3.3.3 Planning Area

All the wastewaters from the urbanized and semi-urbanized areas both present and future are considered to be potential pollution sources to the rivers. Therefore, the urbanized and semi-urbanized areas indicated in Figs. 3.3.1 and 3.3.2 are considered to be a planning area for the formulation of the Basic plan. Pollutant load generations in those areas will be taken into the considerations for pollution analysis and the study of improvement measures.

3.4 POLLUTANT SOURCES

Domestic and industrial wastewater are considered to be the major sources of the water pollution of the rivers. The amount of pollutant generation from those wastewater are estimated from present and projected future population and industrial activities.

3.4.1 Population

(1) Present

The present population in the study area has been discussed in the Section 2.2.1 in this report. The present population by district (by the Sanitation Unit) is given in Table 2.2.3 which indicates the population in the Central Zone and the South Zone together with the population in the upstream areas. The population in the study areas is regarded as almost the same as that in the planning area because the population in the upstream areas is negligible as compared to the total of the Central Zone and the South Zone, i.e. the planning area.

(2) Future

The population growth of the La Paz city has been showing a relatively low rate while the growth rates of the country and the capital zone including both La Paz City and El Alto City are as high as 3 % or more, as shown in Table 3.4.1. This is because the population growth in the capital zone is concentrated to El Alto City where the large scale land developments have been popular and it is easy to obtain lands as compared to La Paz City where the population in the developed area has almost reached the saturation point and the capacity of new residential development areas is very small.

The population growths in capitals of other states, shown in Table 3.4.2, also show higher rates. This indicates that although the population growth rate for the country is nearly 3 %, the growth is concentrated in cities other than La Paz.

Therefore, it is considered to be reasonable to apply the past trend in the projection of the future population of La Paz City and to estimate the future population from the residential area availability in the future.

TABLE 3.4.1 POPULATION GROWTH OF THE COUNTRY AND THE CAPITAL ZONE

	Census	Data by INE	Census	Mean Yearly Growth	
	1976	1988	1992	1988/1976	1992/1976
Country	4,613,486	6,495,100	-	2.89%	-
Capital Zone	635,283	976,792	1,103,714	3.65%	3.51%
La Paz	538,598	669,398	710,940	1.83%	1.75%
El Alto	96,685	307,394	392,774	10.12%	9.16%

TABLE 3.4.2 POPULATION GROWTHS IN THE STATE CAPITALS

Capitals	Census 1992	Census 1976	Mean yearly growth (%)
La Paz	710,940	539,828	1.76
Santa Cruz	692,039	254,682	6.38
Cochbamba	404,102	204,684	4.34
Oruro	182,916	124,213	2.47
Sucre	130,083	63,625	4.56
Potosi	112,004	77,397	2.36
Tarija	87,740	38,916	5.19
Trinidad	56,846	27,487	4.63
Cobija	9,676	3,650	6.22

Based on the above considerations, the future population was estimated by four regression analyses, liner, logarithmic, exponential, and power, applying the actual population data from 1976 to 1992, and by calculation from the land availability in the future.

Regression Analysis

The result of the regression analyses are shown in Table 3.4.3 and Fig. 3.4.1. The projected populations estimated by four regression range from 900,000 to 980,000.

TABLE 3.4.3 RESULTS OF REGRESSION ANALYSIS

Type of Regression	Liner	Logarithmic	Exponential	Power
Equation	$y=A+B\cdot\chi$	$y=A+B\cdot\log\chi$	$y=A\cdot e^{B\chi}$	$y=A\cdot\chi^{B}$
Constants	A=-20.8 *10^6 B=10.8 *10^3 r=0.99995	A=-162.0 *10^6 B=21.4 *10^6 r=0.99996	A=-21.7 B=0.018 r=0.99939	A=-250 B=34.8 r=0.99942
1976(observed)	538,598	538,598	538,598	538,598
1988(observed)	669,398	669,398	669,398	669,398
1992(observed)	710,940	710,940	710,940	710,940
1995(estimated)	744,055	743,822	752,507	752,167
2000(estimated)	798,061	797,446	821,434	820,622
2005(estimated)	852,066	850,929	896,675	895,054
2010(estimated)	906,071	904,298	978,801	975,959

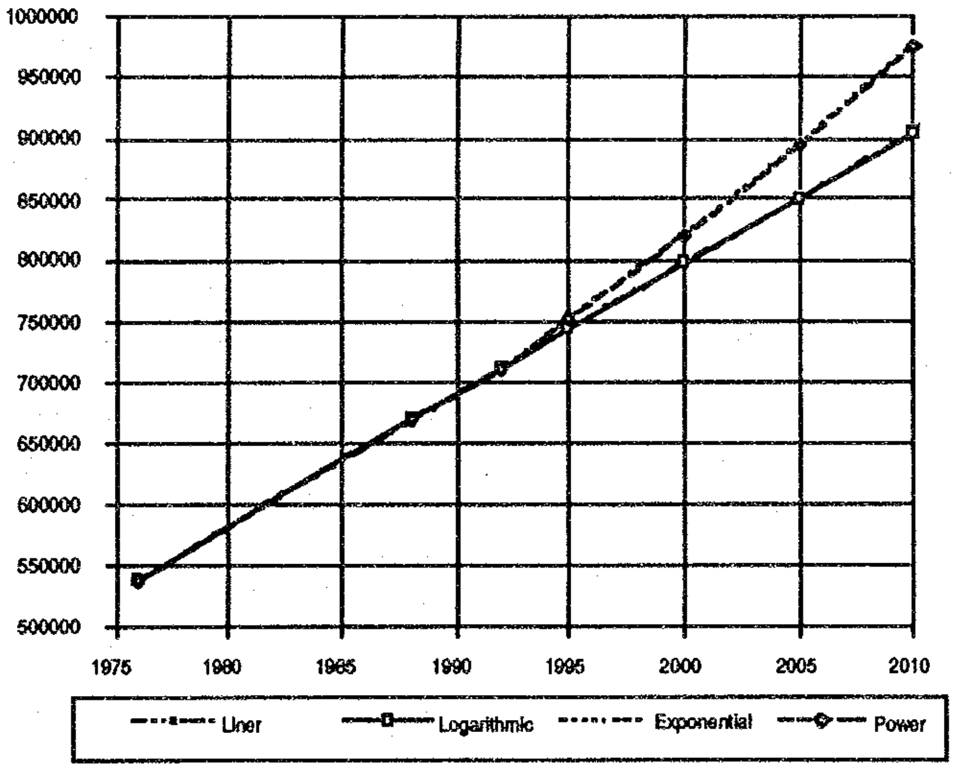

FIG. 3.4.1 RESULTS OF REGRESSION ANALYSIS

Calculation from Land Availability

According to the information from HAM (Ref. I3) the potential residential area developed in the future is given as:

The Choqueyapu River Basin	1,670 ha
The Achocalla River Basin	1,130 ha.
Total	2,800 ha

The standard population density for the areas was calculated by assuming that:

- Ratio of non-residential area (roads, parks, slopes, etc.) 25 %
- Area per house 300 m^2
- Number of people per house 4

The standard population density = 4 * 1000 * 0.75 / 300
= 100 person/ha

Therefore, the population growth in the potential residential area is calculated as,

2,800 * 100 = 280,000

Based on the above results, the future population in the planning area is estimated as shown below.

Year	1992	1995	2000	2005	2010
Population	720,000	750,000	820,000	900,000	1,000,000

The distribution of population in the planning area is given by allocating the population increase to each district considering the future developing potential evaluated from the present population density. Table 3.4.4 shows the estimated future population distribution. A significant population increase is estimated to take place in the South Zone because the population in the Central Zone has nearly reached saturation.

Table 3.4.4 Estimated Population Distribution in Future

Zones	1992	2000	2010
Central Zone	631,000	640,000	650,000
South Zone	84,600	130,000	240,000
(Achocalla)	4,400	50,000	110,000
Total	720,000	820,000	1,000,000

3.4.2 Industries

The present conditions of industrial wastewater in the study area are discussed in Section 2.4.4. Based on that discussion, the industries to be considered in the Basic plan are determined as shown in Table 3.4.5. The listed industries are those having more than 25 m^3/day of wastewater discharge. Total wastewater from these industries covers 75 % of the total industrial wastewater.

For the future industrial growth, the value added of the manufacturing sector in the Department is estimated to increase from Bs.0.8 billion in 1991 to Bs.3.0 billion in 2010 as shown in Table 3.4.6. However the Central zone in the planning area has no rooms for future expansion and it is assumed that new factories will be located outside the planning area, i.e. El Alto. Thus, in the consideration of the Basic Plan, no increase will be assumed for future industrial wastewater.

Table 3.4.5 List of Industries in the Planning Area

AMOUNT OF WASTEWATER (m^3/month)	NAME	MAIN PRODUCTS
Q > 3,000	Universal Tex	Textile (Wool Dyeing & Textile)
	Industria Venado	Food (Instant Food)
	Garcia Maria	Other
	Enbotelladora Salvietti	Food (Soft Drink)
	Fabrica Indupel	Pulp & Paper (Paper Making)
	La Papelera	Pulp & Paper (Paper Making)
	Cerveceria Boliviana	Food (Beer)
3,000 ≥ Q > 1,500	Macobol Neptula Antonia	Textile (Wool Dyeing & Textile)
	Fabrica Estatex	Textile (Cotton & Synthetic Fiber)
	Cortiembre Illimani	Leather (Tannery of Raw Hide)
	Bebidas Gaseosas	Food (Soft Drink)
	Marboltex	Textile (Wool Dyeing & Textile)
	Manufacturas Textiles Forno	Textile (Wool Dyeing & Textile)
	Fabrica Famatex	Textile (Cotton & Synthetic Fiber)
	Marmolera Tiahuanaco	Food (Soft Drink)
	Laboratorio Vita	Pharmacy (Fermentative)
	Fabrica Cascada	Food (Confectionery)
	Marmolera	Other
1,500 ≥ Q > 750	Mendoza Oscar Vertiente	Food (Soft Drink)
	Industria Tabaco	Food (Cigarette)
	Cuaquira Gregorio	Other
	Liendo Romero	Other
	Fabrica Nacional de Vidrios	Glass
	Ponce Lucio	Other
	Pinel Laura Super Taxi	Taxi Service
	Fabrica D. Saligno	Car Repair Shop
	Combogel	Textile (Cotton & Synthetic Fiber)
	Ibusa	Textile (Felt)

Table3.4.6 Projection of GRDP and Value Added by Econonomic Sector in La Paz Department at 1991 Constant Prices : 1991-2010

(Unit: Bs.Million)

Item	1991	1992	1995	2000	2005	2010
1. GRDP at Market Prices	6,062	6,259	6,960	8,229	9,612	11,042
Annual Growth Rate (%)	-	3.3%	3.6%	3.4%	3.2%	2.8%
2. Economic Sector *1						
Agriculture	878	918	1,034	1,272	1,477	1,666
Extraction	412	430	484	596	692	781
Crude oil & natural gas	-	-	-	-	-	-
Mining & quarring	412	430	484	596	692	781
Manufacturing	793	854	1,083	1,568	2,228	2,956
Electricity Gas & Water Supply	68	74	170	244	275	302
Construction	185	194	211	229	254	277
Transportation & Communication	597	617	726	1,016	1,354	1,707
Services	3,129	3,172	3,252	3,305	3,331	3,353
3. Percentage Distribution (%)						
Agriculture	14.5	14.7	14.9	15.5	15.4	15.1
Extraction	6.8	6.9	7.0	7.2	7.2	7.1
Crude oil & natural gas	-	-	-	-	-	-
Mining & quarring	6.8	6.9	7.0	7.2	7.2	7.1
Manufacturing	13.1	13.6	15.6	19.0	23.2	26.8
Electricity Gas & Water Supply	1.1	1.2	2.4	3.0	2.9	2.7
Construction	3.1	3.1	3.0	2.8	2.6	2.5
Transportation & Communication	9.9	9.9	10.4	12.3	14.1	15.5
Services	51.6	50.7	46.7	40.2	34.7	30.4
Total	100.0	100.0	100.0	100.0	100.0	100.0
4. Projected Population (1000)*2	2,063	2,110	2,260	2,532	2,838	3,181
5. GDP per Capita						
-Bolivianos	2,939	2,966	3,080	3,249	3,387	3,471
-US$ equivalent*3	784	791	821	867	903	926

Note: *1 Based on the average composition rates during 1980 and 1986 from Table 2.2.6.
*2 Estimated to grow at average annual rate of 2.31% (based on 1976 and 1988 populations)
*3 Applied the official exchange rate of Bs.3.75/US$

CHAPTER 4
ANALYSIS OF WATER QUALITY OF THE CHOQUEYAPU RIVER FOR PRESENT AND FUTURE

4.1 UNIT LOADING FACTORS FOR POLLUTANT GENERATION

4.1.1 Outline

Pollutant sources are generally classified as follows:

1) Domestic

2) Industrial

3) Others (Commercial, Public Establishment, Natural)

Wastewater discharge and pollution load were estimated by using unit loading factors and socio-economical data: population, volume of water usage, etc.

The concept of estimation and the values applied to the estimation are as follows.

4.1.2 Domestic Wastewater

Wastewater volume and pollution load of domestic wastewater were estimated by multiplying regional population by the wastewater discharge per capita and by the pollution load per capita, respectively. Discharge amounts were estimated using water supply data from SAMAPA, and the pollution load was estimated from reference data.

Data from SAMAPA include water usage by large consumers: major factories, commercial buildings and hotels. Therefore, water usage by these large consumers (that have discharge amount over 750 m^3/month) was subtracted from the total amount to obtain the domestic discharge amount per capita. The discharge amount estimated in this manner includes discharges from small factories and stores. Since, these small consumers are distributed all over the city area, their discharges can be included in the per capita domestic wastewater discharge.

Water supply systems are generally classified into three modes in the City of La Paz: 1) SAMAPA's house connection service, 2) SAMAPA's public hydrants, and 3) various forms such as wells and tank trucks. In this study, water supply modes were classified into two: SAMAPA's house connection service and the supply by other forms. There is a clear difference in water consumption between these two modes, which reflect living standards. Per capita wastewater discharge and pollution load were estimated according to this classification as described below.

(1) House Connection Service Area

In the sewerage master plan by SAMAPA/GTZ (Ref.F1), per capita water demand in the future was estimated as shown in Table 4.1.1. Of these values, the value for minimum demand area is considered to be similar to the present demand.

Table 4.1.1 Unit Water Demand for Domestic Use

Unit: lit/day/person

Area	Net Residential	Business Use	Public Use	Leakage	Total
Min.	135	15	10	40	200
Max.	300	15	10	75	400

Note: - Min.and Max. mean minimum and maximum areas, respectively.
Source: Ref.F1

The future water demand for each item of water use was estimated by arranging the standard value in Japan as shown in Table 4.1.2.

Table 4.1.2 Unit Water Demand for Each Water Use (Daily Maximum)

Unit: lit/day/person

Item	House Connection Service Area	Other Area
Drinking	4	4
Cooking	16	8
Washing Dishes	16	8
Shower/Bath	56	0
Laundry	24	12
Cleaning	8	4
Face/Hand Washing	8	8
Flush Toilet	32	0
Air Conditioning	0	0
Others	36	16
Total	200	60

By referring to the data shown above, the unit wastewater discharge amounts per capita in the future were estimated as shown in Table 4.1.3.

Table 4.1.3 Unit Wastewater Discharge

Unit: lit/day/person

Value	Ratio	1992	1995	2000	2005	2010
Daily Mean	0.8	130	135	145	150	160
Daily Max.	1.0	160	170	180	190	200
Hourly Max.	1.5	245	255	270	280	300

Note:
- Daily Mean in 1992 was considered to be 80% of the min. of water demand for domestic use in Table 4.1.1 excluding leakage.
- Daily Max. in 2010 was derived from the total of the unit water demand for each water use in Table 4.1.2 with 25% additional water demand for business use.
- Other values were estimated by using the above two values and the ratios of daily fluctuation, and by assuming a linear annual increase.

For determining per capita BOD loads, the composition of daily mean wastewater discharge and BOD concentration by kinds of wastewater were estimated as shown in Table 4.1.4.

Table 4.1.4 Composition of Daily Mean Wastewater Discharge and BOD Concentration

Kind	BOD (mg/l)	Unit Wastewater Discharge (lit/day/person)				
		1992	1995	2000	2005	2010
Human waste	600	30	30	30	30	30
Gray water	150	80	85	95	100	110
Business use	250	20	20	20	20	20
Total		130	135	145	150	160

From Table 4.1.4, the per capital BOD load in each year was calculated as follows.

Year	1992	1995	2000	2005	2010
BOD Load (g/day/person)	35	36	38	39	40

(2) Other area

In the sewerage master plan by SAMAPA/GTZ (Ref. F1), the amount of water supply for other areas without house connection service was estimated to be from 43 to 54 lit/day per capita. SAMAPA uses 60 lit/day per capita to plan and operate the pilot treatment plant in Kenko which can be categorized as "other area".

There are no flush toilets in the "other area", and domestic wastewater consists of gray water only. But pollution load should also account for human waste which is considered to be discharged in some manner. Therefore, the unit wastewater discharge was estimated to be 60 lit/day per capita, and the unit BOD load was estimated at 27 g/day per capita.

4.1.3 Industrial Wastewater

Industrial wastewater discharge was estimated by the water usage data from SAMAPA for factories, commercial buildings, hotels, etc. that consume more than 750 m^3/month. The pollution load was calculated by multiplying the discharge amount by the BOD concentration. The BOD concentrations of wastewaters from these sources are found in the existing data (Refs. D2,D3,D4,D5). The BOD concentration of other wastewaters was assumed to be the same as that for the business use of domestic wastewater (250 mg/l).

4.1.4 Others

Natural pollution load and pollution loads which are generated in or permeate into the river bed, farmland, etc. were integrally estimated as "others". Since it is not possible to predetermine the value for these loads, it was estimated through calibration of the water quality simulation model.

4.2 AMOUNT OF POLLUTANT GENERATION

4.2.1 Outline

The Choqueyapu basin was divided into blocks and the river course was divided into reaches. The amount of wastewater discharge and the pollution load were estimated for each block/reach to be used in a mathematical water quality simulation model. Details of the model are explained in Section 4.3.

There are no recent and reliable data for detailed population distribution in the City of La Paz, because the results of the 1992 census is not yet available. Therefore, distribution of the population for each block/reach was roughly estimated.

4.2.2 Pollutant Generation Amount by River Catchment

(1) Domestic Wastewater

Distribution of population was first estimated for the population blocks shown in Fig.4.2.1, which were defined in the census of 1976 and in the data of the La Paz Sanitary Unit (Ref.I5). The population was distributed according to the level of urbanization or the form of land use. Estimated population and population density for each block are shown in Table 4.2.1.

The estimated populations for population blocks were then distributed to the discharge blocks. The discharge blocks were determined for the water quality simulation model as shown in Fig.4.3.3. The estimated population for each block is shown in Table 4.2.2. Parts of the blocks "4P" and "4Q" and the whole block "4O" are out of the Choqueyapu River basin, and were omitted from Table 4.2.2.

(2) Industrial Wastewater

There are twenty eight major sources of industrial wastewater in the Choqueyapu River basin, whose names, products, volume of water consumption and BOD concentration of raw wastewater are shown in Table 4.2.3.

The wastewater discharge amount and the BOD load from the major water consumers (over 750 m^3/month) including commercial and others were estimated for each discharge block as shown in Table 4.2.4.

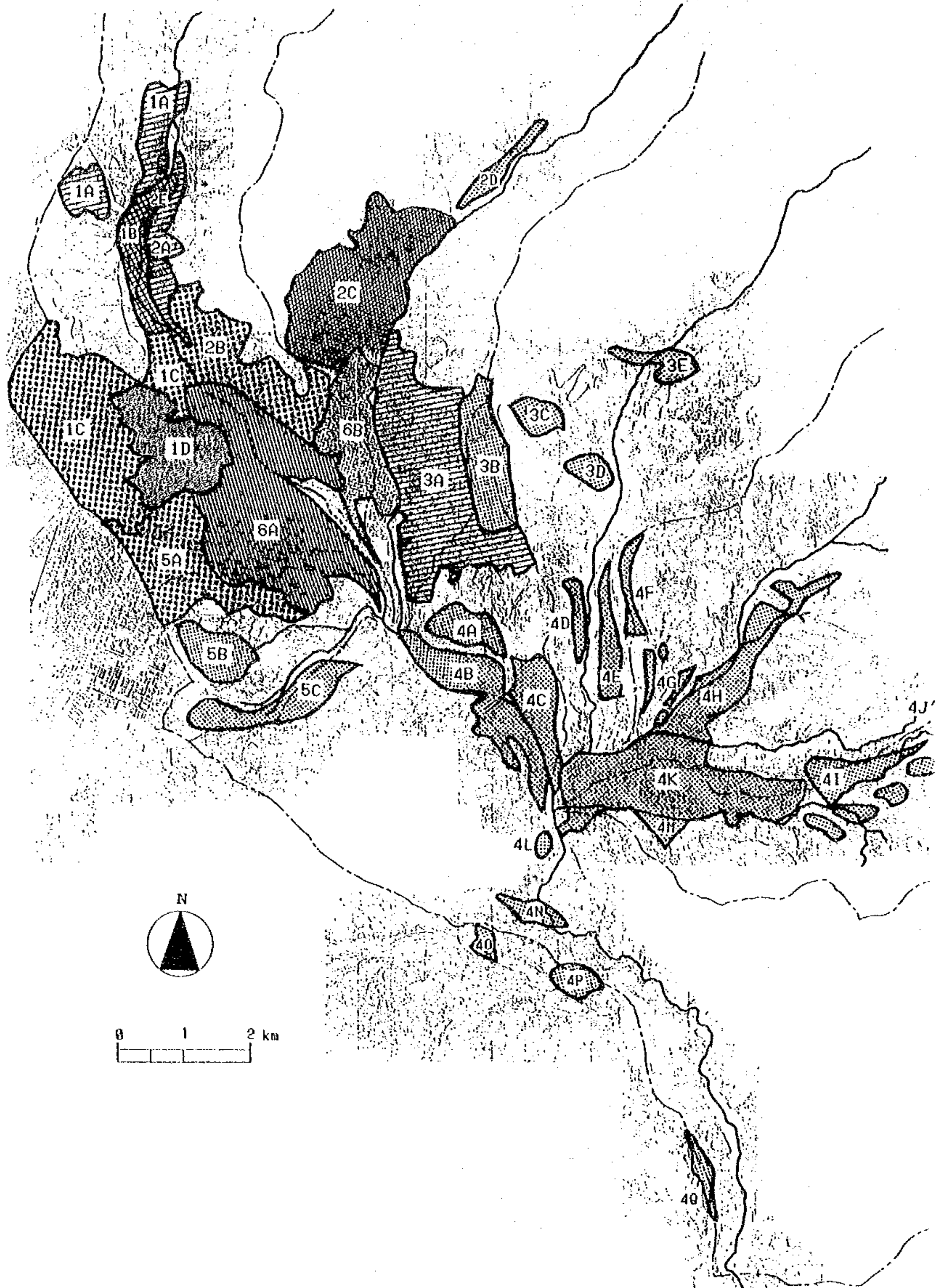

Fig. 4.2.1 Population Blocks

Table 4.2.1 Population/Population Density by Population Block

BLOCK	1				
Sub-Block	A	B	C	D	Total
Population	20,669	2,480	94,702	59,458	177,309
Area (ha)	134.0	59.4	434.4	172.4	800.2
Density	154.2	41.8	218.0	344.9	221.6

BLOCK	2					
Sub-Block	A	B	C	D	E	Total
Population	12,693	48,767	40,310	3,034	1,240	106,044
Area (ha)	79.6	216.4	379.2	36.0	31.0	742.2
Density	159.5	225.4	106.3	84.3	40.0	142.9

