7.2 Soil

7.2.1 Impact Caused by Cleaving of Woods

If the cleaving of woods is restricted to road-side areas, large-scale soil erosion will not result.

7.2.2 Impact Caused by Earth Work

The performance of earth work will have some impact on the soil. For example, amount of gray soil on the upstream side of the road project area will increase due to the expansion of the flood area resulting from road improvement work. In response, the water from the flood area is planned to be drained using numerous drainage facilities, including steel corrugated pipes and bridges, thus keeping the water level at or below current levels. Accordingly, the influences of road improvement work can be considered minimized.

7.2.3 Impact Caused by Drainage Facilities

To minimize the soil erosion at the drainage facilities that will occur during the rainy season, the inlets and outlets of the steel corrugated pipes will be reinforced, in addition to their sides on both the upstream and downstream sides of the river.

7.3 Hydrology

7.3.1 Impact Caused by Cleaving of Woods

If the cleaving of woods is restricted to road-side areas, large-scale hydrological change will be prevented.

7.3.2 Impact Caused by Earth Work and Drainage Facilities

The periodic inundation of the eastern part of the project area is a natural phenomenon. However, the existing road also has a relatively large influence on the flood area. Such influence, include raising the water level on the upstream side of the road project due to the low capacity of the drainage system, even though numerous steel corrugated pipes have been constructed to provide adequate drainage.

The improvement of the road by the construction of the embankment will raise the road in the flood area to 60 cm above the water level, a factor that will certainly create a greater influence on the flood area.

A flowchart on the method used to forecast changes in the water level due to the road embankment project is shown in Figure 7-3-1. Basic calculations and simulations for hydrological and hydraulic analyses were examined as part of the Feasibility Study carried out by JICA in 1987. The results of this examination proved to be acceptable and are shown below. Since complete rainfall data was not available, correlation method was used to estimate the necessary data

(1) Forecasting Annual Rainfall

Rainfall data from Bolivia's 19 weather stations (Figure 7-3-2) was obtained from the Autonomous Administration of Auxiliary Services for Aerial Navigation (Administración Autónoma de Servicios Auxiliares a la Navegación Aérea-AASANA) and from the National Service of Meteorology and Hydrology (Servicio Nacional de Meteorología e Hidrología-SENAHMI.) The collected data extended across the 35 year from 1950 and 1984. Additional data was collected for the 10-year period from 1985 to 1994.

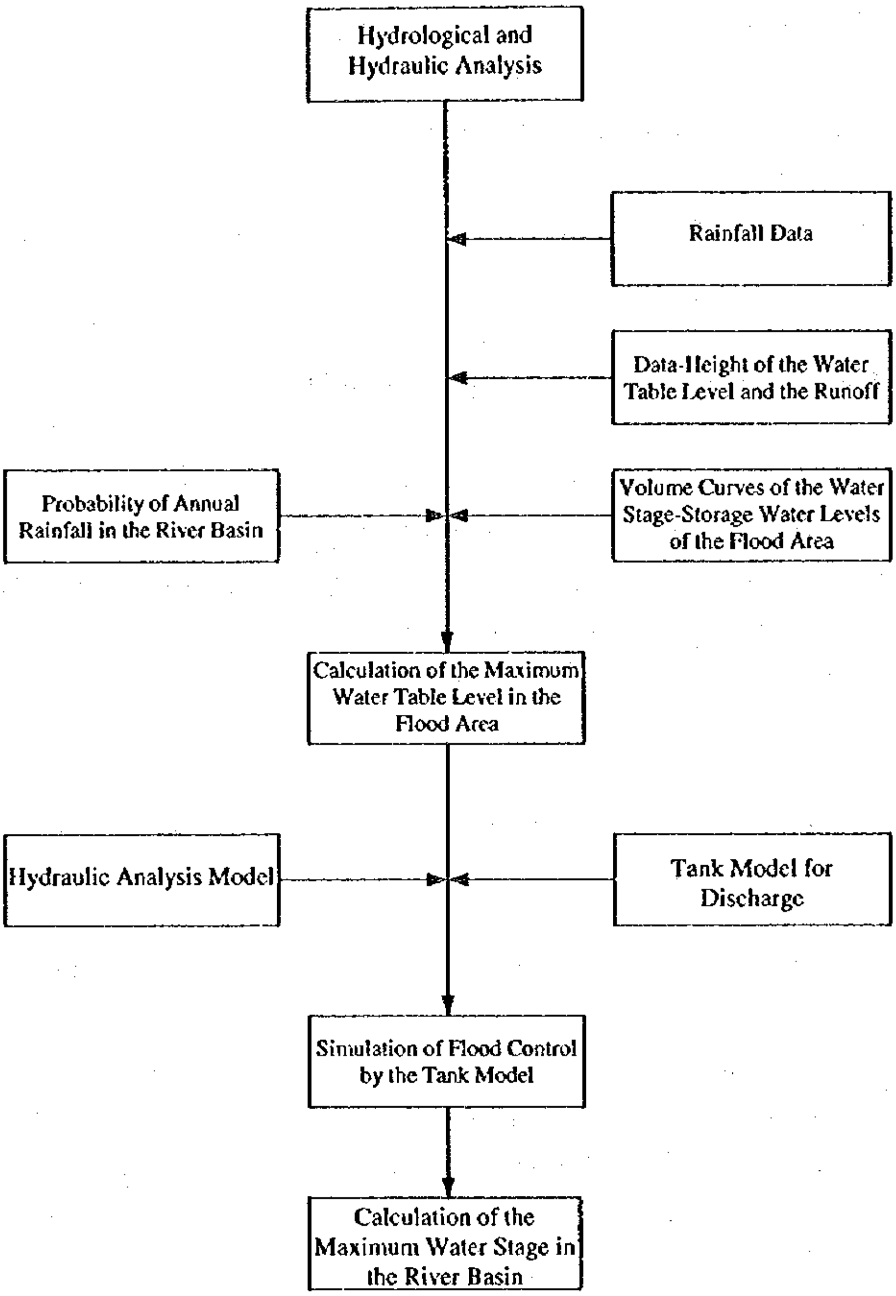


Figure 7-3-1 Flowchart on the Method Used to Forecast the River Basins

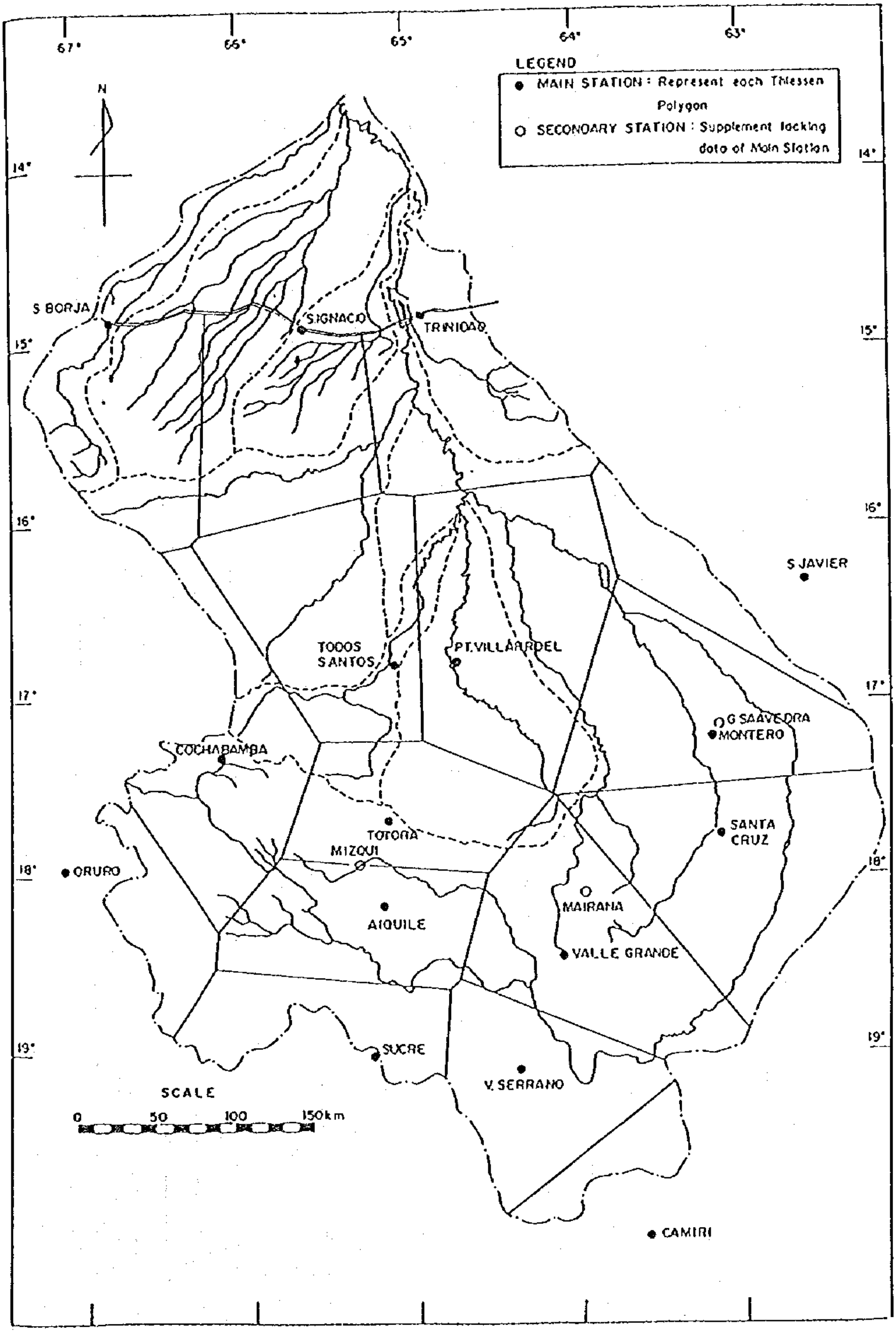


Figure 7-3-2 Meteorological Stations and Thiessen Polygons

The annual rainfall in the project area averaged 1,330 mm, with a maximum of 1,830 mm. The average annual rainfall in each river basin was calculated using the Thiessen method, as shown in Figure 7-3-2. The Thiessen coefficients are shown in Table 7-3-1.

Table 7-3-1 Thiessen Coefficients

Station	Tijamuchi R/B*1		Mamoré R/B		Ibare R/B		Whole Basin	
	*2	*3	*2	*3	*2	*3	*2	*3
Trinidad	640	0.10	4,290	0.03	6,720	1.00	11,040	0.06
San Ignacio	5,620	0.90	5,835	0.04	-	-	11,455	0.06
San Borja	-	-	2,555	0.02	-	-	2,555	0.01
San Javier	-	-	4,520	0.03	-	-	4,520	0.03
Montero	-	-	16,365	0.10	-	-	16,365	0.09
Santa Cruz	-	-	17,470	0.10	-	-	17,470	0.10
T. Santos	-	-	16,110	0.09	-	-	16,110	0.09
P. Villaroel	-	-	20,575	0.12	-	-	20,575	0.11
Vallegrande	-	-	15,370	0.09	-	-	15,370	0.09
V. Serrano	-	-	11,735	0.07	-	-	11,735	0.07
Camili	-	-	3,640	0.02	-	-	3,640	0.02
Sucre	-	-	7,515	0.05	-	-	7,515	0.04
Totora	-	-	10,350	0.06	-	-	10,350	0.06
Mizqui	-	-	11,110	0.07	-	-	11,110	0.06
Cochabamba	-	-	13,695	0.08	-	-	13,695	0.08
Oruro	-	-	5,295	0.03	-	-	5,295	0.03
Total	6,260	1.00	166,430	1.00	6,720	1.00	178,800	1.00

Notes: *1 : River Basin
*2 : Area of the Thiessen polygon (km^2)
*3 : Thiessen coefficient

Rainfall statistics by month and season in the Tijamuchi, Mamoré, and Ibare River basins are shown in Table 7-3-2.

Table 7-3-2 Monthly and Seasonal Rainfall

Month/Season	Tijamuchi R/B*1		Mamoré R/B		Ibare R/B		Whole Basin	
	*2	*3	*2	*3	*2	*3	*2	*3
January	307	16.2	215	16.3	322	17.5	219	16.5
February	292	15.4	187	14.4	278	15.1	192	14.4
March	254	13.4	152	11.7	214	11.6	156	11.8
April	136	7.2	100	7.7	135	7.3	102	7.7
May	93	4.9	61	4.7	90	4.9	63	4.7
June	73	3.8	49	3.8	62	3.3	50	3.8
July	39	2.1	35	2.7	44	2.4	35	2.6
August	54	2.8	38	2.9	43	2.3	38	2.9
September	70	3.7	51	4.0	87	4.7	53	4.0
October	154	8.1	106	8.2	133	7.2	108	8.1
November	172	9.0	127	9.8	189	10.2	130	9.8
December	256	13.3	179	13.8	248	13.4	182	13.7
Dry Season*4	483	25.4	340	26.2	459	24.9	347	26.1
Rainy Season*4	1,417	74.6	959	73.8	1,385	75.1	981	73.9
Annual Rainfall	1,900	100.0	1,299	100.0	1,844	100.0	1,328	100.0

Notes: *1 : River Basin
*2 : The monthly and seasonal rainfall is in mm
*3 : Ratio to the annual rainfall in mm
*4 : Dry season - May to October, Rainy season - November to April

The probability of maximum annual rainfall occurring was calculated for each river basin using the Gumbel method and the results are shown in Figure 7-3-3 and Table 7-3-3.

Table 7-3-3 Maximum Possible Rainfall in the River Basins

Return Period (years)	Tijamuchi River Basin (mm/year)	Mamoré River Basin (mm/year)	Ibare River Basin (mm/year)	Whole Basin (mm/year)
5	2,000	1,420	2,090	1,450
10	2,140	1,510	2,260	1,540
20	2,280	1,610	2,430	1,630
30	2,360	1,660	2,520	1,690
50	2,460	1,730	2,640	1,760
100	2,590	1,820	2,800	1,850

(2) Maximum Discharge of Rivers

a) Flood control model

The analysis of the river discharge was carried out over a long period of time because the data for the water stage of the Mamoré and Ibare Rivers covers a period of less than 5 years. The typical volume curves for the heights of the water stage (H) and the storage water (V) are shown in Figure 7-3-4. The hydraulic analysis model used for the flood area is shown in Figure 7-3-5.

The serial tank model analysis shown in Figure 7-3-6 was used to forecast the discharge of rivers and as a means to model flood control measures. The model shows that rainfall is successively infiltrated into the underground and outflows to the surface at each level. The upstream area in the road project acts as a role of a water reservoir.

The flowcharts used in the determination of parameters for the serial tank model and in the flood control simulation using the serial tank model are shown in Figures 7-3-7 and 7-3-8, respectively. The parameters for the serial tank model, as shown in Table 7-3-4, were determined by means of a simulation based on daily records of the water level of the Mamoré river at Puerto Ganadero, as well as on rainfall data from 1981 and 1982.

The serial tank model simulation of the Mamoré River produced a hydrography that closely corresponded to that of present hydrographical conditions as shown in Figure 7-3-8.

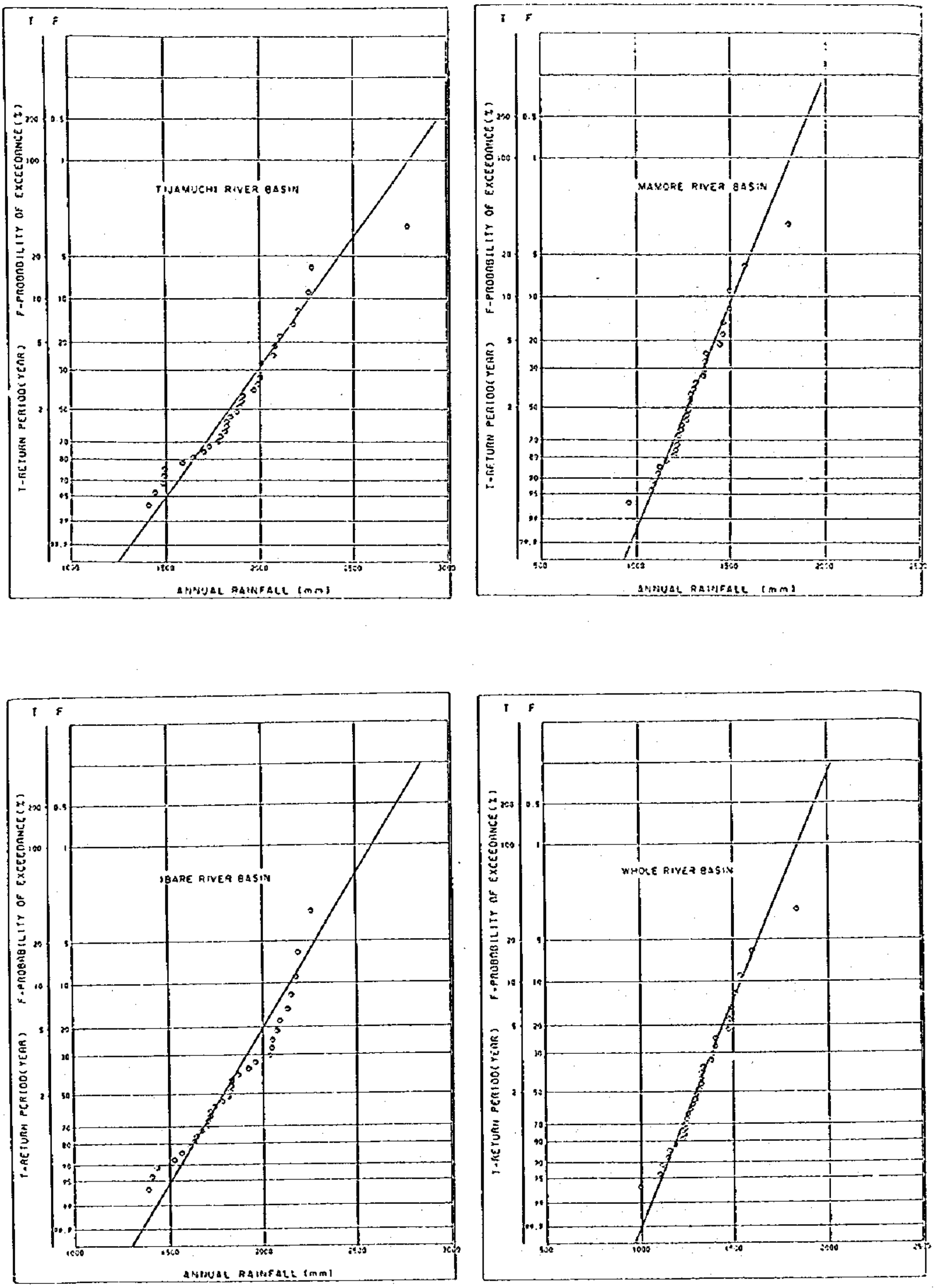


Figure 7-3-3 Probability of Annual Rainfall in the River Basins

Note: The water stages of Ports Almacén, Varador and Tijamuchi, represent the Ibare, Mamoré and Tijamuchi rivers respectively.

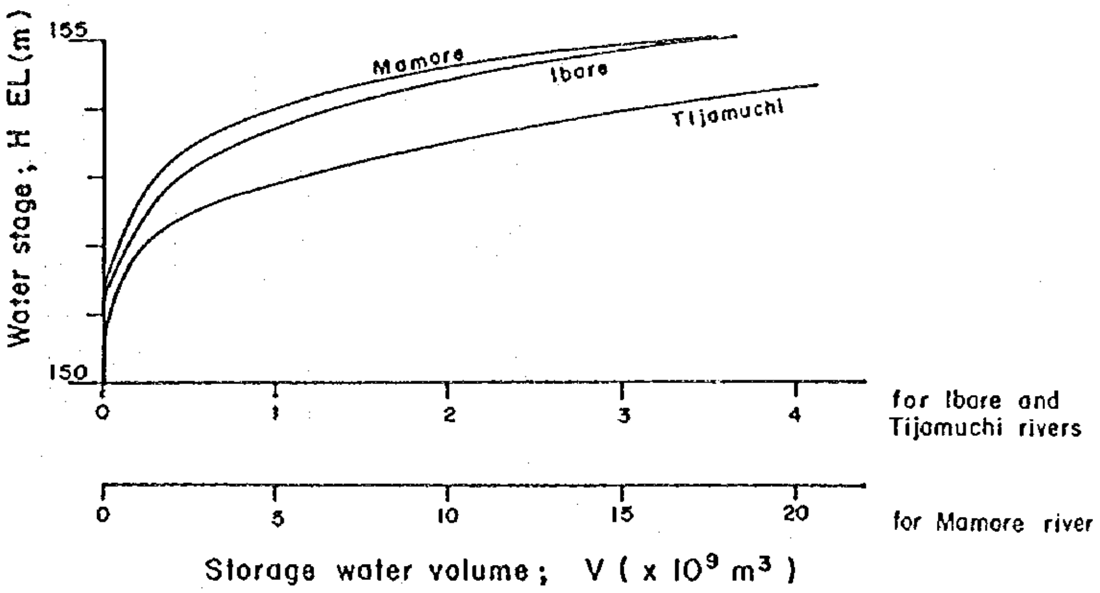
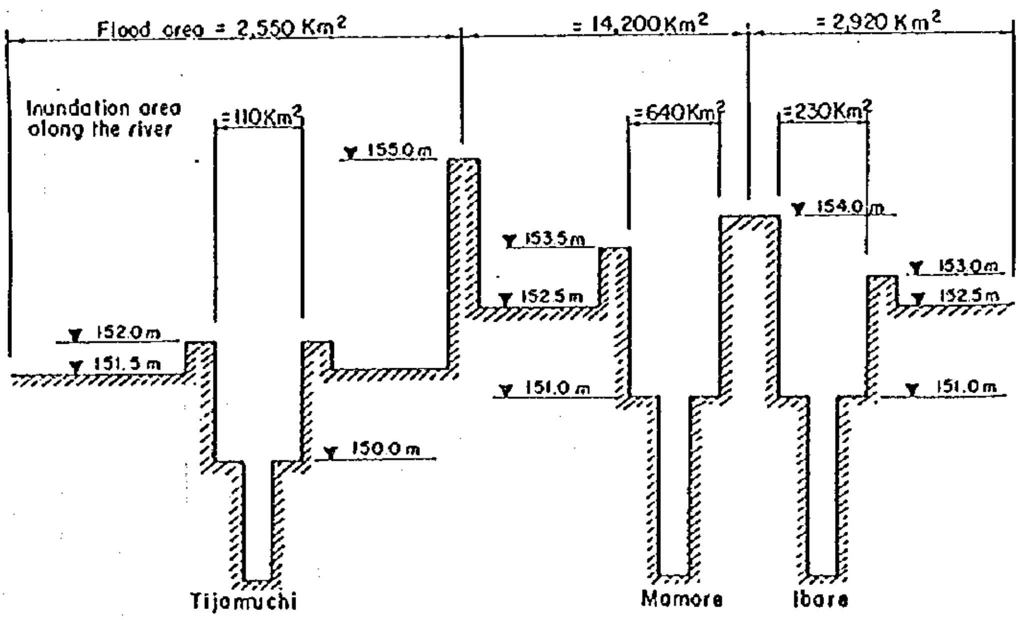


