6-4 Alternative Road Alignment Study

6-4-1 Present Condition of the Existing Road

This section describes the condition of the existing road between Paraguarí and Villarrica, and its branch section to La Colmena.

(1) Existing Road Between Paraguarí and Villarrica

1) Segment 1 : From Paraguarí to Sapucaí

- This stretch of the existing road is 6.0 to 8.0 m in width.
- The surface elevation of the road for this section is about the same as the elevation of the ground adjacent to the road. Road surface and drainage systems are in good condition.
- The horizontal alignment of the road is smooth, except for the section passing through the town. To pass through the towns of Sapucaí and Escobar, which are located between Paraguarí and Sapucaí, the actual vehicles running along the existing road must make six and two right-angle turns, respectively, in the towns, which have grid-formed streets.
- The exiting vertical alignment of the road has grades of 4 to 6% in areas around Sapucaí in the hilly district, but most of the road has gradual grades.
- Areas adjacent to the road, the lower slopes of the mountain to the north and the land in the vicinity of the towns, are cultivated, and much of the land, including the areas south of the road, consists of pasture land.

2) Section 2 : From Sapucaí to Caballero

- This stretch of road is 6.0 to 8.0 m in width.
- The surface elevation of the existing road for this section is slightly lower than the adjacent ground where the ground was cut slightly for the road. Therefore, the drainage of the road seems insufficient and the road surface conditions are not satisfactory. Many ruts can be seen on the surface and it is more difficult to drive here than along other road segments, especially after rainfall.
- The horizontal alignment of the road is generally smooth except for the stretch passing through the town and the sharp bends at the railroad crossing. In the town of Caballero, the road has four right-angled turns. The vertical alignment of the road has very slight grades because the road in this segment passes over flat land.
- In the northern side of the road, inclined land is stretched widely with a gentle and regular slope gradient up to the skirt of the mountains. Almost all of this area is

utilized as for pasturess and some parts around the villages or houses scattered throughout the area are cultivated.

3) Segment 3 : From Caballero to Ybytimí

- The existing road of this section is 6.0 to 7.0 m in width.
- The surface elevation of this road in this segment is slightly lower than that of the adjacent ground, like the previous segment. The road surface condition is also similar to that of the previous segment, that is, fairly bad without sufficient drainage and with many surface undulations along this segment.
- The horizontal alignment of the road is smooth with a few little curves, beyond the boundary of the Caballero urban area. The vertical alignment of the road is also constructed with very gradual lines because the road passes through flat lowlands.
- The lands around the road are used for pasture. Except that flat lowlands stretch along the northern side of the road, instead of inclined hilly land, the general conditions of this segment are very similar to those of the previous segment.

4) Segment 4 : From Ybytimí to Punto Unido via Hector Vera

- The existing road of this segment is 4.0 to 8.0 m in width. Generally speaking, the road width between Ybytimí and Hector Vera is relatively narrow.
- The surface elevation of the road is about the same as the existing ground level of adjacent areas, or slightly lower. Therefore, the road surface condition is very bad due to poor drainage in the section where the road runs along low flatlands. In particular, the conditions of the few kilometers of the road before and after the village of Hector Vera are so bad that even 4-wheel-drive vehicles cannot pass when it rains, even if the rain is not so heavy. However, road conditions become better as one approaches Punto Unido.
- The horizontal alignment of the road is not good because it was constructed as a series of small curves. The vertical alignment has relatively gradual grades, although the road runs through gently undulating hills in some parts.
- Along the road, the adjacent land in the hilly areas close to the town, Ybytimí and Hector Vera, has been cultivated, while all other areas are lowlands used for pasture.

5) Segment 5 : From Punto Unido to Río Tebicuary-mí

- The existing road of this section is 5.0 to 7.0 m in width.
- The surface elevation of this stretch of road is nearly the same as the ground level of adjacent areas, or slightly lower than the existing ground level because the ground was cut slightly for the road. The road runs straight from Punto Unido to the town of Tebicuary on the flatlands along the north rim of a sugar cane plantation. The road

has a crank-like corner in the town of Tebicuary when one approaches the bridge on the Tebicuary-mí River.

- The road surface and drainage conditions are generally good, although the road surface elevation is not higher than the adjacent area, as stated above.
- There are two bridges on the Tebicuary-mí River; the main bridge is about 70 m long, and a supplementary bridge is 20 m long. These bridges are made of wood, and are 3.5 m wide. The structures of these bridges are generally poor. Therefore, periodic reinforcement work has been necessary.