BLOCK	3					
Sub-Block	A	B	C	D	E	Total
Population	64,497	5,256	301	962	1,040	72,056
Area (ha)	413.6	126.4	36.8	30.0	38.0	644.8
Density	155.9	41.6	8.2	32.1	27.4	111.7

BLOCK	4								
Sub-Block	A	B	C	D	E	F	G	H	I
Population	10,788	12,006	7,033	2,932	3,928	204	306	5,906	2,320
Area (ha)	66.8	155.6	88.4	31.2	68.0	32.0	26.0	151.6	58.0
Density	161.5	77.2	79.6	94.0	57.8	6.4	11.8	39.0	40.0

	J	K	L	M	N	O	P	Q	Total
	691	17,339	255	153	714	306	1,836	408	67,125
	52.6	336.0	5.6	10.0	30.0	15.6	30.4	24.4	1182.2
	13.1	51.6	45.5	15.3	23.8	19.6	60.4	16.7	56.8

BLOCK	5			
Sub-Block	A	B	C	Total
Population	48,027	5,090	1,633	54,750
Area (ha)	224.4	79.6	124.0	428.0
Density	214.0	63.9	13.2	127.9

BLOCK	6		
Sub-Block	A	B	Total
Population	198,123	44,549	242,672
Area (ha)	469.6	170.8	640.4
Density	421.9	260.8	378.9

BLOCK	TOTAL
Sub-Block	
Population	719,956
Area (ha)	4437.8
Density	162.2

Note: Population Density (persons/ha)

POPDEN02.XLS

Table 4.2.2 Population by Population/Discharge Block (1/2)

POPULATION (persons)

Discharge Block			Population Block																
			1					2						3					
Zone	Block	Sub-Block	A	B	C	D	total	A	B	C	D	E	total	A	B	C	D	E	total
A	1		12,525	777	0	0	13,301	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	0	0	0	7,399	0	0	0	828	8,227	0	0	0	0	0	0
	3		8,144	388	0	0	8,532	0	0	0	0	0	0	0	0	0	0	0	0
	4		0	1,161	0	0	1,161	0	0	0	0	0	0	0	0	0	0	0	0
	5		0	0	0	0	0	1,850	0	0	0	412	2,262	0	0	0	0	0	0
	6		0	0	0	0	0	2,775	7,392	0	0	0	10,166	0	0	0	0	0	0
	total		20,669	2,326	0	0	22,995	12,023	7,392	0	0	1,240	20,655	0	0	0	0	0	0
B	1		0	154	10,573	0	10,728	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	61,151	31,660	92,811	0	0	0	0	0	0	0	0	0	0	0	0
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4		0	0	22,978	27,798	50,776	0	0	0	0	0	0	0	0	0	0	0	0
	5		0	0	0	0	0	670	9,735	0	0	0	10,405	0	0	0	0	0	0
	6		0	0	0	0	0	0	15,662	0	0	0	15,662	0	0	0	0	0	0
	7		0	0	0	0	0	0	563	0	0	0	563	0	0	0	0	0	0
	8		0	0	0	0	0	0	9,465	0	0	0	9,465	0	0	0	0	0	0
	total		0	154	94,702	59,458	154,314	670	35,426	0	0	0	36,096	0	0	0	0	0	0
C	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4		0	0	0	0	0	0	5,949	0	0	0	5,949	0	0	0	0	0	0
	5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	5,949	0	0	0	5,949	0	0	0	0	0	0
D			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E			0	0	0	0	0	0	0	40,310	3,034	0	43,344	14,370	0	0	0	0	14,370
F			0	0	0	0	0	0	0	0	0	0	0	35,632	961	0	0	0	36,593
G	1	1	0	0	0	0	0	0	0	0	0	0	0	8,857	2,890	0	0	0	11,747
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	0	0	0	5,629	474	0	0	0	6,103
	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	14,487	3,364	0	0	0	17,851
H	1		0	0	0	0	0	0	0	0	0	0	0	0	931	301	962	1,040	3,234
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	0	931	301	962	1,040	3,234
I	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total		20,669	2,480	94,702	59,458	177,309	12,693	48,767	40,310	3,034	1,240	106,044	64,497	5,256	301	962	1,040	72,056

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Table 4.2.2 Population by Population/Discharge Block (2/2)

POPULATION (persons)

Discharge Zone	Block	Sub-Block	Population Block 4																		5				6			Total
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	total	A	B	C	total	A	B	total	Total
A	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13,301
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,227
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,532
	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,161
	5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,262
	6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,166
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43,649
B	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,728
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,561	0	1,561	94,372
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,100	0	8,100	8,109
	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	835	0	0	835	17,888	0	17,888	69,499
	5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,485
	6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,628	0	3,628	19,291
	7		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,661	0	9,661	10,225
	8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14,724	0	14,724	24,189
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	835	0	0	835	55,564	0	55,564	246,809
C	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25,276	0	0	25,276	61,513	0	61,513	86,789
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,291	0	3,291	3,291
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32,864	0	32,864	32,864
	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,847	23,422	31,269	37,219
	5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25,276	0	0	25,276	104,715	23,422	128,137	159,363
D			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,916	5,898	917	27,923	37,844	0	37,844	65,767
E			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13,172	13,172	78,893
F			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,955	7,955	44,548
G	1	1	1,403	2,585	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,990	0	0	0	0	0	0	0	15,737
		2	6,783	4,915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,698	0	0	0	0	0	0	0	11,698
		3	2,600	0	6,691	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,291	0	0	0	0	0	0	0	15,394
	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	716	716	0	0	0	716
		2	0	2,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,500	0	0	0	0	0	0	0	2,500
	total		10,788	10,000	6,691	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27,479	0	0	716	716	0	0	0	46,046
H	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,234
	2		0	0	342	2,932	3,928	48	0	0	0	0	0	0	0	0	0	0	0	7,251	0	0	0	0	0	0	0	7,251
	total		0	0	342	2,932	3,928	48	0	0	0	0	0	0	0	0	0	0	0	7,251	0	0	0	0	0	0	0	10,485
I	1		0	0	0	0	0	0	0	386	996	0	2,529	0	0	0	0	0	0	3,910	0	0	0	0	0	0	0	3,910
	2		0	0	0	0	0	0	0	3,315	0	0	0	0	0	0	0	0	0	3,315	0	0	0	0	0	0	0	3,315
	3		0	0	0	0	0	0	102	242	0	0	0	0	0	0	0	0	0	344	0	0	0	0	0	0	0	344
	4		0	0	0	0	0	156	204	0	0	0	0	0	0	0	0	0	0	359	0	0	0	0	0	0	0	359
	total		0	0	0	0	0	156	306	3,943	996	0	2,529	0	0	0	0	0	0	7,929	0	0	0	0	0	0	0	7,929
J	1		0	0	0	0	0	0	0	1,963	0	0	4,319	0	0	0	0	0	0	6,283	0	0	0	0	0	0	0	6,283
	2		0	0	0	0	0	0	0	0	1,324	691	980	0	0	0	0	0	0	2,995	0	0	0	0	0	0	0	2,995
	3		0	0	0	0	0	0	0	0	0	0	3,378	0	10	0	0	0	0	3,388	0	0	0	0	0	0	0	3,388
	4		0	0	0	0	0	0	0	0	0	0	5,217	0	135	0	0	0	0	5,352	0	0	0	0	0	0	0	5,352
	total		0	0	0	0	0	0	0	1,963	1,324	691	13,887	0	153	0	0	0	0	18,018	0	0	0	0	0	0	0	18,018
K	1	1	0	2,006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,006	0	0	0	0	0	0	0	2,006
		2	0	0	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	255	0	0	0	0	0	0	0	255
	2		0	0	0	0	0	0	0	0	0	0	924	0	0	0	0	0	0	924	0	0	0	0	0	0	0	924
	total		0	2,006	0	0	0	0	0	0	0	0	924	255	0	0	0	0	0	3,185	0	0	0	0	0	0	0	3,185
L	1		0	0	0	0	0	0	0	0	0	0	0	0	0	714	0	0	0	714	0	0	0	0	0	0	0	714
	2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	719	0	719	0	0	0	0	0	0	0	719
	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	201	201	0	0	0	0	0	0	0	201
	total		0	0	0	0	0	0	0	0	0	0	0	0	0	714	0	719	201	1,633	0	0	0	0	0	0	0	1,633
Total			10,788	12,006	7,033	2,932	3,928	204	306	5,996	2,320	691	17,339	255	153	714	0	719	201	65,494	48,027	5,898	1,633	54,750	198,123	44,549	242,672	718,325

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Table 4.2.3 List of Major Water Consumers (Industrial)

CLASS	CODE	NAME	PRODUCT	Water Consumption (m3/month)	BOD (Raw Wastewater) (mg/l)
Q > 3000 m3/month	I-L-01	Universal Tex	Textile (Wool Dyeing & Textile)	9,837	1,250
	I-L-02	Industria Venado	Food (Instant Food)	5,886	1,500
	I-L-03	Garcia Maria	Other	3,962	1,000
	I-L-04	Enbotelladora Salvietti	Food (Soft Drink)	3,284	800
	I-L-05	Fabrica Indupel	Pulp & Paper (Paper Making)	10,499	400
	I-L-06	La Papelera	Pulp & Paper (Paper Making)	6,940	400
	I-L-07	Cerveceria Boliviana	Food (Beer)	5,562	1,650
	I-L-08	"	"	49,883	1,650
1500 < Q < 3000 m3/month	I-M-01	"	"	1,562	1,650
	I-M-02	Macobol Neptula Antonia	Textile (Wool Dyeing & Textile)	1,882	1,250
	I-M-03	Fabrica Estatex	Textile (Cotton & Synthetic Fiber)	2,579	1,250
	I-M-04	Cortiembre Illimani	Leather (Tannery of Raw Hide)	1,902	1,400
	I-M-05	Bebidas Gaseosas	Food (Soft Drink)	2,064	800
	I-M-06	Marboltex	Textile (Wool Dyeing & Textile)	1,688	1,250
	I-M-07	Manufacturas Textiles Forno	Textile (Wool Dyeing & Textile)	1,939	1,250
	I-M-08	Fabrica Famatex	Textile (Cotton & Synthetic Fiber)	1,554	1,250
	I-M-09	Marmolera Tiahuanaco	Food (Soft Drink)	2,220	800
	I-M-10	Laboratorio Vita	Pharmacy (Fermentative)	1,845	1,600
	I-M-11	Fabrica Cascada	Food (Confectionery)	2,348	800
	I-M-12	Marmolera	Other	2,079	1,000
750 < Q < 1500 m3/month	I-S-01	Mendoza Oscar Vertiente	Food (Soft Drink)	1,076	800
	I-S-02	Industria Tabaco	Food (Cigarette)	1,029	400
	I-S-03	Cuaquira Gregorio	Other	1,130	1,000
	I-S-04	Liendo Romero	Other	1,380	1,000
	I-S-05	Fabrica Nacional de Vidrios	Glass	1,347	800
	I-S-06	Ponce Lucio	Other	996	1,000
	I-S-07	Pinel Laura Super Taxi	Car Repair Shop	869	200
	I-S-08	Fabrica D. Saligno	Car Repair Shop	1,346	200
	I-S-09	Combogel	Textile (Cotton & Synthetic Fiber)	1,380	1,250
	I-S-10	Ibusa	Textile (Felt)	1,054	200

WSPIND01.XLS

Table 4.2.4(1) Discharge Volume and Pollution Load of Major Consumers

Discharge Sub-Block	Code Name	Water Consumption (m3/month)	Discharge Rate	Discharge Volume (m3/day)	Water Quality (BOD5) (mg/l)	Pollution Load (kg/day)
A4	I-S-05	1,347	1.000	45	800	35.92
	I-S-10	1,054	1.000	35	200	7.03
	E-S-45	1,131	1.000	38	250	9.43
	I-L-05	10,499	1.000	350	400	139.99
	I-L-06	6,940	1.000	231	400	92.53
	I-M-09	2,220	1.000	74	800	59.20
	I-L-12	2,079	1.000	69	1000	69.30
	Total			842		413.39
A5	E-L-01	8,279	1.000	276	2300	634.72
	E-M-01	2,066	1.000	69	250	17.22
	I-M-01	1,562	1.000	52	1650	85.91
	I-M-08	1,554	1.000	52	1250	64.75
	Total			449		802.60
A6	I-M-02	1,882	1.000	63	1250	78.42
B1	H-M-01	2,681	1.000	89	250	22.34
B2	H-S-06	983	1.000	33	250	8.19
	E-L-09	6,784	1.000	226	250	56.53
	E-M-14	1,563	1.000	52	250	13.03
	E-M-15	2,416	1.000	81	250	20.13
	E-M-25	2,175	1.000	73	250	18.13
	O-L-05	7,315	1.000	244	250	60.96
	O-M-06	1,557	1.000	52	250	12.98
	O-S-13	835	1.000	28	250	6.96
	O-S-22	1,296	1.000	43	250	10.80
	O-S-24	1,459	1.000	49	250	12.16
	O-S-38	879	1.000	29	250	7.33
	O-S-39	1,244	1.000	41	250	10.37
	I-L-02	5,886	1.000	196	1500	294.30
	I-L-03	3,962	1.000	132	1000	132.07
	I-M-10	1,845	1.000	62	1600	98.40
	I-S-02	1,029	1.000	34	400	13.72
	Total			1,374		776.04
B3	H-S-04	794	1.000	26	250	6.62
	E-M-18	2,188	1.000	73	250	18.23
	E-M-19	1,684	1.000	56	250	14.03
	E-S-44	762	1.000	25	250	6.35
	E-S-50	1,281	1.000	43	250	10.68
	E-S-51	907	1.000	30	250	7.56
	I-L-07	5,562	1.000	185	1650	305.91
	I-L-08	49,883	1.000	1,663	1650	2,743.57
	Total			2,102		3,112.94
B4	E-M-05	2,766	1.000	92	250	23.05
	E-M-06	2,123	1.000	71	250	17.69
	E-S-05	911	1.000	30	250	7.59
	E-S-06	766	1.000	26	250	6.38
	E-S-20	860	1.000	29	250	7.17
	E-S-33	811	1.000	27	250	6.76
	E-S-34	882	1.000	29	250	7.35
	C-M-02	1,841	1.000	61	250	15.34
	C-M-04	1,599	1.000	53	250	13.33

BODLOAD1.XLS

Table 4.2.4(2) Discharge Volume and Pollution Load of Major Consumers

Discharge Sub-Block	Code Name	Water Consumption (m3/month)	Discharge Rate	Discharge Volume (m3/day)	Water Quality (BOD5) (mg/l)	Pollution Load (kg/day)
B4	C-S-02	1,062	1.000	35	250	8.85
	C-S-03	884	1.000	29	250	7.37
	C-S-04	1,357	1.000	45	250	11.31
	C-S-08	865	1.000	29	250	7.21
	O-M-05	1,536	1.000	51	250	12.80
	O-M-07	1,621	1.000	54	250	13.51
	O-M-11	1,621	1.000	54	250	13.51
	O-S-09	928	1.000	31	250	7.73
	O-S-10	934	1.000	31	250	7.78
	O-S-18	1,472	1.000	49	250	12.27
	O-S-19	843	1.000	28	250	7.03
	O-S-23	1,366	1.000	46	250	11.38
	O-S-34	1,290	1.000	43	250	10.75
	O-S-37	1,320	1.000	44	250	11.00
	I-S-03	1,130	1.000	38	1000	37.67
	Total			1,026		284.82
B5	E-S-09	1,128	1.000	38	250	9.40
	I-M-03	2,579	1.000	86	1250	107.46
	Total			124		116.86
B6	E-M-11	2,270	1.000	76	250	18.92
	E-S-08	1,256	1.000	42	250	10.47
	E-S-27	852	1.000	28	250	7.10
	E-S-28	791	1.000	26	250	6.59
	O-S-14	1,038	1.000	35	250	8.65
	I-L-04	3,284	1.000	109	800	87.57
	I-M-07	1,939	1.000	65	1250	80.79
	Total			381		220.09
B7	H-S-03	1,433	1.000	48	250	11.94
	E-M-04	1,757	1.000	59	250	14.64
	E-M-17	1,837	1.000	61	250	15.31
	E-S-04	773	1.000	26	250	6.44
	E-S-43	752	1.000	25	250	6.27
	C-M-01	1,562	1.000	52	250	13.02
	C-M-05	2,172	1.000	72	250	18.10
	C-M-06	2,890	1.000	96	250	24.08
	C-S-01	975	1.000	33	250	8.13
	C-S-06	1,365	1.000	46	250	11.38
	C-S-09	857	1.000	29	250	7.14
	C-S-17	1,311	1.000	44	250	10.93
	O-M-03	1,706	1.000	57	250	14.22
	O-M-04	2,237	1.000	75	250	18.64
	O-S-05	1,375	1.000	46	250	11.46
	O-S-06	1,373	1.000	46	250	11.44
	O-S-07	1,095	1.000	37	250	9.13
	O-S-08	834	1.000	28	250	6.95
	O-S-21	1,394	1.000	46	250	11.62
	O-S-26	780	1.000	26	250	6.50
	O-S-28	1,300	1.000	43	250	10.83
	Total			993		248.15
B8	E-M-02	1,948	1.000	65	250	16.23

BODLOAD1.XLS

Table 4.2.4(3) Discharge Volume and Pollution Load of Major Consumers

Discharge Sub-Block	Code Name	Water Consumption (m3/month)	Discharge Rate	Discharge Volume (m3/day)	Water Quality (BOD5) (mg/l)	Pollution Load (kg/day)
B8	E-M-03	1,612	1.000	54	250	13.43
	E-M-08	2,231	1.000	74	250	18.59
	E-M-20	2,255	1.000	75	250	18.79
	E-M-26	2,044	1.000	68	250	17.03
	E-S-01	952	1.000	32	250	7.93
	E-S-03	927	1.000	31	250	7.73
	E-S-11	994	1.000	33	250	8.28
	E-S-12	1,026	1.000	34	250	8.55
	E-S-13	927	1.000	31	250	7.73
	E-S-23	1,262	1.000	42	250	10.52
	E-S-24	948	1.000	32	250	7.90
	E-S-46	1,239	1.000	41	250	10.33
	E-S-47	1,168	1.000	39	250	9.73
	C-S-07	970	1.000	32	250	8.08
	O-S-25	723	1.000	24	250	6.03
	O-S-27	948	1.000	32	250	7.90
	O-S-29	1,074	1.000	36	250	8.95
	Total			775		193.73
C1	H-S-05	871	1.000	29	250	7.26
	H-L-02	4,990	1.000	166	250	41.58
	E-M-21	1,741	1.000	58	250	14.51
	E-M-22	1,616	1.000	54	250	13.47
	E-M-23	1,890	1.000	63	250	15.75
	E-S-02	953	1.000	32	250	7.94
	E-S-22	1,461	1.000	49	250	12.18
	E-S-48	1,119	1.000	37	250	9.33
	E-S-52	932	1.000	31	250	7.77
	C-M-03	1,818	1.000	61	250	15.15
	C-S-05	991	1.000	33	250	8.26
	C-S-10	746	1.000	25	250	6.22
	C-S-11	915	1.000	31	250	7.63
	C-S-16	1,190	1.000	40	250	9.92
	O-L-06	6,009	1.000	200	250	50.08
	O-M-02	1,526	1.000	51	250	12.72
	O-M-08	2,739	1.000	91	250	22.83
	O-M-09	1,574	1.000	52	250	13.12
	O-S-02	1,047	1.000	35	250	8.73
	O-S-04	1,498	1.000	50	250	12.48
	O-S-30	1,413	1.000	47	250	11.78
	O-S-35	1,489	1.000	50	250	12.41
	O-S-36	1,455	1.000	49	250	12.13
	Total			1,333		333.19
C2	H-L-01	8,657	1.000	289	250	72.14
	E-S-36	823	1.000	27	250	6.86
	E-S-37	1,078	1.000	36	250	8.98
	O-S-01	1,132	1.000	38	250	9.43
	Total			390		97.42
C3	H-S-01	1,023	1.000	34	250	8.53
	H-S-02	926	1.000	31	250	7.72
	E-S-25	783	1.000	26	250	6.53

BODLOAD1.XLS

Table 4.2.4(4) Discharge Volume and Pollution Load of Major Consumers

Discharge Sub-Block	Code Name	Water Consumption (m3/month)	Discharge Rate	Discharge Volume (m3/day)	Water Quality (BOD5) (mg/l)	Pollution Load (kg/day)
C3	E-S-38	860	1.000	29	250	7.17
	E-S-39	1,356	1.000	45	250	11.30
	E-S-40	1,029	1.000	34	250	8.58
	E-S-41	1,382	1.000	46	250	11.52
	E-S-42	1,285	1.000	43	250	10.71
	C-L-01	5,062	1.000	169	250	42.18
	C-S-12	1,441	1.000	48	250	12.01
	C-S-13	1,335	1.000	45	250	11.13
	O-L-01	3,009	1.000	100	250	25.08
	O-L-04	4,105	1.000	137	250	34.21
	O-M-10	2,415	1.000	81	250	20.13
	O-M-12	1,551	1.000	52	250	12.93
	O-M-13	1,509	1.000	50	250	12.58
	O-S-03	1,334	1.000	44	250	11.12
	O-S-20	1,393	1.000	46	250	11.61
	I-S-06	996	1.000	33	1000	33.20
	Total			1,093		298.18
C4	E-L-04	5,732	1.000	191	250	47.77
	E-L-08	3,626	1.000	121	250	30.22
	E-S-07	1,373	1.000	46	250	11.44
	E-S-10	1,049	1.000	35	250	8.74
	E-S-16	1,106	1.000	37	250	9.22
	O-M-01	2,178	1.000	73	250	18.15
	O-S-11	997	1.000	33	250	8.31
	I-S-04	1,380	1.000	46	1000	46.00
	Total			581		179.84
D	E-M-16	1,655	1.000	55	250	13.79
	E-S-21	919	1.000	31	250	7.66
	O-L-03	3,753	1.000	125	250	31.28
	O-M-14	1,944	1.000	65	250	16.20
	O-S-32	1,433	1.000	48	250	11.94
	O-S-33	925	1.000	31	250	7.71
	I-S-07	869	1.000	29	200	5.79
	Total			383		94.37
E	E-M-27	2,334	1.000	78	250	19.45
	O-S-12	963	1.000	32	250	8.03
	I-L-01	9,837	1.000	328	1250	409.88
	I-M-04	1,902	1.000	63	1400	88.76
	I-M-05	2,064	1.000	69	800	55.04
	I-M-06	1,688	1.000	56	1250	70.33
	I-M-07	2,348	1.000	78	800	62.61
	I-S-01	1,076	1.000	36	800	28.69
	Total			740		742.79
F	E-L-02	5,282	1.000	176	250	44.02
	E-L-03	6,870	1.000	229	250	57.25
	E-L-05	9,138	1.000	305	250	76.15
	E-L-06	3,135	1.000	105	250	26.13
	E-L-07	4,251	1.000	142	250	35.43
	E-M-07	2,708	1.000	90	250	22.57
	E-M-09	2,416	1.000	81	250	20.13