Figure 7-3-4 H-V Volume Curves of the River Basins

a. H – V Curves of Flood Areas



b. Cross Section of the Flood Area along the Project Road

Figure 7-3-5 Hydraulic Analysis Model

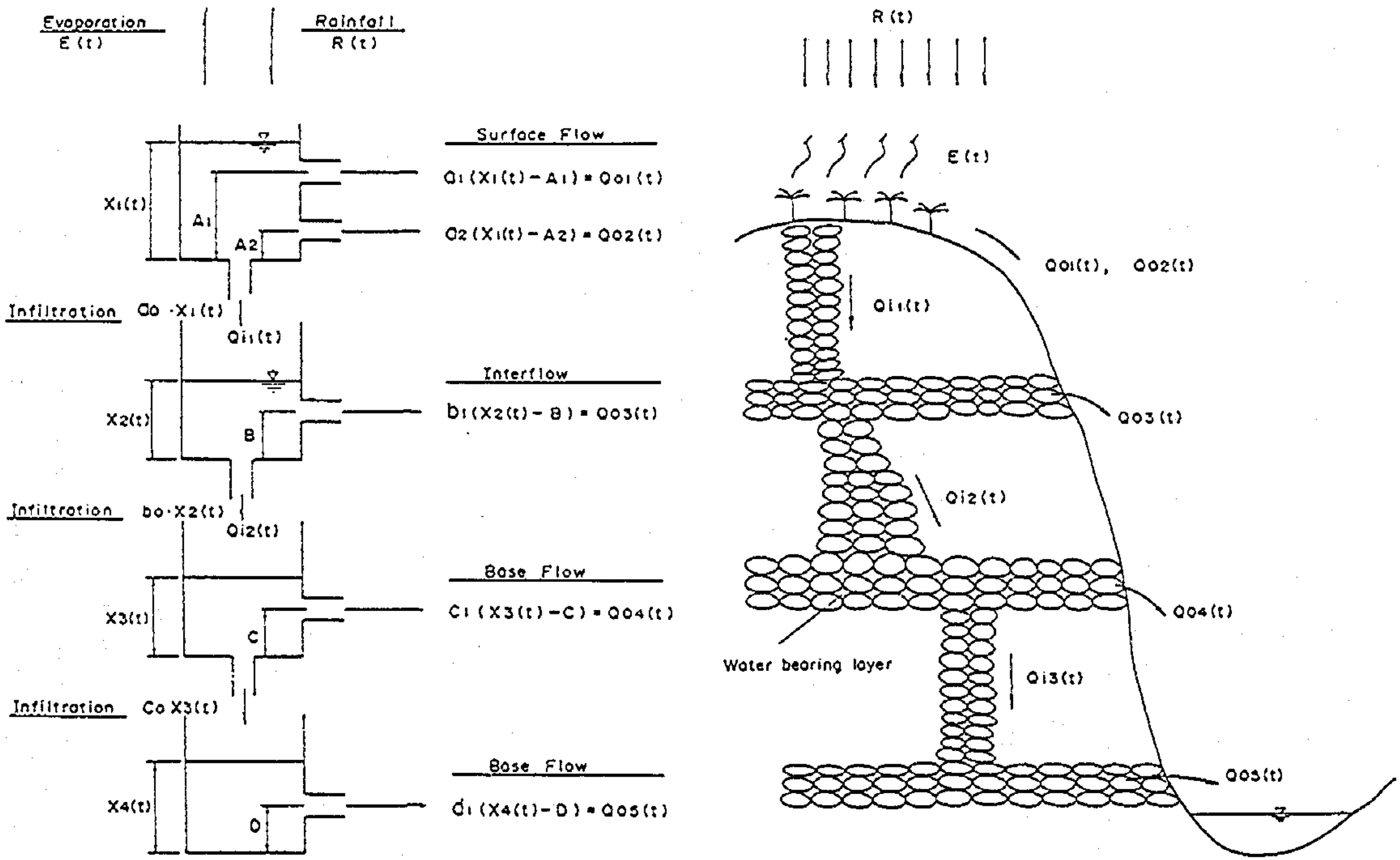


Figure 7-3-6 Serial Tank Model for the Hydrological Analysis

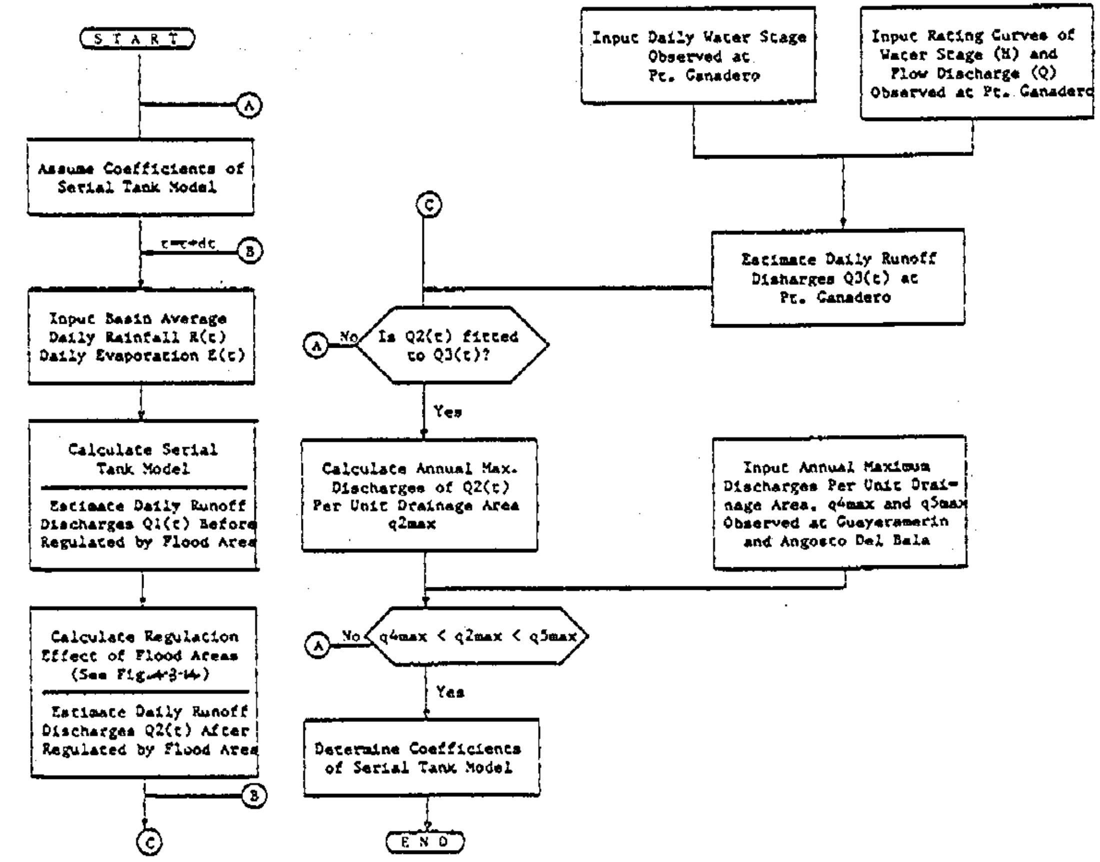
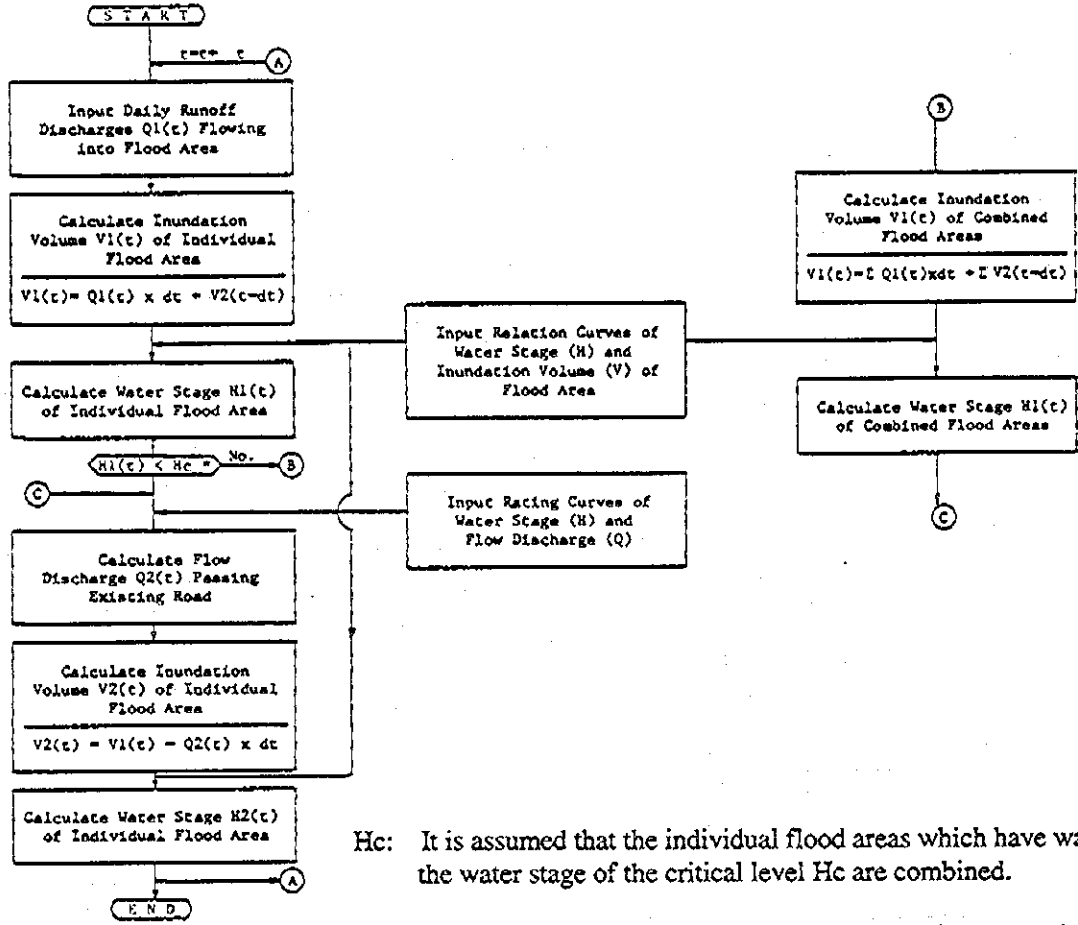


Figure 7-3-7 Flowchart for the determination of Parameters for the Serial Tank Model



Hc: It is assumed that the individual flood areas which have water stages that exceed the water stage of the critical level Hc are combined.

Hc between the flood areas of the Ibare and Mamoré rivers: Elevation 154.0 m

Hc between the flood areas of the Mamoré and Tijamuchi rivers: Elevation 155.0 m

Figure 7-3-8 Flowchart for the Hydrological Analysis

The parameters for the flood control simulation of the Tijamuchi and Ibare Rivers (shown in Table 7-3-4) were determined by means of a multiplier coefficient that was calculated using the following formula:

$$X_i = XM_i \times \left(\frac{am}{a}\right)^{1/2}$$

where,

X_i = Assumed runoff coefficient in the Tijamuchi and Ibare river basins

XM_i = Assumed runoff coefficient in the Tijamuchi river basin

am = Catchment area of the Mamoré river

a = Catchment area of the Tijamuchi and Ibare rivers

Table 7-3-4 Parameters for the Flood Control Model of the Tijamuchi, Mamoré, and Ibare River Basins

Parameter	Symbol*	Mamoré River Basin (166,430 m²)	Ibare River Basin (6,720 m²)	Tijamuchi River Basin (6,260 m²)
A. Multiplier				
1. First tank				
• Runoff orifice (superior)	a1	0.014	0.070	0.072
• Runoff orifice (inferior)	a2	0.009	0.045	0.046
• Infiltration orifice	a0	0.002	0.010	0.010
2. Second tank				
• Runoff orifice	b1	0.002	0.010	0.010
• Infiltration orifice	b0	0.002	0.010	0.010
3. Third tank				
• Runoff orifice	c1	0.0005	0.0025	0.0026
• Infiltration orifice	c0	0.0005	0.0025	0.0026
4. Fourth tank				
• Runoff orifice	d	0.0002	0.0002	0.0002
B. Height of the runoff orifice (mm)				
1. First tank				
• Superior	A1	30	30	30
• Inferior	A2	10	10	10
2. Second tank	B	10	10	10
3. Third tank	C	10	10	10
4. Fourth tank	D	0	0	0
C. Initial storage height (mm)**				
1. First tank	X1	0	0	0
2. Second tank	X2	0	0	0
3. Third tank	X3	0	0	0
4. Fourth tank	X4	165	165	165

Note : * See Figure 4-3-12

** On October 1, when the basin storage level is at is minimum.

As a result of the simulation of the Tijamuchi River using the serial tank model, the maximum water stage of the river, which has an elevation of 153.54 m, corresponds to the maximum water stage registered between 1951 and 1982, as shown in Table 7-3-6.

On the other hand, the parameters for the Maniqui and Apere-Matos River basins (shown in Table 7-3-5) were calculated based on the following conditions:

- The determining factors of the serial tank model are the same of those of the Tijamuchi River.

• The hydrological data, including rainfall, evaporation, etc., is the same as that of the Tijamuchi River.

Table 7-3-5 Parameters for the Flood Control Model of the Maniqui and Matos-Apere River Basins

Parameter	Symbol*	Matos-Apere River Basin (7,120 m²)	Maniqui River Basin (3,140 m²)
A. Multiplier			
1. First tank			
• Runoff orifice (superior)	a1	0.068	0.102
• Runoff orifice (inferior)	a2	0.044	0.066
• Infiltration orifice	a0	0.010	0.066
2. Second tank			
• Runoff orifice	b1	0.010	0.015
• Infiltration orifice	b0	0.010	0.015
3. Third tank			
• Runoff orifice	c1	0.002	0.004
• Infiltration orifice	c0	0.002	0.004
4. Fourth tank			
• Runoff orifice	d	0.0002	0.0002
B. Height of the runoff orifice (mm)			
1. First tank			
• Superior	A1	30	30
• Inferior	A2	10	10
2. Second tank	B	10	10
3. Third tank	C	10	10
4. Fourth tank	D	0	0
C. Initial storage height (mm)**			
1. First tank	X1	0	0
2. Second tank	X2	0	0
3. Third tank	X3	0	0
4. Fourth tank	X4	165	165

Note: * See Figure 4-3-12
** On October 1, when the basin storage level is at is minimum.

(2) Annual Maximum Discharge and Water Stage

The annual maximum values for the water stage, discharge of rivers, and overflow as determined by means of the simulation method explained above, are shown in Tables 7-3-6, 7-3-7, and 7-3-8, respectively. The maximum discharge of the Mamoré river is approximately ten times that of the Tijamuchi and Ibare Rivers. The elevation of the water stage of the Tijamuchi River is lower than that of either the Mamoré or Ibare River. Therefore, the river basins of the Tijamuchi, Mamoré and Ibare Rivers are independent of each other. The water from the Ibare river flows into the Mamoré River, and, in the same way, the water from the Mamoré River flows into the Tijamuchi River after it overflows the natural levee of each river.

Table 7-3-6 Maximum Water Stage in the River Basins

(Unit : m)

Hydrological Year	Tijamuchi River Basin	Mamoré River Basin	Ibare River Basin
1951	152.35	153.27	153.97
1952	152.39	153.64	153.27
1953	152.46	152.34	153.27
1954	152.40	153.46	153.76
1955	152.37	153.54	153.04
1956	153.14	154.38	153.14
1957	152.72	153.05	153.96
1958	152.18	152.77	152.93
1959	152.84	154.06	154.06
1960	152.37	152.51	152.54
1961	152.10	152.47	152.55
1962	152.98	153.52	153.97
1963	152.09	153.64	153.01
1964	153.38	153.90	153.90
1965	152.18	153.00	153.98
1966	152.57	152.39	153.14
1967	151.98	152.73	153.13
1968	152.68	153.70	153.46
1969	152.25	152.16	152.97
1970	151.43	152.67	153.24
1971	152.48	152.50	153.65
1972	152.46	152.45	152.68
1973	152.34	152.17	153.37
1974	152.85	154.23	154.23
1975	152.84	153.54	153.40
1976	153.10	153.97	153.87
1977	152.33	154.16	154.16
1978	152.65	153.51	153.62
1979	152.26	154.41	154.41
1980	153.25	153.53	153.97
1981	152.80	154.16	154.16
1982	153.54	154.47	154.47
Average	152.85	153.32	153.59

(3) Forecasting the Water Stage and Discharge in the River Basins

a) Probable water stage

The results of the simulation method utilized to determine the elevation of the water stage in the individual flood areas are shown in Figures 7-3-9 to 7-3-11 and Table 7-3-9, respectively. The elevations of the water stages of the Tijamuchi, Mamoré and Ibare Rivers (which are 153.54 m, 154.47 m and 154.47 m, respectively, and the maximum water stages registered in the hydrological year of 1982) correspond to a 10-year return period for the water stage of each river basin. The flood in 1982, which corresponds to a 10-year return period was generated by the rainfall of a 100-year return period. Therefore, as a countermeasure, drainage facilities must be designed to support water stages for 10 and 20-year return periods.

Table 7-3-7 Maximum Discharge in the Upper Part of the Road Project

Hydrological Year	Tijamuchi River Basin		Mamoré River Basin		Ibare River Basin	
	*1	*2	*1	*2	*1	*2
1951	1,148	357	9,438	576	1,312	811
1952	2,252	961	10,882	887	1,202	254
1953	1,232	404	8,193	142	979	660
1954	1,204	379	10,026	664	1,210	258
1955	1,219	366	10,431	737	852	113
1956	1,704	760	14,235	4,420	1,204	526
1957	1,489	527	9,341	477	1,525	317
1958	1,141	296	9,159	346	780	103
1959	1,839	590	12,450	1,593	1,249	358
1960	1,249	283	8,646	244	700	78
1961	1,173	274	8,253	207	807	79
1962	1,863	659	10,158	706	2,519	320
1963	1,149	271	10,368	886	749	109
1964	2,548	954	11,015	1,255	1,349	299
1965	1,156	298	9,805	454	1,366	324
1966	1,375	454	8,062	168	1,013	128
1967	805	242	7,143	0	823	126
1968	1,769	506	10,666	969	1,107	182
1969	1,193	319	7626	58	1,018	105
1970	783	145	7,060	0	877	141
1971	1,329	409	8,648	217	1,100	227
1972	1,345	403	8,343	195	893	87
1973	1,250	355	7,683	64	921	166
1974	1,528	594	12,559	2,429	921	434
1975	1,796	587	10,080	739	1,168	170
1976	1,657	733	11,584	1,367	852	290
1977	1,323	350	13,317	2,030	1,289	405
1978	1,399	494	9,891	695	1,201	211
1979	1,033	320	15,327	4,925	1,223	555
1980	1,774	834	10,344	720	1,337	321
1981	1,430	568	12,465	1,992	1,271	402
1982	2,709	1,171	13,699	5,858	1,541	930
Average	1,464	496	10,216	1,164	1,136	743

Notes: *1 : Maximum discharge in m^3/s
*2 : Maximum regulated volume in 10^6 m^3

In the case of the Tijamuchi, Mamoré and Ibare River basins, the maximum elevation of the water stage to be used in the design of the drainage facilities was set at 154.8 m. The reasons leading the establishment of this value are as follows:

- The elevation of 154.8 m corresponds to a water stage for a 20-year flood return period.
- This water stage is higher than that registered by the Mamoré River in 1982.
- This water stage is higher than that of the Tijamuchi River and was used in the flood control simulation for the Tijamuchi and Ibare River basins.

Table 7-3-8 Maximum Overflow throughout the Road Project

(Unit: m³/s)

Hydrological Year	Tijamuchi River Basin *1	Tijamuchi River Basin *2	Tijamuchi River Basin *3	Mamoré River Basin *1	Mamoré River Basin *2	Mamoré River Basin *3	Ibare River Basin *1	Ibare River Basin *2	Ibare River Basin *3
1951	337	384	761	7,933	1,161	9,094	714	97	811
1952	453	768	1,221	8,502	1,232	9,734	687	83	762
1953	385	420	804	6,591	1,042	7,633	603	57	660
1954	380	401	781	8,226	1,196	9,422	680	84	764
1955	378	390	768	8,342	1,211	9,552	569	46	614
1956	434	663	1,097	9,685	1,420	11,105	783	126	909
1957	403	506	910	7,611	1,128	8,739	712	96	809
1958	365	334	699	7,200	1,091	8,291	554	41	595
1959	412	450	962	9,167	1,332	10,498	729	103	833
1960	362	321	683	6,834	1,062	7,895	498	26	524
1961	360	313	672	6,783	1,057	7,840	499	26	526
1962	422	600	1,022	8,309	1,206	9,515	714	97	811
1963	359	310	669	8,501	1,232	9,733	564	44	609
1964	452	765	1,217	8,902	1,290	10,192	702	92	795
1965	365	336	701	7,537	1,120	8,657	716	98	814
1966	392	455	848	6,669	1,048	7,717	584	51	635
1967	352	282	633	7,143	0	7,143	582	50	632
1968	400	492	891	8,589	1,244	9,834	633	67	700
1969	370	357	727	6,351	1,022	7,373	558	43	601
1970	316	156	472	7,060	0	7,060	598	55	653
1971	385	424	809	6,813	1,060	7,873	662	77	739
1972	384	419	803	6,747	1,054	7,801	517	31	549
1973	376	382	759	6,368	1,023	7,391	619	62	681
1974	412	553	966	9,437	1,376	10,813	757	115	872
1975	411	548	960	8,343	1,211	9,554	623	63	686
1976	430	646	1,077	9,026	1,993	10,335	697	90	788
1977	375	379	754	9,332	1,358	10,691	747	110	857
1978	398	482	881	8,297	1,205	9,502	658	76	734
1979	370	357	728	9,736	1,430	11,165	788	128	916
1980	442	709	1,152	8,323	1,208	9,532	714	97	811
1981	409	535	944	9,322	1,358	10,679	745	110	855
1982	464	833	1,297	9,830	1,447	11,277	798	132	930
Average	393	471	865	8,047	1,129	9,176	656	77	734

Notes: *1 : Maximum discharge in the river (m³/s)
*2 : Maximum discharge that overflows the road section (m³/s)
*3 : Total discharge volume (m³/s)

Table 7-3-9 Probable Water Stage in the Flood Areas

(Unit: elevations are in meters)

Return Period (years)	Tijamuchi River Basin	Mamoré River Basin	Ibare River Basin
2	152.5	153.2	153.5
5	153.0	153.9	154.0
10	153.3	154.4	154.4
20	153.6	154.8	154.8
30	155.1*	155.1	155.1*
50	155.4*	155.5	155.4*
100	155.8*	155.8	155.8*

Note : * The values for the elevation of the water stages are the same of those for the Mamoré River, assuming that all the flood areas are united.

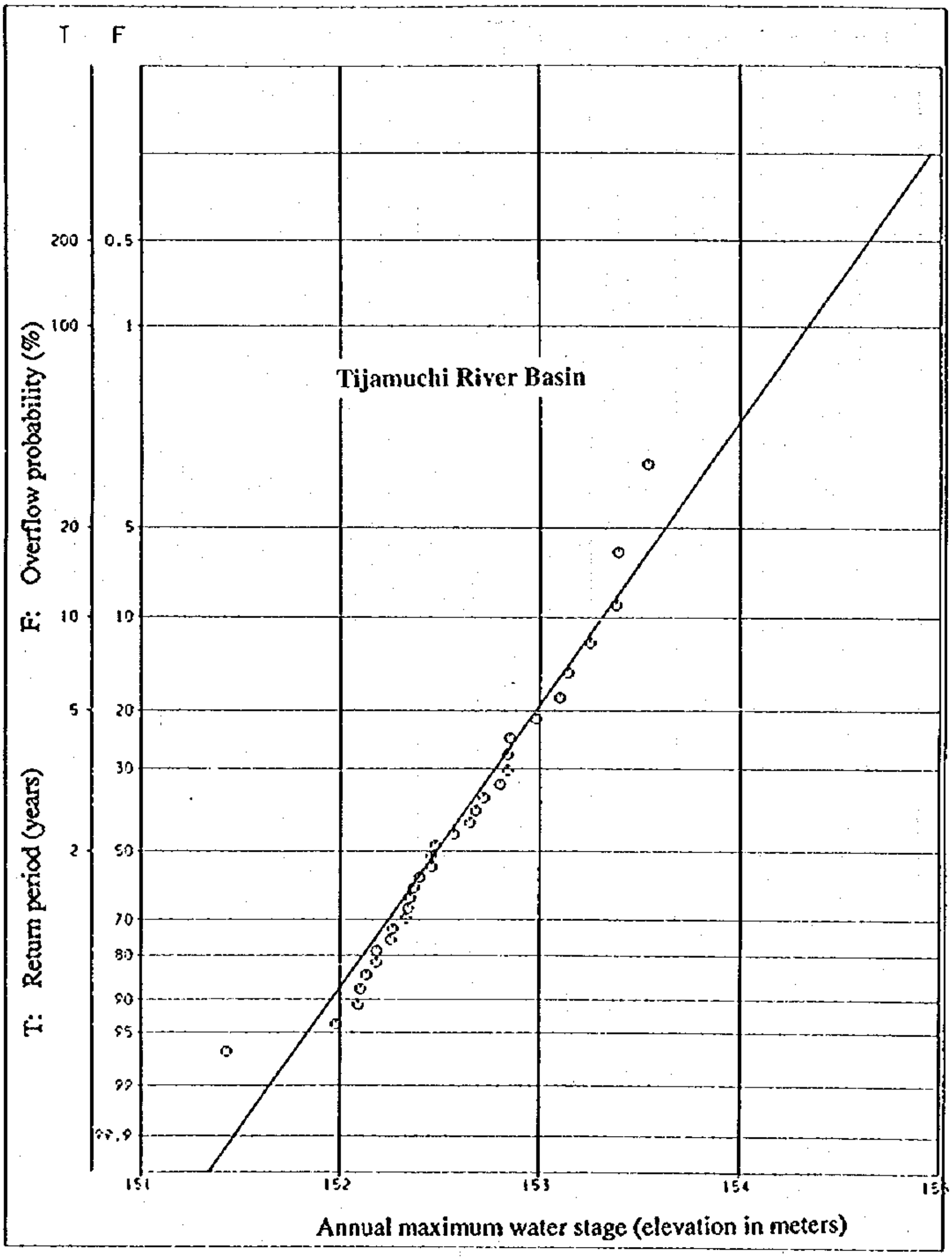


Figure 7-3-9 Overflow Probability of the Annual Maximum Water Stage in the Tijamuchi River Basin

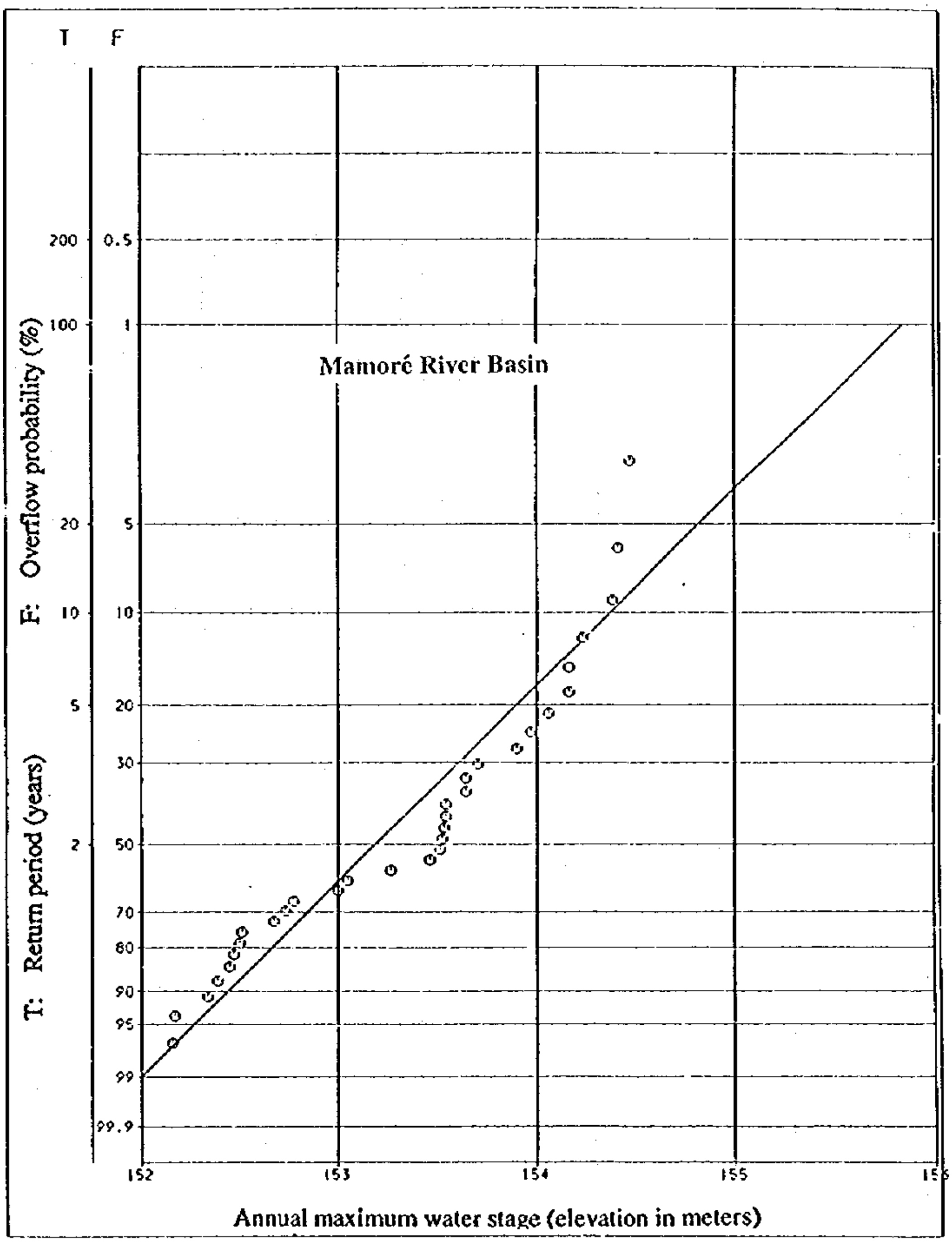


Figure 7-3-10 Overflow Probability of the Annual Maximum Water Stage in the Mamoré River Basin

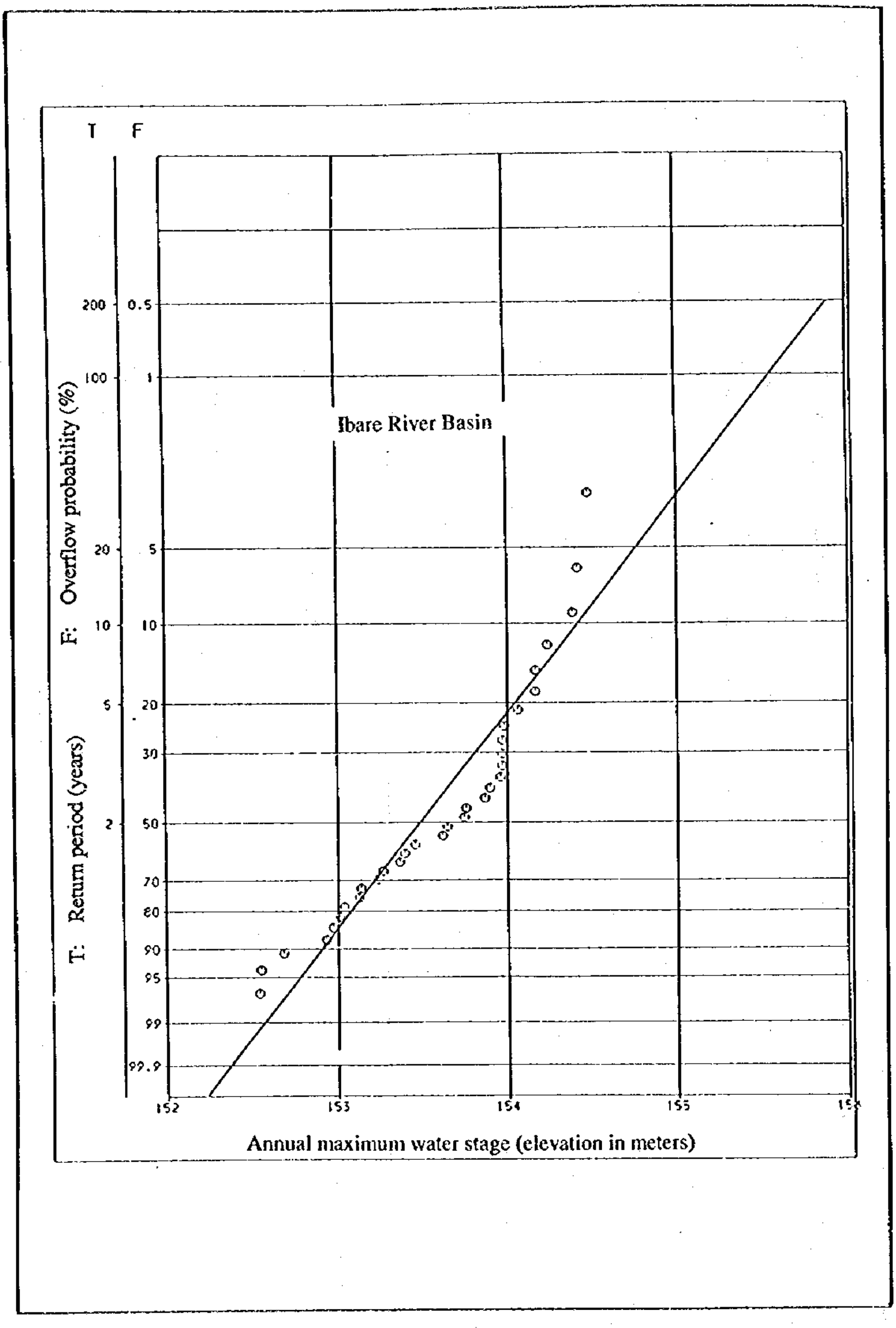


Figure 7-3-11 Overflow Probability of the Annual Maximum Water Stage in the Ibare River Basin

Based on an elevation of the water stage equal to 154.8 m, the required discharge volume and water head difference for the road sections between Fátima- Tijamuchi, Tijamuchi-Mamoré and Ibare-Trinidad are shown in Table 7-3-10. The water course of the Maniqui River can be discharged by the river itself. However, the Matos-Apere River basin has a runoff drainage capacity of approximately 60%, which means that the remaining 40%, or approximately 600 m³/s, should be drained the drainage facilities.

