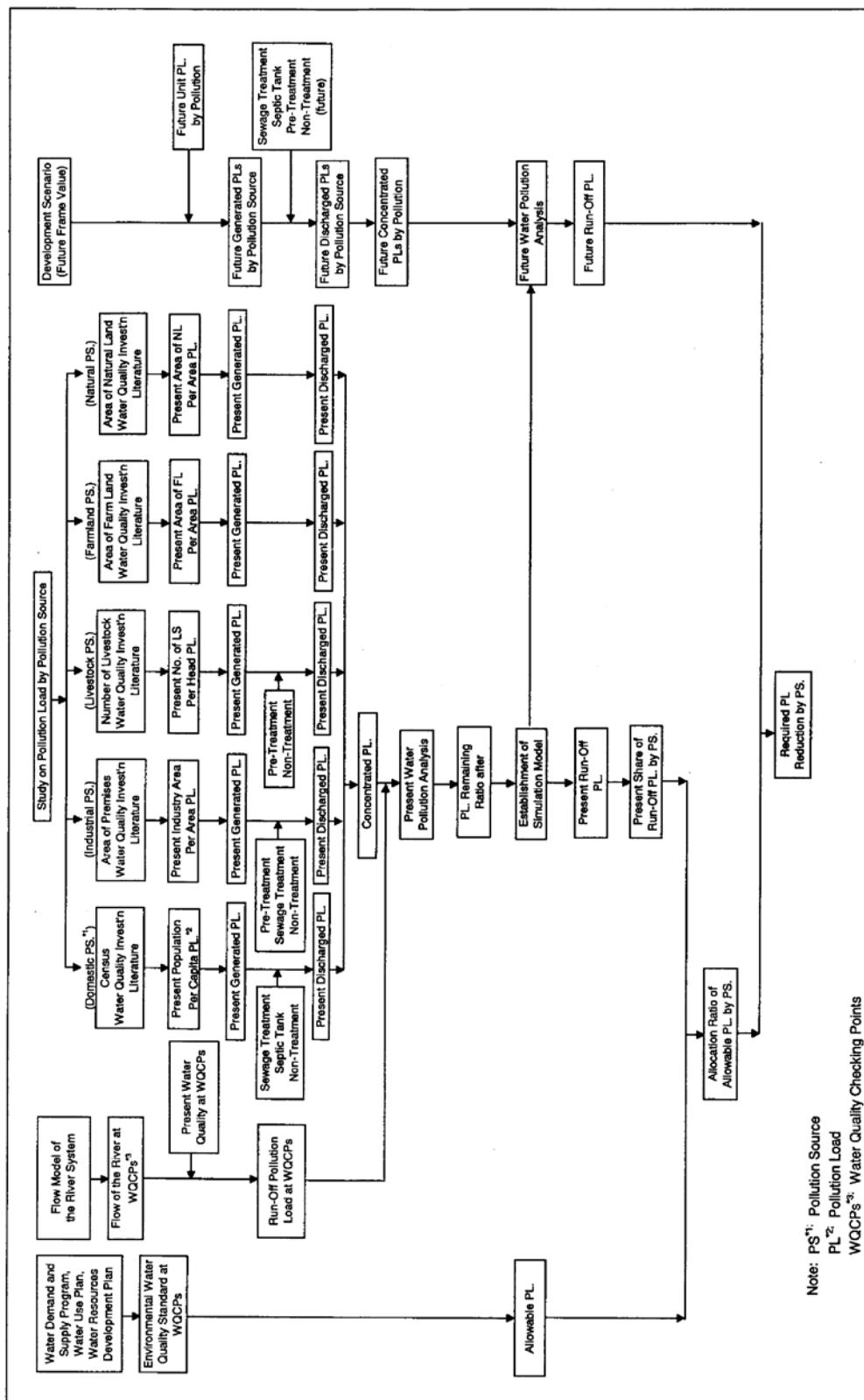


Figure A6.3.1 Flow Diagram of Water Pollution Study (River)

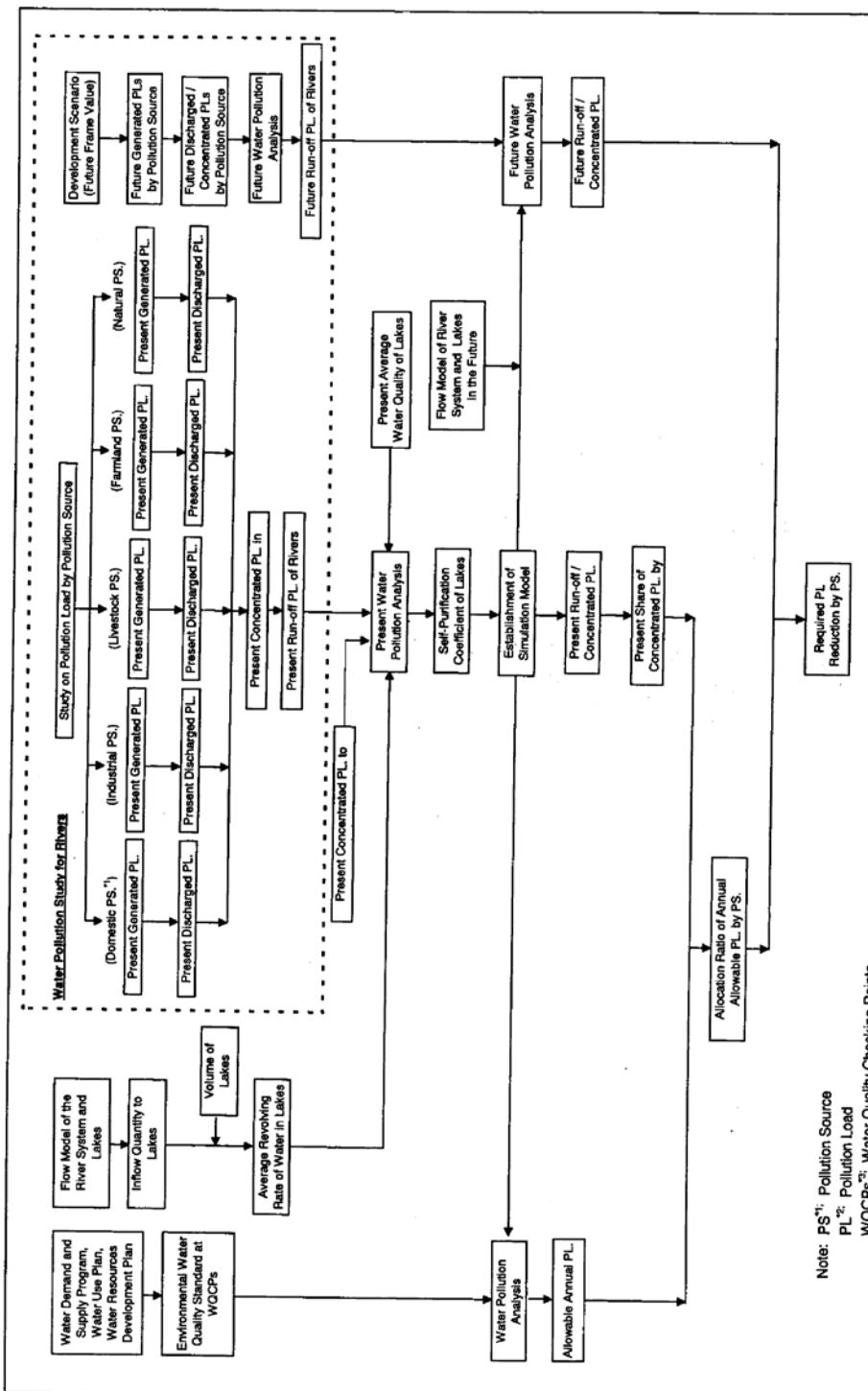


Figure A6.3.2 Flow Diagram of Water Pollution Study (Lakes)

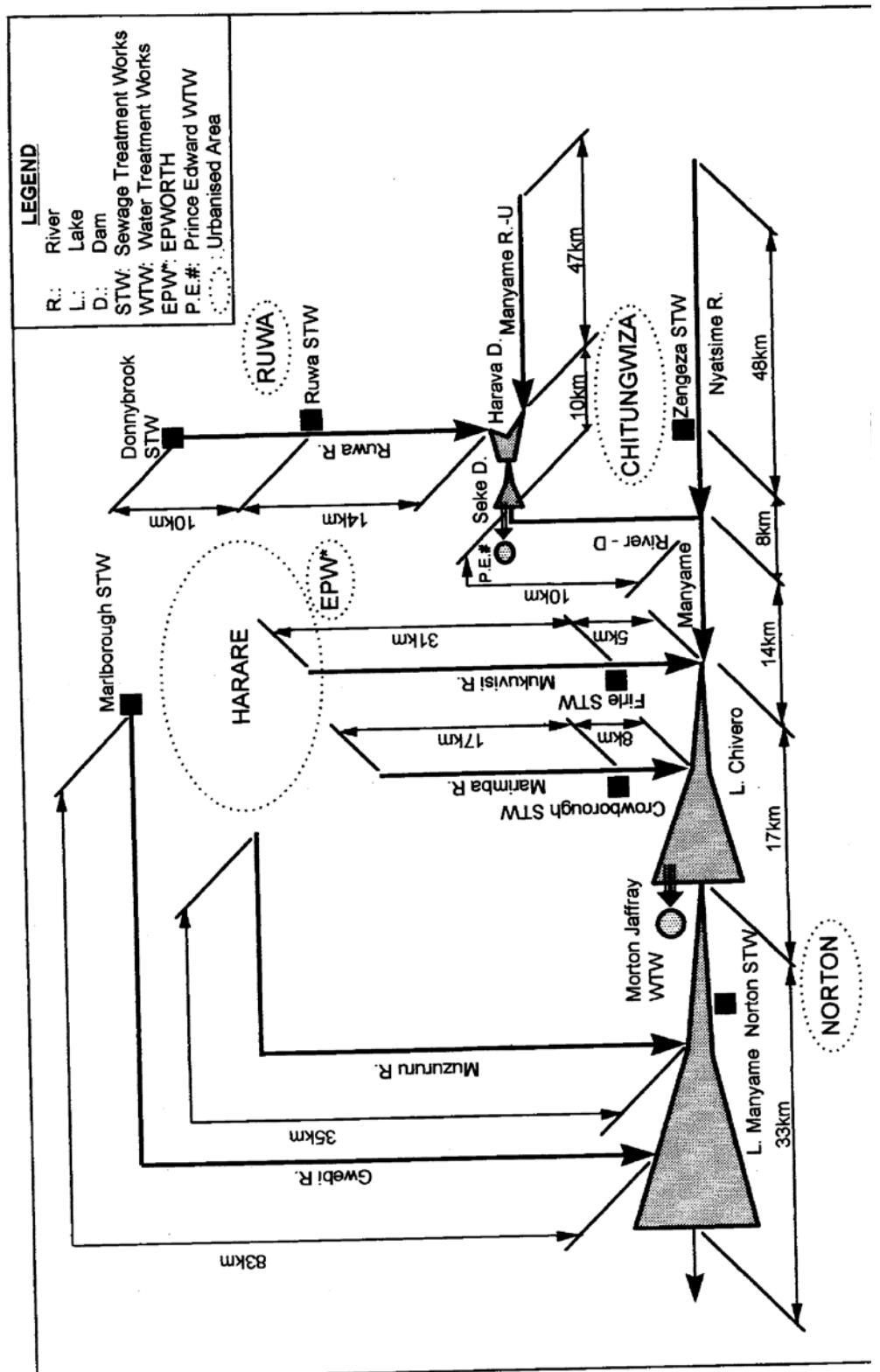


Figure A6.3.3 Location of Rivers, Lakes and STPs

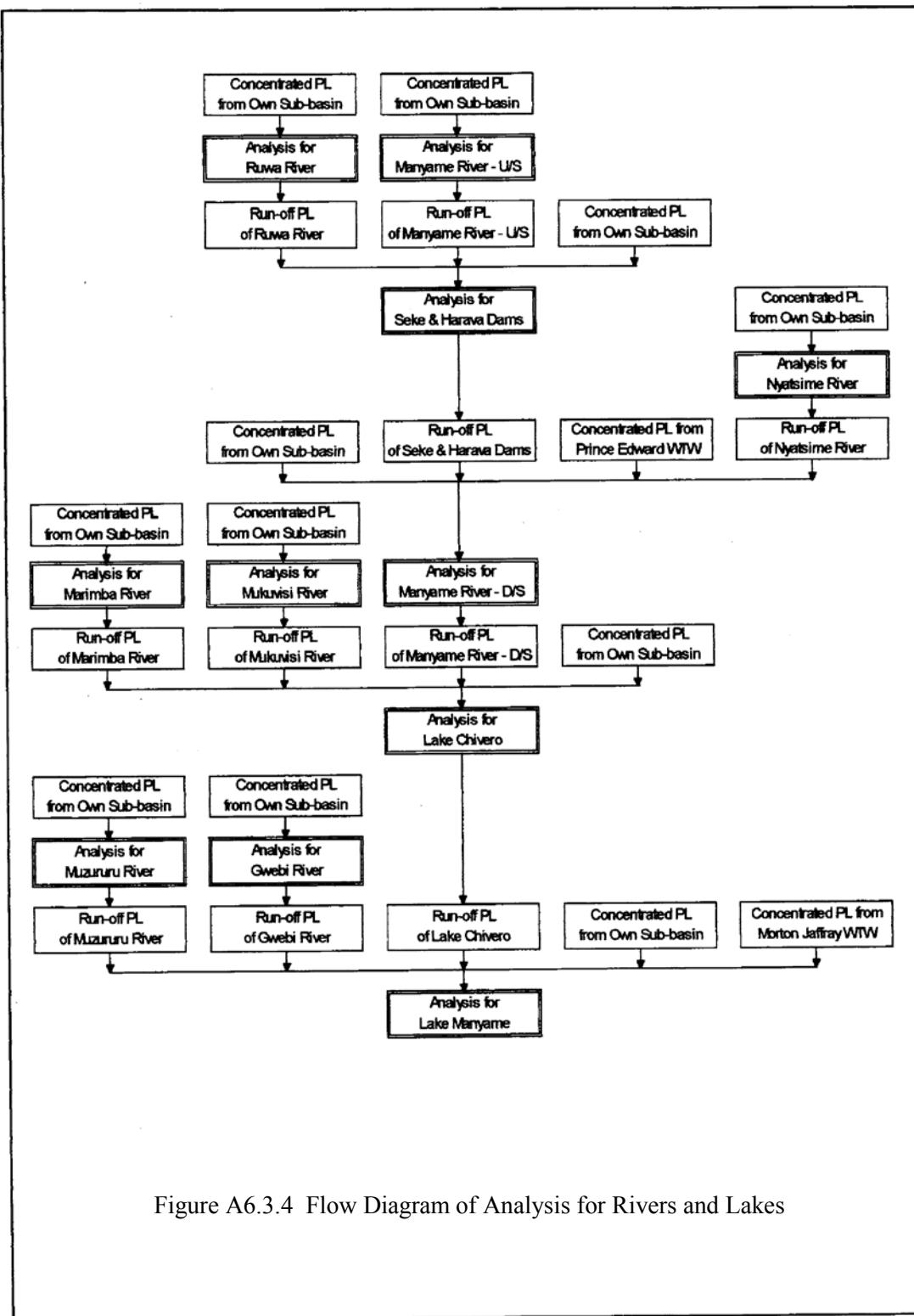
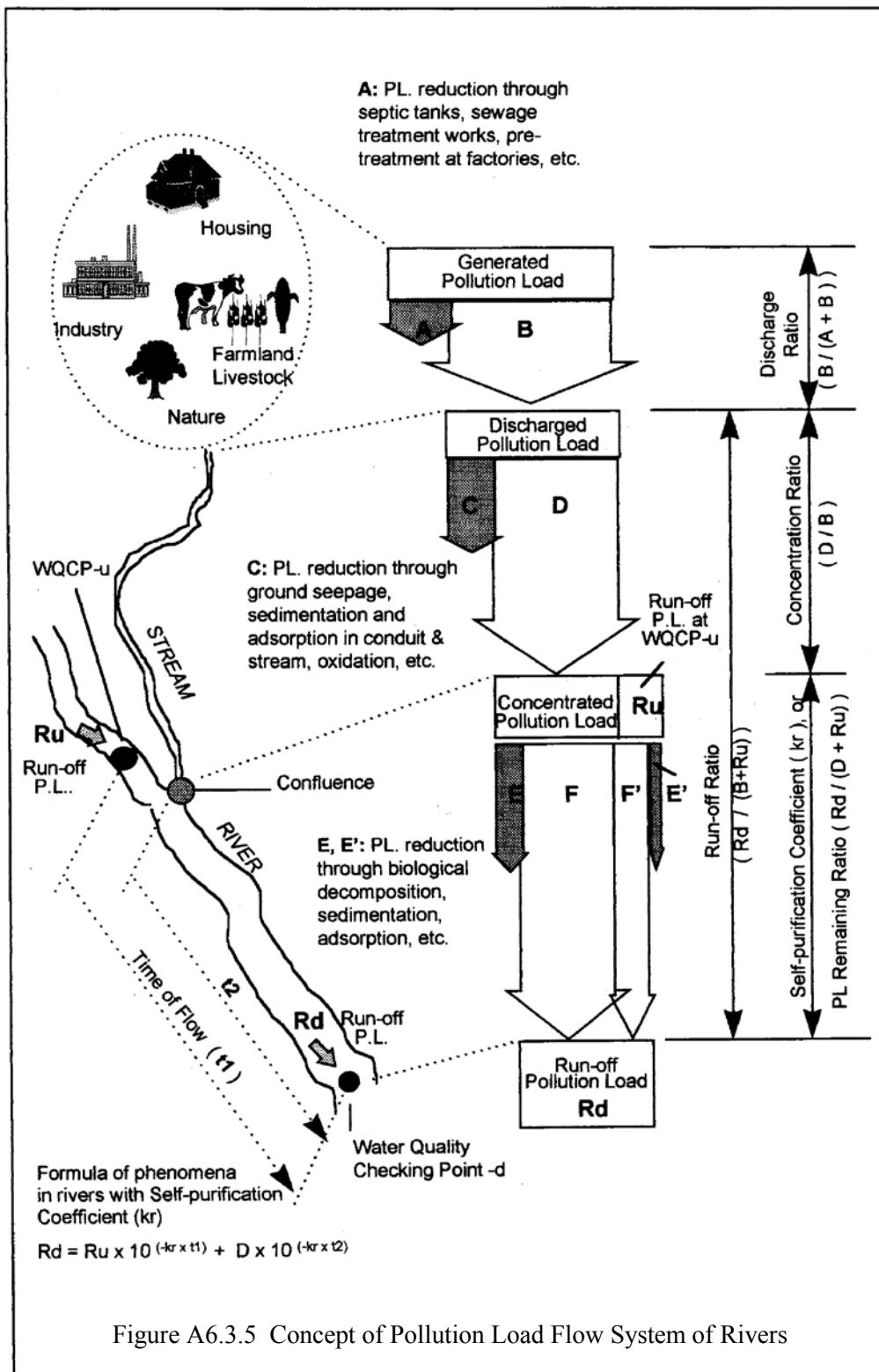


Figure A6.3.4 Flow Diagram of Analysis for Rivers and Lakes

Source: JICA Project Team



Source: JICA Project Team

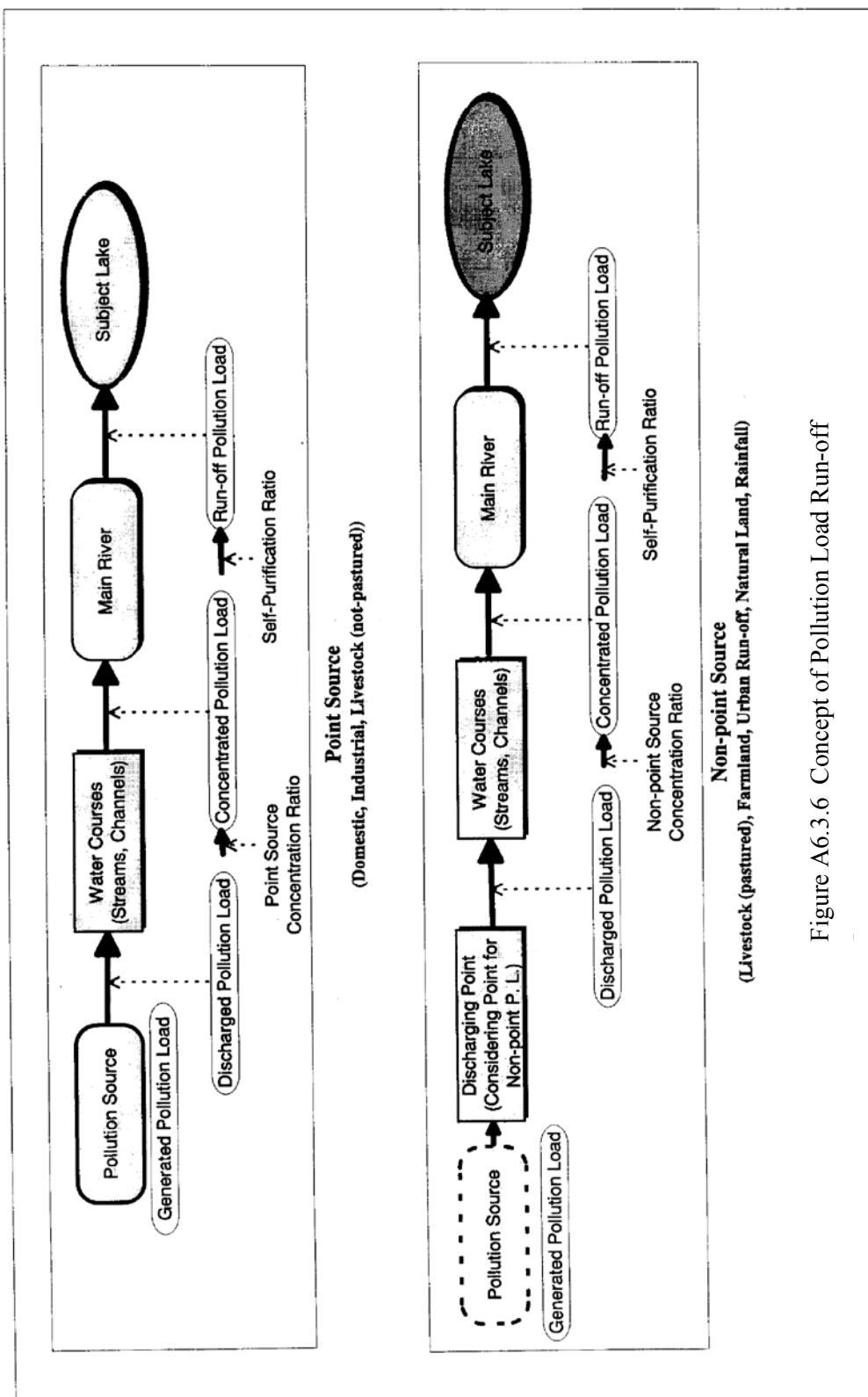


Figure A6.3.6 Concept of Pollution Load Run-off

In the study, the residual ratio of the pollution load of each river was derived through the analysis of self-purification. Reached pollution load was estimated using frame values, unit pollution load and assumed reaching ratio. Run-off load was estimated based on the existing data on flow rate and water quality of rives.

(2) Lakes/Dams

The water pollution study for the lakes was also conducted in the same way. Water quality indices used in the study were T-N, T-P and COD. COD was utilised to eliminate the influence of algae in the examination of BOD. In the study, COD was made as a reference. The Vollenweider Model was adopted for the water pollution simulation model in terms of T-N, T-P and COD, and the increase of COD caused by elution from sediment in the lake is considered in this concept.

6.3.3 Fundamentals for the Analysis

(1) Domestic/Commercial/Institutional/ Sewage

The pollution load collected from the seweraged area will flow into the sewage treatment plant. The pollution load was calculated using existing data at the STPs. Results of the analysis are presented in Table A6.3.2. BOD load was adopted for the water pollution analysis of rivers; while COD, T-N and T-P load were selected for the pollution analysis of lakes. It was also assumed that 8% of the pollution load for irrigation reuse reaches the subject water bodies.

(2) Industrial Wastewater

1) Industrial wastewater Flow

Industrial wastewater flow was examined using the data of industrial wastewater flow per employee and the number of employees. The result is shown in Table A6.3.7

2) Pollution load

Pollution load was calculated by multiplying the unit pollution load of industrial wastewater per employee and the number of employee at present. The result is presented in Table A6.3.9

3) Sewered/Unsewered Wastewater

Wastewater flow and pollution load were calculated for seweraged/unsewered by public sewerage system based on the present conditions described below. The results are shown in Table A6.3.1.

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Table A6.3.1 Population by Sewered/Unsewered by Sub-basin (Present)

Sub-basin/District	Total Population		Estimated Sewered %	Sewered Area				Unsewered Area			
	Sewered	Unsewered		Low	Medium	High	Total	Low	Medium	High	Total
1. Manyame River (U.stream) S/B											
Goromonzi Rural	-	2,255	0%	-	-	-	-	-	-	2,255	2,255
Harare Rural	-	76	0%	-	-	-	-	-	-	76	76
Manyame Rural	-	1,498	0%	-	-	-	-	-	-	1,498	1,498
Total	-	3,829		-	-	-	-	-	-	3,829	3,829
2. Ruwa River S/B											
Harare City	107,148	-	100%	-	-	107,148	107,148	-	-	-	-
Ruwa Local Board	24,763	237	99%	2,023	512	22,228	24,763	237	-	-	237
Epworth Local Board	-	87,333	0%	-	-	-	-	-	-	87,333	87,333
Goromonzi Rural	-	535	0%	-	-	-	-	-	-	535	535
Harare Rural	-	2,606	0%	-	-	-	-	-	-	2,606	2,606
Total	131,911	90,711		2,023	512	129,376	131,911	237	-	90,474	90,711
3. Seke & Harava Dams S/B											
Epworth Local Board	-	9,441	0%	-	-	-	-	-	-	9,441	9,441
Goromonzi Rural	-	10	0%	-	-	-	-	-	-	10	10
Harare Rural	-	4,780	0%	-	-	-	-	-	-	4,780	4,780
Manyame Rural	-	623	0%	-	-	-	-	-	-	623	623
Total	-	14,854		-	-	-	-	-	-	14,854	14,854
4. Nyatsime River S/B											
Chitungwiza Municipality	260,071	-	100%	-	-	260,071	260,071	-	-	-	-
Manyame Rural	-	6,519	0%	-	-	-	-	-	-	6,519	6,519
Marondera Rural	-	60,000	0%	-	-	-	-	-	-	60,000	60,000
Total	260,071	66,519		-	-	260,071	260,071	-	-	66,519	66,519
5. Mukuvizi River S/B											
Harare City	764,852	34,549	96%	48,128	77,689	639,035	764,852	34,549	-	-	34,549
Epworth Local Board	-	34,226	0%	-	-	-	-	-	-	34,226	34,226
Harare Rural	-	1,180	0%	-	-	-	-	-	-	1,180	1,180
Zvimba Rural	-	142	0%	-	-	-	-	-	-	142	142
Total	764,852	70,097		48,128	77,689	639,035	764,852	34,549	-	35,548	70,097
6. Manyame River (D.stream) S/B											
Chitungwiza Municipality	69,929	-	100%	-	-	69,929	69,929	-	-	-	-
Harare Rural	-	6,487	0%	-	-	-	-	-	-	6,487	6,487
Manyame Rural	-	939	0%	-	-	-	-	-	-	939	939
Total	69,929	7,426		-	-	69,929	69,929	-	-	7,426	7,426
7. Marimba River S/B											
Harare City	644,458	-	100%	73,046	35,163	536,249	644,458	-	-	-	-
Zvimba Rural	-	882	0%	-	-	-	-	-	-	882	882
Total	644,458	882		73,046	35,163	536,249	644,458	-	-	882	882
8. Lake Chivero S/B											
Harare City	-	-	-	-	-	-	-	-	-	-	-
Chegutu Rural	-	672	0%	-	-	-	-	-	-	672	672
Manyame Rural	-	1,292	0%	-	-	-	-	-	-	1,292	1,292
Zvimba Rural	-	1,563	0%	-	-	-	-	-	-	1,563	1,563
Total	-	3,527		-	-	-	-	-	-	3,527	3,527
9. Muzururu River S/B											
Zvimba Rural	-	4,606	0%	-	-	-	-	-	-	4,606	4,606
Total	-	4,606		-	-	-	-	-	-	4,606	4,606
10. Gwebi River S/B											
Harare City	12,421	86,572	13%	12,421	-	-	12,421	86,572	-	-	86,572
Mazowe Rural	-	5,100	0%	-	-	-	-	-	-	5,100	5,100
Zvimba Rural	-	6,688	0%	-	-	-	-	-	-	6,688	6,688
Total	12,421	98,360		12,421	-	-	12,421	86,572	-	11,788	98,360
11. Lake Manyame S/B											
Norton Town	48,045	2,955	94%	605	648	46,792	48,045	2,955	-	-	2,955
Chegutu Rural	-	2,928	0%	-	-	-	-	-	-	2,928	2,928
Zvimba Rural	-	4,119	0%	-	-	-	-	-	-	4,119	4,119
Total	48,045	10,002		605	648	46,792	48,045	2,955	-	7,047	10,002
Grand Total	1,931,687	370,813	84%	136,223	114,011	1,681,452	1,931,687	124,313	-	246,500	370,813

Source: JICA Project Team

Table A6.3.2 Discharged Pollution Load at Sewage Treatment Works (Present)

Sub-basin	Sewage Treatment Works	Eff. Flow (m ³ /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-P ^a	T-N	T-P	BOD (dry)	COD	
Mainimba R.	Crowborough (TF)	16,800	16,800	29%	28.0	84	471	1,354	637	141	346	996	
do	Crowborough (BNR)	-	-	0%	18.9	9.3	2.7	-	-	-	-	-	
do	Crowborough Total	16,800	16,800	-	-	-	-	-	-	-	-	-	
L. Chivero	Firle Units 1&2 (TF)	30,000	30,000	68%	137.8	268.0	7.2	4,134	8,040	1,161	216	1,532	
Mukuvisi R.	Firle Unit 3 (BNR)	-	-	0%	13.8	107.6	4.7	-	-	-	-	-	
do	Firle Unit 4 (BNR)	-	-	0%	18.2	94.7	13.0	3.7	-	-	-	-	
do	Firle Total (Mukuvisi)	-	-	-	-	-	-	-	-	-	-	-	
Gwebi R.	Marlborough (WSP) ^b	2,000	2,000	100%	51.4	161.9	36.4	6.5	103	324	73	13	
Ruwa R.	Donnybrook-1 (WSP) ^b	400	400	100%	40.6	162.1	99.6	17.3	97	389	239	26	
do	Donnybrook-2 (WSP) ^b	-	-	1400	100%	40.6	162.1	99.6	17.3	73	292	179	20
do	Donnybrook-3 (WSP) ^b	-	-	1400	100%	40.6	162.1	99.6	17.3	154	616	378	42
do	Donnybrook-4 (WSP) ^b	-	-	2,400	100%	40.6	162.1	99.6	17.3	154	616	378	42
do	Donnybrook Total ^h	5,600	5,600	-	-	-	-	-	-	479	1,913	1,175	129
Nyatsime R.	Zengeza (TF) ^b	-	-	22,000	0%	800.0	1,600.0	54.0	16.6	17,600	35,200	1,188	161
	% to Total	-	-	27%	-	-	-	-	-	72%	69%	27%	23%
L. Manyame	Norton (TF)	2,700	2,700	0%	520.0	1,191.9	65.8	12.0	1,404	3,218	178	32	1,404
Ruwa R.	Ruwa (WSP) ^b	2,900	2,900	100%	123.0	278.0	6.1	4.0	357	806	18	12	64
Total		82,000	82,000	-	-	-	-	-	-	24,548	50,855	4,429	704
												20,957	40,300
													2,028
													487

Note: a) T-P is calculated from P-P values using following correlation formula which is derived from measurement results by the Study Team.

$$T-P = P - P \times 1.5482 + 0.2682$$

P-P, Phosphate Phosphorus

b) COD values of STWs with "b" are calculated from BOD values using following correlation formula which is derived from measurement results of other STWs with trickling filter method.

$$COD = BOD \text{ (annual average)} \times 2.08$$

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

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

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

f) Concentration ratios of pollution loads are;

for direct discharge 100%

; for irrigation reuse

80%

)

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.