BODLOAD1.XLS

Table 4.2.4(5) Discharge Volume and Pollution Load of Major Consumers

Discharge Sub-Block	Code Name	Water Consumption (m3/month)	Discharge Rate	Discharge Volume (m3/day)	Water Quality (BOD5) (mg/l)	Pollution Load (kg/day)
F	E-M-10	2,850	1.000	95	250	23.75
	E-S-14	696	1.000	23	250	5.80
	E-S-15	983	1.000	33	250	8.19
	E-S-17	1,057	1.000	35	250	8.81
	E-S-18	1,277	1.000	43	250	10.64
	E-S-19	923	1.000	31	250	7.69
	C-M-07	1,595	1.000	53	250	13.29
	C-S-14	1,075	1.000	36	250	8.96
	C-S-15	1,595	1.000	53	250	13.29
	O-L-02	3,117	1.000	104	250	25.98
	I-S-09	1,380	1.000	46	1250	57.50
	Total			1,678		465.57
G1.1	E-L-10	3,041	1.000	101	250	25.34
	E-M-12	2,095	1.000	70	250	17.46
	E-S-29	984	1.000	33	250	8.20
	E-S-30	784	1.000	26	250	6.53
	E-S-31	855	1.000	29	250	7.13
	O-S-16	934	1.000	31	250	7.78
	O-S-17	1,045	1.000	35	250	8.71
	Total			325		81.15
G1.2	E-M-13	1,765	1.000	59	250	14.71
	E-S-32	1,033	1.000	34	250	8.61
	Total			93		23.32
G2.1	O-S-15	914	1.000	30	250	7.62
G2.2	O-S-31	770	1.000	26	250	6.42
H2	E-L-11	14,341	1.000	478	250	119.51
	E-M-28	2,242	1.000	75	250	18.68
	Total			553		138.19
I1	O-S-42	1,168	1.000	39	250	9.73
I3	O-M-17	1,666	1.000	56	250	13.88
J1	O-M-15	1,505	1.000	50	250	12.54
	O-M-16	2,931	1.000	98	250	24.43
	I-S-08	1,346	1.000	45	200	8.97
	Total			193		45.94
J4	O-S-41	922	1.000	31	250	7.68
K1.1	E-M-24	2,347	1.000	78	250	19.56
	E-S-26	1,400	1.000	47	250	11.67
	E-S-35	867	1.000	29	250	7.23
	E-S-49	951	1.000	32	250	7.93
	Total			186		46.38
K2	O-S-40	1,327	1.000	44	250	11.06
Total				15,991		8,872.10

Note: Code Name (I: Industy, H: Hotel, C: Commercial Building,
E: Public Establishment, O: Others; L: Q>100m3/day, M: 50<Q<100m3/da
S: 25<Q<50m3/day)

BODLOAD1.XLS

4.3 DEVELOPMENT OF WATER QUALITY SIMILATION MODEL

4.3.1 Outline of the Model

A water quality simulation model for BOD and DO have been established based on the following equations which are modifications of the Streeter-Phelps model.

$$L_l = \left(L_u - \frac{L_a}{K_r}\right)\exp(-K_r t) + \frac{L_a}{K_r}$$

$$D_l = \frac{K_1}{K_2 - K_r}\left(L_u - \frac{L_a}{K_r}\right)\left\{\exp(-K_r t) - \exp(-K_2 t)\right\}$$

$$+\frac{K_1}{K_2}\left(\frac{L_a}{K_r} + \frac{D_B}{K_1}\right)\left\{1 - \exp(-K_2 t)\right\} + D_u \exp(-K_2 t)$$

Where,

L : Ultimate BOD (mg/l)

D : Saturation deficit of dissolved oxygen (mg/l)

= Ds - Do

Ds : Saturation concentration of dissolved oxygen (mg/l)

Do : Actual concentration of dissolved oxygen (mg/l)

Subscripts :

u : Value at an upstream point

l : Value at a downstream point

K_r : BOD diminution rate of river water (/day)

(= $K_1 + K_3$)

K_1 : Diminution rate associating the consumption of dissolved oxygen (/day)

K_2 : Reaeration rate (/day)

K_3 : Diminution rate including sedimentation without consumption of dissolved oxygen (/day)

L_a : BOD supplied by river bed (mg/l/day)

D_B : Supply or consumption of oxygen excluding reaeration (mg/l/day)

It is difficult to apply the above equations directly for water quality simulation of a river having many inflows from tributaries and drains that frequently increase the river flowrate. Since the above equations can be only applied to a reach with a constant flowrate, many reaches have to be defined in accordance with such inflows.

To simplify and to establish a concrete simulation model, it is assumed that there are many water flows in a reach. These water flows consist of a basic flow from an upper reach, inflows from tributaries and drains, and inflow/outflow of subsurface water, that have constant flowrates. BOD concentration (L) can be interpreted as the pollution load on the basis of such assumptions. Pollution load of the base flow decreases as it flows down to a lower end of the reach. This change can be simulated by the above equation. Flowrates and pollution loads of water flows are summed up separately for the reach. Finally, a summed pollution load is divided by a summed flowrate to obtain a water quality value at the lower end of the reach.

The concept of the above-mentioned method for the BOD simulation model is described below. The model for DO was also established in the similar manner.

River flowrate Q_n in a reach "n" is described by the following equation.

$$Q_n = Q_0 + \sum_{i=1}^{n} (Q_i + Q_{0i} - Q_{1i})$$

Where,

- Q_n: River flowrate in a reach "n"
- Q_0: River flowrate at the upper end of whole reaches
- Q_i: Total flowrate of inflow tributaries in reach "i"

$$Q_i = \sum_{j=1}^{m} Q_{ij}$$

Where,
- Q_{ij} : Flowrate of inflow tributary "j"
- m : Number of tributaries in reach "i"

- Q_{0i}: Flowrate of inflow subsurface water in reach "i"
- Q_{1i}: Intake volume in reach "i"

Pollution load run-off L_n in a reach "n" is described by the following equation.

$$L_n = L_{n-1}\exp(-K_{rn}t_n) + \sum_{j=1}^{m} L_{nj}\exp(-K_{rn}t_{nj}) + L_{0n} - L_{1n} \qquad (1)$$

Where,

- L_n : Pollution load run-off (final BOD) in reach "n"
- L_{n-1}: Pollution load run-off (final BOD) in reach "n-1"
- L_{nj} : Pollution load of inflow tributary "j"
- t_n : Flow time in reach "n"

t_{nj} : Flow time from the inflow point "j" to the lower end of reach "n"

$t_{nj}=d_{nj}/v_n$

Where,

d_{nj} : Flow length between inflow point "j" and the lower end of reach "n"

v_n : Average flow velocity in reach "n"

K_{rn}: BOD diminution rate of river water in reach "n"

$K_r=K_1+K_3$

where,

K_1: Deoxygenation coefficient

K_3: Diminution rate including sedimentation without consumption of dissolved oxygen

L_{0n}: Pollution load of inflow subsurface water in reach "n"

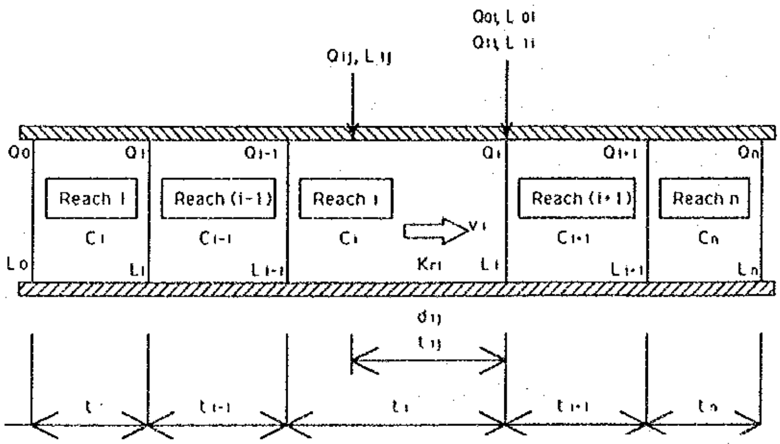
L_{1n}: Pollution load of intake volume in reach "n"

Then, river water quality in reach "n" is estimated by the following equation.

$C_n = L_n/Q_n$

Where,

C_n : Concentration of BOD (final BOD) in reach "i"



The altitude of evaluation points should be taken into consideration to establish a model for DO. The saturation concentration of DO varies with temperature and atmospheric pressure, and these meteorological parameters vary with altitude. The difference of altitude between the evaluation points R1 and R15 is 1,300 meters. Therefore, the effects of altitude difference was incorporated into the model and necessary parameters were estimated in the manner explained below.

Air Temperature

The following equation was established from the existing meteorological observation data.

$$AT = 16.2 + 0.0070 \times (3632 - H)$$

Where,

AT : Air temperature (°C)

H : Altitude (meters above the sea level)

Water Temperature

The following equation was established from the results of the river water survey.

$$WT = 7.5 + 0.0043 \times (4320 - H)$$

Where,

WT : Water temperature (°C)

Atmospheric Pressure

The following meteorological equation was applied.

$$P = \frac{P_o}{10^{\left\{\frac{H}{18400\,(1 + 0.00366 \times AT)}\right\}}}$$

Where,

P : Atmospheric pressure at H meter (hecto Pa)

P_o : Atmospheric pressure at the sea level (hecto Pa)

Saturated Vapor Pressure

The following meteorological equation was applied.

$$\begin{aligned}\text{Log } P_e = {} & 10.79574\left(1-\frac{273.16}{T}\right) - 5.02800 \log\left(\frac{T}{273.16}\right) \\ & + 1.50475 \times 10^{-4}\left\{1-10^{-8.2969(T/273.16-1)}\right\} \\ & + 0.42873 \times 10^{-3}\left\{10^{4.76955(1-273.16/T)} - 1\right\} \\ & + 0.78614\end{aligned}$$

Where,

P_e : Saturated vapor pressure (hecto Pa)

T : AT + 273.16 (°K)

Saturation Concentration of Dissolved Oxygen

The following equation was applied.

$$D = 0.509 (P - P_e) / (WT + 35)$$

Where,

D : Saturation concentration of dissolved oxygen (mg/l)

The flowchart of activities used to establish the model is shown in Fig. 4.3.1 .

4.3.2 Pollutant Run-off Model

The entire basin of the Choqueyapu River, including all tributaries, was divided into eight reaches as shown in Fig.4.3.2. The lower ends of the reaches are the points of water quality and flowrate measurement conducted in this Study. These points are also the representative points to evaluate the water quality of the Choqueyapu River.

[Reach]	[Representative Point]	[Remarks]
1	R1	Unpolluted Area
2	R2	Some Villages, Pasture of Alpacas, Sheep, etc.
3	R3	Industrial Zone, Some Community
4	R4	Densely Populated Area, Commercial Zone
5	R5	Residential Zone, Some Hospitals
6	R9	Residential, Industrial Zone, Inflow of Tributaries (Kotahuma, Orkojahuira)
7	R14	New Residential Zone, Inflow of Tributaries (Irpavi, Achumani, Huañajahuira)
8	R15	Suburban Area

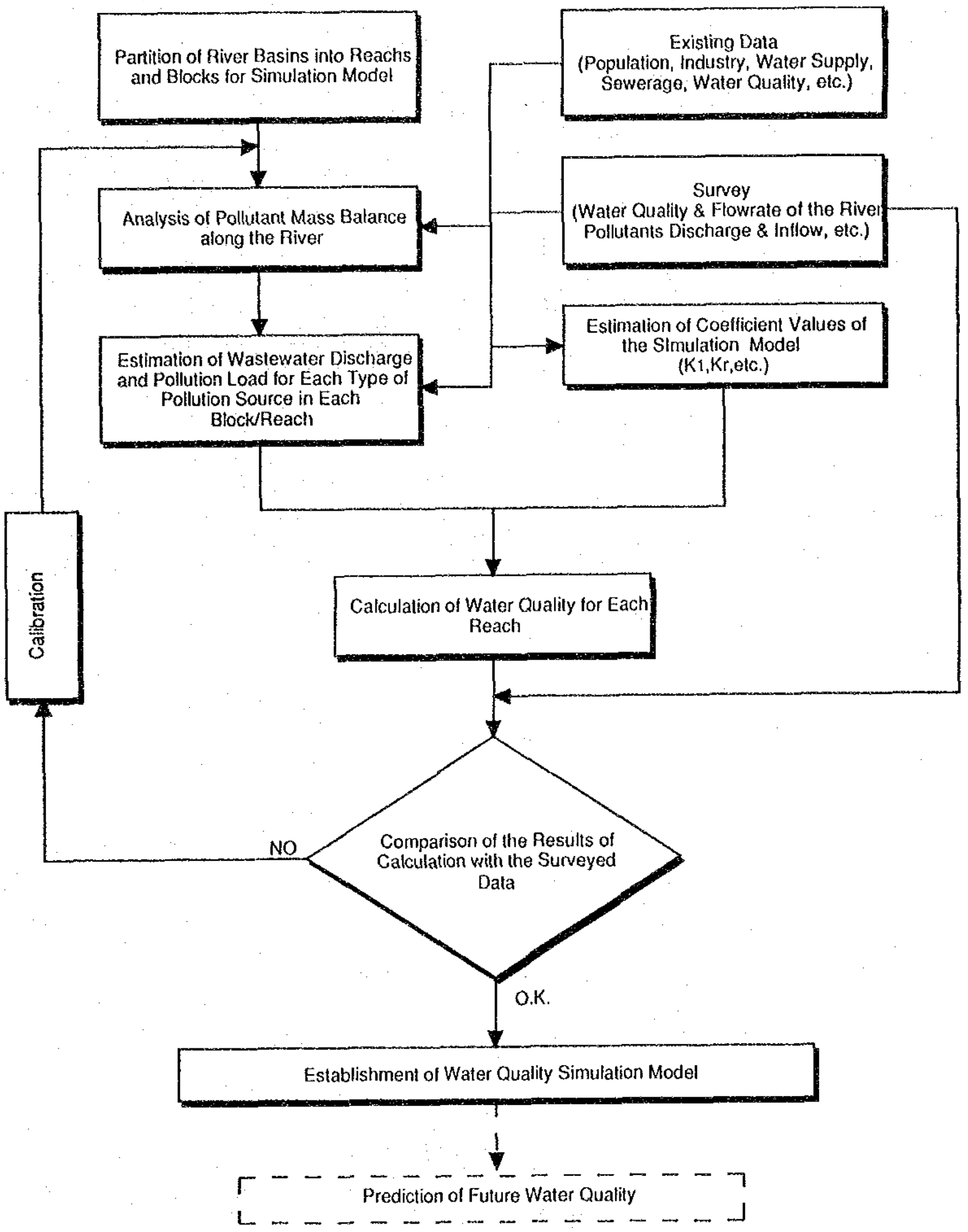


Fig. 4.3.1 Flowchart of Construction of Water Quality Simulation Model

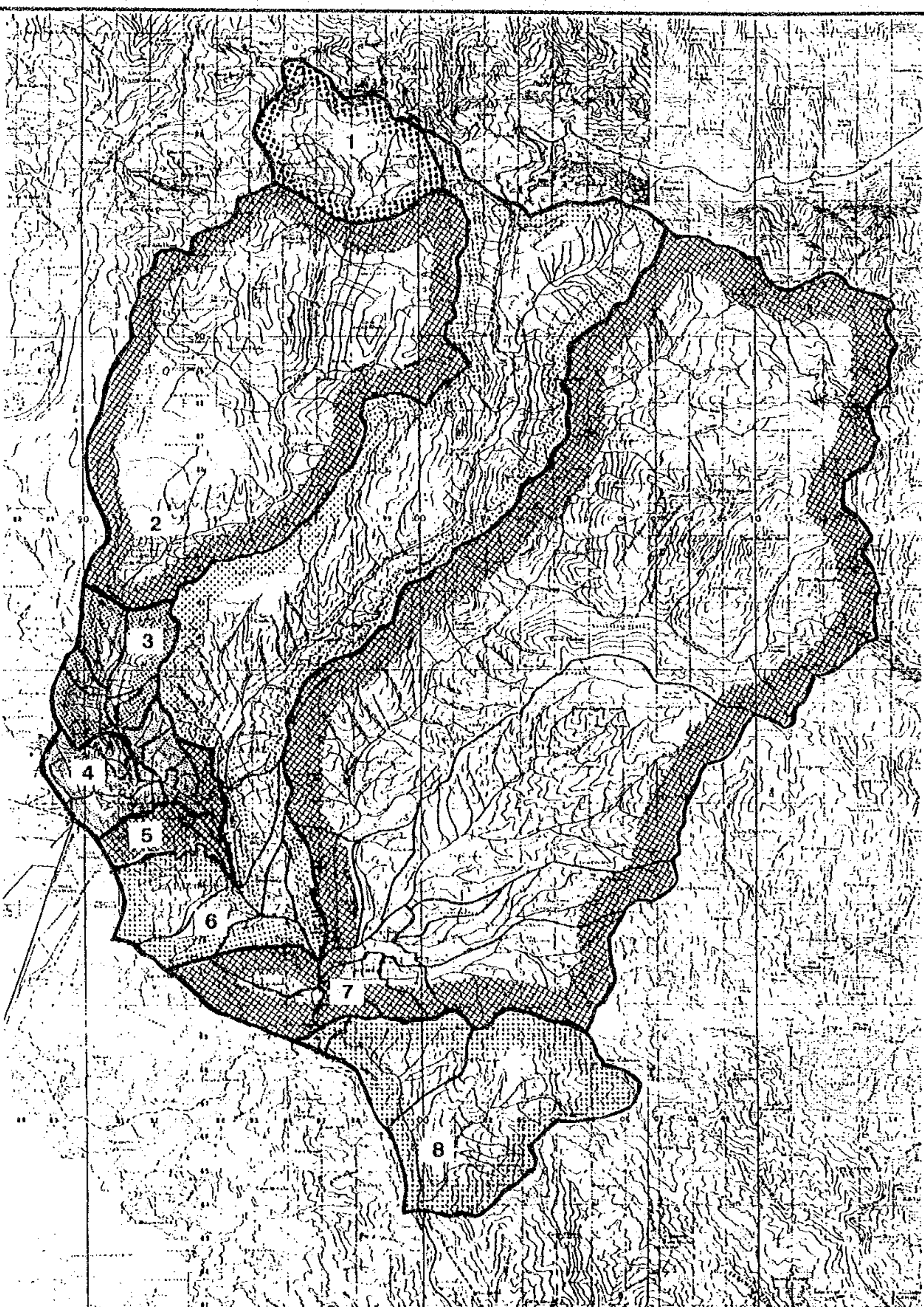


Fig. 4.3.2 Partition of Reaches for Water Quality Simulation Model

The reaches were further divided into blocks to estimate wastewater discharge and pollution load according to the discharge system as shown in Fig.4.3.3. Arrows in Fig. 4.3.3 show representative inflow points of the discharge blocks.

The amounts of wastewater discharge and pollution load for each discharge block were determined by comparing the computed values with the actually observed values.

4.3.3 Water Purification Rate

The water purification rate for BOD is described by a function of BOD diminution rate (K_r) and flow time (t). K_r was estimated by substituting the measured values of BOD and flowrate into Equation (1).

The value of K_r for reach "6" was estimated to be from 2.76 to 4.25, and the K_r for reach "8" was estimated to be from 1.13 to 1.75. As appropriate values for the model, K_r=0.50 ~ 3.71 were applied through the calibration of the model.

K_2 was also estimated in a similar manner. Appropriate values were determined to be 0.43 ~ 4.68/day through the calibration of the model.

Values of the deoxygenation coefficient (K_1) were obtained from the laboratory analyses performed along with the river water quality survey.

4.3.4 Discussion on the Present Water Quality

Discharged wastewater amounts and pollution loads for all the reaches in the model are shown in Table 4.3.1. Simulated flow rate in the dry season and BOD values are shown in Table 4.3.2, and simulated DO values are shown in Table 4.3.3.

In the urbanized areas excluding the reach "R2-R3", the pollution loads from domestic wastewater are dominant as compared with industrial wastewater.

The simulated values for flow rate in the dry season are also shown in Table 4.3.4 and Fig.4.3.4. Those for BOD are shown in Table 4.3.5 and Fig.4.3.5, and for DO in Table 4.3.6 and Fig. 4.3.6, each being compared with observed values. From these results, the model can be judged to be capable of simulating the actual water quality of the Choqueyapu River. Therefore, this simulation model can be applied to predict future water quality and to evaluate the effects of pollution control measures to be considered in the present Study.

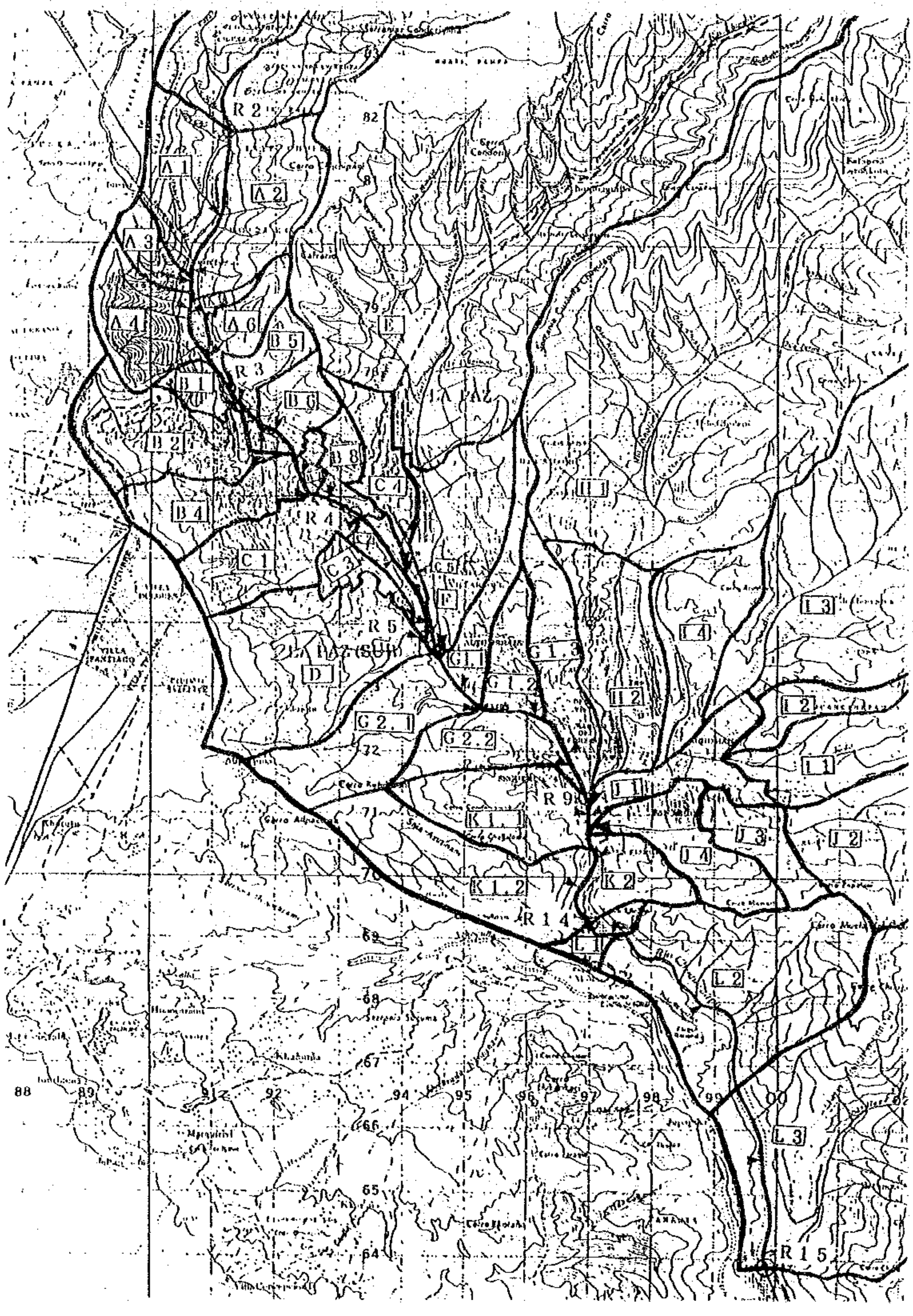


Fig. 4.3.3 Discharge Blocks and Inflow Points of Water Quality Simulation Model

Table 4.3.1 List of Discharged Wastewater Amount and Pollution Load for All Reaches of the Model (Present : 1992)