Table 7-3-10 Required Discharge and Water Head Difference *1

Item	Matos-Apere	Fátima-Tijamuchi	Tijamuchi-Mamoré	Ibare-Trinidad
1. Required discharge volume (m³/s)	600	560	280	120
2. Expected maximum water level (elev. in m)	160.3	153.5	153.5	154.5
3. Water depth (m) *2	1.0	2.5	1.9	2.9
4. Water head difference (m)	0.15	0.10	0.10	0.01

Note - *1 : Corresponds to a 10-year flood return period.
*2 : Average water depth at the places where some drainage facilities may be constructed.

The allowable runoff for the road section between San Borja and San Ignacio, based on a 10-year flood return period, is shown in Table 7-3-11.

Table 7-3-11 Allowable Discharge between San Borja and San Ignacio

River Name (River Basin)	Roughness Coefficient	Longitudinal Gradient	High Water Level (m)	Flow Area (m²)	Flow Velocity (m/s)	Flow Capacity (m³/s)	Design Discharge (m³/s)
1. Maniqui	0.050	1/2,500	193.2	687	1.24	852	850
2. Matos-Apere							1,410
• Curiraba	0.060	1/3,000	189.3	57	0.48	27	-
• Curirabita	0.060	1/3,000	187.9	38	0.47	18	-
• Matos	0.060	1/3,500	171.5	85	0.50	42	-
• Chebejecure	0.060	1/3,500	163.0	47	0.50	23	-
• Museruna	0.060	1/3,500	161.6	66	0.54	36	-
• Mururita	0.060	1/3,500	160.3	36	0.45	16	-
• Cuverene	0.050	1/5,000	160.3	252	0.75	190	-
• Apere	0.050	1/5,000	160.2	490	0.93	457	-

b) Forecasting the water stage on the road improvement

Present conditions along the Tijamuchi, Mamoré and Ibare Rivers are relatively open-ended. Specifically, plans are in place to construct a bridge across the Tijamuchi River and to use a ferry boat on the Mamoré River; a bridge has already been constructed across the Ibare River. In general, the existing conditions of the flood area, except for the three rivers mentioned above, are relatively open because the water in the flood area has over-flowed along the existing road.

The results of the serial tank model simulation under the existing conditions and under closed conditions for the road embankment in the flood area are shown in Table 7-3-12. Using the correlation between the existing conditions and the closed conditions for the embankment, the peak water stage is estimated to rise in elevation from 29 to 59 cm; it was also estimated that the number of flooded days would also increase, ranging from 20 to 95 days depending on the prevailing conditions.

Table 7-3-12 Forecasting Flood Conditions

Study Case	Existing Conditions	Closed Conditions
1. Conditions of the river basins		
• Tijamuchi:		
♢River	Open	Open
♢Flood area	Open	Closed
• Mamoré:		
♢River	Open	Open
♢Flood area	Open	Closed
• Ibare:		
♢River	Open	Open
♢Flood area	Open	Closed
2. Calculation results for the three river basins		
a. Peak water stage (elevation in m)*1		
• Tijamuchi River basin	153.54	154.13
• Mamoré River basin	154.47	154.76
• Ibare River basin	154.47	154.76
b. Peak discharge (m^3/s)*2		
• Tijamuchi River basin	1,280	510
• Mamoré River basin	11,190	10,320
• Ibare River basin	930	850
c. Peak flood depth (m)*3		
• Tijamuchi River basin	1.77	2.07
• Mamoré River basin	1.73	1.88
• Ibare River basin	1.73	1.88
d. Peak storage water volume (10^9 m^3)		
• Tijamuchi River basin	1.17	3.84
• Mamoré River basin	5.87	11.77
• Ibare River basin	0.61	1.07
e. Flood period (days)		
• Tijamuchi River basin	164	259
• Mamoré River basin	141	172
• Ibare River basin	135	135

Notes *1: On the upstream side of the road project
*2: Throughout the road project
*3: Average for the flood area

c) Drainage

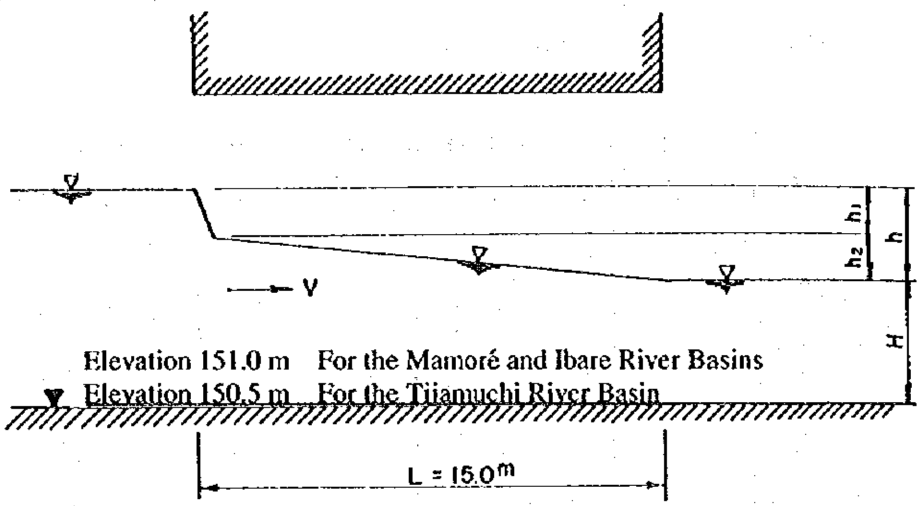
According to the project design, numerous culverts consisting of steel corrugated pipes and bridges will be installed in order to drain the stagnant to the upstream side of the project road. The drainage capacity of such facilities was calculated by using the formulas shown in Figure 7-3-12. The number and capacity of the drainage facilities on the road section between Fátima and Trinidad are shown in Table 7-3-13. The location of such facilities along the road project is shown in Figure 7-3-13. The total drainage capacity of this road section will be 1,003.78 m³/s.

Table 7-3-13 Drainage Facilities between Fátima and Trinidad

Type of Structure	Capacity (m³/s)	Number of Units	Total Capacity (m³/s)
(1) Fátima-Tijamuchi Section			
1. Steel corrugated pipes (diameter)			
• 0.90 m	0.66	1	0.66
• 1.20 m	1.33	2	2.26
• 1.50 m	2.26	1	2.26
• 1.80 m	2.90	1	2.90
• 2.10 m	4.20	2	8.40
• 2.40 m	5.77	5	28.85
• 2.70 m	7.61	3	22.83
• 3.00 m	9.73	25	243.25
2. Bridge			
• Length: 30 m	253.90	1	253.90
Total			565.71
(2) Tijamuchi-Mamoré Section			
1. Steel corrugated pipes (diameter)			
• 1.50 m	2.26	2	4.52
• 2.70 m	7.61	7	53.27
• 3.00 m	9.73	6	58.38
2. Bridge			
• Length: 30 m	253.90	1	186.90
Total			303.07
(3) Ibare-Trinidad Section			
1. Bridge			
• Length: 25.46m	45.00	1	135.00
Total			135.00

The results of the serial tank model simulation are shown in Table 7-3-14. The peak water stage and flood period are 154.46 m and 163 days, respectively. As can be seen, these values are slightly lower than those that prevail throughout the entire flood area. Results of the drainage capacity calculation show that the total capacity (1,003.78m³/s) of the area's numerous drainage facilities is sufficient to discharge the water volume (approximately 600m³/s) to be drained along the road section between Fátima and Trinidad.

This indicates that the seasonal flood area that is formed by the Tijamuchi, Mamoré, and Ibare Rivers during the wet season will not expand due to the construction of the road embankment and the presence of sufficient drainage facilities.



where:

B: Width (3 m)
N: Roughness coefficient (0.04)
V: Velocity of the stream flow (m/s)
Q: Volume of flow (m^3/s)

(1) Entrance loss: h_1

$$h1 = 0.4 \times \frac{V^2}{2g}$$

(2) Loss by friction: h_2

$$h2 = \left\{ \frac{H \times V}{\left(\frac{H \times B}{2H \quad B}\right)^{2/3}} \right\}^2 \times L$$ ...... Manning's Equation

(3) Total loss: $h_1 + h_2$

$$h = h1 \quad h2$$

$$= \left\{ \frac{0.4}{2g} \quad \frac{N^2 \times L}{\left(\frac{H \times B}{2H \quad B}\right)^{4/3}} \right\} \times V^2$$

Consequently,

$$V = \sqrt{\frac{h}{\frac{0.4}{2g} \quad \frac{N2 \times L}{2H\left(\frac{H \times B}{B}\right)^{4/3}}}}$$

$$Q = V \times B \times (H \quad \frac{h2}{2})$$

Figure 7-3-12 Hydraulic Characteristics of the Drainage Facilities in the Project Road

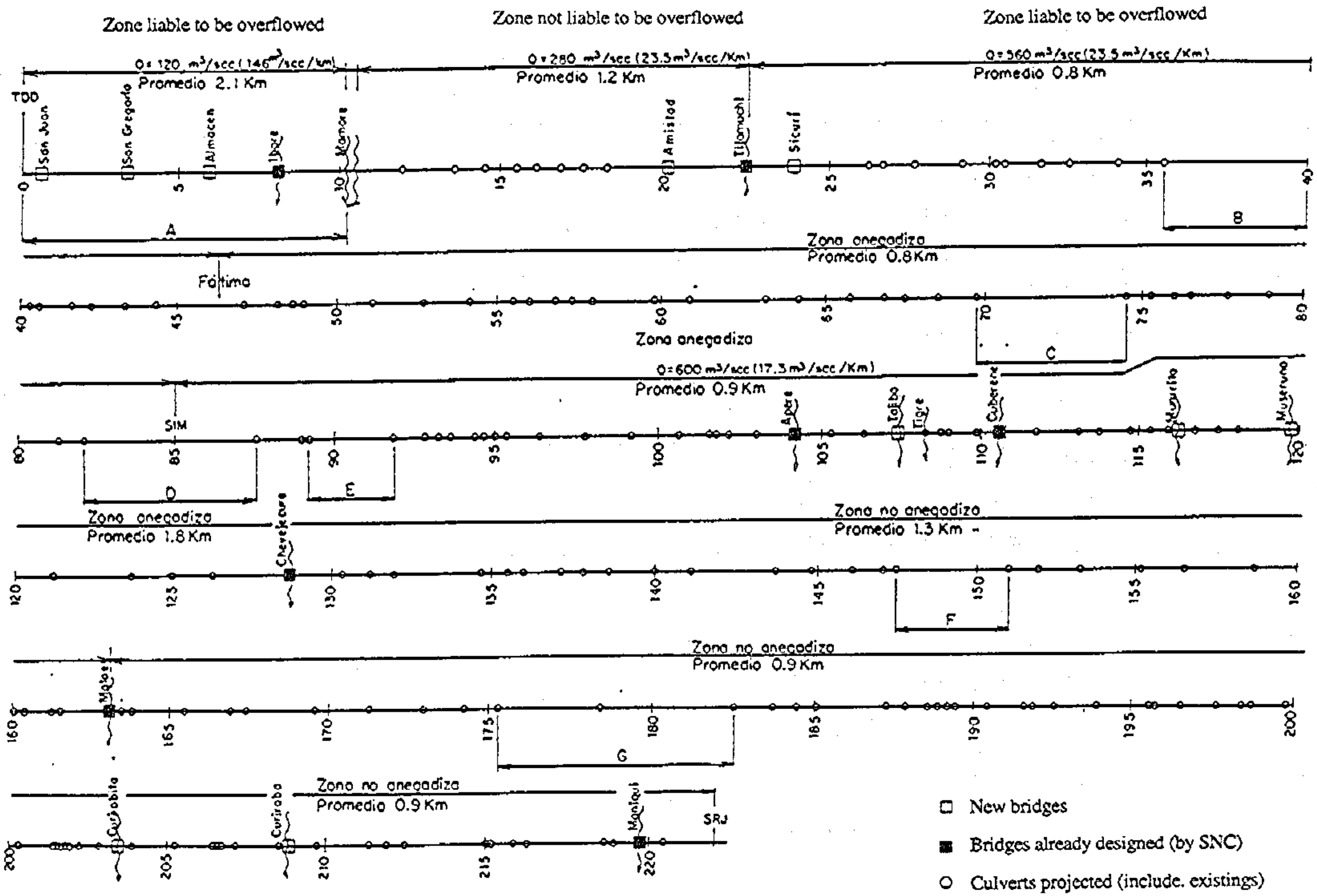


Figure 7-3-11 Location of Drainage Facilities throughout the Project Road

Table 7-3-14 Forecasting of Drainage Conditions

Study Case	Existing Conditions	Closed Conditions
1. Conditions of the river basins		
• Tijamuchi:		
✧River	Open	Open
✧Flood area	Open	Drainage by pipes
• Mamoré:		
✧River	Open	Open
✧Flood area	Open	Drainage by pipes
• Ibare:		
✧River	Open	Open
✧Flood area	Open	Drainage by pipes
2. Calculation results for the three river basins		
a. Peak water stage (elevation in m)*1		
• Tijamuchi River basin	153.54	153.50
• Mamoré River basin	154.47	154.46
• Ibare River basin	154.47	154.46
b. Peak discharge (m^3/s)*2		
• Tijamuchi River basin	1,280	1,310
• Mamoré River basin	11,190	11,190
• Ibare River basin	930	970
c. Peak flood depth (m)*3		
• Tijamuchi River basin	1.77	1.76
• Mamoré River basin	1.73	1.73
• Ibare River basin	1.73	1.73
d. Peak storage water volume (10^9 m^3)		
• Tijamuchi River basin	1.17	1.09
• Mamoré River basin	5.87	5.89
• Ibare River basin	0.61	0.60
e. Flood period (days)		
• Tijamuchi River basin	164	163
• Mamoré River basin	141	141
• Ibare River basin	135	131

Notes *1: On the upstream side of the road project
*2: Throughout the road project
*3: Average for the flood area

7.4 Flora

7.4.1 Impact Caused by the Cleaving of Woods

The existing forest zones along the road project, such as the forest of the Biological Station of Beni (E.B.B.), the Forest of Chimanes, the Yacuma Regional Park forest, and various gallery forests, are generally cleaved within the right-of-way area (100 m wide) in the course of road improvement work. The cleaving area of forests is estimated at 579 ha. A considerable quantity of forest along the road will disappear, and the influence of such cleaving will extend a certain distance into the forests. The end result is a decrease in plant life and vegetation formation in the cleaving area.

7.4.2 Impact by Waste

The road improvement work will generate a very limited amount of waste, thus presenting no cause for concern regarding the impact on local flora.

7.5 Fauna

7.5.1 Impact Caused by the Cleaving of Woods

The forests along the project road include valuable forests such as the Biological Station of Beni (E.B.B.), the forests of Chimanes, the forests of Yacuma Regional Park, the gallery forests of the Matos and Apere Rivers, etc., all of which play an important role in the movement of fauna between the northern forests and the southern forests of the project road.

Therefore, any decrease of the size of the forest area along the road project would likely be accompanied by a decrease in the existing fauna whose habitat is located along the road.

Photo 7.5.1 Forests along the Project Road Near the Chevejecure River

7.5.2 Impact Caused by Earth Works

(1) Embankment

The road embankment will likely be an obstacle preventing small animals living near the project road from getting across the road.

(2) Side-borrow Pit

The borrow pits along the road should prove very useful for domestic and wild animals, especially in the dry season when they will serve as a source of water supply.

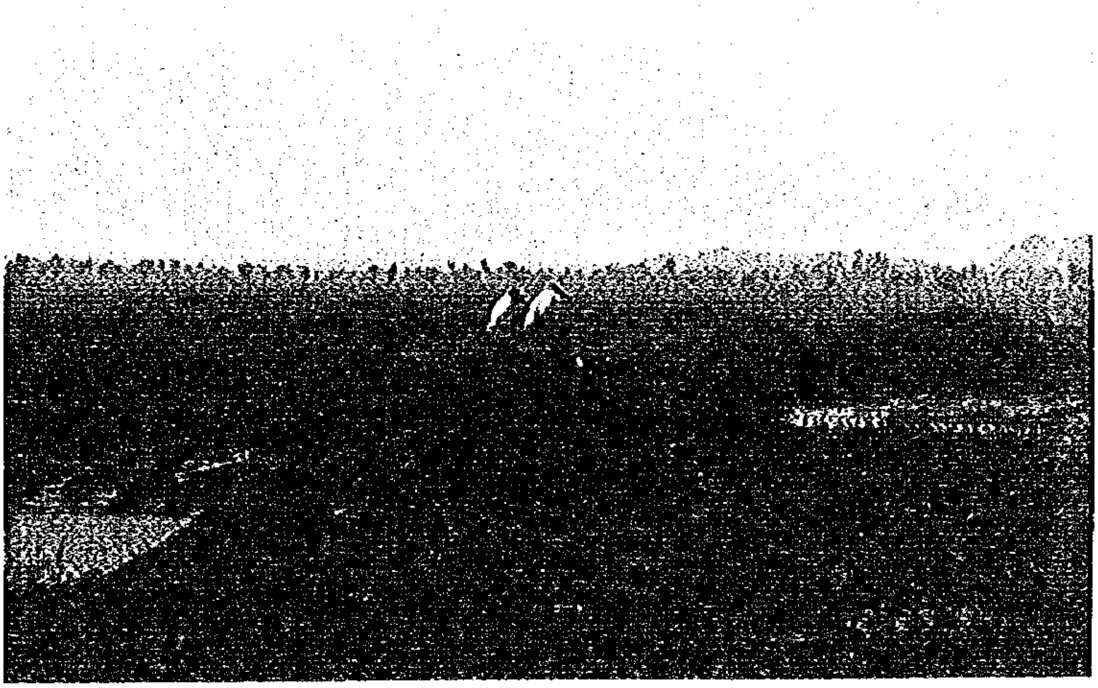


Photo 7.5.2 Side-borrow Pit near the Tijamuchi River

7.5.3 Impact Caused by Waste

The volume of waste expected to be generated by the road improvement is quite limited. Therefore, no serious impact on the fauna is expected.

However, as the volume of waste thrown from passing vehicles will likely increase after the road improvement, a slight impact on animals can be expected.

7.5.4 Impact Caused by Traffic

With the increase in traffic, traffic accidents involving animals crossing the road will increase. Especially, on the road section that passes through the gallery forest between the Matos and Apere Rivers, which is the habitat of many mammals.

Photo 7.5.3 A Deer Crossing the Project Road Near Venado de Los Pantanas (Museruna River)

7.6 Landscape

7.6.1 Impact Caused by the Cleaving of Woods

If the forests along the road project are cleaved with a width of 100 m according to the design, the landscape will be changed remarkably.

7.6.2 Impact Caused by Earth work

(1) Embankment

Although embankments will be built up along the project road, the road itself will remain a gravel road. Accordingly, the road itself will not greatly change the landscape.

(2) Side-borrow Pit

Because of By the side-borrow pitting, artificial ponds will be formed in several places along the project road. However, the ponds once formed for the road embankment have already harmonized with the surroundings in various places.

7.6.3 Impact Caused by Waste

A volume of the waste expected to be generated by road improvement is quite limited. Therefore, no serious change in the landscape is expected.

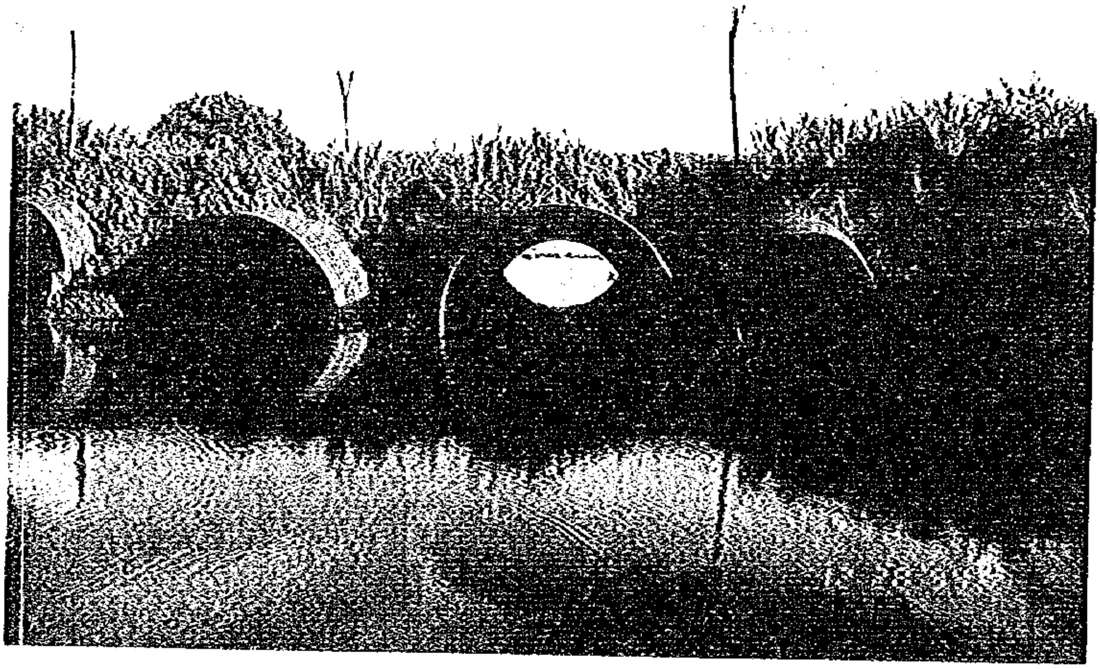
7.6.4 Impact Caused by Road Facilities

(1) Bridge

The landscape will be changed, and the degree of this change will depend on the color of the bridge piers and girders.

(2) Culvert

There will be no serious change in the landscape, since the culverts under the road will usually not be visible, although the corrugated steel pipes used for the culverts will not match the surroundings.



Photograph 7.6.1 Culverts (Corrugated Steel Pipes) between the Fátima and the Tijamuchi Rivers

7.7 Community

7.7.1 Forecasting the Impact on the Community

The San Borja-Trinidad road is already in existence. However, it is very difficult for vehicles to travel smoothly due to poor road conditions and the inundation of a road section 40 - 50 km west of Trinidad during the rainy season. Therefore, those who use this road have always suffered serious inconvenience. It is sure that if this road was improved to serve as an all-weather-road, many inconveniences would disappear completely. However, the improvement of this road could result in a an inhabitants living near the road. The impact on the social environment is enumerated below:

a) Positive Effect

① Communities located in this area would no longer be viewed as solitary islands.
② Population increase would be promoted by improved access to this area.
③ Central and local government policies could be implemented more efficiently.
④ Clinics and hospitals could be reached more quickly in cases of emergency.
⑤ Disasters and accidents could be reported promptly to the appropriate offices.
⑥ Higher education would be more accessible to people living in remote areas.
⑦ Members of different communities could intersect more frequently.
⑧ Regular buses could operate more punctually year round and more shops could be added to current routes.

b) Negative Effects

① There could be increased conflict between native peoples and new immigrants.
② Antagonism between native peoples without property titles and livestock farm owners with property titles might become more severe.
③ The number of traffic accidents might increase in local communities.

Comparing the above positive and negative effects, the benefits of the former far outweigh the problems associated with the latter.

7.7.2 Quantitative Analysis

Although it is very difficult to quantify the above effects, most of the positive ones are related to improved transportation, resulting in significant reductions in travel time. Accordingly, one way to quantify positive effects is by measuring the amount of time saved. In Figure 7-7-1, the time saving is calculated for travel between the core communities (San Borja, San Ignacio, and Trinidad). According to these results, persons who travel from San Borja to Trinidad could save 3.3 hours per trip. Accordingly, the benefits described in items ③ to ⑧ listed above are significant indeed.

Table 7-7-1 Time Saving among Core Communities

(unit : hours)

	Project	San Borja	San Ignacio	Trinidad
San Borja	Without	-	4.5	8.4
	With	-	2.8	5.1
	(Time Saving)	-	1.7	3.3
San Ignacio	Without	4.5	-	3.9
	With	2.8	-	2.3
	(Time Saving)	1.7	-	1.6
Trinidad	Without	8.4	3.9	-
	With	5.1	2.3	-
	(Time Saving)	3.3	1.6	-

Source : Study Team

On the other hand, the impact of the negative effects listed above will depend on the size of population, i.e., the greater the population increase, the more likely it is that conflicts and antagonism will occur. Therefore, recent population increases are examined below.