$$T-N = A \cdot N \times 1.58$$

Table A6.3.3 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/unsewered Area by Sub-basin-BOD (Present) (1/2)

Sub-basin/District	Generated BOD (kg/day)					Reaching BOD (kg/day)					Unsewered Area					Sewered Area					
	Sewered Area		Unsewered Area			Sewered Area		Reaching BOD (kg/day)			Low		Med.			High		C & I		Total	
	Low	Med.	High	C & I	Ind.	Total	Low	Med.	High	C & I	Ind.	Total	Low	Med.	Total	Low	Med.	High	C & I	Total	
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Goromonzi Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyane Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2. Ruwa River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare City	-	-	4,715	-	0	4,715	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ruwa Local Board	101	24	978	56	323	1,482	12	-	-	-	12	101	24	978	56	323	1,482	-	-	-	
Epworth Local Board	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Goromonzi Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	101	24	5,693	56	323	6,197	12	-	-	-	3,981	192	4,185	101	24	5,693	56	323	6,197	-	-
3. Seke & Haraya Dams S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Epworth Local Board	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Goromonzi Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyane Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
4. Nyatsime River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chitungwiza Municipality	-	-	11,443	726	728	12,897	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyane Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Matondera Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	11,443	726	728	12,897	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
5. Mukurvisi River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare City	2,406	3,651	28,118	17,078	17,449	68,702	1,727	-	-	-	1,506	75	1,727	2,406	3,651	28,118	17,078	17,449	68,702	-	
Epworth Local Board	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Zvimba Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	2,406	3,651	28,118	17,078	17,449	68,702	1,727	-	-	-	1,564	75	3,367	2,406	3,651	28,118	17,078	17,449	68,702	-	
6. Manyame River (D-stream) S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chitungwiza Municipality	-	-	3,077	-	0	3,077	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyane Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	3,077	-	0	3,077	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

APPENDIX 6

Table A7.3.3 Estimated Domestic/Commercial/Institutional Pollution Load by Sewered/unsewered Area by Sub-basin-BOD (Present) (2/2)

Sub-basin/District	Generated BOD (kg/day)						Reaching BOD (kg/day)						Reaching BOD (kg/day)						
	Sewered Area			Unsewered Area			Sewered Area			Unsewered Area			Reaching BOD (kg/day)			Reaching BOD (kg/day)			
	Low	Med.	High	C & I	Ind.	Total	Low	Med.	High	C & I	Ind.	Total	Low	Med.	High	C & I	Total		
7. Marimba River S/B	3,652	1,653	23,595	4,269	6,787	39,956	-	-	-	-	-	3,652	1,653	23,595	4,269	6,787	39,956		
Harare City	-	-	-	-	-	-	39	-	-	-	-	39	-	-	-	-	-		
Zvimba Rural	-	-	-	-	-	-	-	39	-	-	-	-	-	-	-	-	-		
Total	3,652	1,653	23,595	4,269	6,787	39,956	-	-	-	-	-	3,652	1,653	23,595	4,269	6,787	39,956		
8. Lake Chivero S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Harare City	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-		
Chegutu Rural	-	-	-	-	-	-	-	-	57	-	-	-	-	-	-	-	-		
Manyame Rural	-	-	-	-	-	-	-	-	-	69	-	-	-	-	-	-	-		
Zvimba Rural	-	-	-	-	-	-	-	-	-	-	155	-	-	-	-	-	-		
9. Muzanunu River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Zvimba Rural	-	-	-	-	-	-	-	203	-	-	-	-	-	-	-	-	-		
Total	-	-	-	-	-	-	-	203	-	-	-	-	-	-	-	-	-		
10. Gwebi River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Harare City	621	-	-	-	-	621	4,329	-	-	-	-	4,329	621	-	-	621	-		
Mazowe Rural	-	-	-	-	-	-	-	224	-	-	-	-	224	-	-	-	-		
Zvimba Rural	-	-	-	-	-	-	-	294	-	-	-	-	294	-	-	-	-		
Total	621	-	-	-	-	621	4,329	-	-	-	-	4,847	621	-	-	621	-		
11. Lake Manyame S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Norton Town	30	30	2,059	113	75	2,308	148	-	-	-	-	148	30	30	2,059	113	75		
Chegutu Rural	-	-	-	-	-	-	-	-	129	-	-	-	-	-	-	-	-		
Zvimba Rural	-	-	-	-	-	-	-	-	181	-	-	-	-	-	-	-	-		
Total	30	30	2,059	113	75	2,308	148	-	-	-	-	458	30	30	2,059	113	75		
Grand Total						6,836	5,382	74,006	22,242	25,362	133,758	6,241	24	10,868	288	17,350	6,811	5,359	73,986
																		22,243	
																		25,363	
																		133,757	
																		-	

Note: 1. Estimated population for year 2012

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 irrigation reuse (STW 8% for unsewered area: High; 8% Low & Medium, 0% for direct discharge (STI 10%)

Table 6.3.4 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/Unsewered Area by Sub-basin COD (Present) (1/2)

Sub-basin/District	Generated COD (kg/day)						Reaching COD (kg/day)											
	Sewered Area			Unsewered Area			Sewered Area			Unsewered Area								
	Low	Med.	High	C & I	Ind.	Total	Low	Med.	High	C & I	Ind.	Total	Low	Med.	High	C & I	Total	
1. Manyame River (Upstream) S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Goromonzi Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyame Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2. Ruwa River S/B	-	-	-	9,429	0	9,429	-	-	-	-	-	-	-	-	-	-	-	
Harare City	-	48	1,956	112	1,168	3,486	24	-	-	-	-	-	-	-	-	-	-	
Ruwa Local Board	202	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Epworth Local Board	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Goromonzi Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	202	48	11,385	112	1,168	12,915	24	-	-	-	-	-	-	-	-	-	-	
3. Seke & Harava Dams S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Epworth Local Board	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Goromonzi Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyame Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
4. Nyatsime River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chitungwiza Municipality	-	-	22,886	1,452	1,754	26,092	-	-	-	-	-	-	-	-	-	-	-	
Manyame Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Marondera Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	22,886	1,452	1,754	26,092	-	-	-	-	-	-	-	-	-	-	-	
5. Mukurvisi River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare City	4,813	7,303	56,235	34,155	43,360	145,866	3,455	-	-	-	-	-	-	-	-	-	-	
Epworth Local Board	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Zvimbwa Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	4,813	7,303	56,235	34,155	43,360	145,866	3,455	-	-	-	-	-	-	-	-	-	-	
6. Manyame River (Dstream) S/B	-	-	-	6,154	0	6,154	-	-	-	-	-	-	-	-	-	-	-	
Chitungwiza Municipality	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyame Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	6,154	0	6,154	-	-	-	-	-	-	-	-	-	-	-	-	

Table 6.3.4 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/Unsewered Area by Sub-basin COD (Present) (2/2)

Sub-basin/District	Generated COD (kg/day)						Reaching COD (kg/day)						Sewered Area						
	Sewered Area			Unsewered Area			Sewered Area			Unsewered Area			Low			Low			
	Low	Med.	C & I	Ind.	Total	Low	Med.	C & I	Total	Low	Med.	Ind.	Total	Low	Med.	High	C & I	Total	
7. Marimba River S/B																			
Harare City	7,305	3,305	47,190	8,539	16,868	83,207	-	-	-	78	-	-	7,305	3,305	47,190	8,539	16,868	83,207	
Zvimba Rural	-	-	-	-	-	-	-	-	-	78	-	-	7,305	3,305	47,190	8,539	16,868	83,207	
Total	7,305	3,305	47,190	8,539	16,868	83,207	-	-	-	78	-	-	7,305	3,305	47,190	8,539	16,868	83,207	
8. Lake Chivero S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare City	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chegutu Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Manyame Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Zvimba Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
9. Muzaruru River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Zvimba Rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10. Gwebi River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Harare City	1,242	-	-	-	-	1,242	8,657	-	-	449	-	8,657	1,242	-	-	-	-	-	
Mazowe Rural	-	-	-	-	-	-	-	-	-	589	-	449	-	-	-	-	-	-	
Zvimba Rural	-	-	-	-	-	1,242	8,657	-	1,037	-	9,695	1,242	-	-	-	-	-	-	
Total	1,242	-	-	-	-	1,242	8,657	-	1,037	-	9,695	1,242	-	-	-	-	-	-	
11. Lake Manyame S/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Norton Town	60	61	4,118	227	230	4,696	296	-	-	296	60	61	4,118	227	230	4,696	-	-	
Chegutu Rural	-	-	-	-	-	-	-	-	-	258	-	258	-	-	-	-	-	-	
Zvimba Rural	-	-	-	-	-	-	-	-	-	362	-	362	-	-	-	-	-	-	
Total	60	61	4,118	227	230	4,696	296	-	-	620	916	60	61	4,118	227	230	4,696	-	-
Grand Total	13,672	10,764	148,012	44,485	63,380	280,172	12,481	47	21,736	576	34,700	13,623	10,718	147,969	44,486	63,381	280,172	-	1,735
																		46	
																		1,781	

Note: 1. Estimated population for year 2012

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 irrigation reuse (STW 8%) for unsewered area:

for direct discharge (STW 100%) for sewerage area:

0%

APPENDIX 6

Table 6.3.5 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/Unsewered Area by Sub-basin T-N (Present) (1/2)

Sub-basin/District	Generated T-N(kg/day)					Concentrated T-N(kg/day)									
	Sewered Area			Unsewered Area		Sewered Area			Unsewered Area						
	Low	Med.	C & I	Ind.	Total	Low	Med.	C & I	Total	Low	Med.	High	C & I	Ind.	Total
1. Manyame River (Upstream) S/B															
Goromonzi Rural	-	-	-	-	-	-	-	-	25	-	-	-	-	-	2
Harare Rural	-	-	-	-	-	-	-	-	1	-	-	-	-	-	0.1
Manyame Rural	-	-	-	-	-	-	-	-	16	-	16	-	-	-	1
Total	-	-	-	-	-	-	-	-	42	-	42	-	-	-	3
2. Ruwa River S/B															
Harare City	-	-	1,179	0	1,179	-	-	-	-	-	-	1,179	-	-	-
Ruwa Local Board	26	6	245	14	60	351	3	-	-	3	26	6	245	14	60
Epworth Local Board	-	-	-	-	-	-	-	-	961	48	1,009	-	-	-	-
Goromonzi Rural	-	-	-	-	-	-	-	-	6	-	6	-	-	-	0.5
Harare Rural	-	-	-	-	-	-	-	-	29	-	29	-	-	-	2
Total	26	6	1,423	14	60	1,530	3	-	995	48	1,046	26	6	1,424	14
3. Seke & Harava Dams S/B															
Epworth Local Board	-	-	-	-	-	-	-	-	104	5	109	-	-	-	-
Goromonzi Rural	-	-	-	-	-	-	-	-	0	-	0	-	-	-	0.01
Harare Rural	-	-	-	-	-	-	-	-	53	-	53	-	-	-	4
Manyame Rural	-	-	-	-	-	-	-	-	7	-	7	-	-	-	1
Total	-	-	-	-	-	-	-	-	163	5	169	-	-	-	13
4. Nyatsime River S/B															
Chitungwiza Municipality	-	-	2,861	182	29	3,071	-	-	-	-	-	2,861	182	29	3,072
Manyame Rural	-	-	-	-	-	-	-	-	72	-	72	-	-	-	6
Matondera Rural	-	-	-	-	-	-	-	-	660	-	660	-	-	-	53
Total	-	-	2,861	182	29	3,071	-	-	732	-	732	-	-	-	59
5. Mukurvisi River S/B															
Harare City	626	932	7,029	4,305	935	13,827	449	-	376	-	449	626	932	7,029	4,305
Epworth Local Board	-	-	-	-	-	-	-	-	395	-	395	-	-	-	-
Harare Rural	-	-	-	-	-	-	-	-	13	-	13	-	-	-	1
Zvimba Rural	-	-	-	-	-	-	-	-	2	-	2	-	-	-	0.1
Total	626	932	7,029	4,305	935	13,827	449	-	391	19	859	626	932	7,029	4,305
6. Manyame River (D.stream) S/B															
Chiungwiza Municipality	-	-	769	0	769	-	-	-	-	-	-	769	-	-	-
Harare Rural	-	-	-	-	-	-	-	-	71	-	71	-	-	-	6
Manyame Rural	-	-	-	-	-	-	-	-	10	-	10	-	-	-	1
Total	-	-	769	0	769	-	-	-	82	-	82	-	-	-	7

APPENDIX 6

Table 6.3.5 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/Unsewered Area by Sub-basin T-N (Present) (2/2)

Sub-basin/District	Generated T-N (kg/day)						Concentrated T-N (kg/day)					
	Sewered Area			Unsewered Area			Sewered Area			Unsewered Area		
	Low	Med.	High	C & I	Ind.	Total	Low	Med.	High	C & I	Ind.	Total
7. Marimba River S/B												
Harare City	950	422	5,899	1,076	363	8,710	-	-	-	-	-	-
Zvimba Rural	-	-	-	-	-	-	10	-	10	950	422	5,899
Total	950	422	5,899	1,076	363	8,710	-	-	-	-	-	-
8. Lake Chivero S/B												
Harare City	-	-	-	-	-	-	-	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	7	-	7	-	-	-
Manyame Rural	-	-	-	-	-	-	14	-	14	-	-	-
Zvimba Rural	-	-	-	-	-	-	17	-	17	-	-	-
Total	-	-	-	-	-	-	39	-	39	-	-	-
9. Muzaruru River S/B												
Zvimba Rural	-	-	-	-	-	-	51	-	51	-	-	-
Total	-	-	-	-	-	-	51	-	51	-	-	-
10. Gwebi River S/B												
Harare City	161	-	-	-	161	1,125	-	-	1,125	161	-	-
Mazowe Rural	-	-	-	-	-	-	56	-	56	-	-	-
Zvimba Rural	-	-	-	-	-	-	74	-	74	-	-	-
Total	161	-	-	-	161	1,125	-	130	1,255	161	-	-
11. Lake Manyame S/B												
Norton Town	8	8	515	28	11	570	38	-	38	8	515	28
Chegutu Rural	-	-	-	-	-	-	32	-	32	-	-	-
Zvimba Rural	-	-	-	-	-	-	45	-	45	-	-	-
Total	8	8	515	28	11	570	38	-	116	8	515	28
Grand Total	1,777	1,374	18,501	5,605	1,398	28,638	1,623	6	2,717	72	4,400	1,772

Note: 1. Estimated population for year 2012

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 (S1 100% for irrigation reuse (STV 8%) for unsewered area: High, 8%; Low & Medium, 0%

Table A6.3.6 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/Unsewered Area by Sub-basin T-P (Present) (1/2)

Sub-basin/District	Generated T-P (kg/day)						Concentrated T-P (kg/day)									
	Sewered Area			Unsewered Area			Sewered Area			Unsewered Area						
	Low	Med.	C & I	Ind.	Total	Low	Med.	C & I	Ind.	Total	Low	Med.	High	C & I	Total	
1. Manyane River (Upstream) S/B																
Goromonzi Rural	-	-	-	-	-	3	-	3	-	-	-	-	0.2	-	0.2	
Harare Rural	-	-	-	-	-	0	-	0	-	-	-	-	-	-	-	
Manyame Rural	-	-	-	-	-	2	-	2	-	-	-	-	0.1	-	0.1	
Total	-	-	-	-	-	5	-	5	-	-	-	-	0.4	-	0.4	
2. Ruwa River S/B																
Harare City	-	129	0	129	-	-	-	-	-	129	-	-	-	-	-	
Ruwa Local Board	3	0.7	27	2	8	40	0.3	-	0	3	1.0	27	2	8	41	
Epworth Local Board	-	-	-	-	-	-	-	105	5	110	-	-	-	-	8	
Goromonzi Rural	-	-	-	-	-	-	-	0.6	-	0.6	-	-	-	-	0.4	
Harare Rural	-	-	-	-	-	-	-	3	-	3	-	-	-	-	0.3	
Total	3	0.7	155	2	8	168	0.3	-	109	5	114	3	1.0	156	2	8
3. Seke & Harava Dams S/B																
Epworth Local Board	-	-	-	-	-	-	-	11	0.6	12	-	-	-	-	0.9	-
Goromonzi Rural	-	-	-	-	-	-	-	0	-	0	-	-	-	-	-	-
Harare Rural	-	-	-	-	-	-	-	6	-	6	-	-	-	-	0.5	-
Manyame Rural	-	-	-	-	-	-	-	0.7	-	0.7	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	18	0.6	18	-	-	-	-	1.4	-
4. Nyatsime River S/B																
Chitungwiza Municipality	-	312	20	10	342	-	-	-	-	-	312	20	10	342	-	-
Manyame Rural	-	-	-	-	-	-	-	8	-	8	-	-	-	-	0.6	-
Marondera Rural	-	-	-	-	-	-	-	72	-	72	-	-	-	-	6	-
Total	-	312	20	10	342	-	-	80	-	80	-	312	20	10	342	-
5. Mukurvisi River S/B																
Harare City	67	101	767	468	227	1,631	48	-	41	2	43	-	-	-	3	0.2
Epworth Local Board	-	-	-	-	-	-	-	-	1.4	-	1.4	-	-	-	0.1	-
Harare Rural	-	-	-	-	-	-	-	0.2	-	0.2	-	-	-	-	0.1	-
Zvimbba Rural	-	-	-	-	-	-	-	43	2	93	67	101	767	468	227	1,630
Total	67	101	767	468	227	1,631	48	-	-	-	-	-	-	-	3	0.2
6. Manyane River (Dstream) S/B																
Chitungwiza Municipality	-	84	-	-	84	-	-	-	-	-	84	-	-	84	-	-
Harare Rural	-	-	-	-	-	-	-	8	-	8	-	-	-	-	0.6	-
Manyame Rural	-	-	-	-	-	-	-	1.1	-	1.1	-	-	-	-	0.1	-
Total	-	84	-	-	84	-	-	9	-	9	-	84	-	-	0.7	-

APPENDIX 6

Table A6.3.6 Estimated Domestic/Commercial/institutional Pollution Load by Sewered/Unsewered Area by Sub-basin T-P (Present) (2/2)

Sub-basin/District	Generated T-P (kg/day)						Concentrated T-P (kg/day)						
	Sewered Area			Unsewered Area			Sewered Area			Unsewered Area			
	Low	Med.	C & I	Ind.	Total	Low	Med.	C & I	Total	Low	Med.	C & I	Total
7. Marimba River S/B													
Harare City	102	46	643	117	90	999	-	-	-	102	46	643	117
Zvimbura Rural	-	-	-	-	-	-	1.1	-	1.1	-	-	-	-
Total	102	46	643	117	90	999	-	1.1	1.1	102	46	643	117
8. Lake Chivoro S/B	-	-	-	-	-	-	-	-	-	-	-	-	-
Harare City	-	-	-	-	-	-	-	-	-	-	-	-	-
Chegutu Rural	-	-	-	-	-	-	1	-	1	-	-	-	-
Manyame Rural	-	-	-	-	-	-	2	-	2	-	-	-	-
Zvimbura Rural	-	-	-	-	-	-	2	-	2	-	-	-	-
Total	-	-	-	-	-	-	4	-	4	-	-	-	-
9. Muzururu River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-
Zvimbura Rural	-	-	-	-	-	-	6	-	6	-	-	-	-
Total	-	-	-	-	-	-	6	-	6	-	-	-	-
10. Gwebi River S/B	-	-	-	-	-	-	-	-	-	-	-	-	-
Harare City	17	-	-	-	17	121	-	-	121	17	-	-	17
Mazowe Rural	-	-	-	-	-	6	-	6	-	-	-	-	-
Zvimbura Rural	-	-	-	-	-	8	-	8	-	-	-	-	-
Total	17	-	-	-	17	121	-	14	135	17	-	-	17
11. Lake Manyame S/B	-	-	-	-	-	-	-	-	-	-	-	-	-
Norton Town	0.8	0.8	56	3	1.0	62	4	-	4	1.0	1.0	56	3.0
Chegutu Rural	-	-	-	-	-	-	4	-	4	-	-	-	-
Zvimbura Rural	-	-	-	-	-	-	5	-	5	-	-	-	-
Total	0.8	0.8	56	3	1.0	62	4	-	8	13	1.0	56	3
Grand Total	191	149	2,018	610	336	3,303	175	0.7	296	8	478	191	150

Note: 1. Estimated population for year 2012

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 irrigation reuse (ST 80% for unsewered area: High: 80% Low & Medium: 0%)

Table A6.3.7 Present and Future Industrial Wastewater Flow

Local Authority	Sub-Basin	Present		2020 Year		2030 Year	
		Number of Employee	Wastewater Flow (m ³ /day)	Number of Employee	Wastewater Flow (m ³ /day)	Number of Employee	Wastewater Flow (m ³ /day)
Harare City	Marimba River	14,004	21,729	22,300	34,612	22,300	34,612
	Mukuvisi River	40,004	62,079	74,900	116,242	82,400	127,881
	Ruwa River	—	—	—	—	50,200	77,901
	Manyame River	—	—	77,400	120,120	77,400	120,120
	Total	54,008	83,808	174,600	270,974	232,300	360,514
Chitungwiza Municipality	Nyatsime River	1,570	994	2,261	1,423	17,333	10,899
	Manyame River	—	—	—	—	3,266	2,054
	Total	1,570	994	2,261	1,423	20,598	12,953
Norton Town Council	Lake Manyame	1,381	1,444	3,592	3,750	11,288	11,795
Ruwa Local Board	Ruwa River	1,444	1,081	12,400	9,234	16,200	12,064
	Total	58,403	87,327	192,853	285,381	280,386	397,326

Source: JICA Project Team

(3) Other Wastewater

1) Livestock

Table A6.3.8 shows the result of the comparison between current total number with the previous study's total number of Cattle, Pigs, Sheep, Horses and shows the ratio of change. In this study, the number of each livestock in each sub-basin is determined by multiplying the previous number by calculated ratio.

Table A6.3.8 Comparison of Total Livestock Number

Livestock	Previous Number	Current Number	Ratio
Cattle	26,964	24,268	0.90
Pigs	4,175	11,481	2.75
Sheep/Goats	17,189	5,672	0.33
Horses	2,190	88	0.04

Source: JICA Project Team

The computed results are shown in Table 6.3.10. Generated and reached 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 6.3.2. The summary of calculation is shown in Table 6.3.12.

Table A6.3.9 Present and Future Industrial Wastewater Quantity

Local Authority	Sub-Basin	Present Industrial Wastewater Pollution Load (kg/day)				
		BOD	COD	SS	T-N	T-P
Harare City	Mariniba River	14,004	6,787	16,868	5,884	363
	Mukuvizi River	40,004	19,389	48,179	16,809	1,039
	Ruwa River	0	0	0	0	0
	Manyame River	0	0	0	0	0
	Total	54,008	26,176	65,047	22,693	1,402
						343
Chitungwiza Municipality	Nyatsime River	1,570	728	1,754	380	29
	Manyame River	0	0	0	0	0
	Total	1,570	728	1,754	380	29
Norton Town Council	Lake Manyame	1,381	427	1,329	497	61
Ruwa Local Board	Ruwa River	1,444	323	1,168	998	60
Total		58,403	27,654	69,298	24,568	1,552
		Year 2020 Industrial Wastewater Pollution Load (kg/day)				
Local Authority	Sub-Basin	BOD	COD	SS	T-N	T-P
Harare City	Mariniba River	22,300	10,809	26,858	9,369	577
	Mukuvizi River	74,900	36,303	90,207	31,472	1,943
	Ruwa River	0	0	0	0	0
	Manyame River	77,400	37,514	93,218	32,523	2,007
	Total	174,600	84,626	210,283	73,364	4,527
					1,107	232,300
Chitungwiza Municipality	Nyatsime River	2,261	1,050	2,527	548	42
	Manyame River	0	0	0	0	0
	Total	2,261	1,050	2,527	548	42
Norton Town Council	Lake Manyame	3,592	1,109	3,459	1,294	158
Ruwa Local Board	Ruwa River	12,400	2,779	10,035	8,571	519
Total		192,853	89,564	226,304	83,777	5,246
		Year 2030 Industrial Wastewater Pollution Load (kg/day)				
Local Authority	Sub-Basin	BOD	COD	SS	T-N	T-P
Harare City	Mariniba River	22,300	10,809	26,858	9,369	577
	Mukuvizi River	82,400	39,939	99,241	34,622	2,138
	Ruwa River	50,200	24,332	60,460	21,093	1,302
	Manyame River	77,400	37,514	93,218	32,523	2,007
	Total	232,300	112,594	279,777	97,607	6,024
						1,474
Chitungwiza Municipality	Nyatsime River	16	17,333	8,045	19,367	4,202
	Manyame River	0	3,266	1,515	3,649	790
	Total	2,261	1,050	2,527	548	42
Norton Town Council	Lake Manyame	3,592	1,109	3,459	1,294	158
Ruwa Local Board	Ruwa River	12,400	2,779	10,035	8,571	519
Total		192,853	89,564	226,304	83,777	5,246
		Year 2030 Industrial Wastewater Pollution Load (kg/day)				
Local Authority	Sub-Basin	BOD	COD	SS	T-N	T-P
Harare City	Mariniba River	22,300	10,809	26,858	9,369	577
	Mukuvizi River	82,400	39,939	99,241	34,622	2,138
	Ruwa River	50,200	24,332	60,460	21,093	1,302
	Manyame River	77,400	37,514	93,218	32,523	2,007
	Total	232,300	112,594	279,777	97,607	6,024
						1,474
Chitungwiza Municipality	Nyatsime River	16	17,333	8,045	19,367	4,202
	Manyame River	0	3,266	1,515	3,649	790
	Total	2,261	1,050	2,527	548	42
Norton Town Council	Lake Manyame	3,592	1,109	3,459	1,294	158
Ruwa Local Board	Ruwa River	12,400	2,779	10,035	8,571	519
Total		192,853	89,564	226,304	83,777	5,246

Table A6.3.10 Present and Future Industrial Wastewater Pollution Load

Sub-Basin	Industrial Wastewater Quantity (m ³ /day)		Industrial Wastewater Pollution Load (kg/day)											
	Total	Sewered	Un-sewered	BOD	COD	Total	T-N	T-P	BOD	COD	SS	T-N	T-P	Un-Sewered
Manyane R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murinba River	21,729	21,729	-	5,787	16,868	5,844	363	90	6,787	16,868	5,884	362	90	-
Mukivisi River	62,079	55,871	6,208	19,389	48,179	16,899	1,039	253	17,450	43,361	15,128	935	228	1,939
Ruwa River	1,081	1,081	-	323	1,168	998	60	8	323	1,168	998	60	8	-
Manyane R. (Downstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nyatsume River	994	994	-	728	1,754	380	29	10	728	1,754	380	29	10	-
Lake Manyame	1,444	253	1,191	427	1,329	497	61	9	75	233	87	11	2	352
Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sake & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	87,327	79,928	7,399	27,654	69,298	24,568	1,552	370	25,363	63,384	22,477	1,398	338	2,291
Manyane R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murinba River	34,612	34,612	-	10,809	26,858	9,369	577	141	10,809	26,858	9,369	577	141	-
Mukivisi River	116,242	110,034	6,208	36,303	90,207	31,472	1,943	475	34,364	85,389	29,791	1,839	450	1,939
Ruwa River	2,234	9,234	-	2,779	10,035	8,571	519	65	2,779	10,035	8,571	519	65	-
Manyane R. (Downstream)	120,120	120,120	-	37,514	93,218	32,533	2,007	491	37,514	93,218	32,533	2,007	491	-
Nyatsume River	1,423	1,423	-	1,050	2,527	548	42	16	1,050	2,527	548	42	16	-
Lake Manyame	3,750	1,836	1,894	1,109	3,459	1,294	158	24	549	1,712	640	78	12	560
Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sake & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	285,381	277,279	8,102	89,564	226,304	83,777	5,246	1,212	87,065	219,739	81,442	5,062	1,175	2,499
Manyane R. (Upstream)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Murinba River	34,612	34,612	-	10,809	26,858	9,369	577	141	10,809	26,858	9,369	577	141	-
Mukivisi River	127,881	121,673	6,208	39,939	9,924	34,622	2,138	523	38,000	94,423	32,941	2,034	498	1,939
Ruwa River	89,965	89,965	-	27,964	73,573	32,291	1,980	404	27,964	73,573	32,291	1,980	404	1,681
Manyane R. (Downstream)	122,174	122,174	-	39,029	96,867	33,313	2,068	513	39,029	96,867	33,313	2,068	513	-
Nyatsume River	10,899	10,899	-	8,045	19,367	4,202	323	121	8,045	19,367	4,202	323	121	-
Lake Manyame	11,795	9,901	1,894	3,486	10,867	4,067	499	74	2,956	9,122	3,414	419	62	560
Lake Chivero	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Muzururu River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gwebi River	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sake & Harava Dam	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	397,336	389,224	8,102	129,272	326,773	117,864	7,585	1,776	126,773	320,210	115,530	7,401	1,739	2,499
														334
														184
														32

Table A6.3.11 Number of Major Livestock by Sub-basin

Cattle							Pigs							
Sub-basin	Total	Nyabira	Marondera	Mel/Ruwa	Harare C.	Manyame	Sub-basin	Total	Nyabira	Marondera	Mel/Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	2,186	-	859	725	-	602	Manyame R. (U/S)	704	-	201	465	-	39	-
Ruwa River	1,072	-	-	443	629	-	Ruwa River	503	-	-	283	220	-	-
Seke & harava D.	910	-	-	-	310	596	Seke & harava D.	146	-	-	-	107	39	-
Nyatsime River	3,695	-	1,611	-	-	2,084	Nyatsime River	512	-	380	-	-	132	-
Manyame R. (D/S)	302	-	-	-	302	-	Manyame R. (D/S)	105	-	-	-	105	-	-
Mukuvisi River	719	-	-	-	207	-	Mukuvisi River	149	-	-	-	72	22	8
Marimba River	282	-	-	-	282	-	Marimba River	99	-	-	-	99	-	-
Lake Chivero	1,172	-	-	-	882	-	Lake Chivero	325	-	-	-	308	-	17
Muzunzu River	4,033	3,148	-	-	856	-	Muzunzu River	2,574	-	2,272	-	-	300	3
Gwebi River	8,050	7,764	-	-	239	-	Gwebi River	5,690	5,605	-	-	-	83	3
Lake Manyame	1,848	-	822	-	235	-	Lake Manyame	723	594	-	-	-	83	-
Study Area Total	24,268	11,734	2,470	1,68	3,941	3,646	Study Area Total	11,309	8,470	580	748	1,375	231	47
Sheep / Goats							Horses							
Sub-basin	Total	Nyabira	Marondera	Mel/Ruwa	Harare C.	Manyame	Sub-basin	Total	Nyabira	Marondera	Mel/Ruwa	Harare C.	Manyame	Chegutu
Manyame R. (U/S)	1,025	-	622	258	-	145	Manyame R. (U/S)	4	-	-	3	-	-	-
Ruwa River	342	-	-	158	184	-	Ruwa River	9	-	-	2	8	-	-
Seke & harava D.	234	-	-	-	91	143	Seke & harava D.	4	-	-	-	4	-	-
Nyatsime River	1,669	-	1,169	-	-	500	Nyatsime River	1	-	-	-	-	-	-
Manyame R. (D/S)	88	-	-	-	88	-	Manyame R. (D/S)	4	-	-	-	4	-	-
Mukuvisi River	156	-	-	-	61	87	Mukuvisi River	3	-	-	-	3	-	0
Marimba River	83	-	-	-	83	-	Marimba River	3	-	-	-	3	-	-
Lake Chivero	274	-	-	-	258	15	Lake Chivero	11	-	-	-	11	-	0
Muzunzu River	619	367	-	-	251	-	Muzunzu River	19	8	-	-	10	-	0
Gwebi River	977	905	-	-	70	-	Gwebi River	24	21	-	-	3	-	0
Lake Manyame	206	96	-	-	69	-	Lake Manyame	6	2	-	-	3	-	1
Study Area Total	5,672	1,367	1,791	416	1,155	875	Study Area Total	88	31	2	51	48	1	1

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

APPENDIX 6

Table A6.3.12 Pollution Load of Sub-basin

(unit: kg/day)

Sub-basin	BOD			COD		T-N		T-P	
	Generated	Reached	Reached (dry)	Generated	Reached	Generated	Reached	Generated	Reached
Manyame R. (U/S)	1,607	128	10	3,213	257	894	71	146	11
Rwu River	811	65	5	1,621	130	440	35	75	6
Seke & harava D.	627	50	4	1,255	100	360	29	56	4
Nyatsime River	2,574	206	17	5,150	411	1,480	119	229	19
Manyame R. (D/S)	221	17	1	441	35	122	9	20	1
Mukurusi River	491	40	3	982	79	282	22	44	3
Marimba River	206	16	1	414	33	114	9	18	1
Lake Chivero	835	66	5	1,670	133	468	37	76	6
Muzururu River	3,140	250	20	6,279	502	1,653	132	294	23
Gwebi River	6,358	508	40	12,714	1,017	3,312	264	599	47
Lake Manyame	1,342	108	9	2,683	214	736	59	122	9
Study Area Total	18,212	1,454	115	36,422	2,911	9,861	786	1,679	130

Source: JICA Project Team

2) Farmland / Natural land

The pollution loads derived from farmland and natural land were calculated for each sub-basin as shown in Table 6.3.12 using the area of each sub-basin and unit pollution load presented in Tables 6.3.13.

