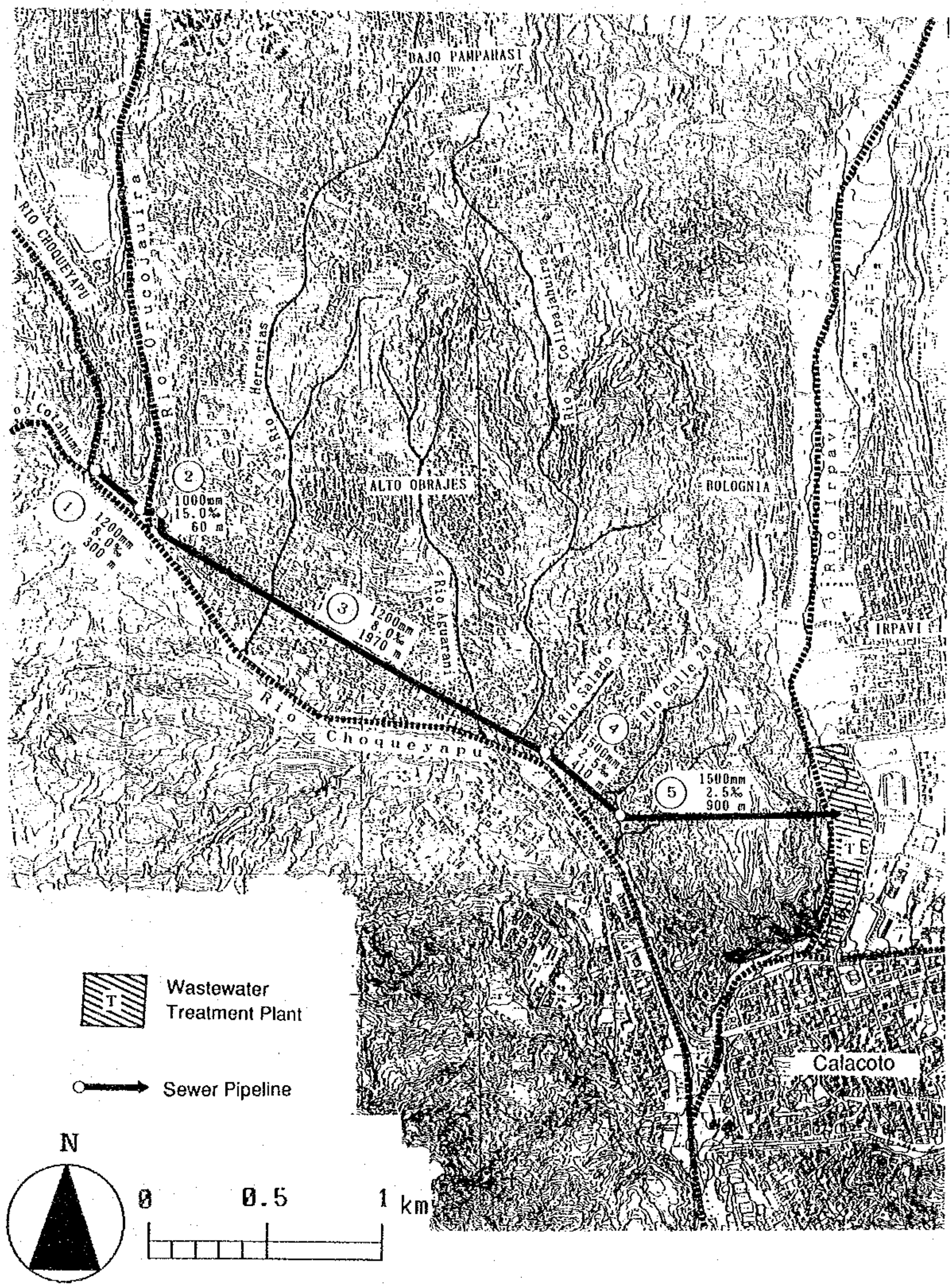


Fig. 5.2.2 Route of Main Sewer Interceptor (Irpavi Option)

Effluent water quality	BOD 50 mg/l SS 70 mg/l
Location	Left bank of the downstream of the Irpavi river (See Fig. 5.2.3)
Treatment process	High-rate activated sludge: primary sedimentation + rapid aeration and sedimentation + disinfection
Sludge treatment process	Thickening + digestion + drying bed

B. Primary Sedimentation

Supposing that the return flow from the sludge treatment process is 5 %, the design flow rate to the sedimentation basin is estimated at :

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

Assuming a surface loading of 30 $m^3/m^2/day$, the required surface area of the sedimentation basin is calculated as follows:

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

C. 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:

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

The general layout of the wastewater treatment plant is shown in Figs. 5.2.4 .

(2) Lipari Option

1) Sewage Collection/Transmission

In the Lipari option, a main sewer interceptor would be installed from an intake facilities upstream of the Choqueyapu-Orkojahuira confluence to the wastewater treatment plant site above the Lipari bridge. This main interceptor would collect wastewater from the central area, the Irpavi basin, and other areas, and transmit them to the plant site.

The proposed route of the main sewer interceptor, which was selected after discussion with the Bolivian counterparts is shown in Fig. 5.4.2.

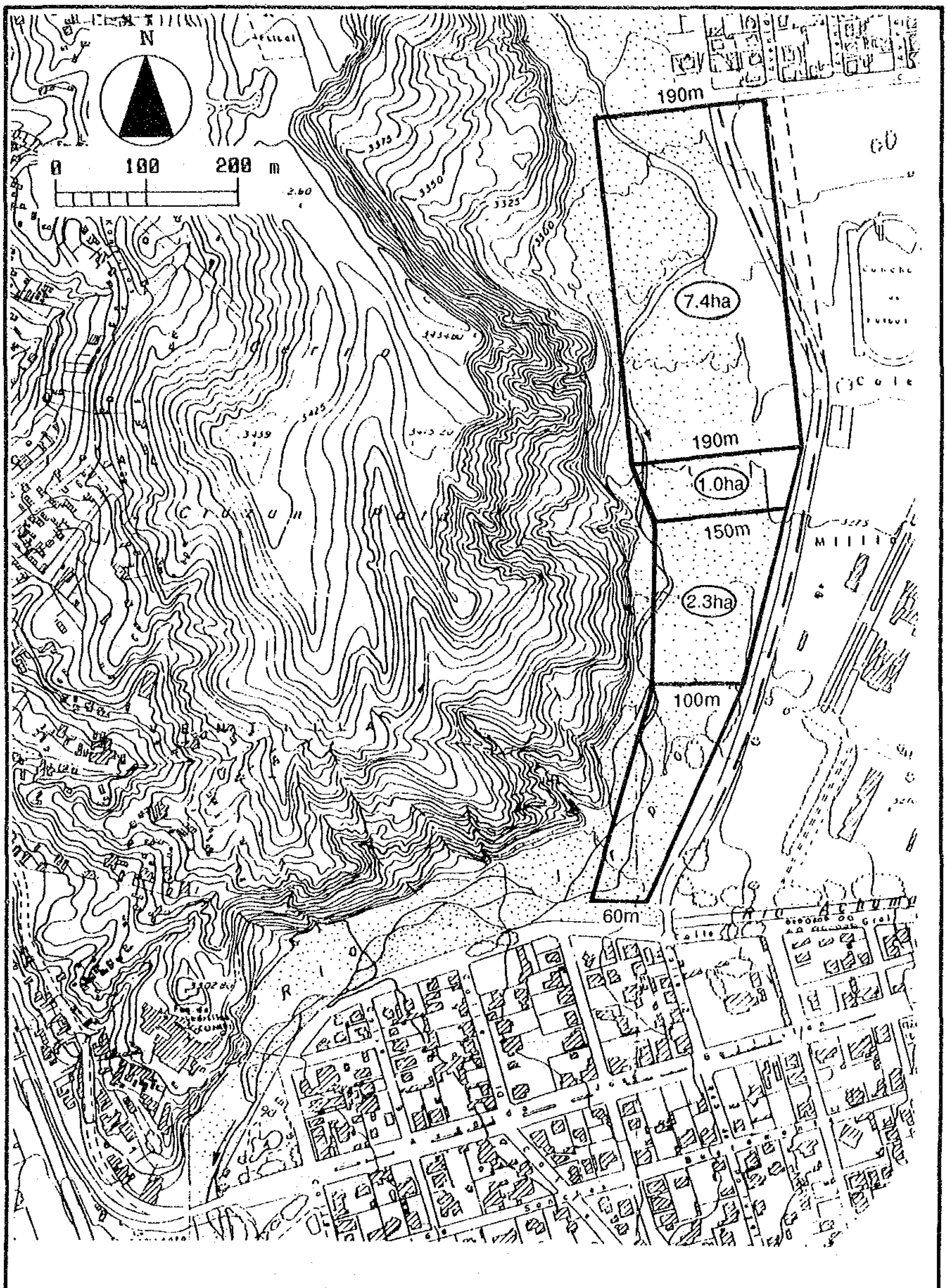


Fig. 5.2.3 Site for Wastewater Treatment Plant (Irpavi Option)

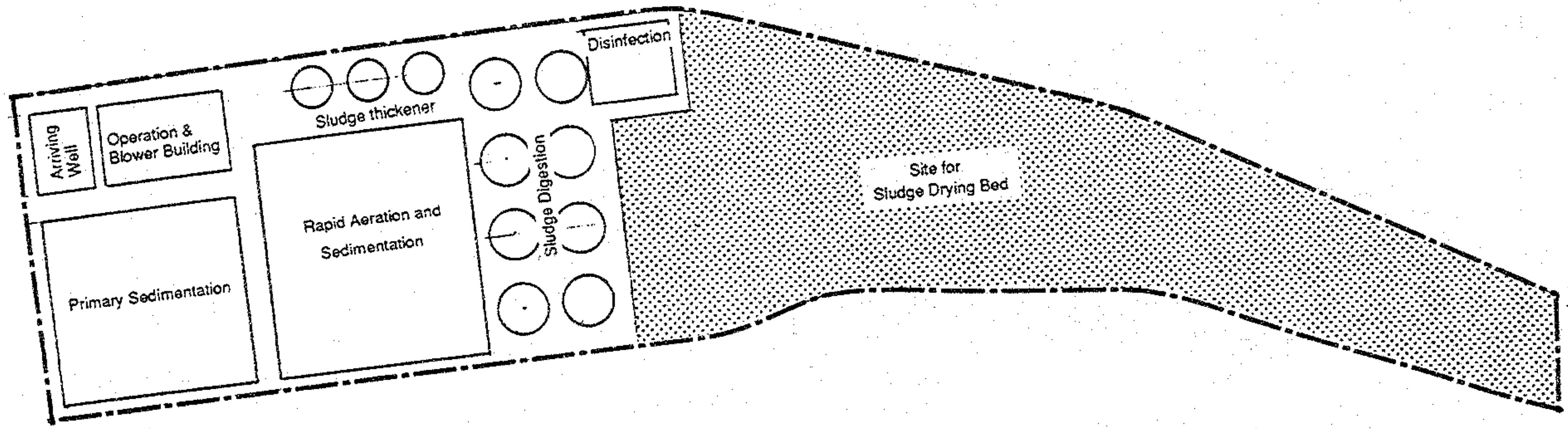


Fig. 5.2.4 General Layout of Wastewater Treatment Plant (Irpavi Option)

2) Treatment Method

Wastewater treatment methods for a centralized plant of the Irpavi option were discussed in the previous section. In the Irpavi option, a high rate activated sludge treatment process was selected because of extreme area limitations, although it was not preferable from view points of costs and suitability of technology.

However, the activated sludge method was only one of the alternatives studied in the Lipari option. In addition, in case of the Lipari option, it was possible to consider other methods, which require more area but less construction costs, such as aerated lagoons or ponds.

Typical design parameters for several types of stabilization ponds are shown in Table 5.2.1.

TABLE 5.2.1 TYPICAL DESIGN PARAMETERS FOR SEVERAL TYPES OF STABILIZATION PONDS

Parameters	Type of Ponds		
	Aerobic lagoons (high rate)	Facultative lagoons	Aerated lagoons
Flow Regime	Intermittently mixed	Mixed surface layer	Completely Mixed
Pond size (ha)	0.2 - 0.8	0.8 - 4	0.8 - 4
Operation	Series	Series or parallel	Series or parallel
Detention time (day)	4 - 6	5 - 30	3- 10
Depth (m)	0.3 - 0.5	1.2 - 2.4	2 - 6
Temperature (°C)	5 - 30	0 - 50	0 - 30
BOD conversion (%)	80 - 95	80 - 95	80 - 95

Extract from Metcalf & Eddy, Wastewater Engineering: Treatment, Disposal and Reuse: Third Edition, MacGraw Hill, Inc. New York, N.Y., (1991)

Table 5.2.2 shows the areas required to treat the wastewater by stabilization ponds, calculated by the design parameters (using minimum detention times and maximum depths) shown in Table 5.2.1.

TABLE 5.2.2 REQUIRED SIZES OF POND TO TREAT WASTEWATER BY SEVERAL TYPES OF STABILIZATION PONDS (LIPARI OPTION)

(DESIGN WASTEWATER FLOWS = 230,000 m3/day)

Type of Ponds	Detention Time (day)	Volume of Ponds (m^3)	Depth (m)	Size of Ponds (ha)*
Aerobic Lagoons	4	920,000	0.5	184
Facultative Lagoons	5	1,150,000	2.4	48
Aerated Lagoons	3	690,000	6.0	12

* Assumes vertical side slope.

The required areas for aerobic lagoons and facultative lagoons exceed the total area of the four available sites, thus, such lagoons cannot be applied for the treatment process for the Lipari option. Aerated lagoons are considered to be applicable from the stand point of the required area even though they will require further areas for sedimentation.

Therefore, aerated lagoons are one of the alternatives for the Lipari option. Trickling filters, which was eliminated from consideration for the Irpavi option due to its area requirements, can also be applied as a treatment method for the Lipari option. This method has advantages with regard to area requirement and operating costs as compared to the aerated lagoons.

5.2.3 Selected Alternatives

In the Basic Plan, it is proposed:

i) to collect the wastewaters from the Central area (excluding the Orkojahuira catchment) by taking wastewater from the Choqueyapu River upstream of the confluence with the Orkojahuira River. The Choqueyapu River is considered as a sewer channel,

ii) to install sewer interceptors in other areas except the Central area to collect wastewaters from the existing sewer pipes,

iii) to install a main sewer interceptor between the water intake point at the Choqueyapu river and the proposed wastewater treatment site,

iv) to transmit the wastewaters from the Central area and sewer interceptors in the other areas through the main sewer interceptor to the plant site, and

v) to construct one centralized wastewater treatment plant to treat the wastewaters.

There are two general plant site alternatives as follows:

i) A site located left bank of the Irpavi river in Calacoto area (Irpavi option)

ii) One or more sites located along the Choqueyapu River at the upstream and downstream of the Lipari bridge (Lipari option)

For the Irpavi option, it was determined that the activated sludge method (high rate activated sludge method) is the only applicable method for wastewater treatment because of area limitations. For the Lipari option, it is considered that aerated lagoons and trickling filters, which have been eliminated from the Irpavi option because of their land requirements, are applicable, as well as activated sludge. Therefore, the basic plan will be selected from four alternatives shown in Table 5.2.3.

TABLE 5.2.3 DESCRIPTIONS OF ALTERNATIVES FOR BASIC PLAN

Options	Alternatives	Plant site	Treatment method	Main Sewer Interceptor
Irpavi	1	Left bank of the Irpavi river in the Calacoto area	High Rate Activated Sludge	from the upstream of the confluence with the Orkojahuira river to Irpavi, mainly along roads.
Lipari	2A	Near Lipari, #1	Conventional Activated Sludge	from the upstream of the confluence with the Orkojahuira river to Lipari, along roads and river beds.
Lipari	2B	Near Lipari, #1	Trickling filters	same as above
Lipari	2C	Near Lipari, #1 and #2	Aerated Lagoons	same as above

Note : For location of plant sites #1 and #2, see Fig. 5.4.1.

5.3 EVALUATION OF THE ALTERNATIVES

5.3.1 Costs Comparison

(1) Estimates of Construction/Operation Costs

Cost estimates were prepared for four alternatives.

Tables 5.3.1 and 5.3.2 show construction cost estimates for a main sewer interceptor (including water intake facilities) of the Irpavi and Lipari options. The unit prices shown in the cost estimates presented were generally increased by about 50 % over those based on preliminary studied by Bolivian counterparts; this allowance was made considering the preliminary nature of these studies and the anticipated conservative design and construction supervision by international consultants.

Construction costs for three types of wastewater treatment plant are shown in Table 5.3.3. Operation costs for three types of wastewater treatment are shown in Table 5.3.4. Costs estimates for wastewater treatment methods were prepared on the basis of data from several references published in the U.S.A. In the absence of cost data from similar wastewater treatment plants in the high elevations of Bolivia, this cost data is believed to be the best available information for these studies. Although unit prices for civil works are less expensive in Bolivia than in the U.S.A., this is offset by imported equipment costs and special design consideration related to the altitude in the study area.

TABLE 5.3.1 PRELIMINARY ESTIMATES OF CONSTRUCTION COSTS FOR MAIN SEWER INTERCEPTOR (IRPAVI OPTION, 1992 PRICES)

Section	Quantity (m)	Unit Price (US$)	Total (US$)
Main Roads	3640	861	3,134,040
Tunnel	900	1500	1,350,000
Total			4,484,040

TABLE 5.3.2 PRELIMINARY ESTIMATES OF CONSTRUCTION COSTS FOR MAIN SEWER INTERCEPTOR (LIPARI OPTION, 1992 PRICES)

Section	Quantity (m)	Unit Price (US$)	Total (US$)
Main Roads	3630	861	3,125,430
Secondary Roads	1260	745.5	939,330
Populated Area	485	811.5	393,578
Tunnel	260	1500	390,000
River Bed *	4215	1000	4,215,000
Sub Total			9,063,338

* Includes access roads and protection over pipe.

TABLE 5.3.3 PRELIMINARY ESTIMATES OF CONSTRUCTION COSTS FOR WASTEWATER TREATMENT PLANT BY TREATMENT METHODS ($U.S. MILLION, 1992 PRICES) Design Wastewater = 230,000 m3/day

Aerated Lagoons		Trickling Filters		Activated Sludge	
Site Preparation (40ha)	8.50	Site Preparation (20ha)	4.50	Site Preparation (20ha)	4.50
Preliminary Treatment	1.20	Preliminary Treatment	1.20	Preliminary Treatment	1.20
Aerated Lagoons	4.50	Preliminary Clarifier	4.80	Preliminary Clarifier	4.80
Sedimentation Basins	2.00	Trickling Filters ***	16.50	Activated Sludge ***	18.0
Sludge Lagoons	1.20	Sludge Digesters	6.00	Sludge Digesters	6.00
Interface Piping	0.45	Sludge Drying Beds	4.50	Sludge Drying Beds	6.70
Electr. & Instrum	0.57	Interface Piping	3.75	Interface Piping	4.12
Operation Building *	0.30	Electr. & Instrum	3.38	Electr. & Instrum	3.60
Miscellaneous Buildings **	0.20	Operation Building *	0.40	Operation Building *	0.40
Access Roads	0.20	Miscellaneous Buildings **	0.30	Miscellaneous Buildings **	0.30
		Access Roads	0.20	Access Roads	0.20
Total	19.12	Total	45.53	Total	49.82

* Office, lab, meeting room, etc
** Garage, storage, maintenance
*** Includes Final Clarifiers/Recycle Pumps.