The San Borja - Trinidad road passes through four provinces in Beni: Ballivian, Yacuma, Moxos, and Cercado. The population change in these four provinces before and after the construction of the existing San Borja - Trinidad road is shown in Table 7-7-2.

Table 7-7-2 Population of Influenced Province in Beni

Province	1976	1992	Average Growth Rate (%)
Ballivian	24,789	47,420	4.1
Yacuma	15,714	25,068	3.0
Moxos	15,028	17,602	1.0
Cercado	35,172	63,128	3.7
Sub total	90,703	153,218	3.3
other provinces	77,914	122,956	2.9
Total	168,617	276,174	3.1

As seen in the above table, provinces influenced by the San Borja - Trinidad road construction showed a 3.3% population increase. On the other hand, the population increase in other provinces in Beni Department was only 2.9%. The difference of 0.4% is considered a rough indicator of the effects of road completion.

The completion of the Yucumo-Rurrenabaque road resulted in a population expansion of 4.15 times in communities along the road over a 16-year period (with an average growth rate was 9.3% per annum). Even though there were almost no communities in this area before the completion of the road, the impact of road construction was tremendously large. On the other hand, before the construction of the San Borja - Trinidad road, the city of Trinidad was already showing population increases. Therefore, although the situation was different than that surrounding the from the Yucumo - Rurrenabaque road, if the San Borja - Trinidad road had been improved as an all-weather road, the population increase would have been much higher.

Given that vehicles cannot pass through the existing San Borja - Trinidad road during the rainy season (which lasts almost half the year), the aforementioned increase of 0.4% would have been much greater if the road had been constructed as an all-weather road. Since the road is not passable for almost six months during the rainy season, an increase of 0.8% (0.4% × 2) would have resulted if the road had been usable year round. Therefore, if the San Borja - Trinidad road is improved, the population should increase at the average rate (the rate without road improvement) plus an additional 0.4%.

If the future population growth rate is assumed to be 3.3% per annum in the case of "No Improvement" listed in Table 7-7-2, the population of the aforementioned influenced provinces in Beni would reach 274,863 in 2010. On the other hand, since the population growth rate is assumed to be 3.7% per annum (3.3% + 0.4%), the population in this case would reach 285,693 in 2010. This population difference can be considered the result of population inflows from other areas. Since the average family size is 4.36 persons, about 2,484 additional families could be expected to settle in or around local communities, stoke farms, forest, etc. If these new immigrants did not abide by local laws and customs, the aforementioned negative effects would naturally increase. In short, more new immigrants mean increased conflict.

7.8 Economic Activities

7.8.1 Forecasting the Impact on Economic Activities

Good roads are essential to the development of a regional economy. By improving roads, transportation activities become much more efficient and significant time savings result, as shown in Table 7-7-1. On the other hand, road construction can have a to negative impact on the natural environment due to deforestation and other activities. The positive and negative effects of road construction on economic activities can be summarized as follows;

a) Positive effects

① Commodity flows will become more active not only among communities but also with outside areas.

② The existing agricultural and livestock industries with become much more active.

③ Commercial agglomeration will be promoted in core communities along the road.

④ New business will inflow from outside areas.

⑤ Overall unemployment levels might decrease.

⑥ Communication, with other region, become more efficient.

⑦ Real estate values along the road will increase.

b) Negative effects

① Illegal deforestation activities might increase.

② Competition for jobs among local inhabitants might increase.

③ Income disparities between the rich and the poor might become bigger.

Since the above positive effects would directly result form road improvement work, this is clearly a key opportunity to develop local industry.

On the other hand, road construction could promote deforestation along the road, which is considered a serious negative effect. However, this would mainly be the case for new roads that are built through forest areas. In cases of road improvement projects like the one in San Borja - Trinidad, deforestation would not be so severe as compared to cases of new road construction. On the other hand, savings on transportation time and vehicle operation costs resulting from road improvements would decrease the carryout cost for timber, which in turn decreases the timber supply and strengthens timber prices. As a result, deforestation activities might be promoted. Once demand exceeded supply in the domestic and foreign timber market, deforestation in the objective area would be promoted by using the improved San Borja - Trinidad road.

Another negative effect would be the increased disparity in income levels between the rich and poor due to land price increases associated with the road improvement work. In the objective area, it is not the custom for most habitants to hold property titles. However, the rich livestock owners do hold property titles and thus would benefit from increases in real estate value. Those persons without property titles could not obtain any benefit from such increases, and this would further polarize the rich and poor. The negative effects related to the struggle for jobs would disappear once the growth of the regional economy exceeded the increase in local population.

7.8.2 Quantitative Analysis

As shown in Table 2-2-6, the main industry in Beni Department is livestock, which in 1992 accounted for 26.4% of the total RGDP of Beni Department. Over the past five years, livestock production has not fluctuated so much, remaining steady at approximately 2.2 billion mark Bs. On the other hand, beef produced in Beni Department is sold mostly for domestic consumption. The export ratio is only 10.9%. Therefore, beef production in Beni Department depends mostly on domestic consumption, which is determined by population, increases in per capita income, and price. In Bolivia, the population and per capita income are increasing as shown in Table 2-2-3. If the price of beef decreases, the beef demand in Beni Department is likely to increase further.

The improvement of the San Borja - Trinidad road makes transportation costs lower, which results in price reductions. This price reduction will surely lead to an increase in beef demand in Beni Department. However, since there is no information on the price elasticity between increases in beef consumption and decreases in transportation costs, the effects of the improvement of the San Borja - Trinidad road can not be quantified at the moment. However, the increase in RGDP can be forecast as follow:

The RGDP and population of Beni Department in 1988 and 1992 are shown below.

Table 7-8-1 RGDP and Population of Beni Department

Year	RGDP	Population	RGDP/Population
1988	782,025	244,125	3.203
1992	849,725	276,174	3.076

Unit: RGDP and RGDP/Population are million Bs.
RGDP is at 1990 price.

The RGDP in Beni Department increased to 849,725 million Bs. in 1992 from 782,025 million Bs. in 1988, at an average growth rate of 2.1%. As the population grew at a higher rate of 3.1%, the per capita RGDP decreased from 3.2 million Bs. to 3.1 million Bs. As mentioned in section 7.8.2, in the year 2010, the population difference between the "Improvement Case" and the "Non-Improvement Case" of the San Borja - Trinidad road was estimated at 10,830 persons. If the per capita RGDP in Beni Department is assumed to be same as that of 1992 (3.1 million Bs.), the RGDP in the "Improvement Case" would exceed the RGDP of the "Non-Improvement Case" by 33,248 million Bs. This represents the quantitative benefit obtained from road improvement.

On the other hand, regarding deforestation, reflecting the recent intensive timber demand, the volume of timber sold has been increasing. The rate of this increase has exceeded 20% during the past five years, as shown in Table 7-8-2. In particular, top-quality timber, like mala, has sold much faster than the second class of timber. In addition, timber exports have increased rapidly in past years (the average growth rate has been 24.1%, from $25,496 million in 1985 to $48,778 million in 1991).

Table 7-8-2 Amount of Deforestation

(Unit: km^2)

Region	Class	1988	1989	1990	1991	1992	Average Annual Growth Rate
Bolivia	First Class	62,577	72,424	96,529	121,399	145,773	23.5%
	Second Class	23,022	34,498	46,011	57,618	65,714	30.0%
	Total	85,599	106,922	142,540	179,017	211,487	25.4%
Beni	First Class	17,296	19,936	26,547	33,420	40,296	23.5%
	Second Class	3,221	3,128	4,168	5,215	6,064	17.1%
	Total	20,517	23,064	30,715	38,635	46,360	22.6%

Source: Anuario Estadístico 93, 1993

Judging from the recent stagnation in economic activity, this trend toward deforestation is likely to continue in the future, driven by favorable profit growth.

There is the vast forest area along the San Borja - Trinidad road. Therefore, the improvement of this road will strengthen economic activity and hence promote deforestation. According to the results of satellite image analysis from 1985 to 1990 (conducted by CUMAT), 470.31 km^2 of forest area disappeared during these five years (an average of 98.05 km^2 per annum). Therefore, this forest currently measures only 83,411.74 km^2.

In fact, most of the forests in Beni Department are classed as "Reserved Forests for Native Peoples", "Concession Forests for Deforestation" or "Conservation Forests" (some forest areas have overlapping designations) as shown in Figure 2-1-7. According to information from the Centro de Desarrllo Forestal - Regional Norte - (CDF), in 1994 the volume of sanctioned deforestation by timber companies was 27,966.79 m^3 and the volume of deforestation within privately owned areas was 31,646.51 m^3 (data was not available except for the three branch offices of Rurrenabaque, San Borja and Reyes). Although deforestation volume in the latter area was larger than in the former, when it comes to the felling of valuable timbers such as mala, 24,548.13 m^3 (87.8%) of timber was felled in sanctioned areas as opposed to 5,766.41 m^3 in privately owned areas. This indicates that, within sanctioned areas, it is mostly valuable timber that is felled. This trend is expected to continue in the future.

In conclusion, the road improvement might promote deforestation in the forest area, especially in privately owned areas.

7.9 Ruins and Cultural Properties

During the construction of the San Borja - Trinidad road (1976-1978), some archaeological sites were destroyed due to a lack of information on their location. In fact, the ruins were not known to exist until the construction of this road. Unfortunately, road construction resulted in significant archaeological losses, as the road was constructed through the complex of ridges and extensive tractor work was required. Fortunately, the intervention of archaeologists enabled many sites to be rescued, and urgent exploration and excavations were performed after the completion of the road. Since then, there has been no further large-scale destruction of archaeological sites, with the exception of artificial earth elevations in the complex of ridges, which might be destroyed due to human activities and natural earth erosion. Causes of such destruction in the future are as follows:

- Cattle are eroding the ridges and embankments.
- Construction of privately-used roads or paths cut through embankments and sawhorse units.
- Land plowing with tractors destroys large artificial structures.

These three causes could apply in any of the archaeological areas shown in Figure 6-10-1.

7.10 Air Quality

The air quality around the road is influenced mainly by dust raised from expand ground and exhaust fumes from heavy construction machinery and from vehicles traveling on the road. The heavy machinery, which have diesel engines with large exhaust volumes, generally exhaust small quantities of NO_2 and CO. Gasoline engines generally exhaust small quantities of SO_2. Therefore, only SO_2 from heavy machinery and NO_2 and CO from vehicles are forecasted have a serious impact on air quality. Forecasts of air quality by location are limited to urban areas such as San Borja, San Ignacio, and Trinidad.

7.10.1 Impact Caused by Earth Work

Earth work conducted on embankment and side-borrow pitting, stirs up dust from exposed ground during, especially during the dry season.

7.10.2 Impact Caused by Heavy Machinery and Dump Trucks

The generation of pollutants, including Sox, from heavy machinery during the road improvement work can be controlled by the selection of machinery. Heavy machinery, which use diesel engines with large exhaust volumes, generally exhaust a small quantity of NO_2 and CO. Therefore, when trying to protect air quality, SO_2 is the main problem as far as heavy machinery is concerned.

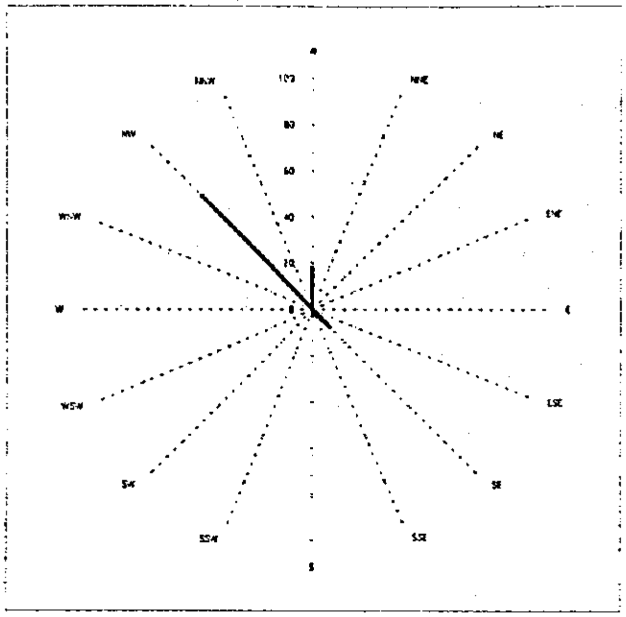
(1) Forecast Conditions

a) Wind conditions

Figure7-10-1 shows data on wind conditions (see Tables7-10-2 and 7-10-3) from San Borja, San Ignacio and Trinidad in 1983-1984, presented by AASANA. These data are used to forecast wind conditions. The predominant direction and speed of wind in San Borja, San Ignacio and Trinidad in 1983-1984 are as follows:

Table 7-10-1 Predominant Direction and Speed of wind

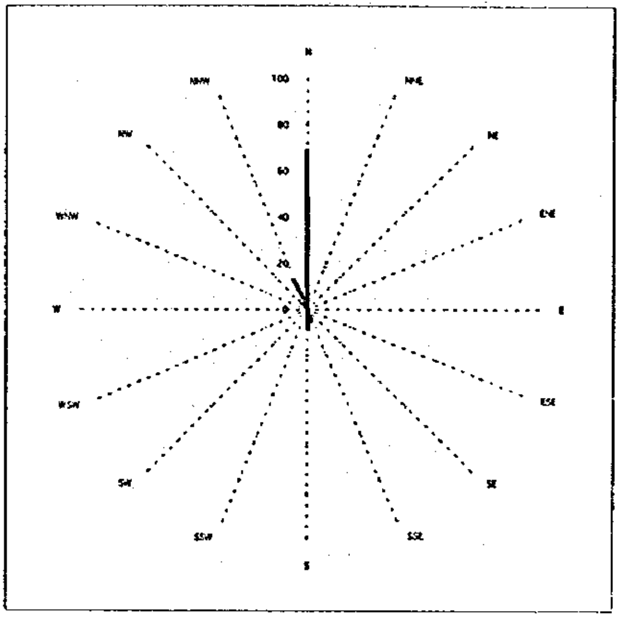
	San Borja	San Ignacio	Trinidad
Direction of wind	North	Northwest	Northwest
Speed of wind	4.2 m/s	5.2 m/s	5.7 m/s



1983~1994

SAN IGNACIO DE MOXOS

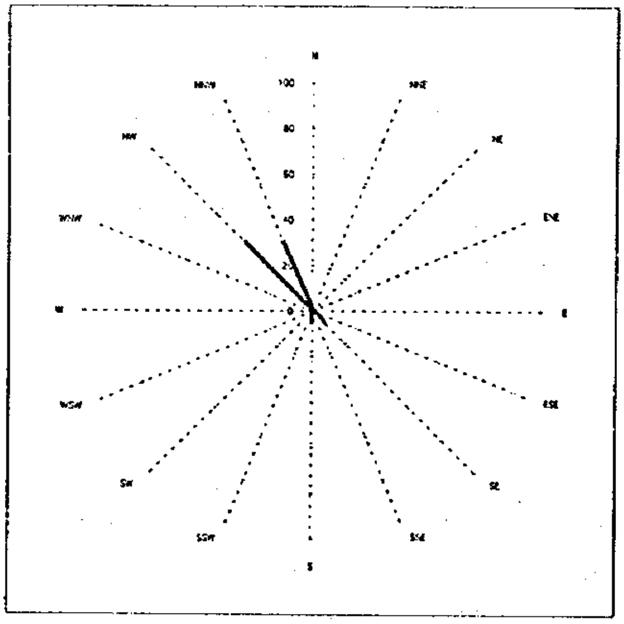
Speed of Wind
(m/s)
①NW : 5.2
②N : 4.7
③SE : 5.4
④S : 4.2
⑤SSE : 5.5



1983~1994

SAN BORJA

Speed of Wind
(m/s)
①N : 4.2
②NNW : 5.1
③S : 4.8
④SSE : 4.1
⑤NW : 4.8



1983~1994

TRINIDAD

Speed of Wind
(m/s)
①NW : 5.3
②NNW : 6.0
③SE : 5.7
④N : 5.8
⑤S : 6.1
⑥SSE : 5.8
⑦ESE : 6.0

Figure 7-10-1 Wind Direction and Wind Speed in the Project Area

Table 7-10-2 Wind Direction in the Project Area

San Borja

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pre.
1983	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	NW	N	NW	N	N	N	n.a.
1984	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	NW	N	N	N	N	n.a.
1985	N	N	N	S	N	N	S	N	N	N	S	N	N
1986	N	N	N	N	N	N	N	N	N	SSE	N	N	N
1987	NNW	NNW	NNW	NNW	SSE	NNW	NNW	NNW	N	NNW	N	NNW	NNW
1988	N	SSE/N	N	NNW	SSE	N	S	S	N	N	N	N	N
1989	N	N	N	SSE	SSE	N	NNW	NNW	NNW	N	WNW	N	N
1990	N	SSE	NW	NNW	NNW	S	S	N	N	N	N	N	N
1991	N	N	N	N	N	N	N	N	N	N	N	N	N
1992	N	N	N	N	N	N	S	S	S	N	N	N	N
1993	N	N	N	N	NW	N	S	N	N	N	N	N	N
1994	N	N	N	N	N	N	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pre.	N	N	N	N	N	N	S	N	N	N	N	N	-

San Ignacio de Moxos

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pre.
1983	N	N	NW	N	NW	SE	NW	NW	SE	NW	NW	NW	NW
1984	NW	NW	NW	SE	NW	S	S	SE	NW	NW	NW	NW	NW
1985	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
1986	NW	NW	NW	NW	NW	NW	N	NW	SE	NW	NW	NW	NW
1987	NW	NW	NW	NW	SE	SE	NW	NW	NW	NW	NW	NW	NW
1988	n.a.	n.a.	n.a.	NW	SE	NW	SE	NW	NW	NW	NW	NW	NW
1989	NW	NW	SE	SE	SE	NW	NW	NW	SE	NW	NW	NW	NW
1990	NW	NW	NW	NW	NW	SE	SE	NW	NW	NW	NW	NW	NW
1991	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
1992	NW	NW	NW	N	N	N	N	SSE	SSE	N	N	N	N
1993	N	N	N	N	N	N	N	S	S	N	N	N	N
1994	NW	NW	N	N	NW	NW	N	N	NW	NW	NW	NW	NW
Pre.	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	-

Trinidad

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pre.
1983	NW	NW	NW	NW	NW	SE	NW	NW	NW	NW	NW	NW	NW
1984	NW	NW	NW	SE	NW	NW	NW	SE	NW	NW	NW	NW	NW
1985	NW	NW	NW	SE	NW	NW	NW	SE	NW	NW	NW	NW	NW
1986	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
1987	N	NW	NW	NW	SE	NW	NW	SE	SE	NW	NW	NW	NW
1988	NW	SE	NW	NW	SE	NNW	SE	NNW	NNW	NW	NNW	NW	NW
1989	NW	NW	NW	NW	SSE	NNW	NNW	NNW	SSE	NNW	NNW	NW	NNW
1990	NW	NNW	NNW	N	N	SSE	SSE	NNW	NNW	NNW	NNW	NNW	NNW
1991	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW	NNW
1992	NNW	NNW	NNW	NNW	NNW	NNW	SSE	S	S	NNW	NNW	NNW	NNW
1993	NNW	ESE	NNW	NW	NNW	NW	NNW	S	S	N	NNW	NNW	NNW
1994	NNW	NNW	S	S	N	N	N	S	NNW	N	NNW	NNW	NNW
Pre.	NW	NW	NW	NW	NW	NW	NW	NNW	NW	NW	NNW	NW	-

Source : AASANA

Table 7-10-3 : Wind Speed in the Project Area

San Borja

(Unit : m/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pre.
1983	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4	5	8	6	5	8	6.0
1984	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4	8	5	4	5	5.5
1985	5	4	7	5	3	4	6	7	5	7	4	3	5.0
1986	6	5	4	4	4	4	4	5	4	5	5	5	4.6
1987	5	6	4	5	5	5	6	6	6	5	5	6	5.4
1988	6	4	5	5	4	5	7	5	7	8	6	5	5.6
1989	7	4	5	4	4	4	5	5	6	4	4	6	4.6
1990	6	3	4	4	4	4	5	4	6	5	7	6	4.7
1991	5	3	6	4	3	5	3	4	4	6	5	8	4.6
1992	3	4	3	4	4	3	4	4	4	5	3	4	3.8
1993	4	2	2	3	4	4	5	4	6	6	5	5	4.0
1994	4	5	3	3	4	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.7
Pre.	5	3.9	4.2	4	4.1	4.1	4.8	4.9	5.9	5.6	4.7	5.5	-

San Ignacio de Moxos

(Unit : m/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pre.
1983	6	2	4	5	5	4	6	5	5	4	4	4	5.0
1984	4	3	3	4	4	3	3	5	4	5	3	6	4.0
1985	4	5	6	7	6	7	6	8	6	8	5	4	6.0
1986	9	6	6	8	6	5	4	4	5	6	7	6	6.0
1987	9	8	7	6	7	7	8	7	7	7	5	7	7.0
1988	n.a.	n.a.	n.a.	6	6	6	8	5	7	7	5	5	6.0
1989	6	4	4	4	5	4	6	6	7	5	5	6	5.0
1990	6	3	4	5	3	4	5	5	6	5	6	6	5.0
1991	5	4	6	4	4	6	4	4	4	6	4	8	5.0
1992	3	5	3	4	6	5	5	4	5	6	4	5	5.0
1993	3	4	3	4	5	5	6	3	8	6	4	6	5.0
1994	5	6	5	4	4	5	6	5	5	5	6	6	5.0
Pre.	5.0	4.0	5.0	5.0	5.0	5.0	6.0	5.0	6.0	6.0	5.0	6.0	-

San Ignacio de Moxos

(Unit : m/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pre.
1983	6	4	4	4	5	5	6	5	8	5	5	6	5.3
1984	5	5	4	4	5	4	6	7	6	6	5	6	5.3
1985	6	4	6	6	4	4	5	7	6	7	3	3	5.1
1986	7	8	4	5	4	4	8	4	9	5	6	5	5.8
1987	6	6	6	4	5	5	6	9	5	6	5	10	6.1
1988	7	4	4	5	5	4	6	4	5	6	5	4	5.0
1989	5	4	4	3	4	4	6	5	7	5	4	5	4.7
1990	5	3	4	5	4	4	6	4	8	7	4	5	4.9
1991	5	5	6	5	4	8	6	6	6	9	7	10	6.3
1992	6	5	6	7	9	7	8	6	7	9	7	7	6.8
1993	6	6	5	5	6	6	8	7	8	6	6	6	6.3
1994	7	7	5	5	5	5	7	5	6	7	8	6	5.0
Pre.	5.9	5.1	4.7	4.8	4.9	4.9	6.5	5.8	6.8	6.4	5.5	6.2	-

Source : AASANA

b) Work schedule for heavy machinery during road improvement work

Road improvement work will be divided into eight work sections (I, II, III, IV, V, VI, VII and VIII). According to the work schedule shown in Figure 7-10-2, the maximum number of heavy machinery that ca be used in each work section is as follows:

Bulldozers	: 5
Backdigger	: 1
Tractor shovel	: 1
Dump trucks	: 28
Tire roller	: 1
Vibration roller	: 1
Motor grader	: 1
Concrete mixer	: 1

Name of Machine	Capacity	No.	1st Year	2nd Year	3rd Year	4th Year	Max *1
Bulldozer	21 t	26					5
Backhoe	0.6 m³	6					1
Tractor Shovel	2.1 m³	4					1
Dump Truck	11 t	141					28
Tired Roller		4					1
Vibration Roller		2					1
Motor Grader	3.7 m³	2					1
Concrete Mixer	0.6 m³	6					1
Asphalt Plant	Unit	1					*2
Asphalt Finisher		1					*2
Chankadolar	Unit	1					*3

Note : *1 : Maximum number of heavy machinery in a road section
*2 : Work section No.1
*3 : Quarry sites

Figure 7-10-2 Work Schedule of Heavy Machinery

c) Model for heavy machinery arrangement to minimize air pollution

Based on the maximum number of heavy machinery to be used in each work section shown above, a model for heavy machinery arrangement was established to minimize pollution. The pollution generated by each type of machine is as follows:

• List of heavy machinery :

Table 7-10-4 List of Heavy Machinery

Type of Machine	Capacity	Volume of the Cylinder (lt)	Fuel Consumption (lt/h)
1. Bulldozer	21 t	10.5	19 - 25
2. Backdigger or trench hoe	0.6 m^3	4.4	5.75 - 8.5
3. Tractor shovel	2.1 m^3	7.0	9.5 - 13
4. Dump truck	10 t	9.6	14 -20
5. Tire roller	20 t	5.7	10 - 14
7. Vibration roller	20 t	6.6	20.5 - 28
8. Motor grader	140 G	10.5	13 - 15

• Height of stack : 2.5 m

• Arrangement of machines : Scattered

• Topography : Flat

• Volume of pollutants :

Table 7-10-5 Volume of Pollutants

Type of Machine	Volume of Emission (Nm^3/h)	SOx (Nm^3/h)	NOx (Nm^3/h)
1. Bulldozer	382	0.029	0.348
2. Backdigger or trench hoe	160	0.012	0.146
3. Tractor shovel	255	0.019	0.232
4. Dump truck	336	0.022	1.043
5. Tire roller	207	0.039	0.484
7. Vibration roller	240	0.018	0.219
8. Motor grader	382	0.029	0.348
9. Motor scrapper	382	0.029	0.348

• Main construction work and number of heavy machines that will be used:

The main types of construction work that will require the use of heavy machines are indicated below. The construction work for the earthfill body (construction of the embankment) will require a large number of heavy machines, and therefore air quality forecasts will be carried out at the embankment construction site.

Table 7-10-6 Main Types of Construction Work Require Heavy Machinery

Construction Works	Heavy Machine	No. of Units
1. Installation works for steel corrugated pipes	Backdigger or trench hoe	1
2. Construction work on the earthfill body	Bulldozer	4
	Motor scrapper	2
	Motor grader	2
	Roller	2
	(Dump truck)	(5)
3. Subbase construction work	Dump truck	5
	Motor grader	2
	Roller	2

- Arrangement of heavy machines:

The number of units considered to be a source of pollutants is two (2), and their arrangement is as follows:

125 m ______ 250 m ______ 125 m

* * 100 m wide

______500 m long ______

* : Source of emission

- Width of the road : 100 m in general
- Forecasting sites : Urban areas
  1. San Borja
  2. San Ignacio
  3. Trinidad

There are four forecasting points in each urban area of San Borja, San Ignacio and Trinidad, as shown in Figure 6-11-3.