Block	Sub Block	Population	Rate of Water Supply Service (%)	Rate of Sewerage Service (%)	Water Supply Area (by House Connection) Discharge Amount(m3/day)		Water Supply Area (by House Connection) BOD Load (kg/day)		Leakage of Water Supply			Other Area Discharge Amount (m3/day)		Other Area BOD Load (kg/day)		Major Consumers' Waste Water Discharge Volume	Major Consumers' Waste Water BOD Load	Inflow to the river Discharge Volume		Inflow to the river BOD Load	
					Per Capita	Gross	Per Capita	Gross	Discharge (m3/day)	BOD (mg/l)	BOD Load (kg/day)	Per Capita	Gross	Per Capita	Gross	(m3/day)	(kg/day)	Inflow Rate	Gross (m3/day)	Inflow Rate	Gross (kg/day)
A	1	13,301	96.2	100	0.130	1,663	0.035	447.86	416	2.5	1.04	0.060	30	0.027	13.65			0.89	1,087	0.79	364.16
	2	8,227	96.2	100	0.130	1,029	0.035	277.00	257	2.5	0.64	0.060	15	0.027	8.44			0.89	1,167	0.79	225.23
	3	8,532	96.2	100	0.130	1,067	0.035	287.29	267	2.5	0.67	0.060	19	0.027	8.75			0.89	1,210	0.98	292.00
	4	1,161	96.2	100	0.130	145	0.035	39.08	36	2.5	0.09	0.060	3	0.027	1.19	842	413.39	0.98	1,007	1.00	453.11
	5	2,262	96.2	100	0.130	283	0.035	76.15	71	2.5	0.18	0.060	5	0.027	2.32	449	802.60	0.95	769	1.00	880.00
	6	10,166	96.2	100	0.130	1,271	0.035	342.30	318	2.5	0.79	0.060	23	0.027	10.43	63	78.42	0.90	1,505	0.99	426.33
	total	43,649				5,459		1,469.68	1,365		3.41		100		44.70	1,354	1,294.41		7,545		2,640.84
B	1	10,728	96.2	100	0.130	1,342	0.035	361.20	335	2.5	0.84	0.060	24	0.027	11.01	89	22.34	0.90	1,611	0.99	989.47
	2	94,372	96.2	100	0.130	11,802	0.035	3,177.51	2,951	2.5	7.38	0.060	215	0.027	96.83	1,374	776.04	0.90	14,759	0.79	3,204.52
	3	8,100	96.2	100	0.130	1,013	0.035	272.74	253	2.5	0.63	0.060	18	0.027	8.31	2,102	3,112.94	0.96	3,251	1.00	3,390.16
	4	69,499	96.2	100	0.130	8,692	0.035	2,340.02	2,173	2.5	5.43	0.060	158	0.027	71.31	1,026	284.82	0.90	10,883	0.79	2,130.56
	5	10,405	96.2	100	0.130	1,301	0.035	350.34	325	2.5	0.81	0.060	24	0.027	10.68	124	116.86	0.90	1,599	0.79	378.35
	6	19,291	96.2	100	0.130	2,412	0.035	649.51	603	2.5	1.51	0.060	44	0.027	19.79	361	220.09	0.91	3,117	0.79	704.20
	7	10,225	96.2	100	0.130	1,279	0.035	344.27	320	2.5	0.80	0.060	23	0.027	10.49	993	248.15	0.93	2,443	0.99	598.07
	8	24,189	96.2	100	0.130	3,025	0.035	814.45	756	2.5	1.89	0.060	55	0.027	24.82	775	193.73	0.91	4,206	0.79	817.23
	total	246,809				30,866		8,310.05	7,716		19.29		563		253.23	6,864	4,974.97		41,870		11,612.56
C	1	86,789	96.2	100	0.130	10,854	0.035	2,922.18	2,713	2.5	6.78	0.060	198	0.027	89.05	1,333	333.19	0.90	13,642	0.89	2,972.96
	2	3,291	96.2	100	0.130	412	0.035	110.80	103	2.5	0.26	0.060	8	0.027	3.38	390	97.42	0.94	856	0.99	210.03
	3	32,064	96.2	100	0.130	4,010	0.035	1,079.60	1,002	2.5	2.51	0.060	73	0.027	32.90	1,093	298.18	0.91	5,641	0.99	1,395.49
	4	37,219	96.2	100	0.130	4,655	0.035	1,253.16	1,164	2.5	2.91	0.060	85	0.027	38.19	581	179.84	0.90	5,860	0.89	1,308.19
	5	0			0.130	0	0.035	0.00	0	2.5	0.00	0.060	0	0.027	0.00				0		0.00
	total	159,363				19,930		5,365.74	4,982		12.46		363		163.51	3,397	908.63		25,000		5,886.67
D		65,767	67	100	0.130	5,728	0.035	1,542.23	1,432	2.5	3.58	0.060	1,302	0.027	585.98	383	94.37	0.65	7,479	0.69	1,545.11
E		70,893	62.5	100	0.130	5,760	0.035	1,550.79	1,440	2.5	3.60	0.060	1,595	0.027	717.80	740	742.79	0.84	8,018	0.53	1,592.57
F		44,540	62.5	100	0.130	3,620	0.035	974.49	905	2.5	2.26	0.060	1,002	0.027	451.05	1,678	465.57	0.87	6,251	0.70	1,333.37
G	1.1	15,737	73.1	100	0.130	1,496	0.035	402.64	374	2.5	0.93	0.060	254	0.027	114.30	325	91.15	0.87	2,134	0.90	541.40
	1.2	11,698	73.1	100	0.130	1,112	0.035	299.29	278	2.5	0.69	0.060	189	0.027	84.96	93	23.32	0.86	1,438	0.90	365.44
	1.3	15,394	73.1	100	0.130	1,463	0.035	393.87	366	2.5	0.91	0.060	248	0.027	111.81			0.85	1,770	0.89	450.23
	Sub-total	42,830				4,070		1,095.80	1,018		2.54		691		311.07	418	104.47		5,342		1,357.07
	2.1	716	3.1	100	0.130	3	0.035	0.78	1	2.5	0.00	0.060	42	0.027	18.74	30	7.62	0.72	55	0.65	17.77
	2.2	2,500	3.1	100	0.130	10	0.035	2.71	3	2.5	0.01	0.060	145	0.027	65.41	26	6.42	0.60	110	0.56	41.84
	Sub-total	3,216				13		3.49	3		0.01		187		84.15	56	14.03		164		59.60
	total	46,046				4,083		1,099.29	1,021		2.55		878		395.22	474	118.50		5,507		1,416.67
H	1	3,234	9.4	0	0.130	40	0.035	10.64	10	2.5	0.02	0.060	176	0.027	79.12			0.59	132	0.28	25.11
	2	7,251	64.4	100	0.130	607	0.035	163.43	152	2.5	0.38	0.060	155	0.027	69.69	553	138.19	0.90	1,313	0.91	336.65
	total	10,485				647		174.07	162		0.40		331		148.81	553	138.19		1,445		361.76
I	1	3,910	61.1	100	0.130	311	0.035	83.62	78	2.5	0.19	0.060	91	0.027	41.07	39	9.73	0.84	434	0.91	108.78
	2	3,315	45.9	100	0.130	199	0.035	53.26	49	2.5	0.12	0.060	108	0.027	48.43			0.78	276	0.76	77.06
	3	344	45.9	100	0.130	21	0.035	5.53	5	2.5	0.01	0.060	11	0.027	5.02	56	13.88	0.91	84	0.84	20.49
	4	359	45.9	100	0.130	21	0.035	5.77	5	2.5	0.01	0.060	12	0.027	5.25			0.78	30	0.76	8.35
	total	7,929				550		148.18	138		0.34		222		99.77	94	23.62		824		214.68
J	1	5,283	61.1	100	0.130	499	0.035	134.36	125	2.5	0.31	0.060	147	0.027	65.99	193	45.94	0.86	827	0.92	226.71
	2	2,995	61.1	100	0.130	238	0.035	64.06	59	2.5	0.15	0.060	70	0.027	31.46			0.82	303	0.80	76.62
	3	3,388	61.1	100	0.130	269	0.035	72.45	67	2.5	0.17	0.060	79	0.027	35.59			0.82	342	0.80	86.66
	4	5,352	61.1	100	0.130	425	0.035	114.45	106	2.5	0.27	0.060	125	0.027	56.21	31	7.68	0.83	571	0.91	161.67
	total	18,018				1,431		385.32	358		0.89		421		189.24	223	53.62		2,044		551.65
K	1.1	2,006	61.1	100	0.130	159	0.035	42.90	40	2.5	0.10	0.060	47	0.027	21.07	186	46.38	0.90	388	0.94	104.10
	1.2	255	61.1	100	0.130	20	0.035	5.45	5	2.5	0.01	0.060	6	0.027	2.68			0.82	26	0.90	7.34
	Sub-total	2,261				180		48.35	45		0.11		53		23.75	186	46.38		414		111.43
	2	924	61.1	100	0.130	73	0.035	19.75	18	2.5	0.05	0.060	22	0.027	9.70	44	11.06	0.87	138	0.93	37.64
	total	3,185				253		68.11	63		0.16		74		33.45	230	57.43		551		149.07
L	1	714	0	100	0.130	0	0.035	0.00	0	2.5	0.00	0.060	43	0.027	19.28			0.50	21	0.50	9.64
	2	719	0	100	0.130	0	0.035	0.00	0	2.5	0.00	0.060	43	0.027	19.40			0.50	22	0.50	9.70
	3	201	0	100	0.130	0	0.035	0.00	0	2.5	0.00	0.060	12	0.027	5.42			0.50	6	0.50	2.71
	total	1,633				0		0.00	0		0.00		98		44.10	0	0.00		49		22.05
Total		718,325				78,327		21,087.94	19,582		48.95		6,949		3,126.94	15,991	8,872.10		107,583		27,327.00

Table 4.3.2 Results of Water Quality Simulation (Flowrate and BOD)

Reach Upper Side	Reach Lower Side	Block	Catchment Area (km2)	Distance (m)	Flow Velocity (m/s) (V)R1	(V)R2	Ave. V	Kr (1/day)	Inflow Pollution Load: Domestic & Industrial (m3/day)	Others (m3/day)	Sub-total (m3/day)	Domestic & Industrial (kg/day)	Others (kg/day)	Sub-total (kg/day)	K1 (1/day)	Last-BOD (kg/day)	Flow Distance (m)	Basic Pollution Load: Specific Discharge Q(m3/day/km2)	BOD5 (mg/l)	Q (m3/day)	L (kg/day)	Last-L (kg/day)	Qi (m3/day)	Qi (m3/sec)	Li (kg/day)	BOD5 (mg/l)
Origin	R1	Qu.Lu									0			0.00	0.120	0.00	0.0								0.00	
		total	18.2	5,000		0.29	0.29	3.71			0				0.120	0.00		518.40	1.2	8,398	10.08	22.34	8,398	0.10	22.34	1.2
R1	R2	Qu.Lu									8,398					22.34	15,650.0						8,398	0.10	1.68	
		(Dam)									0			0.00	0.120	0.00	7,825.0						0	0.00	0.00	
		total	90.8	15,650	0.29	0.23	0.26	3.71			8,398			0	0.120	0.00		136.20	3.6	12,367	44.52	98.68	20,765	0.24	100.36	2.2
R2	R3	Qu.Lu									20,765					100.36	4,550.0						20,765	0.24	78.78	
		A1							1,887		1,887	364.16		364.16	0.124	788.13	3,125.0						1,887	0.02	667.39	
		A2							1,167		1,167	225.23		225.23	0.124	487.48	2,000.0						1,167	0.01	438.25	
		A3							1,210		1,210	292.00		292.00	0.124	631.98	1,800.0						1,210	0.01	574.23	
		A4							1,007		1,007	453.11		453.11	0.124	980.64	1,500.0						1,007	0.01	905.41	
		A5							789		789	880.00		880.00	0.124	1,904.54	1,400.0						789	0.01	1,767.80	
		A6							1,505		1,505	426.33		426.33	0.124	922.68	500.0						1,505	0.02	898.45	
		total	12.9	4,550	0.23	0.64	0.44	2			7,545			2,640.84	0.124	5,715.41		657.90	3.6	8,487	30.55	66.12	36,797	0.43	5,396.44	67.8
R3	R4	Qu.Lu									36,797					5,396.44	2,800.0						36,797	0.43	4,570.15	
		B1							1,611		1,611	389.47		389.47	0.124	842.91	2,450.0						1,611	0.02	722.83	
		B2							14,759		14,759	3,204.52		3,204.52	0.124	6,935.35	1,300.0						14,759	0.17	6,420.34	
		B3							3,251		3,251	3,390.16		3,390.16	0.124	7,337.12	2,000.0						3,251	0.04	6,515.85	
		B4							10,883		10,883	2,130.56		2,130.56	0.124	4,611.06	650.0						10,883	0.13	4,436.55	
		B5							1,599		1,599	378.35		378.35	0.124	818.85	2,750.0						1,599	0.02	685.53	
		B6							3,117		3,117	704.20		704.20	0.124	1,524.06	1,750.0						3,117	0.04	1,373.70	
		B7							2,443		2,443	598.07		598.07	0.124	1,294.36	1,025.0						2,443	0.03	1,217.96	
		B8							4,206		4,206	817.23		817.23	0.124	1,768.68	500.0						4,206	0.05	1,716.96	
		total	10.7	2,800	0.64	0.53	0.59	3			78,866			11,612.56	0.124	25,132.39		535.00	2.2	5,725	12.59	27.26	84,391	0.98	27,703.14	151.7
R4	R5	Qu.Lu									84,391					27,703.14	2,640.0						84,391	0.98	23,620.75	
		C1							13,642		13,642	2,972.96		2,972.96	0.127	6,324.58	2,450.0						13,642	0.16	5,454.80	
		C2							856		856	210.03		210.03	0.127	446.82	1,500.0						856	0.01	408.13	
		C3							5,641		5,641	1,395.49		1,395.49	0.127	2,968.71	575.0						5,641	0.07	2,867.40	
		C4							5,860	1,825	7,685	1,308.19		1,308.19	0.127	2,783.01	1,200.0						7,685	0.09	2,588.47	
		C5							0		0	0.00		0.00	0.127	0.00	400.0						0	0.00	0.00	
		total	6.2	2,640	0.53	0.62	0.58	3			112,215			5,886.67	0.127	12,523.12		434.00	2.2	2,691	5.92	12.59	114,906	1.33	34,952.14	143.0
R5	R9	Qu.Lu									114,906					34,952.14	4,100.0						114,906	1.33	26,702.01	
		D	5.8						7,479	8,803	16,282	1,545.11	7.40	1,552.51	0.154	2,891.14	4,000.0	580.00	2.2	3,384	7.40	13.78	16,282	0.19	2,223.27	
		E	88.2						8,018	15,558	23,577	1,592.57	34.23	1,626.80	0.122	3,562.47	3,700.0	176.40	2.2	15,558	34.23	74.98	23,577	0.27	2,794.02	
		F	4.3						6,251	92	6,344	1,333.37	0.20	1,333.57	0.122	2,920.35	3,700.0	21.50	2.2	92	0.20	0.45	6,344	0.07	2,290.41	
		G1.1							2,134	0	2,134	541.40		541.40	0.134	1,108.77	3,000.0						2,134	0.02	910.51	
		G1.2							1,438	0	1,438	365.44		365.44	0.134	748.40	1,800.0						1,438	0.02	684.96	
		G1.3							1,770	0	1,770	450.23		450.23	0.134	922.05	1,075.0						1,770	0.02	859.21	
		G2.1							55	0	55	17.77		17.77	0.134	36.39	2,650.0						55	0.00	30.57	
		G2.2							110	0	110	41.84		41.84	0.134	85.68	725.0						110	0.00	81.69	
		total	11.4	4,100	0.62	0.79	0.71	4			166,615			5,929.55	0.134	12,275.25		-2,622.00	107.1	-29,891	-3,202.35	-6,558.28	138,724	1.58	29,998.36	107.1
R9	R14	Qu.Lu									138,724					29,998.36	1,900.0						138,724	1.58	29,570.26	
		H1	159.5						132	25,440	25,573	25.11	55.97	81.08	0.114	186.61	1,875.0	159.50	2.2	25,440	55.97	128.82	25,573	0.30	183.88	
		H2	4.4						1,313	3,872	5,185	338.65	13.94	350.59	0.114	808.94	1,875.0	880.00	3.6	3,872	13.94	32.08	5,185	0.06	795.57	
		I1							434	0	434	108.78		108.78	0.114	250.37	1,875.0						434	0.01	248.84	
		I2							276	0	276	77.06		77.06	0.114	177.37	1,875.0						276	0.00	174.88	
		I3							84	0	84	20.49		20.49	0.114	47.16	1,875.0						84	0.00	46.50	
		I4	62.1						30	19,282	19,312	8.35	69.42	77.78	0.114	178.98	1,875.0	310.50	3.6	19,282	69.42	159.77	19,312	0.22	176.46	
		J1							827	6,500	7,327	226.71	21.74	248.45	0.114	571.83	1,750.0						7,327	0.08	564.31	
		J2							303	0	303	76.62		76.62	0.114	176.35	1,600.0						303	0.00	174.23	
		J3							342	0	342	86.66		86.66	0.114	199.46	1,600.0						342	0.00	197.06	
		J4	18.4						571	2,370	2,941	161.67	8.53	170.20	0.114	391.73	1,600.0	128.60	3.6	2,370	8.53	19.64	2,941	0.03	387.02	
		K1.1							388	0	388	104.10		104.10	0.129	218.99	1,825.0						388	0.00	215.99	
		K1.2							26	0	26	7.34		7.34	0.129	15.43	850.0						26	0.00	15.34	
		K2							138	0	138	37.64		37.64	0.129	79.18	1,150.0						138	0.00	78.49	
		WWTP(Irpavi)																								
		total	10.1	1,900	0.79	0.74	0.77	0.5			199,054			1,446.76	0.129	3,300.40		2,121.00	3.6	21,422	77.12	162.24	220,476	2.55	32,989.18	71.1
R14	R15	Qu.Lu									220,476					32,989.18	7,250.0						220,476	2.55	31,391.20	
		L1							21		21	9.64		9.64	0.115	22.04	7,025.0						21	0.00	21.01	
		L2							22		22	9.70		9.70	0.115	22.19	5,000.0						22	0.00	21.44	
		L3							6		6	2.71		2.71	0.115	6.19	1,575.0						6	0.00	6.13	
		WWTP(Lipan)																								
		total	34.1	7,250	0.74	0.95	0.85	0.5			220,525			22.05	0.115	50.42		1,023.00	3.6	34,884	125.58	287.18	255,409	2.96	31,726.96	54.3

Table 4.3.3 Results of Water Quality Simulation (DO)