TABLE 5.3.4 PRELIMINARY ESTIMATES OF ANNUAL OPERATION COSTS FOR WASTEWATER TREATMENT PLANT BY TREATMENT METHODS ($U.S. MILLION, 1992 PRICES)

Aerated Lagoons		Trickling Filters		Activated Sludge	
Aerated Lagoons	2.60	Trickling Filters	1.10	Activated Sludge	3.00
Sludge Lagoons	0.08	Preliminary Clarifier	0.25	Preliminary Clarifier	0.25
		Digesters	0.10	Digesters	0.10
		Sludge Drying Beds	0.70	Sludge Drying Beds	0.90
Haul Sludge	0.08	Haul Sludge	0.03	Haul Sludge	0.03
Total	2.76	Total	2.18	Total	4.28

Note: Does not include preliminary treatment, which is common to all alternatives.

(2) Project Costs

Based on the construction/operation costs above, project costs for four alternatives are estimated as shown in Table 5.3.5. The total project cost estimates presented herein include Engineering (final design and construction supervision), estimated at 10% of construction costs, and Contingencies, estimated at 15% of construction costs.

TABLE 5.3.5 COMPARISON OF ALTERNATIVES ($U.S. MILLION, 1992 PRICES)

Costs	Alternatives			
	1	2 A	2 B	2 C
Capital Costs				
Main sewer Interceptor	4.48	9.06	9.06	9.06
WWTP	49.82	49.82	45.53	19.12
Intake Facilities	1.15	1.15	1.15	1.15
Sewer interceptors	3.22	3.22	3.22	3.22
Sub-Total	58.67	63.25	58.96	32.55
Land and R.O.W.'s	17.25	2.94	2.94	5.34
Engineering	5.87	6.33	5.90	3.26
Contingency	8.80	9.49	8.84	4.88
Total	90.59	82.00	76.64	46.03
Annual Operation Costs	5.00	5.00	2.50	3.50

Note: For descriptions of each alternative, refer to Table 5.2.8.

5.3.2 Technological Adaptability

Required technological levels in the operation and maintenance of treatment facilities are qualitatively compared below for the treatment methods of the four basic plan alternatives.

Method	Basic plan Alternative No.	Simplicity of operation	Ease of maintenance	Local availability of equipment /supplies	Level of personnel skill required
Activated sludge	1 2-A	xx	xxx	xx	x
Trickling filter	2-B	xx	xx	xxx	xx
Aerated lagoon	2-C	xxx	xxx	xxx	xx

Note: xxx : simpler, easier, higher availability, lower level of skill
xx : medium
x : not simple, not easy, lower availability, higher level of skill

The aerated lagoon method is considered to be most favorable among the three methods in view of technological adaptability, followed by the trickling filter method and the activated sludge method. It should be noted that heated/mixed equipment and spare parts, are required in the sludge treatment for the activated sludge and the tricking filter methods.

5.3.3 Water Quality Improvement

(1) Cases Analyzed

Expected water quality improvement effects of the Irpavi and Lipari options in terms of BOD were predicted using the simulation model described in Chapter 4. Water quality improvement effects of three Lipari alternatives were assumed to be essentially the same. The computations were carried out for the following cases for 2010:

i) Implementation of the Irpavi option

ii) Implementation of the Lipari option

iii) Industrial wastewater control (Applying the effluent standards, maximum 300 mg/l of BOD, to industries with wastewater discharge over 100m^3/day)

iv) Industrial wastewater control (Applying the effluent standards, maximum 300 mg/l of BOD, to industries with wastewater dischargeover 25m^3/day)

v) Dilution by water from a dam (0.2m^3/sec)

Cases iii) and iv) were included to compare the effects of applying the industrial wastewater discharge regulation to relatively large industries only and applying the regulation to industries including smaller ones. Case v) was included, for reference, to see the effect of diluting the low flows of the river by discharge from a dam.

(2) Effects

The predicted BOD concentrations along the Choqueyapu river for above cases are summarized in Table 5.3.6.

TABLE 5.3.6 COMPARISON OF THE WATER QUALITY IMPROVEMENT EFFECTS BY VARIOUS MEASURES (2010)

(unit: mg/l BOD)

Evaluation Point	Present (1992)	Estimated water Quality in 2010					
		Uncontrolled	Implementation of the Irpavi Option	Implementation of the Lipari Option	Applying Wastewater Discharge Control		Dilution by Dam Water
					Industries over 100 m^3/d	Industries over 25 m^3/d	
R1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
R2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
R3	67.8	70.4	70.4	70.4	54.6	48.8	58.1
R4	151.7	147.6	147.6	147.6	116.1	112.2	135.6
R5	143.0	138.7	138.7	138.7	119.0	116.2	130.8
R9	107.1	106.7	8.5	8.5	95.9	93.9	115.6
R14	71.1	87.7	26.1	49.2	81.4	80.1	85.1
R15	54.3	72.1	23.1	46.4	67.3	66.3	70.3

The effects of the Irpavi option and the Lipari option are presented in Fig.5.3.1 in comparison with the present water quality and the uncontrolled water quality in 2010. The effect of the Irpavi option for the lower reach is more profound than that of the Lipari option. The BOD values at Lipari Bridge (R15) in 2010 are 23 mg/l in the Irpavi option, 49 mg/l in the Lipari option, and 68 mg/l in the uncontrolled case. The results indicate that the water quality target would be achieved at the Lipari bridge by either option for the basic plan. At Calacoto (R9), another evaluation point of the water quality target, its BOD is estimated at 8.5 mg/l in both options. This is because in both cases the entire dry-season flows of the Choqueyapu and Kantutani Rivers and all wastewater in the Orkojahuira basin would be diverted through the pipeline to the wastewater treatment plant. Therefore, although there would be only a little water in the river above the Irpari River confluence during the dry season, the present adverse conditions in this area such as obnoxious odors would be greatly improved.

Fig. 5.3.2 shows the effects of the implementation of the industrial wastewater discharge regulation. As can be seen from the figure, the industrial wastewater discharge control will improve the river water quality, but it is not sufficient to achieve the water quality target. A difference in the effect between two cases, 100 m^3/day and 25 m^3/day, is negligible, indicating that the improvement can be achieved effectively by controlling only the large scale industries.

Fig. 5.3.3 shows the effect of dilution water from a dam being discussed to construct in the upstream of the Choqueyapu river. Having no reliable information, the yield of the dam was assumed to be 0.2 m^3/sec, which is less than 10 % and 5 % of the low flow rate at R9 and R15, respectively. Since the dilution rate is small, the expected effect is negligible.

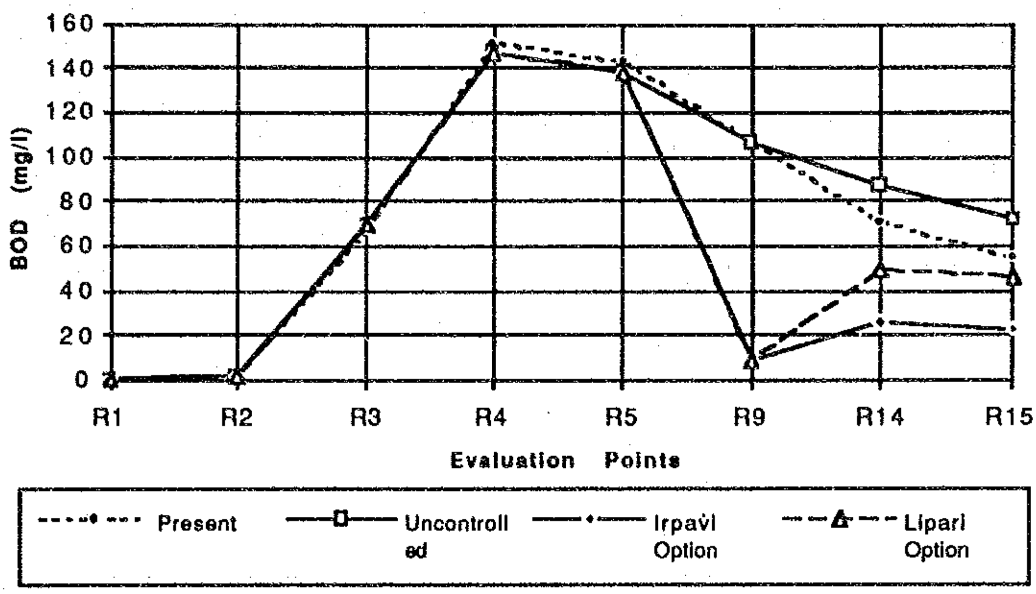


Fig. 5.3.1 EFFECTS OF STRUCTURAL MEASURES FOR BASIC PLAN (YEAR 2010)

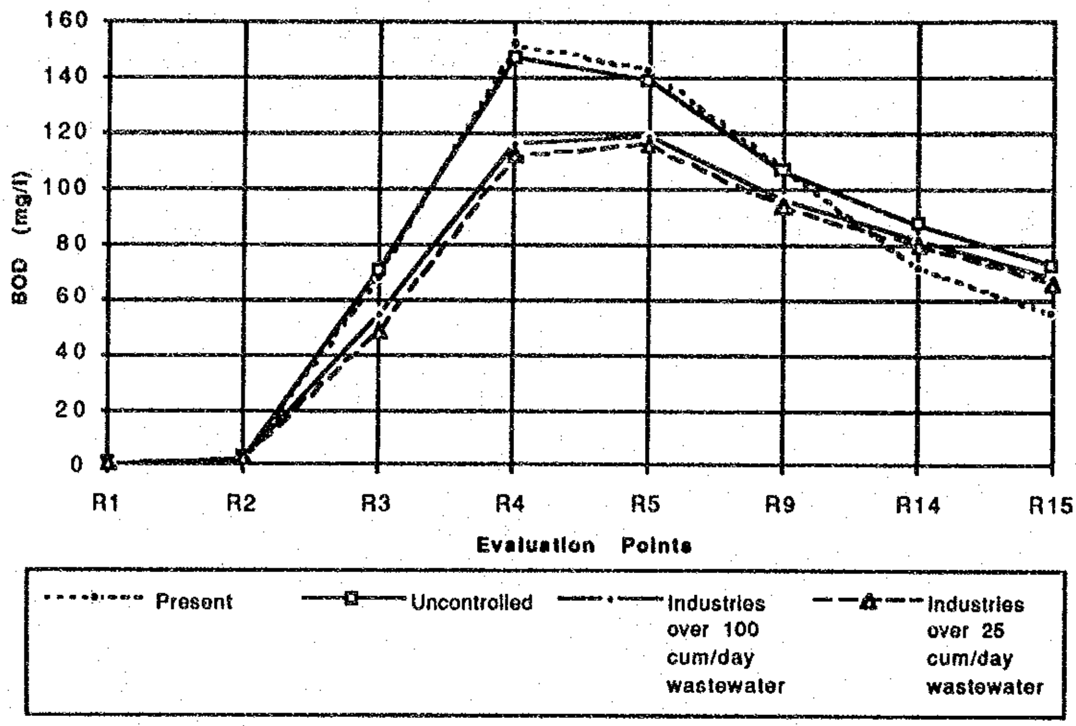


Fig. 5.3.2 EFFECTS OF INDUSTRIAL WASTEWATER CONTROL

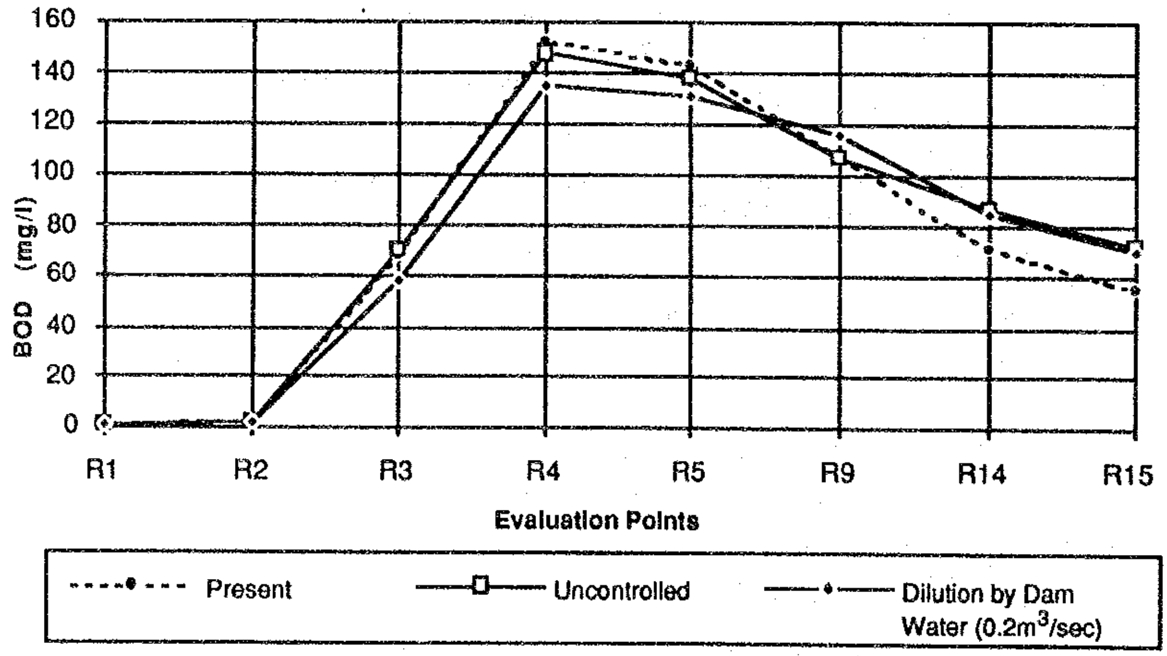


Fig. 5.3.3 EFFECTS OF DILUTION BY DAM WATER

5.3.4 Social and Environmental Impacts

Implementation of any of the basic plan alternatives will bring about various social and environmental impacts. Potential impacts are qualitatively analyzed for each of the four alternatives in the form of a checklist as shown in Tables 5.3.7. Explanations on the checklist are given below.

(1) Social Environment

1) Transportation/Public Facility

During the construction period of the main sewer interceptor and other sewer interceptors that are generally installed under the existing roads, there will be certain inconveniences in road traffic conditions, although they will be temporary. This impact will be greater in the three Lipari alternatives (2A, 2B and 2C) than in the Irpavi alternative (1), since the length of the interceptor in the roads is longer in the Lipari alternatives.

The Irpavi site is presently designated for the development of an educational complex. There is also a construction plan for a peripheral road passing through the site along the Irpavi river. Therefore, locating the treatment plant at this site would have a significant impact.

2) Agriculture/Water Use

All four alternatives would have a significant positive impact on the irrigation use of the Choqueyapu river water in the downstream farmlands.

However, the three Lipari alternatives require the farmland(s) around Lipari to be taken for the treatment plant site. This impact on agriculture is greater in the alternative 2C (aerated lagoon) since the required area is larger than that in the alternatives 2A (activated sludge) and 2B (trickling filter).

3) Public Health/Sanitation

All four alternatives will contribute to improve significantly the sanitation conditions around the lower section of the Choqueyapu River and the urban sections of the other main tributaries.

TABLE 5.3.7 CHECKLIST FOR SOCIAL/ENVIRONMENTAL IMPACT

Alternative 1 : Irpavi - High-rate Activated Sludge
Alternative 2A : Lipari - Conventional Activated Sludge
Alternative 2B : Lipari - Trickling Filter
Alternative 2C : Lipari - Aerated Lagoon

Activities that may have impact on the environment	During construction				During facility operation											
	Construction activities				Occupation of spaces				Facility operation							
Negative or Positive impact	Negative				Negative				Positive				Negative			
Alternative No.	1	2A	2B	2C	1	2A	2B	2C	1	2A	2B	2C	1	2A	2B	2C
Social Environment																
1. Transportation/public facility	x	xx	xx	xx	xxx	–	–	–	–	–	–	–	–	–	–	–
2. Agriculture/water use	–	–	–	–	–	x	x	xx	xxx	xxx	xxx	xxx	–	–	–	–
3. Public health/sanitation	–	–	–	–	–	–	–	–	xxx	xxx	xxx	xxx	–	–	–	–
4. Solid waste	–	–	–	–	–	–	–	–	–	–	–	–	xx	xx	xx	xx
Natural Environment																
1. Stream flow	–	–	–	–	x	xx	xx	xx	–	–	–	–	–	–	–	–
2. Plants/animals	–	–	–	–	–	x	x	xx	–	–	–	–	–	–	–	–
3. Landscape	–	–	–	–	xx	x	x	x	–	–	–	–	–	–	–	–
Pollution																
1. Water pollution	–	–	–	–	–	–	–	–	xxx	xxx	xxx	xxx	–	–	–	–
2. Noise/vibration	x	x	x	x	–	–	–	–	–	–	–	–	–	–	–	–
3. Odors	–	–	–	–	–	–	–	–	xxx	xxx	xxx	xxx	xx	–	–	–

Note: xxx : Significant impact xx : Some extent of impact x : Small impact
– : No impact

4) Solid Waste

New solid waste in the form of sewage sludge will be generated through operation of wastewater treatment facilities in all four alternatives. This sludge must be disposed of at a certain place, or places to be determined.

(2) Natural Environment

1) Stream Flow

The water intake facilities in the Choqueyapu river in all four alternatives may be a potential obstacle to the smooth flow of the river at times of flood.

In addition, the three Lipari alternatives include the section of the main sewer interceptor under the river bed for several kilometers and reductions of the river sections at the plant site(s). These reduced sections may also be potential obstacles to flood flows.

These structures must be given adequate attention and maintained properly so as not to present undo obstacles.

2) Plants/Animals

The three Lipari alternatives transform the green area(s), i.e., the farmland(s) into treatment plant areas by abolishing trees, thereby making the area(s) less favorable to wild life such as birds. The impact is greater in the alternative 2C since it requires a larger area.

3) Landscape

The presence of the treatment plant will constitute a rather negative component to the landscape. This negative impact would be greater in the Irpavi alternative since the area in the vicinity of the site is much more populated than the area around Lipari.

(3) Pollution

1) Water Pollution

All four alternatives are themselves aimed at the mitigation of river water pollution. There will be a significant degree of improvement.

2) Noise/Vibration

A certain degree of noise and vibration would be caused during the construction period in all four alternatives. However, these would be temporary phenomena.

3) Odors

All four alternatives will contribute significantly to reduce obnoxious odors presently experienced along the rivers particularly in the South zone of the City.

However, in the Irpavi alternative, handling of the sludge generated in the treatment plant would present some odor problems to the many inhabitants near the sedimentation basins and sludge storage basins.

5.3.5 Economic Evaluation

(1) Economic Costs

The economic costs of alternatives were converted from financial estimates applying the conversion factor of 0.9. The costs of land and right-of ways were eliminated in economic costs. The economic costs were calculated as follows:

(US$ million, 1992 Prices)

Cost	Alternatives			
	1	2A	2B	2C
Construction Cost	66.52	71.15	66.33	36.62
Annual O&M Cost	4.50	4.50	2.25	3.15

(2) Economic Benefits

A questionnaire survey (poll) was carried out during this study to know how much the people of the study area are willing to pay for receiving direct services from sewerage facilities. This willingness to pay for services is considered to reflect their desire regarding environmental living conditions. It also is a convincing factor to convert their desire to monetary terms. The number of samples reached 976 households broken down into 898 general residents and 78 apartment residents.