- Sources of emission at each site:

The sources of emission at each site are as follows:

Table 7-10-7 Sources of Emission at Each Site

Forecasting Sites *2	Type of Machine	No. of Units	Vol. *1 (Nm^3/s)	SOx (Nm^3/s)	NOx (Nm^3/s)
1. San Borja	Bulldozer	1	382	0.029	0.348
	Dump truck *3	5	168	0.011	0.521
	Motor grader	2	764	0.058	0.696
	Roller	1	240	0.018	0.219
	Total		1,554	0.116	1.784
2. San Ignacio	Bulldozer	2	764	0.058	0.696
	Dump truck *3	5	168	0.011	0.521
	Motor scrapper	1	382	0.029	0.348
	Motor grader	1	382	0.029	0.348
	Roller	1	240	0.018	0.219
	Total		1,936	0.145	2.132
3. Trinidad	Bulldozer	2	764	0.058	0.696
	Dump truck *3	5	168	0.011	0.521
	Motor scrapper	1	382	0.029	0.348
	Motor grader	1	382	0.029	0.348
	Roller	1	240	0.018	0.219
	Total		1,936	0.145	2.132

Note - *1 : Volume of gas emission
*2 : There are two (2) sources of emission in the road construction work section
*3 : The operation rate of a dump truck at the construction site is 10%.

(2) Forecast Method

Simulation methods of the Plume - Paph model (Formulas 7-11-1 and 7-11-2) are used to forecast the concentration of pollutants.

a) Wind duration : Formula 7-11-1 (Plume model)

$$C(x,y,z) = \frac{Q_p}{2\pi \cdot \sigma_y \cdot \sigma_z \cdot U} \exp\left(-\frac{y^2}{2\sigma_y}\right) \cdot \left\{ \exp\left[-\frac{(z-He)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+He)^2}{2\sigma_z^2}\right] \right\}$$

where,

C = Concentration (ppm)
x = Leeward distance along the wind direction (m)
y = Horizontal distance perpendicular to the X axis (m)
z = Vertical distance perpendicular to the X axis (m)
Q_p = Volume of exhausted gas (Nm^3/s)
σ_y = Parameter for the width of diffusion in the vertical [y] direction (m)
σ_z = Parameter for the width of diffusion in the horizontal [z] direction (m)
U = Wind speed (m/s)
He = Height of stack (m)

(Width if diffusion)

$$\sigma_z = 1.5 + 0.31 \cdot L^{0.83}$$

$$\sigma_y = \frac{W}{2} + 0.46 \cdot L^{0.81}$$

L = Distance from the border of the road to the forecasting point (m)

b) Calm time (less than 1.0m in wind speed) : Formula 7-11-2 (Paph model)

$$C(x,y,z) = \frac{Q_p}{(2\pi)^{3/2} \cdot \alpha^2 \cdot \gamma} \cdot \left\{ \frac{1-\exp\left(-\frac{\ell}{t_0^2}\right)}{2\ell} + \frac{1-\exp\left(-\frac{m}{t_0^2}\right)}{2m} \right\}$$

where,

$$\ell = \frac{1}{2}\left[\frac{x^2+y^2}{\alpha^2} + \frac{(z-He)^2}{\gamma^2}\right]$$

$$m = \frac{1}{2}\left[\frac{x^2+y^2}{\alpha^2} + \frac{(z+He)^2}{\gamma^2}\right]$$

$$t_o = \frac{W}{2\alpha}$$

α, γ = Coefficients of the widths of diffusion

$\alpha = 0.3$

$\gamma = 0.18$ (day time)

$= 0.09$ (night time)

(3) Forecast Results

The simulation results concerning SOx and NOx at the stage of road construction are shown in Figure 7-10-3. The concentration of Sox ranges from 0.00001 ppm (0.000029 mg/m^3) to 0.00023ppm (0.00066 mg/m^3). The concentration of NOx ranges from 0.00016 ppm (0.00031 mg/m^3) to 0.00335 ppm (0.00658 mg/m^3).

Most of the concentration values are below those of present conditions. The actual values for Sox concentration in the dry season are almost the same as the forecasted values.

7.10.3 Impact Caused by Traffic

Gasoline engines generally exhaust small quantities of SO_2. Therefore, only NO_2 and CO values are forecast.

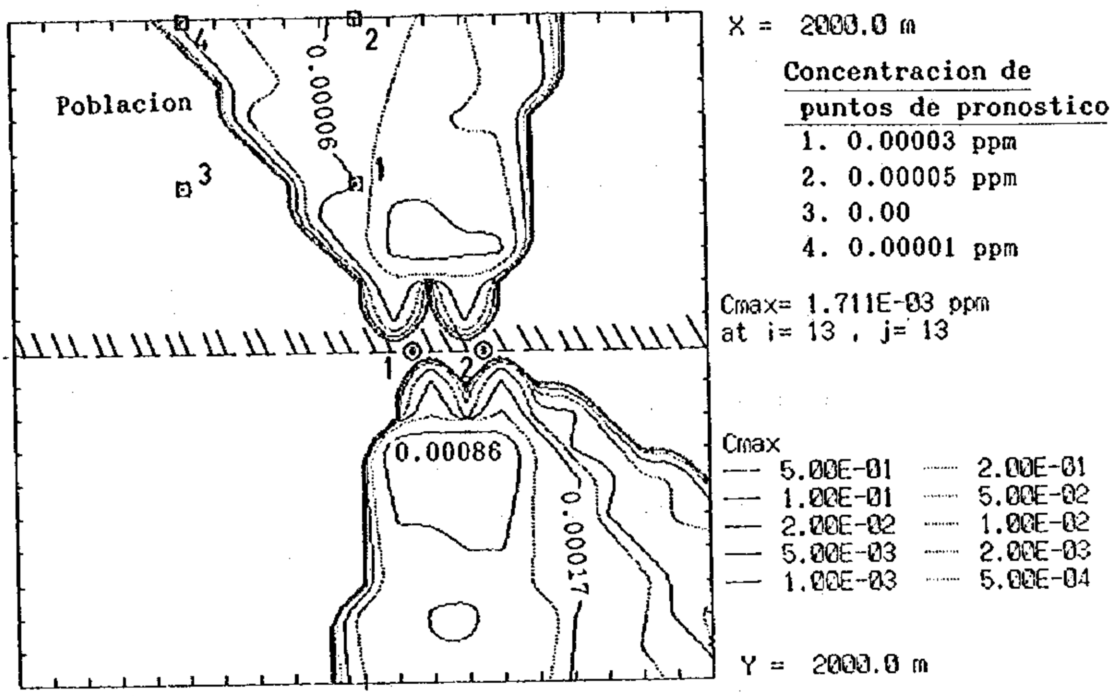
(1) Forecast Conditions

a) Wind conditions

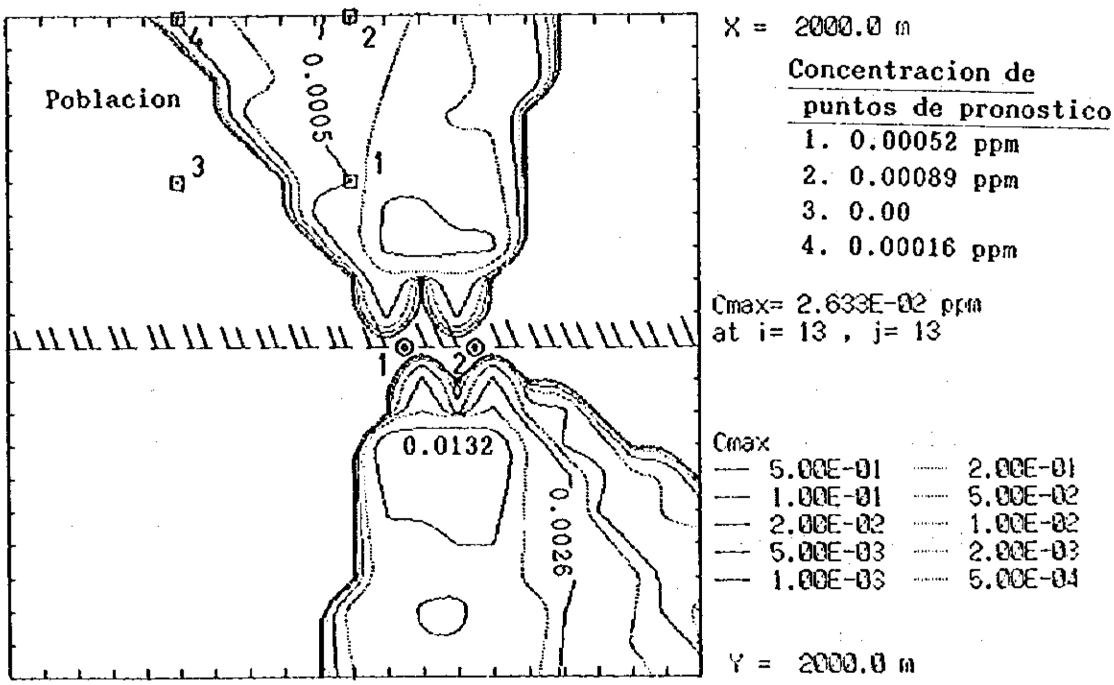
The Figure 7-10-1 is used to forecast wind conditions.

San Borja

SOx



NOx

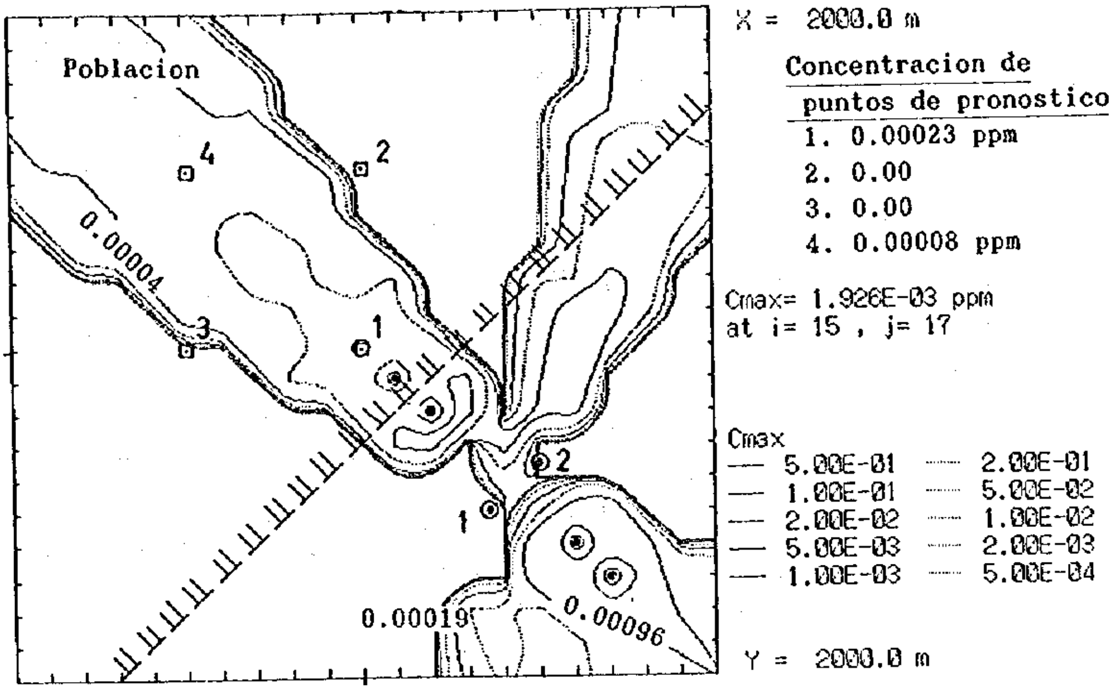


⊙2 Fuentes de deslarba
⊡2 Puntos de pronostico

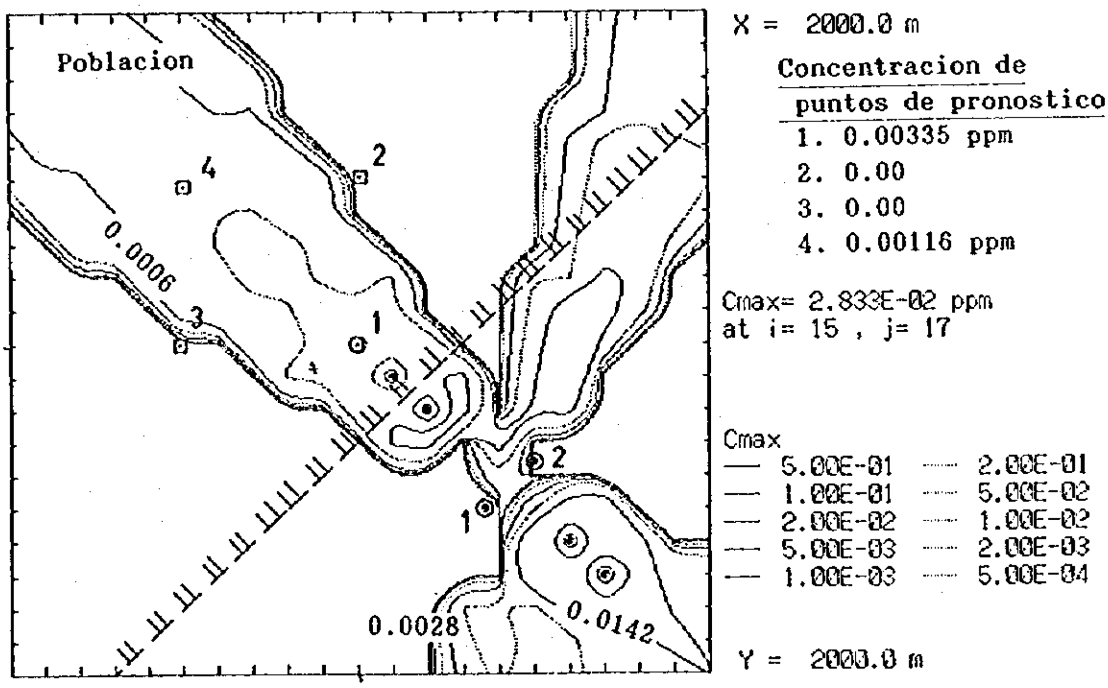
Figure 7-10-3 Result of Forecasting Air Quality at the Stage of Road Construction(1)

San Ignacio

SOx



NOx

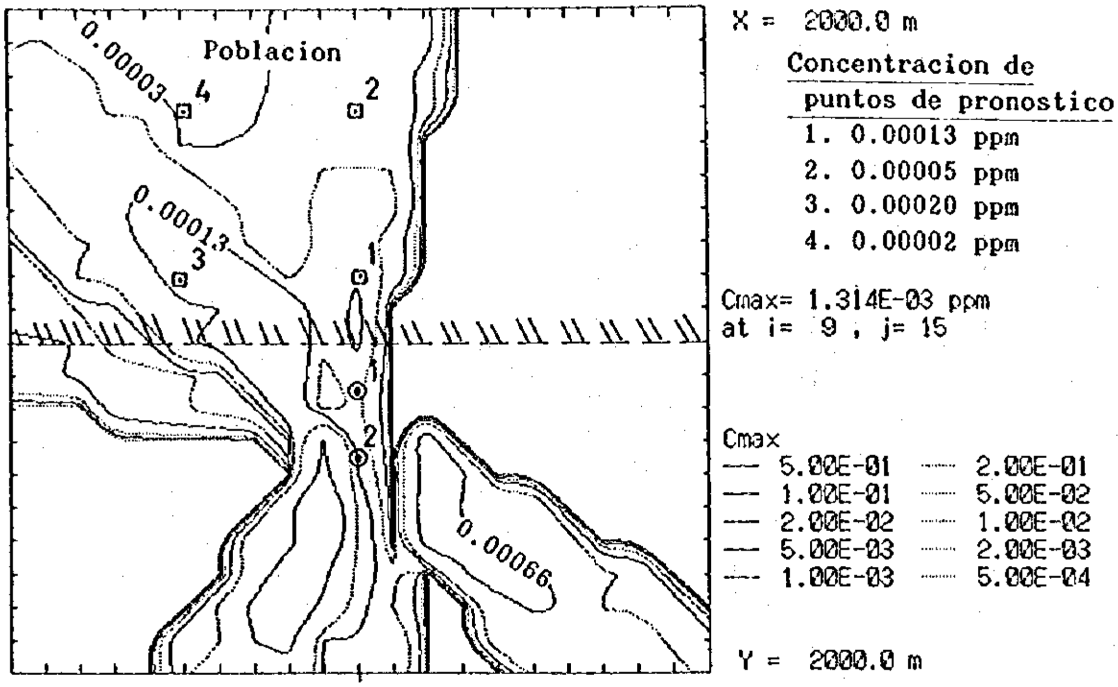


⊙2 Fuentes de deslarba
⊡2 Puntos de pronostico

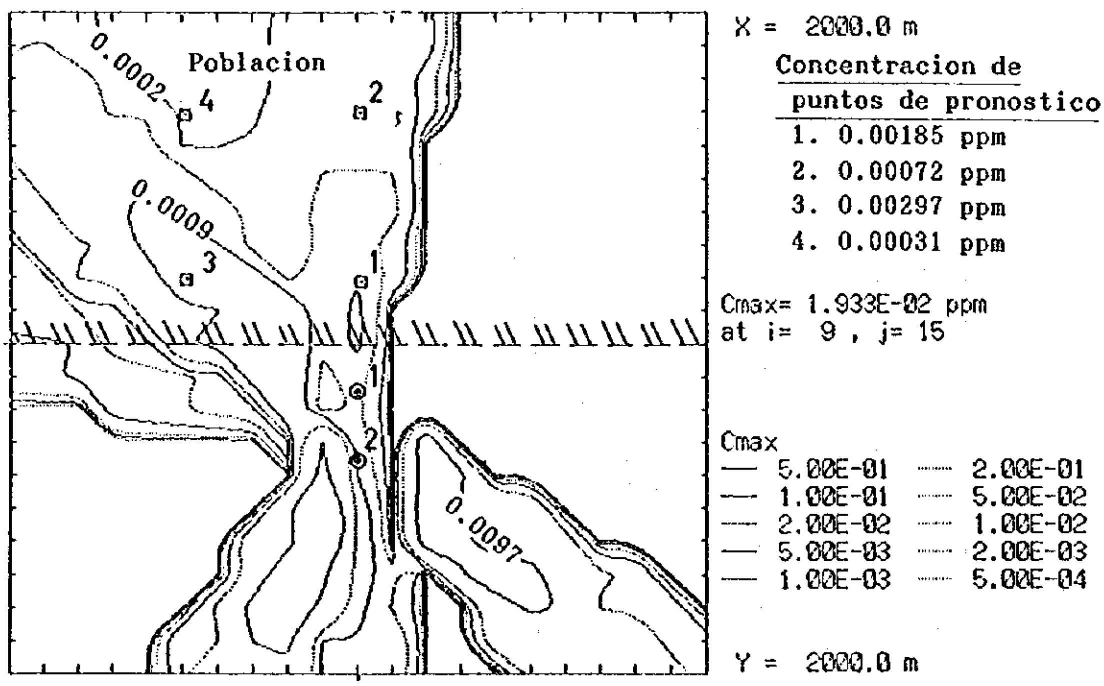
Figure 7-10-3 Result of Forecasting Air Quality at the Stage of Road Construction(2)

Trinidad

SOx



NOx



⊙2 Fuentes de deslarba
⊡2 Puntos de pronostico

Figure 7-10-3 Result of Forecasting Air Quality at the Stage of Road Construction(3)

b) Other forecasting condition

- Speed of vehicle : 80 km/h on average
- Traffic volume :

Table 7-10-8 Future Traffic Volume Used for Forecasting Air Quality

(Unit : vehicles)

Year	San Borja-San Ignacio	San Ignacio-P. Ganadero	P. Ganadero-P. Varador	P. Varador-Trinidad
1994	67	69	69	523
2001	88	91	91	686
2020	193	198	198	1,519
(HVR)	(20.6%)	(20.0%)	(20.0%)	(42.5%)

RHV : Heavy vehicle Ratio

- Topography : Flat
- Volume of pollutants : NOx 523 ml/g, CO 859ml/g
- Coefficient of emission (g/km×vehicle):

NOx Light vehicle : 0.266

Heavy vehicle : 1.85

CO Light vehicle : 0.689

Heavy vehicle : 1.62

- Average of source : Length of 80 m and intervals of 10 m
- Width of road : 100 m wide in general
- Prediction point : 0, 5, 10, 20, 30 ,50, 100 and 200m from the border of the road

(2) Forecasting Method

The Plume-Paph model (Formulas 3 and 4 shown before) were used to forecast the concentration of pollutants.

(3) Forecasting Result

Air quality simulation results concerning the values of NOx and CO at the stage of road use are shown in Figures 7-10-4, 7-10-5 and Table 7-10-9. The forecast concentration for 2020 varies from 0.0060 ppm to 0.0155 ppm and from 0.0000 ppm to 0.2805 ppm, respectively.

On the other hand, the forecast concentration in Trinidad for 2020 is higher than at other sites because the traffic volume on the road section between Puerto Varador and Trinidad is larger than that on other road sections along the project road.

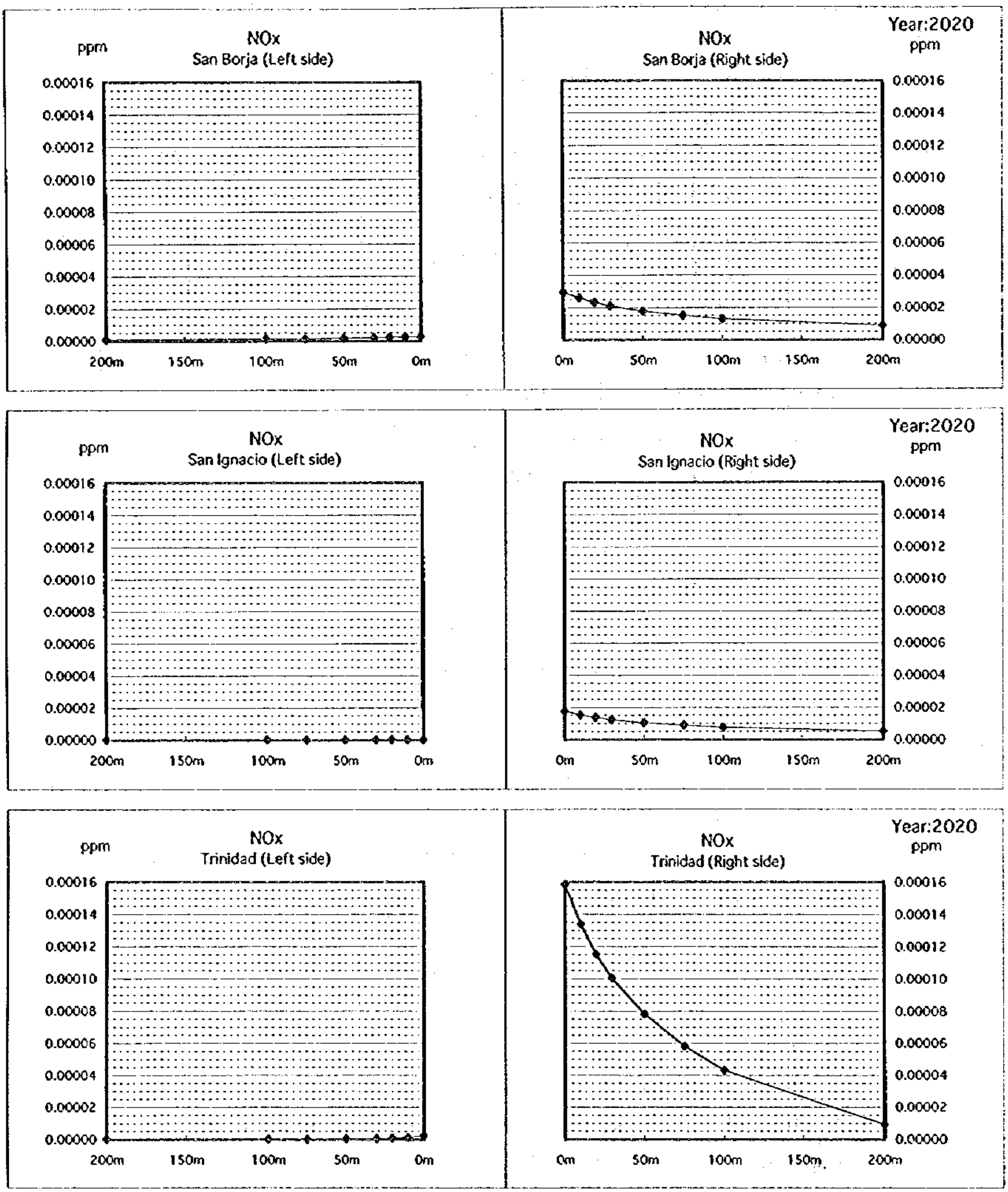


Figure 7-10-4 Result of Simulation Concerning NOx

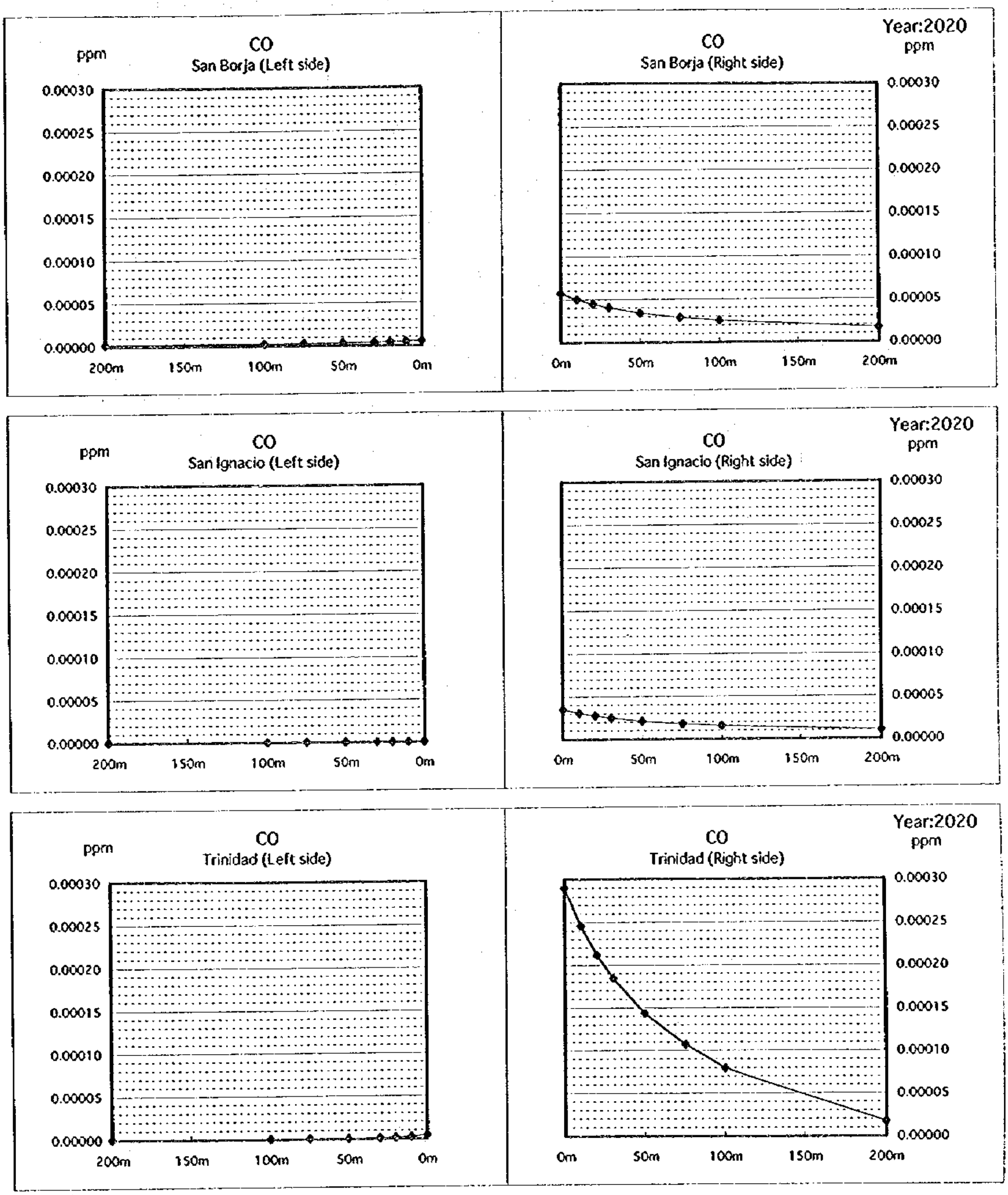


Figure 7-10-5 Result of Simulation Concerning CO

Table 7-10-9 Forecast Concentrations of NOx and CO from the Project Road

NOx

(Unit : ppm)

Location	Side	Distance from the Road Side							
		0 m	10 m	20 m	30 m	50 m	75 m	100 m	200 m
San Borja	Right	0.0000296	0.0000260	0.0000232	0.0000210	0.0000177	0.0000150	0.0000130	0.0000087
	Left	0.0000027	0.0000024	0.0000021	0.0000019	0.0000016	0.0000013	0.0000012	0.0000008
San Ignacio	Right	0.0000174	0.0000153	0.0000136	0.0000123	0.0000104	0.0000088	0.0000076	0.0000051
	Left	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Trinidad	Right	0.0001582	0.0001339	0.0001153	0.0001005	0.0000781	0.0000582	0.0000432	0.0000093
	Left	0.0000023	0.0000013	0.0000007	0.0000005	0.0000004	0.0000002	0.0000002	0.0000001

CO

(Unit : ppm)

Location	Side	Distance from the Road Side							
		0 m	10 m	20 m	30 m	50 m	75 m	100 m	200 m
San Borja	Right	0.0000570	0.0000500	0.0000446	0.0000404	0.0000341	0.0000288	0.0000250	0.0000167
	Left	0.0000052	0.0000045	0.0000040	0.0000037	0.0000031	0.0000026	0.0000023	0.0000015
San Ignacio	Right	0.0000350	0.0000307	0.0000274	0.0000248	0.0000209	0.0000177	0.0000153	0.0000102
	Left	0.0000001	0.0000001	0.0000001	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Trinidad	Right	0.0002900	0.0002456	0.0002115	0.0001843	0.0001433	0.0001068	0.0000793	0.0000171
	Left	0.0000043	0.0000024	0.0000014	0.0000008	0.0000004	0.0000002	0.0000002	0.0000001

7.11 Water Quality

7.11.1 Impact Caused by Earth Work

According to the project plan and design, water from rivers on the upstream side of the project road will be drained by numerous steel corrugated pipes and bridges, thus preventing the water level in the flood area from increasing beyond that of present conditions. Accordingly, water quality, on both the upstream and downstream sides of the road project, will not be altered by the road project.