6) Segment 6 : From Tebicuary to Martínez

- After crossing the river at the town of Tebicuary, a road that is 5 to 7 m wide runs through low flatlands to the town of Martínez, which is located on the rim of a hilly plateau. These flatlands are low and form part of the so-called flood reserve of the Tebicuary Mí River.
- The existing road here is barely elevated, so that it is sometimes covered by floodwater. This occurs more often at the part of the road near Tebicuary. Nevertheless, not understanding these circumstances, the surface conditions of the road are not so bad, provided that does not rain. The horizontal alignment of the road is straight from the bridge to the entrance of the town of Martínez. The road inclines gently from the entrance, and takes two right-angle corners in the town as in the other towns.

7) Section 7 : From Martínez to Cardozo

- The existing road is 5.0 to 7.0 m in width over this stretch.
- The surface elevation of this stretch of road is slightly lower than the existing ground level because the ground was cut slightly in constructing the road. The road surface conditions are comparatively good, but a few sections in the lowland areas are not well drained.
- The horizontal alignment of the road generally consists of smooth lines, except for one location with a small "S" curve. The vertical alignment is constructed of gradual grades not only in the flat area but also in the hilly land.
- Most of the land along the road is pasture land and the surrounding areas of the town and villages are used for agriculture.

8) Section 8 : From Cardozo to Villarrica

- The existing road is 4.0 to 6.0 m in width over this stretch.
- The surface elevation of this road segment is nearly the same as the existing adjacent ground, although in a few locations it has been brought down by cutting. The road

surface and drainage conditions are generally good. However, the drainage conditions in the lowlands just outside the city of Villarrica are not goodl.

- The horizontal alignment of the road is generally smooth, except for two locations with "S" curves at railroad crossings. The vertical alignment consists of gradual lines.
- The areas along the road are either cultivated lands or pasture lands that are relatively highly utilized.

(2) Branch to La Colmena

The following describes the current conditions of the three existing roads considered as possible alternatives for connecting the Paraguarí/Villarrica Road with La Colmena.

1) Alternative 1 : La Colmena to Tebicuary via Tebicuary-mí

a) La Colmena to Tebicuary-mí

- The existing road of this section is 4.0 to 6.0 m in width, and it has been built by cutting through gently undulating hills. Nevertheless, the road surface elevation is nearly the same as the natural ground level of the surroundings when the road passes through the lowland areas.
- The road surface condition from La Colmena to areas close to Empalme (the starting point of alternative 2 route on alternative 1) is good, but the stretch from there to Tebicuary-mi is not so good because of rutting. Lowland areas are not well drained.
- The horizontal alignment of the road is smooth, except for two sharp bends. The vertical alignment is generally flat.
- Along the road, the adjacent land in the hilly areas close to the town has been cultivated, while all other areas are lowlands used for pasture.

b) Tebicuary-mí to Tebicuary

- The existing road of this segment is 6.0 to 8.0 m in width. From a geographical viewpoint, this road segment can be clearly divided into two parts; from Tebicuary-mí to mid-way to Tebicuary, and the remainder. The former is the road running in low flatlands used as pasture land and covered by flood water on rare occasions, and the latter is the road passing through relatively higher ground surrounded by woods or sugar cane plantations.
- The road running along lowland areas has been constructed on an embankment of 1 to 1.5 m above the ground level. The surface level of the road of the remaining half is generally the same as that of the adjacent ground.

- Road surface conditions are fairly good in general, but in part of the lowland areas, i.e., between points No. 253 and No. 273, where the road height is least, the surface conditions of the road are not so good.
- Both the horizontal and vertical alignments are smooth.

2) Alternative 2 : Empalme to Punto Unido via Vera
- The existing road of this section is 4.0 to 6.0 m in width.
- The elevation of this road surface is nearly the same as the adjacent existing ground. The road surface conditions are comparatively good, but some parts of the road in the lowland areas are not well drained. The areas between points No. 162 and No. 178 are located within the flood zone of the Río Tebicuary-mí.
- The horizontal alignment of this section is generally smooth, except for two existing sharp jogs. The vertical alignment has gradual slopes.
- All the land along the road is cultivated, except for the pasture land located in the two lowland areas.
- The latter half of this alternative route, i.e., from Hector Vera to Punto Unido is the same as the road segment from Ybytimí to Punto Unido, the present conditions of which have already been described.