As a result, the economic benefit of the basic plan was estimated: US$1,718 thousand in 1992, US$2,135 thousand in 2000 and US$2,629 thousand in 2010. These benefits show the matured benefits, i.e., the benefits to be expected from the complete facilities. Thus, until the completion of the works, only the partial benefit could be expected.

(3) Economic Evaluation

The economic evaluation for respective alternatives were examined in economic feasibility by means of the Net Present Value (NPV), Benefit-Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR). As indicated earlier, however, the quantifiable economic benefits in the future were determined to be quite small as compared with the costs. For instance, even in 2010 the matured benefit was estimated at US$2.63 million per year. This value does not cover even the O&M costs of respective alternative plans except for Alternative 2B. However, the construction cost of Alternative 2B was much larger than that of Alternative 2C.

From the economic point of view, Alternative 2C is the most economical scheme among the alternatives. The NPV discounted at 10% was a negative US$29.4 million and B/C was 0.32. EIRR was also worked out to be negative. Thus, the basic plan was not said to be viable from the economic point of view. The project should be promoted on the basis of basic human needs and improvement of environmental conditions.

5.3.6 Overall Evaluation and Selection of an Alternative for the Basic Plan

Evaluations of the four alternatives from various aspects described earlier are summarized as shown in Table 5.3.8.

By referring to Table 5.3.8, Alternatives 2B and 2C are considered to be clearly advantageous over the other two. Closer examination should be made to select from these two alternatives, i.e., 2B and 2C.

The most critical factor governing realization of the plan is considered to be the financial capability to cover the initial and the operating costs. Since the financial resources of the City of La Paz and Bolivia are limited, it is of course considered that the lower the costs, the better the alternative.

From the above considerations, Alternative 2C should be chosen as the basic plan for control of water pollution of the rivers in the City of La Paz.

TABLE 5.3.8 SUMMARY OF EVALUATION OF THE BASIC PLAN ALTERNATIVES

Alternative No.	1	2A	2B	2C
Plant Site	Irpavi	Lipari	Lipari	Lipari
Treatment Method	High rate activated sludge	Conventional activated sludge	Trickling filters	Aerated lagoons
Initial Costs	x	x	x	xxx
Operation Costs	x	x	xxx	xx
Site Availability	x	xxx	xxx	xx
Improvement Effect on River Water Quality	xxx	xx	xx	xx
Technological Adaptability	x	x	xx	xxx
Degree of Environmental Impact	x	xxx	xxx	xx
Degree of Social Impact	x	xxx	xxx	xx

Note xxx : favorable (or easy) xx: average x : not favorable (or difficult)

5.4. BASIC PLAN

The basic plan comprises structural and non-structural measures. The structural measures are those included in Alternative 2C which has been selected as described in the previous section. Their details, necessary non-structural measures, effects on water quality improvement, an implementation program, project costs, and financial evaluation for the basic plan are presented hereinafter.

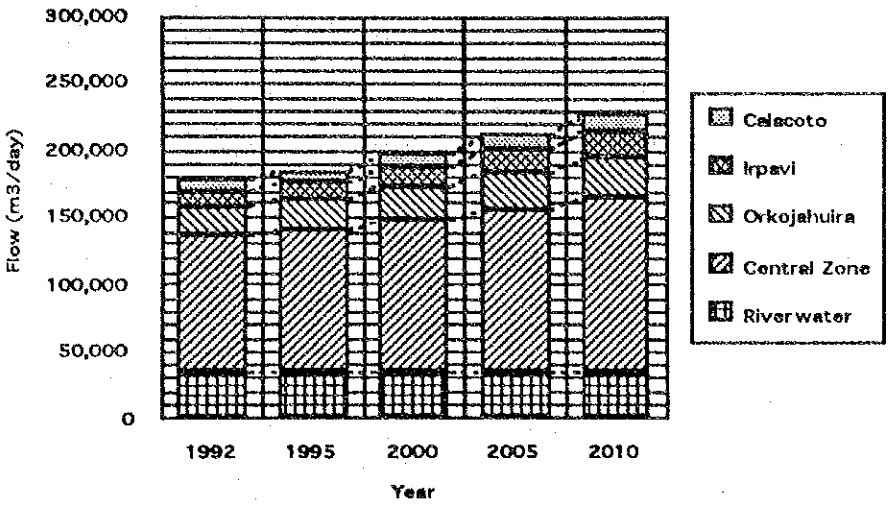
5.4.1 Wastewater Flows

Wastewater flows for the basic plan were calculated as shown in Table 5.4.1 and the subsequent figure.

TABLE 5.4.1 DESIGN WASTEWATER FLOWS FOR THE BASIC PLAN

(m^3/day)

	1992	1995	2000	2005	2010
River water	34,560	34,560	34,560	34,560	34,560
Central Zone	102,609	106,442	113,049	121,359	130,103
Orkojahuira	21,646	23,198	25,920	28,308	30,948
Irpavi	11,223	12,018	13,497	16,622	20,027
Calacoto	8,318	8,667	9,335	10,938	12,728
Total	178,356	184,885	196,361	211,787	228,366



DESIGN WASTEWATER FLOWS BY SEWER COLLECTION ZONES

Note: Not all of these flows would be collected and transmitted to the WWTP until the final stage; see Implementation Program (Table 5.4.3)

5.4.2 Structural Components of the Basic Plan

The structural components of the basic plan are as follows:

- Water intake facilities;	to divert wastewater from the Choqueyapu river to the main sewer interceptor.
- Main Sewer Interceptor;	to transmit wastewater to the Wastewater Treatment Plant.
- Sewer Interceptors;	to collect wastewater from the existing sewer collection systems and transmit them to the Main Sewer Interceptor.
- Wastewater Treatment Plant;	to treat collected wastewater by the aerated lagoon system.

The layout of these facilities is shown in Fig. 5.4.1 and details of preliminary design of each facility are presented in Appendix-D of the Supporting Report. Descriptions of each facility are summarized as follows:

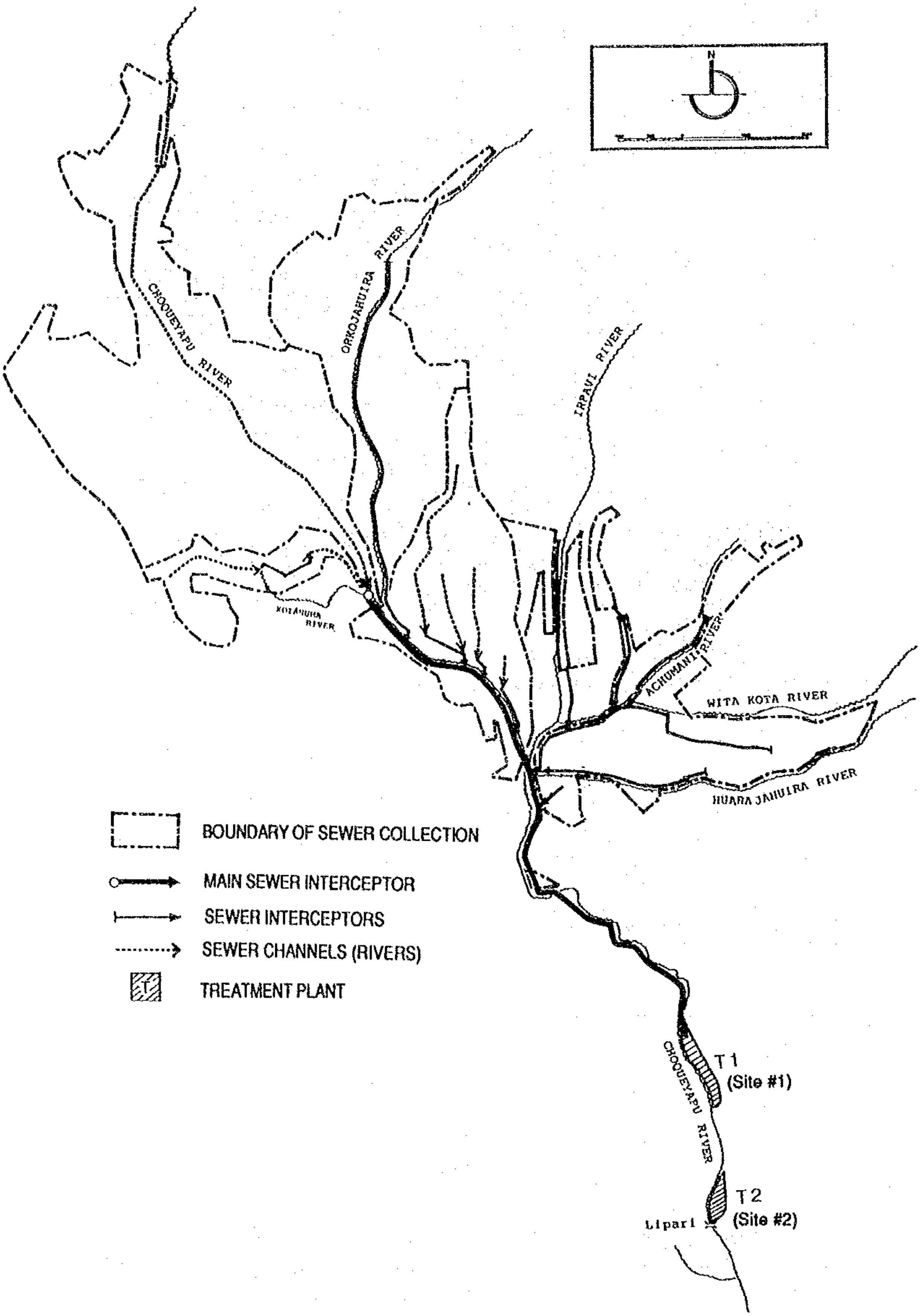


Fig. 5.4.1 GENERAL LOCATION OF THE BASIC PLAN

(1) Water intake facilities

Water intake facilities are to be installed in the Choqueyapu river upstream of the confluence with the Orkojahuira river to collect the wastewater from the central area, where separate collection of sewage by installing sewer interceptors is considered to be difficult.

The Choqueyapu river at the water intake facilities would consist of the wastewater from the central area and river water from upstream. It is proposed to install a water intake weir and sluice gate to divert a fixed amount of water to avoid excess increase of wastewater to the treatment plant in the rainy season.

(2) Main sewer interceptor

The proposed route of the main sewer interceptor is shown in Fig. 5.4.2. The size of the interceptor has tentatively been determined to be 2000 x 2000 mm, based on the provisionally prepared longitudinal profile of the route shown in Fig. 5.4.3 and the design daily maximum wastewater flow, 347,700m^3/day.

The route of the interceptor is divided into the following sections:

Along main roads (with asphalt pavement)	3630 m
Along secondary roads (with stone pavement)	1260 m
Passing through populated areas	485 m
Tunnel	260 m
In river bed (including gabion protection)	4215 m

The proposed cross sections of the interceptor and the proposed tunnel are shown in Figures 5.4.4 to 5.4.6.

(3) Wastewater treatment plant

Site preparation:	Filling river bed and cultivated areas, Site #1 (20 ha) and Site #2 (12 ha)	
Preliminary treatment:	Bar screens,	Bar size; 1 x 5cm Spacing; 5 cm Slope; 45 ° from vertical Velocity ; 0.5 - 0.9 m/sec Cleaning; Manual
	Grit Chambers,	Detention time; 0.8 - 1.0 minutes Water depth; 0.7 - 1.0 m Length; 18.0 m Horiz. Velocity; 0.31 - 0.37 m/s
	Flow measuring,	Parshall Flumes

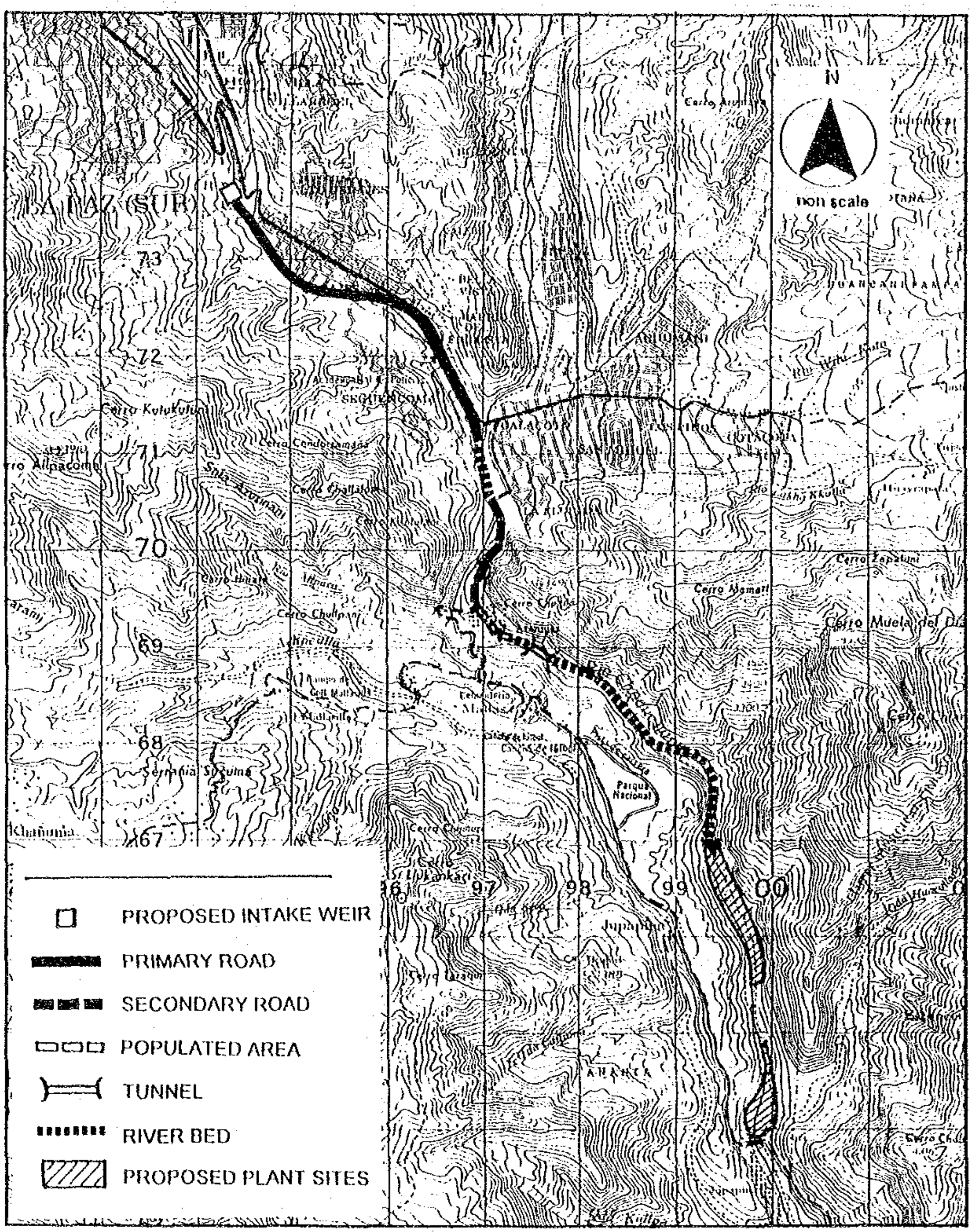


Fig. 5.4.2 ROUTE OF MAIN SEWER INTERCEPTOR

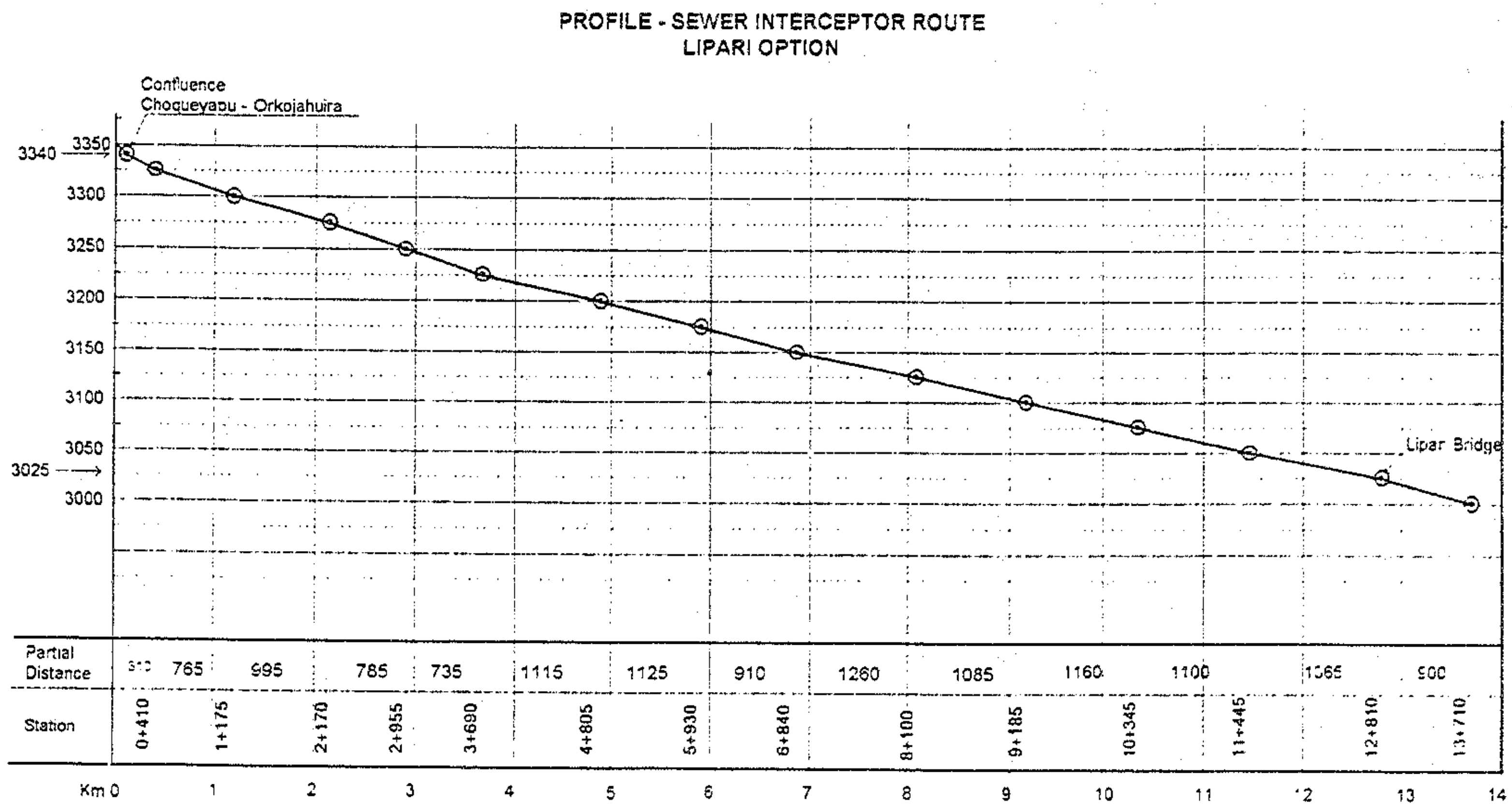


Fig. 5.4.3 Longitudinal Profile of Main Sewer Interceptor (Provisional)