3) Water Treatment Works

Pollution load from Water Treatment Works is shown in Figure A6.3.9, A6.3.11, A6.3.13, A6.3.15. Pollution load from Prince Edward Water Treatment Works is calculated for the available concentration data for each component (BOD, COD, T-N, T-P). Pollution load from Morton Jeffry is assumed that amount of pollution load coming from Lake Chivero all goes to Lake Manyame through Morton Jaffray Water Treatment Works.

6.3.4 Modelling of Pollution Load Run-off

(1) Rivers

1) Flow Run-off Model

The pollution analysis of the rivers was conducted for BOD_5 under the dry season condition. The river flow adopted in the analysis was derived from the average figures during the dry season in the last 10 years. The river flow run-off model was established as illustrated in Figure A6.3.7 with pollution load discharging points and water quality checking points.

Table A6.3.13 Pollution Load of Farmland / Natural land

(unit: kg/km²/day, kg/day)

Sub-basin	Area (km ²)	BOD	BOD(dry)	COD	COD(dry)	T-N	T-P
Manyame R. (U/S)	574	456	37	6,762	541	566	47
Ruwa River	245	195	16	2,886	231	242	20
Seke & harava D.	115	91	7	1,355	108	113	9
Nyatsime River	780	620	50	9,189	735	769	64
Manyame R. (D/S)	230	183	15	2,710	217	227	19
Mukuvisi River	166	132	11	1,956	156	164	14
Marimba River	315	250	20	3,711	297	311	26
Lake Chivero	255	203	16	3,004	240	251	21
Muzururu River	310	246	20	3,652	292	306	25
Gwebi River	970	771	62	11,428	914	956	80
Lake Manyame	590	469	38	6,951	556	582	48
Study Area Total	4,550	3,616	292	53,604	4,287	4,487	373

Source: JICA Project Team

2) Pollution Load Run-off Model

The reached BOD load calculated in the previous section is summarized in Table A6.3.14. Most of the reached load were discharged from the sewage treatment works because of high sewerage service coverage ratio and low river flow (little rainfall during dry season).

(2) Lakes/Dams

1) Pollution load run-off model

The reached pollution loads calculated in the previous chapter are summarised in Tables A6.3.14, A6.3.15, A6.3.16 and 6.3.17 for BOD, COD, T-N and T-P, respectively. The reached loads coming from livestock and natural pollution occupy large share of the total loads. These pollution loads were assumed to reach the subject lakes with reduction (purification) when flowing in the main rivers.

Pollution load reduction ratio is calculated before reaching the rivers. Using the pollution load and the water balance, the pollution load run-off model/s for present pollution analysis of the lakes were established as presented in Figures A6.3.12, A6.3.14 and A6.3.16 for COD, T-N and T-P, respectively.

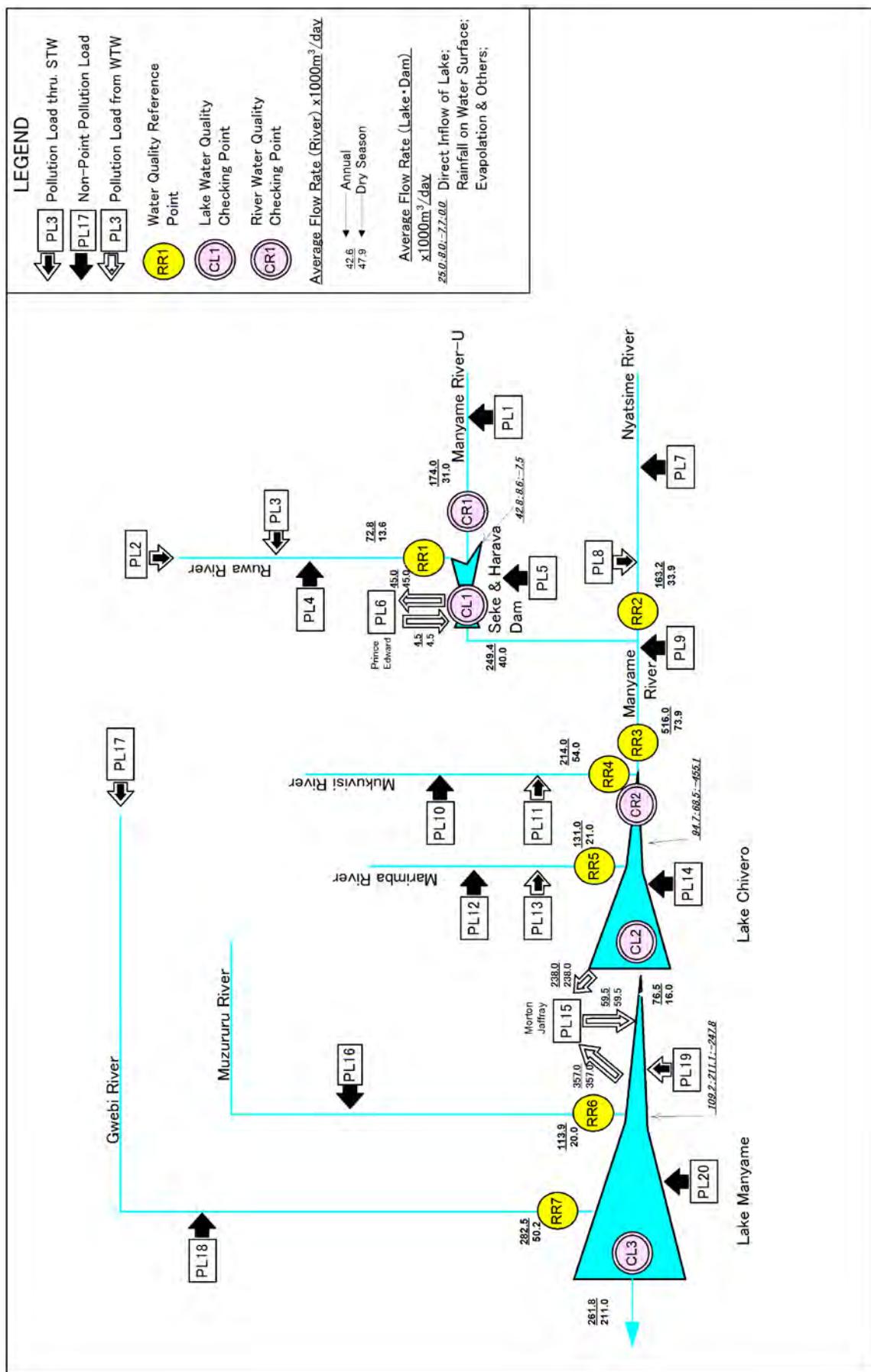


Figure A6.3.7 Flow Model for Present Water Pollution Analysis

Table A6.3.14 Reached Pollution Load by Sub-basin by Pollution Source (Present, BOD, Dry Season)

Water Quality Checking Points	Sub-basin	Dom./Com./hs.Sewage				Industrial Unsewered*	Livestock	Natural Pollution	Water Treatment Works***	(kg/day) Total
		Sewered	Unsewered	Total	Unsewered**					
C _{R1}	1 Manyane R (Upstream)	-	13	13	-	10	36	-	-	59
R _{R1}	2 Ruwa River	6,197	334	6,531	-	5	16	-	-	6,552
C _{L1}	3 Seke & Harava Dams	-	54	54	-	4	7	-	-	65
R _{R2}	4 Nyatsime River	12,897	234	13,131	-	17	50	-	-	13,198
R _{R4}	5 Mukuvisi River	68,702	131	68,833	155	1	15	-	-	69,004
C _{R2}	6 Manyane R. (Downstream)	3,077	26	3,103	-	3	11	2	2	3,119
R _{R5}	7 Marimba River	39,956	3	39,959	-	1	20	-	-	39,980
C _{L2}	8 Lake Chivero	-	12	12	-	5	16	-	-	33
R _{R6}	9 Muzururu River	-	16	16	-	20	20	-	-	56
R _{R7}	10 Gwebi River	621	41	662	-	40	62	-	-	764
C _{L3}	11 Lake Manyame	2,307	25	2,332	28	9	38	250	2,657	
	Grand Total	133,757	891	134,648	183	115	291	252	135,489	

*: Before confluence of Mukuvisi River

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

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;

BOD concentration of intake water;

Concentrated BOD load;

45,000 m³/day(Seke Dam, Av
(to Manyame River (Downstream))

Morton Jaffray WTW;

Amount of water intake;

BOD concentration of intake water;

Concentrated BOD load;

1.2 mg/l

(20.63)

(to Manyame River (Downstream))

1.9 kg/day

329 kg/day

329 *0.76 = 250.04

Therefore pollution load of Water Treatment Works reach to Manayme river is

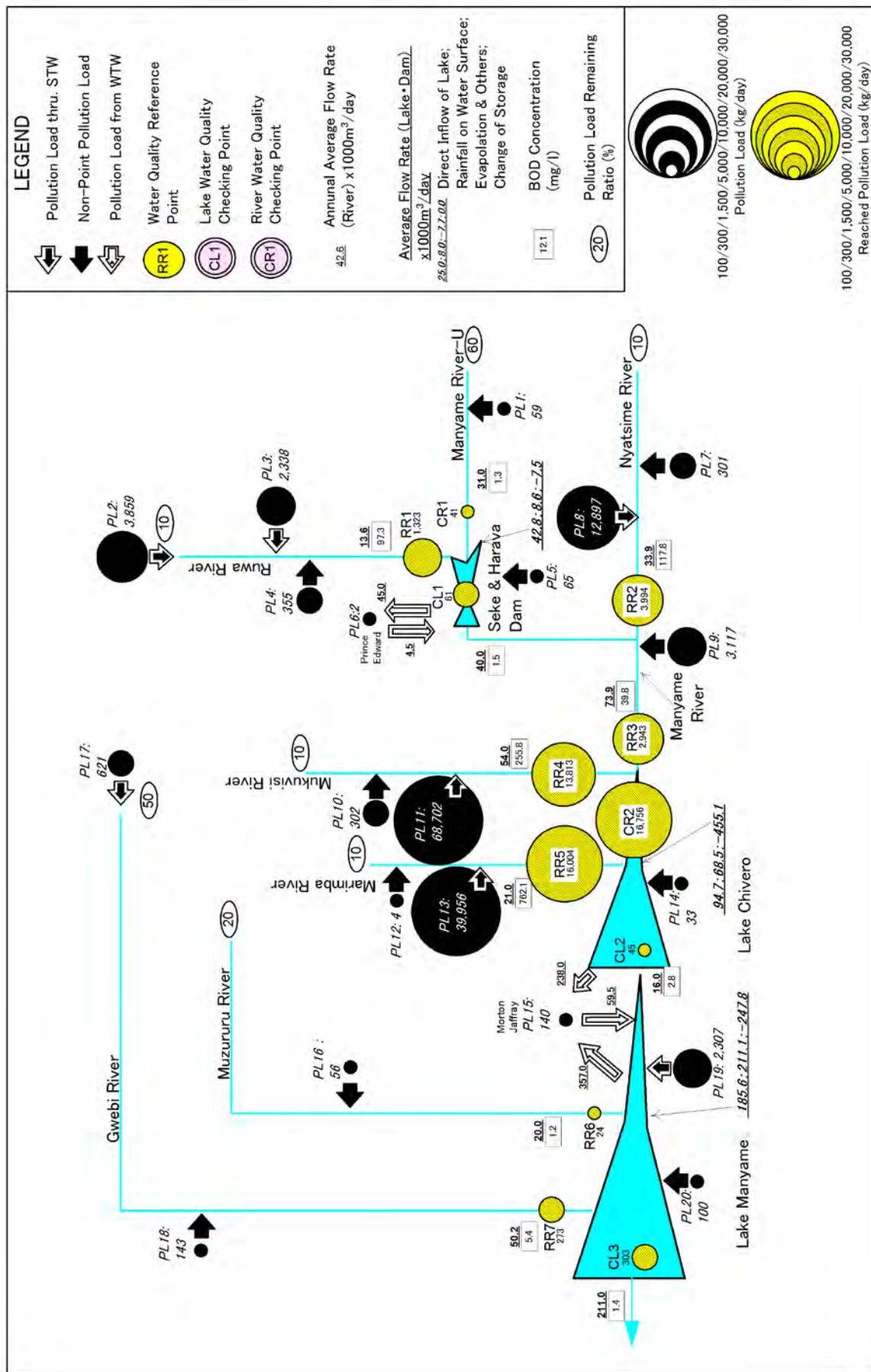


Figure A6.3.8 Pollution Load Run-off Model for Present Water Pollution Analysis (BOD, Dry Season)

APPENDIX 6

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Dry Season (1000*m ³ /d)	Conc. (mg/L)
C _{R1}	Manyame R (Upstream)	[PL1] [PL1']	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	23 36	-	-
		C _{R1} ' [C _{R1} '] NP _{CRL}	C _{R1} ' + NP _{CRL} PL1 * 0.2 PL1'	41 5 36	31.0 1.3	-
R _{R1}	1 Ruwa River	[PL2] [PL3] [PL4] [PL4']	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	3.859 2.38 3.39 16	-	-
		R _{R1} ' [R _{R1} '] NP _{RRL}	R _{R1} ' + NP _{RRL} (PL2 + PL3 + PL4)*0.2 PL4'	1.323 1.307 16	97.3	-
	13 Seke & Harava Dams (C _{R1} +R _{R1} + α)	[PL5] [PL5']	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	58 7	-	-
		C _{R1} ' [C _{R1} '] NP _{CRL1}	C _{R1} ' + NP _{CRL} + NP _{CRL1} (C _{R1} '+R _{R1})*Self Purification Coefficient NP _{CRL} + NP _{RRL} +PL5'	61 2 59	40.0 1.5	-
R _{R2}	14 Nyatiene River	[PL7] [PL7'] [PL8]	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	251 50 12.897	-	-
		R _{R2} ' [R _{R2} '] NP _{R2}	R _{R2} ' + NP _{R2} (PL7 + PL8)*0.3 PL7	3.994 3.944 50	117.8	-
R _{R3}	5 Mukwisi River	[PL10] [PL10']	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	287 15	-	-
		R _{R3} ' [R _{R3} '] NP _{R34}	R _{R3} ' + NP _{R34} (PL10 + PL10')*0.2 PL10'	13.813 13.798 15	54.0 255.8	-
R _{R3}	6 Manyame R (Downstream)	PL6 PL9 PL9'	Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2 3.106 11	-	-
		R _{R3} '* [R _{R3} ']* NP _{R33}	R _{R3} * + NP _{R33} (C _{L1} ' + R _{R2} + PL9)* 0.4 NP _{CRL} + NP _{R2} + PL6 + PL9'	2.943 2.821 122	73.9 398	-

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution though STW"
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.9 Reached Pollution Load by Sub-basin (Present, BOD, Dry Season) (1/2)

APPENDIX 6

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Dry Season (1000*m ³ /d)	Conc. (mg/L)
C_{R2} $(R_{R3}+R_{R4})$		iC_{R2} C_{R2}' NP_{C2}	$C_{R2}' + NP_{C2}$ $R_{R3}' + R_{R4}'$ $NP_{R3} + NP_{R4}$	16,756 16,619 137	21.0	6.5
R_{R5}	7 Mariniba River	$iPL12$ $PL12'$ $PL13$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	4 20 39,956		
		R_{R5} R_{R5}^* NP_{R5}	$R_{R5}' + PL13$ $PL12 + PL13$ $PL12'$	16,004 15,984 20	21.0	762.1
C_{L2} $(C_{R2}+R_{R5}+\alpha)$	8 Lake Chivero	$PL14$ $PL14'$ C_{L2}' C_{L2}' NP_{C12}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $C_{L2}' + NP_{C12}$ $(C_{32} + R_{R5} + PL14) * Self.Purification Coefficient * 0.243$ $NP_{C2} + NP_{R5} + PL14 * 0.243$	17 16 80 38 42		
			※'0.243' is the ratio of volume to Lake Manyame River from Lake Chivero (Rest of volume heads to WTP).			
R_{R6}	9 Muzumru River	$PL16$ $PL16'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	36 20		
		R_{R6} R_{R6}' NP_{R6}	$R_{R6}' + NP_{R6}$ $PL16 * 0.1$ $PL16'$	24 4 20	20.0	1.2
R_{R7}	10 Gwebi River	$PL17$ $PL18$ $PL18'$	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	621 81 62		
		R_{R7} R_{R7}' NP_{R7}	$R_{R7}' + NP_{R7}$ $(PL17 + PL18) * 0.3$ $PL18'$	273 211 62	50.2	5.4
C_{L3} $(C_{L2}+R_{R6}+\alpha)$	11 Lake Manyame	$PL15$ $PL19$	Pollution Loading from Morton Jaffray WTP Pollution Loading through STP	250 2,307		
		$PL20$ $PL20'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	62 38		
		C_{L3}' C_{L3}' NP_{C13}	$C_{L3}' + NP_{C13}$ $(C_{12}' + R_{R6}' + R_{R7}' + PL19 + PL20) * Self.Purification Coefficient$ $NP_{C12} + NP_{R6} + NP_{R7} + PL15 + PL20$	413 1 412	211.0	2.0

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution though STW"

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.9 Reached Pollution Load by Sub-basin (Present, BOD, Dry Season) (2/2)

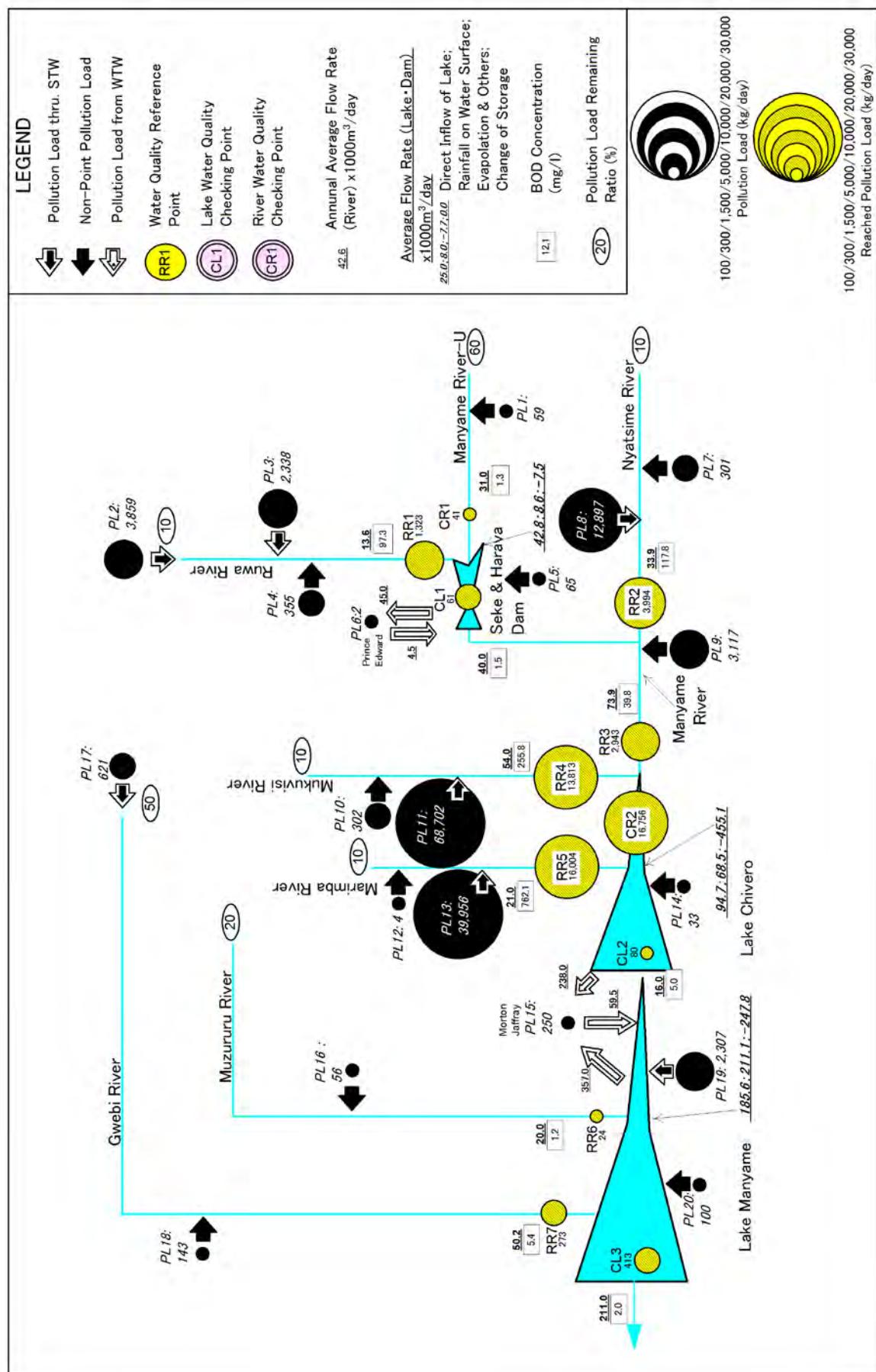


Figure A6.3.10 Pollution Load Run-off Model for Present Water Pollution Analysis (BOD, Dry Season)

Table A6.3.15 Reached Pollution Load by Sub-basin by Pollution Source (Present, COD, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial		Natural Pollution	Water Treatment Works**	(kg/day)
		Sewered	Unsewered	Total	Unsewered*#	Livestock			
C _{R1}	1 Manyame R (Upstream)	-	27	27	-	257	541	-	825
R _{Se1}	2 Ruwa River	12,915	668	13,583	-	130	231	-	13,944
C _{L1}	3 Seke & Harava Dams	-	108	108	-	100	108	-	316
R _{Se2}	4 Nyatsime River	26,092	468	26,560	-	411	735	-	27,706
R _{Se4}	5 Mukuvusi River	145,866	262	146,128	385	35	217	-	146,766
C _{R2}	6 Manyame R. (Downstream)	6,154	52	6,206	-	79	156	34	6,476
R _{Se5}	7 Marimba River	83,207	6	83,213	-	33	297	-	83,543
C _{L2}	8 Lake Chivero	-	25	25	-	133	240	-	398
R _{Se6}	9 Muzururu River	-	32	32	-	502	292	-	827
R _{Se7}	10 Gwebi River	1,242	83	1,325	-	1,017	914	-	3,256
C _{L3}	11 Lake Manyame	4,696	50	4,746	88	214	556	2,196	7,799
	Grand Total	280,172	1,781	281,953	473	2,911	4,288	2,230	291,856

*: Before confluence of Mukuvusi River

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

***. Pollution load of Water Treatment Works;
Prince Edward WTW;Amount of water intake;
COD concentration of intake water;
Reaced COD load;45,000 m³/day
20.63 mg/l
34 kg/day(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

According to "9-4-2Fr", Pollution Load reached to C_{L2} is

2,889 kg/day

And according to "9-5-4Fr", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).

Therefore pollution load of Water Treatment Works reach to Manyame river is

2,889 *0.76 = 2,196kg/day

APPENDIX 6

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000* m ³ /d)	Conc. (mg/L)
C _{R1}	1 Manyame R (Upstream)	PL1 PL1'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	284 541	-	-
		C _{R1'} C _{R1'} NP _{CR1}	C _{R1'} + NP _{CR1} PL1*0.2 PL1'	598 57 541	174.0	3.4
R _{R1}	2 iRuwa River	PL2 PL3 PL4 PL4'	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	8,041 4,874 798 231	-	-
		R _{R1'} R _{R1'} NP _{RR1}	R _{R1'} + NP _{RR1} (PL2 + PL3 + PL4)*0.2 PL4'	2,973 2,743 231	72.8	40.8
C _{L1} (C _{R1} +R _{R1} + α)	3 Seke & Harava Dams	PL5 PL5'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	208 108	-	-
		C _{L1'} C _{L1'} NP _{CL1}	C _{L1'} + NP _{CL1} (C _{R1} +R _{R1} +PL5)*SelP Purification Coefficient NP _{RR1} +NP _{RS1} +PL5'	886 5 880	249.4	3.6
R _{S2}	4 Nyatisine River	PL7 PL7' PL8 R _{R2} R _{R2'} NP _{RS2}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP R _{R2} + NP _{RS2} (PL7 + PL8)*0.3 PL7'	879 735 26,092 8,827 8,091 73.5	-	-
R _{S4}	5 Mukurisi River	PL10 PL10' PL11 R _{R4} R _{R4'} NP _{RS4}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP R _{R4} + NP _{RS4} (PL10 + PL11)*0.2 PL10'	693 217 145,866 29,527 29,310 217	163.2	54.1
R _{S3} (C _{L1} +R _{R2} + α)	6 Manyame R (Downstream)	PL6 PL9 PL9' R _{R3*} R _{R3*} NP _{RS3}	Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) R _{R3} *+ NP _{RS3} (C _{L1} + R _{R2} + PL9) * 0.4 NP _{CL1} + NP _{RS2} + PL6 + PL9	34 6,285 156 7,559 5,753 1,806	516.0	14.6

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Natural Pollution" Figure
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.11 Reached Pollution Load by Sub-basin (Present, COD, Annual) (1/2)

APPENDIX 6

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R2} ($R_{R3}+R_{R4}$)			$C_{R2}' + NP_{CL2}$ $R_{R3}' + R_{R4}'$ $NP_{R3} + NP_{R4}$	37,085 35,063 2,023	730.0	50.8
R_{R5}	7 Marmiba River	PL12	Non point Pollution Loading (Unsewered, Livestock)	39		
		PL12'	Non point Pollution Loading (Natural Pollution)	297		
		PL13	Pollution Loading through STP	83,207		
		R_{R5}	$R_{R5}' + PL13$	33,595		
		R_{R5}^*	$PL12 + PL13$	33,298		
		NP_{R5}	$PL12'$	297		
C_{L2} ($C_{R2}+R_{R5}+a$)	8 Lake Chivero	PL14	Non point Pollution Loading (Unsewered, Livestock)	158		
		PL14'	Non point Pollution Loading (Natural Pollution)	240		
		C_{L2}'	$C_{L2}' + NP_{CL2}$	702		
		C_{L2}^*	$(C_{R2}+R_{R5}+PL14)*Self Purification Coefficient*0.243$	80		
		$NP_{C2} + NP_{R5} + PL14 * 0.243$		622		
R_{R6}	19 Mizunzu River	PL16	Non point Pollution Loading (Unsewered, Livestock)	534		
		PL16'	Non point Pollution Loading (Natural Pollution)	292		
		R_{R6}	$R_{R6}' + NP_{R6}$	346		
		R_{R6}^*	$PL16*0.1$	53		
		NP_{R6}	$PL16'$	292		
R_{R7}	10 Gwebi River	PL17	Pollution Loading through STP	1,242		
		PL18	Non point Pollution Loading (Unsewered, Livestock)	1,100		
		PL18'	Non point Pollution Loading (Natural Pollution)	914		
		R_{R7}	$R_{R7}' + NP_{R7}$	1,617		
		R_{R7}^*	$(PL17 + PL18)*0.3$	703		
		NP_{R7}	$PL18'$	914		
C_{L3} ($C_{L2}+R_{R6}$ $+R_{R7}+a$)	11 Lake Manyame	PL15	Pollution Loading from Morton Jaffray WTP	2,196		
		PL19	Pollution Loading through STP	4,696		
		PL20	Non point Pollution Loading (Unsewered, Livestock)	351		
		PL20'	Non point Pollution Loading (Natural Pollution)	536		
		C_{L3}'	$C_{L3}' + NP_{R7}$	4,582		
		C_{L3}^*	$(C_{L2}' + R_{R6}' + R_{R7}' + PL19 + PL20)*Self Purification Coefficient$	2		
		$NP_{C2} + NP_{R6} + NP_{R7} + PL15 + PL20'$		4,580		

※*0.243" is the ratio of volume to Lake Manyame River from Lake Chivero (Rest of volume heads to WTP).

※Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution though STW".
※Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.11 Reached Pollution Load by Sub-basin (Present, COD, Annual) (2/2)

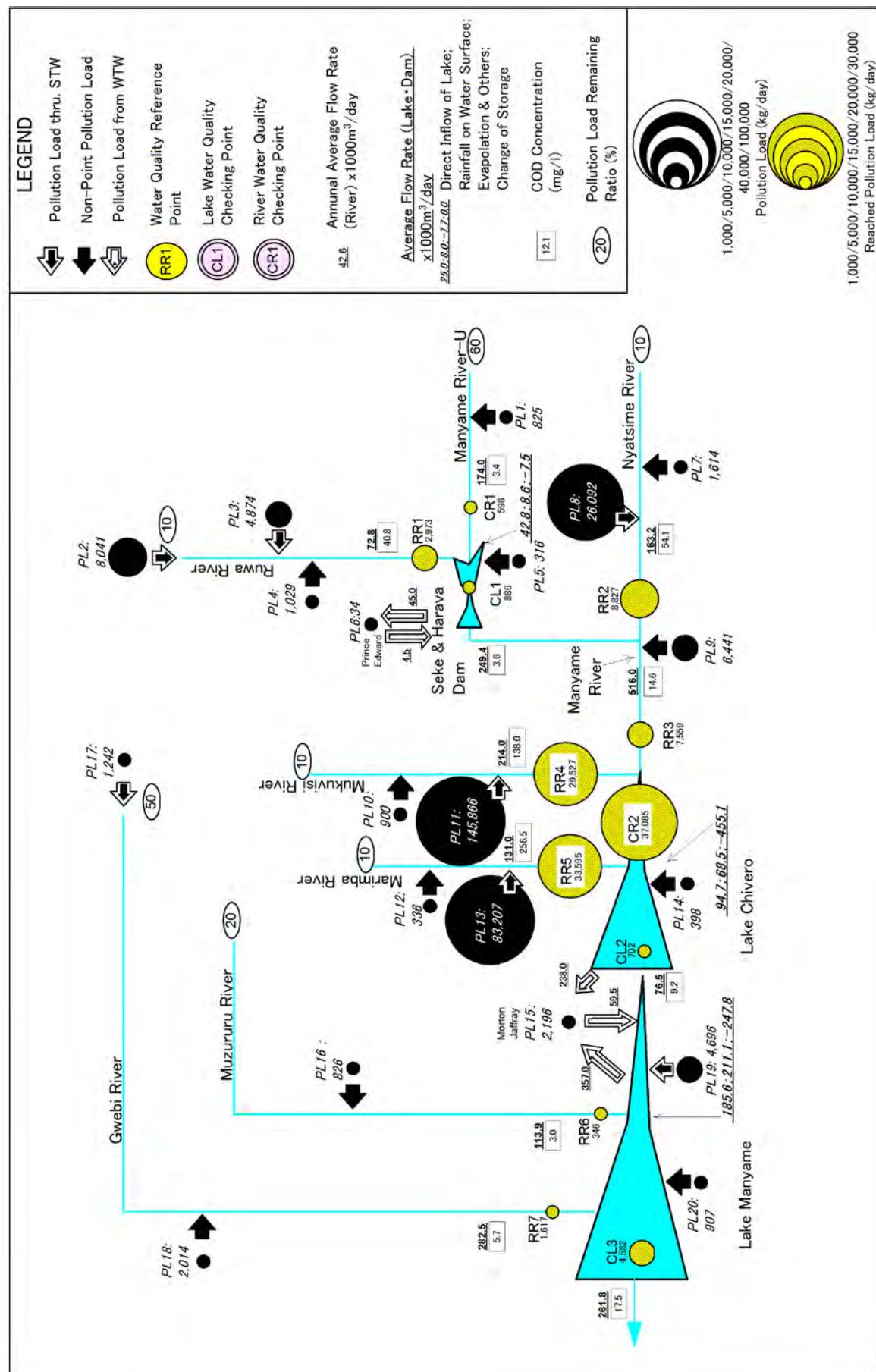


Figure A6.3.12 Pollution Load Run-off Model for Present Water Pollution Analysis (COD, Dry Season)

Table A6.3.16 Reached Pollution Load by Sub-basin by Pollution Source (Present, T-N, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial	Natural Pollution	Water Treatment Works***	(kg/day)
		Sewered	Unsewered	Total				
C _{R1}	1 Manyame R (Upstream)	-	3	3	-	71	566	-
R _{R1}	2 Ruwa River	1,530	83	1,613	-	35	242	-
C _{L1}	3 Seke & Harava Dams	-	13	13	-	29	113	-
R _{R2}	4 Nyatsume River	3,072	59	3,131	-	119	769	-
R _{R4}	5 Mukavisi River	13,827	33	13,860	8	9	227	-
C _{R2}	R _{R3} * 6 Manyame R. (Downstream)	769	7	776	-	22	164	1
R _{R5}	7 Marimba River	8,710	1	8,711	-	9	311	-
C _{L2}	8 Lake Chivero	-	3	3	-	37	251	-
R _{R6}	9 Muzururu River	-	4	4	-	132	306	-
R _{R7}	10 Gwebi River	161	10	171	-	264	956	-
C _{L3}	11 Lake Manyame	570	6	576	4	59	582	2,145
	Grand Total	28,639	223	28,862	12	786	4,487	36,293

*: Before confluence of Mukurusi River

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

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;
T-N concentration of intake water;
Concentrated T-N load;45,000 m³/day
0.645 mg/l
1 kg/day(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.
According to "9-4-2F", Pollution Load reached to C_{L2} is
And according to "9-5-4F", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).
Therefore pollution load of Water Treatment Works reach to Manyame river is2,823 *0.76 =
2,145kg/day

※Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution"Figure

APPENDIX 6

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m ³ /d)	Conc. (mg/L)
C _{R1}	1 Manyane R (Upstream)	PL1	Non point Pollution Loading (Unsewered, Livestock)	74		
		PL1'	Non point Pollution Loading (Natural Pollution)	566		
		C _{R1}	$C_{R1}' + NP_{CR1}$	581		
		NP _{CR1}	$PL1 * 0.2$	15	174.0	3.3
R _{R1}	2 Ruwa River	PL2	Pollution Loading through STP	953		
		PL3	Pollution Loading through STP	577		
		PL4	$\frac{\text{Non point Pollution Loading (Unsewered, Livestock)}}{\text{Non point Pollution Loading (Natural Pollution)}}$	118		
		PL4'	$\frac{\text{Non point Pollution Loading (Unsewered, Livestock)}}{\text{Non point Pollution Loading (Natural Pollution)}}$	242		
C _{L1} (C _{R1} +R _{R1} + α)	3 Seke & Harava Dams	PL5	Non point Pollution Loading (Unsewered, Livestock)	42		
		PL5'	Non point Pollution Loading (Natural Pollution)	113		
		C _{L1}	$C_{L1}' + NP_{CR1} + NP_{RL1}$	1,007		
		C _{L1} '	$(C_{R1}' + R_{R1} + PL5) * \text{Self-Purification Coefficient}$	86	249.4	4.0
R _{R2}	4 Nyatsume River	PL7	Non point Pollution Loading (Unsewered, Livestock)	178		
		PL7'	Non point Pollution Loading (Natural Pollution)	769		
		PL8	Pollution Loading through STP	3,072		
		R _{R2}	$R_{R2}' + NP_{R2}$	1,744		
R _{R4}	5 Mukwisi River	PL10	Non point Pollution Loading (Unsewered, Livestock)	50		
		PL10'	Non point Pollution Loading (Natural Pollution)	227		
		PL11	Pollution Loading through STP	13,827		
		R _{R4}	$R_{R4}' + NP_{R4}$	3,002		
R _{R3}	6 Manyane R (Downstream),PL6 (C _{L1} +R _{R2} + α)	PL10	$(PL10 + PL11) * 0.2$	2,775	214.0	14.0
		R _{R4}	$PL10$	227		
		PL6	Pollution Loading from Prince Edward WTP	1		
		PL6'	Non point Pollution Loading (Unsewered, Livestock)	798		
R _{R3}	7 Manyane R (Downstream),PL6 (C _{L1} +R _{R2} + α)	PL9	Non point Pollution Loading (Natural Pollution)	164		
		PL9'	$R_{R3}' + NP_{R3}$	2,598		
		R _{R3} *	$(C_{L1}' + R_{R1}' + PL9) * 0.4$	743	516.0	5.0
		R _{R3} '*	$NP_{CR1} + NP_{R2} + PL6 + PL9'$	1,855		

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution through STW"
※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.13 Reached Pollution Load by Sub-basin (Present, T-N, Annual) (1/2)

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R2} ($R_{R3}+R_{R4}$)			$C_{R2}' + NP_{C_{L2}}$ $R_{R3}' + R_{R4}'$ $NP_{R3} + NP_{R4}$	5,601 3,519 2,082	730.0 3,710	7.7
R_{R5}	7 Marimba River	PL12 PL12 PL13	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	10 311 8,710		
		R_{R5} R_{R5}^* NP_{R5}	$R_{R5}' + PL13$ $PL12 + PL13$ $PL12'$	3,799 3,488 311	131.0	29.0
C_{L2} ($C_{R2}+R_{R5}+\alpha$)	8 Lake Chivero	PL14 PL14'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	40 251		
		C_{L2}' C_{L2}' $NP_{C_{L2}}$	$C_{L2}' + NP_{C_{L2}}$ $(C_{R2}' + R_{R5}' + PL14) * Self Purification Coefficient * 0.243$ $NP_{C_{R2}} + NP_{R5} + PL14 * 0.243$	686 44 642	76.5	9.0
R_{R6}	9 Muzaruru River	PL16 PL16'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	136 306		
		R_{R6} R_{R6}' NP_{R6}	$R_{R6}' + NP_{R6}$ $PL16 * 0.1$ $PL16'$	320 14 306	113.9	2.8
R_{R7}	10 Gwebi River	PL17 PL18 PL18'	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	161 274 956		
		R_{R7} R_{R7}' NP_{R7}	$R_{R7}' + NP_{R7}$ $(PL17 + PL18) * 0.3$ $PL18'$	1,087 131 956	282.5	3.8
C_{L3} ($C_{L2}+R_{R6}$ $+R_{R7}+\alpha$)	11 Lake Manyame	PL15 PL19 PL20 PL20'	Pollution Loading from Morton laffray WTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2,145 570 69 582		
		C_{L3}' C_{L3}' $NP_{C_{L3}}$	$C_{L3}' + NP_{R87}$ $(C_{L2}' + R_{R6}' + R_{R7}' + PL19 + PL20) * Self Purification Coefficient$ $NP_{C_{L2}} + NP_{R6} + NP_{R7} + PL15 + PL20'$	4,650 18 4,632	261.8	17.8

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution though STW"
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution"Figure

Figure A6.3.13 Reached Pollution Load by Sub-basin (Present, T-N, Annual) (2/2)

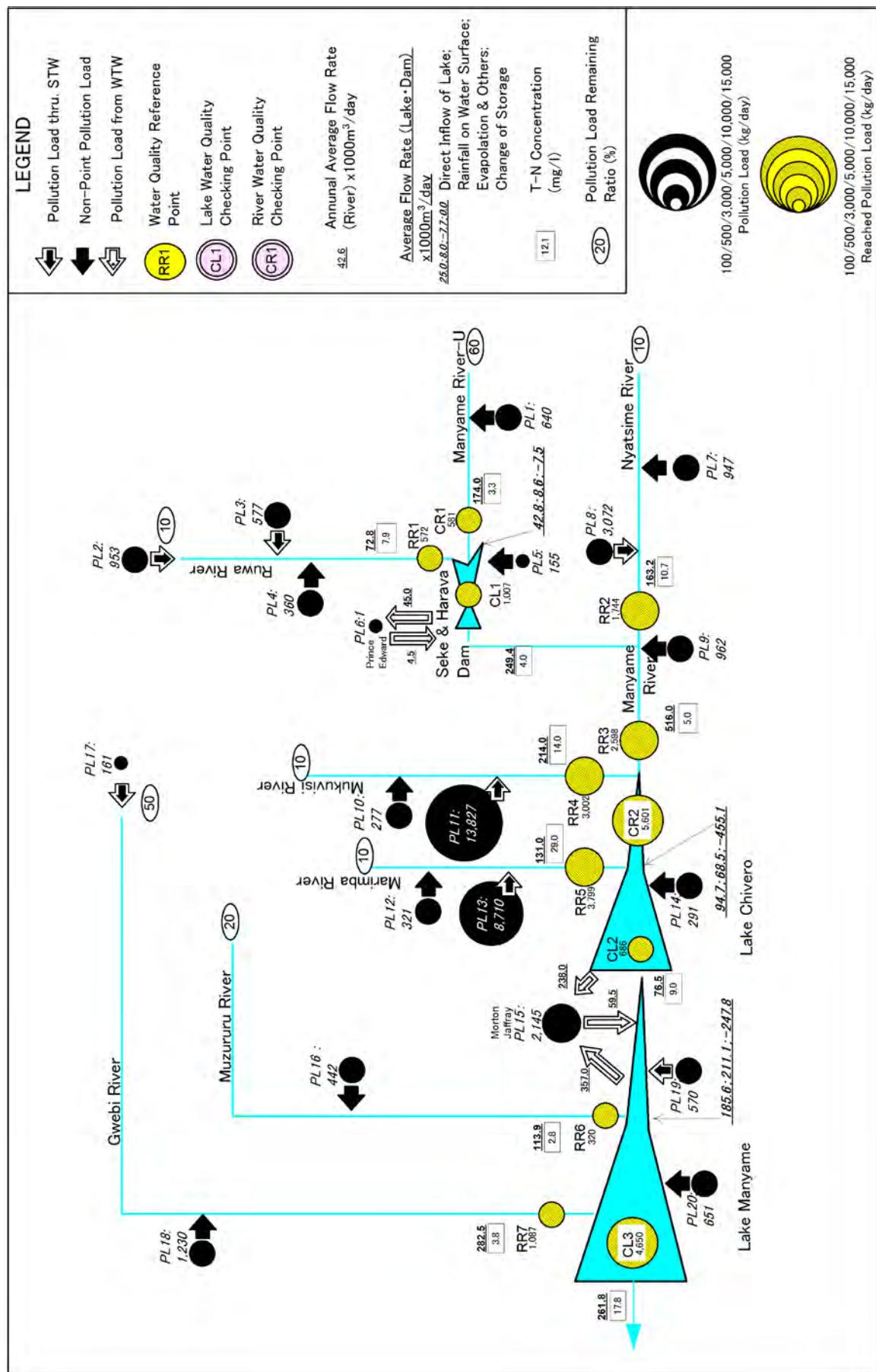


Figure A6.3.14 Pollution Load Run-off Model for Present Water Pollution Analysis (T-N, Dry Season)

Table A6.3.17 Reached Pollution Load by Sub-basin by Pollution Source (Present, T-P, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial		Natural Pollution	Water Treatment Works***	Total
		Sewered	Unsewered	Total	Unsewered**	Livestock			
C _{R1}	1 Manyame R (Upstream)	-	0.4	0.4	-	11	47	-	58
R _{R1}	2 Ruwa River	170	9	179	-	6	20	-	205
C _{L1}	3 Seke & Harava Dams	-	1	1	-	4	9	-	14
R _{R2}	4 Nyatsime River	342	6	348	-	19	64	-	431
R _{R4}	5 Mukuvizi River	1,630	4	1,634	2	1	19	-	1,656
C _{R2}	R _{R3} *	6 Manyame R. (Downstream)	84	1	85	-	3	14	-
R _{R5}	7 Marinima River	998	0.1	998	-	1	26	-	1,025
C _{L2}	8 Lake Chivero	-	0.3	0.3	-	6	21	-	27
R _{R6}	9 Muzururu River	-	0.4	0.4	-	23	25	-	48
R _{R7}	10 Gwebi River	17	1	18	-	47	80	-	145
C _{L3}	11 Lake Manyame	62	1	63	1	9	48	173	293
	Grand Total	3,303	24	3,327	3	130	373	173	4,006

* : Before confluence of Mukuvizi River
 **: Pollution load of industries in seawered area is counted as a part of domestic pollution load seawered area.
 ***: Pollution load of Water Treatment Works:

Prince Edward WTW;
 Morton Jaffray WTW;

Amount of water intake; 45,000 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;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

※ According to "9-4-2FI", Pollution Load reached to C_{L2} is

228 kg/day

And according to "9-5-4FF", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).

Therefore pollution load of Water Treatment Works reach to Manyame river is

228 * 0.76 =

173kg/day

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m ³ /d)	C conc. (mg/L)
C _{R1}	1 Manyane R (Upstream)	PL1	Non point Pollution Loading (Unsewered, Livestock)	11		
		PL1'	Non point Pollution Loading (Natural Pollution)	47		
R _{R1}	2 Ruwa River	C _{R1} '	$C_{R1}' + NP_{CR1}$	49		
		NP _{CR1}	$PL1 * 0.2$	2	174.0	0.3
C _{R1}	3 Sekे & Harava Dams	PL2	Pollution Loading through STP	106		
		PL3	Pollution Loading through STP	64		
R _{R2}	4 Nyatsume River	PL4	Non point Pollution Loading (Unsewered, Livestock)	15		
		PL4'	Non point Pollution Loading (Natural Pollution)	20		
C _{R2}	5 Mukuvizi River	R _{R2}	$R_{R2}' + NP_{RR2}$	57		
		NP _{RR2}	$(PL2 + PL3 + PL4) * 0.2$	37	72.8	0.8
R _{R2}	6 Manyame R (Downstream)	PL5	Non point Pollution Loading (Unsewered, Livestock)	5		
		PL5'	Non point Pollution Loading (Natural Pollution)	9		
C _{R2}	7 Manyame R (Downstream)	C _{L1}	$C_{L1}' + NP_{CR1} + NP_{CL1}$	82		
		C _{L1} '	$(C_{R1}' + R_{R1}) + PL5 * Self Purification Coefficient$	6	249.4	0.3
R _{R3}	(C _{R2} +R _{R3} + α)	NP _{CL1}	$NP_{CR1} + NP_{RR2} + PL5'$	76		
		PL6	Pollution Loading through STP	25		
R _{R3}	(C _{R3} +R _{R2} + α)	PL7	Non point Pollution Loading (Natural Pollution)	64		
		PL8	Pollution Loading through STP	342		
R _{R4}	8 Manyame R (Downstream)	R _{R2}	$R_{R2}' + NP_{RR2}$	174		
		R _{R2} '	$(PL7 + PL8) * 0.3$	110	163.2	1.1
R _{R4}	9 Manyame R (Downstream)	NP _{RR2}	PL7	64		
		PL10	Pollution Loading through STP	7		
R _{R4}	10 Manyame R (Downstream)	PL10'	Non point Pollution Loading (Natural Pollution)	19		
		PL11	Pollution Loading through STP	1,630		
R _{R5}	11 Manyame R (Downstream)	R _{R4}	$R_{R4}' + NP_{RR4}$	346		
		R _{R4} '	$(PL10 + PL11) * 0.2$	327	214.0	1.6
R _{R5}	(C _{R3} +R _{R2} + α)	NP _{RR4}	PL10'	19		
		PL16	Pollution Loading from Prince Edward WTP	0		
R _{R5}	(C _{R3} +R _{R2} + α)	PL9	Non point Pollution Loading (Unsewered, Livestock)	88		
		PL9'	Non point Pollution Loading (Natural Pollution)	14		
R _{R5}	(C _{R3} +R _{R2} + α)	R _{R3} *	$R_{R3}'' + NP_{RR3}$	236		
		R _{R3} **	$(C_{L1}' + R_{R2}') + PL9 * 0.4$	82	516.0	0.5
R _{R5}	(C _{R3} +R _{R2} + α)	NP _{RR3}	$NP_{CL1} + NP_{RR2} + PL6 + PL9$	154		

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution though STW", "Natural Pollution" Figure

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.15 Reached Pollution Load by Sub-basin (Present, T-P, Annual) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m ³ /d)	Conc. (mg/L)
C_{R2} $(R_{k3}+R_{k4})$		C_{R2}' C_{R2}' NP_{CR2}	$C_{R2}' + NP_{CR2}$ $R_{k3}' + R_{k4}'$ $NP_{R3} + NP_{R4}$	582 409 173	730.0	0.8
R_{R5}	7 Marimba River	PL12 PL12' PL13 R _{RS} R _{k5} '* NP _{RS}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP R _{RS} ' + PL13 PL12 + PL13 PL12'	1 26 998		
C_{L2} $(C_{R2}+R_{k5}+\alpha)$	8 Lake Chivero	PL14 PL14' C _{L2} C _{L2} ' NP _{CL2}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) C _{L2} ' + NP _{CL2} ($C_{R2}' + R_{k5}' + PL14$)*Self-Purification Coefficient*0.243 NP _{CL2} ' + NP _{R5} + PL14' * 0.243	6 21 55 2 53	76.5	0.7
			※"(0.243)" is the ratio of volume to Lake Manyame River from Lake Chivero (Rest of volume heads to WTP).			
R_{R6}	9 Muzaruru River	PL16 PL16' R _{RS6} R _{k6} ' NP _{RS6}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) R _{RS} ' + NP _{RS6} PL16*0.1 PL16'	23 25 27 2 25	113.9	0.2
R_{R7}	10 Gwebi River	PL17 PL18 PL18' R _{RS7} R _{k7} ' NP _{RS7}	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) R _{RS} ' + NP _{RS7} (PL17 + PL18)*0.3 PL18'	17 48 80 100 20 80	282.5	0.4
C_{L3} $(C_{L2}+R_{k6}+\alpha)$	11 Lake Manyame	PL15 PL19 PL20 PL20' C _{L3} C _{L3} ' NP _{CL3}	Pollution Loading from Morton Jaffray WTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) C _{L3} ' + NP _{RS7} ($C_{L2}' + R_{k6}' + PL19 + PL20$)*Self Purification Coefficient NP _{CL2} + NP _{RS6} + NP _{RS7} + PL15 + PL20'	173 62 10 48 381 1 379	261.8	1.5

※Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock", "Pollution though STW"
※Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.3.15 Reached Pollution Load by Sub-basin (Present, T-P, Annual) (2/2)

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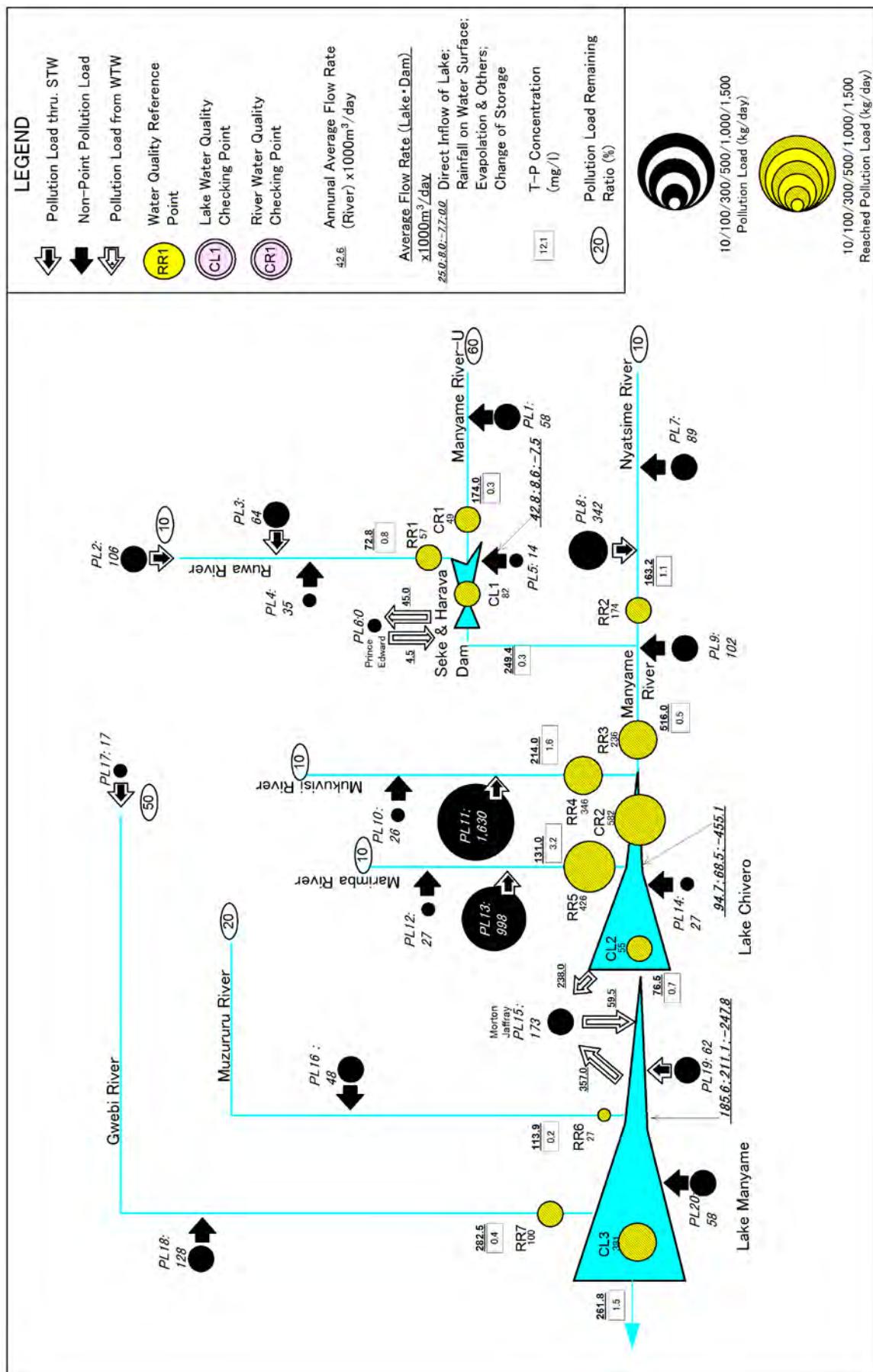


Figure A6.3.16 Pollution Load Run-off Model for Present Water Pollution Analysis (T-P, Dry Season)

6.3.5 Current Water Pollution Analysis

(1) General

In the pollution analysis of the rivers, the pollution load ratios of the respective rivers were identified in terms of BODs under the dry season conditions. These ratios were adopted for future pollution analysis. In the pollution analysis of lakes, self-purification coefficients of the respective lakes were sampled for T-N, T-P and COD under the annual average conditions. These coefficients were also adopted for future pollution analysis.

(2) Rivers

The self-purification coefficient of the river is usually computed to express the self-purification capacity of rivers with reference to the pollution load discharge location. However, sufficient data on time of flow, flow rate and water quality for each sub-section of the rivers are essential for the analysis. Because of the lack of these data in the study area and the limited period for the study, the pollutant load remaining ratios of each river section were roughly computed.

The pollution load remaining ratios of the respective rivers were computed using a pollution load run-off model as presented in Table A6.3.18. Muzururu River shows comparatively high self-purification capacity, i.e. six percent of pollution load remaining ratios, while Manyame River (downstream) and Marimba River show rather low self-purification capacity, i.e. 36% and 32%, respectively.

These remaining ratios imply not only the self-purification capacity of the river, but also an adjustment factor on assumptions of concentration ratios and generated pollution loads. The application of pollution load remaining ratios to future pollution analysis was modified as presented in Table A6.3.18.

Table A6.3.18 Pollution Load Remaining Ratio of River

	Calculated PLRR	Applied
Manyame River (Upstream)	18.6%	20%
Ruwa River	17.5%	20%
Nyatsime River	29.2%	30%
Mukuvisi River	18.6%	20%
Manyame River (Downstream)	35.9%	40%
Marimba River	31.6%	40%
Muzururu River	6.0%	10%
Gwebi River	21.7%	30%

Source: JICA Project Team

(3) Lakes/Dams

Based on the pollution load run off models presented in Figures A6.3.17 to A6.3.19, self-purification coefficients of the lakes for each pollutant were computed as presented in Tables A6.3.14 to A6.3.17. Calculation results are summarised in Table A6.3.19. These values were adopted for future pollution analysis of the lakes.

Table A6.3.19 Self-purification Coefficients of Lakes

Coefficients*	Seke & Harava Dams	Lake Chivero	Lake Manyame
σN	0.48008	0.09858	0.00362
σP	0.35005	0.04144	0.01725
σCOD	0.08888	0.02732	0.00608
$\alpha(N)$	202.1%	167.9%	202.1%

*Self-Purification coefficients in following formula (refer Table 9.5.3 to 9.5.5);

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

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

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

$$\Delta COD = \alpha(N) \times T-N \times 17.73$$

Source: JICA Project Team

Table A6.3.20 Pollution Load Remaining Ratio of the Rivers (Present, BOD, Dry

Water Quality Checking Points	Sub-basin	Run-off BOD Load at Upstream(kg/day)	Reached BOD Load in Sub-basin (kg/day)	Total BOD Load in Sub-basin (kg/day)	BOD Concentration at Downstream(mg/l)	Flow Rate at Downstream ¹ (m ³ /day)	Run-off BOD Load at Downstream ² (kg/day)	Pollution Load Remaining Ratio (%)
C _{R1}	1 Manyane R (Upstream)	0	183	183	1.1	31,000	34	18.6%
R _{K1}	2 Ruwa River	0	297	297	3.8	13,600	52	17.5%
C _{L1}	3 Seke & Harava Dams	86	77	163	1.6	40,000	64	—
R _{K2}	4 Nyaisine River	0	243	243	2.1	33,900	71	29.2%
R _{K4}	5 Mukavisi River	0	581	581	2.0	54,000	108	18.6%
C _{R2}	R _{K3} * 6 Manyane R. (Downstream)	135	71	206	1.0	73,900	74	35.9%
R _{K5}	7 Marimba River	0	580	580	8.7	21,000	183	31.6%
C _{L2}	8 Lake Chivero	365	968	1,333	2.4	16,000	38	—
R _{K6}	9 Muzunuru River	0	167	167	0.5	20,000	10	6.0%
R _{K7}	10 Gwebi River	0	369	369	1.6	50,200	80	21.7%
C _{L3}	11 Lake Manyame	129	1,146	1,275	2.0	211,000	414	—

Note: 1. Before confluence of Mukavisi River

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

3. Total BOD load of Manyame River (downstream) includes Run-off load from Nyaisine River.

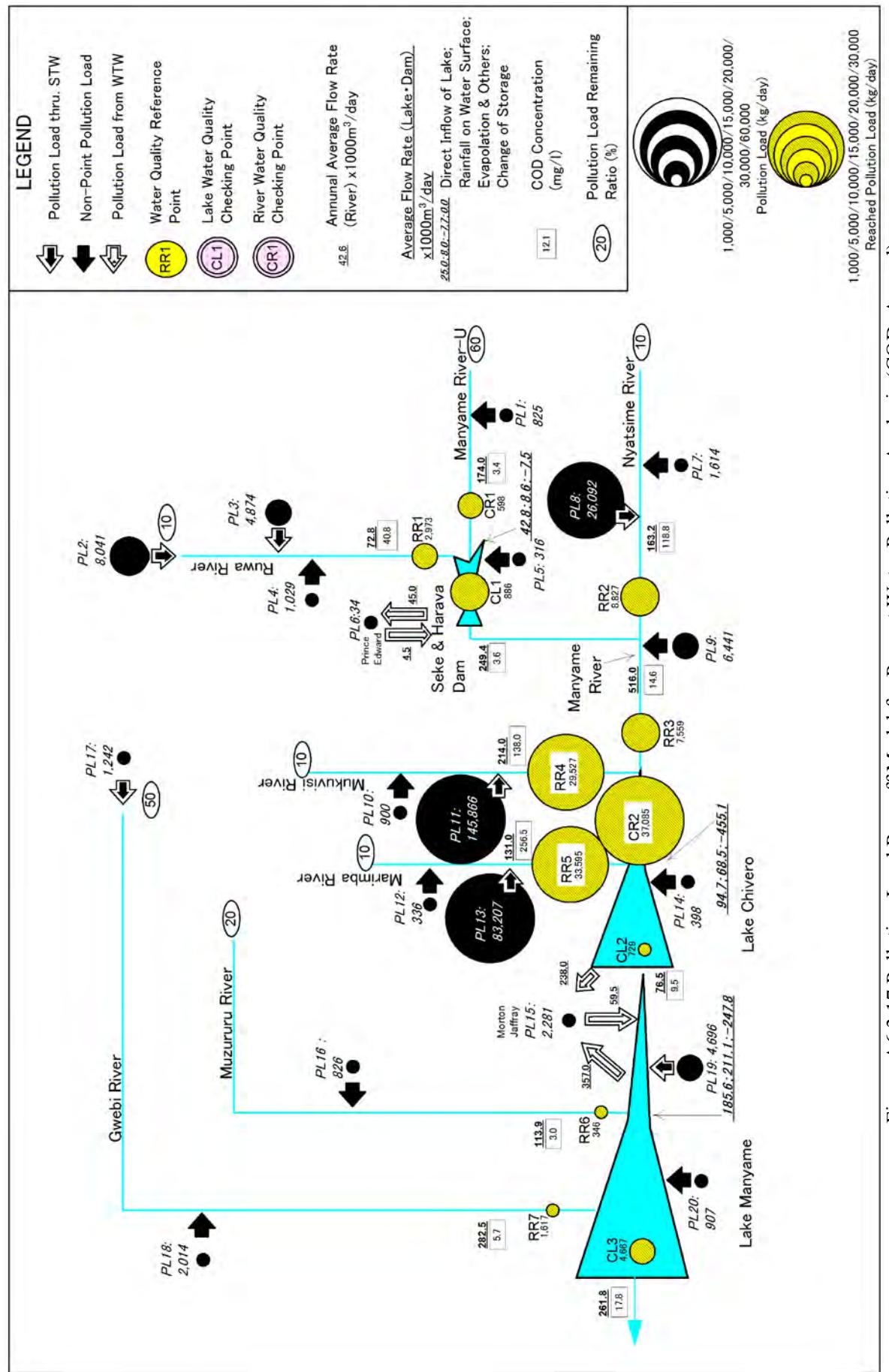


Figure A6.3.17 Pollution Load Run-off Model for Present Water Pollution Analysis (COD, Annual)

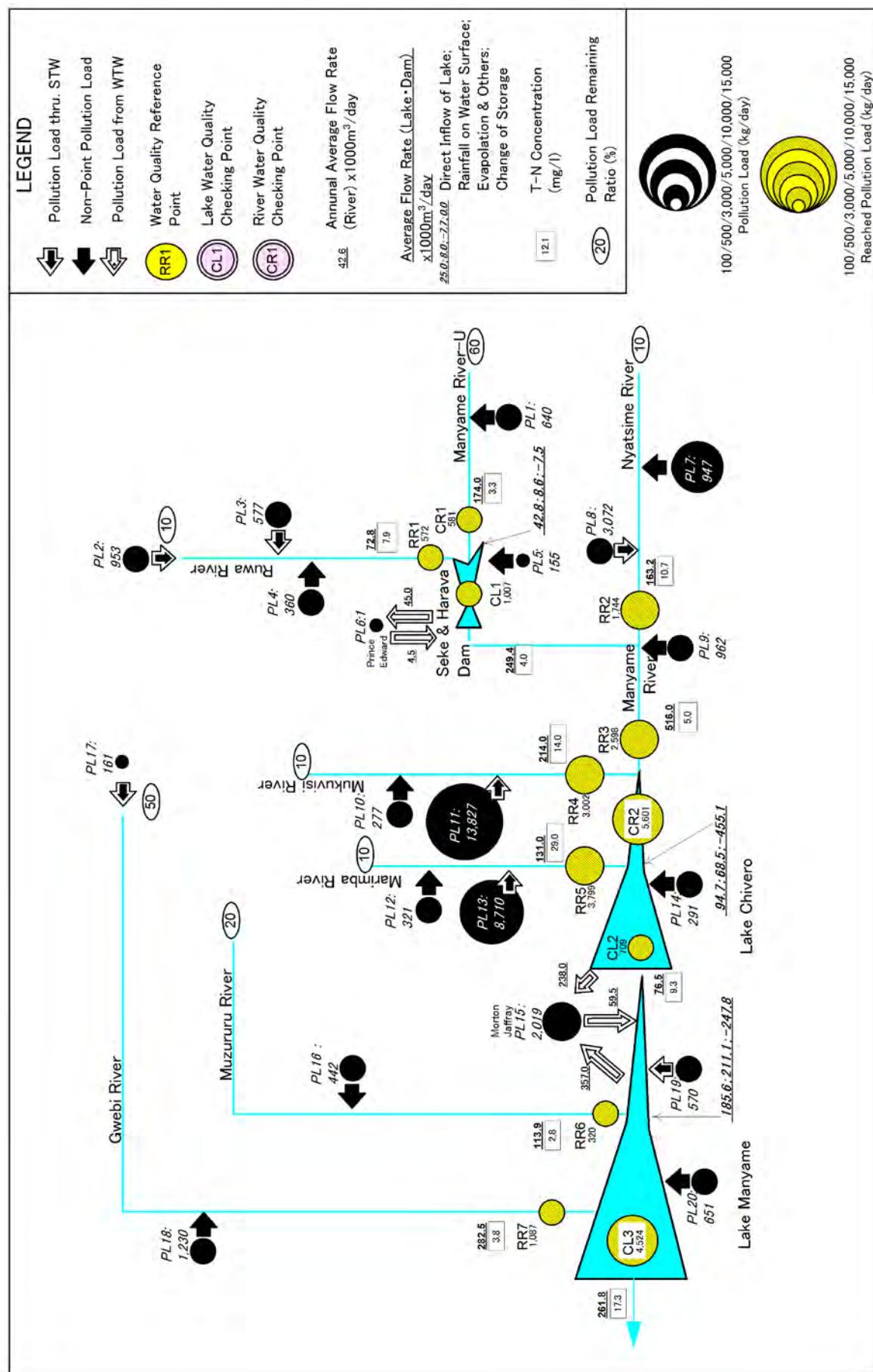


Figure A6.3.18 Pollution Load Run-off Model for Present Water Pollution Analysis (T-N, Annual)