3) Alternative 3 : La Colmena to Punto Unido via Martínez Cue
- This alternative route runs north directly from the city of La Colmena, passing a village called Martínez Cue, then joining with the existing road between Paraguarí and Tebicuary at Hector Vera.
- The existing road between La Colmena and Hector Vera along this route is approximately 4.0 m in width.
- The surface elevation of this road section is nearly the same as the existing ground level. Road surface conditions are extremely bad because there is little traffic no maintenance work has ever been done on this road.
- The horizontal alignment is generally smooth except for three sharp jogs. The vertical alignment generally consists of very gradual gradients because the road passes through flat lowland areas. The road, however, does also pass through hilly areas located near the center of this stretch of road.
- Almost all the land along the road is pasture land.
- The section from Hector Vera and Punto Unido is the same as the alternative 2 route described above.

The present conditions of existing roads are summarized in Table 6.4.1.

Table 6.4.1 Present Condition of the Existing Roads

Road Section	Section between Paraguari and Villarrica								Branch Section to La Colmena				
Road / Segment	Paraguari -Sapucai	Sapucai -Caballero	Caballero -Ybytimi	Ybytimi -P.Unido	P.Unido -Rio Teb.	Rio Teb. -Martinez	Martinez -Cardozo	Cardozo -Villarrica	Colmena -Teb.-mi	Tebicuary-mi	-Tebicuary	Empalme -H.Vera	Colmena -H.Vera
Road Width	6.0-8.0	6.0-8.0	6.0-7.0	4.0-8.0	5.0-7.0	5.0-7.0	5.0-7.0	4.0-6.0	4.0-6.0	6.0-8.0		4.0-6.0	4.0
Surface Height relative to Adjacent Ground	even	lower	lower	even or lower	even or lower	even or lower	lower	even or lower	even or lower	high	even	even	even
Surface Condition	○	△	×	×	○	○	○	○	△	△	○	○	×
Drainage Condition	○	×	△	×	○	×	△	○	△	△	○	△	△
Horizon. Alignment	○	○	◎	×	○	○	○	○	○	○	○	○	○
Vertical Alignment	○	○	◎	△	○	○	○	○	△	○	○	○	○
Land Use of Adjacent Ground	cultivated & pasture	cultivated & pasture	pasture	cultivated & pasture	cultivated & pasture	cultivated & pasture	cultivated & pasture	cultivated & pasture	cultivated & pasture	pas-ture	culti-vated	cultivated & pasture	pasture
No. of Bridges:<10m	1	0	0	0	0	0	1	0	1	1		0	1
30> >10m	0	1	2	1	1	0	0	0	1	5		1	2
>30m	0	0	0	0	1	0	0	0	0	1		0	0
Total Length	6.7m	24.5m	30.5m	12.0m	90.0m	0m	5.0m	0m	19.0m	117.9m		12.5m	30.0m

Note: ◎ = No problem, ○ = Good, △ = Poor, × = Bad

6-4-2 Selection of Alternative Routes

(1) General Description of the Selection of Alternative Routes

As described in the previous section, roads do exist between the cities at the beginning and end points of the objective roads of the Study, i.e., Paraguarí, Villarrica, and La Colmena. However, the present conditions of these roads and their service level are considerably bad.

Although utilization of existing roads for the new development must prove advantageous, taking into account of future traffic forecasts, the road category, and in order to complying with the geometric criteria described in 6.2, the need to alter the existing road alignment or to select new routes was examined at some places from the following viewpoints.

i) To improve (or to comply with the geometric criteria for) road alignment
ii) To maintain a better relationship between existing urban areas and the road, considering the increase of through traffic in the future
iii) To find the most advantageous route for future development of a nationwide road network
iv) To select the most feasible route from a socio-economic viewpoint

As the result, the new alignment of the study road in most parts coincided with that of the existing road, but a few alternative routes in some parts were proposed for comparative examination. Those alternatives can be divided into two groups as follows:

i) small-scale alternative detours around the towns, and
ii) large-scale alternatives.

(2) Small-scale Detours Around the Towns

Several alternative detour routes were set out at Sapucaí and Gral. Fernandino Caballero. At Escobar, since the existing road passes along the edge of the town, it was considered unnecessary to make a new detour there. Therefore, small-scale modification of the existing road alignment at the east end of the town was selected. Detouring around other towns along the study road such as Ybytymí, Hector Vera, Cnel Martínez, and Félix Pérez Cardozo was examined as part of another group of large scale alternatives.

The physical relation or access control between a town and a trunk or arterial road, such as the study road, whose role is mainly for long-distance and high-speed transport, is to be determined considering the traffic volume of the road, as well as the size and other local conditions of the town; however, there are no standard criteria for this purpose.