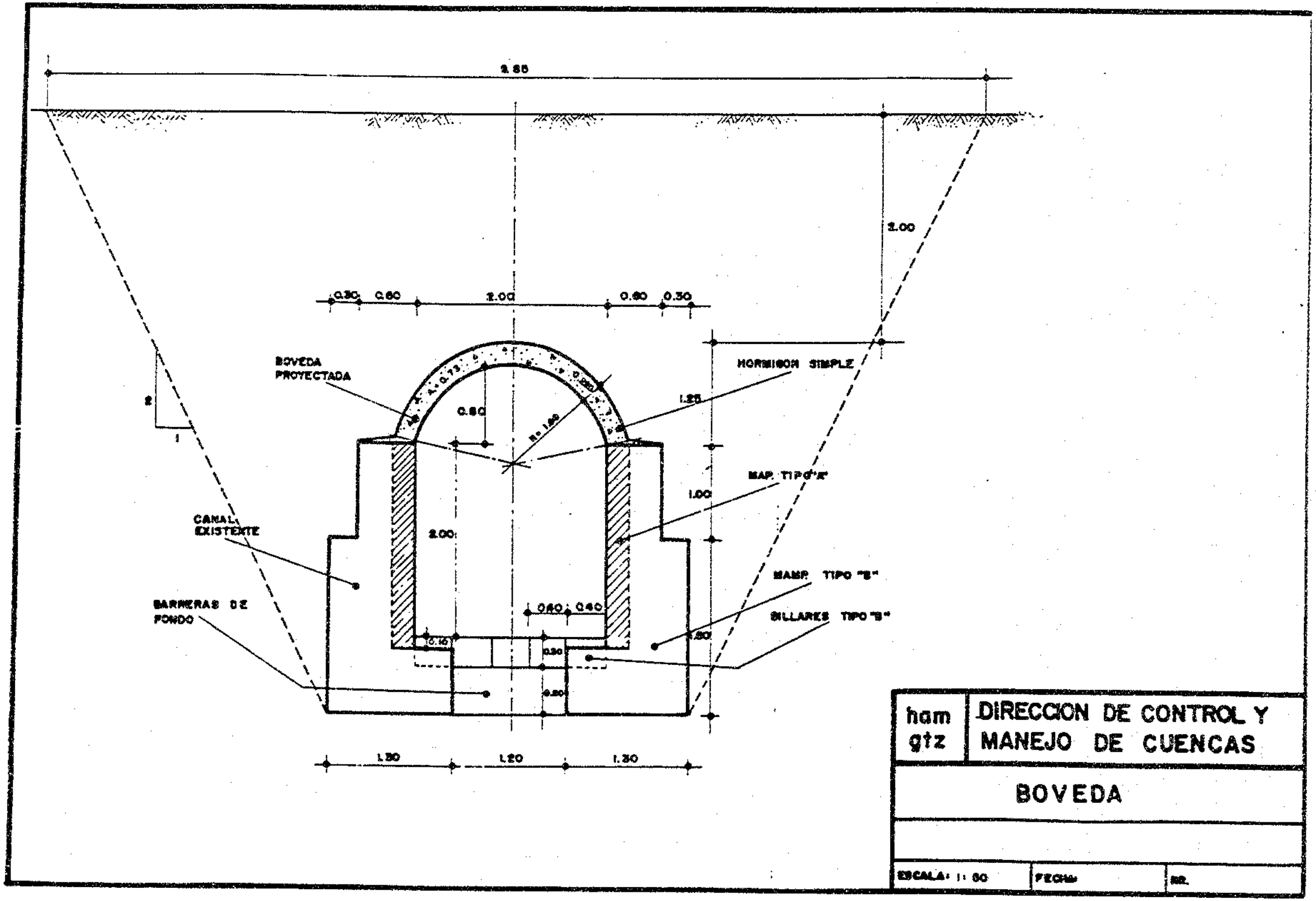


Fig 5.4.4 Typical Cross Section of Main Sewer Interceptor (Roads Section)

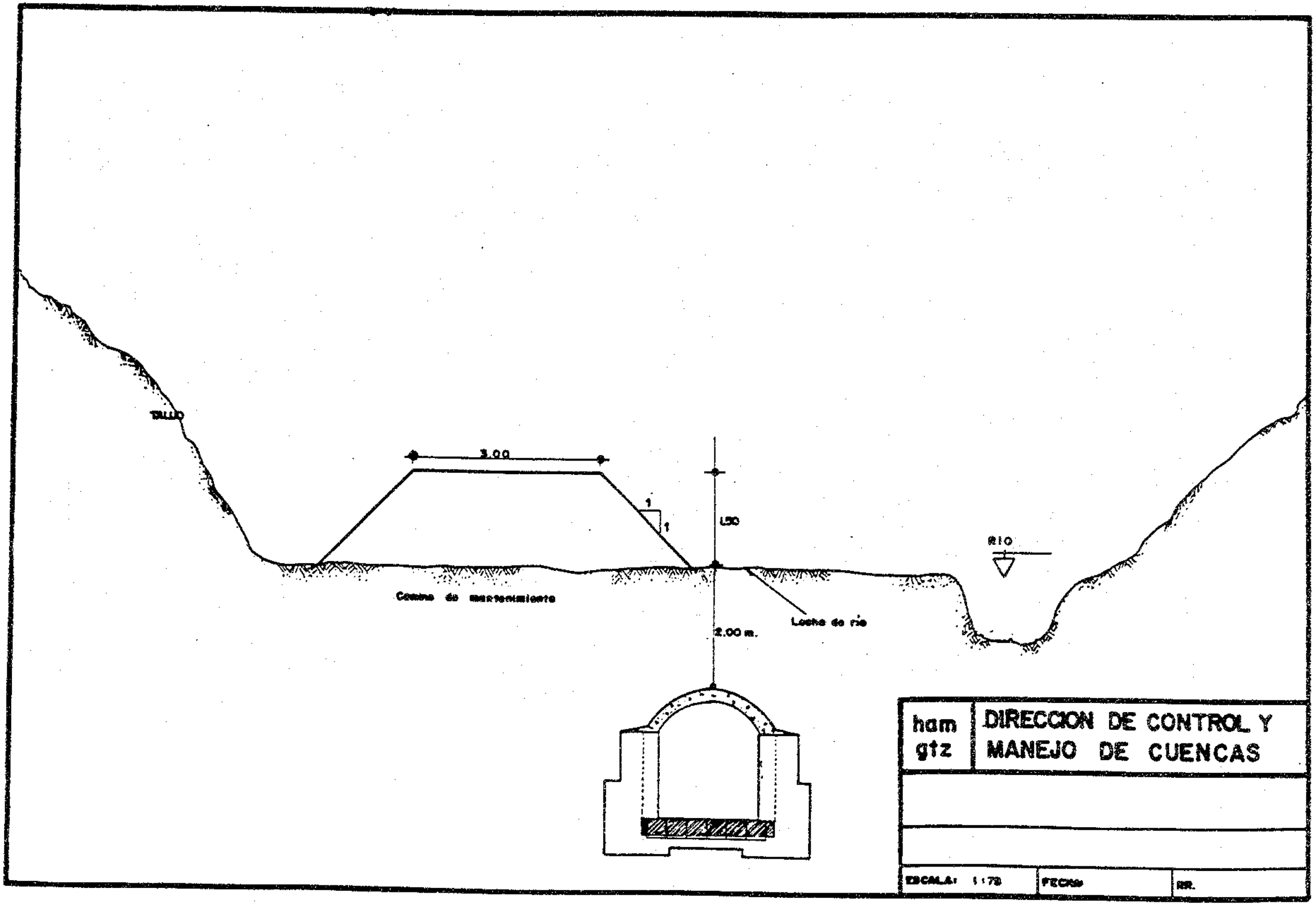


Fig 5.4.5 Typical Cross Section of Main Sewer Interceptor
(River Bed Section)

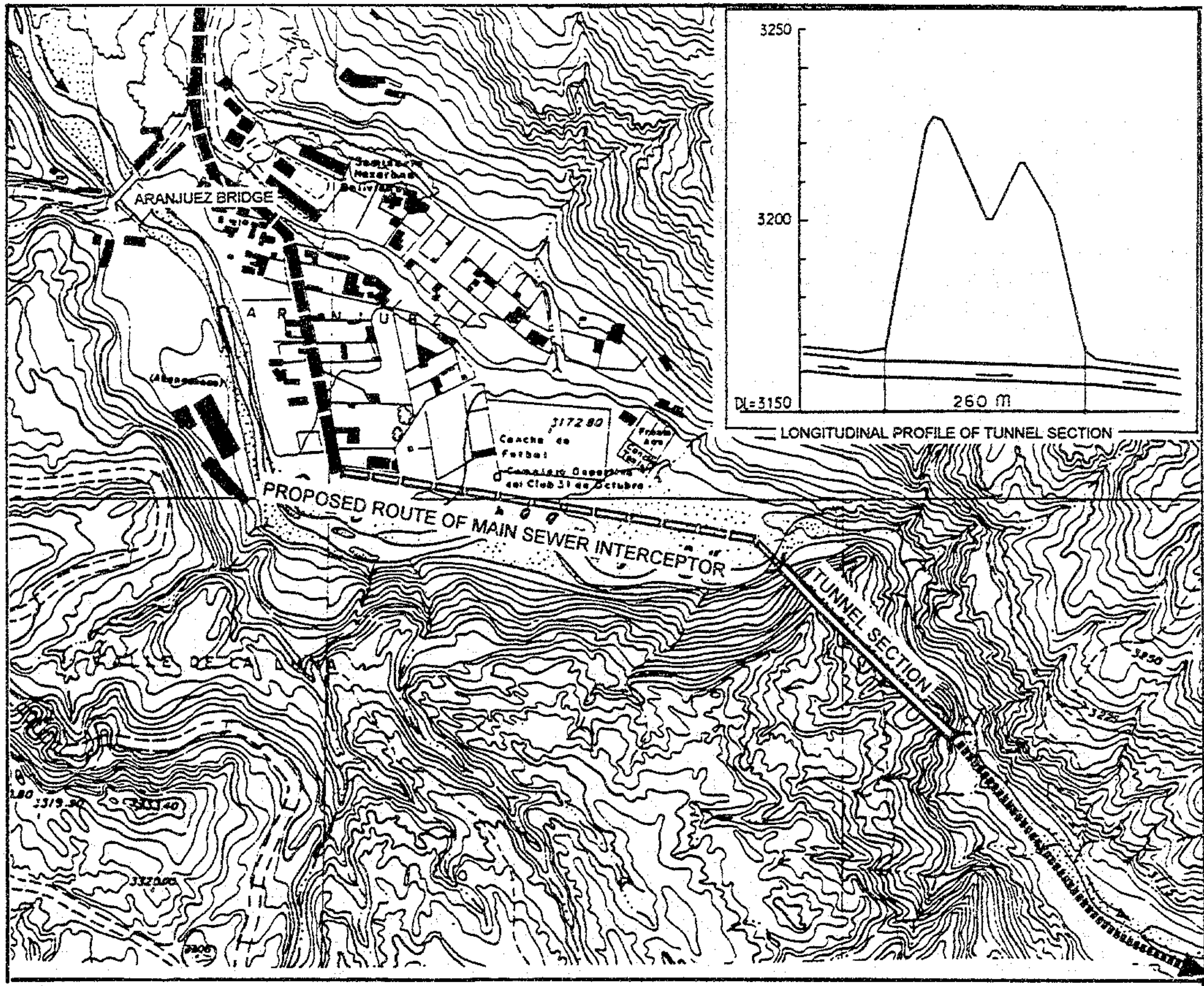


Fig. 5.4.6 Plan and Longitudinal Profile of the Proposed Tunnel for Main Sewer Interceptor

Aerated lagoons:	Type,	Completely mixed by mechanical means
	Volume,	690,000 m3
	Surface Area,	16 ha
	Max. Depth,	6.0 m
	Detention time,	3 days
Solids separation basins:	Surface area,	11.5 ha
	Max. Depth,	6.00 m
	Overflow rate,	2 m/day
	Sludge storage,	4 years

5.4.3 Non-structural Measures for the Basic Plam

Implementation of the proposed structural measures for the Basic Plan must be supported by appropriate institutional provisions (non-structural measures). The following measures are particularly important:

a) Reinforcement of existing industrial effluent quality standards

b) Monitoring of industrial effluent discharges and enforcement of the effluent quality standards

c) Monitoring of river water quality

d) Control of solid wastes disposal into the rivers

e) Control of errosion and disorderly extraction of sand and gravel from the river beds

f) Reinforcement of organizations in charge of above tasks and development, operation and management of sewerage works

(1) Reinforcement of Industrial Effluent Quality Standards

"The Regulation on Discharge of Industrial Wastes into Waterbodies" in Bolivia sets forth the effluent water quality standards as discussed in Section 2.3.2, and they apply nation-wide. Enforcement of the regulation will undoubtedly contribute to the mitigation of water pollution in Bolivia. However, to implement the proposed sewerage development plan, the Bolivian

national standards should be reinforced and partly modified by taking into consideration the particular situations in the City of La Paz. It is proposed that the maximum permissible values of BOD of effluents be modified depending on the location or the source of discharge. The proposed limits are shown in Table 5.4.2.

In newly developing areas, each community or each discharger must have its own treatment facility to meet above requirement.

TABLE 5.4.2 PROPOSED LIMITS FOR EFFLUENT BOD

Area	BOD (mg/l)
Choqueyapu river basin in the Central Zone of the City above the water intake point	300
Other areas where wastewater is discharged into sewer lines connected to a treatment plant	300
Newly developing area (*)	50
Other wastewater including treatment plant effluents	50

(*) : Includes domestic and industrial wastewater. Wastewater treatment to be required either as a community or independently.

(2) Monitoring of Effluent Water and Enforcement of the Quality Standards

The Bolivian wastewater discharge regulation stipulates procedures for enforcement of the effluent water quality standards. However, to ensure industries' compliance with the standards, some reinforcement and clarification concerning the present discharge regulation would be necessary. The following provisions are recommended:

1. Factories should be under obligation to periodically submit monitoring data on quality and quantity of wastewater discharge rather than to submit them on the request of the appropriate entity (SAMAPA).

2. The appropriate entity should be given the power to conduct spot inspections of wastewater treatment and discharge facilities in the factories without prior notice.

3. The regulation should be strictly enforced for factories discharging large amount of wastewater, e.g., over 750 m3/month.

(3) Monitoring of River Water Quality

The general purposes of environmental water quality monitoring are:

a) To judge the suitability of a waterbody for a desired use by contrasting measured quality against applicable environmental quality standards

b) To obtain basic data for planning pollution control measures necessary to achieve the water quality standards or specific target quality

c) To ascertain the degree of achievement of environmental water quality standards corresponding to the progress of implementing pollution control measures

d) To obtain an indication of the state of compliance of wastewater dischargers with discharge regulations

It is recommended that the City of La Paz establish its own monitoring program to attain all of above purposes. The following program is proposed.

1) Monitoring Station

Fixed monitoring stations should be set up along the Choqueyapu River and its major tributaries. The following points selected from those set up in this Study are proposed:

Choqueyapu River

R2 Achachicala
R4 Ave. Ejercito
R9 Calacoto
R14 Aranjuez bridge
R15 Lipari bridge

Tributaries

R6 Kotauma (downstream end)
R8 Orkojahuira (downstream end)
R11 Irpavi (downstream end)
R12 Achumani (downstream end)

2) Monitoring Items and Frequency

Item	Frequency
pH, DO, BOD, SS, coliform bacteria, flow rate	Once per month; 12 times per year
As, Cr(VI), Hg	Once each in dry season and wet season at selected stations

Note: Other items specified in the environmental quality standards can be included in the future.

(4) Control of Solid Waste Disposal Into Rivers

Owing to various efforts of the municipal authority, a significant improvement has been made in collection and disposal of domestic solid wastes.

On the other hand, industrial solid wastes have not been controlled adequately. Construction wastes are still often dumped into the rivers. These wastes not only disturb the flow of the rivers and urban aesthetics but also aggravate the high level of suspended solids (SS) concentration in the rivers. Therefore, dumping of industrial solid wastes into rivers should be strictly controlled from the view points of stream flow protection, urban sanitation, and water quality management. It is recommended that strong administrative measures be taken to stop the dumping of industrial solid wastes.

(5) Control of Erosion and Extraction of Sand and Gravel in the Rivers

Levels of suspended solids (SS) are particularly high in the Orkojahuira river and the Kotauma river; the observed SS concentrations ranged from 750 to 1,640 mg/l in the Kotauma river, and from 2,440 to 6,570 mg/l in the Orkojahuira river at their downstream ends. Because of the inflows from these two tributaries, the SS concentration of the Choqueyapu River increases sharply from approximately 300 mg/l (at R5) to a range of 650 - 1,100 mg/l (at R9).

Major causes of the high concentration of SS in these tributaries are considered to be as follows:

1) Fragile soil formation of the basin so as to be eroded easily by natural forces

2) Disorderly extraction of sand and gravel from the river beds

3) Disturbance of the river beds by placer mining activities

Among the above causes, soil erosion is considered to be the greatest, and therefore, appropriate measures for its control should be considered and implemented.

Human activities within the river basins such as items 2) and 3) above should be properly regulated.

(6) Organizational Reinforcement

1) Administrative Organs

The major executing organizations of the structural and non-structural measures proposed in the Basic Plan will be the Municipality of La Paz (HAM-LP) and SAMAPA . Their respective responsibilities and desirable organizational improvements are discussed below.

HAM-LP

HAM-LP's responsibility concerning implementaion of the Basic Plan should cover the following tasks:

a) Preparation of appropriate local rules, regulations and standards concerning water pollution control in coordination with MAU including reinforcement of the effluent quality standards and designation of waterbodies to specific classes of the existing environmental water quality standards

b) Water quality monitoring of the rivers

c) Solid wastes management

d) River basin management works including errosion control and regulation of human activities within the river banks

The bureau of Control and Management of Watershed and Environment (DICOMAC) within HAM-LP should assume the above tasks except solid waste management which is the responsibility of the Bureau of Urban Sanitation (DSU). It is recommended that DICOMAC reinforce staff capacity in the area of water quality protection.

SAMAPA

SAMAPA's tasks concerning implementation of the Basic Plan includes the following:

a) Sewerage development, operation and management

b) Enforcement of the industrial wastewater discharge regulations

SAMAPA has four management units under the general manager, i.e., Management of Engineering and Projects (GIP), Management of Operation and

Maintenance (GOM), Management of Administration and Finance, and Sales Management. Development of sewerage is a responsibility of GIP, and operations and maintenance of sewerage systems are a responsibility of GOM.

Since this organization is not sufficient to perform above-mentioned tasks, the following reinforcements are proposed:

i) To create a Department of Sewerage Development (DSD) within GIP: DSD would have two divisions, i.e., a division in charge of sewerage planning and design, and a division in charge of sewerage construction.

ii) To create a Department of Operations and Maintenance of Sewerage (DOMS) within GOM: DOMS would have two divisions, i.e., a division dealing with operations and maintenance of sewer lines, and a division dealing with operations and maintenance of treatment facilities.

iii) To create a division in charge of enforcement of the industrial wastewater discharge regulation.