During the construction stage of road improvement, suspended solids (SS) will be produced from the exposed ground during the rainy season. However, construction work will be halted during strong rains that are expected to arrive from January to March. In the same way, slope protection work to prevent the erosion of the embankment slope is planned to be completed before the start of the rainy season.

In addition, turbid water containing suspended solids coming from exposed ground during the road improvement work under rainfall, both before and after the rainy season (November, December, April and May), will mostly flow into borrow pits that form a treatment pond. Thus, most of the suspended solids will settle in the borrow pits without flowing into existing water courses.

7.11.2 Impact Caused by Using Heavy Machinery and Dump Trucks

Gasoline, engine oil, etc., used by heavy machines and dump trucks during the road improvement work may permeate underground or flow into rivers, thus contaminating underground water or river water.

7.11.3 Impact Caused by Drainage Facilities

The soil near the inflow and outflow of culverts may erode and thus increase the amount of suspended solids in the river water.

7.11.4 Impact Caused by Waste

The waste oil exhausted by heavy machinery and dump trucks during the road improvement work, may permeate underground or flow into rivers, thus contaminating underground water or river water.

7.11.5 Impact Caused by Worker Facilities

The utility water discharged from the worker's camp or workshop may contaminate river water.

7.12 Noise

7.12.1 Forecasting Noise Conditions During Road Use

Noise levels were forecast for the year 2020 based on the same measurement points used now for major urban areas (San Borja, San Ignacio and Trinidad).

(1) Forecasting Condition

Forecasting condition of noise are as follows:

- Height of stack : 0.3 m
- Speed of vehicles : 80 km/h
- Topography : Flat land
- Average power level (L_w) in {dB(A)}:

$$L_w = 86 + 0.2V + 10\log(a^1 + 8a^2)$$

where,

V = Average speed (km/h)

a^1, a^2 = Vehicle composition (%)
1: Light vehicles
2: Heavy vehicles

- Width of road : 100 m in general
- Forecasting points : 0, 5, 10, 20, 30, 50, 100 y 200 m from the border of the road
- Traffic volume :

Table 7-12-1 Future Traffic Volume Used for Forecasting Noise

(Unit : vehicles)

Year	San Borja-San Ignacio	San Ignacio-P. Ganadero	P. Ganadero-P. Varador	P. Varador-Trinidad
1994	67	69	69	523
2001	88	91	91	686
2020	193	198	198	1,519
(HVR)	(20.6%)	(20.0%)	(20.0%)	(42.5%)

RHV : Heavy vehicle Ratio

(2) Forecasting Method

The formula used to forecast noise levels is as follows:

$$L_{50} = L_w - 8 - 20\log \ell + 10\log\left(p \cdot \frac{\ell}{d} \cdot \tanh\frac{2p\ell}{d}\right) + a_i$$

where,

L_{50} = Central value of noise {dB(A)}

L_w = Average power level per vehicle {dB(A)}

ℓ = Distance between the noise source and the measured point (m)

a_i = Revised factor

p = Circular constant

(3) Composite Noise with Background Noise

The composite noise, which is equivalent to the noise at the forecasting point and in the forecast year, is calculated with the following formula:

$Lf_{50} = 10\times\log(10^{LB/10}+10^{L50/10})$

Lf_{50} = Noise level (dB(A))at the forecasting point

L_B = Present noise level (dB(A))at the forecasting point

L_{50} = forecasting noise level (dB(A))caused only by vehicles

7.12.2 Forecast Results

The noise levels forecast for the year of 2020 are shown in Figure 7-12-1 and Table 7-12-2. The composite noise levels at the forecasting points in the year 2020 year are shown in Table 7-12-3.

San Borja

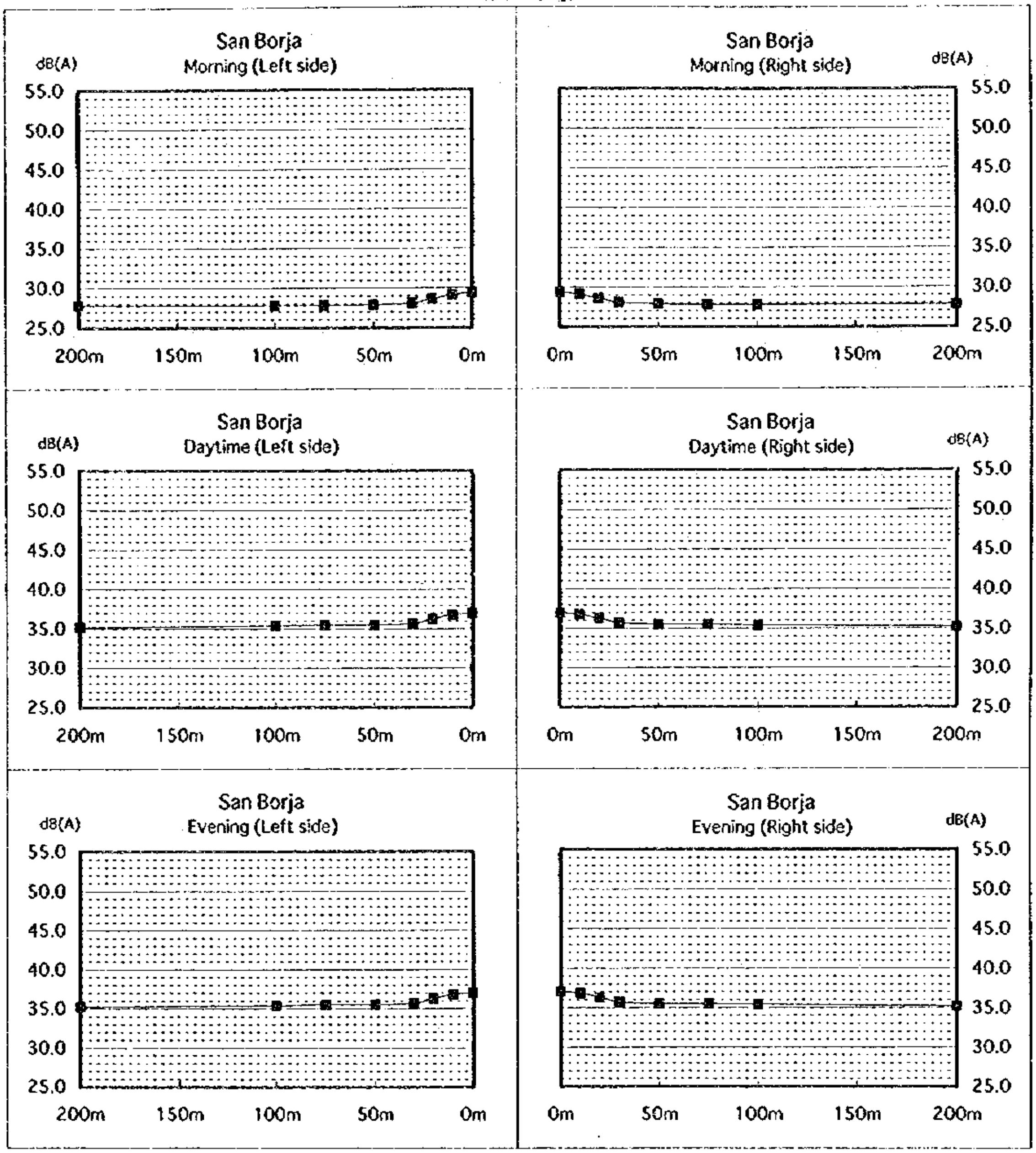


Figure 7-12-1 Noise Level Forecast for the Year of 2020 (1)

San Ignacio

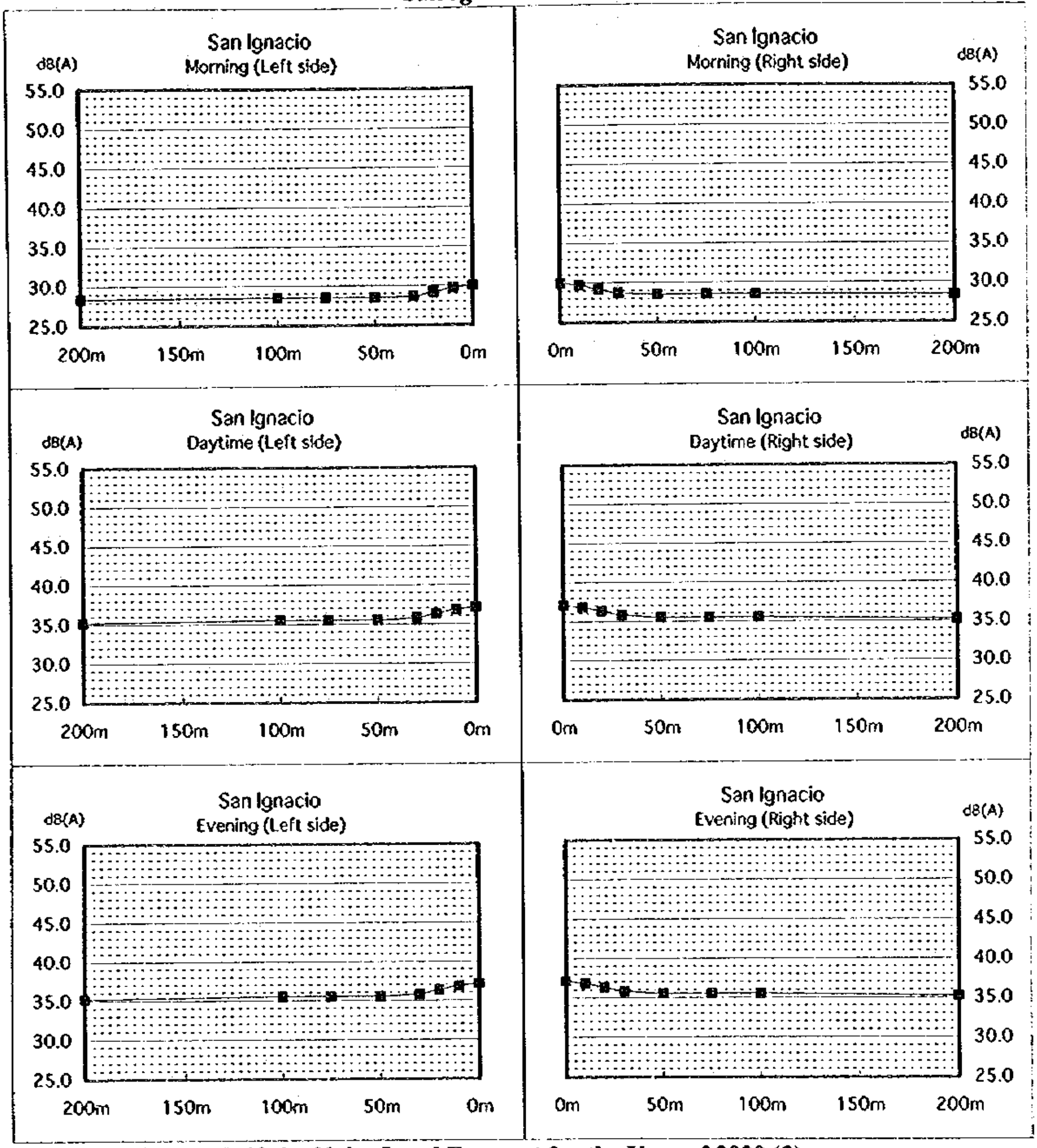


Figure 7-12-1 Noise Level Forecast for the Year of 2020 (2)

Trinidad

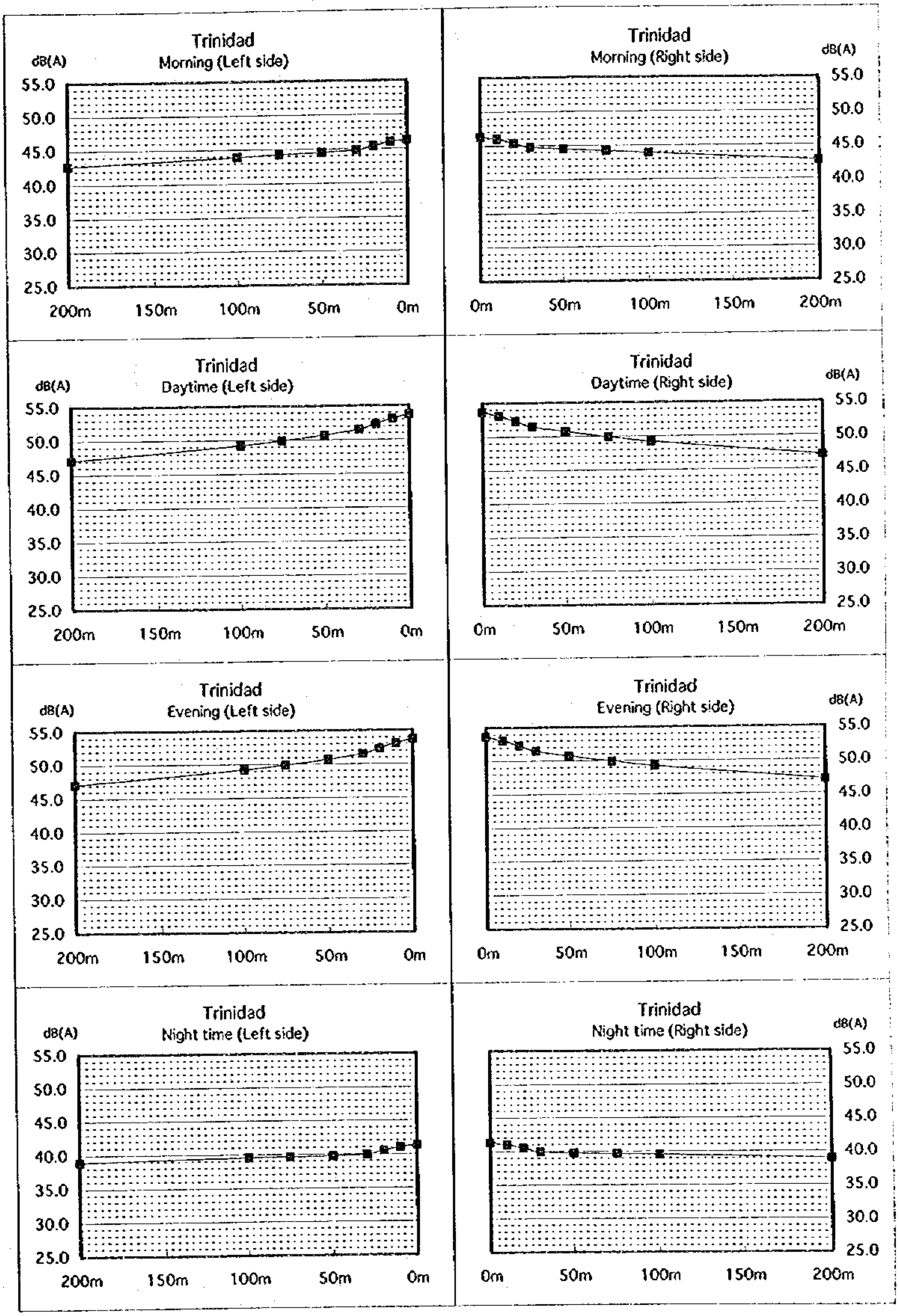


Figure 7-12-1 Noise Level Forecast for the Year of 2020 (3)

Table 7-12-2 Noise Level Forecast for the Year of 2020

San Borja

(Unit : dB(A))

Duration	Side	Distance from the Road Side							
		0 m	10 m	20 m	30 m	50 m	75 m	100 m	200 m
Morning	Right	29.4	29.1	28.6	28.1	27.9	27.8	27.8	27.8
	Left	29.4	29.1	28.6	28.1	27.9	27.8	27.8	27.8
Daytime	Right	37.0	36.8	36.3	35.7	35.5	35.5	35.4	35.2
	Left	37.0	36.8	36.3	35.7	35.5	35.5	35.4	35.2
Evening	Right	37.0	36.8	36.3	35.7	35.5	35.5	35.4	35.2
	Left	37.0	36.8	36.3	35.7	35.5	35.5	35.4	35.2

San Ignacio

(Unit : dB(A))

Duration	Side	Distance from the Road Side							
		0 m	10 m	20 m	30 m	50 m	75 m	100 m	200 m
Morning	Right	30.0	29.7	29.2	28.7	28.5	28.5	28.5	28.4
	Left	30.0	29.7	29.2	28.7	28.5	28.5	28.5	28.4
Daytime	Right	37.1	36.8	36.3	35.8	35.5	35.5	35.5	35.2
	Left	37.1	36.8	36.3	35.8	35.5	35.5	35.5	35.2
Evening	Right	37.1	36.8	36.3	35.8	35.5	35.5	35.5	35.2
	Left	37.1	36.8	36.3	35.8	35.5	35.5	35.5	35.2

Trinidad

(Unit : dB(A))

Duration	Side	Distance from the Road Side							
		0 m	10 m	20 m	30 m	50 m	75 m	100 m	200 m
Morning	Right	46.3	46.0	45.4	44.8	44.5	44.2	43.9	42.7
53.7	Left	46.3	46.0	45.4	44.8	44.5	44.2	43.9	42.7
Daytime	Right	53.7	53.1	52.3	51.5	50.7	49.9	49.2	47.1
	Left	53.7	53.1	52.3	51.5	50.7	49.9	49.2	47.1
Evening	Right	53.7	53.1	52.3	51.5	50.7	49.9	49.2	47.1
	Left	53.7	53.1	52.3	51.5	50.7	49.9	49.2	47.1
Nighttime	Right	41.3	41.0	40.5	39.9	39.7	39.6	39.5	38.9
	Left	41.3	41.0	40.5	39.9	39.7	39.6	39.5	38.9

Table 7-12-3 Composite Noise Level at Forecasting Points

Wet Season

(Unit : dB(A))

Location	Duration	Present Noise Level	Forecasting Noise Only from Vehicles	Forecasting Composite Noise
San Borja	Morning	44.2	29.4	44.3
	Daytime	46.4	37.0	46.9
	Evening	48.1	37.0	48.4
San Ignacio	Morning	54.2	30.0	54.2
	Daytime	45.9	37.1	46.4
	Evening	49.5	37.1	49.7
Trinidad	Morning	50.4	46.3	51.8
	Daytime	55.4	53.7	57.6
	Evening	60.5	53.7	61.3

Dry Season

(Unit : dB(A))

Location	Duration	Present Noise Level	Forecasting Noise Only from Vehicles	Forecasting Composite Noise
San Borja	Morning	44.7	29.4	44.8
	Daytime	45.2	37.0	45.8
	Evening	48.8	37.0	49.0
San Ignacio	Morning	47.6	30.0	47.7
	Daytime	46.0	37.1	46.5
	Evening	40.7	37.1	42.2
Trinidad	Morning	46.7	46.3	49.5
	Daytime	47.2	53.7	54.6
	Evening	53.8	53.7	56.7

CHAPTER 8

AIMS OF ENVIRONMENTAL CONSERVATION AND EVALUATION

CHAPTER 8 AIMS OF ENVIRONMENTAL CONSERVATION AND EVALUATION

8.1 Aims of Environmental Conservation

(1) Topography and Geology

To avoid substantially changing the present topography and geology, and to prevent natural disasters related to both topography and geology such as large-scale landslide and slope collapse.

(2) Soil

To prevent soil erosion and the soil flow out, and preserve present soil conditions.

(3) Hydrology

To avoid causing any substantial hydrological change of rivers, underground water, or flooded area.

(4) Flora

To avoid substantially affecting existing flora.

(5) Fauna

To avoid substantially affecting fauna habitats.

(6) Landscape

To conserve an excellent landscape by not creating any incongruities in the area.

(7) Community

To assist in the formation of harmonious and peaceful communities, without adversely affecting the living environment of communities.

(8) Economic Activity

To promote a solid development of the economic activities of local societies, without adversely affecting sustainable development.

(9) Ruins and Cultural Properties

To avoid damaging ruins and cultural properties in the area.

(10) Air Quality

To avoid exceeding present air quality levels or the National Ambient Air Quality Standards of USA for the purpose of health protection (see Table 8-1-1).

Table 8-1-1 Environmental Air Quality Standards

Items	Standard Value
CO	$10mg/m^3/8hours$ (9ppm) $40mg/m^3/1hour$ (35ppm)
SO_2	$80ug/m^3/day$ (0.03ppm) $365ug/m^3/24hours$ (0.14ppm)
NOx	$100ug/m^3/year$ (0.05ppm) variable in 24hours with NO_2
HC	$160mg/m^3/3hours$ (0.24ppm)
Macro-Particular	$25mg/m^3/year$ or $260g/m^3/24hours$
Suspended Particulate Matter	$260mg/m^3/day$ $75mg/m^3$ *1
O_3	$235mg/m^3/hours$ (0.12ppm)
Pb-Ps	$1.5mg/m^3/3months$

Note : *1 - Annual arithmetic mean
Source : National Ambient Air Quality Standards of USA

(11) Water Quality

To avoid exceeding present water quality levels or the water quality standards of the Ministry of Urban Affairs (MAU). Water quality standards for environmental bodies of water and wastewater effluents have been established and enforced under the provisions of the Article 80 of Law 1333 and Supreme Decree 22965 of the MAU in 1985.

Regulations establish specific water quality values as the upper limits for the environmental bodies of water and industrial wastewater. The former values are shown in Table 8-1-2.

Table 8-1-2 Environmental Water Quality Standards

Parameter	Unit	Special	Class A	Class B	Class C	Class D
Physical-biological parameters						
BOD	mg/l	<2	<5	<10	<50	<300
DO	mg/l	80% sat.	70% sat.	60% sat.	50% sat.	2
Floating solids	mg/l	absent	absent	absent	*1	*1
Suspended solids	mg/l	500	1000	1500	2000	5000
Greases & oils	mg/l	absent	0.8	1	10	20
Colliform bacteria	MPN	<500	<5000	<10000	<20000	
(in 80% of samples)		<50	<1000	<2000	<5000	100000
pH		6.5-9.0	6.0-9.5	5.5-9.5	5.0-10.0	4.5-10.0
Color (color unit)		<20	<50	<100	<200	<1000
Chemical parameters						
As	mg/l	0.05	0.05	0.05	0.1	0.1
Ba	mg/l	1	1	2	5	10
B	mg/l	0.1	0.1	0.5	2	5
Cd	mg/l	0.01	0.05	0.2	0.5	1
Cu	mg/l	1	1.5	2	3	5
Cr6+	mg/l	0.05	0.05	0.1	1	5
Hg	mg/l	0.001	0.005	0.01	0.02	0.05
Pb	mg/l	0.05	0.1	0.1	0.2	2
Se	mg/l	0.01	0.01	0.05	0.1	0.5
Cyanide	mg/l	0.05	0.05	0.1	0.2	1
Phenols	mg/l	0.001	0.002	0.005	0.01	0.1
Detergents	mg/l	0.15	0.5	1	2	5
Total-NO_3	mg/l	45	50	60	80	100
Zn	mg/l	5	10	15	20	50
Mn	mg/l	0.5	1	2	5	10
Fe	mg/l	0.5	1	2	5	10
Mg	mg/l	100	200	300	400	500
Ca	mg/l	200	300	400	500	700
F	mg/l	0.6-1.7	0.6-1.7	2	3	5
Chlorides	mg/l	500	500	700	1000	5000
Sulfates	mg/l	400	400	600	1000	8000
Herbicides& insecticides						
Aldrin	mg/l	0.017	0.017			
Chlordane	mg/l	0.003	0.003			
D.D.T	mg/l	0.042	0.042			
Dieldrin	mg/l	0.017	0.017			
Endrin	mg/l	0.001	0.001			
Hepta-chlorine	mg/l	0.018	0.018			
Epoxy-chlorine	mg/l	0.018	0.018			
Lindane	mg/l	0.056	0.056			
Metoxy-chlorine	mg/l	0.035	0.035			
Organic phosphates with carbonates	mg/l	0.1	0.1			
Foxatene	mg/l	0.005	0.005			
Total herbicides	mg/l	0.1	0.1			

In the table, Class C of five classes is defined as water designated for public water supply after treatment, for irrigation, scenic harmony and navigation purposes, and for electric power generation.

The water in the project area is designated as Class C. Therefore, Class C is used for the evaluation purposes.

(12) Noise

To avoid exceeding present noise levels.

8.2 Environmental Evaluation

8.2.1 Topography and Geology

(1) Impact of Cleaving Woods

If the cleaving area is restricted to the right of way area, neither topography nor geology will be greatly changed by the cleaving of woods.