In case of the towns described above, that is, towns with a population of less than 5,000, the following plan could generally be applied:

1) Case-1 : Traffic volume of the road < 1,000 pcu[1]
Since the effect of the through traffic would seem to have a negligible effect on the town which the road passes, direct access by the road to the center of the town is allowed. If a bypass system is introduced in this case, the road would not really benefit the town.

2) Case-2 : Traffic volume of the road <3,000 pcu[1]
Careful consideration is necessary at this level. In general, an one-way loop system would be a useful solution in this case, because most of these towns have similar grid road patterns.

3) Case-3 : Traffic volume of the road > 3,000 pcu[1]
A bypass system can be recommended in this case.

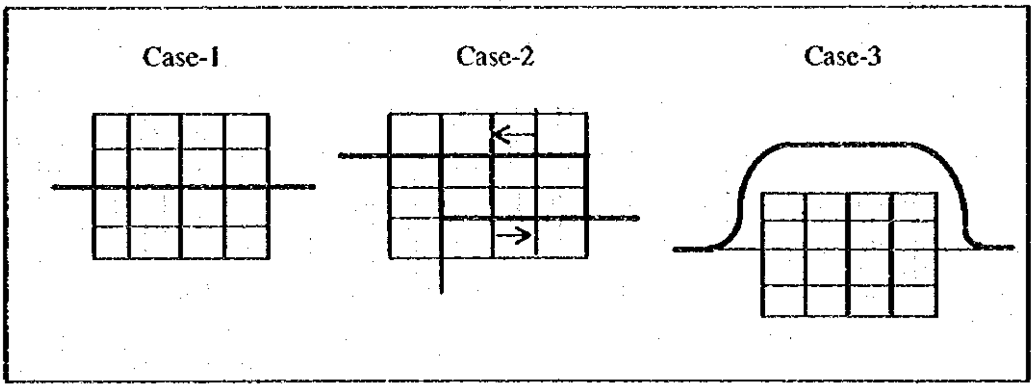


Figure 6.4.1 Model Access System Patterns

The traffic volume forecast for the year of 2015 at Sapucaí and Gral Fernardino Caballero is shown in the following table. (Refer to Table 5.5.1) The figures in the table show that those towns must have a bypass system, in general, since the estimated pcu in each town exceeds 5,000.

[1] : pcu = passenger car unit = Passenger car × 1.0 + Bus × 3.0 + Truck × 3.5

Table 6.4.2 Traffic Volume and PCU in 2015

Town	P. Car	Bus	Truck	pcu
Sapucaí	1,638	436	1,362	10,768
Gral F. Caballero	1,518	411	1,301	7,301

Adding to the general considerations described above, taking into account the geographical features, actual street patterns, position of the present road entrance and exit in each town, the alternative detour (bypass) routes shown in Figure 6.4.2 were selected.

(3) Large-scale Alternative Route Alignment

Along the study roads between Paraguarí and Villarrica and its branch section to La Colmena, alternative route alignments, each with a fairly long span, were set out at the following four sections to be examined and compared from various viewpoints such as traffic aspects, natural conditions, engineering aspects, socio-economic activities, etc. In other words, to examine why the alternatives in those four sections were not only for detouring around a town like the small-scale alternatives which were described in the previous sub-section for Sapucaí and G.F. Caballero.

i) from Ybytymí to a point about 10 km east (hereinafter, known as "Punto Unido")
ii) Río Tebicuary-mí crossing section : 4 km long
iii) from Félix Pérez Cardozo to the entrance of Villarrica
iv) the branch section to La Colmena

Those alternative routes are shown in Figures 6.4.3 to 6.4.6, and in section 6-4-4 a detailed examination of each was conducted to determine the optimum route.

Detours around the towns of Ybytymí, Hector Vera, Tebicuary, Tebicuary-mí, Cnel Martínez, and Félix Pérez Cardozo were also taken into account in the comparative study of those alternatives.

(4) Connection with Existing Principal Roads

Needless to say, the study road must be connected to National Roads Nos.1 and 8, and the Acahay-La Colmena Road at Paraguarí, Villarrica, and La Colmena, respectively, in order to ensure the positive effects of road development.