2) Water Quality Laboratories

The industrial wastewater discharge regulation requires that sampling and analysis of effluent wastewater be entrusted by factories to MAU-authorized laboratories. Therefore, it is proposed that sampling and analysis of river water in the monitoring program of HAM-LP be also entrusted to these authorized laboratories. Accordingly, the availability of laboratories having sufficient capacity in the analyais of wastewater and natural water is very important.

In La Paz, the laboratory of Institute of Sanitary Engineering (IIS) in University of San Andres (UMSA) has been the most experienced in this field. Moreover, most of the analytical equipment brought into La Paz by JICA for this Study were installed in the IIS laboratory, and analyses were conducted by a member of the JICA Study Team in cooperation with the members of the IIS laboratory. Accordingly, IIS's capability in water quality analysis has been further improved.

For the moment, the IIS laboratory is considered to be only the laboratory eligible for the MAU's authorization. It is desirable, however, that there be more than one eligible laboratory, since the demand for water quality analysis should increase as the discharge regulation is enforced and the river water quality monitoring program is implemented. In this context, the IIS laboratory may better function as a center for fostering laboratory engineers and analytical specialists.

5.4.4 Water Quality Improvement

Fig. 5.4.7 shows the overall effect in the year 2010 of the pollution control measures proposed in the Basic Plan in terms of the BOD during low flow conditions. The proposed measures are:

1) Sewerage development (Lipari option)
2) Wastewater effluent control of the industries discharging over 100 m^3/day of wastewater, with an effluent BOD limit of 300 mg/l
3) Wastewater effluent control of newly developed area with an effluent BOD limit of 50 mg/l

The overall effect of above measures is shown to be significant.

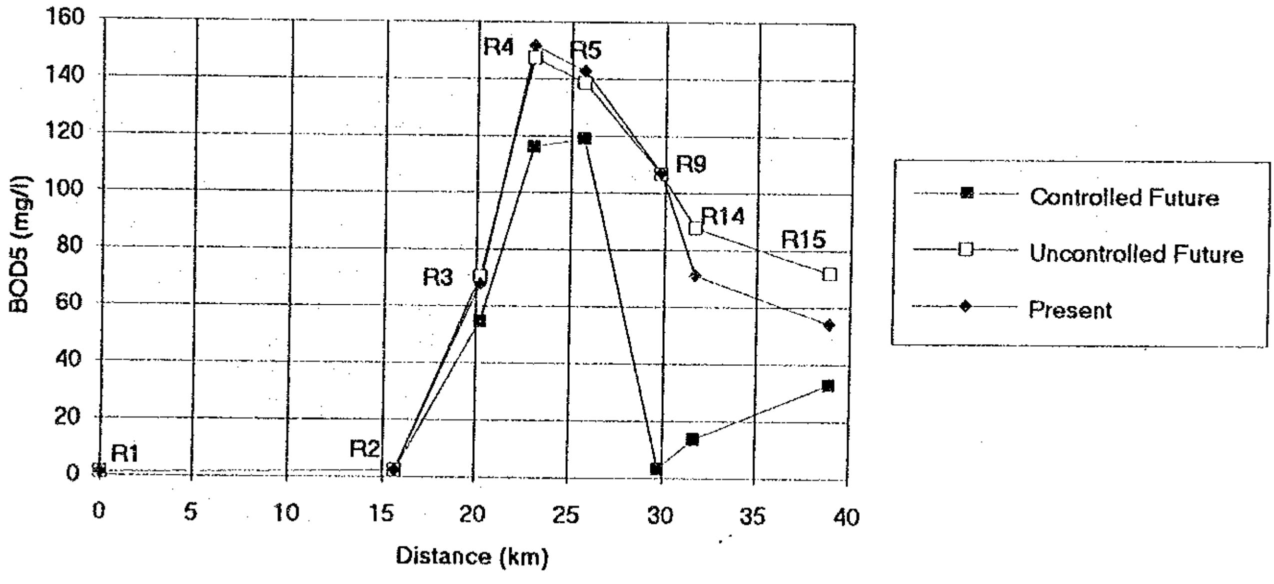


Fig. 5.4.7 Overall Effect of the Basic Plan

5.4.5 Implementation Program

The purpose of the proposed basic plan is to achieve the goals of water quality improvement by the year 2010. Judging from a comparison between the required project costs and budget expenditures relating to the sewerage sector of the central government or SAMAPA, as mentioned in a later section, it is proposed to phase the project so that annual investments during a project period could be as small as practicable. It is also required to phase the project so that benefits of the project could be gained in proportion to the investments.

The implementation program shown in Table 5.4.3 was prepared considering the above requirements.

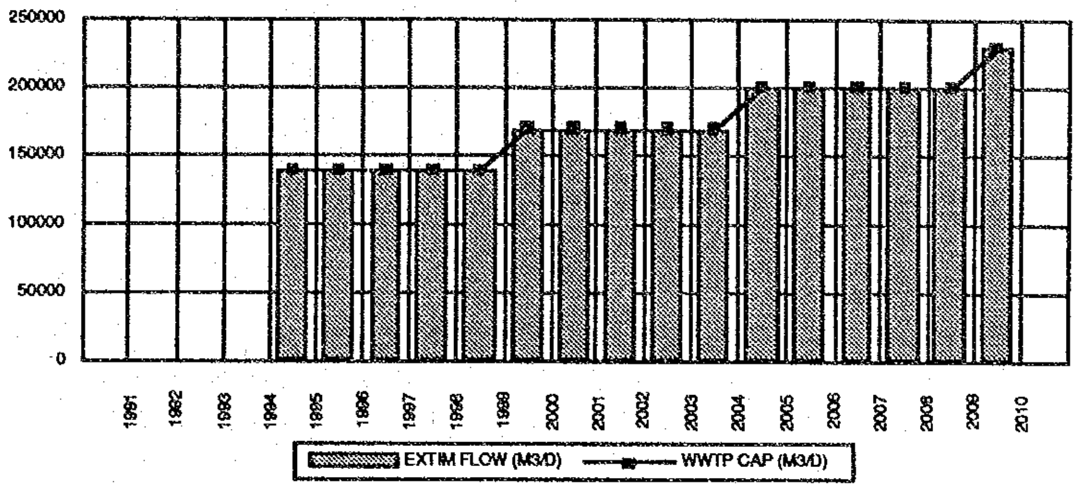
While it is desirable to phase the project in similar stages as mentioned above, major project facility construction is concentrated in the first phase of the proposed project. The reason is that priority should be given to the treatment of wastewater from the central area which is presently the major cause of pollution. Any projects not including some treatment of the wastewater would not contribute significantly to the improvement of the present pollution.

The wastewater treatment capacity and the design wastewater flows for the proposed implementation program are shown in the subsequent figure.

TABLE 5.4.3 IMPLEMENTATION PROGRAM

Implementation Period	Phase	Served areas	Treatment Capacity (m3/d)	Facilities to be Constructed
1993-1995	Phase 1	Central area	140,000 (partial mixed aerated lagoons)	Intake facilities. Main sewer interceptor Site preparation - 20 Ha (site #1) Operations/other misc. buildings Aerated lagoons (12 Ha) Sedimentation basins (4 Ha)
1996-2000	Phase 2	Orkojahuira basin	170,000	Conversion of 4 Ha of sed. basins to aerated lagoons Conversion of 12 partially aerated lagoons to completely mixed lagoons Add aeration equipment Site preparation - 12 Ha (site #2) Sedimentation basins (11.5 Ha) Sewer interceptor for Orkojahuira basin
2001-2005	Phase 3	Irpavi basin	200,000	Add aeration equipment Sewer interceptor for Irpavi basin
2006-2010	Phase 4	Calacoto, etc	230,000	Sewer interceptor for Calacoto area

FLOW VS WWTP CAPACITY



5.4.6 Project Costs

The project costs for the proposed basic plan were estimated at US$33.32 million, and its breakdown by phase based on the proposed implementation program is shown in Table 5.4.4. In consideration of the phased construction, the required size of the WWTP site was reviewed and reduced to 32 ha from 40 ha, which was estimated in comparison of the Alternatives (Section 5.3.1), resulting in reducing the total construction costs.

TABLE 5.4.4 ESTIMATED PROJECT COSTS FOR EACH PHASE (1992 PRICES)

Phase	Major construction works*	Project costs (million US$)	Costs for each phase (million US$)
1	Water intake facilities	1.15	23.83
	Main sewer interceptor	9.06	
	Wastewater treatment plant (Site #1)	13.62	
2	Sewer interceptor (Orkojakuira basin)	1.92	8.19
	Wastewater treatment plant (expansion to #2)	6.27	
3	Sewer interceptor (Irpavi basin)	0.15	0.15
4	Sewer interceptor (Calacoto area)	1.15	1.15
Total			33.32

5.4.7 Financial Evaluation

(1) Cost Recovery and Sewerage Service Charges

The construction costs of the proposed project is US$33.3 million in total. The estimates for each stage is shown in Table 5.4.5. The capital investment ceiling amounts projected by the study team for respective entities are also shown in the same table, in comparison with the requirement of construction costs.

According to the table, the total ceiling of SAMAPA during the same period, i.e., 1993 to 2010, was estimated at US$45.29 million. The project cost is 74% of the total ceiling. The entire amount of the ceiling was not always available for the proposed project only. Thus, the project could not be implemented without procurement of fund from external financial organizations. In this report, the total amount assumed to be procured was as follows: 60% of the total by foreign loan and 40% by the local budget. The total amount procured by loans would be US$20.0 million and the local portion would be US$13.3 million.

The total cost is equivalent to 7% of the national investment ceiling for sewerage systems in the country. In the past, the share of SAMAPA to the national total was about 4.5%. Thus, if the entire capital investment for the project is covered by the national finance, the central government would be obliged to make a considerable policy change in terms of environment issues for implementation of the proposed project.

TABLE 5.4.5 CAPITAL INVESTMENT BY PHASE AND INVESTMENT CEILING BY ENTITY

(Unit: US$ Million)

Implementation Schedule	Project Cost	SAMAPA		Central Government	
		Investment Ceiling (*)	Ratio of Project Cost to Ceiling	Investment Ceiling (*)	Ratio of Project Cost to Ceiling
1. Phase 1 (1993-1995)	23.83	4.99	477%	55.35	43%
Priority Project					
Treatment capacity: 140,000 cu.m./day					
Partial mixed aerated lagoon					
Served area: Central area					
2. Phase 2 (1996-2000)	8.19	10.33	79%	114.53	7%
Treatment capacity: 170,000 cu.m./day					
Served area: Orkojahuira basin					
3. Phase 3 (2001-2005)	0.15	13.29	1%	147.38	0.1%
Treatment capacity: 200,000 cu.m./day					
Served area: Irpavi basin					
4. Phase 4 (2006-2010)	1.15	16.69	7%	185.10	0.6%
Treatment capacity: 230,000 cu.m./day					
Served area: Calacoto, etc.					
5. Total	33.32	45.29	74%	502.37	7%

Note: (*) The ceiling amounts for the respective phase periods were estimated by the study team based on the existing data in Bolivia for investment projection.

The total capital cost was annualized by means of a capital recovery factor. The annualized capital cost for the basic plan was calculated as US$3.54 million. Since the O&M cost is estimated at US$2.70 million per annum, the total annual cost, i.e., the annualized capital cost plus O/M cost after completion of the basic plan, is estimated at US$6.24 million.

The total volume of sewage in the project area in the year 2010 was estimated as about 195,000 m^3/day, or 71.0 million m^3/annum. Then, the average unit cost would be estimated at US$6.24 million divided by 71.0 million m^3 or US$0.088/$m^3$.

According to the annual report of SAMAPA in December 1990, the average unit charge of supplied water and sewage treatment was Bs.1.06/m^3, equivalent to US$0.33/$m^3$. According to SAMAPA's financial statements, the sewage charge was said to be 22% of the above charge, so the sewage charge was estimated at US$0.073/$m^3$. The above unit cost was somewhat higher than the present unit charge. Moreover, if this unit cost is recovered by a new tariff, this charge might be newly added to the present unit charge. Accordingly, the required unit charge would be US$0.161/$m^3$, 2.2 times as much as the present charge of US$0.073/$m^3$.

In the case of the "O&M cost recovery policy", the flat sewage service charges are estimated as follows. As mentioned above, the O&M cost for the basic plan is estimated at US$2.70 million per annum. The total volume of sewage in the project area in 2010 was estimated as about 195,000 m^3/day, or 71.0 million m^3/annum. Then, the average unit cost could be estimated as US$2.70 million divided by 71.0 million m^3 or US$0.038/$m^3$. This would require the service charge of US$0.111/$m^3$, an increase by 52% from the present charge of US$0.073/$m^3$.

(2) Procurement of Funds and Reimbursement Schedule

In this section, the following two fund procurement plans are discussed to examine the feasibility of reimbursement by the local budget.

a) Case 1: Procurement of foreign loan only

Total amount is procured as follows: US$20.0 million by foreign loans and US$13.3 million by local funds.

Case 1-A

Terms of loan:

- Repayment period: 15 years after completion of construction
- Grace period: 1 year after completion of construction
- Interest rate: 11% per annum

These terms are almost the same as those of the Choqueyapu River canalization project financed by Inter-American Development Bank (BID).

Case 1-B

Terms of loan:

- Repayment period: 30 years after completion of construction
- Grace period: 10 year after completion of construction
- Interest rate: 3% per annum

These terms are almost the same conditions as financed by Overseas Economic Cooperation Fund of Japan (OECF).

b) Case 2: Procurement of grant plus loan

Under this case, only the capital cost of Phase I is covered by foreign grant. Other capital costs of Phase II to IV would be covered by foreign loans of which terms are the same as those of Case 1-A. Thus, the total amount is procured as follows: US$23.8 million by foreign grant, US$5.7 million by foreign loan and US$3.8 million by local funds.

A payment schedule of Case 1, including both reimbursement and interest payment of foreign loan (60% of the total cost) and procurement of local portion (40% of the total cost), is tabulated in Table 5.4.6 and 5.4.7. As mentioned above, the local portion was assumed to be procured by local governmental funds. The largest investment by local funds for local portion was US$3.42 million in 1994 and 1995. This amount is about 1.9 times of the expected investment (US$1.8 million) for sewerage project by SAMAPA in 1995. Thus, even for the local portion only, SAMAPA could not afford to implement this project without assistance of central or municipal governments.

In Case 1-A, the maximum payment occurs in the third year (1995) from the beginning of construction. Its amount will be US$5.00 million, broken down into US$1.57 million for foreign portion and US$3.42 million for local portion. This amount exceeds the annual investment budget of SAMAPA which is estimated at US$1.8 million in the same year, as mentioned above. Thus, the total payment would be about 2.8 times the investment budget of SAMAPA.

TABLE 5.4.6 REPAYMENT SCHEDULE OF LOANS: CASE 1-A

(Unit: US$ million)

No.	Year	Phase	Foreign Loan Annual Total	Foreign Loan Accumulation by Phase	Repayment of Foreign Loan Portion and Interest Payment Phase 1	Phase 2	Phase 3	Phase 4	Total	Local Portion	Total Payment
1	1993	Phase 1	4.02	4.02	0.44				0.44	2.68	3.13
2	1994		5.14	9.16	1.01				1.01	3.42	4.43
3	1995		5.14	14.30	1.57				1.57	3.42	5.00
4	1996	Phase 2	0.98	0.98	1.57	0.11			1.68	0.66	2.34
5	1997		0.98	1.97	2.59	0.22			2.81	0.66	3.47
6	1998		0.98	2.95	2.48	0.32			2.81	0.66	3.46
7	1999		0.98	3.93	2.37	0.43			2.80	0.66	3.46
8	2000		0.98	4.91	2.26	0.54			2.80	0.66	3.45
9	2001	Phase 3	0.02	0.02	2.14	0.54	0.00		2.69	0.01	2.70
10	2002		0.02	0.04	2.03	0.89	0.00		2.93	0.01	2.94
11	2003		0.02	0.05	1.92	0.85	0.01		2.78	0.01	2.79
12	2004		0.02	0.07	1.81	0.81	0.01		2.63	0.01	2.64
13	2005		0.02	0.09	1.70	0.78	0.01		2.48	0.01	2.49
14	2006	Phase 4	0.14	0.14	1.58	0.74	0.01	0.02	2.35	0.09	2.44
15	2007		0.14	0.28	1.47	0.70	0.02	0.03	2.22	0.09	2.31
16	2008		0.14	0.41	1.36	0.66	0.02	0.05	2.08	0.09	2.17
17	2009		0.14	0.55	1.25	0.62	0.01	0.06	1.94	0.09	2.03
18	2010		0.14	0.69	1.13	0.58	0.01	0.08	1.81	0.09	1.90
19	2011					0.54	0.01	0.08	0.63		0.63
20	2012					0.51	0.01	0.13	0.64		0.64
21	2013					0.47	0.01	0.12	0.60		0.60
22	2014					0.43	0.01	0.11	0.55		0.55
23	2015					0.39	0.01	0.11	0.51		0.51
24	2016						0.01	0.10	0.11		0.11
25	2017						0.01	0.10	0.11		0.11
26	2018						0.01	0.09	0.10		0.10
27	2019						0.01	0.09	0.10		0.10
28	2020						0.01	0.08	0.09		0.09
29	2021							0.08	0.08		0.08
30	2022							0.07	0.07		0.07
31	2023							0.07	0.07		0.07
32	2024							0.06	0.06		0.06
33	2025							0.05	0.05		0.05
Total			19.99		30.69	11.13	0.20	1.56	43.59	13.33	56.91

TABLE 5.4.7 REPAYMENT SCHEDULE OF LOANS: CASE 1-B

(Unit: US$ million)

No.	Year	Phase	Foreign Loan Annual Total	Foreign Loan Accumu-lation by Phase	Repayment of Foreign Loan Portion and Interest Payment Phase 1	Phase 2	Phase 3	Phase 4	Total	Local Portion	Total Payment
1	1993	Phase 1	4.02	4.02	0.12				0.12	2.68	2.80
2	1994		5.14	9.16	0.27				0.27	3.42	3.70
3	1995		5.14	14.30	0.43				0.43	3.42	3.85
4	1996	Phase 2	0.98	0.98	0.43	0.03			0.46	0.66	1.11
5	1997		0.98	1.97	0.43	0.06			0.49	0.66	1.14
6	1998		0.98	2.95	0.43	0.09			0.52	0.66	1.17
7	1999		0.98	3.93	0.43	0.12			0.55	0.66	1.20
8	2000		0.98	4.91	0.43	0.15			0.58	0.66	1.23
9	2001	Phase 3	0.02	0.02	0.43	0.15	0.00		0.58	0.01	0.59
10	2002		0.02	0.04	0.43	0.15	0.00		0.58	0.01	0.59
11	2003		0.02	0.05	0.43	0.15	0.00		0.58	0.01	0.59
12	2004		0.02	0.07	0.43	0.15	0.00		0.58	0.01	0.59
13	2005		0.02	0.09	0.43	0.15	0.00		0.58	0.01	0.59
14	2006	Phase 4	0.14	0.14	1.12	0.15	0.00	0.00	1.28	0.09	1.37
15	2007		0.14	0.28	1.10	0.15	0.00	0.01	1.26	0.09	1.35
16	2008		0.14	0.41	1.08	0.15	0.00	0.01	1.24	0.09	1.33
17	2009		0.14	0.55	1.06	0.15	0.00	0.02	1.22	0.09	1.32
18	2010		0.14	0.69	1.04	0.15	0.00	0.02	1.21	0.09	1.30
19	2011				1.02	0.39	0.00	0.02	1.42		1.42
20	2012				0.99	0.38	0.00	0.02	1.40		1.40
21	2013				0.97	0.37	0.00	0.02	1.37		1.37
22	2014				0.95	0.36	0.00	0.02	1.34		1.34
23	2015				0.93	0.36	0.00	0.02	1.31		1.31
24	2016				0.91	0.35	0.01	0.02	1.28		1.28
25	2017				0.89	0.34	0.01	0.02	1.26		1.26
26	2018				0.87	0.33	0.01	0.02	1.23		1.23
27	2019				0.84	0.33	0.01	0.02	1.20		1.20
28	2020				0.82	0.32	0.01	0.02	1.17		1.17
29	2021				0.80	0.31	0.01	0.05	1.17		1.17
30	2022				0.78	0.30	0.01	0.05	1.14		1.14
31	2023				0.76	0.30	0.01	0.05	1.11		1.11
32	2024				0.74	0.29	0.01	0.05	1.08		1.08
33	2025				0.71	0.28	0.01	0.05	1.05		1.05
34	2026					0.28	0.01	0.05	0.33		0.33
35	2027					0.27	0.01	0.05	0.32		0.32
36	2028					0.26	0.01	0.05	0.31		0.31
37	2029					0.25	0.01	0.05	0.30		0.30
38	2030					0.25	0.01	0.04	0.30		0.30
39	2031						0.01	0.04	0.05		0.05
40	2032						0.00	0.04	0.05		0.05
41	2033						0.00	0.04	0.05		0.05
42	2034						0.00	0.04	0.05		0.05
43	2035						0.00	0.04	0.04		0.04
44	2036							0.04	0.04		0.04
45	2037							0.04	0.04		0.04
46	2038							0.04	0.04		0.04
47	2039							0.04	0.04		0.04
48	2040							0.03	0.03		0.03
Total			19.99		23.49	8.23	0.15	1.16	33.02	13.33	46.35

In Case 1-B, the maximum payment also occurs in the third year from the beginning of construction. This amount will be US$3.85 million, broken down into US$0.43 million for the foreign portion and US$3.42 million for the local portion. This amount also exceeds the annual investment budget of SAMAPA. Thus, the total payment would be about 2.1 times the investment budget of SAMAPA. Thus, even if SAMAPA gets the low interest loan like OECF, it could not implement the proposed project without other assistance.