Reach Upper Side	Reach Lower Side	Block	Q (m3/day)	Lest-BOD (Lu) (kg/day)	Flow Velocity (m/s)	Flow Distance (m)	Existing DO Concentration (mg/l)	Existing DO Load (kg/day)	Altitude (m)	Air Temperature (deg. C)	Water Temperature (deg. C)	Atmospheric Pressure (hecto Pa)	Saturated Vapor Pressure (hecto Pa)	Saturated DO Concentration (mg/l)	Saturated DO Load (kg/day)	K1 (1/day)	K2 (1/day)	Kr (1/day)	Deficient DO (Du) Concentration (mg/l)	Deficient DO (Du) Load (kg/day)	Deficient DO (Dl) Concentration (mg/l)	Deficient DO (Dl) Load (kg/day)	DO (mg/l)
Origin	R1	Qu,Lu	0	0.00	0.29	5,000	3.0	0.00	5,352	3.9	2.8	520.3	8.1	6.9	0.00	0.120	3.000	3.710	3.9	0.00		0.00	
		Basic Load	8,398	22.34	0.29	0	3.0	25.19	4,320	11.4	7.5	603.0	13.5	7.1	59.24	0.120	3.000	3.710	4.1	34.05		34.05	
		total	8,398	22.34	0.29				4,320	11.4	7.5	603.0	13.5	7.1		0.120	3.000	3.710			4.1	34.05	3.00
R1	R2	Qu,Lu	8,398	22.34	0.26	15,650	3.0	25.19	4,320	11.4	7.5	603.0	13.5	7.1	59.24	0.120	0.430	3.710	4.1	34.05		31.09	
		(Dam)	0	0.00	0.26	7,825	3.0	0.00	4,140	12.6	8.3	617.5	14.6	7.1	0.00	0.120	0.430	3.710	4.1	0.00		0.00	
		Basic Load	12,367	98.69	0.26	0	3.4	42.05	3,960	13.9	9.1	632.3	15.9	7.1	87.98	0.120	0.430	3.710	3.7	45.93		45.93	
		total	20,765	121.01	0.26				3,960	13.9	9.1	632.3	15.9	7.1		0.120	0.430	3.710			3.7	77.02	3.40
R2	R3	Qu,Lu	20,765	100.36	0.44	4,550	3.4	70.70	3,960	13.9	9.1	632.3	15.9	7.1	147.72	0.124	2.630	2.000	3.7	77.02		56.47	
		A1	1,887	788.13	0.44	3,125	2.5	4.72	3,882	14.5	9.4	638.8	16.4	7.1	13.45	0.124	2.630	2.000	4.6	8.73		9.68	
		A2	1,167	487.46	0.44	2,000	2.5	2.92	3,820	14.9	9.7	643.9	16.9	7.1	8.33	0.124	2.630	2.000	4.6	5.41		5.83	
		A3	1,210	631.96	0.44	1,800	2.5	3.03	3,809	15.0	9.7	644.8	17.0	7.1	8.64	0.124	2.630	2.000	4.6	5.61		6.28	
		A4	1,007	980.64	0.44	1,500	2.5	2.52	3,792	15.1	9.8	646.2	17.1	7.1	7.19	0.124	2.630	2.000	4.6	4.67		5.97	
		A5	769	1,904.54	0.44	1,400	2.5	1.92	3,797	15.1	9.8	646.7	17.2	7.1	5.50	0.124	2.630	2.000	4.6	3.57		6.44	
		A6	1,505	922.68	0.44	500	2.5	3.76	3,737	15.5	10.0	650.8	17.6	7.2	10.76	0.124	2.630	2.009	4.7	7.00		7.34	
		Basic Load	8,487	65.12	0.44	0	3.7	31.40	3,710	15.7	10.2	653.1	17.8	7.2	60.73	0.124	2.630	2.000	3.5	29.33		29.33	
		total	36,797	5,881.89	0.44				3,710	15.7	10.2	653.1	17.8	7.2		0.124	2.630	2.000			3.5	127.35	3.70
R3	R4	Qu,Lu	36,797	5,396.44	0.59	2,800	3.7	135.98	3,710	15.7	10.2	653.1	17.8	7.2	253.33	0.124	3.470	3.000	3.5	127.35		111.92	
		B1	1,611	842.91	0.59	2,450	2.5	4.03	3,630	15.8	10.2	654.8	17.9	7.2	11.53	0.124	3.470	3.000	4.7	7.51		7.30	
		B2	14,759	6,935.35	0.59	1,300	2.5	36.90	3,624	16.3	10.5	660.4	18.5	7.2	105.84	0.124	3.470	3.000	4.7	68.94		67.55	
		B3	3,251	7,337.12	0.59	2,000	2.5	8.13	3,664	16.0	10.3	657.0	18.1	7.2	23.29	0.124	3.470	3.000	4.7	15.16		20.21	
		B4	10,883	4,611.06	0.59	650	2.5	27.21	3,597	16.5	10.7	663.6	18.8	7.2	78.11	0.124	3.470	3.000	4.7	50.90		50.24	
		B5	1,599	818.85	0.59	2,750	2.5	4.00	3,707	15.7	10.2	653.4	17.8	7.2	11.45	0.124	3.470	3.000	4.7	7.45		7.19	
		B6	3,117	1,524.06	0.59	1,750	2.5	7.79	3,650	16.1	10.4	658.2	18.3	7.2	22.34	0.124	3.470	3.000	4.7	14.59		14.19	
		B7	2,443	1,294.36	0.59	1,025	2.5	6.11	3,609	16.4	10.6	661.7	18.6	7.2	17.52	0.124	3.470	3.000	4.7	11.42		11.31	
		B8	4,206	1,768.68	0.59	500	2.5	10.51	3,579	16.6	10.7	664.3	18.8	7.2	30.19	0.124	3.470	3.000	4.7	19.68		19.48	
		Basic Load	5,725	27.26	0.59	0	3.3	18.60	3,550	16.8	10.8	666.7	19.1	7.2	41.12	0.124	3.470	3.000	3.9	22.52		22.52	
		total	84,391	30,556.08	0.59				3,550	16.8	10.8	666.7	19.1	7.2		0.124	3.470	3.000			3.9	331.92	3.25
R4	R5	Qu,Lu	84,391	27,703.14	0.58	2,640	3.3	274.31	3,550	16.8	10.8	666.7	19.1	7.2	606.23	0.127	2.460	3.000	3.9	331.92		338.40	
		C1	13,642	6,324.58	0.58	2,450	2.5	34.11	3,538	16.9	10.9	667.7	19.2	7.2	98.03	0.127	2.460	3.000	4.7	63.92		66.72	
		C2	856	446.92	0.58	1,500	2.5	2.14	3,481	17.3	11.1	672.6	19.7	7.2	6.16	0.127	2.460	3.000	4.7	4.02		4.19	
		C3	5,641	2,968.71	0.58	575	2.5	14.10	3,425	17.7	11.4	677.5	20.2	7.2	40.64	0.127	2.460	3.000	4.7	26.54		27.03	
		C4	7,686	2,783.01	0.58	1,200	2.5	19.21	3,463	17.4	11.2	674.2	19.8	7.2	55.32	0.127	2.460	3.000	4.7	36.11		36.36	
		C5	0	0.00	0.58	400	2.5	0.00	3,414	17.7	11.4	678.4	20.3	7.2	0.00	0.127	2.460	3.000	4.7	0.00		0.00	
		Basic Load	2,691	12.59	0.58	0	3.0	8.07	3,390	17.9	11.5	680.5	20.5	7.2	19.40	0.127	2.460	3.000	4.2	11.33		11.33	
		total	114,906	40,238.85	0.58				3,390	17.9	11.5	680.5	20.5	7.2		0.127	2.460	3.000			4.2	484.03	3.00
R5	R9	Qu,Lu	114,906	34,952.14	0.71	4,100	3.0	344.58	3,390	17.9	11.5	680.5	20.5	7.2	828.61	0.134	4.680	4.000	4.2	484.03		462.09	
		D	15,282	2,891.14	0.71	4,000	3.7	50.47	3,386	17.9	11.6	680.8	20.5	7.2	117.42	0.154	4.680	4.000	4.1	66.95		59.40	
		E	23,577	3,562.47	0.71	3,700	3.6	84.08	3,375	18.0	11.6	681.7	20.6	7.2	170.07	0.122	4.680	4.000	3.6	85.20		73.50	
		F	6,344	2,920.35	0.71	3,700	3.6	22.84	3,375	18.0	11.6	681.7	20.6	7.2	45.76	0.122	4.680	4.000	3.6	22.92		24.94	
		G1.1	2,134	1,108.77	0.71	3,000	2.5	5.34	3,350	18.2	11.7	683.9	20.9	7.2	15.40	0.134	4.680	4.000	4.7	10.07		10.73	
		G1.2	1,438	748.40	0.71	1,800	2.5	3.60	3,306	18.5	11.9	687.8	21.3	7.2	10.39	0.134	4.680	4.000	4.7	6.80		7.12	
		G1.3	1,770	922.06	0.71	1,075	2.5	4.43	3,279	18.7	12.0	690.1	21.5	7.2	12.80	0.134	4.680	4.000	4.7	8.37		8.64	
		G2.1	55	36.39	0.71	2,650	2.5	0.14	3,337	18.3	11.8	685.1	21.0	7.2	0.39	0.134	4.680	4.000	4.7	0.26		0.29	
		G2.2	110	85.68	0.71	725	2.5	0.27	3,267	18.8	12.1	691.2	21.6	7.2	0.79	0.134	4.680	4.000	4.7	0.52		0.55	
		Basic Load	-29,891	-6,558.29	0.71	0	3.4	-100.13	3,240	18.9	12.2	693.5	21.9	7.2	-216.32	0.134	4.680	4.000	3.9	-116.19		-116.19	
		total	136,724	40,669.10	0.71				3,240	18.9	12.2	693.5	21.9	7.2		0.134	4.680	4.000			3.9	531.08	3.35
R9	R14	Qu,Lu	136,724	29,939.36	0.77	1,900	3.4	458.40	3,240	18.9	12.2	693.5	21.9	7.2	989.48	0.129	1.480	0.500	3.9	531.08		612.80	
		H1	25,573	186.61	0.77	1,675	3.5	98.45	3,239	19.0	12.2	693.6	21.9	7.2	185.07	0.114	1.480	0.500	3.4	86.62		83.62	
		H2	5,195	806.94	0.77	1,875	3.9	19.96	3,239	19.0	12.2	693.6	21.9	7.2	37.53	0.114	1.480	0.500	3.4	17.56		19.28	
		I1	434	250.37	0.77	1,875	3.9	1.67	3,239	19.0	12.2	693.6	21.9	7.2	3.14	0.114	1.480	0.500	3.4	1.47		2.17	
		I2	276	177.37	0.77	1,875	3.5	1.06	3,239	19.0	12.2	692.6	21.9	7.2	2.00	0.114	1.480	0.500	3.4	0.94		1.42	
		I3	84	47.16	0.77	1,875	3.9	0.32	3,239	19.0	12.2	693.6	21.9	7.2	0.61	0.114	1.480	0.500	3.4	0.29		0.42	
		I4	19,312	178.98	0.77	1,875	3.9	74.35	3,239	19.0	12.2	693.6	21.9	7.2	139.77	0.114	1.480	0.500	3.4	65.41		63.26	
		J1	7,327	571.83	0.77	1,750	1.7	12.46	3,234	19.0	12.2	694.0	21.9	7.2	53.04	0.114	1.480	0.500	5.5	40.58		40.64	
		J2	303	176.35	0.77	1,600	2.5	0.74	3,229	19.0	12.2	694.5	22.0	7.2	2.19	0.114	1.480	0.500	4.8	1.45		1.85	
		J3	342	193.46	0.77	1,600	2.5	0.84	3,229	19.0	12.2	694.5	22.0	7.2	2.49	0.114	1.480	0.500	4.8	1.64		2.10	
		J4	2,941	391.73	0.77	1,600	2.5	7.21	3,229	19.0	12.2	694.5	22.0	7.2	21.29	0.114	1.480	0.500	4.8	14.09		14.60	
		K1.1	386	218.59	0.77	1,825	2.5	0.97	3,237	19.0	12.2	693.7	21.9	7.2	2.81	0.129	1.480	0.500	4.7	1.84		2.49	
		K1.2	35	15.43	0.77	850	2.5	0.06	3,201	19.2	12.4	696.9	22.3	7.2	0.19	0.129	1.480	0.500	4.7	0.12		0.14	
		K2	138	79.18	0.77	1,150	2.5	0.34	3,212	19.1	12.3	695.9	22.2	7.2	1.00	0.129	1.480	0.500	4.7	0.65		0.80	
		WWTP(Irpavi)			0.77	1,875	3.1	0.00	3,239	19.0	12.2	693.6	21.9	7.2	0.00	0.114	1.490	0.500	4.1	0.00		0.00	
		Basic Load	21,422	162.24	0.77	0	3.1	66.41	3,170	19.4	12.5	699.6	22.6	7.2	155.29	0.129	1.480	0.500	4.1	88.88		88.88	
		total	220,476	33,461.01	0.77				3,170	19.4	12.5	699.6	22.6	7.2		0.129	1.480	0.500			4.2	934.50	3.01
R14	R15	Qu,Lu	220,476	32,989.16	0.85	7,250	3.0	863.77	3,170	19.4	12.5	699.6	22.6	7.2	1,598.26	0.115	0.780	0.500	4.2	934.50		892.56	
		L1	21	22.04	0.85	7,025	2.5	0.05	3,165	19.5	12.5	700.0	22.6	7.2	0.16	0.115	0.780	0.500	4.7	0.10		0.11	
		L2	22	22.19	0.85	5,000	2.5	0.05	3,123	19.8	12.7	703.7	23.0	7.3	0.16	0.115	0.780	0.500	4.8	0.10		0.11	
		L3	6	6.19	0.85	1,575	2.5	0.02	3,053	20.3	13.0	710.0	23.7	7.3	0.04	0.115	0.780	0.500	4.8	0.03		0.03	
		WWTP(Lipari)			0.85	2,000	3.3	0.00	3,051	20.2	13.0	709.2	23.7	7.3	0.00	0.115	0.780	0.500	4.0	0.00		0.00	
		Basic Load	34,884	297.18	0.85	0	3.3	115.12	3,020	20.5	13.2	712.9	24.1	7.3	253.79	0.115	0.780	0.500	4.0	138.67		138.67	
		total	255,409	33,326.79	0.85				3,020	20.5	13.2	712.9	24.1	7.3		0.115	0.780	0.500			4.0	1,031.49	3.24

Table 4.3.4 Comparison of Simulated River Flowrate with Observed Data

Evaluation Point	Distance (km)	Flow Rate (m3/sec) Observed Value (22/Apr./1992)	Observed Value (29/Apr./1992)	Result of Simulation
R1	0	0.11	0.08	0.10
R2	16	0.31	0.17	0.24
R3	20	0.62	0.31	0.43
R4	23	1.03	0.74	0.98
R5	26	1.31	1.34	1.33
R9	30	1.55	1.58	1.58
R14	32	2.48	2.62	2.55
R15	39	2.82	3.00	2.96

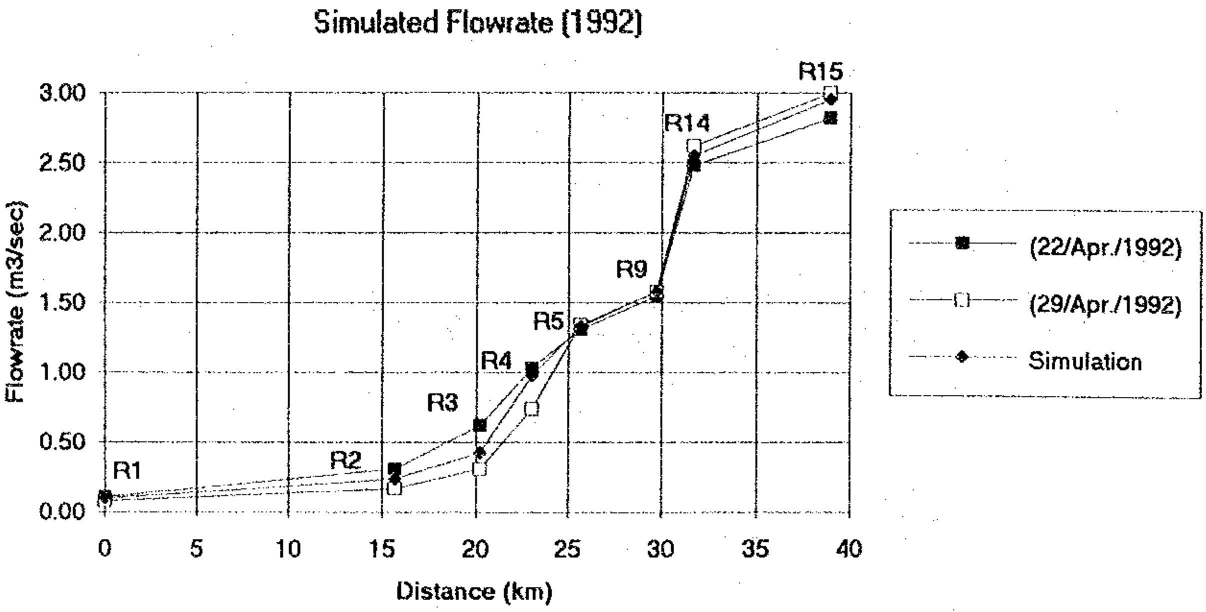


Fig. 4.3.4 Comparison of Simulated River Flowrate with Observed Data

Table 4.3.5 Comparison of Simulated River Water Quality (BOD) with Observed Data

Evaluation Point	Distance (km)	BOD Concentration (mg/l)		
		Observed Value		Result of Simulation
		(22/Apr./1992)	(29/Apr./1992)	
R1	0	1.3	0.9	1.2
R2	16	2.2	2.1	2.2
R3	20	67.5	68.4	67.8
R4	23	115.0	169.0	151.7
R5	26	127.0	151.0	143.0
R9	30	109.0	97.0	107.1
R14	32	75.0	76.0	71.1
R15	39	51.0	58.0	54.3

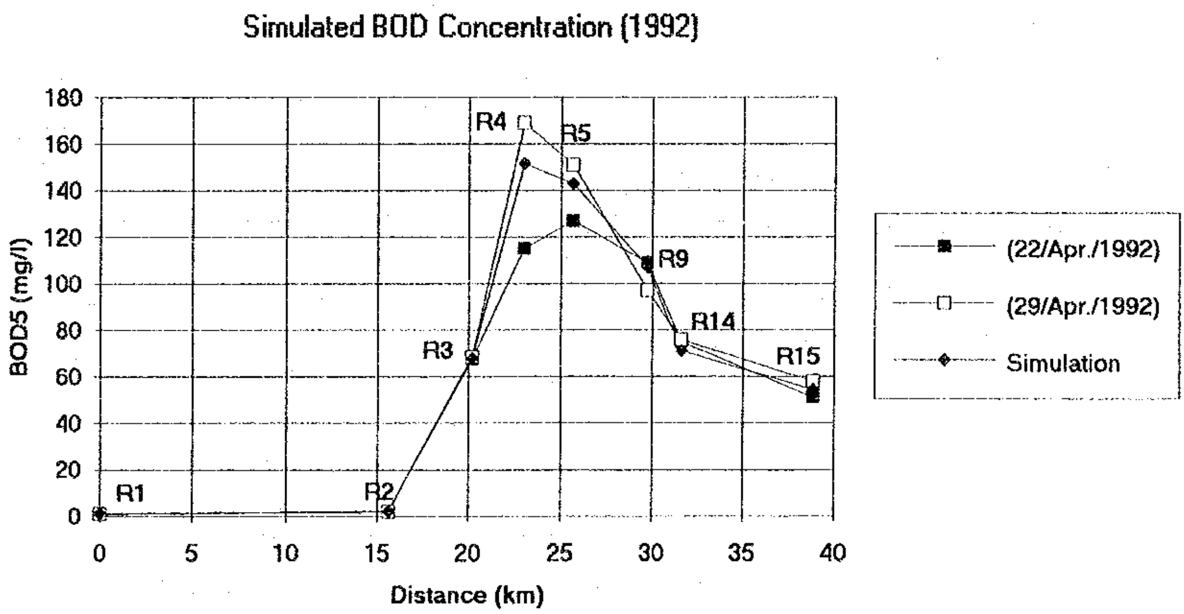


Fig. 4.3.5 Comparison of Simulated River Water Quality (BOD) with Observed Data

Table 4. 3. 6 Comparison of Simulated River Water Quality (DO) with Observed Data

Evaluation Point	Distance (km)	DO Concentration (mg/l) Observed Value (22/Apr./1992)	(29/Apr./1992)	Result of Simulation	Rate of Saturation (%)
R1	0	2.3	3.7	3.0	42.5
R2	16	2.7	4.1	3.4	47.9
R3	20	2.8	4.6	3.7	51.6
R4	23	2.7	3.8	3.3	45.2
R5	26	3.3	2.7	3.0	41.6
R9	30	3.6	3.1	3.4	46.3
R14	32	3.2	3.0	3.0	41.5
R15	39	3.7	2.9	3.2	44.5

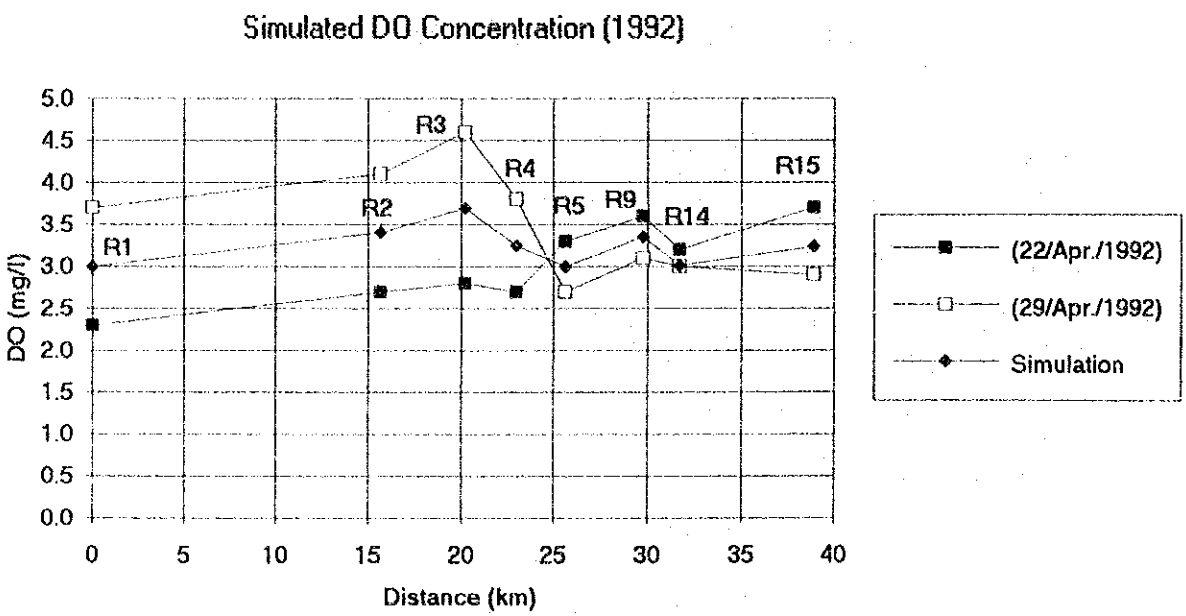


Fig. 4.3.6 Comparison of Simulated River Water Quality (DO) with Observed Data

4.4 PREDICTION OF FUTURE WATER QUALITY WITHOUT POLLUTION CONTROL

4.4.1 Amount of Pollutant Generation

The future water quality of the Choqueyapu river was predicted for the years 1995 and 2010. The manner to estimate pollutant generation is the same as that in Section 4.1. The social framework for the future described in Section 3.4 was used as the basis to estimate the future amount of pollutant generation.

The amounts thus estimated are shown in Table 4.4.1 (1995) and Table 4.4.2 (2010), which are based on the condition that no pollution control measures will be adopted.

In the Central Zone (Block A ~ F), the population is expected to increase only 3.0% in the following eighteen years (from 1992 until 2010), because the present population has nearly reached the saturation point. On the other hand, the population of the South Zone is expected to increase to about three times the present population. The increase of pollutant generation in the future will reflect this situation. The rates of increase of wastewater discharge were estimated to be 5% (by 1995) and 35% (by 2010) in the Central Zone, and 38% (by 1995) and 500% (by 2010) in the South Zone. The rates of increase of BOD load were estimated to be 3% (by 1995) and 18% (by 2010) in the Central Zone, and 29% (by 1995) and 390% (by 2010) in the South Zone.

The increase of wastewater discharge in the Central Zone is mainly caused by the increase of the per capita discharge which reflects the improvement of living standards, and that in the South Zone is mainly caused by the increase in population.

Thus, water pollution of the Choqueyapu River tends to spread out toward the lower reaches corresponding to the direction of urban development of the City of La Paz.

4.4.2 River Water Quality

River water qualities in the dry season in 1995 and in 2010 were predicted by the developed simulation model. The results for BOD are shown in Fig. 4.4.1, Fig. 4.4.2, Table 4.4.3 and Table 4.4.4. The results for DO are shown in Fig. 4.4.3, Fig. 4.4.4, Table 4.4.5 and Table 4.4.6.