(2) Impact of Earth Works

Neither topography nor geology will be greatly altered by earth works such as the building of embankments and side-borrow pitting. The bare surface of the embankments, however, may be subject to gully erosion.

- The slopes of the embankments are stable
- Gully erosion may occur at the slopes of embankments due to rainfall.
- Erosion at the downstream side of the drainage culvert of the road will be limited by protection works.
- Borrow pits will be limited to within the area of the project road.
- Cutting slopes maintaining a standard slope gradient will be stable at the quarry sites.
- Influence caused by a partial change in the canal alignment will be very low.

8.2.2 Soil

(1) Impact of Cleaving Woods

Cleaving of woods within the right of way area exclusively will not cause any large-scale soil erosion.

(2) Impact of Earth Works and Drainage Facilities

As the flood water will be drained by numerous culverts established under the embankments of the project road, the flood area will not expand beyond it's present boundaries.

Consequently, influence on the soil, which covers the area to the upstream side of the project road, will be minimized.

The surface soil of the embankments and the soil at the lower stream side of the culverts may be subject to erosion.

8.2.3 Hydrology

(1) Impact of Cleaving Woods

Clearing of woods will not cause any drastic hydrological change such as the expansion of the flooded area.

(2) Impact of Earth Works and Drainage Facilities

As the flood water will be drained by numerous culverts under the embankments of the project road, the flood area will not expand beyond it's present boundaries. That is, the hydrology in the area will not change drastically. Maintenance of the culverts is necessary because the culverts will not function properly if they are blockaded by driftwoods, etc.

8.2.4 Flora

(1) Impact of Cleaving Woods

If the woods along the project road are cleaved according to the Design, the existing flora will be drastically affected. Consequently, cleaving of the woods should be avoided, especially in the forests between Maniqui and Apere Rivers where the forests of EBB, the forests of Yakuma Regional Park, the forests of Chimanes, etc. are located.

(2) Impact of Waste

The volume of the waste generated by the road improvement work and as a result of garbage thrown from vehicles using the road will not seriously affect the flora.

8.2.5 Fauna

(1) Impact of Cleaving Woods

If the forests along the project road, which play a important role in the movement of fauna, are cleaved, this will have a great negative impact on fauna inhabits.

(2) Impact of Earth Works

a) Embankment

Road embankment will be an obstacle preventing small animals living near the project road from crossing the road.

b) Side-borrow pitting

As the ponds formed by the side-borrow pitting will become useful watering holes for the wild animals, they should be kept in good condition.

(3) Impact of Waste

With an increase in traffic volume, animals such as deer and monkeys are more likely to eat the waste thrown away from vehicles. In this case, such waste could have a negative impact on fauna inhabits.

(4) Impact of Traffic

An increase in traffic accidents involving animals will have a negative impact on fauna.

8.2.6 Landscape

(1) Impact of Cleaving Woods

Cleaving of woods would adversely affect the beautiful landscape. Accordingly, it is necessary to avoid such cleaving.

(2) Impact of Earth Works

The formation of artificial ponds is a positive impact since they will, in the future, harmonize with the surroundings as well as existing ponds. Therefore, they should be left in good condition after the road improvement work is completed.

(3) Impact of Waste

An increase in waste thrown from vehicles will negatively impact on the landscape. However, this may not be a serious problem.

(4) Impact of Road Facilities

Artificial structures such as bridges may have a negative impact on the surroundings. Therefore, such structures should be made to harmonize with the surroundings as much as possible.

8.2.7 Community

The improvement of the San Borja - Trinidad road will allow local people, information and various goods to move much easily and smoothly among communities around the road, and this will promote mutual understanding. In addition, it will be possible to take emergency cases to clinics and hospitals promptly, and students, if they so desire, will have an opportunity to enjoy higher levels of education because of the improvement of access to educational facilities. Therefore, road improvement will contribute to the formation of harmonious and peaceful communities. Especially, those who do not have cars will be able to move among communities more easily because of improved bus services.

As described in section 7.8.2, conflicts between native peoples and stock farm owners will increase because native people don't usually have legal titles, and also antagonism between native people and immigrants will also increase because of illegal entry into private lands or preservation areas by immigrants. Moreover, after improving the road, traffic accidents might increase because of the increase in traffic and vehicle speed. These changes will not be favorable for the local people and societies.

8.2.8 Economic Activities

As described in Section 7.8, the improvement of the San Borja - Trinidad road will develop the regional economy around the area by shortening the time distance from large consumption areas like La Paz. Aiming at such active economic activity in this area, immigration will increase, causing an increase in population. This population increase will further promote commercial agglomeration in the core communities, which again will make the regional economy much more active. This phenomenon will stimulate the demand of land for housing and economic activities. As a result, land prices will increase gradually, favorably affecting local economy.

As described in Section 7.9, judging from the increase of the recent timber demand in the domestic and foreign markets, deforestation may possibly be intensified after the road is improved. However, according to the CDF, the volume of deforestation per year within concessions is regulated within the definite concession period. Furthermore, after cutting trees, aforestation becomes an obligation. Therefore, if these rules are followed, the impact to the forest within the concession area would be small. However, deforestation within private areas and illegal deforestation may be promoted because of easy access to the forest and the convenience of transportation. It should be kept in mind that such deforestation will continue to be a problem.

At the same time, the increase of land prices will also complicate matters. Generally the increase in land prices is considered to be one of the benefits of road improvement. However, in the objective area of this Study, the native people do not have legal land titles, although stock farm owners do. Therefore, every stock farm owner with a legal land title will be able to obtain the benefit realized by land price increases, however, native people will not be able to have this benefit because they do not have land titles. The problem is that actually the livestock owners are much richer than native people. As a result, the discrepancy in income between rich and poor will increase.

8.2.9 Ruins and Cultural Properties

Since the San Borja - Trinidad road was constructed, it has been used to research archaeological complexes in the area. Therefore, to date many archaeological sites have been excavated in the archaeological complex. These archaeological sites have provided Bolivian and foreign researchers much information on still unknown archaeological ruins in many places. However, recent new discoveries by aero-photografic studies have clarified that it is necessary to investigate the forest area and the flatlands in order to make a true calculation of the artificial embankment area. The existing calculation of artificial embankment area seems to be a conservative estimate because some areas may be covered by sediment and forest. During improving the San Borja - Trinidad road, some archaeological ruins might be discovered, especially, within the planned borrow-pit area. Therefore, the risk of destroying such archaeological ruins is not considered to be high. In addition, the destruction of the ruins might occur during constructing private houses and roads, and the plowing of fields around the archaeological ruins.

8.2.10 Air Quality

(1) Impact of Earth Works

Dust scattering by earth works will be a problem during the dry season. Therefore, proper countermeasures to prevent this should be taken during the road improvement

(2) Impact of Using Heavy Machines and Dump Trucks

Environmental quality standards for SO_2 (24 hours) and NO (1 hour) are both 0.05 ppm. The forecast concentrations generated by heavy machines being used during road construction are 0.0 to 0.00014 ppm and 0.0 to 0.00026 ppm, lower than environmental standards. Therefore, the influence on air quality (except dust) will be very small. Dust, however, will increase.

(3) Impact of Traffic

Environmental quality standards for NO_2 (1 hour) and CO (1 hour) are 0.05 ppm and 35 ppm, respectively. The forecast concentrations of NO_2 and CO from vehicles for the years 2020 are 0.0011 to 0.0029 ppm and 0.000 to 0.055 ppm, lower than environmental standards. Therefore, the influence on air quality (except dust) will be very small. Dust, however, will increase.

8.2.11 Water Quality

(1) Impact of Earth Works

Earth works may increase suspended solids in the river water. Therefore, proper countermeasures should be taken during road improvement.

(2) Impact of Using Heavy Machines and Dump Trucks

The aims of environmental conservation, as shown in Table 8-1-1, are established based on the natural and social conditions of the project area.

(3) Impact of Drainage Facilities

The soil near the flowout of culverts may increase the suspended solids in the river water. Therefore, proper countermeasures should be taken during road improvement.

(4) Impact of Waste

Waste oil exhausted by heavy machines and dump trucks may contaminate underground water or river water. Proper countermeasures should therefore be taken during road improvement.

(5) Impact of Worker Facilities

Water discharged from worker's camps or workshops may locally contaminate river water, but not to a substantial. Therefore, it will be sufficient to follow the SENAC standard.

8.2.12 Noise

The forecast noise levels at San Borja, San Ignacio and Trinidad will only be 3 dB(A) higher than that of present noise levels. Therefore, the influence of noise is considered to be very small.

CHAPTER 9

ENVIRONMENTAL MANAGEMENT PLAN

CHAPTER 9 ENVIRONMENTAL MANAGEMENT PLAN

9.1 Environmental Management Plan

9.1.1 Countermeasures for the Cleaving of Woods

The woods should not be cleaved in the forests between the Maniqui and the Apere Rivers including the forests of EBB, the forests of Yacuma Regional Park, the forests of Chimanes, and other gallery forests (Figure 9-1-1).

Accordingly, the original plan that woods within the right of way area (100 m wide) should be cleaved and stripped during road improvement should be changed.

9.1.2 Countermeasures for Earth Works

(1) Slope Protection of Embankment

The execution flow of slope protection work is shown in Figure 9-1-2.

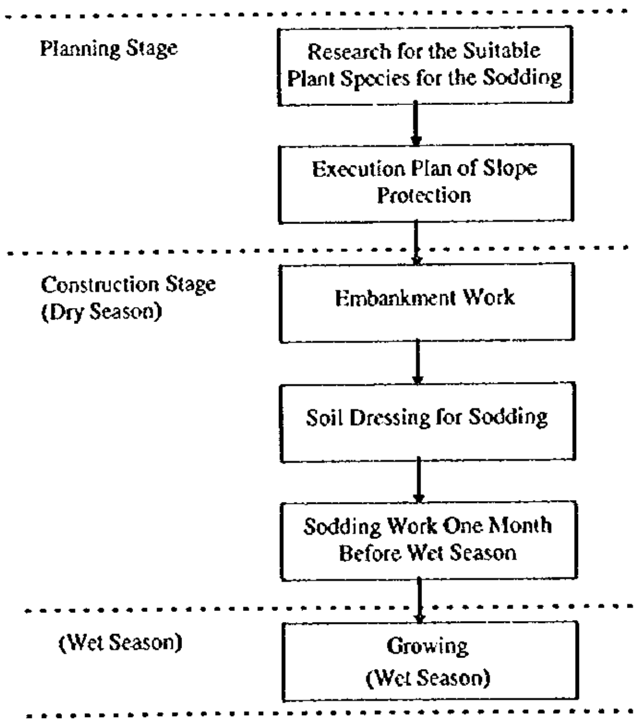


Figure 9-1-2 Flow of the Slope Protection Works

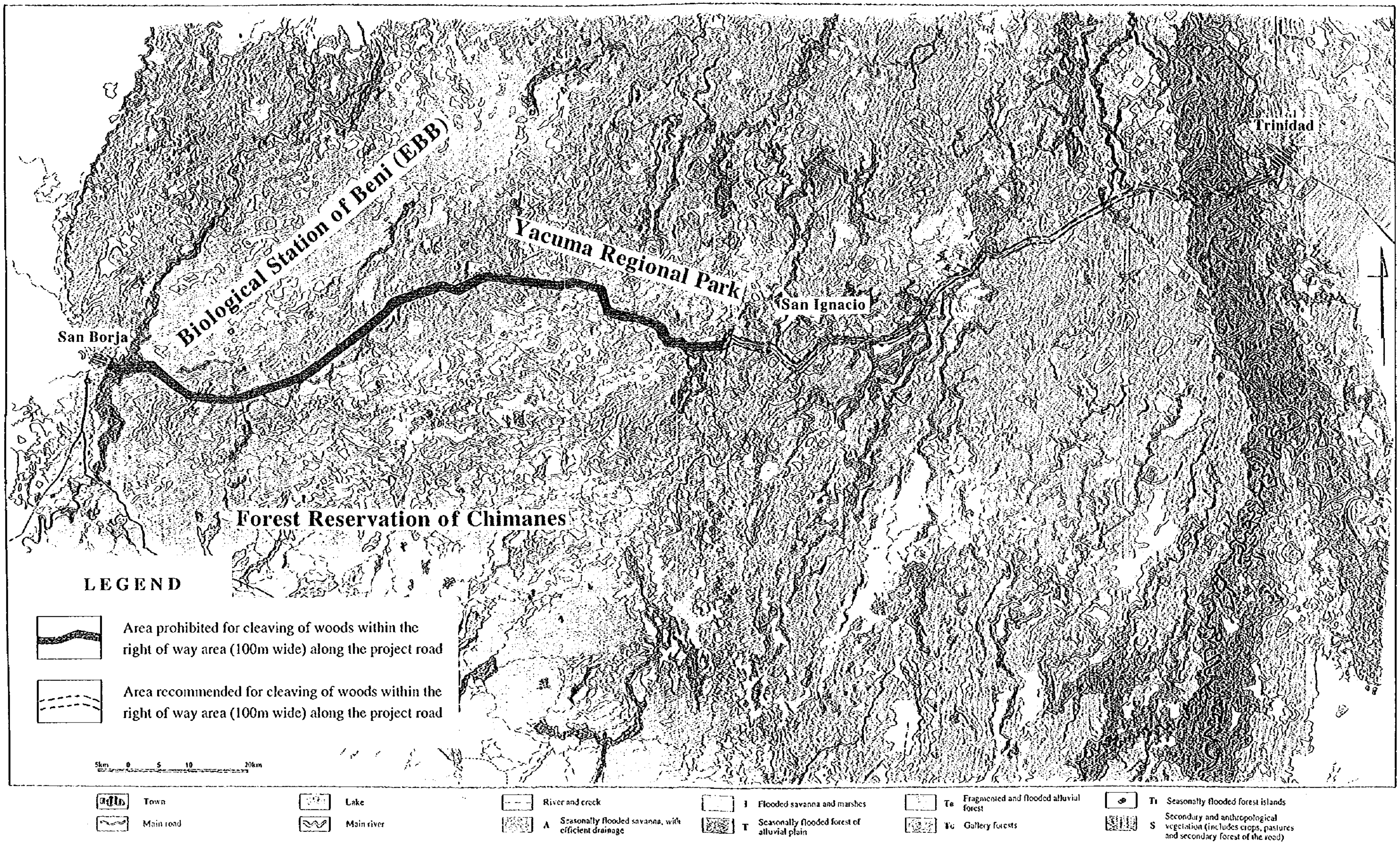
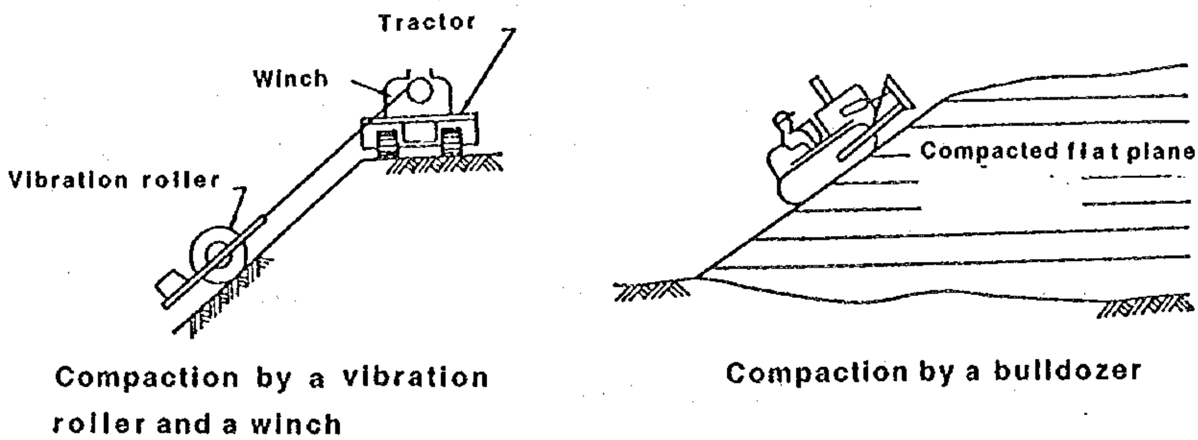


Figure 9-1-1 Prohibited Area for Cleaving of Woods

The slope protection of embankment should be done in two stages : one to give sufficient compaction to the embankment slope, and the other to sod the slope after the embankment work.

There are two ways to give sufficient compaction to the slope (Figure 9-1-3).

- One way causes vibration on the slope from the top using a winch and a 3-ton vibration roller in dead load after rough embankment work.
- Another way involves compaction using a bulldozer after rough embankment work, if the soil is of better quality.



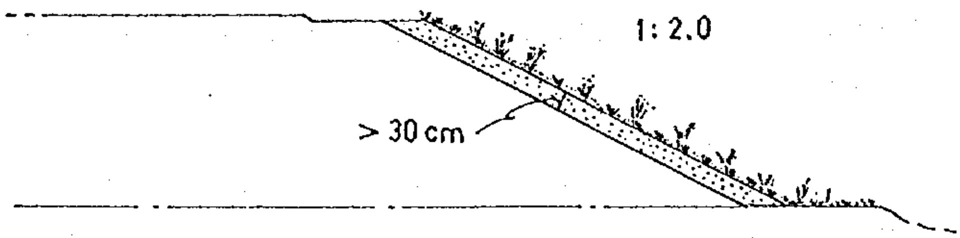
Source : JICA F/S Study Report, 1989

Figure 9-1-3 Compacting the Embankment Slope

Although a kind of *Graminea* may be suitable for sodding, the details are not well known. Therefore, research on a suitable plant species should be conducted before the embankment. Sodding of the slope should be done using the plant species selected by the research, with the embankment process taking place one month before the wet season. The slope materials prepared by stripping should be used for the surface soils for the sodding. The thickness of the surface soil should be at least 30 cm (Figure 9-1-4).

(2) Maintenance of Side-borrow Pits

The ponds formed by the side-borrow pitting should be left, so that they can serve as animal habitats and feeding places as much as possible. Side-borrow pitting should be restricted to the right-of-way area.



Source : JICA F/S Study Report, 1989

Figure 9-1-4 Sodding the Embankment Slope

(3) Proper Treatment of Suspended Solids Caused by Earth Works

Drained water containing suspended solids should be discharged through the borrow pits to existing water courses. In this case, the borrow pits can be used as settlement ponds.

9.1.3 Countermeasures Against the Use of Heavy Machines and Dump Trucks

(1) Proper Use of Heavy Machines and Dump Trucks

When using heavy machines and dump trucks, the engines should be managed so as to prevent air contamination and noise.

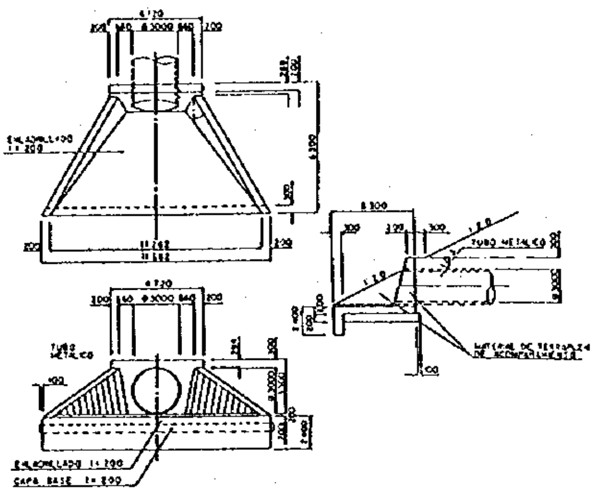
(2) Proper Control of Oil and Grease for Use with Heavy Machines

Gasoline, engine oil, etc., used by heavy machines and dump trucks should be managed so as not to contaminate underground water or river water, during the road improvement.

9.1.4 Countermeasures for Drainage Facilities

(1) Protection Work at the Both Sides of the Culverts

As in the original plan (Figure 9-1-5), both sides of the culverts (corrugated steel pipes) should be protected with concrete to prevent soil erosion.



Source : JICA F/S Study Report, 1989

Figure 9-1-5 Standard Protection Work at the Both Sides of the Culverts

9.1.5 Countermeasures Against the Impact of Waste

Waste oil exhausted by heavy machines and dump trucks should be managed so as not to contaminate underground water and river water during road improvement work.

9.1.6 Countermeasures for Workers Facilities

The gray water discharged from worker's camps or workshops should be drained properly according to SENAC standards.

9.1.7 Countermeasures for Road Facilities

Bridge girders and piers should not be painted with a color incompatible with the surroundings.

9.1.8 Countermeasures Against Traffic

(1) Installation of Traffic Signs and Tunnels for Small Animals

The following countermeasures should be taken to avoid traffic accidents involving wild animals crossing the project road and domestic animals moving on the road;

- Installation of traffic signs warning drivers to pay attention to wild animals.
- Installation of corrugated pipes as "eco-tunnels" under the embankment at the site of embankments higher than 2 m. The "eco-tunnel" is a tunnel installed to allow small animals to cross the road easily and safely. The plan is shown in Figure 9-1-6. Eco-tunnels are recommended at least 36 sites, as shown in Table 9-1-1.

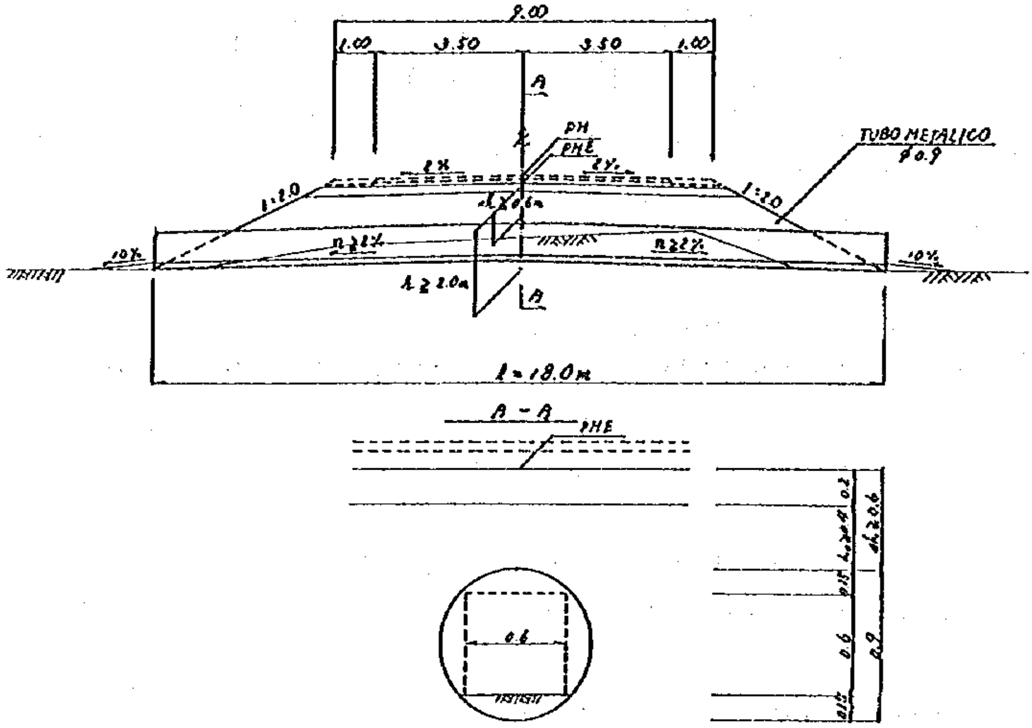


Figure 9-1-6 Eco-tunnel Plan

(2) Prevention of Dust Scattering

To prevent dust from scattering around the town areas, either an asphalt road should be constructed or periodic watering should be done.

Table 9-1-1 Location of Eco-tunnels

Location and distribution of steel corrugated pipes

Span or Section		Bridge	Location of the Pipes (m)
10+400 - 11+300	h > 2.0 m		11+100
		Tijamuchi	
		Sicuri	
37+800 - 40+200	h > 2.0 m		38+800
40+700 - 41+400	h < 2.0 m		
42+600 - 47+800			43+000
			44+000
			45+000
50+200 - 51+200	h > 2.0 m		
51+800 - 54+200	h < 2.0 m		
72+600 - 82+800	h ≷ 2.0 m		75+200
			78+000
88+400 - 91+600	h < 2.0 m		
96+000 - 96+800	h > 2.0 m		96+600
97+600 - 100+400			97+600
102+800 -105+200		Apere	103+000
			104+100
			104+400
106+400 - 108+000		Los Tajibos	107+400
			107+800
110+200 - 112+800		Cuberene	110+200
			110+500
			112+000
113+600 - 116+800			114+200
		Mururita	116+200
			116+400
118+200 - 120+400		Muscruna	118+600
121+800 - 123+400	h < 2.0 m		
127+200 - 130+800	h < 2.0 m	Chevejecure	128+200
133+800 - 134+000			134+000
136+000 - 136+700	h < 2.0 m		
139+600 - 140+400			140+200
155+800 - 156+800	h < 2.0 m		
159+600 - 160+000			159+800
162+600 - 165+000		Matos	163+000
			163+200
172+200 - 172+600	h < 2.0 m		
183+000 - 183+400	h < 2.0 m		
203+200 - 203+600		Curirabita	203+400
			203+500
207+800 - 210+200		Curiraba	208+700
			208+900
711+000 - 212+400	h < 2.0 m		
214+800 - 215+200	h < 2.0 m		
218+000 - 220+600		Maniqui	218+600
			219+000
			219+400
			220+000
			220+400
Total			36 Pipes

9.1.9 Community

In Section 8.2.6, an environmental evaluation was provided for the Community. The following are measures to promote a positive impact and diminish any negative impact.

(1) To Promote Easy Movement Between Communities

Most of the road section between San Borja and Trinidad is embanked to avoid inundation during the rainy season. Therefore, access roads to communities are lower than the improved San Borja - Trinidad road, which is very inconvenient for passing through junctions. Therefore, the entrance points to the communities from the San Borja - Trinidad road will have to be embanked at least 50 m from the access road from the junction. The 15 points must be embanked as shown in Figure 9-1-7. The design of the embankment is shown in Figure 9-1-8. The cost of such embankment has been estimated as US$16,000 (US$1,067 × 15 = 16,000).