In Case 2 in Table 5.4.8, the maximum payment would total US$1.20 million in the 8th year (2000) from the beginning of construction. It is broken down to US$0.54 million for foreign portion and US$0.66 million for local portion. In the same year, the annual investment budget of SAMAPA is estimated at US$2.3 million, so the total payment might be lower than the local budget. Thus, if the foreign grant for Phase I portion is available, the scheme of the basic plan could be considered to be feasible from the financial view point.

(3) Household Budget for Sewerage Charge

The household expenditure for sewerage services was estimated at US$6.0 in 1990, and it is expected to be US$7.0 in 2010.

As described earlier, if the total capital cost plus O/M cost is to be recovered by the sewage service charge, the required rate is estimated as US$0.161/m^3. When the annual discharge of sewage by a household was assumed to be 165 m^3, the annual total charge of sewage would amount to US$26.6. This amount is 3.8 times the expected household expenditure for sewerage service of US$7.0 per annum. This case approximately corresponds to the above Case 1-A.

If the capital cost of Phase I is covered by a grant and not included in the depreciable assets, the total capital cost would be US$9.5 million. Then, the annualized capital cost was calculated at US$1.0 million. The total annual cost, that is, the annualized construction cost plus O&M cost (US$2.7 million/year) after completion of the project, was estimated at US$3.7 million. The average unit cost would then be estimated at US$3.7 million divided by 71.0 million m^3 or US$0.052/m^3. In this case, since the total sewerage service rate is US$0.125/m^3, the annual total charge of sewage would amount to US$20.6, or almost three times the expected expenditure of US$7.0. This case approximately corresponds to the above Case 2.

TABLE 5.4.8 REPAYMENT SCHEDULE OF LOANS: CASE 2

(Unit: US$ million)

No.	Year	Phase	Foreign Grant and Loan: Grant Annual Total	Loan Annual Total	Accumulation by Phase	Repayment of Foreign Loan Portion and Interest Payment: Phase 1*1	Phase 2	Phase 3	Phase 4	Total	Local Portion	Total Payment
1	1993	Phase 1	6.70	0.00	6.70	0.00				0.00		0.00
2	1994		8.57	0.00	15.27	0.00				0.00		0.00
3	1995		8.57	0.00	23.83	0.00				0.00		0.00
4	1996	Phase 2		0.98	0.98		0.11			0.11	0.66	0.76
5	1997			0.98	1.97		0.22			0.22	0.66	0.87
6	1998			0.98	2.95		0.32			0.32	0.66	0.98
7	1999			0.98	3.93		0.43			0.43	0.66	1.09
8	2000			0.98	4.91		0.54			0.54	0.66	1.20
9	2001	Phase 3		0.02	0.02		0.54	0.00		0.54	0.01	0.55
10	2002			0.02	0.04		0.89	0.00		0.90	0.01	0.91
11	2003			0.02	0.05		0.85	0.01		0.86	0.01	0.87
12	2004			0.02	0.07		0.81	0.01		0.82	0.01	0.83
13	2005			0.02	0.09		0.78	0.01		0.79	0.01	0.80
14	2006	Phase 4		0.14	0.14		0.74	0.01	0.02	0.76	0.09	0.85
15	2007			0.14	0.28		0.70	0.02	0.03	0.75	0.09	0.84
16	2008			0.14	0.41		0.66	0.02	0.05	0.72	0.09	0.81
17	2009			0.14	0.55		0.62	0.01	0.06	0.70	0.09	0.79
18	2010			0.14	0.69		0.58	0.01	0.08	0.67	0.09	0.76
19	2011						0.54	0.01	0.08	0.63		0.63
20	2012						0.51	0.01	0.13	0.64		0.64
21	2013						0.47	0.01	0.12	0.60		0.60
22	2014						0.43	0.01	0.11	0.55		0.55
23	2015						0.39	0.01	0.11	0.51		0.51
24	2016							0.01	0.10	0.11		0.11
25	2017							0.01	0.10	0.11		0.11
26	2018							0.01	0.09	0.10		0.10
27	2019							0.01	0.09	0.10		0.10
28	2020							0.01	0.08	0.09		0.09
29	2021								0.08	0.08		0.08
30	2022								0.07	0.07		0.07
31	2023								0.07	0.07		0.07
32	2024								0.06	0.06		0.06
33	2025								0.05	0.05		0.05
	Total		23.83	5.69		0.00	11.13	0.20	1.56	12.90	3.80	16.69

Note: *1 The costs of Phase I are covered by foreign grant.

Table 5.4.9 STREAM OF INCOME AND EXPENDITURE: CASE 2

(Unit: US$ Million)

No.	Year	Capital Balance						Revenue Balance					
		Income			Expenditure		Balance	Income	Expenditure			Balance	Cash Balance *1
		Foreign Grant	Foreign Loan	Local Portion *1	Construction Cost	Repayment of Loan		Sewerage Treatment Service	M&O Expenses	Depreciation	Interest of Loan		
1	1993	6.70			6.70		0.00					0.00	0.00
2	1994	8.57			8.57		0.00					0.00	0.00
3	1995	8.57			8.57		0.00					0.00	0.00
4	1996		0.98	0.66	1.64		0.00	1.94	1.64		0.11	0.18	0.18
5	1997		0.98	0.66	1.64		0.00	1.95	1.64		0.22	0.09	0.09
6	1998		0.98	0.66	1.64		0.00	1.97	1.64		0.32	0.00	0.00
7	1999		0.98	0.66	1.64		0.00	1.98	1.64		0.43	-0.09	-0.09
8	2000		0.98	0.66	1.64		0.00	2.00	1.64		0.54	-0.18	-0.18
9	2001		0.02	0.01	0.03		0.00	2.45	2.00	0.27	0.54	-0.36	-0.09
10	2002		0.02	0.01	0.03	0.35	-0.35	2.47	2.00	0.27	0.51	-0.31	-0.39
11	2003		0.02	0.01	0.03	0.35	-0.35	2.49	2.00	0.27	0.47	-0.25	-0.33
12	2004		0.02	0.01	0.03	0.35	-0.35	2.51	2.00	0.27	0.43	-0.19	-0.27
13	2005		0.02	0.01	0.03	0.35	-0.35	2.53	2.00	0.27	0.40	-0.14	-0.21
14	2006		0.14	0.09	0.23	0.35	-0.35	3.00	2.35	0.28	0.37	0.00	-0.07
15	2007		0.14	0.09	0.23	0.36	-0.36	3.02	2.35	0.28	0.35	0.05	-0.03
16	2008		0.14	0.09	0.23	0.36	-0.36	3.05	2.35	0.28	0.32	0.10	0.02
17	2009		0.14	0.09	0.23	0.36	-0.36	3.07	2.35	0.28	0.30	0.15	0.07
18	2010		0.14	0.09	0.23	0.36	-0.36	3.10	2.35	0.28	0.28	0.20	0.12
19	2011					0.36	-0.36	3.56	2.70	0.32	0.24	0.31	0.27
20	2012					0.41	-0.41	3.56	2.70	0.32	0.19	0.35	0.26
21	2013					0.41	-0.41	3.56	2.70	0.32	0.15	0.40	0.31
22	2014					0.41	-0.41	3.56	2.70	0.32	0.10	0.44	0.35
23	2015					0.41	-0.41	3.56	2.70	0.32	0.06	0.49	0.40
24	2016					0.06	-0.06	3.56	2.70	0.32	0.05	0.49	0.75
25	2017					0.06	-0.06	3.56	2.70	0.32	0.05	0.50	0.76
26	2018					0.06	-0.06	3.56	2.70	0.32	0.04	0.51	0.77
27	2019					0.06	-0.06	3.56	2.70	0.32	0.03	0.51	0.77
28	2020					0.06	-0.06	3.56	2.70	0.32	0.03	0.52	0.78
29	2021					0.05	-0.05	3.56	2.70	0.32	0.02	0.52	0.79
30	2022					0.05	-0.05	3.56	2.70	0.32	0.02	0.53	0.80
31	2023					0.05	-0.05	3.56	2.70	0.32	0.01	0.53	0.80
32	2024					0.05	-0.05	3.56	2.70	0.32	0.01	0.54	0.81
33	2025					0.05	-0.05	3.56	2.70	0.32	0.00	0.55	0.81
	Total	23.83	5.69	3.80	33.32	5.69	-5.69	90.94	70.43	7.50	6.58	6.42	8.23

Note: *1 (Capital balance)+(Revenue balance)+(Depreciation)

Incidentally, in the case of the "O&M cost recovery policy", the flat service charge was US$0.111/m^3. Then, the annual total charge for sewage service would amount to US$18.3, 2.6 times the expected expenditure.

Since the required charges to beneficiaries may substantially exceed the regulated tariffs they have to pay, the resulting rates of return represent a minimum estimate rather than a best estimate of the actual rate of return of the project to the economy. In this context, the above charge of US$7.0 may be too small for the best estimate of the actual rate of return. Nevertheless, this charge accounts for only 26% of the estimated charge of US$26.6 in Case 1-A, and even in Case 2, it accounts for 34% of that (US$20.6). Furthermore, even in the case of the "O&M cost recovery policy", it accounts for 38% of the estimated annual charge (US$18.3). Thus, this amount would become a heavy burden for the people in the project area. In the case of continued implementation of the project, careful consideration should be given by the authorities concerned.

(4) Financial Status

To examine the financial status after the implementation of the proposed project, the financial cash stream is made for the above fund cases. The following conditions were assumed to make the stream:

(a) The management of the proposed project was looked upon as an independence undertaking. Thus, the existing financial income and expenses of SAMAPA were not included in the stream.

(b) Considering the affordability of the people, the sewerage service rates were assumed as US$0.038/m^3 (corresponding to US$6.2 per household) in 1995 and US$0.042/m^3 (US$7.0 per household) in 2010. Between 1995 and 2010, the rates were set as increasing in proportion to the growth of per capita GRDP. Beyond 2010, the rates were set to be constant.

Table 5.4.9 shows the financial stream of Case 2. In this Case, the cash balance was negative only between 1999 and 2007, so the undertaker might have to procure the short borrowing for this period. The total balance for 30 years was US$6.42 million, which could not cover the capital costs of US$23.83 million. This means that the undertaker would have to procure the grant for replacement of the first phase facilities after the economic life of 30 years.

(5) Conclusions

The capital investment for the proposed project might be a burden on SAMAPA's financial management, as discussed in the above section (2). In Case 1-A in particular, the annual payment including reimbursement and interest exceeds the limits of SAMAPA's capability for the annual investment. In Case 2 only, the annual payment is within the limits of SAMAPA's budget capabilities. Thus, SAMAPA should strive for foreign grants.

From the point of view of affordability, the sewage service charge might be a burden on people's budgets, even if the authorities concerned adopt the "O&M cost recovery policy". Thus, to implement the sewerage system successfully, it is most important for the authorities to promote understanding on the part of the beneficiaries as well as to pursue low cost of funds.

5.5 PRIORITY PROJECT

5.5.1 Identification of the Priority Project

In Section 5.4.5, an implementation program for the Basic Plan was proposed, from which the Phase 1 project (up to 1995) in the Basic Plan can be identified as the priority project.

In the priority project, the wastewater from the Central Zone will be collected from the Choqueyapu river and treated at a wastewater treatment plant.

Facilities to be constructed in the priority project are as follows:

- Water intake facilities in the Choqueyapu river (at Kantutani)
- Main sewer interceptor (9.85 km)
- Aerated lagoons (12 ha, 140,000 m^3/day)
- Sedimentation basins (4 ha)
- Operations/miscellaneous buildings

While the treatment plant in the basic plan will occupy two plant sites (#1 and #2), all the treatment facilities for the priority project will be installed at Plant Site #1 (20 ha). The treatment system of the priority project will be composed of partially mixed aerated lagoons and sedimentation basins. In a later phase, all of this system in Site #1 will be converted to completely mixed aerated lagoons and new sedimentation basins will be constructed at Site #2.

5.5.2 Effect of the Priority Project

The water quality improvement effect of the priority project was predicted using the water quality simulation model under following conditions :

- Dry season flow raate
- BOD removal efficiency of 60% in the proposed plant
- No other measures such as industrial effluent control are taken.

The results are shown in Table 5.5.1 and Fig. 5.5.1. While the BOD would exceed the target value of 50 mg/l in the downstream area if no control measures were to be taken taken by 1995, the implementation of the priority project would achieve the target BOD value of 50 mg/l; 40 mg/l at R14 and 47 mg/l at R15.

TABLE 5.5.1 IMPROVEMENT OF WATER QUALITY (BOD) BY THE PRIORITY PROJECT (1995)

Evaluation	Distance	BOD5 Concentration (mg/l)				
		Results of Simulation		Rate of	Simulated	Rate of
Point	(km)	Controlled Future	Uncontrolled Future	Reduction (%)	Present	Reduction (%)
R1	0	1.2	1.2	0.0	1.2	0.0
R2	16	2.2	2.2	0.0	2.2	0.0
R3	20	68.4	68.4	0.0	67.8	-0.9
R4	23	151.4	151.4	0.0	151.7	0.2
R5	26	142.7	142.7	0.0	143.0	0.2
R9	30	94.6	107.3	11.9	107.1	11.7
R14	32	39.9	73.7	45.8	71.1	43.8
R15	39	47.1	56.9	17.2	54.3	13.3

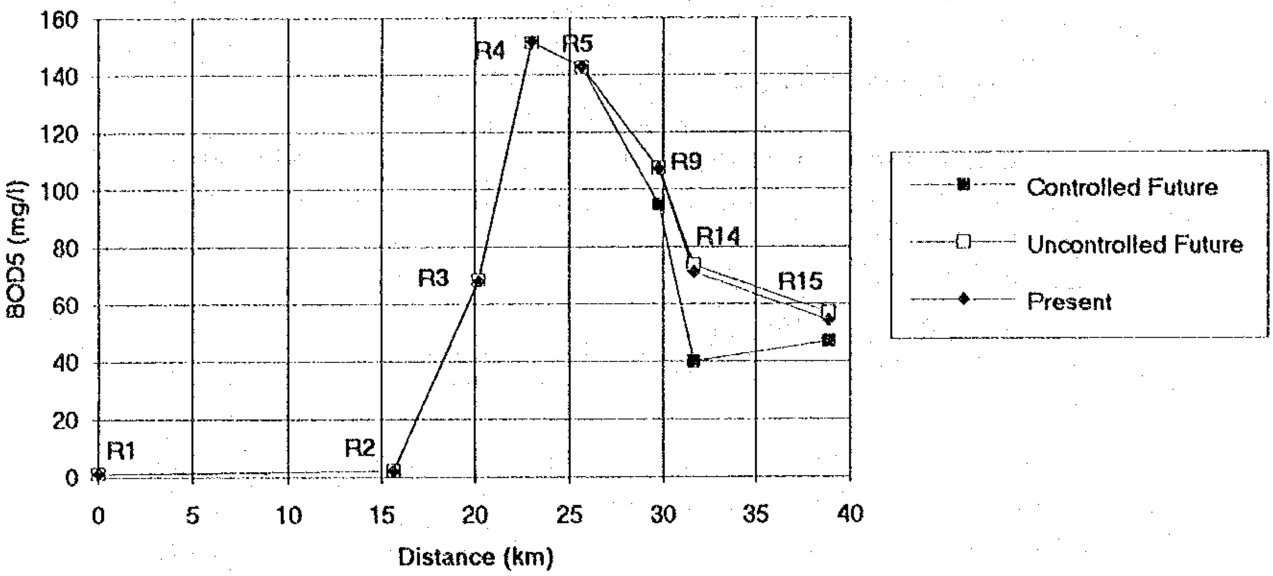


FIG. 5.5.1 IMPROVEMENT OF WATER QUALITY BY THE PRIORITY PROJECT (WITHOUT INDUSTRIAL EFFLUENT CONTROL)

CHAPTER 6
RECOMMENDATIONS - BASIC PLAN

1. Financial Considerations

The proposed basic plan has been developed attempting to keep the initial and operation costs of the required facilities as low as possible. However, the initial cost is roughly equivalent to SAMAPA's investment ceiling which must also cover other sewerage projects including those in El Alto.

On the other hand, the total project cost is equivalent to 7% of the estimated national investment ceiling for the sewerage sector, and the SAMAPA's investment ceiling has been equivalent to only 4.5% of the national ceiling. These figures indicate that it is impracticable to implement the proposed plan by the SAMAPA's financial capacity alone. It may be practicable that the national government extends strong support to SAMAPA by considerably changing the present policy of financing local sewerage development projects. It is recommended that the national government consider this possibility.

2. Integration of Sewerage Development Into Urban Planning

The present water pollution of the rivers in the City of La Paz is, in a large part, a result of lack of a balanced urban development policy. Residential, industrial, commercial, and infrastructural developments have been carried out without a clearly defined environmental conservation policy.

Hence, development of the sewer system has been aimed largely at promotion of the convenience of domestic and social activities rather than protection of the aquatic resources, resulting in the extensive sewer networks but without a wastewater treatment facility.