As mentioned in the previous section, a remarkable increase of the BOD concentration in 2010 was predicted in the lower reaches represented by the points R14 and R15. A little decrease of the DO concentration in 2010 was predicted inversely proportional to the increase of BOD. However, the BOD concentration in the reaches between the points R3 and R5 decreases slightly despite the increase of BOD loads. In such reaches, the

Table 4.4.1 List of Discharged Wastewater Amount and Pollution Load for All Reaches of the Model (Future : 1995)

Block	Sub Block	Population	Rate of Water Supply Service (%)	Rate of Sewerage Service (%)	Water Supply Area (by House Connection)				Leakage of Water Supply			Other Area				Major Consumers' Waste Water		Inflow to the river			
					Discharge Amount (m3/day)		BOD Load (kg/day)		Discharge	BOD	BOD Load	Discharge Amount (m3/day)		BOD Load (kg/day)		Discharge Volume	BOD Load	Discharge Volume		BOD Load	
					Per Capita	Gross	Per Capita	Gross	(m3/day)	(mg/l)	(kg/day)	Per Capita	Gross	Per Capita	Gross	(m3/day)	(kg/day)	Inflow Rate	Gross (m3/day)	Inflow Rate	Gross (kg/day)
A	1	13,330	96.9	100	0.135	1,744	0.036	465.01	436	2.5	1.09	0.060	25	0.027	11.16			0.90	1,974	0.79	376.91
	2	8,245	96.9	100	0.135	1,079	0.036	287.61	270	2.5	0.67	0.060	15	0.027	6.90			0.90	1,221	0.79	233.12
	3	8,551	96.9	100	0.135	1,119	0.036	298.30	280	2.5	0.70	0.060	16	0.027	7.16			0.90	1,266	0.99	302.22
	4	1,163	96.9	100	0.135	152	0.036	40.58	38	2.5	0.10	0.060	2	0.027	0.97	642	413.39	0.98	1,015	1.00	454.50
	5	2,267	96.9	100	0.135	297	0.036	79.07	74	2.5	0.19	0.060	4	0.027	1.90	449	802.60	0.95	784	1.00	882.71
	5	10,188	96.9	100	0.135	1,333	0.036	355.41	333	2.5	0.83	0.060	19	0.027	8.53	63	78.42	0.90	1,572	0.99	438.51
	total	43,744				5,722		1,525.98	1,431		3.58		81		35.61	1,354	1,294.41		7,832		2,687.98
B	1	10,751	96.9	100	0.135	1,406	0.036	375.04	352	2.5	0.88	0.060	20	0.027	9.00	69	22.34	0.90	1,682	0.99	402.32
	2	94,578	96.9	100	0.135	12,372	0.036	3,299.24	3,093	2.5	7.73	0.060	176	0.027	79.16	1,374	776.04	0.90	15,381	0.79	3,294.96
	3	9,118	96.9	100	0.135	1,062	0.036	283.19	265	2.5	0.66	0.060	15	0.027	6.79	2,102	3,112.94	0.96	3,304	1.00	3,399.86
	4	69,650	96.9	100	0.135	9,111	0.036	2,429.67	2,278	2.5	5.69	0.060	130	0.027	58.30	1,026	284.92	0.90	11,341	0.79	2,197.18
	5	10,428	96.9	100	0.135	1,364	0.036	363.76	341	2.5	0.85	0.060	19	0.027	8.73	124	116.86	0.90	1,668	0.79	388.33
	6	19,333	96.9	100	0.135	2,529	0.036	674.40	632	2.5	1.58	0.060	36	0.027	16.18	351	220.09	0.91	3,244	0.79	722.69
	7	10,247	96.9	100	0.135	1,340	0.036	357.46	335	2.5	0.84	0.060	19	0.027	8.58	993	248.15	0.93	2,510	0.99	610.32
	8	24,242	96.9	100	0.135	3,171	0.036	845.65	793	2.5	1.98	0.060	45	0.027	20.29	775	193.73	0.91	4,365	0.79	840.42
	total	247,346				32,357		8,628.42	8,089		20.22		460		207.03	6,864	4,974.97		43,495		11,856.11
C	1	86,978	96.9	100	0.135	11,378	0.036	3,034.13	2,844	2.5	7.11	0.060	162	0.027	72.80	1,333	333.19	0.99	14,214	0.89	3,066.55
	2	3,298	96.9	100	0.135	431	0.036	115.05	108	2.5	0.27	0.060	6	0.027	2.76	390	97.42	0.94	878	0.99	213.98
	3	32,134	96.9	100	0.135	4,204	0.036	1,120.95	1,051	2.5	2.63	0.060	60	0.027	26.90	1,093	298.18	0.91	5,852	0.99	1,433.91
	4	37,300	96.9	100	0.135	4,879	0.036	1,301.17	1,220	2.5	3.05	0.060	69	0.027	31.22	581	179.84	0.90	6,105	0.89	1,348.33
	5	0			0.135	0	0.036	0.00	0	2.5	0.00	0.060	0	0.027	0.00				0		0.00
	total	159,710				20,892		5,571.31	5,223		13.06		297		133.68	3,397	908.63		27,049		6,062.77
D		65,800	72.5	100	0.135	6,440	0.036	1,717.38	1,610	2.5	4.03	0.060	1,086	0.027	488.57	383	94.37	0.86	8,171	0.71	1,646.43
E		72,342	69.3	100	0.135	6,768	0.036	1,804.76	1,692	2.5	4.23	0.060	1,333	0.027	599.64	740	742.79	0.86	9,021	0.54	1,709.70
F		45,458	69.3	100	0.135	4,253	0.036	1,134.09	1,063	2.5	2.66	0.060	837	0.027	376.80	1,678	465.57	0.88	6,881	0.72	1,431.51
G	1.1	15,726	77.6	100	0.135	1,647	0.036	439.33	412	2.5	1.03	0.060	211	0.027	95.11	325	81.15	0.88	2,284	0.92	568.55
	1.2	11,690	77.6	100	0.135	1,225	0.036	326.57	306	2.5	0.77	0.060	157	0.027	70.70	93	23.32	0.87	1,550	0.92	385.62
	1.3	15,384	77.6	100	0.135	1,612	0.036	429.76	403	2.5	1.01	0.060	207	0.027	93.04			0.86	1,916	0.91	476.79
	Sub-total	42,800				4,484		1,195.66	1,121		2.80		575		258.85	418	104.47		5,750		1,430.96
	2.1	913	36.6	100	0.135	45	0.036	12.03	11	2.5	0.03	0.060	35	0.027	15.63	30	7.62	0.81	99	0.70	27.48
	2.2	3,187	36.6	100	0.135	157	0.036	41.99	39	2.5	0.10	0.060	121	0.027	54.55	26	6.42	0.77	263	0.73	75.72
	Sub-total	4,100				203		54.02	51		0.13		156		70.18	56	14.03		362		103.21
	total	46,900				4,686		1,249.68	1,172		2.93		731		329.04	474	118.50		6,112		1,534.17
H	1	6,300	61.9	0	0.135	526	0.036	140.39	132	2.5	0.33	0.060	144	0.027	64.81			0.83	664	0.42	86.48
	2	7,800	71.8	100	0.135	756	0.036	201.61	189	2.5	0.47	0.060	132	0.027	59.39	553	138.19	0.90	1,469	0.93	369.74
	total	14,100				1,283		242.00	321		0.80		276		124.20	553	138.19		2,134		456.22
I	1	4,889	74.8	77.7	0.135	494	0.036	131.66	123	2.5	0.31	0.060	74	0.027	33.27	39	9.73	0.86	631	0.84	147.39
	2	7,590	81.5	40.2	0.135	835	0.036	222.70	209	2.5	0.52	0.060	84	0.027	37.91			0.87	982	0.86	223.49
	3	787	81.5	40.2	0.135	87	0.036	23.10	22	2.5	0.05	0.060	9	0.027	3.93	56	13.88	0.91	157	0.87	35.68
	4	822	81.5	40.2	0.135	90	0.036	24.13	23	2.5	0.06	0.060	9	0.027	4.11			0.87	106	0.86	24.21
	total	14,089				1,505		401.58	376		0.94		176		79.22	94	23.62		1,877		430.78
J	1	7,856	74.8	77.7	0.135	793	0.036	211.53	198	2.5	0.50	0.060	119	0.027	53.45	193	45.94	0.88	1,145	0.95	295.23
	2	3,745	74.8	77.7	0.135	378	0.036	100.85	95	2.5	0.24	0.060	57	0.027	25.48			0.86	454	0.84	106.20
	3	4,236	74.8	77.7	0.135	428	0.036	114.07	107	2.5	0.27	0.060	64	0.027	28.82			0.86	513	0.84	120.12
	4	6,692	74.8	77.7	0.135	676	0.036	180.19	169	2.5	0.42	0.060	101	0.027	45.53	31	7.69	0.86	841	0.94	220.04
	total	22,529				2,275		606.65	569		1.42		341		153.29	223	53.62		2,953		741.60
K	1.1	2,508	74.8	77.7	0.135	253	0.036	67.54	63	2.5	0.16	0.060	38	0.027	17.07	186	46.38	0.91	489	0.96	125.98
	1.2	319	74.8	77.7	0.135	32	0.036	8.59	8	2.5	0.02	0.060	5	0.027	2.17			0.66	39	0.94	10.12
	Sub-total	2,827				285		76.13	71		0.18		43		19.24	186	46.38		528		136.10
	2	1,155	74.8	77.7	0.135	117	0.036	31.10	29	2.5	0.07	0.060	17	0.027	7.86	44	11.06	0.89	184	0.95	47.71
	total	3,982				402		107.23	101		0.25		60		27.09	230	57.43		712		183.81
L	1	2,272	73.6	31.4	0.135	226	0.036	60.19	56	2.5	0.14	0.060	36	0.027	16.19			0.85	272	0.89	68.36
	2	2,287	73.6	31.4	0.135	227	0.036	60.59	57	2.5	0.14	0.060	36	0.027	16.30			0.85	274	0.89	68.81
	3	638	73.6	31.4	0.135	63	0.036	16.92	16	2.5	0.04	0.060	10	0.027	4.55			0.85	76	0.89	19.21
	total	5,197				516		137.70	129		0.32		82		37.04	0	0.00		622		156.38
Total		741,197				87,101		23,226.82	21,775		54.44		5,760		2,592.21	15,991	9,872.10		116,859		28,897.45

Table 4.4.2 List of Discharged Wastewater Amount and Pollution Load for All Reaches of the Model (Future : 2010)

Block	Sub Block	Population	Rate of Water Supply Service (%)	Rate of Sewerage Service (%)	Water Supply Area (by House Connection)				Leakage of Water Supply			Other Area				Major Consumers' Waste Water		Inflow to the river			
					Discharge Amount(m3/day)		BOD Load (kg/day)		Discharge	BOD	BOD Load	Discharge Amount (m3/day)		BOD Load (kg/day)		Discharge Volume	BOD Load	Discharge Volume		BOD Load	
					Per Capita	Gross	Per Capita	Gross	(m3/day)	(mg/l)	(kg/day)	Per Capita	Gross	Per Capita	Gross	(m3/day)	(kg/day)	Inflow Rate	Gross (m3/day)	Inflow Rate	Gross (kg/day)
A	1	13,404	100	100	0.160	2,145	0.04	536.17	536	2.5	1.34	0.060	0	0.027	0.00			0.90	2,413	0.80	429.47
	2	8,291	100	100	0.160	1,326	0.04	331.62	332	2.5	0.83	0.060	0	0.027	0.00			0.90	1,492	0.80	265.63
	3	8,598	100	100	0.160	1,376	0.04	343.94	344	2.5	0.86	0.060	0	0.027	0.00			0.90	1,548	1.00	344.37
	4	1,170	100	100	0.160	187	0.04	46.79	47	2.5	0.12	0.060	0	0.027	0.00	842	413.39	0.98	1,053	1.00	460.24
	5	2,279	100	100	0.160	365	0.04	91.17	91	2.5	0.23	0.060	0	0.027	0.00	449	802.60	0.95	859	1.00	893.88
	5	10,245	100	100	0.160	1,639	0.04	409.80	410	2.5	1.02	0.060	0	0.027	0.00	63	78.42	0.90	1,907	1.00	488.72
	total	43,987				7,038		1,759.48	1,759		4.40		0		0.00	1,354	1,294.41		9,271		2,882.31
B	1	10,811	100	100	0.160	1,730	0.04	432.43	432	2.5	1.08	0.060	0	0.027	0.00	89	22.34	0.90	2,035	1.00	455.31
	2	95,102	100	100	0.160	15,216	0.04	3,804.08	3,804	2.5	9.51	0.060	0	0.027	0.00	1,374	776.04	0.91	16,493	0.80	3,667.90
	3	8,163	100	100	0.160	1,306	0.04	326.52	327	2.5	0.82	0.060	0	0.027	0.00	2,102	3,112.94	0.96	3,571	1.00	3,439.87
	4	70,036	100	100	0.160	11,206	0.04	2,801.45	2,801	2.5	7.00	0.060	0	0.027	0.00	1,026	284.82	0.91	13,633	0.80	2,471.81
	5	10,486	100	100	0.160	1,678	0.04	419.42	419	2.5	1.05	0.060	0	0.027	0.00	124	116.86	0.91	2,011	0.80	429.44
	6	19,440	100	100	0.160	3,110	0.04	777.59	778	2.5	1.94	0.060	0	0.027	0.00	381	220.09	0.91	3,880	0.80	798.92
	7	10,304	100	100	0.160	1,649	0.04	412.16	412	2.5	1.03	0.060	0	0.027	0.00	993	248.15	0.93	2,847	1.00	660.82
	8	24,376	100	100	0.160	3,900	0.04	975.05	975	2.5	2.44	0.060	0	0.027	0.00	775	193.73	0.91	5,163	0.80	936.00
	total	248,718				39,795		9,948.71	9,949		24.87		0		0.00	6,864	4,974.97		51,633		12,860.09
C	1	87,460	100	100	0.160	13,994	0.04	3,498.41	3,498	2.5	8.75	0.060	0	0.027	0.00	1,333	333.19	0.91	17,076	0.90	3,452.37
	2	3,316	100	100	0.160	531	0.04	132.65	133	2.5	0.33	0.060	0	0.027	0.00	390	97.42	0.94	987	1.00	230.23
	3	32,312	100	100	0.160	5,170	0.04	1,292.49	1,292	2.5	3.23	0.060	0	0.027	0.00	1,093	298.19	0.91	6,909	1.00	1,592.29
	4	37,507	100	100	0.160	6,001	0.04	1,500.27	1,500	2.5	3.75	0.060	0	0.027	0.00	581	179.84	0.91	7,333	0.90	1,513.79
	5	0			0.160	0	0.04	0.00	0	2.5	0.00	0.060	0	0.027	0.00				0		0.00
	total	160,595				25,695		6,423.81	6,424		16.06		0		0.00	3,397	908.63		32,304		6,788.68
D		75,800	100	86.8	0.160	12,128	0.04	3,032.00	3,032	2.5	7.56	0.060	0	0.027	0.00	383	94.37	0.90	14,027	0.80	2,504.13
E		74,245	100	100	0.160	11,879	0.04	2,969.82	2,970	2.5	7.42	0.060	0	0.027	0.00	740	742.79	0.90	14,105	0.60	2,229.79
F		46,655	100	100	0.160	7,465	0.04	1,866.18	1,866	2.5	4.67	0.060	0	0.027	0.00	1,678	465.57	0.92	10,076	0.80	1,867.26
G	1.1	19,695	100	100	0.160	3,151	0.04	787.79	788	2.5	1.97	0.060	0	0.027	0.00	325	81.15	0.91	3,870	1.00	869.92
	1.2	14,640	100	100	0.160	2,342	0.04	585.58	586	2.5	1.46	0.060	0	0.027	0.00	93	23.32	0.90	2,728	1.00	609.63
	1.3	19,266	100	100	0.160	3,083	0.04	770.63	771	2.5	1.93	0.060	0	0.027	0.00			0.90	3,468	1.00	771.59
	Sub-total	53,600				8,576		2,144.00	2,144		5.36		0		0.00	418	104.47		10,066		2,251.15
	2.1	1,426	100	100	0.160	228	0.04	57.02	57	2.5	0.14	0.060	0	0.027	0.00	30	7.62	0.91	287	1.00	64.71
	2.2	4,974	100	100	0.160	796	0.04	198.99	199	2.5	0.50	0.060	0	0.027	0.00	26	6.42	0.90	921	1.00	205.64
	Sub-total	6,400				1,024		256.00	256		0.64		0		0.00	56	14.03		1,208		270.35
	total	60,000				9,600		2,400.00	2,400		6.00		0		0.00	474	118.50		11,274		2,521.50
H	1	32,000	100	0	0.160	5,120	0.04	1,280.00	1,280	2.5	3.20	0.060	0	0.027	0.00			0.90	5,760	0.50	640.80
	2	14,500	100	100	0.160	2,320	0.04	580.00	580	2.5	1.45	0.060	0	0.027	0.00	553	138.19	0.92	3,163	1.00	718.92
	total	46,500				7,440		1,860.00	1,860		4.65		0		0.00	553	138.19		8,923		1,359.72
I	1	14,014	100	27.1	0.160	2,242	0.04	560.54	561	2.5	1.40	0.060	0	0.027	0.00	39	9.73	0.90	2,561	0.90	514.09
	2	35,889	100	8.5	0.160	5,742	0.04	1,435.56	1,436	2.5	3.59	0.060	0	0.027	0.00			0.90	6,460	0.90	1,294.15
	3	3,723	100	8.5	0.160	596	0.04	148.92	149	2.5	0.37	0.060	0	0.027	0.00	56	13.88	0.91	726	0.90	146.75
	4	3,888	100	8.5	0.160	622	0.04	155.52	156	2.5	0.39	0.060	0	0.027	0.00			0.90	700	0.90	140.20
	total	57,514				9,202		2,300.54	2,301		5.75		0		0.00	94	23.62		10,447		2,095.19
J	1	22,516	100	27.1	0.160	3,603	0.04	900.63	901	2.5	2.25	0.060	0	0.027	0.00	193	45.94	0.90	4,246	1.00	948.15
	2	10,735	100	27.1	0.160	1,718	0.04	429.40	429	2.5	1.07	0.060	0	0.027	0.00			0.90	1,932	0.90	387.11
	3	12,142	100	27.1	0.160	1,943	0.04	485.69	486	2.5	1.21	0.060	0	0.027	0.00			0.90	2,186	0.90	437.85
	4	19,180	100	27.1	0.160	3,069	0.04	767.19	767	2.5	1.92	0.060	0	0.027	0.00	31	7.68	0.90	3,483	1.00	776.21
	total	64,573				10,332		2,582.91	2,583		6.46		0		0.00	223	53.62		11,847		2,549.31
K	1.1	7,190	100	27.1	0.160	1,150	0.04	287.56	288	2.5	0.72	0.060	0	0.027	0.00	186	46.38	0.91	1,480	1.00	334.46
	1.2	914	100	27.1	0.160	146	0.04	36.55	37	2.5	0.09	0.060	0	0.027	0.00			0.90	164	1.00	36.62
	Sub-total	8,103				1,297		324.14	324		0.81		0		0.00	186	46.38		1,644		371.08
	2	3,310	100	27.1	0.160	530	0.04	132.41	132	2.5	0.33	0.060	0	0.027	0.00	44	11.06	0.91	640	1.00	143.70
	total	11,414				1,826		456.55	457		1.14		0		0.00	230	57.43		2,284		514.78
L	1	17,850	100	4	0.160	2,856	0.04	714.00	714	2.5	1.79	0.060	0	0.027	0.00			0.90	3,213	1.00	714.89
	2	17,967	100	4	0.160	2,875	0.04	718.70	719	2.5	1.80	0.060	0	0.027	0.00			0.90	3,234	1.00	719.60
	3	5,016	100	4	0.160	803	0.04	200.66	201	2.5	0.50	0.060	0	0.027	0.00			0.90	903	1.00	200.91
	total	40,834				6,533		1,633.35	1,633		4.08		0		0.00	0	0.00		7,350		1,635.39
Total		930,834				148,933		37,233.35	37,233		93.08		0		0.00	15,991	8,672.10		183,541		39,809.17

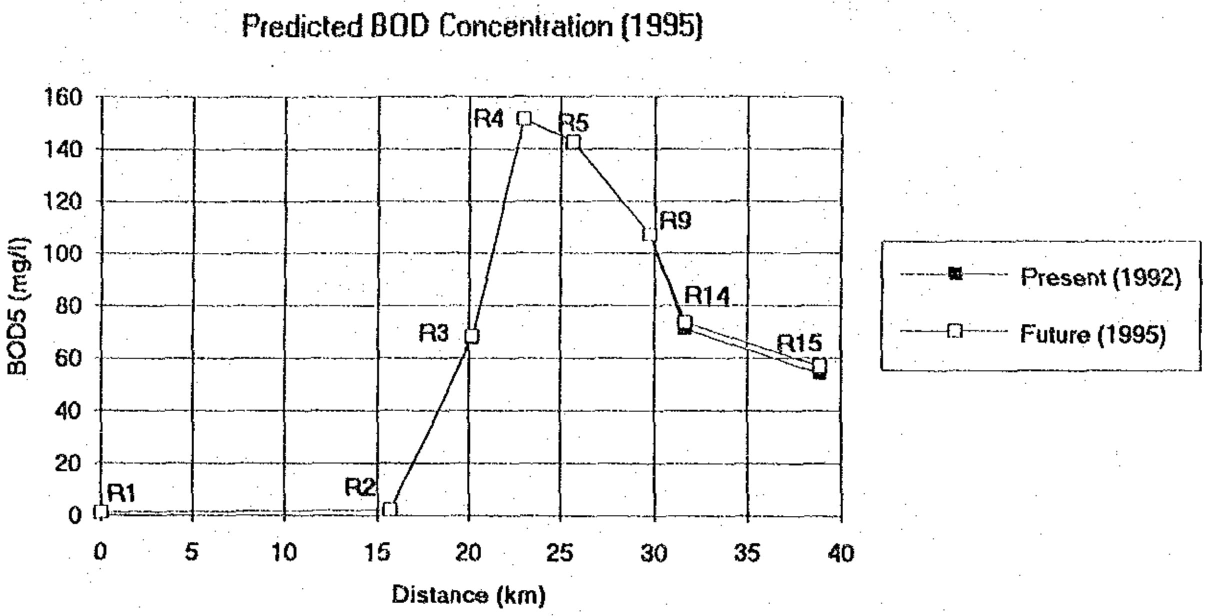


Fig. 4. 4. 1 Predicted Future (Uncontrolled) River Water Quality [BOD] in 1995

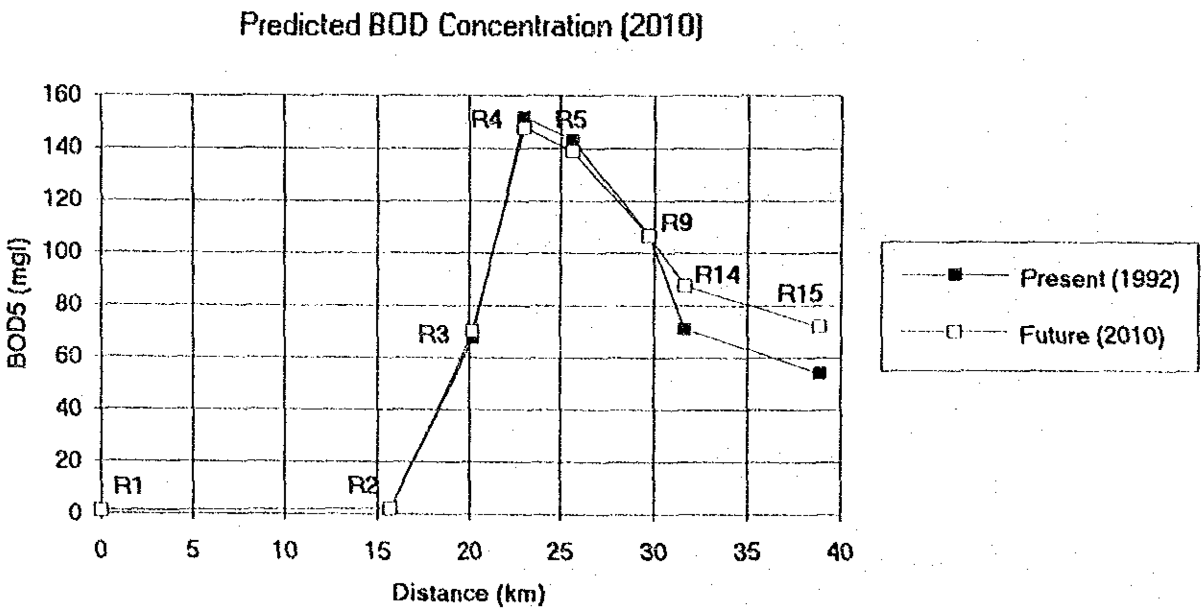


Fig. 4. 4. 2 Predicted Future (Uncontrolled) River Water Quality [BOD] in 2010

Table 4.4.3 Future (Uncontrolled) and Present River Water Quality [BOD] in 1995

Evaluation Point	Distance (km)	Flow Rate (m3/sec) Results of Simulation Present (1992)	Future (1995)	Rate of Increase (%)
R1	0	0.10	0.10	0.0
R2	16	0.24	0.24	0.0
R3	20	0.43	0.43	0.8
R4	23	0.98	1.00	2.3
R5	26	1.33	1.36	2.6
R9	30	1.58	1.65	4.3
R14	32	2.55	2.65	3.9
R15	39	2.96	3.06	3.6

Evaluation Point	Distance (km)	BOD5 Concentration (mg/l) Results of Simulation Present (1992)	Future (1995)	Rate of Increase (%)
R1	0	1.2	1.2	0.0
R2	16	2.2	2.2	0.0
R3	20	67.8	68.4	0.9
R4	23	151.7	151.4	-0.2
R5	26	143.0	142.7	-0.2
R9	30	107.1	107.3	0.2
R14	32	71.1	73.7	3.6
R15	39	54.3	56.9	4.7

Evaluation Point	Distance (km)	Last BOD Load (kg/day) Results of Simulation Present (1992)	Future (1995)	Rate of Increase (%)
R1	0	22.3	22.3	0.0
R2	16	100.4	100.4	0.0
R3	20	5,396.4	5,489.1	1.7
R4	23	27,703.1	28,272.4	2.1
R5	26	34,952.1	35,775.3	2.4
R9	30	29,998.4	31,346.5	4.5
R14	32	32,989.2	35,526.7	7.7
R15	39	31,727.0	34,437.5	8.5

Table 4.4.4 Future (Uncontrolled) and Present River Water Quality [BOD] in 2010

Evaluation Point	Distance (km)	Flow Rate (m3/sec) Results of Simulation Present (1992)	Future (2010)	Rate of Increase (%)
R1	0	0.10	0.10	0.0
R2	16	0.24	0.24	0.0
R3	20	0.43	0.45	4.7
R4	23	0.98	1.11	13.6
R5	26	1.33	1.54	15.5
R9	30	1.58	2.05	29.3
R14	32	2.55	3.35	31.1
R15	39	2.96	3.84	29.7