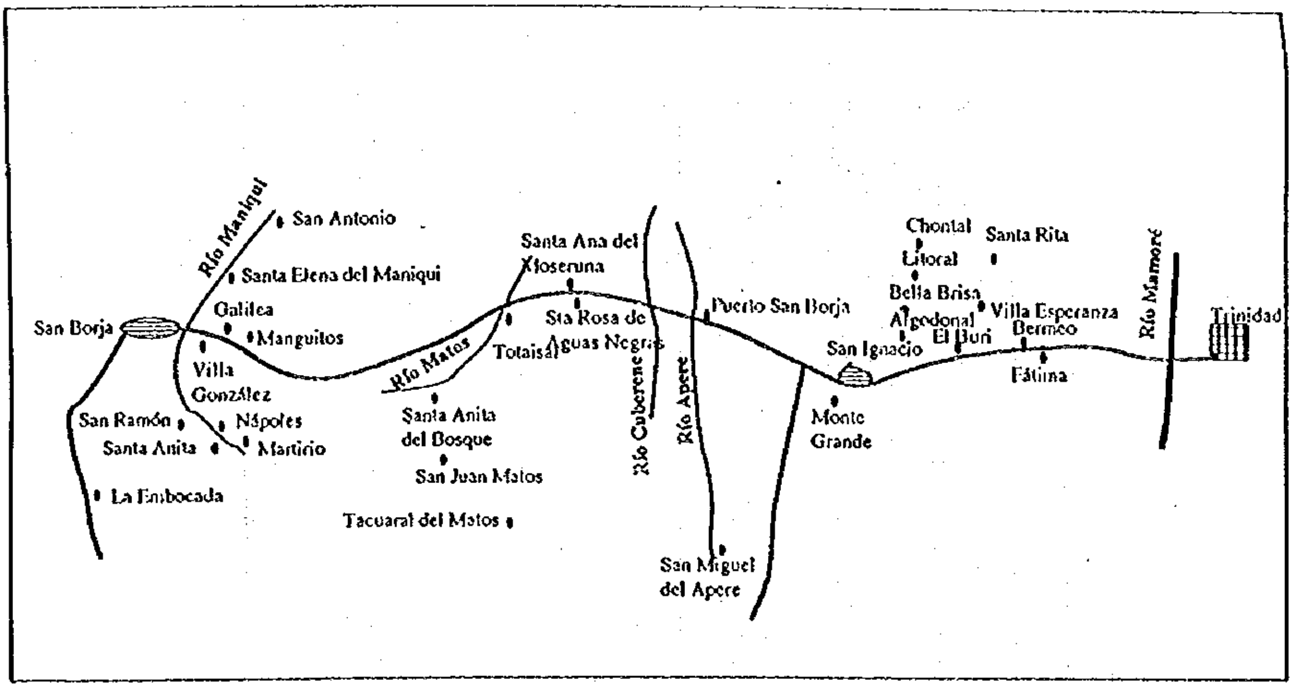


Figure 9-1-7 Location of Access Road Sections with Embankments

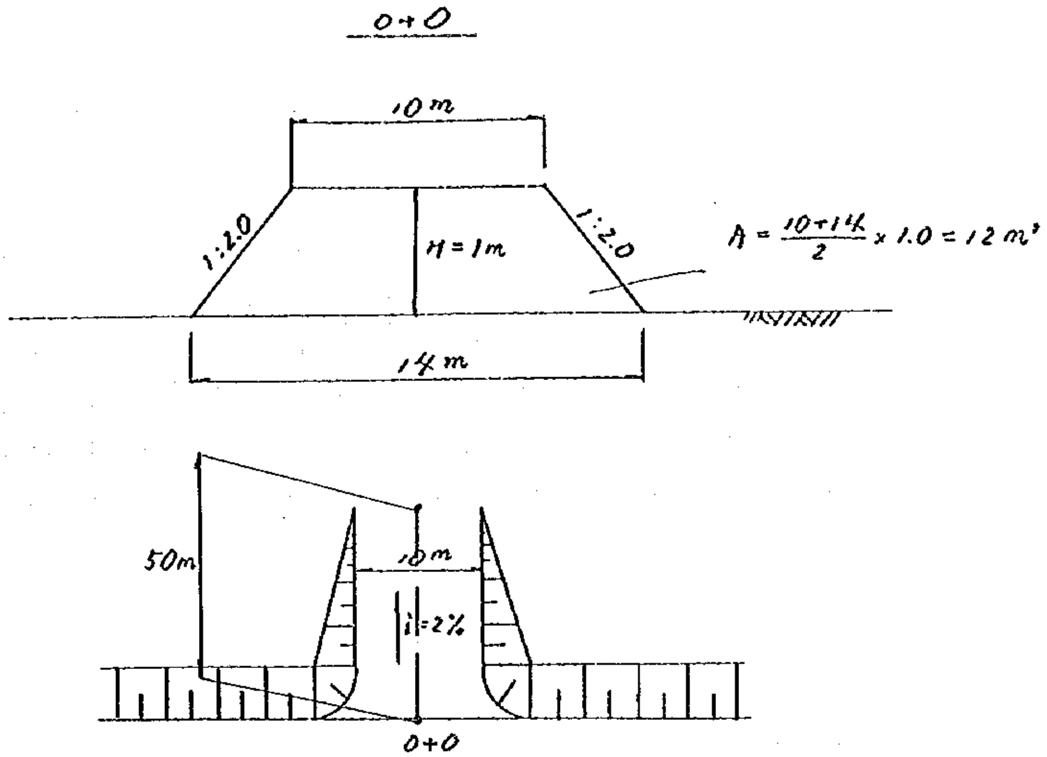


Figure 9-1-8 Design of Access Road Sections with Embankments

(2) To Handle Emergency Cases

The most important and easily feasible measure is to establish a system which will allow emergency cases to go to hospitals or clinics. At the moment there is no such system even in the core communities along the road. Therefore, at least in the core communities medical facilities including medical staff, ambulances, medical instruments such as stretchers, oxygen masks, etc. should be provided. At this moment, it is recommended to allocate one ambulance with the necessary medical equipment in San Ignacio. Costs are as follows (excluding the construction costs of the hospital and the salaries of staff such as doctors, nurses, drivers, etc. These cost should be assigned based on the national health policy);

One Ambulance	: US$70,000
Medical Equipment	: US$10,000
Total	: US$80,000

(3) To Promote Higher Education

In Bolivia there is compulsory education even in the small communities of rural areas. Therefore, primary educational facilities are provided at various locations. However, in rural areas it is not easy for children to enjoy higher education because there are no such schools near their communities. This situation is the same as in most of communities located along the San Borja - Trinidad Road. After the road is improved, children will have access to higher education because movement from their homes to schools will be facilitated. Therefore, higher education facilities should be improved at least in San Ignacio. In the initial stage no additional costs will be necessary because costs can be saved by using existing facilities more efficiently.

(4) To Improve Bus Services

By improving the road, punctual bus service can be provided. Therefore, the number of bus passengers will increase. If bus stops along the road are built with roofs, bus bays and concrete surfaces to ensure convenience and safety, users will increase further, which will increase the frequency of service. This will make the movement of local peoples more convenient. The above-mentioned bus stops should be installed at 13 locations (2 bus stops at one location). Necessary costs for installing bus stops is US$6,500 (US$250/one bus stop×26 bus stops = US$6,500). Bus stop materials are as follows:

Roof	: Leaves of coconuts
Pillars and Walls	: Wood
Floor	: Concrete
Chairs	: Wood
Space	: 2m×6m

(5) To Decrease the Conflicts and Antagonism

As mentioned in Section 8.2.7, the causes of conflicts and antagonism in the communities are as follows:

- Existence of native people without legal land titles.
- Illegal settlement and illegal economic activities by immigrants.

The former conflict is between native people without land titles and stock owners with land titles. To solve this problem land titles should be given to native people as soon as possible. To solve the latter problem, illegal activities should be closely supervised by the proper authorities. Another indispensable measure will be to establish public functions such as a law center to solve disputes among inhabitants. For this purpose, lawyers and legal advisors should be employed in a law center. The costs involved in resolving conflicts and antagonism are described in Section 10.1.4 as necessary costs of the environmental management plan.

(6) To Install Traffic Signs

After improving the road, both traffic volume and vehicle speed will increase considerably. In addition, the population will also increase. Therefore, around the entrance of communities traffic signs warning drivers should be installed. The cost of such traffic signs is estimated to be about US$3,000.

9.1.10 Economic Activities

Section 8.2.8 provides an environmental evaluation of economic activities. The following are measures to promote a positive impact and/or diminish any negative impact.

(1) To Promote Economic Activities

In order to develop the regional economy, the infrastructure related to economic activities should be improved. Since commodity transactions will increase in the objective area, market and delivery facilities will have to be improved gradually.

At the same time, in order to develop the economy in the objective area, existing industries will have to become more active and new industries will have to be introduced into the region. Both are important for increasing job opportunities for the local people. For this purpose, in the forestry industry it will be necessary to stop carrying out logs. Instead, factories like sawmills will have to be set up to employ more local people in sawing work, which will add value to products coming from the region.

As for new industries, the eco-tour industry looks promising. Attractive tour resources include the vast natural forests around the EBB and the magnificent spectacle of the tremendous inundation from near Fatima to Trinidad during the rainy season. In order to foster the eco-tour industry, it will be necessary to improve access from La Paz to San Borja and to arrange accommodation facilities and restaurants along the road. A preparatory organization to promote plans for the eco-tour industry in more detail should be set up.

(2) To Restrain the Deforestation

The likelihood of deforestation along the road was explained in Section 8.2.8. The problem is primarily due to weak organization in preventing deforestation. At present, deforestation is controlled by the CDF (Centro de Desarrollo Forestal); however, the CDF has not obtained any data or information on the objective area. In addition, even the CDF Regional Norte (branch office of the CDF in the objective area) does not function efficiently. Therefore, the establishment of a new organization related to this administration is now being discussed in the National Assembly. If agreement is reached in the National Assembly, the existing CDF will be converted into a new organization, that is, Servicio Forestal de la Nacion (SERFOR). Then this new organization will have to take the following measures to prevent deforestation:

- 16 forestal engineers in each province will have to be hired to perform work such as evaluation, control, and forest supervision.
- US$30 million will have to be committed by the IDB to buy various equipment such as helicopters, jeeps, motorcycles, portable GPS (Global Positioning System), etc.
- Forest engineers should paid salaries of US$700 in order to avoid corruption.

If this new organization is established, illegal deforestation will stop in the near future. To deal with illegal deforestation, a coordinating committee between Ministerio de Desarrollo Sostenible y Medio Ambiente, Secretaria Nacional de Asuntos Etnicos de Genero y Generacionales, and Instituto Nacional de Colonización should be established as soon as possible. At present, these organizations are working separately, therefore, forest administration lacks a systematic policy. The most important measure at the moment is to expand the number of forest keepers as soon as possible.

To promote afforestation, an afforestation deposit system should be established. Under the present law, lumber company have to plant five trees for each one they fell. However, in private forest areas there is no guarantee that this rule being kept. Therefore, by collecting a certain percentage from the value amount of what is carried out, the cost of afforestation can be secured.

(3) To Decrease the Income Discrepancy Between the Rich and the Poor

As described in Section 8.2.8, a land price increase might widen the income gap between rich and poor. The road improvement project will not have a favorable effect if the rich become richer through the resulting land price increase. If this phenomenon occurs, a tax should be imposed appropriately on capital gains obtained by rich land owners.

9.1.11 Ruins and Cultural Properties

In order to protect archaeological ruins and rescue them from possible destruction, the following measures are necessary;

(1) Observation of the Borrow-pit Area During the Construction Stage

During the construction stage, at least one archaeologist will have to stay at the construction site and observe the borrow-pit area for archaeological ruins. If some archaeological ruins are discovered, he or she must stop the borrow-pit works and examine the ruins in more detail. Of course, this area can not be utilized as a borrow-pit area until it is certified that the ruins are not important. The cost for observing the borrow-pit work will be US$28,800 (US$1,200/person × 24 months).

(2) Continuance of Research Work

As explained above, the research works should be continued even in the future, because all the archaeological ruins in the objective area have not yet been discovered. Especially, before the construction works begins, the following research work should be conducted.

a) Purpose

- To formulate an archaeological inventory of the area 50 m from either side of the San Borja - Trinidad road.
- To determine any negative impact on and risk to archaeological ruins.
- To examine the protective measures and facilities necessary for their protection.

b) Budget

Table 9-1-2 Budget for Protection of Archaeological Ruins

Item	Budget	Note
Chief Archaeologist (1 person)	US$ 1,320.-	US$660×2 months
Assistant Archaeologist (2 persons)	US$ 2,200.-	US$550×2×2 months
Equipment (1 vehicle, oil, etc.)	US$ 3,000.-	
Report Making	US$ 600.-	
Others (Driver's salary, Preliminary cost)	US$ 10,000.-	
Total	US$ 17,120.-	

Note: Preliminary Cost applies whenever important ruins are discovered.

9.2 Work Schedule for the Environmental Management Plan

The work schedule for the environmental management plan is shown in Table 9-2-1.

Table 9-2-1 Work Schedule for the Environmental Management Plan

Item of the EMM*	Road Construction Stage				Stage of Road Use									
	1997	1998	1999	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
Environmental Management Work														
Monitoring Work														

Note : * Environmental Management and Monitoring Plans

9.3 Cost Estimation

The total cost for the environmental management plan was estimated as shown in Table 9-3-1.

Table 9-3-1 Cost Estimation for the Environmental Management Plan

(Unit: US$)

Items of Counter Measure	Initial Investment	After Construction			Total Amount
		Unit Cost	Number	Investment	
(1) Environmental Management					
1. Traffic Signs	2,997	-	-	-	2,997
2. Construction of Eco-road	120,830	-	-	-	120,830
3. Embankment at Intersections	16,000	-	-	-	16,000
4. Supervision of Borrow Pit	28,800	-	-	-	28,800
5. Investigation of Ruins	17,120	-	-	-	17,120
(2) Environmental Monitoring					
1. Influence to Flora	-	10,000	6	60,000	60,000
2. Influence to Fauna	-	20,000	6	120,000	120,000
3. Air Quality around City	-	4,000	10	40,000	40,000
4. Noise around City	-	4,000	10	40,000	40,000
5. Investigation of Illegal Activities	37,938	2,600	20	52,000	89,938
6. Periodic Inspections of Ruins		4,000	20	80,000	80,000
(3) Others					
1. Emergency Medical Care	-	80,000	1	80,000	80,000
2. Construction of Bus Stop	6,500	-	-	-	6,500
Total	230,185			472,000	702,185

CHAPTER 10

MONITORING PLAN

CHAPTER 10 MONITORING PLAN

10.1 Monitoring Plan

The monitoring plan is necessary to understand environmental conditions and to examine environmental conservation measures. The components of the monitoring plan are shown in Table 10-1-1. However, landscape and ruins, as well as cultural properties, are excluded from the monitoring plan.

Table 10-1-1 Monitoring Plan

Environmental items	Monitoring	Time*
1. Topography, geology, and soil	Periodical inspection of soil erosion, slope failure, etc.	1 and 2
2. Water	Periodical inspection of the conditions of the water and drainage systems.	1 and 2
3. Flora and Fauna	Periodical inspection of the conditions of flora and fauna, as well as their changes, including existing species of flora, volume of vegetation, amount of deforestation, existing species of fauna, number of wild animals, type and number of wild and domestic animals involved in traffic accidents, etc.	2
4. Community	Periodical investigation of social indicators.	
5. Economic activities	Periodical investigation of illegal deforestation.	
6. Ruins and cultural properties	Periodical inspection of the archaeological ruins.	
7. Air quality	Periodical inspections and measurements of the air quality conditions in urban area.	2
8. Water quality	Periodical inspection of the conditions of suspended solids (SS).	1
9. Noise and vibrations	Periodical measurement of noise levels.	2

Note - 1 : During the project road construction stage.
2 : After the project road construction is completed.

10.1.1 Topography, Geology, and Soil

It will be necessary to periodically inspect the conditions of the topographic features and soil including erosion, slope failure, etc., along the project road during the road construction stage and after construction is completed.

10.1.2 Water

It will be necessary to periodically inspect the conditions of the water and drainage systems, along the project road during the road construction stage and after construction is completed.

10.1.3 Flora and Fauna

It will be necessary to carry out periodic investigations to assess the conditions of the flora and fauna, as well as their changes, including the existing species of flora, volume of vegetation, amount of deforestation, existing species of fauna, number of wild animals, type and number of wild and domestic animals involved in traffic accidents, etc., at fixed observation points after road construction is completed.

10.1.4 Community

It will be necessary periodically investigate illegal acts by new immigrant such as illegal settlement in the national park, protected areas, etc. and at the same time, resolve conflicts among the people in the area. If an illegal act or conflict is discovered, the inspector should report this fact to the Ministry of Sustainable Development and Environment. At the moment this Ministry does not have any local branch office handling such matters.

Therefore, it is recommended that such a branch office be installed in the Beni Department (it is desirable to install it in San Ignacio) with the following staff and equipment:

Staff	: 2 Inspectors
	: 1 law specialist
Equipment	: 1 WD vehicle
	: 2 Motorcycles
	: 1 Boats
	: 1 Potable GPS (Global Positioning System)
	: 1 Computer set
	: 1 Surveying instrument

10.1.5 Economic Activities

It will be necessary to patrol the forest periodically to check for illegal felling and aforestation after the felling of trees. If an illegal act is discovered, it must be reported to the Centro de Desarrollo Forestal (CDF). At the moment CDF regional Norte is in charge of inspecting illegal deforestation in the Beni forest area. Since the salary of the forestal inspector at CDF Regional Norte is very low (about Bs. 300 per month), this administration does not function well because officials maintain a close relation with lumber companies and are easily bribed. Therefore, a new system is necessary to perform the forestal administration properly.

At present, the National Assembly of Bolivia is discussing the creation of a new organization to take over forestal administration from CDF. Under this new organization (known as Servicio Forestal de la Nacion, SERFOR), 16 forestal engineers will be assigned in each province to supervise, control and evaluate the forests. In addition, in order to avoid corruption and close relations with lumber companies, these engineers will receive salaries of about US$700. For this project IDB has already committed itself to supply loans of about US$30 million to SERFOR for purchasing helicopters, jeeps, motorcycles, boats, portable GPSs (Global Positioning System), etc.

Besides the above, patrol posts should be installed in the forestal area as bases for patrolling remote forest areas. In the initial stage at least four patrol posts should be installed in the forests. The necessary costs for constructing one patrol post with a solar panel, radio, furniture, etc. is assumed to be US$20,000, according to the EBB office (the EBB has a plan to set up a control post to control the EBB area). Therefore, SERFOR should prepare more than US$80,000 to construct four patrol posts.

In conclusion, if this new organization functions properly, illegal deforestation will be prevented, and aforestation after the felling of trees will be promoted. Therefore, this new organization should be established as soon as possible.

10.1.6 Ruins and Cultural Properties

Besides during the improvement of the San Borja - Trinidad road, ruins might also be destroyed during the construction of private houses and roads, and the plowing of fields around archaeological ruins. Therefore, it will be necessary to inspect the archaeological area periodically.

At least two inspectors will have to inspect archaeological ruins once every three months. The necessary cost for this is estimated to be US$6,000 per year as shown below.

It takes two weeks to carry out one inspection. Inspections are performed once every three months.

b) Necessary costs per one inspection

Table 10-1-2 Necessary Cost per One Inspection

Item	Cost	Note
Assistant Archaeologist (2 persons)	US$ 500.-	US$250/half month×2 persons
Others (vehicle, oil, transportation cost from La Paz, etc.)	US$ 1,000.-	
Total	US$ 1,500.-	

Therefore, inspections will total US$6,000 per year (US$1,500×4).

10.1.7 Air Quality

It will be necessary to periodically observe and measure the air quality conditions at fixed points in urban areas, including San Borja, San Ignacio and Trinidad, after road construction work is concluded.

10.1.8 Water Quality

It will be necessary to check the amount of suspended solids (SS) by taking physical measurements of the water in the project road during the road construction stage.

10.1.9 Noise

It will be necessary to periodically measure the noise levels at fixed points in urban areas, including San Borja, San Ignacio and Trinidad, after road construction work is concluded.

10.2 Monitoring Plan Work Schedule

The monitoring plan covers the period from the year 2001 to the year 2020. The work schedule of the monitoring plan is shown in Table 9-2-1.

10.3 Monitoring Plan Cost Estimation

The total cost of the monitoring plan has been estimated at US$429,938.- as shown in Table 9-3-1.

CHAPTER 11

ECONOMIC EVALUATION

CHAPTER 11 ECONOMIC EVALUATION

11.1 Cost Estimation

Project costs estimated in 1987 were revised based on 1995 unit costs. To evaluate costs, the bill of quantity and the construction schedule of 1987 remained unchanged. Actually some project road construction works, such as the embankments, were completed; however, they were not considered in the cost estimation. In this Study, the costs of the environmental management plan, including the cost of animal crossing signs at 57 locations along the project road and eco-roads at 36 locations, etc. were calculated. For the evaluation, the costs of the environmental management plan were added to the revised project costs. Estimated project costs based on 1995 price, initial project costs and the cost of environmental management are summarized in Tables 11-1-1, 11-1-2 and 11-1-3, respectively.

Table 11-1-1 Summary of the Project Cost

(Unit: US$)

Description of Activities	Amount	
	Foreign Portion	Local Portion
Earth Fill	4,372,231.82	4,599,854.61
Removal of Existing Corrugated Pipes	3,839.74	9,858.05
Installation of Corrugated Pipes	1,307,340.22	592,059.81
Crossbeam	60,625.10	1,060,594.80
Pavement	8,564,766.53	12,241,067.27
Complementary Works	296,095.27	1,540,069.15
Installation of Crane	466,967.38	623,613.18
Total 9 Bridges	564,926.46	1,286,492.20
Tijamuchi Bridge	351,894.67	880,514.73
Total Direct Cost	15,988,687.19	22,834,123.70
General and Administration Expenses (15%)	2,398,303.08	3,425,118.56
Sub Total	18,386,990.27	26,259,242.26
Utilities (10%)	1,838,699.03	2,625,924.23
Sub Total	20,225,689.30	28,885,166.48
Transactional Taxes (1 %)	202,256.89	288,851.66
Total Construction Costs	20,427,946.19	29,174,018.15
Contingency (10%)	2,042,794.62	2,917,401.81
Sub Total	22,470,740.81	32,091,419.96
Supervision (6%)	1,348,244.45	1,925,485.20
Total	23,818,985.26	34,016,905.16
Grand Total in US$	57,835,890.41	

Table 11-1-2 Initial Project Costs

(Unit : US$1,000)

Year	Local Portion	Foreign Portion	Total
1997	6,254	4,388	10,642
1998	10,264	7,203	17,467
1999	10,841	7,609	18,450
2000	6,625	4,652	11,277
Total	33,984	23,852	57,836

Table 11-1-3 Breakdown of Environmental Management Costs

(Unit: US$)

Items of Counter Measure	Initial Investment	After Construction			Total Amount
		Unit Cost	Number	Investment	
(1) Environmental Management					
1. Traffic Signs	2,997	-	-	-	2,997
2. Construction of Eco-road	120,830	-	-	-	120,830
3. Embankment at Intersections	16,000	-	-	-	16,000
4. Supervision of Borrow Pit	28,800	-	-	-	28,800
5. Investigation of Ruins	17,120	-	-	-	17,120
(2) Environmental Monitoring					
1. Influence to Flora	-	10,000	6	60,000	60,000
2. Influence to Fauna	-	20,000	6	120,000	120,000
3. Air Quality around City	-	4,000	10	40,000	40,000
4. Noise around City	-	4,000	10	40,000	40,000
5. Investigation of Illegal Activities	37,938	2,600	20	52,000	89,938
6. Periodic Inspections of Ruins		4,000	20	80,000	80,000
(3) Others					
1. Emergency Medical Care	-	80,000	1	80,000	80,000
2. Construction of Bus Stop	6,500	-	-	-	6,500
Total	230,185			472,000	702,185

In this Study, the SNC estimation method SNC was adopted to estimate costs. A comparison of the cost estimation method used in the past and the one used in this Study is shown in Table 11-1-4.

The annual investment plan of the revised project costs and environmental management costs was established according to the project implementation schedule. Of the total environmental management cost of US$702,185, US$230,185 is allocated to the installation of traffic signs and eco-roads, embankments at intersections, supervision of borrow pits, pre-investigation for ruins, inspection for illegal activities, and construction of bus stops during the improvement work. After the improvement work, US$ 472,000 will be allocated to survey the influence to Flora and Fauna for 3 years, the survey of air quality and noise for 2 years, annual inspections for illegal activities and ruins, and preparation of emergency medical care equipment.

Table 11-1-4 Comparison of Cost Estimation Methods

Item	Detailed Design (D/D)	Present Study
Direct construction costs	D	D
General and administrative expenses	D×25%	D×15% (G)
Total construction costs	D + G (C)	D + G (S1)
Profits		S1×10% (U)
Supervision	C×65% (I)	
Administration	C×15% (A)	
Sub-total	C + I + A (T)	S1+U (S2)
Transaction taxes		S2×1% (IMP)
Sub-total		S2 + IMP (S3)
Contingency	T×10% (B)	S3×10% (Co)
Supervision		Co×6% (P)
Total	T + B	Co + P

Note - D : Direct cost
G : General administration cost
C : Total construction cost (Detailed design)
S1 : Total construction cost (This study)
U : 10% of total construction cost (Detailed design)
I : 65% of total construction cost (Detailed design)
A : 15% of total construction cost (Detailed design)
T : Total construction cost + supervision + administration (Detailed design)
S2 : Total construction cost + profit (This study)
IMP : 0.1% of (Total construction cost + profit) (This study)
S3 : Total construction cost + profit + transaction tax (This study)
B : 10% of (Total construction cost + supervision + administration) (Detailed design)
Co : 10% of (Total construction cost + profit + transaction tax) (This study)
P : 6% of contingency (This study)

11.2 Economic Evaluation

11.2.1 Objective

The economic evaluation was conducted to judge project feasibility, from a national economic point of view.

11.2.2 Evaluation Method

In this section, substantial benefits, such vehicle operation cost saving, travel time cost saving, reduction of ferry operation cost etc., were estimated. Using the estimated benefit and project cost converted into economic cost, the project was evaluated by comparing two cases, one including project implementation (with project) and the other without project implementation (without project.) The following are the evaluation premises and evaluation indicators considered.

① Evaluation premises

- Construction period : 4 years from 1997 to the year 2000
- Evaluation period : 4 years from 1997 to the year 2000
- Basic price : price in 1995
- Residual value : none

② Evaluation indicators

- Internal Rate of Return (IRR)
- Net Present Value (NPV)
- Benefit-Cost Ratio (B/C)

A discount rate of 12% was applied to the NPV and B/C calculations, as this is the IDB interest.

11.2.3 Benefits of the Project

An economic evaluation was conducted by comparing the two cases, "with project" and "without project". It is necessary to define the concept of these cases, "with project" and "without project", in order to understand project benefits, since some benefits are defined from the difference between their cost "with project" and "without project."

The concept "without project" means that the actual current service level will remain in the future. Table 11-2-1 shows each situation for the cases "with project" and "without project".

Table 11-2-1 Comparison of Two Cases, "With project" and "Without project"

Item		Case "Without project"*	Case "With project"*	
Condition of the pavement		Earth road through the whole road section.	Asphalt: 210.5 km Gravel: 10.5 km	
Number of ferries		6	1	
Travel Speed		Earth	Asphalt	Gravel
	Low	30 km	70 km	50 km
	Medium	30 km	70 km	50 km
	High	30 km	70 km	50 km
Traffic Volume	Dry season	It is possible to pass through the whole road section.	It is possible to pass through the whole road section.	
	Rainy season	It is impossible to pass.	It is possible to pass through the whole road section.	
Means of transportation used for beef transportation		Airplane, ship.	Truck.	

Note - * : Road section between San Borja and Trinidad

The following diverse and tangible benefits are expected to be generated by the project.

- Vehicle operation cost saving
- Travel time saving
- Saving of ferry transportation costs
- Cargo transportation cost saving
- Increase in agricultural production income
- Saving of road maintenance costs

In addition to these tangible benefits, the following intangible benefits are also expected to be generated by the project road.

- Improvement of driving comfort
- Reduction of cargo damage
- Decrease in the number of traffic accidents
- Infiltration of governmental administration
- Constant supply of materials
- Stability of consumption prices
- Promotion of the development of the project area, including rural roads.
- Employment increase in the project area