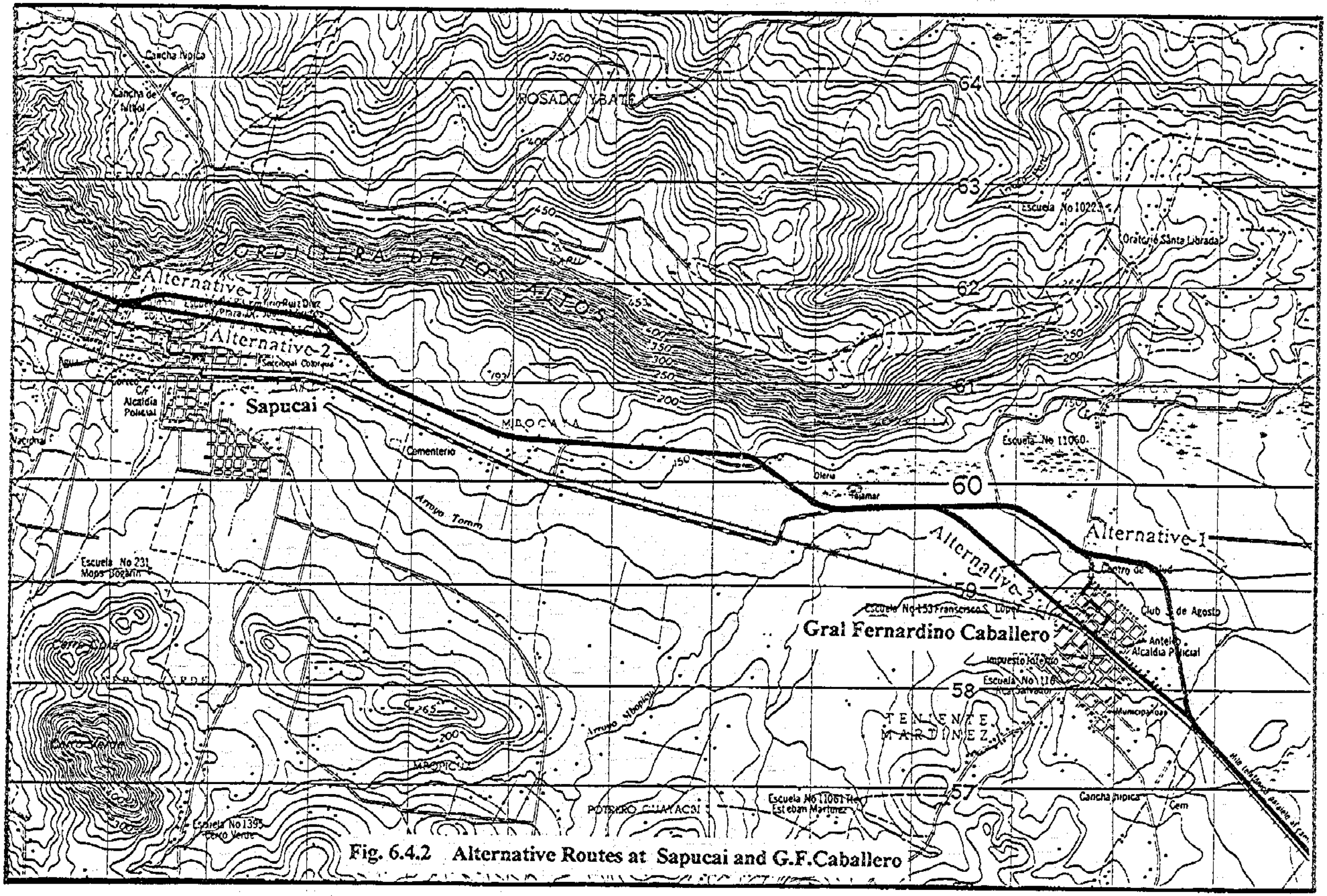


Fig. 6.4.2 Alternative Routes at Sapucai and G.F.Caballero

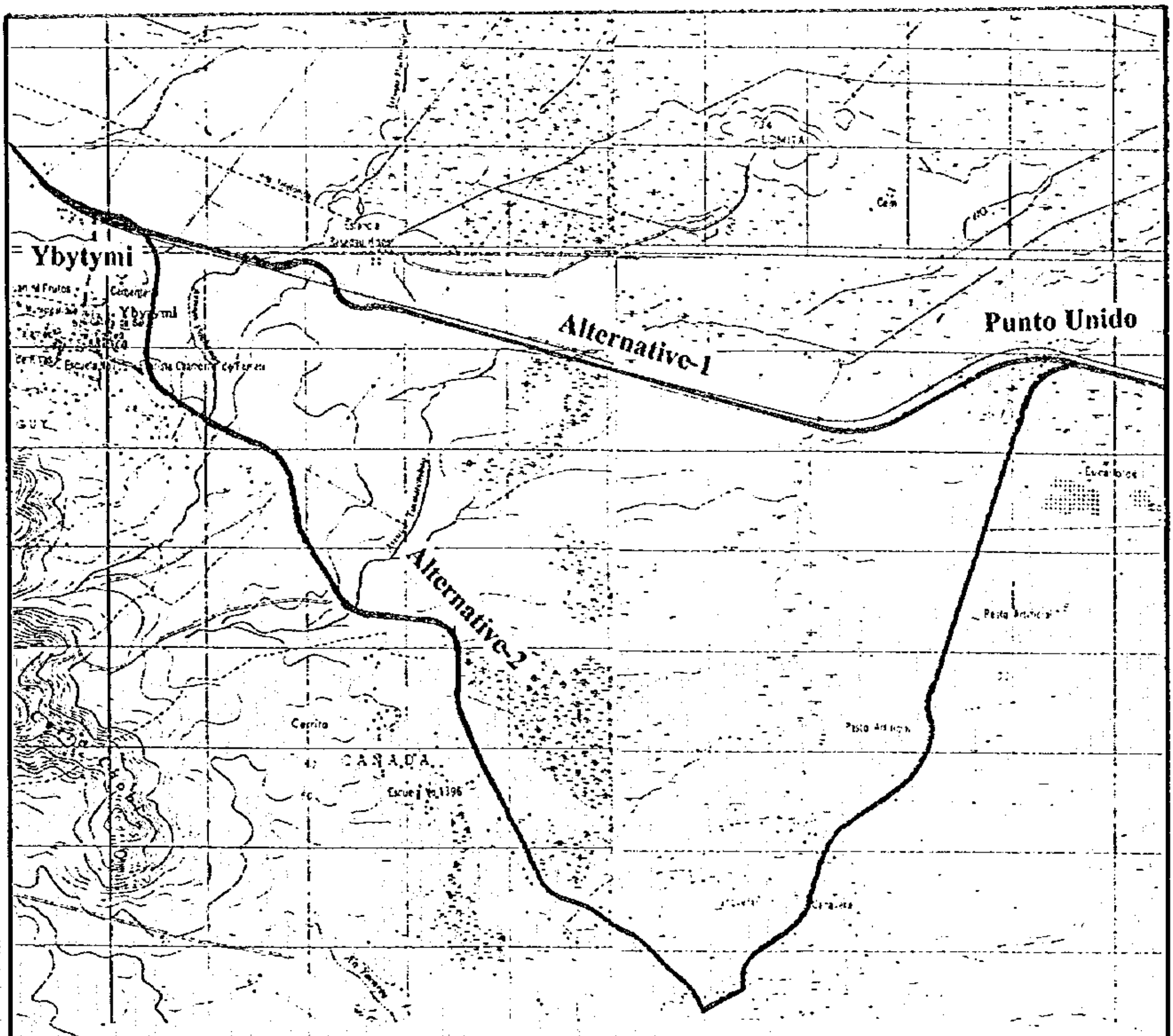