To achieve real improvement of the quality of life in the urban area, a comprehensive urban reorganization plan should be established, in which the development of the sewerage system with wastewater treatment should be given a high priority.

3. Enforcement of Wastewater Discharge Regulation

The wastewater discharge regulation recently established by the Ministry of Urban Affairs provides a good legal basis to control industrial wastewater discharges. However, some reinforcements of the present regulation are recommended regarding the obligations of industries and the power of regulatory authorities. Even when the regulation is enforced only for the relatively large factories, the amount of pollutants discharge will be significantly reduced. Enforcement of the regulation will require factories to install treatment facilities in order to meet the effluent standards. Since many of the large factories in La Paz City are said to have available space, such installation is technically possible. If not so for some large factories, strong measures including relocation of the factories should be taken.

As regards new residential or other development in the administrative and peripheral areas of the city, all developers should be enforced to install wastewater treatment plants to serve the development areas.

4. Rehabilitation of the Existing Sewerage Facilities

The Basic Plan has been developed based on the concept of utilizing the existing facilities as much as possible to reduce total project cost. Therefore, although there are connections between the sewer lines and storm lines and improper pipe laying, the Plan proposes to use the existing sewer collection systems. Except for the Central Zone, the plan provides overflow weirs on sewer lines to prevent excess inflow to interceptor sewers during storms. However, no provision was possible to include in the plan against sewage inflows into storm lines. If the existing sewer collection systems are left as they are without correcting the existing inter-connections, the effects of the sewage discharges into rivers through storm lines would not be negligible and would reduce the water quality improvement effect of the proposed Basic Plan. Therefor, it is strongly recommended to rehabilitate the existing sewer systems to collect maximum amount of sewage into sewer lines.

5. Organizational Reinforcement

Since the organization for water pollution control in the City of La Paz is not adequate at present, its reinforcement is urgently needed.

The tasks of the Municipality of La Paz, as the responsible body to control water pollution of the rivers, include the following:

- Establishment of local rules, regulations and standards concerning water pollution control in coordination with national authorities

- Water quality monitoring of the rivers

- Control of solid wastes dumping into rivers
- Control of erosion
- Control of disorderly activities in riverbeds
- Promotion of public awareness of water pollution control

To execute the above tasks, the capacities of relevant sections of the Municipality should be strengthened.

SAMAPA is responsible for development, operation and management of sewerage system as well as for enforcement of industrial wastewater discharge regulations. It has a considerable degree of experience in developing sewer pipe networks, but it has no experience in developing large-scale wastewater treatment plants. A considerable degree of reinforcement of the organization of SAMAPA is recommended to execute sewerage development, operations and maintenance.

6. Management of Basic Data

To draw up efficiently a rational plan for control of water pollution in the rivers, reliable basic data are necessary including the following:

- Population and its zonal distribution
- Topographical maps
- Up-dated maps of developed areas
- Hydrological and meteorological data
- Drawings of river courses and river sections

Availability of reliable data concerning the above are limited, and sometimes, the existence of useful data is not known to the persons needing it the most. Some data such as hydrological and meteorological data are not systematically compiled so that they can be utilized efficiently .

The basic data should be compiled and processed, and systems of providing the basic data should be established through cooperation between the relevant authorities.

PART (III)

FEASIBILITY STUDY

CHAPTER 7

DESIGN OF THE FACILITIES FOR THE PRIORITY PROJECT

7.1 DESIGN WASTEWATER FLOW

The priority project is to be implemented as the first stage of the Basic Plan. It aims to treat the wastewater from the Central zone, excluding the Orkojahuira basin, by diverting the Choqueyapu River water to the wastewater treatment plant. It is planned to be implemented between 1993 and 1995.

Therefore, the wastewater to be treated in the priority project is the estimated wastewater generation from the Central zone in 1995. However, the capacity of each component of the facilities should be designed as shown below so as to be able to cater to the increased wastewater in later phases:

- Water intake facilities: These facilities will be used in the final phase of the basic plan, without any expansion. Thus it will have the capability to divert the Choqueyapu River low flows in 2010.

- Main sewer interceptor: This sewer will be used in the final phase of the basic plan without any expansion. While the interceptor will transmit only the wastewater from the Central zone from the water intake facilities in the priority project, it will receive all the wastewaters from remaining areas through sub-main sewer interceptors in later phases. Therefore, the capacity of the interceptor is designed based on the total wastewater in the area in 2010.

- Wastewater treatment plant: The wastewater treatment plant has been planned to expand its capacity by phases. It will treat only the wastewater from the Central zone in the priority project and expand its capacity in the later phase according to the increase in the wastewater due to the increase in the areas covered.

Considering the above, design wastewater flows for each component of the Priority Project were determined as follows:

Component	Design wastewater flow	Remarks
Water intake facilities	170,000 m^3/day	River flow (0.4m^3/s) + wastewater generation in the Central zone except the Orkojahuira basin in 2010.
Main sewer interceptor	230,000 m^3/day	Total wastewater generation in the served area in 2010
Wastewater treatment plant	140,000 m^3/day	River flow (0.4m^3/s) + wastewater generation in the Central zone except the Orkojahuira basin in 1995.

7.2 WASTEWATER INTAKE FACILITIES

7.2.1 Location

The location selected for the intake facilities is at the confluence of the Choqueyapu River with the Cotahuma River in Kantutani. The purpose is to divert the Choqueyapu River water which consists of the river low flow and all the wastewater from the Central zone. The facility will be designed to avoid diversion of the Cotahuma River which has an extremely high suspended solids concentration. Also the Kantutani River, which originates in the Sopocachi area carrying a large amount of organic pollutants and runs to the Cotahuma River just upstream of its confluence with the Choqueyapu River, will be diverted to the Choqueyapu River at the upstream end of the proposed water intake facilities. The wastewater from the Sopocachi area will then be diverted to the main sewer interceptor for treatment. The proposed location is shown in Fig. 7.2.1.

7.2.2 Structures

The proposed water intake facilities will comprise a fixed weir, a sluice gate for flow control, a connection pipe, an interface chamber to the main sewer interceptor, and miscellaneous works such as consolidation works for protection of the river bed. The structures are as shown in Fig. 7.2.1.

The river bed at the existing drop structure works is excavated so that the top of the weir is set under the elevation of the existing river bed, not reducing the existing flood discharge capacity of the river.

The facilities will be equipped with a sluice gate to control flow to the interceptor. The sluice gate will be opened in the dry season to divert the all river water and the opening will be reduced, when the river flow increases, to maintain a constant diversion rate. This operation will be carried out manually by monitoring the level of the river flow.

7.2.3 Cost Estimates

The construction costs for the intake facilities shown in Fig. 7.2.1 are estimated as follows:

Civil works	US$49,000
Equipment/Materials	US$31,000
Total	US$80,000

7.3 MAIN SEWER INTERCEPTOR

7.3.1 Routes

The proposed route is shown in Fig. 7.3.1 and is divided into three sections depending on the ground conditions.

Section A: In this section, a major portion of the interceptor is installed under the road. There are two possible routes, one along the left bank and the other along the right bank, as shown in Fig. 7.3.2. The right bank route is selected mainly because of lower construction costs and reduced traffic interruptions than those for the left bank route.

Section B: The route selected follows the existing road considering total length and expected difficulties at the Calacoto bridge in case of the installation in the river bed.

Section C: The route is selected in the river bed because there is no road or suitable terrain along the river. Also, a tunnel is proposed at the sharp meandering section downstream of Aranjuez.

7.3.2 Design Criteria

The design standards currently used by SAMAPA and HAM are applied as basic design criteria. In addition, the following conditions are also considered.

Design flow:	Hourly maximum wastewater flow (150 % of the daily maximum) plus the dry season river flow
Type of interceptor:	Arched masonry interceptor.
Maximum velocity:	3.5 m/sec.
Flow Calculation:	Manning formula
Roughness coefficient:	Concrete products, 0.015 Masonry (wall), 0.022 Masonry (bottom), 0.05
Margin about the design flow:	Concrete pipe: less than 450mm dia, 100% 500 - 1000 mm dia, 50% more than 1100 mm dia, 30% Arched Masonry: 25%
Minimum earth cover:	Under road, 1.0m Under river bed, 2.0m
Interval between manholes:	70 - 100 m

7.3.3 Preliminary Design

The sizes of the interceptor for each section are calculated based on the criteria mentioned above and the design wastewater flow are as shown in Table 7.3.1.

TABLE 7.3.1 SIZES OF THE INTERCEPTOR

Section	No.	Design Wastewater (m^3/sec)	Size (mm x mm)	Gradient (%)	Velocity (m/sec)	Max. Capacity (m^3/sec)
A	1	2.523	1200 dia	1.0	2.99	3.379
	2	2.523	1300, 1300	2.0	2.33	3.155
	3	2.523	1300, 1300	2.0	2.33	3.155
	4	2.553	1500, 1500	2.0	2.57	4.620
	5	3.066	1500, 1950	2.0	2.57	4.620
	6	3.185	1500, 1950	2.0	2.57	4.620
	7	3.261	1500, 1950	2.0	2.57	4.620
	8	3.299	1500, 1950	2.0	2.57	4.620
	9	3.493	1500, 1950	1.8	2.44	4.383
B	10	3.502	1500, 1950	1.5	2.22	4.001
C	11	3.504	1500, 1950	2.0	2.57	4.620
	12	3.504	1500, 1950	2.0	2.57	4.620
	13	3.504	1500, 1950	3.0	3.14	5.659
	14	3.504	1500, 1500	1.8	3.14	4.383

The proposed plan and longitudinal profiles are shown in Figs. 7.3.3 and 7.3.4. Typical cross sections of the interceptor including manhole sections are shown in Fig. 7.3.5.

Groin works are proposed at the meandering sections to protect the buried interceptor in the river bed from exposures due to erosion. The tentative location and structures of groin works are shown in Fig. 7.3.6 and Fig. 7.3.7.

7.3.4 Cost Estimates

The construction costs and the operating costs are estimated as shown in Tables 7.3.2 and 7.3.3. The construction cost were calculated using unit prices for various materials, sizes and ground surface conditions. For details, refer to Table 7.3.3 in Supporting report.

TABLE 7.3.2 ESTIMATES OF CONSTRUCTION COST FOR MAIN SEWER INTERCEPTOR

Work items	Amount (US$)
PC*-pipe installation	36,320
Arched masonry installation	4,807,100
Tunnel construction	513,600
Road construction	38,470
Groin works	72,600
Total	4,954,490

* Prestressed concrete

TABLE 7.3.3 ESTIMATES OF OPERATING COSTS FOR MAIN SEWER INTERCEPTOR

Staff	Salary(US$/Year)
Engineers	4,950
Laborers	9,900
Night watch	1,650
Drivers	3,960
Total	20,460

7.4 WASTEWATER TREATMENT PLANT

7.4.1 Layout

For the priority project, it is proposed to construct only a portion of the proposed lagoons and sedimentation basins at Site #1 as shown in Fig. 7.4.1. For this stage, the lagoons would be of the partially-mixed aerated type and provide only primary treatment.

At Site #1 there is a total of about 20 Ha available. Since about 2 Ha are needed for roads, parking, berms, etc. there is about 18 Ha usable for process of facilities. For the priority project, it is proposed to provide the following facilities:

2 Ha Preliminary (inlet) treatment works and guildings
16 Ha Lagoons - partially-mixed aerated with sedimentation basins

7.4.2 Preliminary Treatment and Buildings

Preliminary treatment works consist of bar screens, grit chambers, and Parshall Flumes and are as shown in Fig. 7.4.2.

The building requirements include an operations buildings with laboratory, office and meeting rooms, and storage/maintenance facilities for the aeration equipment.

7.4.3 Aerated Lagoons

It is proposed that the lagoon system for the priority project be composed of 2 parallel sets of cells, each set consisting of six 1 hectare cells plus one 2 hectare cell with a maximum depth of 6 meters as shown in Figs. 7.4.1 and 7.4.3.

A profile of the lagoon system is shown in Fig. 7.4.4. Inlet facilities are depicted in Figs. 7.4.5 and 7.4.6. The river bed at Site #1 will require fill to raise the plant site above flood levels as shown in Fig. 7.4.7.

The system in the priority phase would have a 3.86 day retention time and BOD removal on the order of 60 %.

The electric power requirements for partially mixed aeration are estimated at 720 Hp.

7.4.4 Sedimentation Basins

The last cells of both sets of lagoons shown in Fig. 7.4.1, serving as sedimentation basins, would have an average depth of 4.7 meters with a total volume of 188,000 m^3. Of this volume, the top 2 meters (with an average depth of 1.9 meters)would be reserved for sedimentation and the bottom portion for sludge storage and digestion. With this volume it is estimated that accumulated sludge can be stored for four years.

7.4.5 Cost Estimates

The construction costs and operation costs for the priority phase are estimated as shown Tables 7.4.1 and 7.4.2.

TABLE 7.4.1 ESTIMATED CONSTRUCTION COSTS FOR WASTEWATER TREATMENT PLANT

Items	Amount (million US$)
Site Preparation	1.68
Prelim. Treatment Works	0.38
Aerated Lagoons	3.75
Sedim. Basins (Site #1)	1.67
Buildings	0.40
Access Road	0.28
Electrical	0.11
Total Construction	*8.27*
Land Acquisition and R.O.W.	3.35
Total	*11.62*

TABLE 7.4.2 ESTIMATED OPERATING COSTS FOR WASTEWATER TREATMENT PLANT

	(US$/year)
Staff salary	74,425
Equip/Material	13,000
Utilities	356,696
Total	444,121

7.5 PROJECT COSTS

7.5.1 Construction Costs

The estimated construction costs for each component for the priority project were indicated in the previous sections and are summarized as shown in Table

7.5.1. The project costs are estimated by adding indirect costs to the calculated direct construction costs. The indirect costs include engineering costs and a contingency. The engineering costs will cover survey/investigation works, detailed designing and construction supervision by international consultants and are calculated as 10 % of the direct construction costs. The contingency is calculated as 10 % of the total of the direct construction cost and the costs for land acquisition.

The calculated costs are considered lower than those estimated for phased implementation in the Master Plan (Ref. Table 5.4.4), because the construction costs for main sewer interceptor and aerators are reduced as a result of feasibility study.

TABLE 7.5.1 ESTIMATED CONSTRUCTION COSTS FOR THE PRIORITY PROJECT (1992 Prices)

(US$million)

Items	Local	Foreign	Total
Construction Costs	**11.49**	**1.82**	**13.31**
Water Intake Facilities	0.05	0.03	0.08
Main Sewer Interceptor	4.95		4.95
Wastewater Treatment Plant	6.49	1.79	8.28
Land Acquisition and ROW	**3.35**		**3.35**
Engineering	**1.15**	**0.18**	**1.33**
Contingency	**1.48**	**0.18**	**1.67**
Total	**17.47**	**2.18**	**19.66**

7.5.2 Operating Costs

Operating costs for the Priority Project have been estimated in the previous sections and they are summarized as shown in Table 7.5.2.

TABLE 7.5.2 ESTIMATED OPERATING COSTS FOR THE PRIORITY PROJECT

		US$/Year
Wastewater collection/transmission		
	Personnel Expenses	20,460
Plant operations		
	Personnel Expenses	74,425
	Materials/Equipment	13,000
	Electricity	356,696
	Sub-Total	444,121
Total		464,581