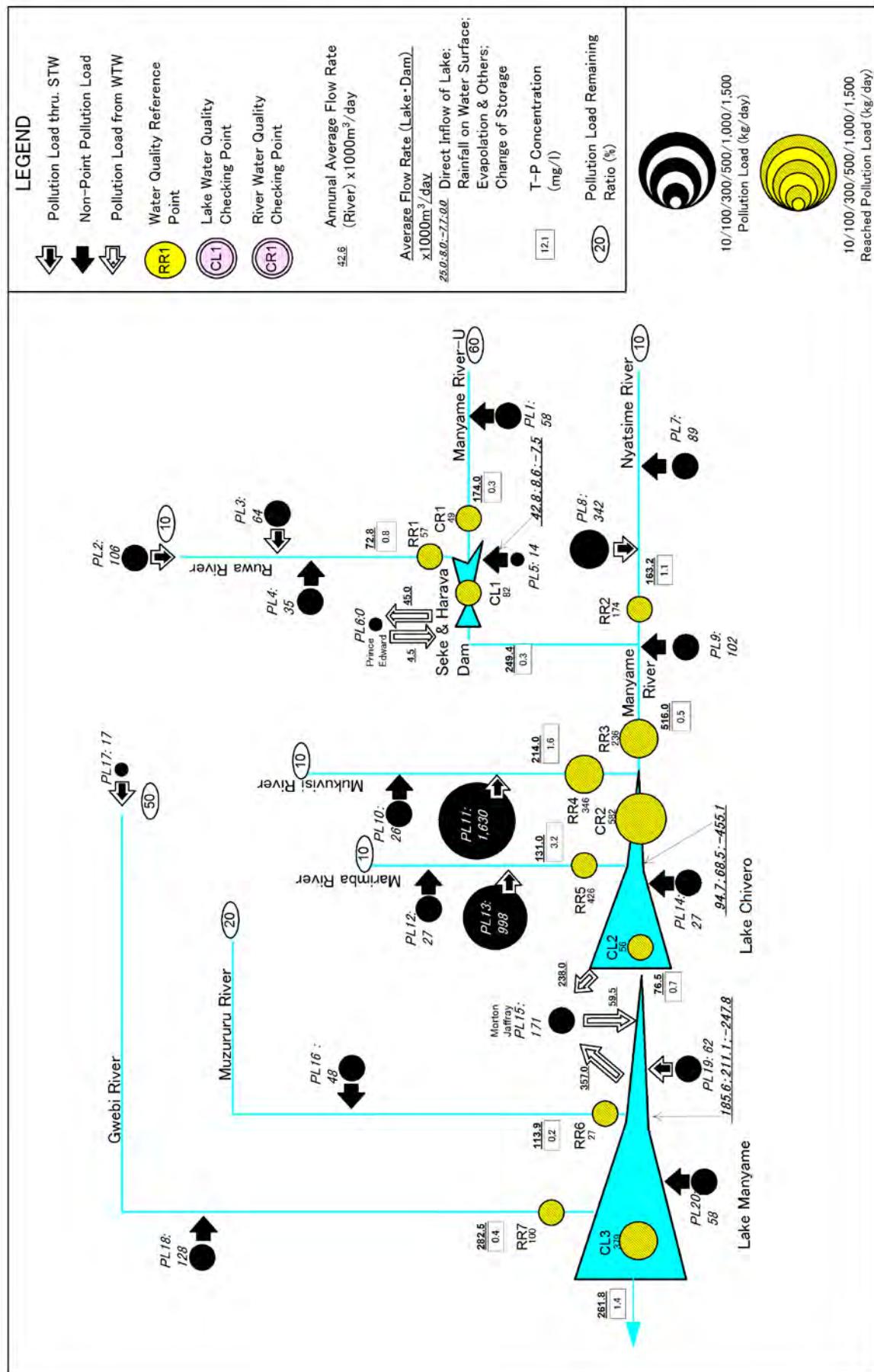


Figure A6.3.19 Pollution Load Run-off Model for Present Water Pollution Analysis (T-P, Annual)

Table A6.3.21 Water Pollution Analysis of the Lakes
(Present for Seke and Harava Dams)

Volume of Dams:	12,406,000	m^3		
Inflow Water Volume:	290,661	m^3/dav		
Rivers; Manyame;	174,000	m^3/dav		
Ruwa;	72,846	m^3/dav		
Direct inflow;	42,750	m^3/dav		
Rainfall;	8,598	m^3/dav		
Evaporation & Others;	-7,533	m^3/dav		
Outflow Water Volume:	290,661	m^3/dav		
Manyame River;	245,661	m^3/dav		
Prince Edward WTW;	45,000	m^3/dav		
Detention Time of Dam	43	days		
Pollution Load Inflow: (kg/day)				
	T-N	T-P	COD	
Manyame(U/S)	581	49	598	
Ruwa	572	57	2,973	
Direct	155	14	316	
Total	1,308	121	3,887	
Present Water Quality: (mg/l)				
	T-N	T-P	COD	Min.COD (soluble COD)
	0.430	0.060	23.00	12.42
				factor 0.54
Formula for Pollution Analysis: (Vollenweider Model)				
$N = L(N) / ((\gamma w + \sigma N) \times V)$				
$P = L(P) / ((\gamma w + \sigma P) \times V)$				
$COD = L(COD) / ((\gamma w + \sigma COD) \times V) + \Delta COD$				
where;				
N: Concentration of Nitrogen of Lake (g/m^3)	=	0.430		
P: Concentration of Phosphorus of Lake (g/m^3)	=	0.060		
COD: Concentration of COD of Lake (g/m^3)	=	23.00		
L(N): Quantity of inflow Nitrogen to Lake (g/day)	=	1,308,000		
L(P): Quantity of inflow Phosphorus to Lake (g/day)	=	121,000		
L(COD): Quantity of inflow COD to Lake (g/day)	=	3,887,000		
γw : Rate of change of water (l/day)	=	0.023429		
σN : Self-purification (reduction) coefficient for Nitrogen				
σP : Self-purification (reduction) coefficient for Phosphorus				
σCOD : Self-purification (reduction) coefficient for inflow COD				
V: Volume of lake (m^3)	=	12,406,000		
ΔCOD : Secondary produced COD (Calculated as below)	=	10.58		
Computation of Self-purification Coefficients:				
$\sigma N = L(N) / (N \times V) - \gamma w =$	0.22176			
$\sigma P = L(P) / (P \times V) - \gamma w =$	0.13913			
$\sigma COD = L(COD) / ((COD - \Delta COD) \times V) - \gamma w =$	0.00180	(adopted Min. COD)		
Computation of Conversion Rate for DCOD				
$\Delta COD = \alpha (N) \times T-N \times 17.73$ or $\alpha (P) \times T-P \times 128.70$				
where;				
$\alpha (N)$: Conversion rate of Nitrogen to ΔCOD				
17.73: Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity				
$\alpha (P)$: Conversion rate of Phosphorus to ΔCOD				
128.70: Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity				
ΔCOD : Average COD - Minimum COD (COD without effect of phytoplankton)				
$\alpha (N) = ((COD - Min.COD) / (T-N \times 17.73))$				
= 138.8%				
$\alpha (P) = ((COD - Min.COD) / (T-P \times 128.70))$				
= 137.0%				
$N/P = 7.2 < 20$ and $P = 0.06 > 0.02$				
Nitrogen is regarded to be the Restriction Factor for Secondary production of COD.				
Conversion Rate of $\alpha(N)$ will be adopted for Future Pollution Analysis.				

Table A6.3.22 Water Pollution Analysis of the Lakes (Present for Lake Chivero)

Volume of Dams:	257,181,000	m ³	
Inflow Water Volume:	569,158	m ³ /day	
Rivers; Manyame;	516,000	m ³ /day	
(Nyatsime;	163,200	m ³ /day)	
(Prince Edward WTW;	4,500	m ³ /day)	
Mukuvisi;	214,000	m ³ /day	
Marimba;	131,000	m ³ /day	
Direct inflow;	94,690	m ³ /day	
Rainfall;	68,532	m ³ /day	
Evaporation & Others;	-455,064	m ³ /day	
Outflow Water Volume:	569,158	m ³ /day	
Lake Manyame;	76,500	m ³ /day	
Morton Jaffray WTW;	238,000	m ³ /day	
Water level Increase;	254,658	m ³ /day	
Detention Time of Dam	452	days	
Pollution Load Inflow: (kg/day)			
	T-N	T-P	COD
Manyame(D/S)	5,069	568	68,448
Mukuvisi	3,043	352	32,566
Marimba	3,799	426	37,009
Direct	291	27	3,162
Total	12,202	1,373	141,185
Present Water Quality: (mg/l)			
	T-N	T-P	COD
	1.100	0.290	71.20
			Min.COD (soluble COD) 38.45
Formula for Pollution Analysis: (Vollenweider Model)			
N = L(N) / ((γw + σ N) x V)			
P = L(P) / ((γw + σ P) x V)			
COD = L(COD) / ((γw + σ COD) x V) + Δ COD			
where;			
N: Concentration of Nitrogen of Lake (g/m ³)	=	1.100	
P: Concentration of Phosphorus of Lake (g/m ³)	=	0.290	
COD: Concentration of COD of Lake (g/m ³)	=	71.20	
L(N): Quantity of inflow Nitrogen to Lake (g/day)	=	12,202,000	
L(P): Quantity of inflow Phosphorus to Lake (g/day)	=	1,373,000	
L(COD): Quantity of inflow COD to Lake (g/day)	=	141,185,000	
γw: Rate of change of water (l/day)	=	0.002213	
σ N: Self-purification (reduction) coefficient for Nitrogen			
σ P: Self-purification (reduction) coefficient for Phosphorus			
σ COD: Self-purification (reduction) coefficient for inflow COD			
V: Volume of lake (m ³)	=	257,181,000	
Δ COD: Secondary produced COD (Calculated as below)	=	32.75	
Computation of Self-purification Coefficients:			
σ N = L(N) / (N x V) - γw =	0.04092		
σ P = L(P) / (P x V) - γw =	0.01620		
σ COD = L(COD) / ((COD - Δ COD) x V) - γw =	0.01206	(adopted Min. COD)	
Computation of Conversion Rate for DCOD			
Δ COD = α (N) x T-N x 17.73 or α (P) x T-P x 128.70			
where;			
α (N): Conversion rate of Nitrogen to Δ COD			
17.73: Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity			
α (P): Conversion rate of Phosphorus to Δ COD			
128.70: Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity			
Δ COD: Average COD - Minimum COD (COD without effect of phytoplankton)			
α (N) = ((COD - Min.COD) / (T-N x 17.73))			
= 167.9%			
α (P) = ((COD - Min.COD) / (T-P x 128.70))			
= 87.8%			
N/P = 3.8 < 20 and P = 0.29 > 0.02			
Nitrogen is regarded to be the Restriction Factor for Secondary production of COD.			
Conversion Rate of α(N) will be adopted for Future Pollution Analysis.			

Table A6.3.23 Water Pollution Analysis of the Lakes (Present for Lake Manyame)

Volume of Dams:	480,236,000	m^3				
Inflow Water Volume:	681,307	m^3/day				
Rivers; Lake Chivero;	76,500	m^3/day				
Muzururu;	113,900	m^3/day				
Gwebi;	282,540	m^3/day				
Direct inflow;	185,640	m^3/day				
Rainfall;	211,066	m^3/day				
Evaporation & Others;	-247,839	m^3/day				
Morton Jaffray WTW;	59,500	m^3/day				
Outflow Water Volume:	681,307	m^3/day				
Lake Manyame;	261,800	m^3/day				
Morton Jaffray WTW;	357,000	m^3/day				
Water level Increase;	62,507	m^3/day				
Detention Time of Dam	705	days				
Pollution Load Inflow: (kg/day)						
	T-N	T-P	COD			
Lake Chivero	84	22	5,447			
Morton Jaffray WTW	2,228	175	24,695			
Muzururu	320	27	3,705			
Gwebi	1,087	100	12,131			
Direct	1,221	120	11,998			
Total	4,939	444	57,977			
Present Water Quality: (mg/l)						
	T-N	T-P	COD	Min.COD (soluble COD)		
	0.430	0.060	33.50	18.09	Result of Harava used for convenience's sake	
Formula for Pollution Analysis: (Vollenweider Model)						
$N = L(N) / ((\gamma_w + \sigma N) \times V)$						
$P = L(P) / ((\gamma_w + \sigma P) \times V)$						
$COD = L(COD) / ((\gamma_w + \sigma COD) \times V) + \Delta COD$						
where;						
	N: Concentration of Nitrogen of Lake (g/m^3)		=	0.430		
	P: Concentration of Phosphorus of Lake (g/m^3)		=	0.060		
	COD: Concentration of COD of Lake (g/m^3)		=	33.50		
	L(N): Quantity of inflow Nitrogen to Lake (g/day)		=	4,939,000		
	L(P): Quantity of inflow Phosphorus to Lake (g/day)		=	444,000		
	L(COD): Quantity of inflow COD to Lake (g/day)		=	57,977,000		
	γ_w : Rate of change of water (l/day)		=	0.001419		
	σN : Self-purification (reduction) coefficient for Nitrogen					
	σP : Self-purification (reduction) coefficient for Phosphorus					
	σCOD : Self-purification (reduction) coefficient for inflow COD					
	V: Volume of lake (m^3)		=	480,236,000		
	ΔCOD : Secondary produced COD (Calculated as below)		=	15.41		
Computation of Self-purification Coefficients:						
	$\sigma N = L(N) / (N \times V) - \gamma_w =$		0.02250			
	$\sigma P = L(P) / (P \times V) - \gamma_w =$		0.01399			
	$\sigma COD = L(COD) / ((COD - \Delta COD) \times V) - \gamma_w =$		0.00525	(adopted Min. COD)		
Computation of Conversion Rate for DCOD						
$\Delta COD = \alpha(N) \times T-N \times 17.73$ or $\alpha(P) \times T-P \times 128.70$						
where;	$\alpha(N)$: Conversion rate of Nitrogen to ΔCOD					
	17.73: Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity					
	$\alpha(P)$: Conversion rate of Phosphorus to ΔCOD					
	128.70: Theoretical COD (assumed to be 90% of TOD) quantity produced by phytoplankton from unit nitrogen quantity					
	ΔCOD : Average COD - Minimum COD (COD without effect of phytoplankton)					
	$\alpha(N) = ((COD - Min.COD) / (T-N \times 17.73))$					
	= 202.1%					
	$\alpha(P) = ((COD - Min.COD) / (T-P \times 128.70))$					
	= 199.6%					
	$N/P = 7.2 < 20$ and $P = 0.06 > 0.02$					
	Nitrogen is regarded to be the Restriction Factor for Secondary production of COD.					
	Conversion Rate of $\alpha(N)$ will be adopted for Future Pollution Analysis.					

6.3.6 Discussion and Conclusion

Result of the pollution analysis for the current status is summarised below:

(1) Generated Pollution Load

The biggest pollution loads in the catchment area are from Harare City, which is about 110,000 kg-BOD/day. The reached pollution load to the Chivero Lake is assumed to be about 33,000 kg-BOD/day, reducing about 70% of the load in the river. Chitungwiza Municipality comes in second, discharging a pollution load about 13,000 kg-BOD/day. The reached pollution load to the Manyame river is assumed to be 3,900 kg BOD/day reducing about 70 % of the load in the river. While the reduction of the pollution load in the river is quite significant, the influence of these loads is still serious as evidenced by the continuing deterioration of water quality in the rivers and lakes as shown in (2).

Influence of non-point sources such as natural pollution and pollution from livestock is not significant compared with the load from the urban area.

(2) Status of River Pollution

Other than the Upper-Manyame river, the entire aquatic environment is seriously polluted.

Upper-Manyame river: Clean (1.3 mg BOD/l) with low pollution load

Ruwa river: Polluted (97 mg BOD/l) with high pollution load from Ruwa

Downstream of Seke: Polluted (1.5 mg BOD/l) with high pollution load from Ruwa

Nyatsime river: Heavily polluted (118 mg BOD/l) by Chitungwiza pollution load

Manyame river before Chivero: Polluted (40 mg BOD/l) with high pollution load

Lake Chivero Polluted (5.0 mg BOD/l, 10.8mg N/l, 0.7 mg P/l)

Lake Manyame Polluted (2.0 mg BOD/l, 19.1mg N/l, 1.5 mg P/l)

Remarks: BOD was used for the Lakes for the simplicity, instead of COD

The rivers receive sewage from Harare and Chitungwiza and are seriously polluted with pollution loads coming from both urban and rural areas.

Eutrophication of the lakes is also serious as indicated by concentrations of N and P. One of the problems is the flow rate of the rivers especially in the dry season when flow rate is one-third that of rainy season, and dilution of nutrients does not work effectively.

(3) Purification capability of the Lakes

The purification of the rivers and lakes of pollution loads is evaluated to be very effective in the improvement of water quality according to the model. Water quality of the intake for the water treatment plant is actually much better than the computed result. It shows the high performance of the lakes in the water treatment capability.

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6.4 FUTURE WATER POLLUTION ANALYSIS

6.4.1 General

Future water pollution analysis was undertaken to predict water quality using a model made from the present water pollution analysis of the rivers and lakes from which four scenarios were conducted as follows:

- Scenario 0 : Same condition with current condition as of 2012 (No improvement)
- Scenario 1 : All the STPs operation under condition after the urgent improvement
- Scenario 2 : All the STPs operation with 3 STPs upgrading BNR (from TF or WSP to BNR)
- Scenario 3 : All the STPs operation with 100% irrigation
- Scenario 4 : No improvement for only ZSTP to confirm the influence of pollutant discharge from Chitungwiza Municipality

Analytic models cover both human and natural pollution loads generated for point and non-point sources. The flow model employs the same flow shown in the current analysis of the entire basin for future water pollution analysis. Population projection was conducted for 2020 and 2030 with 1.6% of population increase ratio in Chitungwiza and 1.4% of ratio in other areas after considering the current status and trends.

- (1) In the scenario 0, no improvement was considered to predict the worst pollution status.
- (2) Scenario 1 took urgent measures for Crowborough STP and Firle STP for Harare (Rehabilitation of BNR and Trickling Filters by Zim Fund), Zengeza STP for Chitungwiza (Rehabilitation of Trickling Filters by AWF project), and rehabilitation of Norton STP by some donor. The Ruwa STP was planned as existing in this case, which is waste stabilization pond.
- (3) Scenario 2 is planned to predict the effect of the employment of the BNR process for Firle STP, Crowborough STP and Zengeza STP (Table A6.4.2).
- (4) Scenario 3 was planned to evaluate the effect of the irrigation by which the pollution loads can be completely transferred outside of the catchment.
- (5) Scenario 4 is excluding the improvement of only Chitungwiza Municipality to evaluate the scale of the effect of the pollutant discharge from the municipality

6.4.2 Planning Frame and Pollution Load by Sub-basin

(1) Domestic/Commercial institutional/ Sewage

The population project in the years 2020 and 2030 were distributed to seweraged and unsewered areas as shown in Tables A6.4.5 respectively. Generated and discharged pollution loads were assumed by seweraged/unsewered area by applying unit pollution load of domestic sewage discussed in the sub-section 6.2.

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The pollution load collected from the seweraged area flows into the sewage treatment works. The discharged pollution load was calculated by using planned treatment efficiency. The calculation results are presented in Tables A6.4.7 to Table A6.4.14 where treatment efficiencies of STWs were assumed from the future arrangements of sewerage systems as follows (Table A6.4.1).

Table A6.4.1 Treatment Efficiency by Treatment Method

Treatment Method	Treatment efficiency (Pollution Load Reducing Ratio)				Memo
	BOD5	COD	T-N	T-P	
Biological Nutrient Removal	95%	90%	80%	75%	Irrigation 0%
Trickling Filter	90%	85%	30%	30%	Irrigation 100%
Wastewater Stabilization Pond	90%	85%	50%	30%	Irrigation 100%
Irrigation	100%	100%	100%	100%	

Source: JICA Project Team

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Table A6.4.2 Comparison of Operation Status between Present and Future (Scenario 1)

Sub-basin	Sewage Treatment Works	2012						2020 and 2030						
		Eff. Flow (m ³ /day)		Irrigation Reuse (%)		Average Effluent Water Quality (mg/l)		Eff. Flow (m ³ /day)		Irrigation Reuse (%)		Average Effluent Water Quality (mg/l)		
		Annual	BOD	COD	T-N	P-P	T-P ^a	Annual	BOD	COD	T-N	P-P	T-P ^a	
Marimba R.	Crownborough (TF)	16,800	29%	28.0	80.6	37.9	5.23	8.4	16,800	100%	98.1	282.0	37.9	
	Crownborough (BNR)	18,000	0%	18.9	91.3	9.3	1.54	2.7	18,000	0%	18.9	91.3	9.3	
	Crownborough Total	34,800							34,800					
L. Chivero	Firle Units 1&2 (TF)	30,000	68%	137.8	268.0	38.7	1.49	1	7.2	83,900	100% ^c	137.8	268.0	38.7
	Firle Unit 3 (BNR)	18,000	0%	13.8	107.6	13.7	1	2.84	1	18,000	0%	13.8	107.6	13.7
	Firle Unit 4 (BNR)	18,000	0%	18.2	94.7	13.0	2.23	1	3.7	18,000	0%	18.2	94.7	13.0
Mukuvizi R.	Firle Unit 5 (BNR)	72,000	0%	18.2	94.7	13.0	2.23	1	3.7	72,000	0%	18.2	94.7	13.0
	Firle Total (Mukuvizi)	108,000							108,000					
	Gwébi R.	Marlborough (WSP) ^b	2,000	100%	51.4	161.9	36.4	1	4.04	1	6.5	2,000	100%	51.4
Ruwa R.	Donnybrook-1 (WSP) ^b	400	100%	40.6	162.1	99.6	10.97	1	17.3	400	100%	40.6	162.1	99.6
	Donnybrook-2 (WSP) ^b	1,400	100%	40.6	162.1	99.6	10.97	1	17.3	1,400	100%	40.6	162.1	99.6
	Donnybrook-3 (WSP) ^b	1,400	100%	40.6	162.1	99.6	10.97	1	17.3	1,400	100%	40.6	162.1	99.6
Nyatsime R.	Donnybrook-4 (WSP) ^b	2,400	100%	40.6	162.1	99.6	10.97	1	17.3	2,400	100%	40.6	162.1	99.6
	Donnybrook Total ^h	5,600							5,600					
	Zengeza (TF) ^b	22,000	0%	800.0	1,600.0	54.0	16.6		22,000	100%	130.0	540.0	54.0	16.6
L. Manyame	Zengeza (1F)b								20,000	100%	60.0	120.0	37.8	16.6
	Norton (TF)	2,700	0%	520.0	1,191.9	65.8	1	7.60	1	12.0	2,700	100%	520.0	1,191.9
	Ruwa (WSP) ^b	2,900	100%	123.0	278.0	6.1	2.38	1	4.0	2,900	100%	123.0	278.0	6.1
Total		208,000							281,900					

Note:

a) T-P is calculated from P-P values using following correlation formula which is derived from measurement results by the Study Team.

$$T-P = P-P \times 1.5482 + 0.2682$$

b) COD values of STPs with " b " are calculated from BOD values using following correlation formula which is derived from measurement results of other STPs with trickling filter method

$$COD = BOD \text{ (annual average)} \times 2.08$$

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

d) The irrigation farm of the Zengeza STP 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 STP is from measurement results surveyed by JICA team.

f) Reaching ratios of pollution loads are;

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 STP is calculated from Ammonia-N values using following correlation formula which is derived from measurement results of same WSP effluent of Donnybrook STP.

$$T-N = A-N \times 1.58$$

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Table A6.4.3 Comparison of Operation Status between Present and Future (Scenario 2)

Sub-basin	Sewage Treatment Works	2012						2020 and 2030					
		Eff. Flow (m ³ /day)		Irrigation Reuse (%)		Average Effluent Water Quality (mg/l)		Eff. Flow (m ³ /day)		Irrigation Reuse (%)		Average Effluent Water Quality (mg/l)	
		Annual	BOD	COD	T-N	P-P	T-P ^a	Annual	BOD	COD	T-N	P-P	T-P ^a
Marimba R.	Crowborough (TF)	16,800	28.0	80.6	37.9	5.23	8.4	16,800	0%	18.9	91.3	9.3	2.7
do	Crowborough (BNR)	18,000	18.9	91.3	9.3	1.54	2.7	18,000	0%	18.9	91.3	9.3	2.7
do	Crowborough Total	34,800	-	-	-	-	-	34,800	-	-	-	-	-
L. Chivero	Firle Units 1&2 (TF)	30,000	137.8	268.0	38.7	4.49	7.2	83,900	0%	13.8	107.6	13.7	2.84
Mukuvisi R.	Firle Unit 3 (BNR)	18,000	13.8	107.6	13.7	2.84	4.7	18,000	0%	13.8	107.6	13.7	2.84
do	Firle Unit 4 (BNR)	18,000	18.2	94.7	13.0	2.23	3.7	18,000	0%	18.2	94.7	13.0	2.23
do	Firle Unit 5 (BNR)	72,000	18.2	94.7	13.0	2.23	3.7	72,000	0%	18.2	94.7	13.0	2.23
do	Firle Total (Mukuvisi)	108,000	-	-	-	-	-	108,000	-	-	-	-	-
Gwebi R.	Marlborough WSP ^b	2,000	100%	51.4	161.9	36.4	4.04	6.5	2,000	100%	51.4	161.9	36.4
Ruwa R.	Donnybrook-1 (WSP) ^b	400	100%	40.6	162.1	99.6	10.97	17.3	400	100%	40.6	162.1	99.6
do	Donnybrook-2 (WSP) ^b	1,400	100%	40.6	162.1	99.6	10.97	17.3	1,400	100%	40.6	162.1	99.6
do	Donnybrook-3 (WSP) ^b	1,400	100%	40.6	162.1	99.6	10.97	17.3	1,400	100%	40.6	162.1	99.6
do	Donnybrook-4 (WSP) ^b	2,400	100%	40.6	162.1	99.6	10.97	17.3	2,400	100%	40.6	162.1	99.6
do	Donnybrook Total ^h	5,600	-	-	-	-	-	5,600	-	-	-	-	-
Nyatsume R.	Zengeza (TF) ^b	22,000	0%	800.0	1,600.0	54.0	16.6	22,000	100%	130.0	54.0	54.0	16.6
Zengeza (TF)b		-	-	-	-	-	-	20,000	0%	18.2	94.7	13.0	2.23
L. Manyame	Norton (TF)	2,700	0%	520.0	1,191.9	65.8	7.60	12.0	2,700	0%	18.2	94.7	13.0
Ruwa R.	Ruwa (WSP) ^b	2,900	100%	123.0	278.0	6.1	2.38	4.0	2,900	100%	123.0	278.0	6.1
Total		208,000	-	-	-	-	-	281,900	-	-	-	-	-

Note:

a) T-P is calculated from P-P values using following correlation formula which is derived from measurement results by the Study Team.

$$T-P = P-P \times 1.5482 + 0.2682$$

b) COD values of STPs with "b" are calculated from BOD values using following correlation formula which is derived from measurement results of other STPs with trickling filter method.

$$COD = BOD \text{ (annual average)} \times 2.08$$

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

d) The irrigation farm of the Zengeza STP 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 STP is from measurement results surveyed by JICA team.

f) Reaching ratios of pollution loads are;

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 STP is calculated from Ammonia-N values using following correlation formula which is derived from measurement results of same WSP effluent of Donnybrook STP.

$$T-N = A-N \times 1.58$$

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Table A6.4.4 Comparison of Operation Status between Present and Future (Scenario 3)

Sub-basin	Sewage Treatment Works	2012						2020 and 2030								
		Eff. Flow (m ³ /day)		Irrigation Reuse (%)		Average Effluent Water Quality (mg/l)		Eff. Flow (m ³ /day)		Irrigation Reuse (%)		Average Effluent Water Quality (mg/l)				
		Annual	BOD	COD	T-N	P-P	T-P ^a	Annual	BOD	COD	T-N	P-P	T-P ^a			
Marimba R.	Crowborough (TF)	16,800	29%	28.0	80.6	37.9	5.23	8.4	-	16,800	100%	98.1	282.0	5.23	8.4	
do	Crowborough (BNR)	18,000	0%	18.9	91.3	9.3	1.54	2.7	-	18,000	100%	18.9	91.3	9.3	1.54	
do	Crowborough Total	34,800	-	-	-	-	-	-	-	34,800	-	-	-	-	2.7	
L. Chivero	Firle Units 1&2 (TF)	30,000	68%	137.8	268.0	38.7	4.49	7.2	83,900	100% ^c	137.8	268.0	38.7	4.49	7.2	
Mukuvisi R.	Firle Unit 3 (BNR)	18,000	0%	13.8	107.6	13.7	2.84	4.7	-	18,000	100%	13.8	107.6	13.7	2.84	4.7
do	Firle Unit 4 (BNR)	18,000	0%	18.2	94.7	13.0	2.23	3.7	-	18,000	100%	18.2	94.7	13.0	2.23	3.7
do	Firle Unit 5 (BNR)	72,000	0%	18.2	94.7	13.0	2.23	3.7	-	72,000	100%	18.2	94.7	13.0	2.23	3.7
do	Firle Total (Mukuvisi)	108,000	-	-	-	-	-	-	-	108,000	-	-	-	-	-	
Gwedi R.	Manlborough (WSP) ^b	2,000	100%	51.4	161.9	36.4	4.04	6.5	-	2,000	100%	51.4	161.9	36.4	4.04	6.5
Ruwa R.	Donnybrook-1 (WSP) ^b	400	100%	40.6	162.1	99.6	10.97	17.3	400	100%	40.6	162.1	99.6	10.97	17.3	
do	Donnybrook-2 (WSP) ^b	1,400	100%	40.6	162.1	99.6	10.97	17.3	-	1,400	100%	40.6	162.1	99.6	10.97	17.3
do	Donnybrook-3 (WSP) ^b	1,400	100%	40.6	162.1	99.6	10.97	17.3	-	1,400	100%	40.6	162.1	99.6	10.97	17.3
do	Donnybrook-4 (WSP) ^b	2,400	100%	40.6	162.1	99.6	10.97	17.3	-	2,400	100%	40.6	162.1	99.6	10.97	17.3
do	Donnybrook Total ^h	5,600	-	-	-	-	-	-	-	5,600	-	-	-	-	-	
Nyatine R.	Zengeza (TF) ^b	22,000	0%	800.0	1,600.0	54.0	4	16.6	-	22,000	100%	130.0	540.0	54.0	16.6	
	Zengeza (TF)b	-	-	-	-	-	-	-	-	20,000	100%	60.0	120.0	37.8	16.6	
L. Manyame	Norton (TF)	2,700	0%	520.0	1,191.9	65.8	7.60	12.0	-	2,700	100%	520.0	1,191.9	65.8	7.60	12.0
Ruwa R.	Ruwa (WSP) ^b	2,900	100%	123.0	278.0	6.1	2.38	4.0	-	2,900	100%	123.0	278.0	6.1	2.38	4.0
	Total	208,000	-	-	-	-	-	-	-	281,900	-	-	-	-	-	