Fig. 6.4.3 Alternative Routes between Ybytymi and Tebicuary

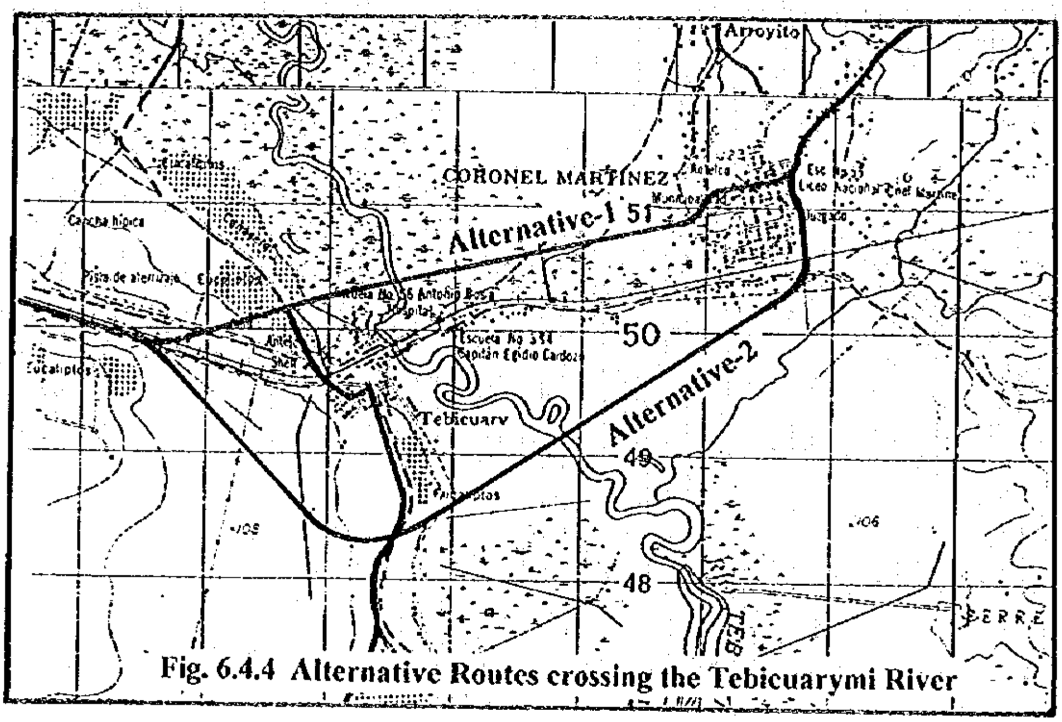


Fig. 6.4.4 Alternative Routes crossing the Tebicuarymi River