Evaluation Point	Distance (km)	BOD5 Concentration (mg/l) Results of Simulation Present (1992)	Future (2010)	Rate of Increase (%)
R1	0	1.2	1.2	0.0
R2	16	2.2	2.2	0.0
R3	20	67.8	70.4	3.9
R4	23	151.7	147.6	-2.7
R5	26	143.0	138.7	-3.0
R9	30	107.1	106.7	-0.4
R14	32	71.1	87.7	23.3
R15	39	54.3	72.1	32.8

Evaluation Point	Distance (km)	Last BOD Load (kg/day) Results of Simulation Present (1992)	Future (2010)	Rate of Increase (%)
R1	0	22.3	22.3	0.0
R2	16	100.4	100.4	0.0
R3	20	5,396.4	5,871.3	8.8
R4	23	27,703.1	30,619.1	10.5
R5	26	34,952.1	39,168.5	12.1
R9	30	29,998.4	38,638.8	28.8
R14	32	32,989.2	53,339.3	61.7
R15	39	31,727.0	54,645.4	72.2

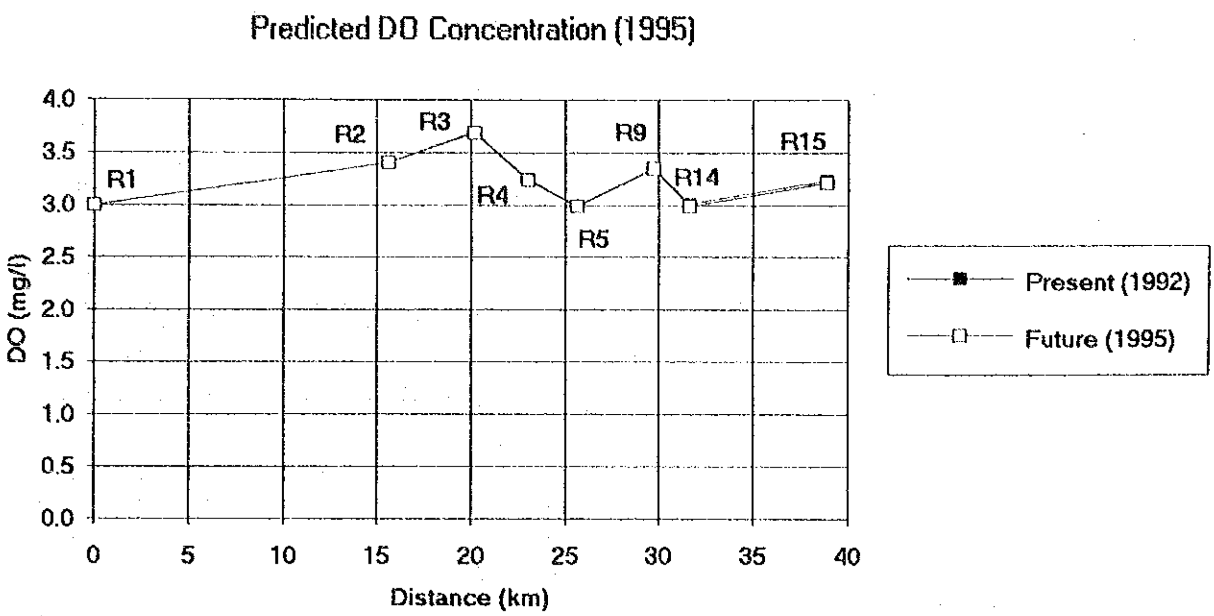


Fig. 4. 4. 3 Predicted Future (Uncontrolled) River Water Quality [DO] in 1995

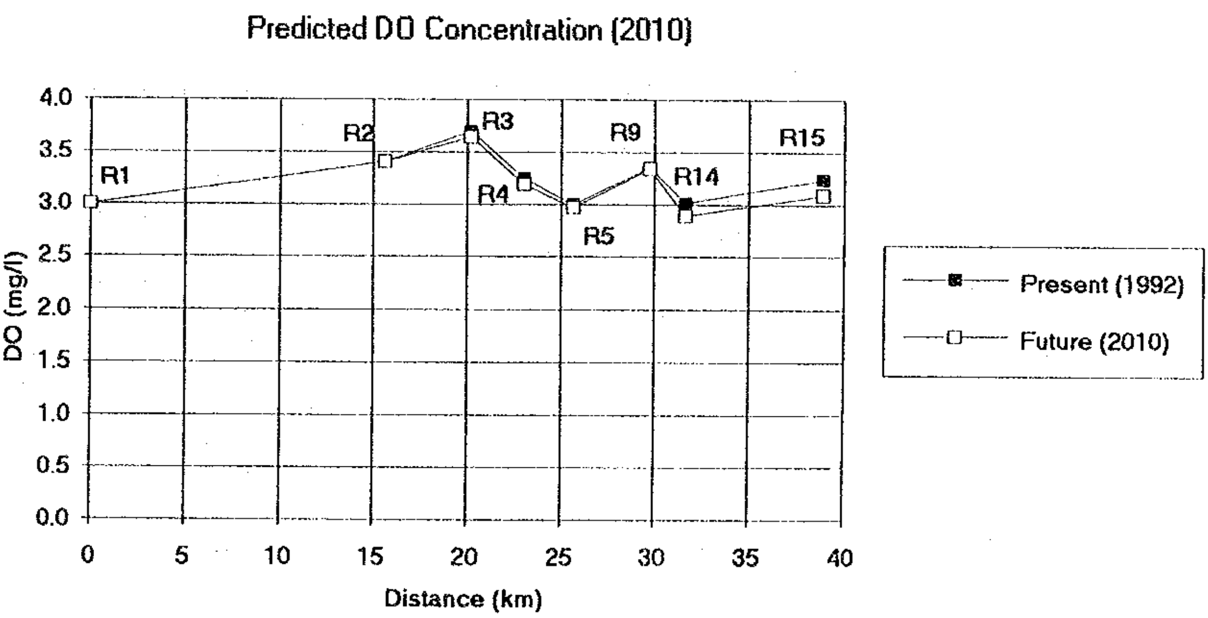


Fig. 4. 4. 4 Predicted Future (Uncontrolled) River Water Quality [DO] in 2010

Table 4.4.5 Future (Uncontrolled) and Present River Water Quality [DO] in 1995

Evaluation Point	Distance (km)	DO Concentration (mg/l) and Ratio of Saturation (%)				
		Results of Simulation				Rate of Increase (%)
		Present (1992)	(%)	Future (1995)	(%)	
R1	0	3.0	42.5	3.0	42.5	0.0
R2	16	3.4	47.9	3.4	47.9	0.0
R3	20	3.7	51.6	3.7	51.5	-0.3
R4	23	3.3	45.2	3.2	45.1	-0.4
R5	26	3.0	41.6	3.0	41.5	-0.3
R9	30	3.4	46.3	3.3	46.3	-0.2
R14	32	3.0	41.5	3.0	41.2	-0.7
R15	39	3.2	44.5	3.2	44.2	-0.7

Table 4.4.6 Future (Uncontrolled) and Present River Water Quality [DO] in 2010

Evaluation Point	Distance (km)	DO Concentration (mg/l) and Ratio of Saturation (%)				
		Results of Simulation				Rate of Increase (%)
		Present (1992)	(%)	Future (2010)	(%)	
R1	0	3.0	42.5	3.0	42.5	0.0
R2	16	3.4	47.9	3.4	47.9	0.0
R3	20	3.7	51.6	3.6	50.9	-1.5
R4	23	3.3	45.2	3.2	44.4	-1.9
R5	26	3.0	41.6	3.0	41.2	-1.0
R9	30	3.4	46.3	3.3	46.1	-0.4
R14	32	3.0	41.5	2.9	39.8	-4.1
R15	39	3.2	44.5	3.1	42.5	-4.5

BOD concentration are very high and the river flow is mostly of wastewater discharged in the reaches. The amounts of wastewater in the reaches increase in future, but the increase is caused by the increase of gray water whose BOD concentration is lower than that of human waste. As a result, wastewater in these reaches are slightly diluted with the increase of gray water. This contradictory result does not mean the improvent of the river water quality, but shows that the river water quality in the Central Zone is and will be worse than gray water.

CHAPTER 5
FORMULATION OF THE BASIC PLAN

5.1 CONCEPTS FOR THE BASIC PLAN

The rivers in the urbanized areas and downstream are so polluted as to be regarded as sewage, and there is no doubt that the causes of this pollution are untreated wastewaters from residences, factories, hospitals, public buildings and others.

The City of La Paz has a sewage collection system covering about 32 % of the urbanized area and 56 % of the population in the Central and the South zones. In other urbanized areas such as those in the catchments of the Irpavi, Achumani, and Huañajahuira Rivers, residential developments are always accompanied by the installation of a sewage collection system. Therefore, in most areas in the city, people enjoy the benefits of a sewage collection system.

However, from the viewpoint of river water quality, the above situation severely contributes to pollution of the rivers. Because such sewage collection system does not reduce the pollution load discharged to the rivers, since there are no wastewater treatment facilities. The collection system efficiently carries all the wastewater generated directly to the river, while in areas without a sewage collection system, the volume of wastewater is considerably reduced before reaching the river.

It is strongly recommended that the basic plan for water quality improvement include measures to reduce the pollutant loads to rivers from the urbanized area. There may be several ways to improve the water quality without reducing the pollutants load: dilution of polluted water by clean water, diversion of polluted water away from the area concerned, and so on. Those measures, however, should not be considered as permanent, because, i) it is a widely recognized principle that any kind of pollutant discharge must be reduced as much as possible to prevent environmental pollution, ii) clean water is a valuable resource to be used to support urban activities, and iii) diversion of the wastewater may cause other pollution problems in downstream areas.

Therefore, the basic plan will propose a water quality improvement system that is based on treatment of wastewater and reduction of industrial wastewater discharges. The wastewater treatment will require large construction costs, a long implementation period and strong organization to manage it. These requirements may exceed the capability of the present organization. Even though it is not possible to exactly follow the schedules proposed in the basic plan, it is worthwhile to draw up an ultimate goal and to make every effort to meet the goal.

5.2 SELECTION OF ALTERNATIVES FOR THE BASIC PLAN

5.2.1 Conceivable Measures

After a preliminary screening, the following 4 structural measures to improve the water quality of the rivers in the project area were considered:

- Reduction of pollutant loads to the river by wastewater treatment
- Dilution of the river water
- Direct purification of the river water
- Diversion

However, those measures other than reduction of pollutant loads were found to be not appropriate for the basic plan as explained below.

(1) Purification of River Water (Direct Purification)

Direct purification of river water is to improve river water quality by applying certain purification methods to river water itself. Typical methods for direct purification are as follows:

- Construction of weirs in the stream
- Widening the stream surface
- Simple sedimentation
- Contact purification
- Infiltration

Facilities involved in the above methods are usually constructed in a river or its vicinity. These are methods to accelerate or enhance the river's self-purification functions. While they use less energy to purify water comparing to conventional wastewater treatment technology, such as activated sludge process, trickling filters, filtration, etc., they require such large areas that it takes long reaches until the river water is purified by the self-purification process. Therefore, these methods are more suitable for additional purification of river water which has already been improved to some extent, thus they are more effective when they are used as supplemental methods.

In the earlier stages of this study, these methods were investigated as one of the improvement methods of the Choqueyapu River. Since the Choqueyapu River is used as a sewage channel, it has been considered that if a certain purification method can be applied to the Choqueyapu River water, water quality improvement may be achieved without a sewage treatment plant. In addition, a large river gradient has been considered advantageous for the hydraulic design of direct purification. For example, in case of purification by weir construction, weirs are constructed at certain intervals so that a combination of impounding and aeration can be repeated. The greater the gradient of the river, the more the numbers of possible repetitions.

However, they cannot be selected as the major improvement methods for of the following reasons (Detailed explanations are given in Appendix B):

- The rivers are too polluted to be improved substantially by these methods.

- The rivers carry a large amount of suspended solids, mainly silt and sand from upstream areas. If the river water is to be treated, a large amount of sludge containing silt and sand must be also treated, and this is not practical.

(2) Dilution of River Water

The quality of river water can be improved by introducing dilution water. This is a very simple improvement method if water for dilution is available.

However, this method is not recommended as a permanent and major component of the pollution control plan for the following reasons:

- Dilution does not reduce the amount of the pollutants discharged.

- Since the City of La Paz has a shortage in potable water especially in the dry season, and the demands of water for drinking and other beneficial uses in the metropolitan area are expected to increase in the future, it is difficult to expect the permanent availability of a sufficient amount of dilution water.

- A preliminary study showed that the available water by a dam would be at most 0.3 m^3/sec (Details are presented in Appendix A).

Therefore, if the clean water is available, this method should be regarded as a temporary or interim method to achieve early improvement of the river water quality, or as a supplemental method to further improve the river water quality after various other efforts to reduce the pollutants discharges have been made.

(3) Wastewater Treatment System (Centralized/Decentralized)

As a result of the discussions of the previous section, it was proposed to implement a wastewater treatment system as the primary structural measure for the Basic Plan. Such a measure would be supplemented by other non-structural measures.

In case of La Paz, the most critical technical condition for the planning of a wastewater treatment system is considered to be the topography; large altitude differences within the area and a deficiency of flat lands. This will cause severe restrictions on capacities of treatment plants located near to the sewage collection areas. Therefore, possibilities for construction of the wastewater treatment plant were carefully studied mainly from a view point of land availability.

1) Land Availability

Lands considered to be available for the wastewater treatment site were proposed by SAMAPA. The study team visited each site with SAMAPA personnel. The locations of the proposed lands are shown in Fig. 5.2.1 and their sizes are shown in Table 5.2.1.

Lands are mostly available in the South zone and the lands in the Central zone are very small in size.

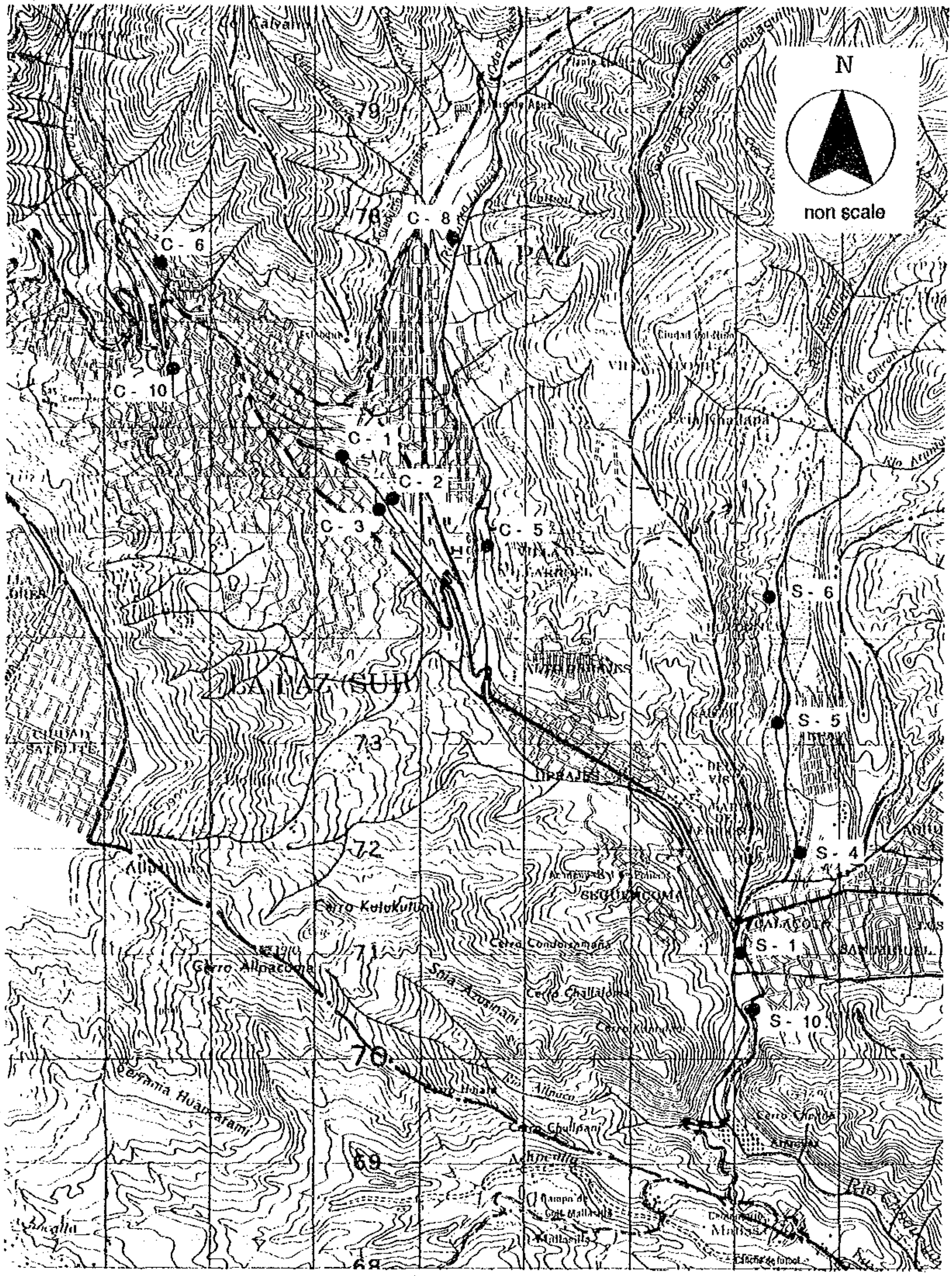


Fig. 5.2.1 Locations of Available Lands for Wastewater Treatment Plant

Table 5.2.1 List of Available Lands and their Sizes

Zone	No.	Location**	Estimated area available	
			m x m	ha
Central Zone	6	Achachicala	120*80	0.96
	10	Av. Manco Kapac	30*40	0.12
	1	Av. Ejercito	40*90	0.36
	2	Del Poeta (left)	35*800	2.80
	3	Del Poeta (right)	25*110	0.28
		Choqueyapu Total		4.52
	8	Villa Fatima- A	50*80	0.40
	8	Villa Fatima-B	20*20	0.04
	5	Gringo Jahuira	100*120	1.20
		Orkojahuira Total		1.64
	Central Total			6.16
South Zone	6	Bolognia Upstream	30*85	0.26
	5	Bolognia Downstream	70*100	0.70
	4	Near Colegio Militar	500*200	10.0
	1	Calle Los Mardos	50*150	0.75
	10	La Florida	80*200	1.60
		South Total		4.71
		Grand Total		10.86

** For location, refer to Fig. 5.2.1

In addition to above list of available lands, additional lands near the Lipari Bridge were proposed by HAM at the feasibility stage of this study.

2) Treatment Capacity Calculated by Land Availability

Treatment capacities of wastewater treatment plants that can be constructed in the available sites are calculated as shown in Table 5.2.2.

As can be seen from the Table, the total maximum treatment capacity permitted in these areas is calculated at about 300,000 m^3/day by conventional treatment methods, while the total wastewater amount to be treated is estimated at about 200,000 m^3/day. However, it should be noted that site No.1 in the south zone (Calle Los Mardos) provides for 200,000 m^3/day of the total, also that the sites in the central zone including the Orkojahuira River basin, where most of wastewater is generated, would provides for only 60,000 m^3/day. Even though it would be possible to construct wastewater treatment plants in all the listed lands and to treat the wastewater at the rate of the estimated maximum capacity, they would treat only less than 50% of the wastewater generated from the central area. Actually, some of these plants would be difficult to be

Table 5.2.2 Treatment Capacity

Zone	No.	Location	Maximum Treatment Capacity (m^3/day)	
			Sedimentation only	Conventional treatment
Central zone	6	Achachicala	72,000	8,000
	10	Av. Manco Kapac	9,000	400
	1	Av. Ejercito	27,000	1,800
	2	Del Poeta (left)	210,000	35,000
	3	Del Poeta (right)	20,625	1,200
		Choqueyapu Total	338,625	46,400
	8	Villa Fatima-A	30,000	2,300
	8	Villa Fatima-B	3,000	100
	5	Gringo Jahuira	90,000	11,000
		Orkojahuira Total	123,000	13,400
	Central Total		461,625	59,800
South zone	6	Bolognia Upstream	19,125	1,000
	5	Bolognia Downstream	52,500	5,000
	4	Near Colegio Militar	105,000	15,000
	1	Calle Los Mardos	56,250	200,000
	10	La Florida	120,000	18,000
	South Total		352,875	198,950
Grand Total			814,500	298,800

constructed because of environmental concerns and pumping would be required for some sites, because they are located at high places. Thus the land for the wastewater treatment plant for the remaining wastewater must be found outside of the central zone; this will require installation of a sewer transmission line from the central zone to the plant site.

In addition to the above discussion, further study was conducted to investigate the feasibility of constructing wastewater treatment plants at desirable locations in the central zone as presented in Appendix C. According to that study, only three sites in the central zone are considered to be suitable for constructing a plant, and for these sites, the total capacity is only 25,000 m^3/day. The estimated costs to construct wastewater treatment plants in 15 proposed sites are 50% higher than those to construct one plant with capacity 20% larger than the total of the 15 plants.

From the above considerations it is concluded that the decentralized treatment option of constructing several wastewater treatment plants is not feasible from view points of land availability and costs.

5.2.2 Alternatives for the Basic Plan (Irpavi Option)

A conceivable measure for the Basic Plan is to install a centralized wastewater treatment plant. There are two possible plant sites in the area; one the lower reaches of the Irpavi River and another near the Lipari Bridge. Therefore it is possible to propose two options with regard to sites. Also there would be several alternative treatment methods.

(1) Treatment Method for the Wastewater Treatment Plant of the Irpavi Option

To determine the most suitable treatment method for the wastewater treatment plant, the following treatment methods were compared:

- Stabilization pond
- Conventional activated sludge
- Rapid aeration and sedimentation (High-rate activated sludge)
- Trickling filter

Stabilization pond requires less mechanical equipment, thus requires less construction and operation costs. Conventional activated sludge is a standard type of activated sludge method. "Rapid aeration and sedimentation" is a variation of the activated sludge methods, which requires less land area than the conventional method, but a somewhat lower performance. The trickling filter is a type of attached biological process.

1) Characteristics of Each Method

A. Stabilization Pond

The most common type of pond is the facultative pond, which is usually 1.2 m to 2.4 m in depth, with an aerobic layer overlying an anaerobic layer, often containing sludge deposits. Usual detention time is 5 to 30 days. Anaerobic fermentation occurs in the lower layer and aerobic stabilization occurs in the upper layer. The key to facultative operation is oxygen production by photosynthetic algae present in the pond and oxygen transfer through surface reaeration. It is used for treatment of municipal wastewater. The facultative pond is the easiest to operate and maintain, but land requirements are high and there are definite limits to its performance. Effluent BOD values range from 20 to 50 mg/l, and SS levels usually range from 30 to 150 mg/l.

In an aerated pond, oxygen is supplied mainly through mechanical or diffused aerators rather than by photosynthesis and surface aeration. Many aerated ponds evolved from overloaded facultative ponds that required aerator installation to increase oxygenation capacity. An aerated pond is generally 2 to 6 m in depth with detention times of 3 to 10 days. It can also be classified by the degree of mixing provided. If energy input is sufficient to keep all solids in suspension, and if secondary clarification with sludge return is utilized, the system approaches an activated sludge process with the associated high BOD and SS removals. However, power costs for this system become very high, and operation and maintenance complexity increases.