Note:

a) T-P is calculated from P-P values using following correlation formula which is derived from measurement results by the Study Team.

$$T-P = P-P \times 1.5482 + 0.2682$$

P-P, Phosphate Phosphorus

b) COD values of STPs with " b " are calculated from BOD values using following correlation formula which is derived from measurement results of other STPs with trickling filter method.

$$COD = BOD \text{ (annual average)} \times 2.08$$

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

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

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

f) Reaching ratios of pollution loads are:

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 STP is calculated from Ammonia-N values using following correlation formula which is derived from measurement results of same WSP effluent of Donnybrook STP.

$$T-N = A-N \times 1.58$$

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Table A6.4.5 Estimated Sewered Ratio and Population in each year (2012 / 2020 / 2030)

Sub-basin/District	Increase Rate	Population					
		2012		2020		2030	
	%	Sewered	Unsewered	Sewered	Unsewered	Sewered	Unsewered
1. Manyame River (U.stream) S/B							
Goromonzi Rural	1.4	-	2,255	-	2,520	-	2,896
Harare Rural	1.4	-	76	-	85	-	98
Manyame Rural	1.4	-	1,498	-	1,674	-	1,924
Total	-	-	3,829	-	4,279	-	4,918
2. Ruwa River S/B							
Harare City	1.4	107,148	-	119,753	-	137,615	-
Ruwa Local Board	1.4	24,763	237	27,941	-	32,109	-
Epworth Local Board	1.4	-	87,333	-	97,607	-	112,166
Goromonzi Rural	1.4	-	535	-	598	-	687
Harare Rural	1.4	-	2,606	-	2,913	-	3,347
Total	-	131,911	90,711	147,694	101,118	169,724	116,200
3. Seke & Harava Dams S/B							
Epworth Local Board	1.4	-	9,441	-	10,552	-	12,126
Goromonzi Rural	1.4	-	10	-	11	-	13
Harare Rural	1.4	-	4,780	-	5,342	-	6,139
Manyame Rural	1.4	-	623	-	696	-	800
Total	-	-	14,854	-	16,601	-	19,078
4. Nyatsime River S/B							
Chitungwiza Municipality	1.6	260,071	-	307,113	-	343,688	-
Manyame Rural	1.4	-	6,519	-	7,286	-	8,373
Marondera Rural	1.4	-	60,000	-	67,059	-	77,061
Total	-	260,071	66,519	290,667	74,345	334,022	85,434
5. Mukuvizi River S/B							
Harare City	1.4	764,852	34,549	893,446	-	1,026,710	-
Epworth Local Board	1.4	-	34,226	-	38,252	-	43,958
Harare Rural	1.4	-	1,180	-	1,319	-	1,516
Zvimba Rural	1.4	-	142	-	159	-	182
Total	-	764,852	70,097	893,446	39,730	1,026,710	45,656
6. Manyame River (D.stream) S/B							
Chitungwiza Municipality	1.6	69,929	-	82,578	-	92,412	-
Harare Rural	1.4	-	6,487	-	7,250	-	8,332
Manyame Rural	1.4	-	939	-	1,049	-	1,206
Total	-	69,929	7,426	78,156	8,300	89,813	9,538
7. Marimba River S/B							
Harare City	1.4	644,458	-	720,275	-	827,709	-
Zvimba Rural	1.4	-	882	-	986	-	1,133
Total	-	644,458	882	720,275	986	827,709	1,133
8. Lake Chivero S/B							
Harare City	1.4	-	-	-	-	-	-
Chegutu Rural	1.4	-	672	-	751	-	863
Manyame Rural	1.4	-	1,292	-	1,444	-	1,659
Zvimba Rural	1.4	-	1,563	-	1,747	-	2,007
Total	-	-	3,527	-	3,942	-	4,530
9. Muzururu River S/B							
Zvimba Rural	1.4	-	4,606	-	5,148	-	5,916
Total	-	-	4,606	-	5,148	-	5,916
10. Gwebi River S/B							
Harare City	1.4	12,421	86,572	110,639	-	127,142	-
Mazowe Rural	1.4	-	5,100	-	5,700	-	6,550
Zvimba Rural	1.4	-	6,688	-	7,475	-	8,590
Total	-	12,421	98,360	110,639	13,175	127,142	15,140
11. Lake Manyame S/B							
Norton Town	1.4	48,045	2,955	57,000	-	65,502	-
Chegutu Rural	1.4	-	2,928	-	3,272	-	3,761
Zvimba Rural	1.4	-	4,119	-	4,604	-	5,290
Total	-	48,045	10,002	57,000	7,876	65,502	9,051
Grand Total	-	1,931,687	370,813	2,297,877	275,499	2,640,622	316,592

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Table A6.4.6 Removal Ratio of Sewered by Each Sub-bas in Each Scenario

Sub-basin/District	Removal Ratio of Each Scenario * ¹				Specification of STP		
	S0	S1	S2	S3	STP Name	Method * ²	Memo
1. Ruwa River S/B Harare City Ruwa Local Board	-	-	-	-	Donnybrook	BNR	*BOD95%, COD90%, N80%, P75%
	0% * * 100%	0% 70% 70% 100%	Donnybrook	WSP			
2. Nyatsime River S/B Chitungwiza Municipality	-	-	-	-	Zengeza	TF	S2 → Change to BNR, *BOD95%, COD90%, N80%, P75%
	0% 100% * 100%						
3. Mukuvizi River S/B Harare City	-	-	-	-	Firle	BNR	*BOD95%, COD90%, N80%, P75%
	0% * * 100%						
4. Manyame River (D.stream) S/B Chitungwiza Municipality	-	-	-	-	Norton	TF	
	0% 100% 100% 100%						
5. Marimba River S/B Harare City	-	-	-	-	Crowgrough	TF, BNR	S2 → Change to BNR, *BOD95%, COD90%, N80%, P75%
	0% 100% * 100%						
6. Lake Chivero S/B Harare City	-	-	-	-	Firle 1&2	TF	S2 → Change to BNR, *BOD95%, COD90%, N80%, P75%
	0% 100% * 100%						
7. Gwebi River S/B Harare City	-	-	-	-	Morlborough	WSP	
	0% 100% 100% 100%						
8. Lake Manyame S/B Norton Town	-	-	-	-	Norton	TF	
	0% 100% 100% 100%						

*1: S0, S1, S2, S3: Scenario0, 1, 2, 3

*2: BNR- Biological Nutrient Removal, TF- Trickling Filter, WSP- Wastewater Stabilization Pond

(2) Industrial Wastewater

1) Industrial Wastewater Flow

The future industrial wastewater flow was calculated by multiplying the unit industrial wastewater flow per employee and the number of employees in the future, as shown in Table A6.4.5 and Table A6.4.6.

2) Pollution load

The future pollution load was calculated by multiplying the unit pollution load of industrial wastewater per employee and the number of employees in the future, as presented in Table A6.3.10.

3) Sewered/Unsewered Wastewater

The future wastewater flow and pollution load were calculated by sub-basin under the category of seweraged and unsewered area based on the present sewerage service coverage. The results are shown in Table A6.4.5 and Table A6.4.6. The pollution load of industrial wastewater in the unsewered area is also presented in Table A6.4.5 and Table A6.4.6. Industrial wastewater in the seweraged area is considered as a part of the effluent discharged from STWs.

(3) Other Pollution Load

In addition to aforementioned pollution loads, that caused by the following pollution sources were considered in the calculation.

1) Livestock

The number of major livestock and unit generation rate of pollution are assumed to be same as 2012.

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The data for livestock is shown in Table A6.3.11.

2) Farmland / Natural land

The pollution loads calculated for each sub-basin are shown in Table A6.3.12. The unit pollution load presented in Table A6.3.13 was assumed to be constant through the future.

3) Water Treatment Works

Pollution Load from water treatment works is assumed to be same as 2012. The calculation is shown in Table A6.4.15 to Table A6.4.22.

6.4.3 Modelling of Pollution Load Run-off

1) Flow Run-off Model

The pollution load remaining ratio of the river and the purification coefficient of the lakes are shown in Table A6.3.5. In the computation, natural pollution was treated as not decreasing since it is considered as non-degradable in the flow. In the scenario 1, 2, 3, the pollution load remaining ratio of the effluent from STPs in the rivers does not decrease since the load that remains after treatment is no longer biodegradable. However, it will be treated as degradable in the lake due to its long detention time. Therefore, purification for each pollution load is assumed as follows:

Table A6.4.7 Biodegradability of the loads

Scenario	Type of Load	Degradability	
		River	Lake
0	Sewered (Dom./Com./Ins./Ind.)	Yes	Yes
	Unsewered (Dom./Com./Ins./Ind.) • Livestock	Yes	Yes
	Natural Pollution, WTP discharging	No	No
1,2,3	Sewered (Dom./Com./Ins./Ind.)	No	Yes
	Unsewered (Dom./Com./Ins./Ind.) • Livestock	Yes	Yes
	Natural Pollution, WTP discharging	No	No

Source: JICA Project Team

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6.4.4 Scenario 0

Table A6.4.8 Reached Pollution Load by Sub-basin by Pollution (2020, BOD, Dry Season)

Water Quality Checking Points	Sub-basin	Dom/Com/Ins.Sewage			Industrial	Livestock	Natural Pollution	Water Treatment Works***	(kg/day) Total
		Sewered	Unsewered	Total					
C _{R1}	1 Manyame R (Upstream)	-	15	15	-	-	10	36	-
R _{S1}	2 Ruwa River	9,356	373	9,729	-	-	5	16	-
C _{L1}	3 Seke & Harava Dams	-	60	60	-	4	7	-	9,750
R _{S2}	4 Nyatsine River	15,387	262	15,649	-	17	50	-	-
R _{S4}	5 Mukuvizi River	93,185	147	93,332	155	1	15	-	15,716
R _{S3} *	6 Manyame R. (Downstream)	3,633	29	3,662	-	3	11	-	93,503
R _{S5}	7 Marimba River	47,746	3	47,749	-	1	20	-	-
C _{L2}	8 Lake Chivero	-	14	14	-	5	16	-	35
R _{S6}	9 Muzururu River	-	18	18	-	20	20	-	58
R _{S7}	10 Gwebi River	5,532	46	5,578	-	40	62	-	5,680
C _{L3}	11 Lake Manyame	3,211	28	3,239	45	9	38	281	3,612
	Grand Total	178,050	996	179,046	200	115	291	283	179,935

*: Before confluence of Mukuvizi River
 **: Pollution load of industries in sewered area is counted as a part of domestic pollution load seawered area.
 ***: Pollution load of Water Treatment Works;

Prince Edward WTW; Amount of water intake; 45,000 m³/day
 BOD concentration of intake water; 1.2 mg/l (Seke Dam, Av to Manyame River (Downstream))
 Concentrated BOD load; 1.9 kg/day

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

※ According to "9-4-2F", Pollution Load reached to C_{L2} is 370 kg/day
 And according to "9-5-4F", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).
 Therefore pollution load of Water Treatment Works reach to Manyame river is 370 * 0.76 = 281 kg/day

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Table A6.4.9 Reached Pollution Load by Sub-basin by Pollution (2030, BOD, Dry Season)

Water Quality Checking Points	Sub-basin	Dom/Com/Ins.Sewage			Industrial		Natural Pollution	Water Treatment Works***	(kg/day) Total
		Sewered	Unsewered	Total	Industrial	Unsewered**			
C _{R1}	1) Manyane R (Upstream) 2) Ruwa River	-	17	17	-	-	10	36	-
C _{L1}	3) Seke & Harava Dams 4) Nyatsime River 5) Mukuvizi River 6) Manyane R. (Downstream) 7) Marimba River 8) Lake Chivero 9) Muzaruru River 10) Gwebi River 11) Lake Manyame Grand Total	429	35,952	35,952	-	-	5	16	-
C _{R2}	-	69	69	69	-	-	4	7	-
C _{R3} *	-	301	24,424	24,424	-	-	17	50	-
C _{R4}	-	168	105,762	105,762	-	-	1	15	-
C _{R5}	-	155	-	-	-	-	1	15	-
C _{L2}	-	-	-	-	-	-	3	11	-
C _{R6}	-	5,615	-	-	-	-	1	2	-
C _{R7}	-	4	53,259	53,259	-	-	1	20	-
C _{L3}	-	1	1	1	-	-	1	20	-
	-	16	16	16	-	-	5	16	-
	-	-	-	-	-	-	1	1	-
	-	21	21	21	-	-	20	20	-
	-	-	-	-	-	-	-	-	61
	-	33	-	-	-	-	40	62	-
	-	-	-	-	-	-	-	-	6,512
	-	32	-	-	-	-	9	38	-
	-	-	-	-	-	-	-	-	305
	-	6,019	45	6,019	-	-	-	-	-
	-	-	-	-	-	-	-	-	6,416
	-	237,564	200	237,564	-	-	-	-	-
	-	-	-	-	-	-	-	-	238,477
	-	1,144	-	1,144	-	-	-	-	-
	-	236,420	-	236,420	-	-	-	-	-
	-	-	-	-	-	-	115	291	-
	-	-	-	-	-	-	-	-	307

*: Before confluence of Mukuvizi River

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

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;
BOD concentration of intake water;
Concentrated BOD load;

45,000 m³/day
1.2 mg/l
1.9 kg/day
(Seke Dam, Av
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.
※According to "9-4-2F", Pollution Load reached to C_{L2} is
And according to "9-5-4F", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).
Therefore pollution load of Water Treatment Works reach to Manyame river is
402 *0.76 = 305kg/day

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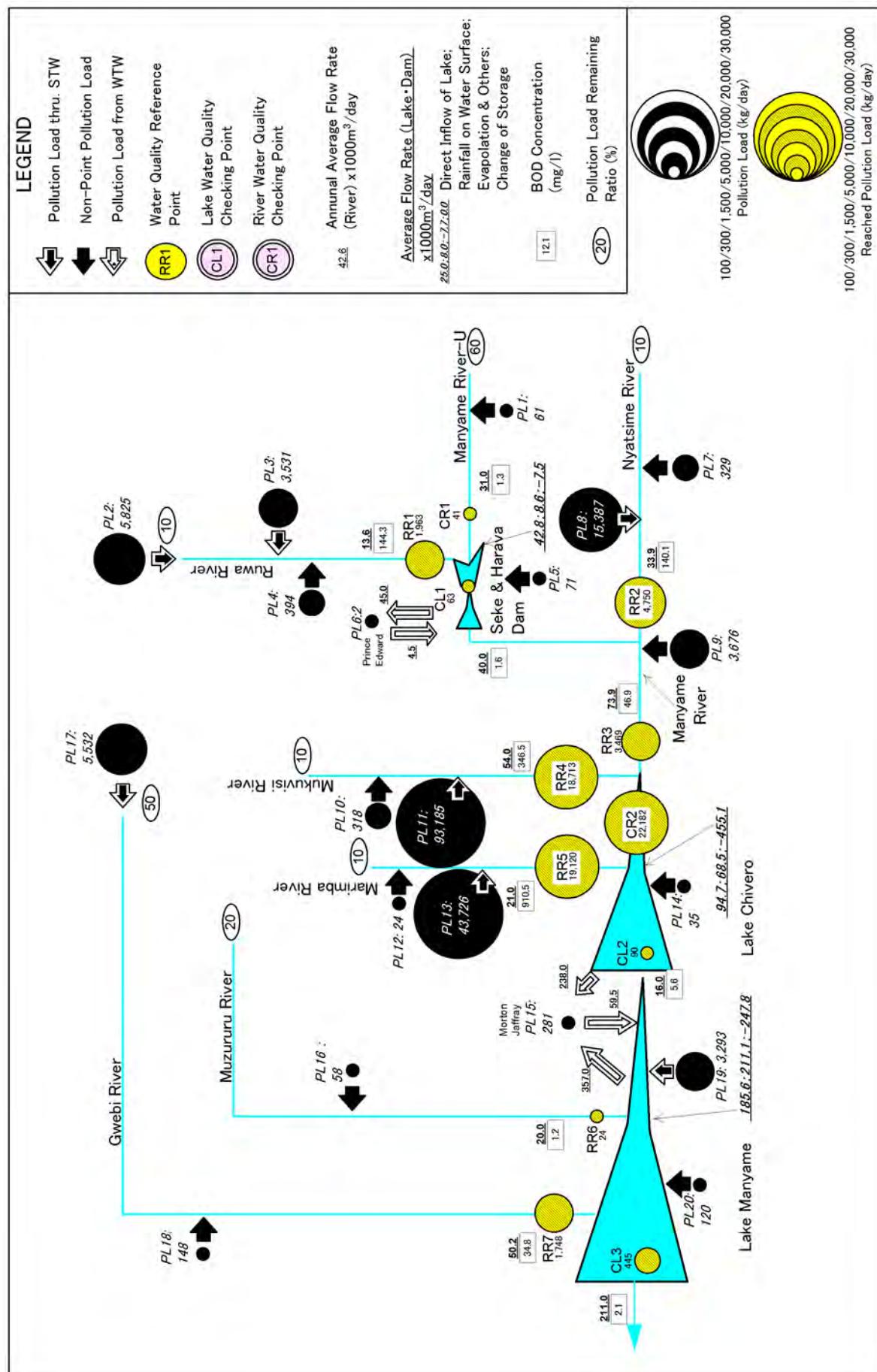


Figure A6.4.1 Pollution Run-off Model for Future Water Pollution Analysis (BOD, 2020)

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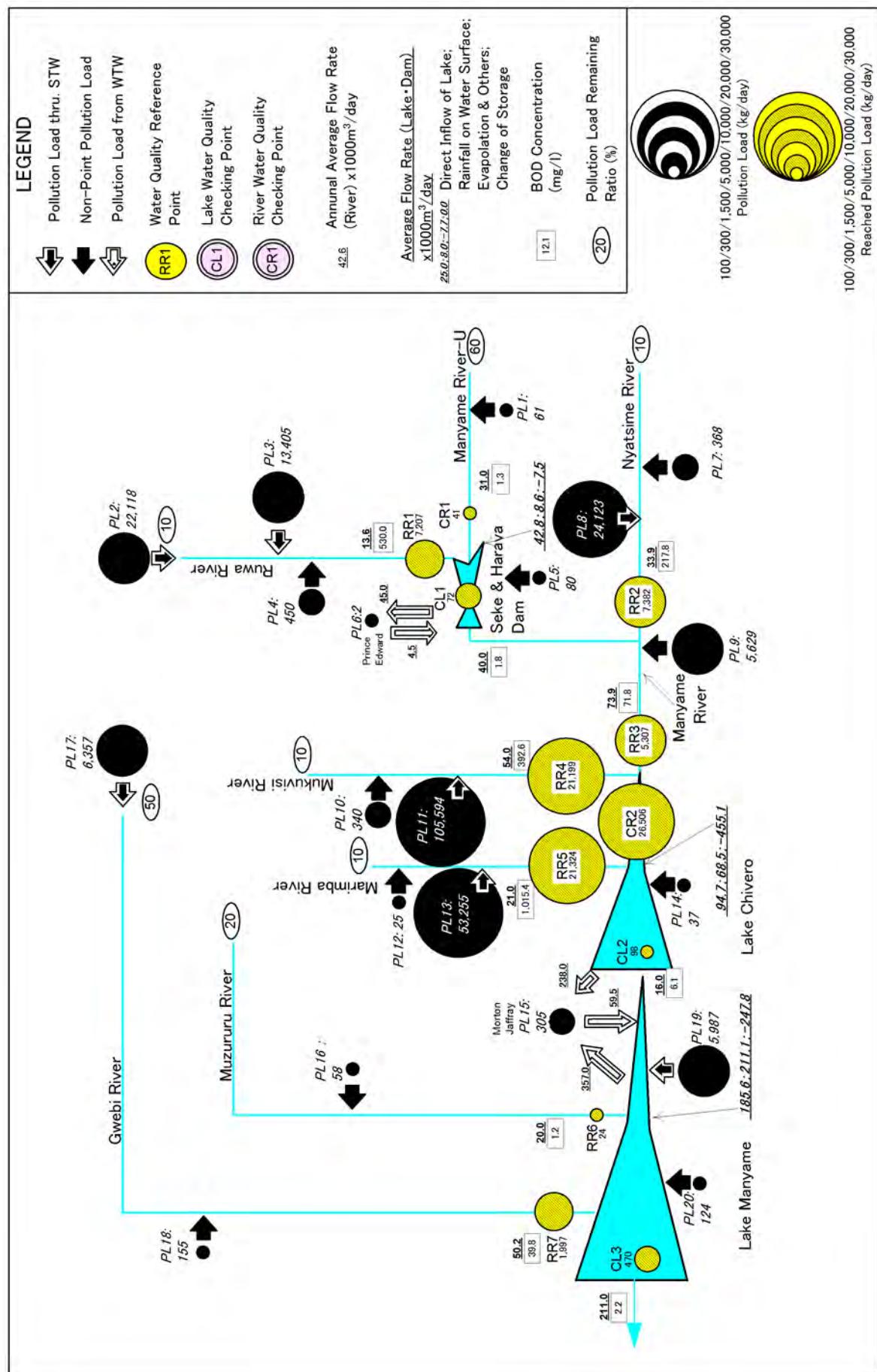


Figure A6.4.2 Pollution Run-off Model for Future Water Pollution Analysis (BOD, 2030)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Dry Season (1000* ³ m ³ /d)	Conc. (mg/L)
C_{R1}	1 Manyame R (Upstream)	$^{i}PL1$ $^{i}PL1'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	25 36		
		$^{i}C_{R1}'$ $(C_{R1})'$ $^{i}NP_{CR1}$	$C_{R1}' + NP_{CR1}$ $PL1 * 0.2$ $PL1'$	41 5 36	31.0	1.3
R_{R1}	2 Ruwa River	$^{i}PL2$ $^{i}PL3$ $^{i}PL4$ $^{i}PL4'$	Pollution Loading through STW Pollution Loading through STW Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	5,825 3,531 378 16		
		$^{i}R_{R1}$ $^{i}R_{R1}'$ $^{i}NP_{RR1}$	$R_{R1}' + NP_{RR1}$ $(PL2 + PL3 * 0.1 + PL4 * 0.2)$ $PL4'$	1,963 1,947 16	13.6	144.3
C_{L1} ($C_{R1} + R_{R1} + \alpha$)	3 Seke & Haraya Dams	$^{i}PL5$ $^{i}PL5'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	64 7		
		$^{i}C_{L1}$ $^{i}C_{L1}'$ $^{i}NP_{CL1}$	$C_{L1}' + NP_{CL1} + NP_{CL1}$ $(C_{R1}' + R_{R1}' + PL5) * Self Purification Coefficient$ $NP_{CL1} + NP_{RR1} + PL5'$	63 4 59	40.0	1.6
R_{R2}	4 Nyatime River	$^{i}PL7$ $^{i}PL7'$ $^{i}PL8$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STW	279 50 15,387		
		$^{i}R_{R2}$ $^{i}R_{R2}'$ $^{i}NP_{RR2}$	$R_{R2}' + NP_{RR2}$ $PL7 * 0.3 + PL8$ $PL7$	4,750 4,700 50	33.9	140.1
R_{R4}	5 Mukurisi River	$^{i}PL10$ $^{i}PL10'$ $^{i}PL11$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STW	303 15 93,185		
		$^{i}R_{R4}$ $^{i}R_{R4}'$ $^{i}NP_{RR4}$	$R_{R4}' + NP_{RR4}$ $PL10 * 0.2 + PL11$ $PL10'$	18,713 18,698 15	54.0	346.5
R_{R3} ($C_{L1} + R_{R2} + \alpha$)	6 Manyame R (Downstream)	$^{i}PL6$ $^{i}PL9$ $^{i}PL9'$	Pollution Loading from Prince Edward WTW Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2 3,665 11		
		$^{i}R_{R3}$ $^{i}R_{R3}'$ $^{i}STW/NP_{RR3}$	$R_{R3}' + NP_{RR3}$ $(C_{L1}' + R_{R2}') from STW + (C_{L1}' + R_{R2}') + PL9 from Unsewered, Livestock * 0.4$ $NP_{CL1} + NP_{RR2} + PL6 + PL9'$	3,469 3,347 122	73.9	46.9

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.3 Concentrated Population Load by Sub-basin (BOD, Dry Season, 2020) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Dry Season (1000*m³/d)	Conc. (mg/L)
C_{R2} ($R_{R3} + R_{R4}$)		C_{R2} C_{R2}' $NP_{C_{R2}}$	$C_{R2}' + NP_{C_{R2}}$ $R_{R3}' + R_{R4}'$ $NP_{R3} + NP_{R4}$	22,182 22,045 137	21.0	6.5
R_{R5}	7 Marimba River	PL12 PL12' PL13	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STW	4 20 47,746		
		R_{R5} R_{R5}' NP_{R5}	$R_{R5} + PL13$ $PL12*0.4 + PL13$ $PL12'$	19,120 19,100 20	21.0	910.5
C_{L2} ($C_{R2} + R_{R5} + \alpha$)	8 Lake Chivero	PL14 PL14'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	19 16		
		C_{L2} C_{L2}' $NP_{C_{L2}}$	$C_{L2}' + NP_{C_{L2}}$ $(C_{R2} + R_{R5} + PL14)*Self Purification Coefficient * 0.243$ $(NP_{C_{R2}} + NP_{R5} + PL14) * 0.243$	90 48 42	16.0	5.6
R_{R6}	9 Muzururu River	PL16 PL16'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	38 20		
		R_{R6} R_{R6}' NP_{R6}	$R_{R6}' + NP_{R6}$ $PL16*0.1$ $PL16'$	24 4 20	20.0	1.2
R_{R7}	10 Gwebi River	PL17 PL18 PL18'	Pollution Loading through STW Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	5,532 86 62		
		R_{R7} R_{R7}' NP_{R7}	$R_{R7}' + NP_{R7}$ $PL17 + PL18*0.3$ $PL18'$	1,748 1,686 62	50.2	34.8
C_{L3} ($C_{L2} + R_{R6}$ + $R_{R7} + \alpha$)	11 Lake Manyame	PL15 PL19 PL20 PL20'	Pollution Loading from Morton JaffrayWTW Pollution Loading through STW Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	281 3,211 82 38		
		C_{L3} C_{L3}' $NP_{C_{L3}}$	$C_{L3}' + NP_{R7}$ $(C_{L2} + R_{R6}' + R_{R7}' + PL19 + PL20)*Self Purification Coefficient$ $NP_{C_{L2}} + NP_{R6} + NP_{R7} + PL15 + PL20$	445 2 443	211.0	2.1

※Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.3 Concentrated Population Load by Sub-basin (BOD, Dry Season, 2020) (2/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Dry Season (1000*m ³ /d)	Cone. (mg/L)
C _{R1}	1 Manyame R (Upstream)	PL1 PL1'	Non point Pollution Loading (Unsewered, Livestock)	27		
		$C_{R1}' + NP_{R1}$ $PL1 * 0.2$ $PL1'$		36		
R _{R1}	2 Ruwa River	PL2 PL3 PL4 PL4'	Pollution Loading through STP	22,118		
		$R_{R1}' + NP_{R1}$ $(PL2 + PL3 + PL4) * 0.2$ $PL4'$	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	13,405 434 16		
C _{R2} $(C_{R1} + R_{R1} + \alpha)$	3 Seke & Harava Dams	PL5 PL5' C _{R1} ' C _{R1} ' NP _{C1}	Non point Pollution Loading (Unsewered, Livestock)	73		
		$C_{R1}' + NP_{C1} + NP_{C1}'$ $(C_{R1}' + NP_{C1}) * PL5'$ $NP_{C1} + NP_{R1} + PL5'$	Non point Pollution Loading (Natural Pollution)	7		
R _{R2}	4 Nyatsme River	PL7 PL7' PL8 R _{R2} R _{R2} ' R _{R2} ' NP _{R2}	Pollution Loading through STP	72		
		$R_{R2}' + NP_{R2}$ $(PL7 + PL8) * 0.3$ $PL7'$	Non point Pollution Loading (Natural Pollution) Non point Pollution Loading (Natural Pollution)	13 59	40.0	1.8
R _{R3}	5 IMukurwa River	PL10 PL10' PL11 R _{R3} R _{R3} ' R _{R3} ' NP _{R3}	Pollution Loading through STP	318		
		$R_{R3}' + NP_{R3}$ $(PL10 + PL11) * 0.2$ $PL10'$	Non point Pollution Loading (Natural Pollution) Non point Pollution Loading (Natural Pollution)	50 24,123 30	7,382	33.9
R _{R4}	6 Manyame R (Downstream)	PL16 PL9 PL9' R _{R3} * R _{R3} * NP _{R3}	Pollution Loading from Prince Edward WTP	325		
		$R_{R3}* + NP_{R3}$ $(C_{R1}' + R_{R2}) * 0.4$ $NP_{C1} + NP_{R2} + PL6 + PL9$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	15 105,594 15	54.0	392.6

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.4 Concentrated Population Load by Sub-basin (BOD, Dry Season, 2030) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Dry Season (1000*m ³ .d)	Conc. (mg/L)
C_{R2} ($R_{R3}+R_{R4}$)		C_{R2} C_{R2}' NP_{CR2}	$C_{R2}' + NP_{CL2}$ $R_{R3}' + R_{R4}'$ $NP_{RR3} + NP_{RR4}$	26,506 26,369 137	21.0	6.5
R_{R5}	7 Marininha River	PL12 PL12' PL13 R_{RS} R_{RS}' NP_{RR5}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP $R_{RS} + PL13$ $PL12 + PL13$ $PL12'$	5 20 53,255 21,324 21,304 20		
C_{L2} ($C_{R2}+R_{R5}+\alpha$)	8 Lake Chivero	PL14 PL14' C_{L2} C_{L2}' NP_{CL2}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $C_{L2}' + NP_{CL2}$ $(C_{R2} + R_{R5} + PL14) * Self-Purification Coefficient * 0.243$ $NP_{CR2} + NP_{RS5} + PL14 * 0.243$	98 56 42	21.0	1015.4
R_{R6}	9 Muzumuri River	PL16 PL16' R_{R6} R_{R6}' NP_{RR6}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $R_{R6}' + NP_{RR6}$ $PL16 * 0.1$ $PL16'$	41 24 4 20	16.0	6.1
R_{R7}	10 Gwebi River	PL17 PL17' PL18 R_{R7} R_{R7}' NP_{RR7}	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $R_{R7}' + NP_{RR7}$ $(PL17 + PL18) * 0.3$ $PL18$	6,357 93 62 1,997 1,935 62	20.0	1.2
C_{L3} ($C_{L2}+R_{R6}$ $+R_{R7}+\alpha$)	11 Lake Manyame	PL15 PL15' PL19 PL20 PL20' C_{L3} C_{L3}' NP_{CL7}	Pollution Loading from Morton Jaffray WTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $C_{L3}' + NP_{RR7}$ $(C_{L2}' + R_{R6}' + PL19 + PL20) * Self-Purification Coefficient$ $NP_{CL2} + NP_{RR6} + NP_{RR7} + PL15 + PL20$	305 5,987 86 38 470 3 467	50.2	2.2

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.4 Concentrated Population Load by Sub-basin (BOD, Dry Season, 2030) (2/2)

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Table A6.4.10 Reached Pollution Load by Sub-basin by Pollution (COD, 2020, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial Unsewered**	Livestock	Natural Pollution	Water Treatment Works***	Total
		Sewered	Unsewered	Total					
C _{R1}	1 Manyame R (Upstream)	-	30	30	-	257	541	-	828
R _{R1}	2 Ruwa River	23,190	746	23,936	-	130	231	-	24,297
C _{L1}	3 Seke & Harava Dams	-	121	121	-	100	108	-	329
R _{R2}	4 Nyatsime River	31,201	523	31,724	-	411	735	-	32,871
R _{R4}	5 Mukuvizi River	203,032	293	203,325	385	35	217	-	203,962
C _{R2} R _{R3} *	6 Manyame R. (Downstream)	7,267	58	7,325	-	79	156	34	7,595
R _{R5}	7 Marimba River	100,731	7	100,738	-	33	297	-	101,068
C _{L2}	8 Lake Chivero	-	28	28	-	133	240	-	401
R _{R6}	9 Muzunuru River	-	36	36	-	502	292	-	830
R _{R7}	10 Gwebi River	11,064	93	11,157	-	1,017	914	-	13,088
C _{L3}	11 Lake Manyame	7,036	55	7,091	140	214	556	2,267	10,268
Grand Total		383,521	1,991	385,512	525	2,911	4,288	2,301	395,537

*: Before confluence of Mukuvizi River

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

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;

COD concentration of intake water;

Reached COD load;

45,000 m³/day
20.63 mg/l
34 kg/day

(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

※According to "9-4-2FI", Pollution Load reached to C_{L2} is

2,982 kg/day

And according to "9-5-4FI", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate). Therefore pollution load of Water Treatment Works reach to Manyame river is

2,982 *0.76 =

2,267kg/day

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Table A6.4.11 Reached Pollution Load by Sub-basin by Pollution (COD, 2030, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage				Industrial	Natural Pollution	Water Treatment Works***	Total
		Sewered	Unsewered	Total	Unsewered**				
C _{R1}	1 Manyame R (Upstream)	-	35	35	-	257	541	-	833
R _{R1}	2 Ruwa River	88,691	858	89,549	-	130	231	-	89,909
C _{L1}	3 Seke & Harava Dams	-	139	139	-	100	108	-	347
R _{R2}	4 Nyatsime River	51,524	601	52,125	-	411	735	-	53,272
R _{R4}	5 Mukuvizi River	229,614	337	229,951	385	35	217	-	230,588
C _{R2}	R _{R3} * 6 Manyame R. (Downstream)	11,781	67	11,848	-	79	156	34	12,118
R _{R5}	7 Marimba River	111,750	8	111,758	-	33	297	-	112,088
C _{L2}	8 Lake Chivero	-	32	32	-	133	240	-	405
R _{R6}	9 Mizururu River	-	42	42	-	502	292	-	836
R _{R7}	10 Gwebi River	12,714	107	12,821	-	1,017	914	-	14,752
C _{L3}	11 Lake Manyame	15,243	64	15,307	140	214	556	2,445	18,661
	Grand Total	521,317	2,288	523,605	525	2,911	4,288	2,479	533,808

*: Before confluence of Mukuvizi River

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

***. Pollution load of Water Treatment Works;
Prince Edward WTW;
Morton Jaffray WTW;

Amount of water intake;
COD concentration of intake water;
Reaced COD load;

45,000 m³/day
20.63 mg/l
34 kg/day

(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from M1 WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

※According to "9-4-2F", Pollution Load reached to C_{1,2} is

3,217 kg/day

And according to "9-5-4F", flow rate from Lake Chivero to M1 WTW is 238,000(76% of total flow rate).