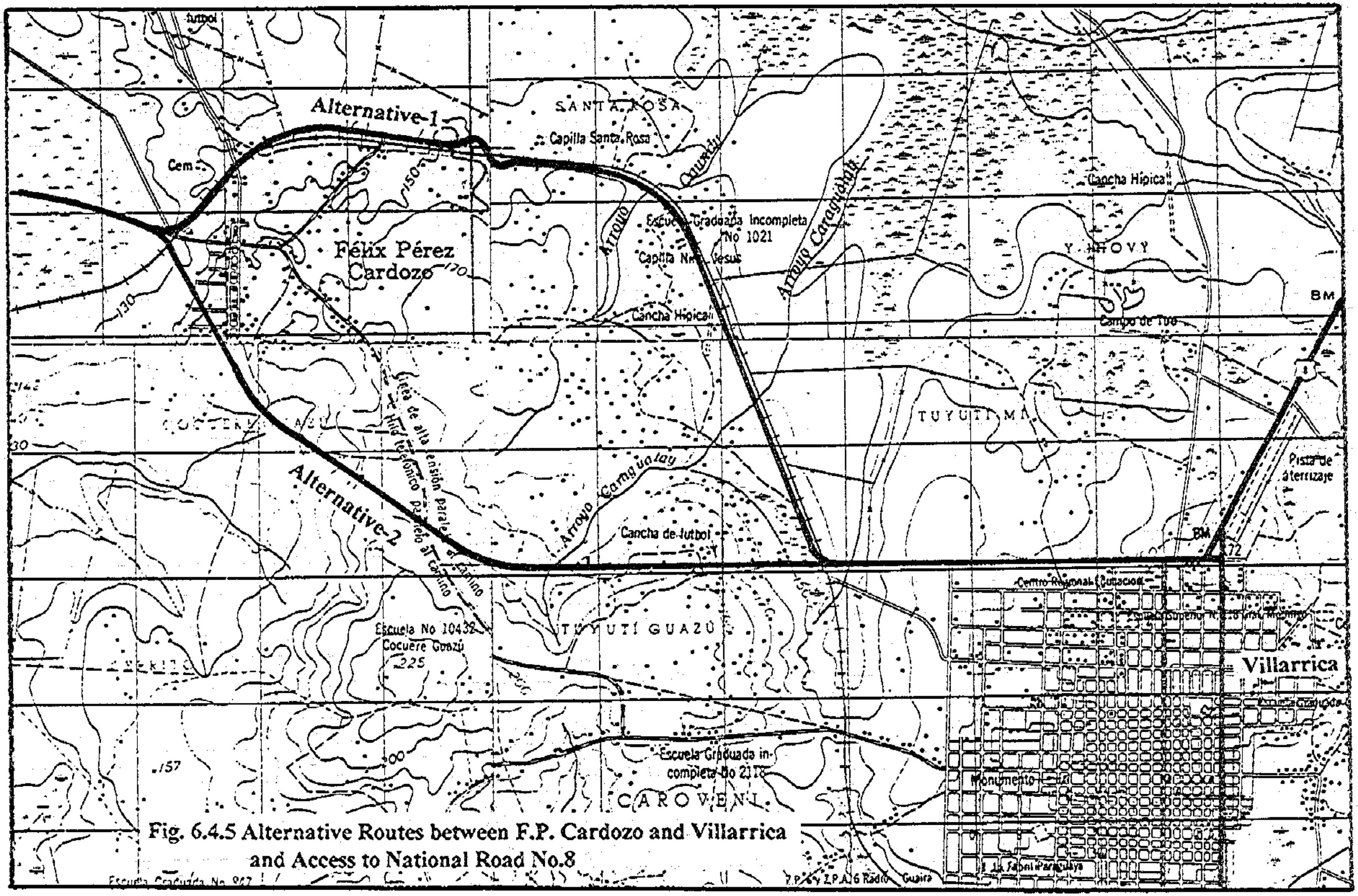


Fig. 6.4.5 Alternative Routes between F.P. Cardozo and Villarrica and Access to National Road No.8