Aerobic ponds, also called high rate aerobic ponds, maintain dissolved oxygen throughout its depth. They are usually 30 to 50 cm in depth, allowing light to penetrate the full depth. Mixing is often provided to expose all algae to sunlight and to prevent deposition and subsequent anaerobic conditions. Oxygen is provided by photosynthesis and surface re-aeration, and aerobic bacteria stabilize the wastes. Detention time is short, three to five days being usual.

Anaerobic ponds receive such heavy organic loading that there is no aerobic zone. They are usually 2.5 to 5 m in depth and have detention times of 20 to 50 days. The principal biological reactions occurring are acid formation and methane fermentation. Anaerobic ponds are usually used for treatment of highly polluted industrial and agricultural wastes, or as a pre-treatment step when an industry is a significant discharger to a municipal sewerage system. An important disadvantage of an anaerobic pond is the production of odorous compounds and a further disadvantage is that the effluent must usually be given further treatment prior to final discharge.

B. Conventional Activated Sludge

Fig. 5.2.2 presents a general scheme of the activated sludge processes. Wastewater and sludge solids are first combined, mixed, and aerated in a aeration basin. Typically, the process operates in a continuous flow mode, but

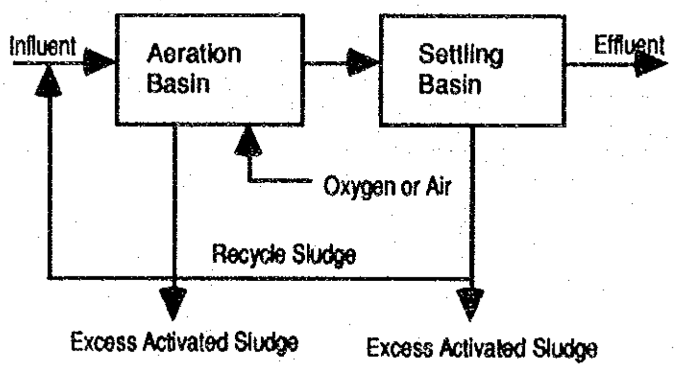


FIG.5.2.2 GENERAL SCHEMATIC OF ACTIVATED SLUDGE PROCESS

can also be operated as a batch process. Contents of the reactor, referred to as mixed liquor, consist of wastewater, microorganisms (living as well as dead), inert, biodegradable, and non biodegradable suspended and colloidal matter. The particulate fraction of the mixed liquor is termed mixed liquor suspended solids (MLSS).

After sufficient time for the biological reactions, the mixed liquor is transferred to a separate settling basin or clarifier to allow gravity separation of the MLSS from the treated wastewater. The settled MLSS are then recycled to the aeration basin to maintain a concentrated microbial population for degradation of pollutants in influent wastewater. Because microorganisms are continuously synthesized in this process, some of the MLSS must be wasted from the system. Wasting is generally from the clarifier, although removal from the aeration basin is an alternative. Depending on the design and operation of the process, either maximizing or minimizing production of biological sludge is possible.

A basic activated sludge process consists of the following components:

- A single aeration basin or multiple basins designed for completely mixed flow, plug flow, or intermediate patterns, and sized to provide a hydraulic retention time (HRT) in the range of 0.5 to 24 hours or more.
- An oxygen source and equipment to diffuse atmospheric or pressurized air or oxygen-enriched air into the aeration basin at a rate sufficient to keep the system aerobic.
- A means of mixing contents of the aeration basin to keep the MLSS in suspension.
- A clarifier to separate the MLSS from the treated wastewater.
- A means of collecting the settled MLSS in the clarifier and recycling it to the aeration basin.
- A means of wasting excess MLSS from the system.

C. Rapid Aeration and Sedimentation (High-rate Activated Sludge)

"Rapid aeration and sedimentation" is one of the variations of conventional activated sludge process incorporating aeration and sedimentation processes structurally united in one basin. In this system, wastewater and sludge solids are mixed in the aeration process and the mixed liquor over-flows to the sedimentation process, where sludge is separated from the treated wastewater. The settled sludge is returned to the aeration process through openings at the bottom of the sedimentation chamber.

Since wastewater, sludge solids and air are well mixed, biodegradation by absorption and oxidation is rather rapid and effective as compared to the conventional method. By keeping the MLSS at a high concentration, this system can be operated with high volumetric loadings.

While it can be designed for shorter detention times in the aeration and sedimentation processes, it is easily affected by the fluctuation of the loading rate, resulting in an instability of the water quality of the treated wastewater. Thus this method is considered to be a medium grade biological treatment.

D. Trickling Filter

The trickling filter process has the biomass attached to fixed media, while the former three methods employ the biomass suspended in wastewater, thus recycling of the settled biomass is generally not required.

Wastewater from a primary settler or screens is applied to the filter media through which the flow percolates. The surface of the media quickly becomes coated with a viscous, jelly-like, slimy substance containing bacteria and other biota. The biota remove organics by adsorption and sedimentation of soluble and suspended constituents. For aerobic metabolism, oxygen is supplied from the natural or forced circulation of air through interstices in the filter media. Oxygen transfer may be direct or by diffusion through the liquid films.

The trickling filter process has been considered as an acceptable secondary treatment for most wastewaters amenable to aerobic biological treatment. It is considered capable of providing adequate treatment of domestic wastewater where required effluent limits of BOD and TSS are 20 to 45 mg/l.

2) Selection of Method

Design and operational characteristics of each process are summarized in Table 5.2.3.

As can be seen in the table, it is obvious that the stabilization pond method is not practical for the Irpavi option because of its low surface loading rate, although it is a preferable method in case where operational experience in wastewater treatment is not sufficient and the budget is extremely limited. Although the trickling filter is a preferable method because of its reduced operation and maintenance requirements, it too is judged not suitable for this option due to its requirement for more area than that available.

Therefore, mainly due to the limited area of land, it is recommended to select an activated sludge process as the treatment method. However, it requires relatively high operation costs and experienced operators. If the activated sludge process is to be selected, the high-rate activated sludge method is preferable to other activated sludge methods, because it will save a considerable area as well as construction costs.

TABLE 5.2.3 Design and Operational Characteristics

Method	Type	BOD loading (kgBOD /m^3)	Surface Loading (m^3/m^2)	Detention Time (hrs)	Aeration (vol. of air /vol. of wastewater)	MLSS (mg/l)
Stabilization Pond	Facultative	0.002 - 0.004	0.001 - 0.08	25- 180 days	none	-
	Aerated	0.008 - 0.3	0.4 - 0.16	7 -20 days	-	-
	Aerobic	0.01 - 0.03	0.05 - 0.012	10 40 days	none	-
	Anaerobic	0.16 - 0.8	0.2 - 0.1	2- -50 days	none	-
Activated Sludge	Conventional	0.3 - 0.8	20 - 15	6 - 8 hrs	3 -7	1500 - 2000
	HRAS*	0.6 - 2.4	55 - 37 (30 - 20)	2 - 3 hrs (4 - 6)	5 - 8	3000 - 6000
Trickling Filter		0.5 - 2.0	25 - 15	-	none	-

* High-rate activated sludge
( ) Including sedimentation process.

(2) Components of the Irpavi Option

The total scheme of the Irpavi option is shown in Fig. 5.2.3. Structural components of the Irpavi option are explained below.

1) Water Intake Weir

A water intake weir would be installed in the Choqueyapu River at the upstream of the confluence with the Orkojahuira River in Kantutani. The Choqueyapu River above this water intake point is regarded as a sewer channel and the dry season flow would be transmitted to the wastewater treatment plant.

2) Sewer Pipelines

The wastewaters from the Central zone would be collected from the Choqueyapu River as mentioned above, and transmitted to the wastewater treatment plant by the main sewer interceptor. The wastewaters from other area would be collected by sewer interceptors and transmitted to the treatment plant. The route of the main sewer interceptor for this option is shown in Fig 5.2.4.

The main sewer interceptor from the water intake at the Choqueyapu River would have a tunnel structure at a certain section to avoid wastewater pumping. The interceptor from the Orkojahuira basin would be connected to the main sewer interceptor. The wastewater from the Calacoto area would require pumping because of its low elevation near the plant site.

Details of the proposed sewers for this option are summarized in Table 5.2.4. In these details, the amounts of sewage for each section are calculated based on the assumption of separate systems, although connections between sewers and storm lines are common in the city. Thus, during the rainy season, it is possible that the designed pipe size cannot cater to the wastewater which may contain a considerable amount of stormwater. Therefore, it will be necessary to install overflow weirs at the inlets to pipelines, in order to divert excess amounts of wastewater. This means that some portion of wastewater would be discharged to rivers without treatment in the rainy season. However, this would not cause significant adverse effects to the river water quality since the river flow would increase during the rainy season.

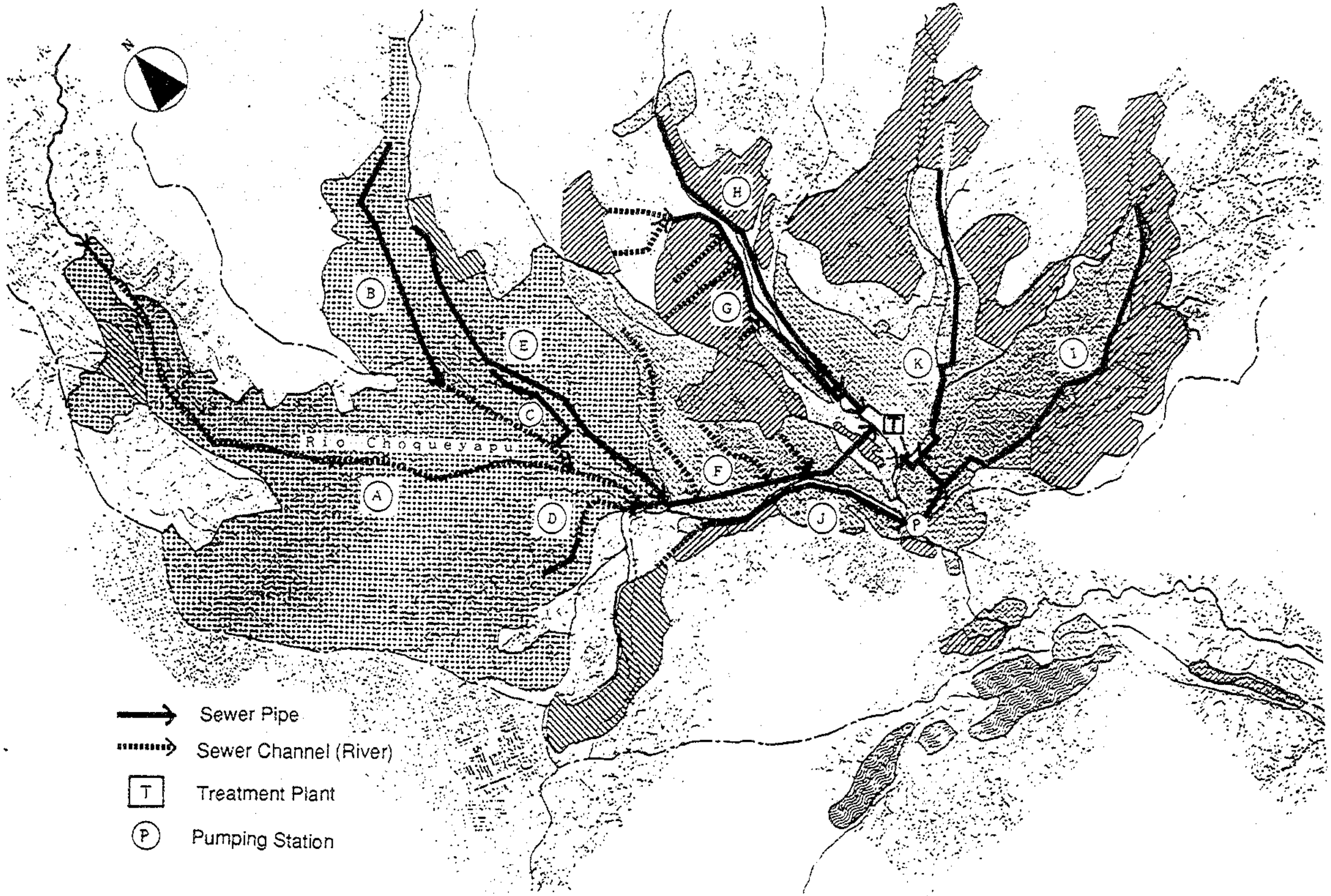


Fig.5.2.3 Routes of Sewer Interceptors (Irpavi Option)

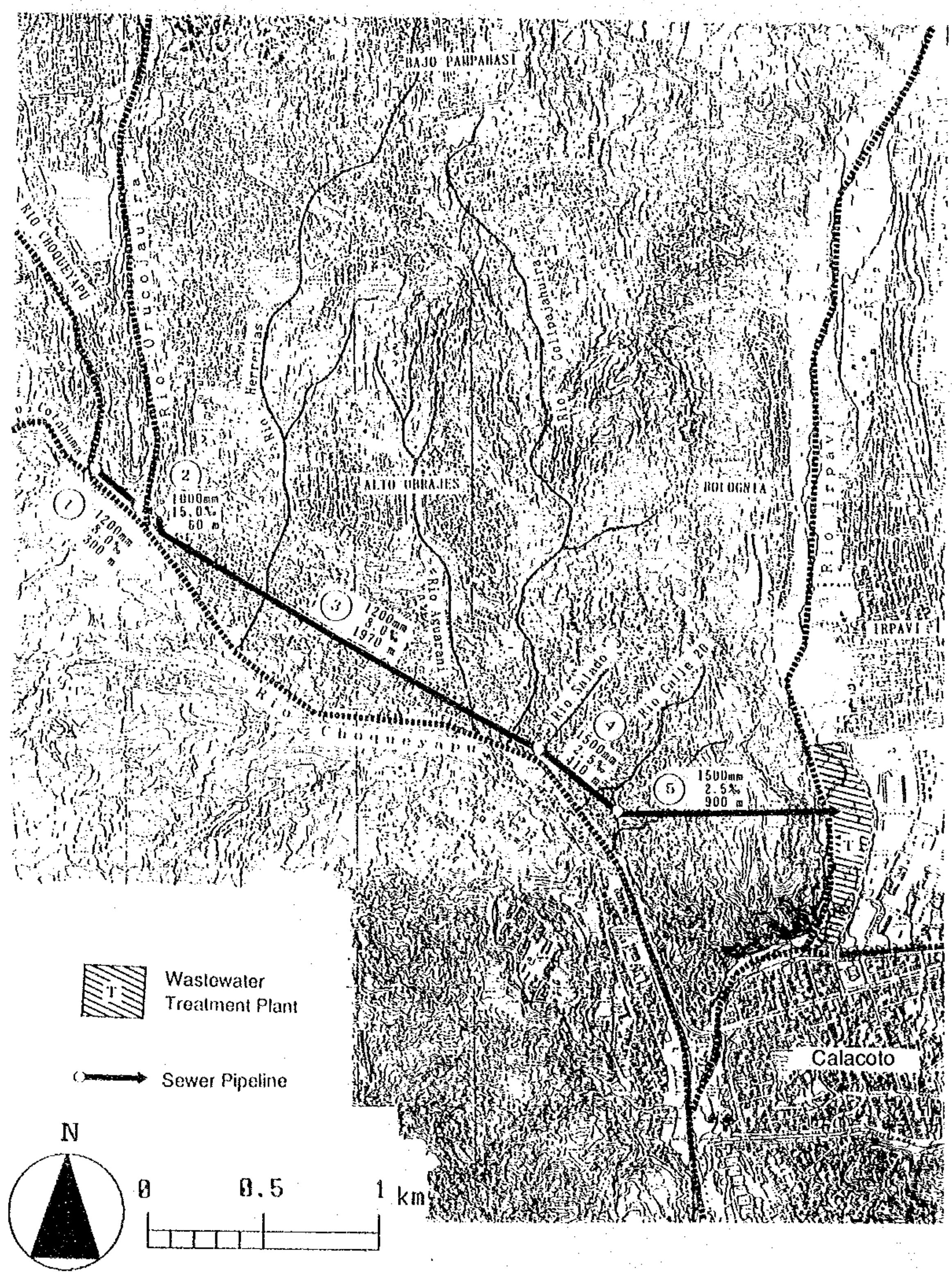


Fig. 5.2.4 Route of Main Sewer Interceptor (Irpavi Option)

TABLE 5.2.4 DETAIL OF PROPOSED SEWERS (1) - IRPAVI OPTION

Pipeline A to F

Number	Area (ha)	Sewer (m3/sec)	Sewer Pipe Size (mm)	Length (m)
A-1	-	0.400	Rio Choqueyapu	-
A-2	1768	1.686	Rio Choqueyapu	-
TO F1	(1768)	(1.686)		
B-1	68	0.019	250	1100
B-2	40	0.031	300	650
B-3	108	0.066	400	960
B-4	124	0.105	450	860
TO F1	(340)	(0.105)		(3570)
C-1	70	0.056	400	1600
C-2	5	0.011	250	130
TO F1	(75)	(0.067)		(1730)
D-1	106	0.071	400	530
D-2	126	0.106	450	560
D-3	40	0.152	450	260
TO F1	(272)	(0.152)		(1350)
E-1	79	0.033	300	1530
E-2	57	0.057	400	1020
E-3	102	0.100	450	570
E-4	200	0.185	600	2510
TO F3	(438)	(0.185)		(5630)
F-1	(2455)	2.010	1200	300
F-2	(2455)	2.010	1000	60
F-3	(3389)	2.318	1200	1970
F-4	(3389)	2.318	1500	410
F-5	(3389)	2.318	1500	900
TO PLANT	(3389)	2.318		(3640)

TABLE 5.2.4 DETAIL OF PROPOSED SEWERS (2) - IRPAVI OPTION

Pipeline J to K

			Sewer Pipe	
Number	Area (ha)	Sewer (m3/sec)	Size (mm)	Length (m)
G-1	134	0.033	300	1150
G-2	145	0.069	400	2190
TO H4	(279)	(0.069)		(3340)
H-1	66	0.016	250	1660
H-2	85	0.038	300	1620
H-3	36	0.047	400	1800
H-4	32	0.123	600	510
TO PLANT	(219)	(0.123)		(5590)
I-1	108	0.027	300	1180
I-2	142	0.062	400	1570
I-3	204	0.113	450	2120
I-4	21	0.223	600	470
I-5	5	0.349	800	310
TO PLANT	(480)	(0.349)		(5650)
J-1	156	0.039	300	1280
J-2	60	0.054	400	1920
J-3	75	0.072	400	650
J-4	133	0.105	250	860
TO I4	(424)	(0.105)		(4710)
K-1	252	0.063	400	1260
K-2	379	0.094	450	2520
K-3	501	0.125	600	340
TO I5	(1132)			(4120)

3) Wastewater Treatment Plant

A provisional design of the wastewater treatment plant at the Irpavi site is shown as follows:

A. Design Conditions

Design flow in the year 2010 is 230,000 m^3/day; daily average wastewater flow plus dry season flow of the Choqueyapu River

Influent water quality	BOD	250 mg/l
	SS	250 mg/l
Effluent water quality	BOD	50 mg/l
	SS	70 mg/l
Location	Left bank of the downstream reach of the Irpavi river (See Fig. 5.2.5)	
Treatment process	High-rate activated sludge: primary sedimentation + rapid aeration and sedimentation + disinfection	
Sludge treatment Process	Thickening + digestion + drying bed	

B. Primary Sedimentation

Assuming a return flow from the sludge treatment process of 5 %, the design flow to the sedimentation is estimated as follows:

$Q = 230{,}000 \times (1 + 0.05) = 241{,}500\ m^3/day.$

Using a surface loading of 30 m^3/m^2/day, the required surface area of the sedimentation pond is calculated as follows;

$241{,}500/30 = 8{,}050\ m^2.$

C. Rapid Aeration and Sedimentation

Assuming each detention time in the aeration chamber and sedimentation chamber of 2.5 hrs, the required volume of the tank is calculated as follows:

$(241{,}500 / 24) \times 2.5 \times 2 = 50{,}313\ m^3$

Applying a cross section of the tank as shown in the following sketch, the required length is calclated as follows:

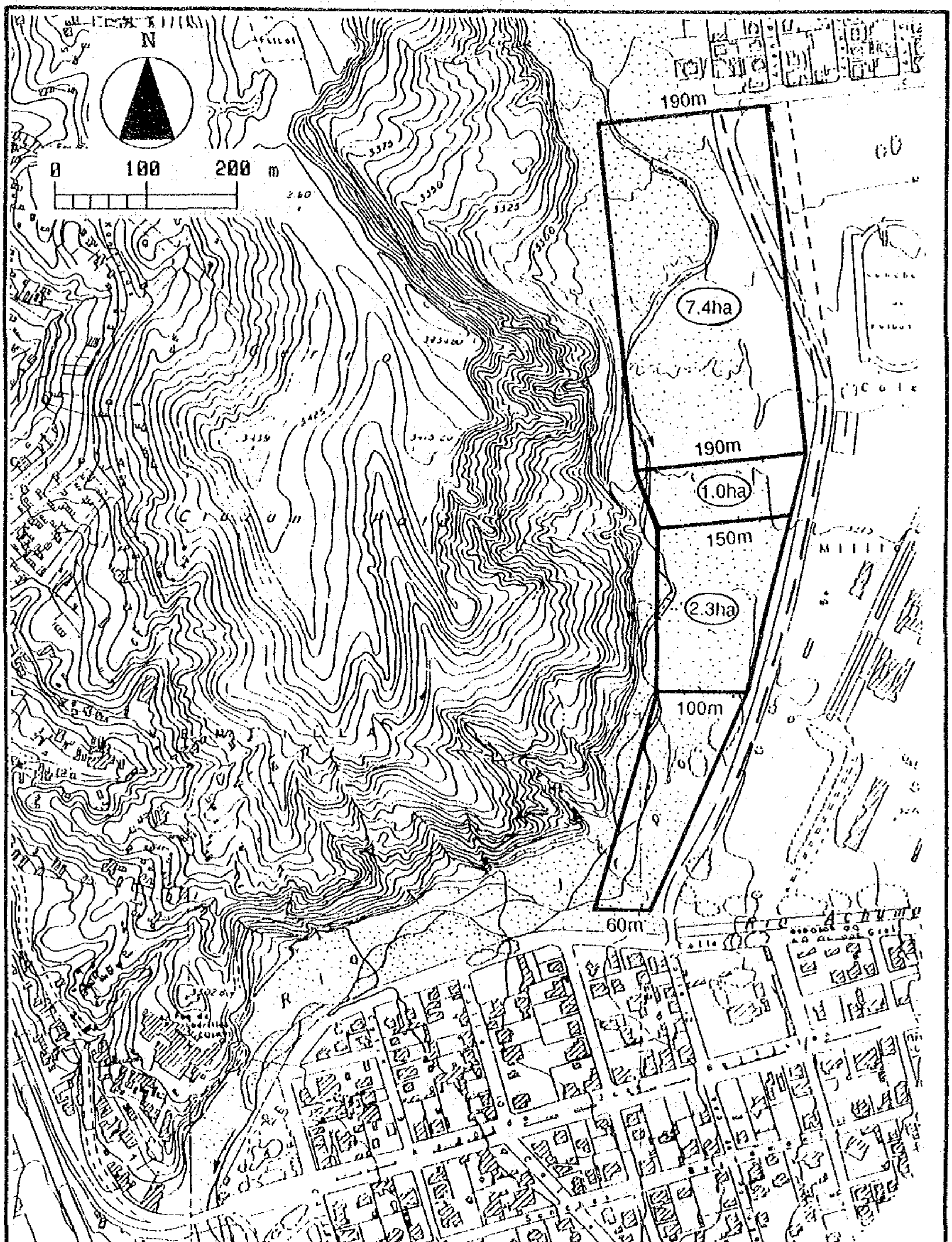


Fig. 5.2.5 Site for Wastewater Treatment Plant (Irpavi Option)