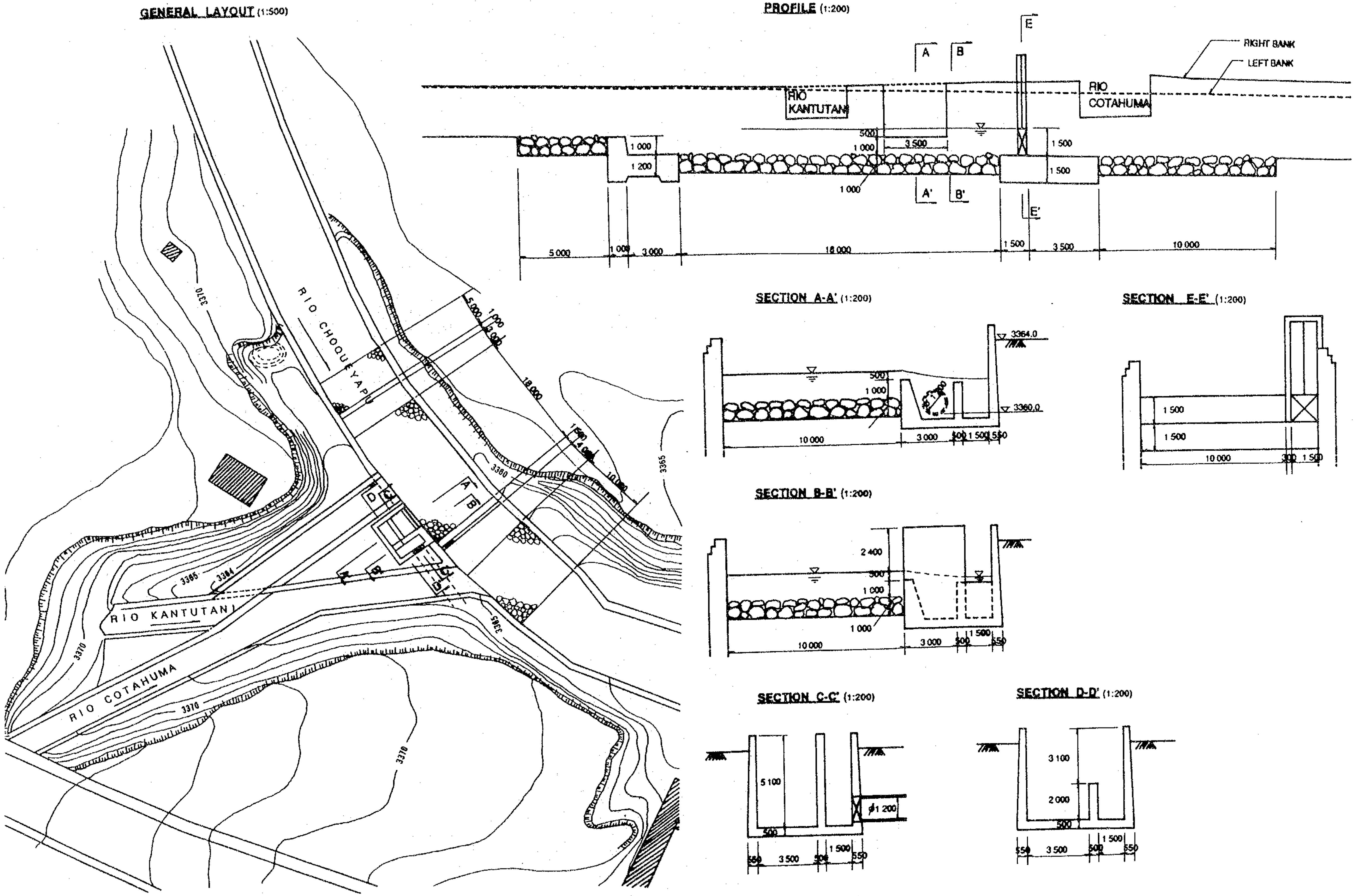


Fig. 7.2.1 GENERAL LAYOUT AND PROFILES OF WATER INTAKE FACILITIES

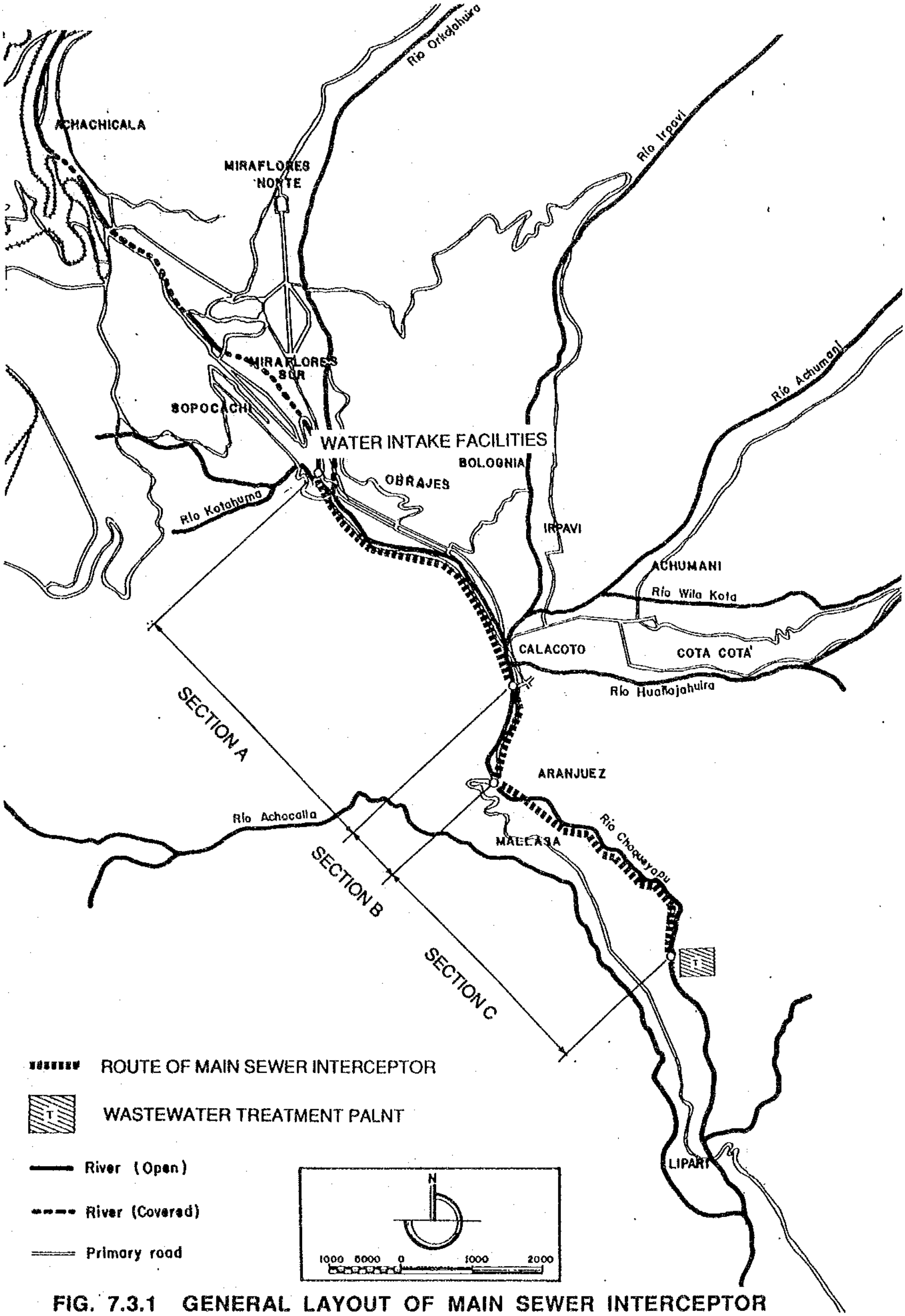


FIG. 7.3.1 GENERAL LAYOUT OF MAIN SEWER INTERCEPTOR

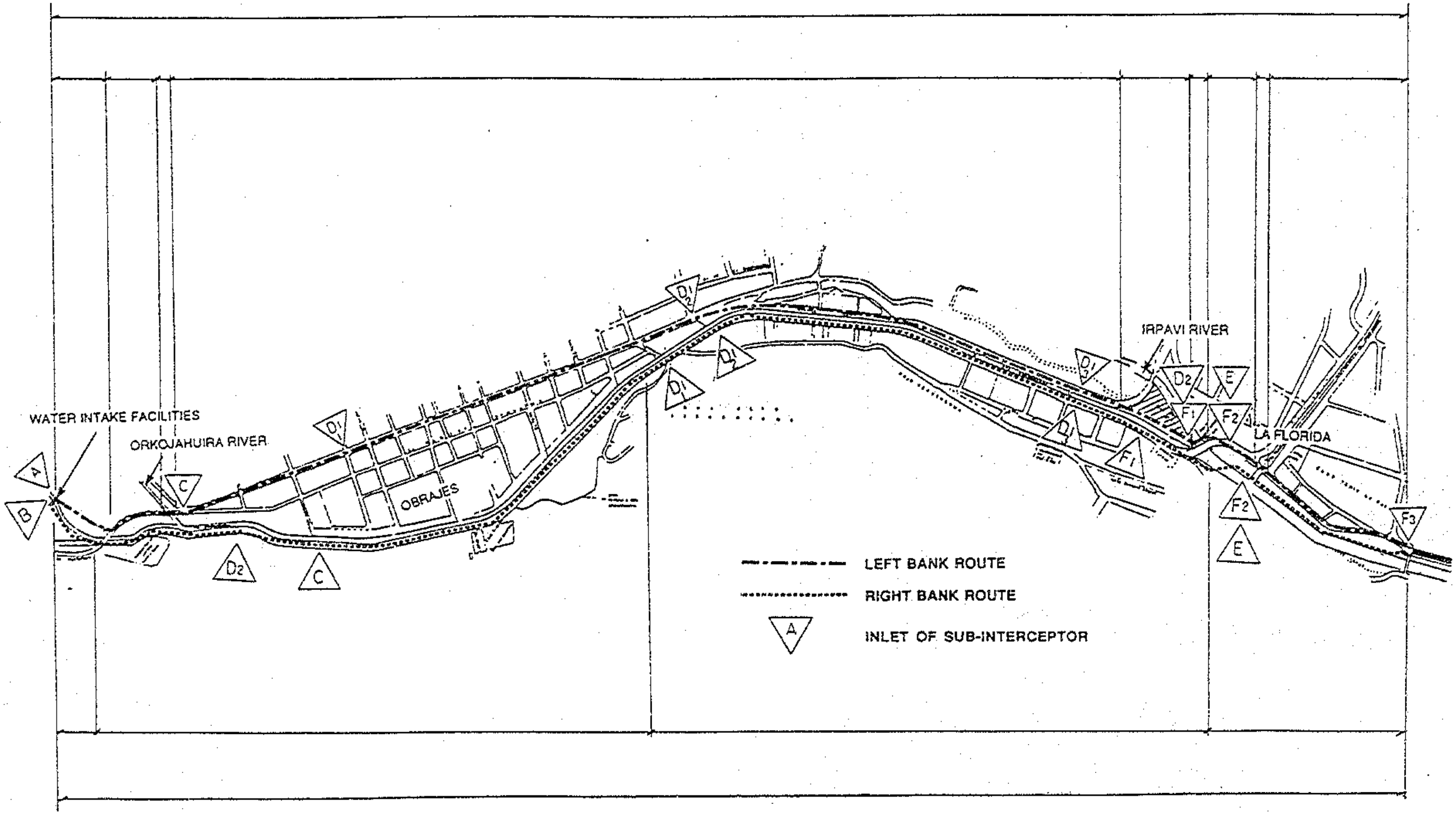


FIGURE 7.3.2 TWO POSSIBLE ROUTES FOR SECTION A

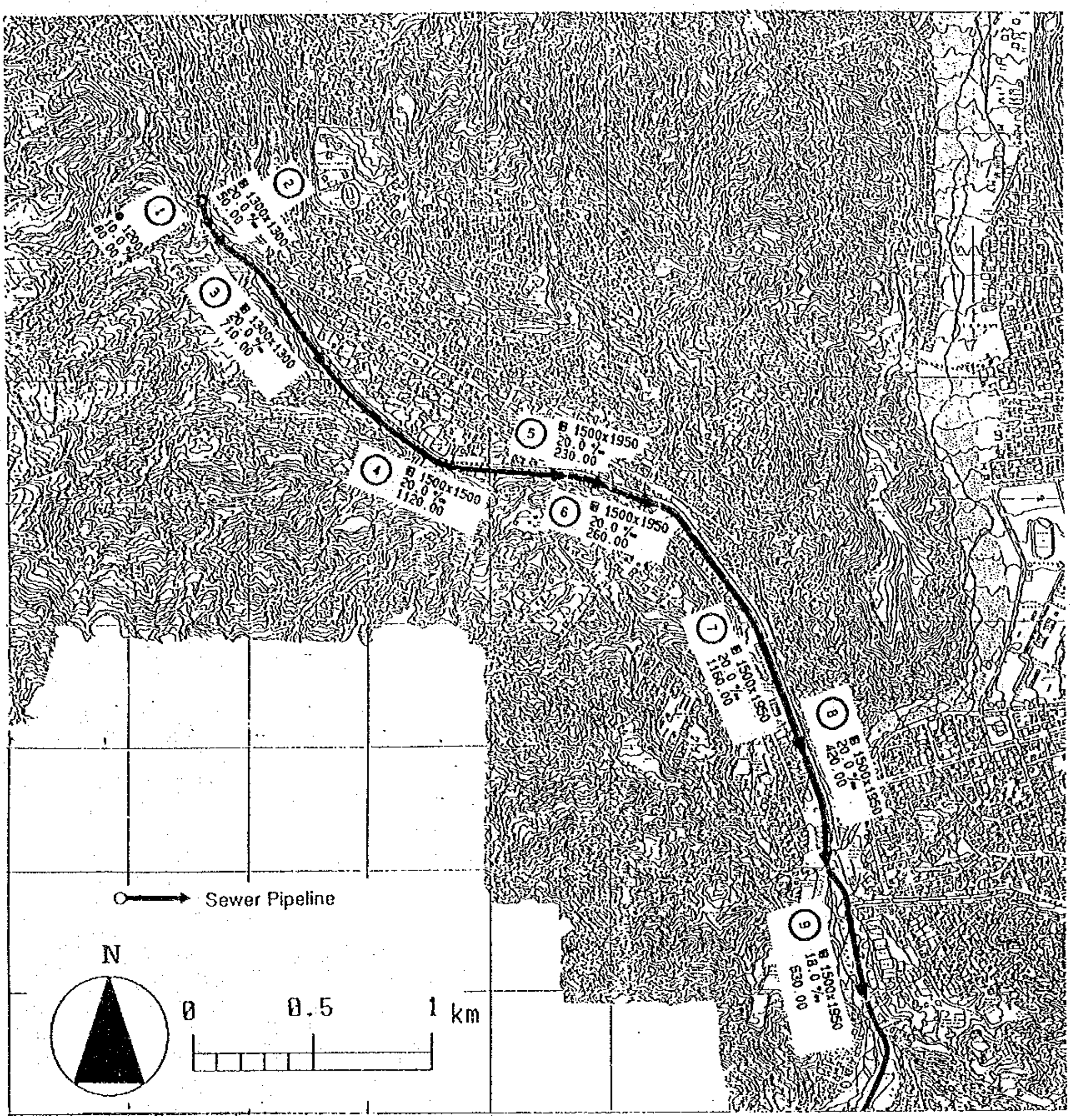


FIG. 7.3.3 PLAN OF PROPOSED MAIN SEWER INTERCEPTOR (1 OF 2)

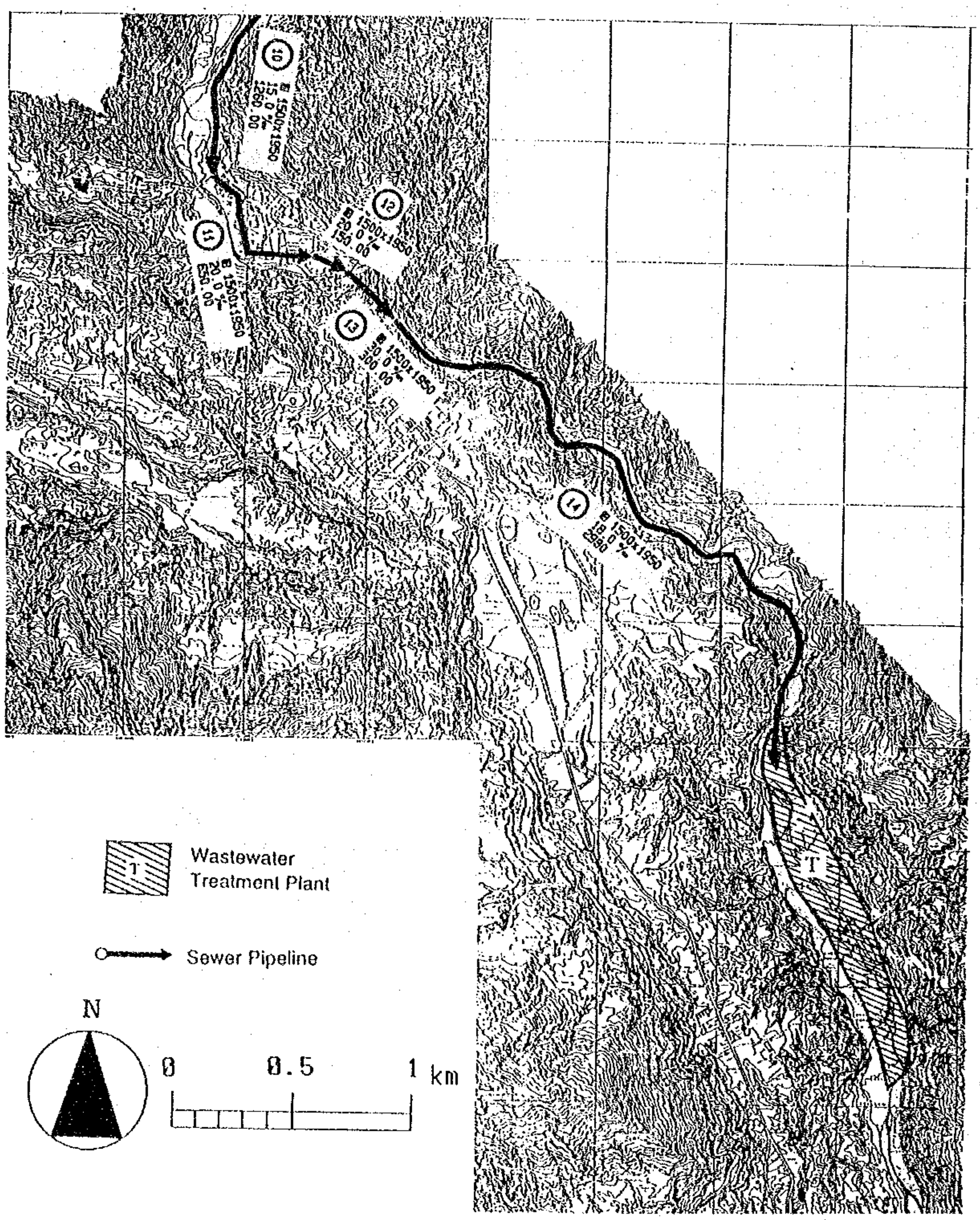


FIG. 7.3.3 PLAN OF PROPOSED MAIN SEWER INTERCEPTOR (2 OF 2)

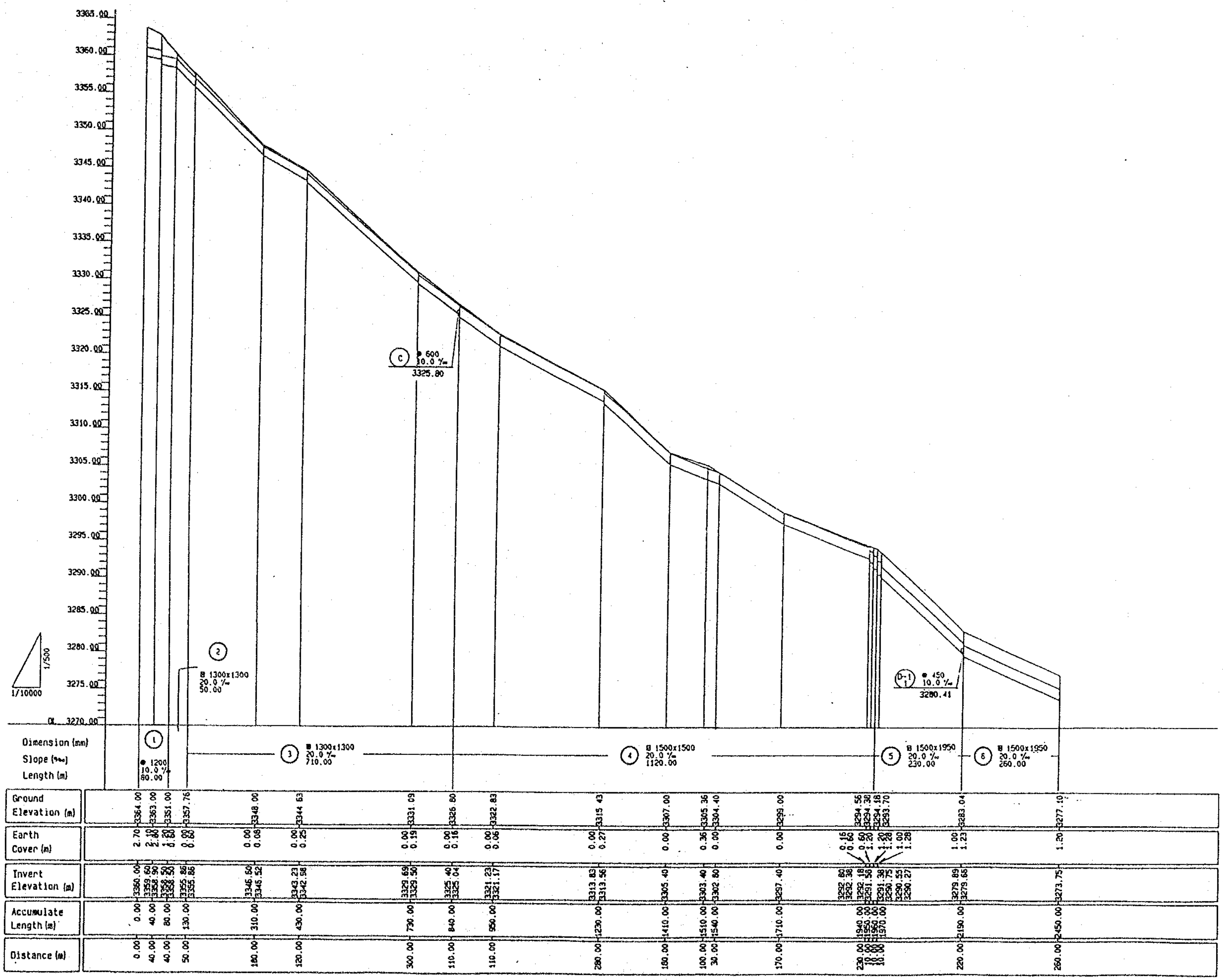


Fig. 7.3.4 LONGITUDINAL PROFILE OF PROPOSED MAIN SEWER INTERCEPTOR (1/4)