Therefore pollution load of Water Treatment Works reach to Manyame river is

3,217 * 0.76 =

2,445kg/day

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc (mg/L)
C_{R1}	1 Manyme R (Upstream) PL1 PL1'	 	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	287 541	-	-
	C_{R1}'	$C_{R1}' + NP_{C1}$		598	-	-
		$PL1*0.2$		57	174.0	3.4
		$PL1'$		541	-	-
R_{k1}	2 Ruwa River PL2 PL3 PL4 PL4'	 	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	14,439 8,751 876 231	-	-
	R_{k1}'	$R_{k1}' + NP_{R1}$		5,044	-	-
		$(PL2 + PL3 + PL4)*0.2$		4,813	72.8	69.3
		$PL4'$		231	-	-
C_{L1} $(C_{R1} + R_{R1} + \alpha)$	3 Seke & Harava Dans PL5 PL5'	 	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	221 108	-	-
	C_{L1}'	$C_{L1}' + NP_{C1} + NP_{C1}$		889	-	-
	C_{L1}'	$(C_{R1}' + R_{R1}' + PL5)*Self Purification Coefficient$		9	249.4	3.6
		$NP_{C1} + NP_{R1} + PL5'$		880	-	-
R_{k2}	4 Nyatsime River PL7 PL7' PL8 R _{k2} R _{k2} ' NP _{R2}	 	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP R _{k2} ' + NP _{R2} $(PL7 + PL8)*0.3$ PL7'	934 735 31,201 10,376 9,641 735	-	-
				163.2	63.6	-
R_{k4}	5 Mukunisi River PL10 PL10' PL11 R _{k4} R _{k4} ' NP _{R4}	 	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP R _{k4} ' + NP _{R4} $(PL10 + PL11)*0.2$ PL10'	714 217 203,032 40,966 40,749 217	-	-
				191.4	-	-
R_{k3} $(C_{L1} + R_{R2} + \alpha)$	6 Manyme R (Downstream) PL6 PL9 PL9'	 	Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	34 7,404 156	-	-
	R_{k3}'	$R_{k3}' + NP_{R3}$		8,628	-	-
	R_{k3}'	$(C_{L1}' + R_{R2}' + PL9)*0.4$		6,822	516.0	16.7
		$NP_{C1} + NP_{R2} + PL6 + PL9'$		1,806	-	-

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.5 Concentrated Population Load by Sub-basin (COD, Annual, 2020) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m ³ /d)	Conc. (mg/L)
C_{R2} ($R_{R3} + R_{R4}$)		C_{R2}' C_{R2}' NP_{RR2}	$C_{R2}' + NP_{C12}$ $R_{R3}' + R_{R4}'$ $NP_{R3} + NP_{R4}$	49,593 47,571 2,023	730.0	67.9
R_{RS}	7 Marinba River	PL12 PL12' PL13	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	40 297 100,731		
		R_{RS}' $R_{RS}'^*$ NP_{RRS}	$R_{RS}' + PL13$ $PL12 + PL13$ $PL12'$	40,605 40,308 297	131.0	310.0
C_{12} ($C_{R2} + R_{RS} + \alpha$)	8 Lake Chivero	PL14 PL14'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	161 240		
		C_{12}' C_{12}' NP_{C12}	$C_{12}' + NP_{C12}$ $(C_{R2}' + R_{RS}') * PL14 * Self-Purification Coefficient * 0.243$ $NP_{C2} + NP_{RS} + PL14' * 0.243$	725 103 622	76.5	9.5
	※ "0.243" is the ratio of volume to Lake Manyame River from Lake Chivero (Rest of volume heads to WTP).					
R_{R6}	9 Muzaruro River	PL16 PL16'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	538 292		
		R_{R6}' R_{R6}' NP_{RR6}	$R_{R6}' + NP_{R6}$ $PL16 * 0.1$ $PL16'$	346 54 292	113.9	3.0
R_{R7}	10 Gwebi River	PL17 PL18 PL18'	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	11,064 1,110 914		
		R_{R7}' $S1W/NP_{RR7}$	$R_{R7}' + NP_{R7}$ $(PL17 / PL18) * 0.3$ $PL18'$	4,566 3,652 914	282.5	16.2
C_{13} ($C_{L2} + R_{R6}$ + $R_{R7} + \alpha$)	11 Lake Manyame	PL15 PL19 PL20 PL20'	Pollution Loading from Morton Jaffray WTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2,267 7,036 409 556		
		C_{L3}' C_{L3}' $S1W/NP_{C13}$	$C_{L3}' + NP_{R7}$ $(C_{L2}' + R_{R6}' + R_{R7}' + PL19 + PL20) * Self-Purification Coefficient$ $NP_{C12} + NP_{R6} + NP_{R7} + PL15 + PL20$	4,655 4 4,651	261.8	17.8

※ Purification coefficient of rivers and lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.
 ※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.5 Concentrated Population Load by Sub-basin (COD, Annual, 2020) (2/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR. Annual (1000*m³/d)	Conc. (mg/L)
C_{R1}	1 Manayame R (Upstream)	'PL1 'PL1' C_{R1} ' C_{R1}' 'NP_{R1}'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	292 541		
			$C_{R1}' + NP_{C_{R1}}$ $PL1 * 0.2$ $PL1'$	599 58 541	174.0	3.4
R_{R1}	2 Ruwa River	'PL2 'PL3 'PL4 'PL4' R_{R1} ' R_{R1}' 'NP_{R1}'	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	55,223 33,468 988 231		
			$R_{R1}' + NP_{R1}$ $(PL2 + PL3 + PL4) * 0.2$ $PL4'$	18,167 17,936 231	72.8	249.5
C_{L1} ($C_{R1} + R_{R1} + \alpha$)	3 Seké & Harava Dams	'PL5 'PL5' C_{L1} ' C_{L1}' 'NP_{C_{L1}}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	239 108		
			$C_{L1}' + NP_{C_{R1}} + NP_{C_{L1}}$ $(C_{R1} + R_{R1} + PL5) * Self Purification Coefficient$ $NP_{R1} + NP_{R1} + PL5'$	913 33 880	249.4	3.7
R_{R2}	4 Nyatsine River	'PL7 'PL7' 'PL8 R_{R2} ' R_{R2}' 'NP_{R2}'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	1,012 735 51,524		
			$R_{R2}' + NP_{R2}$ $(PL7 + PL8) * 0.3$ $PL7'$	16,496 15,761 735	163.2	101.1
R_{R4}	5 Mukuvsi River	'PL10 'PL10' 'PL11 R_{R4} ' R_{R4}' 'NP_{R84}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	757 217 229,614		
			$R_{R4}' + NP_{R84}$ $(PL10 + PL11) * 0.2$ $PL10'$	46,291 46,074 217	214.0	216.3
R_{R3} ($C_{L1} + R_{R2} + \alpha$)	6 Manayame R (Downstream)	'PL6 'PL9 'PL9' R_{R3} ' R_{R3}' 'NP_{R83}	Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	34 11,927 156		
			$R_{R3}' + NP_{R83}$ $(C_{L1} + R_{R2} + PL9) * 0.4$ $NP_{C_{L1}} + NP_{R82} + PL6 + PL9$	12,894 11,088 1,806	516.0	25.0

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewage", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.6 Concentrated Population Load by Sub-basin (COD, Annual, 2030) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R2} ($R_{R3}+R_{R4}$)		C_{R2} $ C_{R2}'$ $ NP_{CL2}$	$C_{R2}' + NP_{CL2}$ $R_{R3}'+R_{R4}'$ $NP_{R3}+NP_{R4}$	59,185 57,163 2,023	730.0	81.1
R_{R5}	7 Marimba River	$ PL12$ $ PL12'$ $ PL13$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	41 297 111,750		
		R_{R6} $ R_{R6}'$ $ NP_{R6S}$	$R_{R6}' + PL13$ $PL12 + PL13$ $PL12'$	45,013 44,716 297	131.0	343.6
C_{L2} ($C_{R2}+R_{R5}+\alpha$)	8 Lake Chivoro	$ PL14$ $ PL14'$ $ C_{L2}$ $ C_{L2}'$ $ NP_{CL2}$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $C_{L2}' + NP_{CL2}$ ($C_{R2}'+R_{R5}' + PL14$)*Self-Purification Coefficient* 0.243 $NP_{CL2} + NP_{R6} + PL14' * 0.243$	165 240 782 160 622		
			※ "0.243" is the ratio of volume to Lake Manyame River from Lake Chivoro (Rest of volume heads to WTP).			
R_{R6}	9 Muzururu River	$ PL16$ $ PL16$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	544 292		
		R_{R6} $ R_{R6}'$ $ NP_{R6S}$	$R_{R6} + NP_{R6}$ $PL16*0.1$ $PL16$	347 54 292	113.9	3.0
R_{R7}	10 Gwebi River	$ PL17$ $ PL18$ $ PL18'$	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	12,714 1,124 914		
		R_{R7} $ R_{R7}'$ $ NP_{R7}$	$R_{R7} + NP_{R7}$ ($PL17 + PL18$)*0.3 $PL18'$	5,066 4,151 914	282.5	17.9
C_{L3} ($C_{L2}+R_{R6}$ $+R_{R7}+\alpha$)	11 Lake Manyame	$ PL15$ $ PL19$ $ PL20$ $ PL20'$	Pollution Loading from Morton JaffrayWTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2,445 15,243 417 556		
		C_{L3} $ C_{L3}'$ $ NP_{CL3}$	$C_{L3}' + NP_{R7}$ ($C_{L2}' + R_{R6}' + R_{R7}' + PL19 + PL20$)*Self-Purification Coefficient $NP_{CL2} + NP_{R6} + NP_{R7} + PL15 + PL20'$	4,836 7 4,829	261.8	18.5

※ Purification coefficient of rivers and lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.
 ※ Purification coefficient of lakes affects the pollution quantity of Natural Pollution Figure
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.6 Concentrated Population Load by Sub-basin (COD, Annual, 2030) (2/2)

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Table A6.4.12 Reached Pollution Load by Sub-basin by Pollution (T-N, 2020, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial	Natural Pollution	Water Treatment Works***	Total
		Sewered	Unsewered	Total				
C _{R1}	1 Manyame R (Upstream)	-	4	4	-	71	566	-
R _{R1}	2 Ruwa River	2,166	93	2,259	-	35	242	-
C _{L1}	3 Seke & Haraya Dams	-	15	15	-	29	113	-
R _{R2}	4 Nyatsime River	3,626	65	3,691	-	119	769	-
R _{R4}	5 Mukuvisi River	16,666	37	16,703	8	9	227	-
C _{R2}	R _{R3} * 6 Manyame R. (Downstream)	908	7	915	-	22	164	1
R _{R5}	7 Marinhiba River	9,873	1	9,874	-	9	311	-
C _{L2}	8 Lake Chivero	-	3	3	-	37	251	-
R _{R6}	9 Muzururu River	-	5	5	-	132	306	-
R _{R7}	10 Gwebi River	1,438	12	1,450	-	264	956	-
C _{L3}	11 Lake Manyame	745	7	752	6	59	582	2,168
	Grand Total	35,422	249	35,671	15	786	4,487	2,169
								43,128

*: Before confluence of Mukuvisi River

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

***: Pollution load of Water Treatment Works;
Prince Edward WTW;

Amount of water intake;
T-N concentration of intake water;
Concentrated T-N load;

45,000 m³/day
0.645 mg/l
1 kg/day

(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.
According to "9-4-2F", Pollution Load reached to C_{L2} is
And according to "9-5-4F", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).

Therefore pollution load of Water Treatment Works reach to Manyame river is
2,853 *0.76 = 2,168kg/day

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Table A6.4.13 Reached Pollution Load by Sub-basin by Pollution (T-N, 2030, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial		(kg/day) Total	
		Sewered	Unsewered	Total	Unsewered**	Livestock		
C _{R1}	1 Manyame R (Upstream)	-	4	4	-	71	566	-
R _{Se1}	2 Ruwa River	3,871	107	3,978	-	35	242	-
C _{L1}	3 Seke & Harava Dams	-	17	17	-	29	113	-
R _{Se2}	4 Nyatsime River	4,343	75	4,418	-	119	769	-
R _{Se4}	5 Mukuvizi River	19,073	42	19,115	8	9	227	-
C _{R2}	R _{Se3} * 6 Manyame R. (Downstream)	1,078	8	1,086	-	22	164	1
R _{Se5}	7 Marimba River	11,259	1	11,260	-	9	311	-
C _{L2}	8 Lake Chivero	-	4	4	-	37	251	-
R _{Se6}	9 Muzanaru River	-	5	5	-	132	306	-
R _{Se7}	10 Gwebi River	1,653	13	1,666	-	264	956	-
C _{L3}	11 Lake Manyame	1,185	8	1,193	6	59	582	2,286
	Grand Total	42,462	286	42,748	15	786	4,487	2,287
								50,323

*: Before confluence of Mukuvizi River

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

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;

T-N concentration of intake water;

Concentrated T-N load;

45,000 m³/day
0.645 mg/l
1 kg/day

(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

According to "9-4-2F", Pollution Load reached to C_{L2} is

3,008 kg/day

And according to "9-5-4F", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).

Therefore pollution load of Water Treatment Works reach to Manayne river is

3,008 * 0.76 =

2,286kg/day

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R1}	1 Manyame R (Upstream) PL1 PL1'	$ C_{R1} $ $ C_{R1}' $ $ NP_{CR1} $	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	75 566		
			$C_{R1}' + NP_{CR1}$ $PL1 * 0.2$ $PL1'$			
R_{R1}	2 Riwa River	$ PL2 $ $ PL3 $ $ PL4 $ $ PL4' $ $ R_{R1} $ $ R_{R1}' $ $ STW/NP_{RR1} $	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	1,349 817 128 242		
			$R_{R1}' + NP_{RR1}$ $(PL2 + PL3 + PL4) * 0.2$ $PL4'$			
C_{L1} $(C_{R1} + R_{R1} + \alpha)$	3 Seke & Haraya Dams $ PL5 $ $ PL5' $ $ C_{L1} $ $ C_{L1}' $ $ STW/NP_{CL1} $	$ PL5 $ $ PL5' $ $ C_{L1} $ $ C_{L1}' $ $ STW/NP_{CL1} $	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	44 113 1,036 115 921		
			$C_{L1}' + NP_{CL1}$ $(C_{R1} + R_{R1} + PL5) * Self-Purification Coefficient$ $NP_{CL1} + NP_{RR1} + PL5'$			
R_{R2}	4 N'zatsine River	$ PL7 $ $ PL7' $ $ PL8 $ $ R_{R2} $ $ R_{R2}' $ $ STW/NP_{RR2} $	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	184 769 3,626		
			$R_{R2}' + NP_{R2}$ $(PL7 + PL8) * 0.3$ $PL7$			
R_{R4}	5 Mukuvizi River	$ PL10 $ $ PL10' $ $ PL11 $ $ R_{R4} $ $ R_{R4}' $ $ STW/NP_{RR4} $	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	54 227 16,666		
			$R_{R4}' + NP_{R4}$ $(PL10 + PL11) * 0.2$ $PL10'$			
R_{R3} $(C_{L1} + R_{R2} + \alpha)$	6 Manyame R (Downstream) PL6 PL6' PL9 PL9' $ R_{R3} $ $ R_{R3}' $ $ STW/NP_{RR3} $	Non point Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	1 937 164 2,733 878 516.0			
			$R_{R3}' * NP_{RR3}$ $(C_{L1} + R_{R2} + PL9) * 0.4$ $NP_{CL1} + NP_{R2} + PL6 + PL9'$ NP_{RR3} $1,855$			

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".
 ※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.7 Concentrated Population Load by Sub-basin (T-N, Annual, 2020) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R2} ($R_{R3}+R_{R4}$)	C_{R2} C_{R2}' STW/NP C_{R2}		$C_{R2}' + NP_{C_{L2}}$ $R_{R3}+R_{R4}$ NP $R_{R3}+NP_{R_{R4}}$	6,304 4,222 2,082	730.0	8.6
R_{R5}	7 Marimba River	PL12 PL12' PL13	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	10 311 9,873		
		R_{R5} R_{R5}^* STW/NP R_{R5}	$R_{R5}' + PL13$ $PL12 + PL13$ PL12'		4,264 3,953 311	32.6
C_{L2} ($C_{R2}+R_{R5}+\alpha$)	8 Lake Chivero	PL14 PL14'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	40 251		
		C_{L2}' C_{L2}' STW/NP C_{L2}	$C_{L2}' + NP_{C_{L2}}$ $(C_{R2}+R_{R5}'+PL14)*Self-Purification Coefficient*\alpha/243$ NP $C_{R2}+NP_{R_{R5}}+PL14*\alpha/243$		693 51 642	9.1
	※"0.243" is the ratio of volum to Lake Manyame River from Lake Chivero (Rest of volum heads to WTP).					
R_{R6}	9 Muzurum River	PL16 PL16'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	137 306		
		R_{R6} R_{R6}' NP R_{R6}	$R_{R6}' + NP_{R_{R6}}$ $PL16*\alpha/1$ PL16'		320 14 306	2.8
R_{R7}	10 Igwebi River	PL17 PL18 PL18'	Pollution Loading through STP	1,438		
		R_{R7} R_{R7}' STW/NP R_{R7}	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	276 956		
			$R_{R7}'+ NP_{R_{R7}}$ $(PL17 + PL18)*\alpha/3$ PL18'	1,470 514 956		
C_{L3} ($C_{L2}+R_{R6}$ $+R_{R7}+\alpha$)	11 Lake Manyame	PL15 PL19 PL20 PL20'	Pollution Loading from Morton JaffrayWTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2,168 745 72 582		
		C_{L7}' C_{L7}' STW/NP C_{L7}	$C_{L7}' + NP_{R_{R7}}$ $(C_{L2}' + R_{R6}' + PL19' + PL20)*Self-Purification Coefficient$ NP $C_{L2}+NP_{R_{R6}}+NP_{R_{R7}}+PL15+PL20'$		4,685 30 4,655	17.9

※Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution"

Figure A6.4.7 Concentrated Population Load by Sub-basin (T-N, Annual, 2020) (2/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m ³ /d)	Conc. (mg/L)
C_{R1}	1 Manyane R (Upstream)	PL1 PL1'	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	75 566		
		C_{R1}'	$C_{R1}' + NP_{CR1}$			
		$[C_{RL}]'$	$PL1' * 0.2$			
		$[NP_{CR1}]'$	$PL1'$			
R_{R1}	2 Ruwa River	PL2 PL3 PL4 PL4' R_{R1}' R_{R1}' $[NP_{RR1}]'$	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	2,410 1,461 142 242		
		$R_{R1}' + NP_{R1}$	$R_{R1}' + NP_{R1}$			
		$(PL2 + PL3 + PL4) * 0.2$	$(PL2 + PL3 + PL4) * 0.2$	1,045 803	72.8	14.3
		$PL4'$	$PL4'$	242		
C_{L1} ($C_{R1} + R_{R1} + \alpha$)	3 Seke & Harava Dams	PL5 PL5 C_{L1}' C_{L1}' $[NP_{CL1}]'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	46 113		
		$C_{R1}' + NP_{CR1} + NP_{CL1}$	$(C_{R1}' + R_{R1}' + PL5) * Self-Purification Coefficient$	1,113 192	249.4	4.5
		$NP_{CR1} + NP_{R1}' + PL5'$	$NP_{CR1} + NP_{R1}' + PL5'$	921		
R_{R2}	4 Nyaisine River	PL7 PL7 PL8 R_{R2}' R_{R2}' $[NP_{R2}]'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	194 769 4,343		
		$R_{R2}' + NP_{R2}$	$R_{R2}' + NP_{R2}$	2,130 1,361	163.2	13.1
		$(PL7 + PL8) * 0.3$	$(PL7 + PL8) * 0.3$	PL7'	769	
R_{R4}	5 Mukuvsi River	PL10 PL10' PL11 R_{R4}' R_{R4}' $[NP_{R4}]'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	59 227 19,073		
		$R_{R4}' + NP_{R4}$	$R_{R4}' + NP_{R4}$	4,053 3,826	214.0	18.9
		$(PL10 + PL11) * 0.2$	$(PL10 + PL11) * 0.2$	PL10'	227	
R_{R3} ($C_{L1} + R_{R2} + \alpha$)	6 Manyane R (Downstream)	PL6 PL9 PL9' R_{R3}' R_{R3}' $[NP_{R3}]'$	Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	1 1,108 164		
		$R_{R3}' * NP_{R3}$	$R_{R3}' * NP_{R3}$	2,919 1,064	516.0	5.7
		$(C_{L1}' + R_{R2}' + PL9) * 0.4$	$(C_{L1}' + R_{R2}' + PL9) * 0.4$	$NP_{CL1} + NP_{R2} + PL6 + PL9$	1,855	

* Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

* Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

Figure A6.4.8 Concentrated Population Load by Sub-basin (T-N, Annual, 2030) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R2} $(R_{R3}+R_{R4})$	C_{R2}		$C_{R2}' + NP_{C_{L2}}$	6,973		
	C_{R2}'		$R_{R3} + R_{R4}'$	4,891	730.0	9.6
	NP_{R6e}		$NP_{R6e} + NP_{R6e}$	2,082		
R _{R5}	7 Marimba River	PL12	Non point Pollution Loading (Unsewered, Livestock)	10		
		PL12'	Non point Pollution Loading (Natural Pollution)	311		
		PL13	Pollution Loading through STP	11,259		
	R_{R6}		$R_{R6} + PL13$	4,819		
	R_{R6}^*		$PL12 + PL13$	4,508	131.0	36.8
	NP_{R6s}		$PL12'$	311		
C_{L2} $(C_{R2}+R_{R5}+u)$	18 Lake Chivero	PL14	Non point Pollution Loading (Unsewered, Livestock)	41		
		PL14'	Non point Pollution Loading (Natural Pollution)	251		
	C_{L2}		$C_{L2}' + NP_{C_{L2}}$	731		
	C_{L2}'		$(C_{R2}' + R_{R6}' + PL14)*Self Purification Coefficient * 0.243$	88	76.5	9.6
	$NP_{C_{L2}}$		$NP_{C_{R2}} + NP_{R6} + PL14' * 0.243$	642		
			※ "0.243" is the ratio of volume to Lake Manyame River from Lake Chivero (Rest of volume heads to WTP).			
R _{R6}	19 Muzururu River	PL16	Non point Pollution Loading (Unsewered, Livestock)	137		
		PL16'	Non point Pollution Loading (Natural Pollution)	306		
	R_{R6}'		$R_{R6}' + NP_{R6e}$	320		
	R_{R6}'		$PL16 * 0.1$	14	113.9	2.8
	NP_{R6e}		$PL16'$	306		
			Pollution Loading through STP			
R _{R7}	10 Gwebi River	PL17	Non point Pollution Loading (Unsewered, Livestock)	1,653		
		PL18	Non point Pollution Loading (Natural Pollution)	277		
		PL18'	Non point Pollution Loading (Natural Pollution)	956		
	R_{R7}'		$R_{R7}' + NP_{R7}$	1,535	282.5	5.4
	R_{R7}'		$(PL17 + PL18) * 0.3$	579		
	NP_{R7}		$PL18'$	956		
C_{L3} $(C_{L2}+R_{R6}+R_{R7}+u)$	11 Lake Manyame	PL15	Pollution Loading from Morton Jaffray WTP	2,286		
		PL19	Pollution Loading through STP	1,185		
	$NP_{C_{L3}}$		Non point Pollution Loading (Unsewered, Livestock)	73		
	$NP_{C_{L3}}$		Non point Pollution Loading (Natural Pollution)	582		
			$C_{L7}' + NP_{R7}$	4,814		
			$(C_{L2}' + R_{R6}' + R_{R7}' + PL19 + PL20) * Self Purification Coefficient$	42	261.8	18.4
			$NP_{C_{L2}} + NP_{R6e} + NP_{R7} + PL15 + PL20'$	4,773		

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".
 ※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.
 ※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.8 Concentrated Population Load by Sub-basin (T-N, Annual, 2030) (2/2)

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Table A6.4.14 Reached Pollution Load by Sub-basin by Pollution (T-P, 2020, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage		Industrial Unsewered**	Livestock	Natural Pollution	Water Treatment Works***	(kg/day) Total
		Sewered	Unsewered					
C _{R1}	1 Manyame R (Upstream)	-	0.4	0.4	-	11	47	- 58
R _{R1}	2 Ruwa River	246	10	256	-	6	20	- 282
C _{L1}	3 Seke & Harava Dams	-	2	2	-	4	9	- 15
R _{R2}	4 Nyatsime River	407	7	414	-	19	64	- 497
R _{R4}	5 Mukuvisi River	2,062	4	2,066	2	1	19	- 2,088
C _{R2}	6 Manyame R. (Downstream)	99	1	100	-	3	14	- 117
R _{R5}	7 Marimba River	1,152	0.1	1,152	-	1	26	- 1,179
C _{L2}	8 Lake Chivero	-	0.4	0.4	-	6	21	- 27
R _{R6}	9 Muzaruru River	-	0.5	0.5	-	23	25	- 48
R _{R7}	10 Gwebi River	155	1	156	-	47	80	- 283
C _{L3}	11 Lake Manyame	84	1	85	1	9	48	175 317
Grand Total		4,205	1	4,232	3	130	373	175 4,913

*. Before confluence of Mukuvisi River

**. Pollution load of industries in sewared area is counted as a part of domestic pollution load seweried area.

***. Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;

T-P concentration of intake water;

Concentrated T-P load;

45,000 m³/day
0.070 mg/l
0 kg/day

(Seke Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.
 According to "9-4-2Fl", Pollution Load reached to C_{1,2} is
 And according to "9-5-4Fl", flow rate from Lake Chivero to MI WTW is 238,000(76% of total flow rate).
 Therefore pollution load of Water Treatment Works reach to Manyame river is
 230 *0.76 = 175kg/day

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Table A6.4.15 Reached Pollution Load by Sub-basin by Pollution (T-P, 2030, Annual)

Water Quality Checking Points	Sub-basin	Domestic Sewage			Industrial	Natural Pollution	Water Treatment Works***	(kg/day) Total
		Sewered	Unsewered	Total				
C _{R1}	1 Manyame R (Upstream)	-	0.5	0.5	-	11	47	-
R _{R1}	2 Ruwa River	610	12	622	-	6	20	-
C _{L1}	3 Seke & Harava Dams	-	2	2	-	4	9	-
R _{R2}	4 Nyatsime River	559	8	567	-	19	64	-
R _{R4}	5 Mukuvizi River	2,351	5	2,356	2	1	19	-
C _{R2}	R _{R3} * 6 Manyame R (Downstream)	133	1	134	-	3	14	-
R _{R5}	7 Marimba River	1,303	0.1	1,303.1	-	1	26	-
C _{L2}	8 Lake Chivero	-	0.4	0.4	-	6	21	-
R _{R6}	9 Muzururu River	-	1	1	-	23	25	-
R _{R7}	10 Gwebi River	178	1	179	-	47	80	-
C _{L3}	11 Lake Manyame	146	1	147	1	9	48	179
	Grand Total	5,280	31	5,311	3	130	373	5,997

*: Before confluence of Mukuvizi River

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

***: Pollution load of Water Treatment Works;

Prince Edward WTW;

Amount of water intake;

T-P concentration of intake water;

Concentrated T-P load;

45,000 m³/day
0.070 mg/l
0 kg/day

(Seku Dam)
(to Manyame River (Downstream))

Morton Jaffray WTW;

Water Quality from MJ WTW to Lake Manyame is assumed that pollution loads come from only Lake Chivero.

According to "9-4-2FF", Pollution Load reached to C_{L2} is

236 kg/day

And according to "9-5-4FF", flow rate from Lake Chivero to MJ WTW is 238,000(76% of total flow rate).

Therefore pollution load of Water Treatment Works reach to Manyame river is

236 * 0.76 =

179kg/day

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	Sub-basin	PL.No	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)	
C_{R1}	1 Manyame R (Upstream)	PL1	Non point Pollution Loading (Unsewered, Livestock)	11			
		PL1'	Non point Pollution Loading (Natural Pollution)	47			
		C_{R1}'	$C_{R1}' + NP_{C_{R1}}$	49			
		$NP_{C_{R1}}$	$PL1 * 0.2$	2	174.0	0.3	
R_{R1}	2 Ruwa River	PL2	Pollution Loading through STP	153			
		PL3	Pollution Loading through STP	93			
		PL4	Non point Pollution Loading (Unsewered, Livestock)	16			
		PL4'	Non point Pollution Loading (Natural Pollution)	20			
C_{L1} $(C_{R1} + R_{R1} + \alpha)$	3 Seké & Harava Dams	PL5	Pollution Loading through STP	72			
		PL5'	Non point Pollution Loading (Unsewered, Livestock)	6			
		C_{L1}'	$C_{L1}' + NP_{C_{R1}} + NP_{C_{L1}}$	9			
		$NP_{C_{R1}} + PL5 * Self Purification Coefficient$	$(C_{R1} + R_{R1} + PL5) * Self Purification Coefficient$	84			
R_{R2}	4 Nyatisine River	PL7	Non point Pollution Loading (Unsewered, Livestock)	433			
		PL7'	Non point Pollution Loading (Natural Pollution)	64			
		PL8	Pollution Loading through STP	407			
		R_{R2}'	$R_{R2}' + NP_{R_{R2}}$	316			
R_{R4}	5 Mukwisi River	PL7	Non point Pollution Loading (Unsewered, Livestock)	252			
		PL7'	Non point Pollution Loading (Natural Pollution)	64			
		PL8	Pollution Loading through STP	163.2			
		R_{R4}'	$(PL7 + PL8) * 0.3$	1.9			
R_{R3} $(C_{L1} + R_{R2} + \alpha)$	6 Manyame R (Downstream)	PL10	Non point Pollution Loading (Unsewered, Livestock)	7			
		PL10'	Non point Pollution Loading (Natural Pollution)	19			
		PL11	Pollution Loading from Prince Edward WTP	2.062			
		R_{R3}'	$R_{R3}' + NP_{R_{R3}}$	433			
		R_{R3}'	$(PL10 + PL11) * 0.2$	414			
		$NP_{C_{L1}} + PL10$	$PL10'$	19			
		$NP_{R_{R2}} + PL11$					
		$NP_{R_{R3}}$					

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.9 Concentrated Population Load by Sub-basin (T-P, Annual, 2020) (1/2)

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	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R2} ($R_{S3}+R_{S4}$)		$ C_{R2}'$ $ C_{R2}'$ $ STW/NP_{R2}$	$C_{R2}' + NP_{C_{R2}}$ $R_{S3}' + R_{S4}'$ $NP_{R3} + NP_{R4}$	732 559 173	730.0	1.0
R_{S5}	7 Marimba River	$ PL12'$ $ PL12'$ $ PL13'$ $ R_{S6}'$ $ R_{S6}*'$ $ STW/NP_{R6}$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP $R_{S6}' + PL13$ $PL12 + PL13$ $PL12'$	1 26 1,152 487 461 26		
C_{L2} ($C_{R2}+R_{S5}+a$)	8 Lake Chivero	$ PL14'$ $ PL14'$ $ C_{L2}'$ $ C_{L2}'$ $ STW/NP_{C_{L2}}$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $C_{L2}' + NP_{C_{L2}}$ $(C_{R2}' + R_{S5}') + PL14) * Self Purification Coefficient * 0.243$ $NP_{C_{R2}} + NP_{R6} + PL14 * 0.243$	6 21 56 2 53	76.5	0.7
R_{S6}	9 Muzanuru River	$ PL16'$ $ PL16'$ $ R_{S6}'$ $ R_{S6}'$ $ NP_{R66}$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $R_{S6}' + NP_{R66}$ $PL16 * 0.1$ $PL16'$	23 25 27 2 25	113.9	0.2
R_{S7}	10 Gwebi River	$ PL17'$ $ PL18'$ $ PL18'$ $ R_{S7}'$ $ R_{S7}'$ $ STW/NP_{R77}$	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $R_{S7}' + NP_{R77}$ $(PL17 + PL18) * 0.3$ $PL18'$	155 48 80 141 61 80	282.5	0.5
C_{L3} ($C_{L2}+R_{S6}$ $+R_{R7}+a$)	11 Lake Manyame	$ PL15$ $ PL19$ $ PL20'$ $ C_{L3}'$ $ C_{L3}'$ $ STW/NP_{C_{L7}}$	Pollution Loading from Morton Jaffray WTP Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) $C_{L3}' + NP_{R77}$ $(C_{L2}' + R_{S6}' + R_{S7}' + PL20) * Self Purification Coefficient$ $NP_{C_{L2}} + NP_{R6} + NP_{R7} + PL15 + PL20'$	175 84 11 48 383 2	261.8	1.5

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock"

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.
※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.9 Concentrated Population Load by Sub-basin (T-P, Annual, 2020) (2/2)

APPENDIX 6

	Sub-basin	PL No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000*m³/d)	Conc. (mg/L)
C_{R1}	1 Manyame R (Upstream)	'PL1' + C_{RL} C_{RI} $ NP_{CR1} $	Non point Pollution Loading (Unsewered Livestock) Non point Pollution Loading (Natural Pollution)	11 47	-	-
		$C_{RL}' + NP_{CR1}$ $PL1 * 0.2$ $ NP_{CR1} $		49 2 47	174.0	0.3
R_{R1}	2 Ruwa River	'PL2' + $PL3$ + $PL4$ + $PL4'$ R_{R1}' $ R_{R1}' $ $ NP_{R1} $	Pollution Loading through STP Pollution Loading through STP Non point Pollution Loading (Unsewered Livestock) Non point Pollution Loading (Natural Pollution)	380 230 18 20	-	-
		$R_{R1}' + NP_{R1}$ $(PL2 + PL3 + PL4) * 0.2$ $PL4'$		146 126 20	72.8	2.0
C_{L1} ($C_{R1} + R_{R1} + \alpha$)	3 Seke & Haraya Dams	'PL5' + $PL5'$ C_{L1}' $ C_{L1}' $ $ NP_{CL1} $	Non point Pollution Loading (Unsewered Livestock) Non point Pollution Loading (Natural Pollution)	6 9	-	-
		$C_{L1}' + NP_{CR1} + NP_{CL1}$ $(C_{R1}' + R_{R1}' + PL5) * Self-Purification Coefficient$ $NP_{CR1} + NP_{R1} + PL5'$		95 19 76	249.4	0.4
R_{R2}	4 Nyasime River	'PL7' + $PL7'$ + $PL8$ $ R_{R2}' $ $ R_{R2}' $ $ NP_{RR2} $	Non point Pollution Loading (Unsewered Livestock) Non point Pollution Loading (Natural Pollution) Non point Pollution Loading (Natural Pollution)	27 64 559	-	-
		$R_{R2}' + NP_{R2}$ $(PL7 + PL8) * 0.3$ $PL7'$		240 176 64	163.2	1.5
R_{R4}	5 Mukawisi River	'PL10' + $PL10'$ + $PL11$ $ R_{R4}' $ $ R_{R4}' $ $ NP_{RR4} $	Non point Pollution Loading (Unsewered Livestock) Non point Pollution Loading (Natural Pollution) Non point Pollution Loading (Natural Pollution)	8 19 2,351	-	-
		$R_{R4}' + NP_{R4}$ $(PL10 + PL11) * 0.2$ $PL10$		491 472 19	214.0	2.3
R_{R3} ($C_{L1} + R_{R2} + \alpha$)	6 Manyame R (Downstream)	'PL6' + $PL9$ $ PL9' $ $ R_{R3}' $ $ R_{R3}' $ $ NP_{RR3} $	Pollution Loading from Prince Edward WTP Non point Pollution Loading (Unsewered Livestock) Non point Pollution Loading (Natural Pollution)	0 137 14	-	-
		$R_{R3}' * NP_{RR3}$ $(C_{L1}' + R_{R2}' + PL9) * 0.4$ $NP_{CL1} + NP_{R2} + PL6 + PL9'$		287 133 154	516.0	0.6

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution"Figure

Figure A6.4.10 Concentrated Population Load by Sub-basin (T-P, Annual, 2030) (1/2)

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	Sub-basin	Pl No.	Type of Loading	Quantity (kg/day)	FR, Annual (1000 ³ m ³ .d)	Conc. (mg/L)
C_{R2} ($R_{R3}+R_{R4}$)	$[C_{R2}]$ $[C_{R2}']$ $[NP_{R2}]$	$C_{R2}' + NP_{CL2}$ $R_{R3}' + R_{R4}'$ $NP_{R33} + NP_{R44}$		777 604 173	730.0	1.1
R_{R5}	7 Marimba River	$PL12$ $PL12'$ $PL13$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution) Pollution Loading through STP	1 26 1,303		
		R_{R5} R_{R5}^* NP_{R5}	$R_{R5} + PL13$ $PL12 + PL13$ $PL12'$	548 522 26	131.0	4.2
C_{L2} ($C_{R2}+R_{R5}+a$)	8 Lake Chivero	$PL14$ $PL14'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	6 21		
		$[C_{L2}]$ $[C_{L2}']$ $[NP_{CL2}]$	$C_{L2}' + NP_{CL2}$ $(C_{R2} + R_{R5} + PL14) * Self-Purification Coefficient * 0.243$ $NP_{R2} + NP_{R5} + PL14 * 0.243$	57 4 53	76.5	0.7
			※ "0.243" is the ratio of volume to Lake Manyame River from Lake Chivero (Rest of volume heads to WTP).			
R_{R6}	9 Muzururu River	$PL16$ $PL16'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	24 25		
		R_{R6} R_{R6}^* NP_{RR6}	$R_{R6} + NP_{R6}$ $PL16 * 0.1$ $PL16'$	27 2 25	113.9	0.2
R_{R7}	10 Gwebi River	$PL17$ $PL18$ $PL18'$	Pollution Loading through STP Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	178 48 80		
		R_{R7} R_{R7}^* NP_{RR7}	$R_{R7} + NP_{R7}$ $(PL17 + PL18) * 0.3$ $PL18'$	148 68 80	282.5	0.5
C_{L3} ($C_{L2}+R_{R6}$ $+R_{R7}+a$)	11 Lake Manyame	$PL15$ $PL19$	Pollution Loading from Morton Jaffray WTP Pollution Loading through STP	179 146		
		$PL20$ $PL20'$	Non point Pollution Loading (Unsewered, Livestock) Non point Pollution Loading (Natural Pollution)	11 48		
		C_{L3} C_{L3}^* NP_{CL3}	$C_{L3}' + NP_{R87}$ $(C_{L2} + R_{R6} + R_{R7} + PL19 + PL20) * Self-Purification Coefficient$ $NP_{CL2} + NP_{R86} + NP_{R87} + PL15 + PL20'$	389 3 386	261.8	1.5

※ Purification coefficient of rivers and lakes affects the pollution quantity of "Unsewered", "Livestock".

※ Purification coefficient of lakes affects the pollution quantity of STW effluent. However Purification Coefficient of rivers doesn't affect.

※ Purification coefficient of rivers and lakes doesn't affect the pollution quantity of "Natural Pollution" Figure

Figure A6.4.10 Concentrated Population Load by Sub-basin (T-P, Annual, 2030) (2/2)

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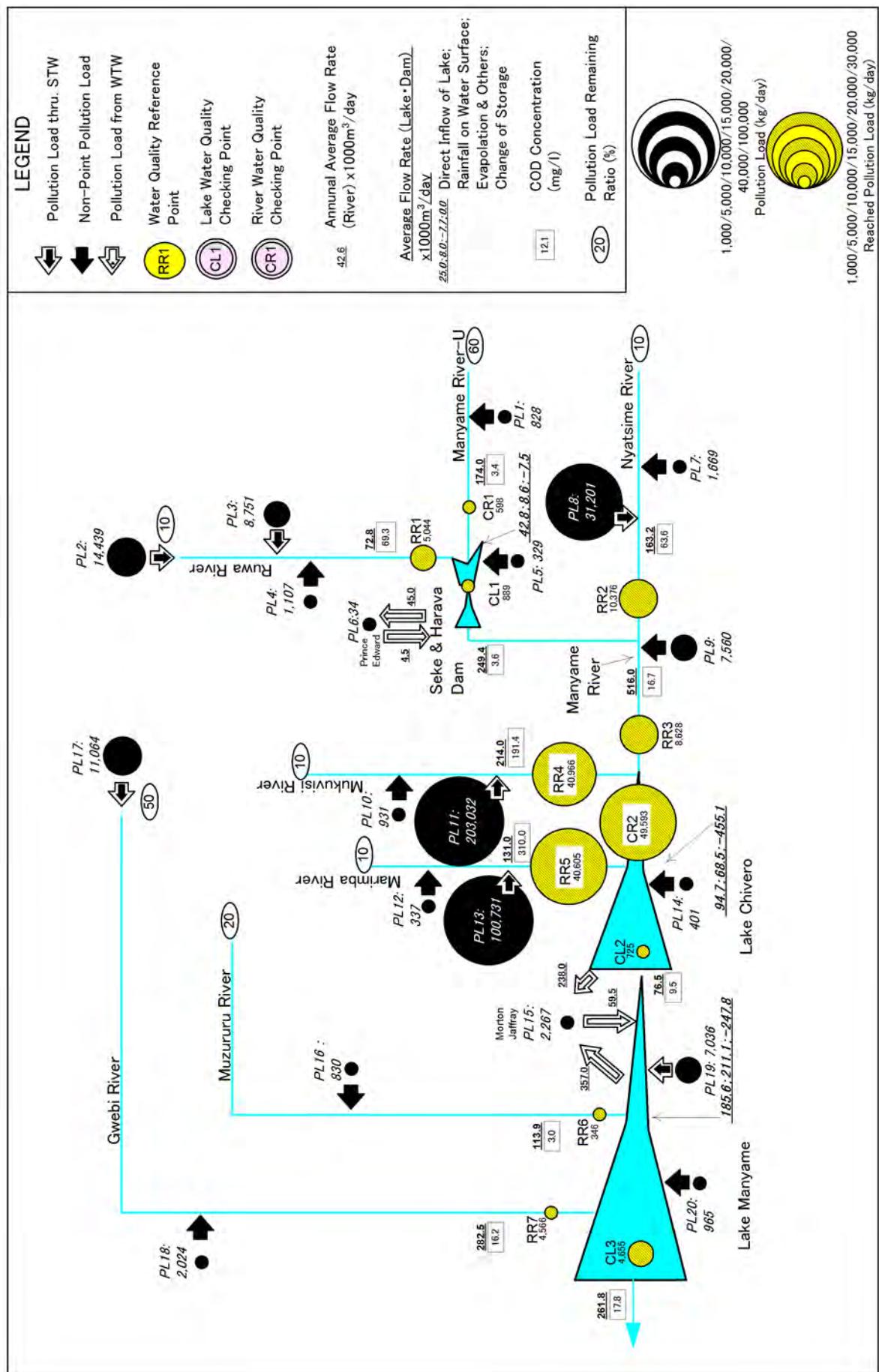


Figure A6.4.11 Pollution Run-off Model for Future Water Pollution Analysis (COD, 2020)

APPENDIX 6

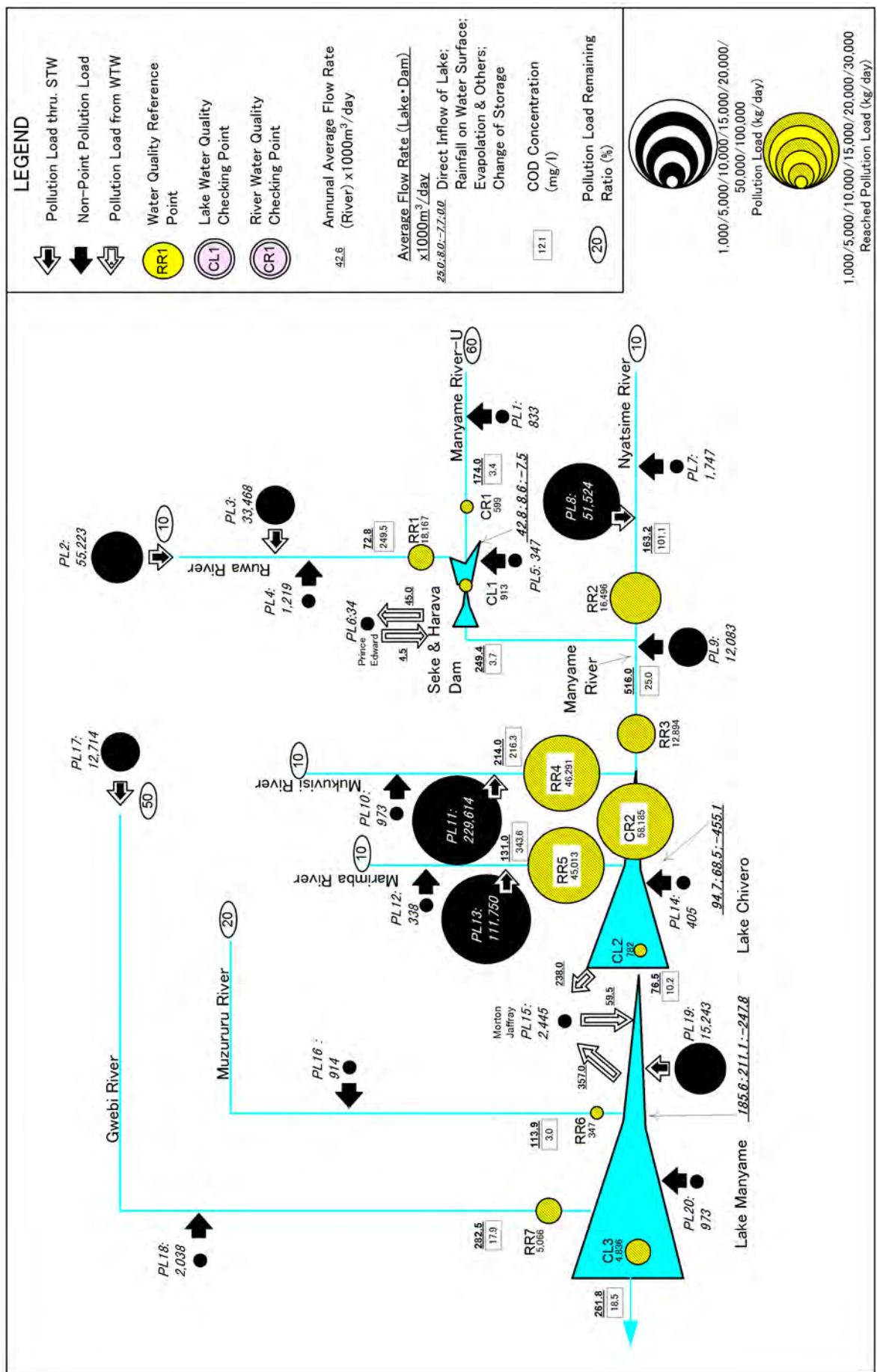


Figure A6.4.12 Pollution Run-off Model for Future Water Pollution Analysis (COD, 2030)

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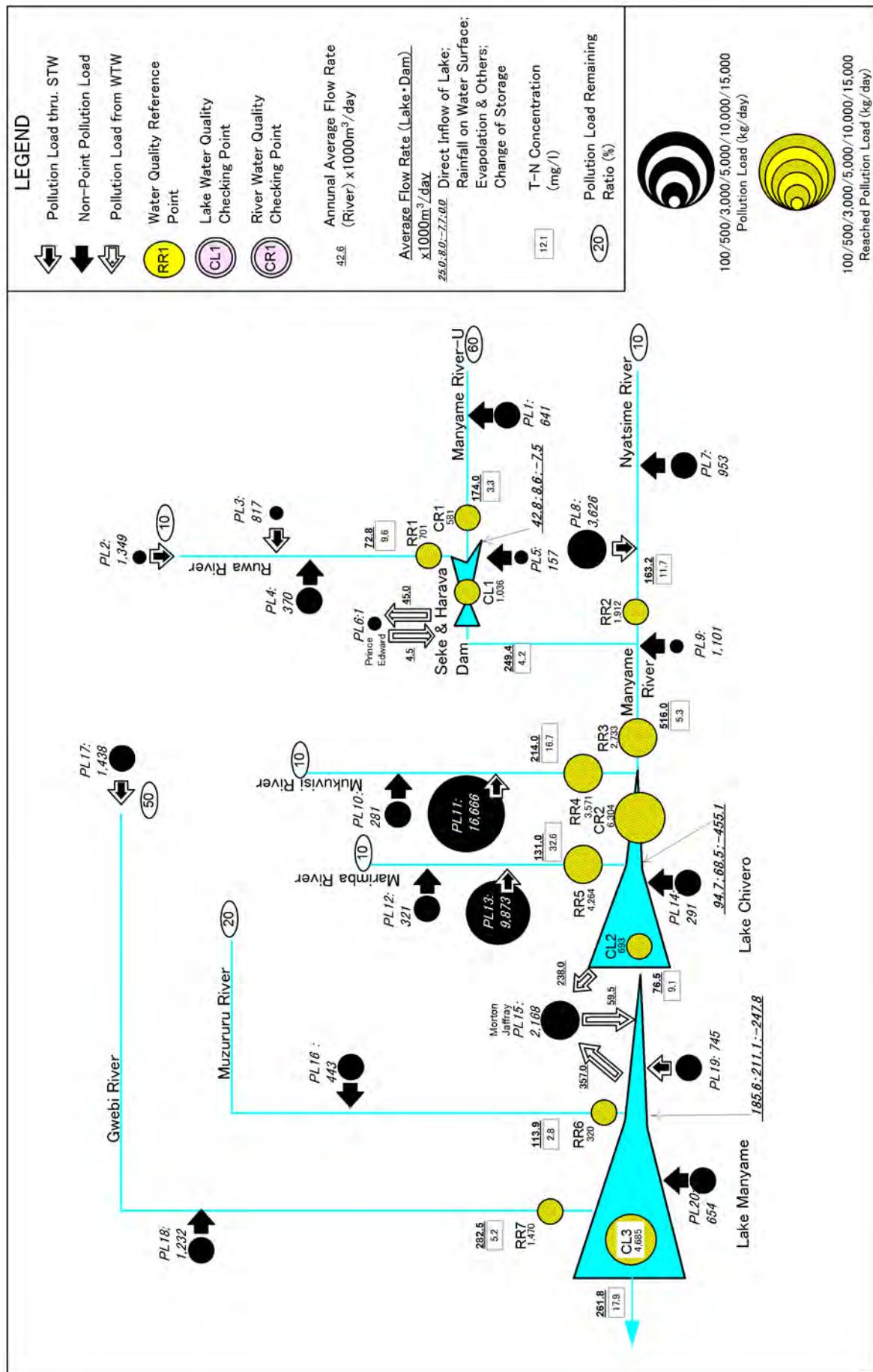


Figure A6.4.13 Pollution Run-off Model for Future Water Pollution Analysis (T-N, 2020)

APPENDIX 6

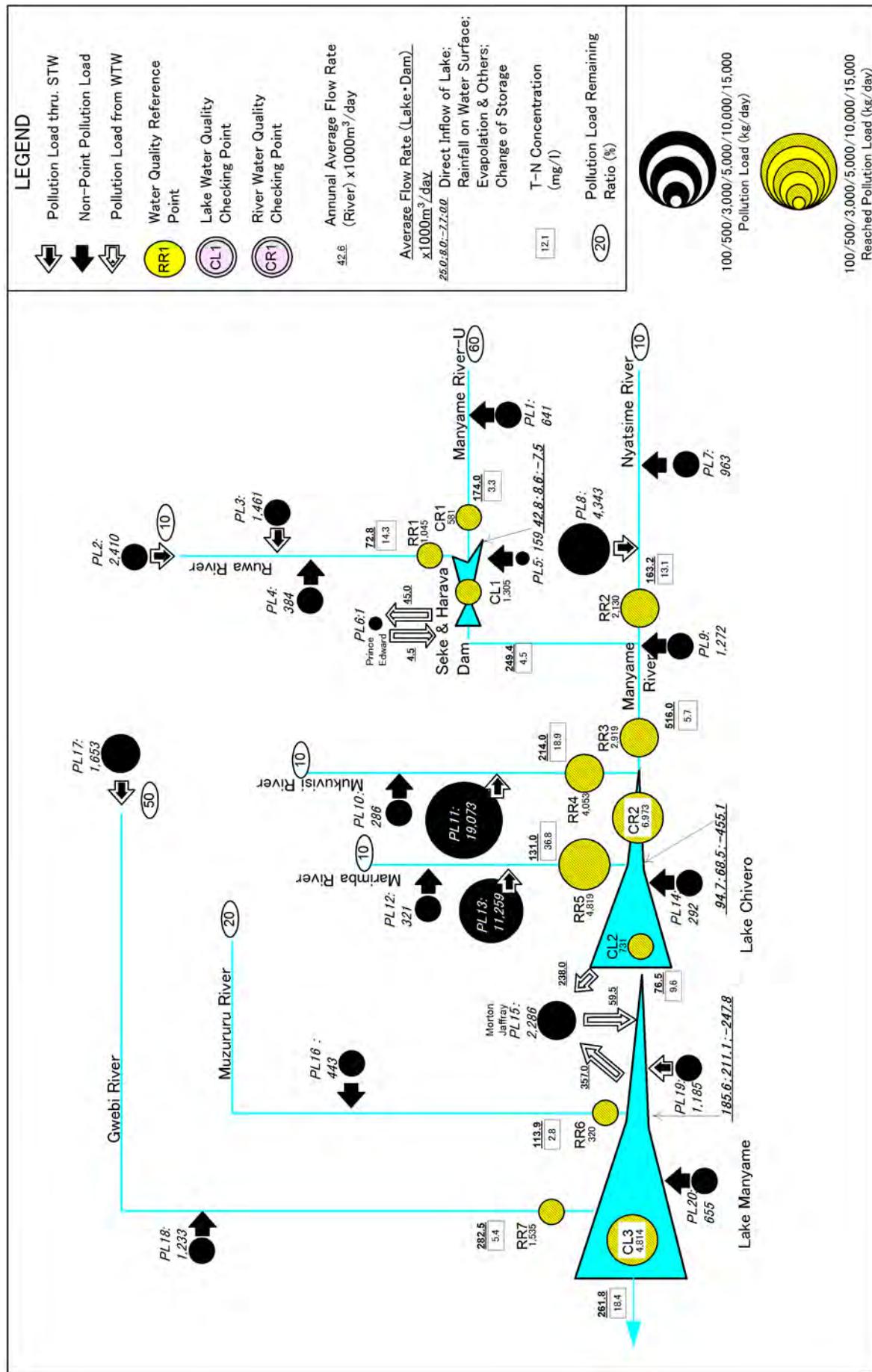


Figure A6.4.14 Pollution Run-off Model for Future Water Pollution Analysis (T-N, 2030)

APPENDIX 6

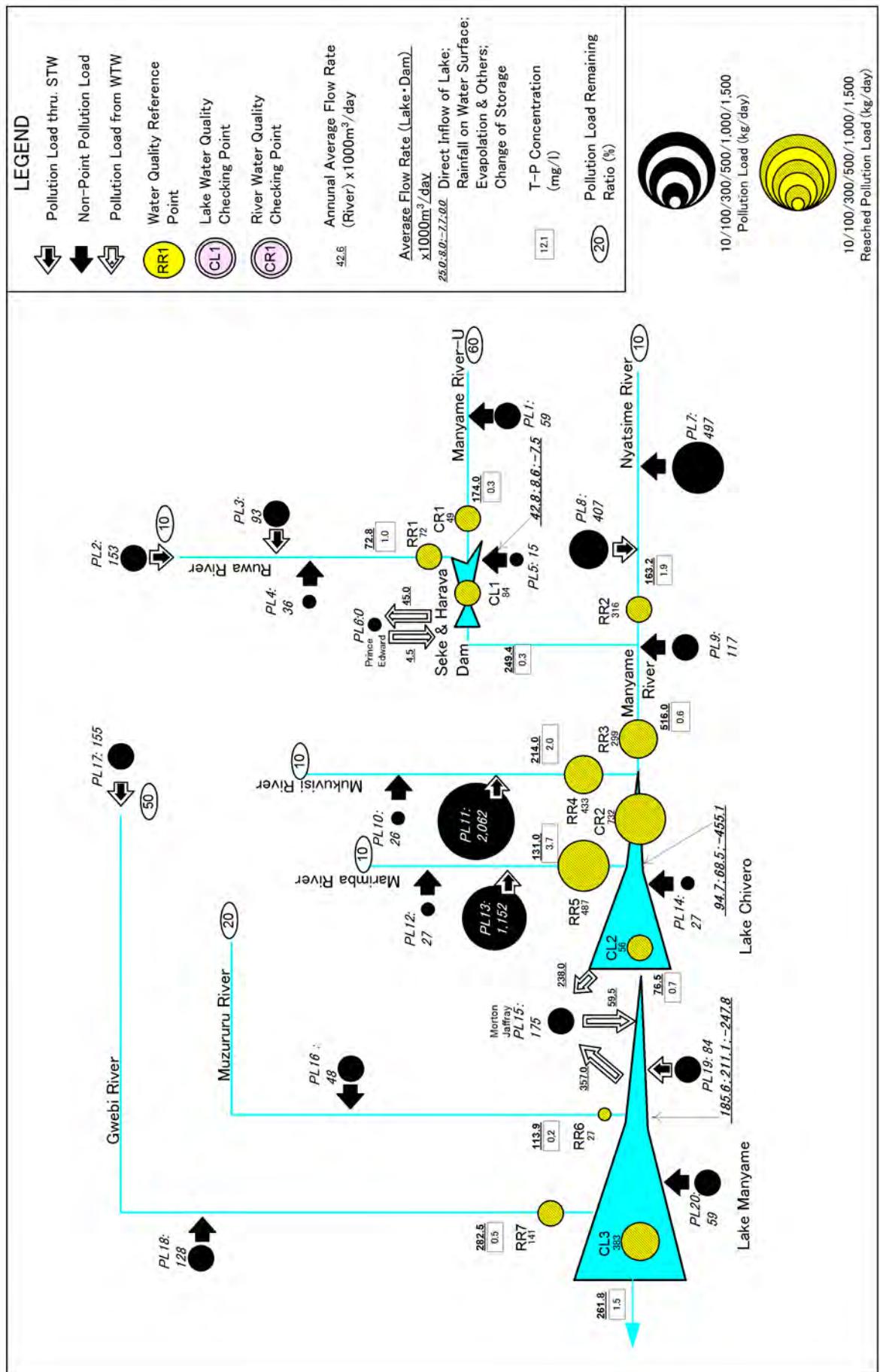


Figure A6.4.15 Pollution Run-off Model for Future Water Pollution Analysis (T-P, 2020)

APPENDIX 6

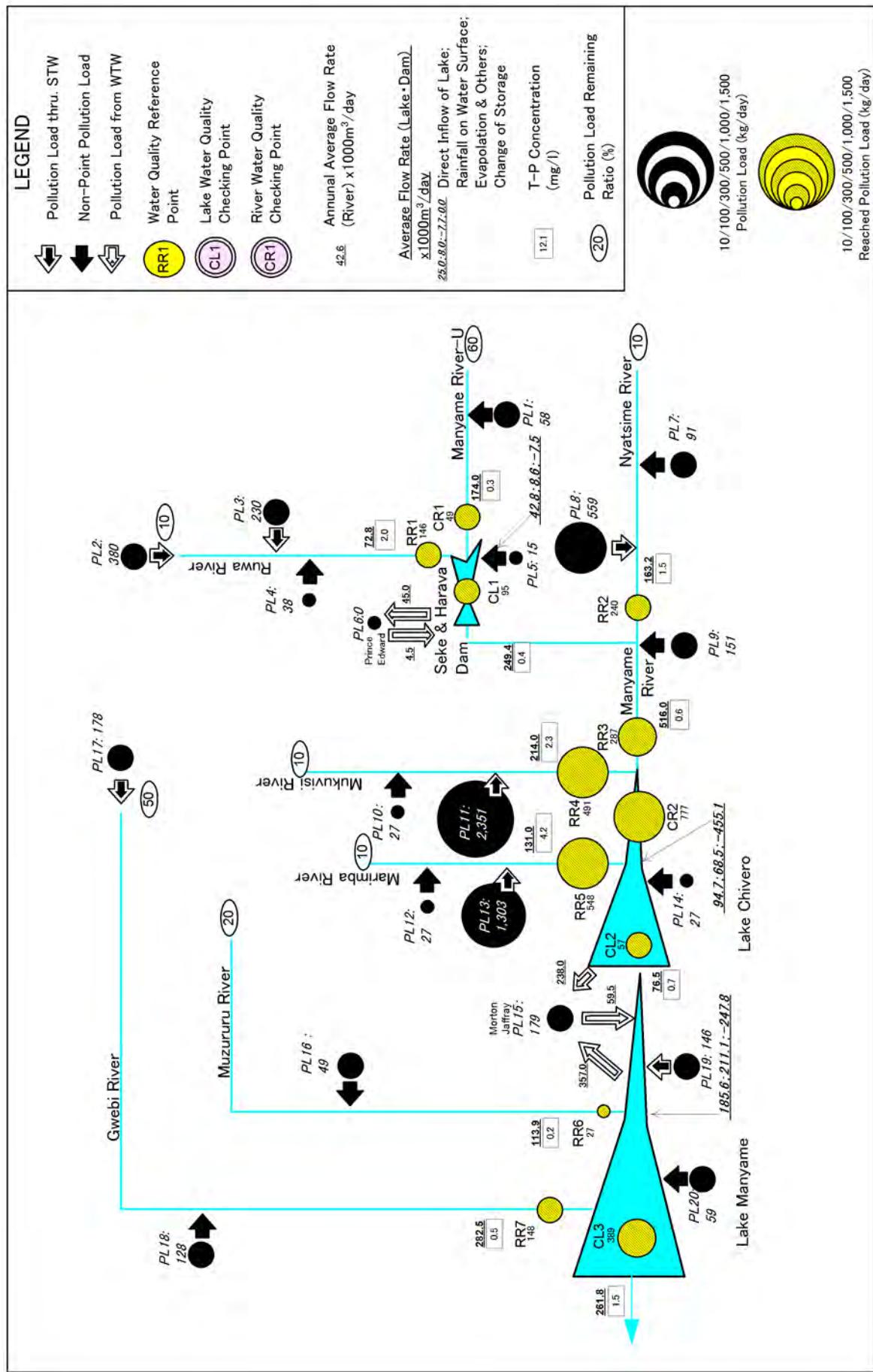


Figure A6.4.16 Pollution Run-off Model for Future Water Pollution Analysis (T-P, 2030)