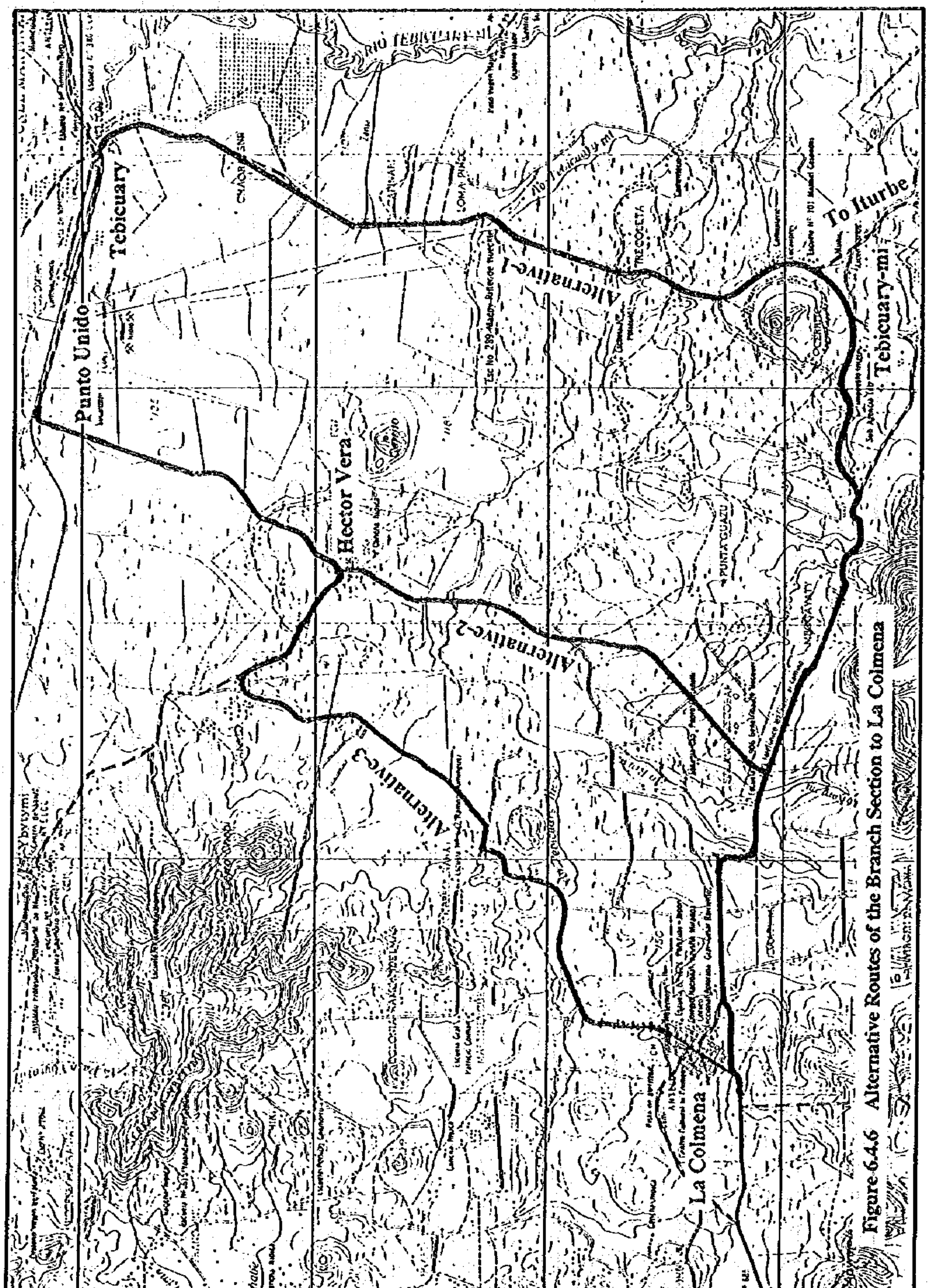


Figure 6.4.6 Alternative Routes of the Branch Section to La Colmena

As present, the existing road route considered in the study passes right through the center of those three cities; therefore, a new route alignment of the study road connecting with said Principal Roads must be developed. However, considering the structure of those cities and streets, present land use, number of obstacles to be removed, the forecast traffic volume, and its origin-destination characteristics, no meaningful options in the selection of the route exist in those three cities. That is;

1) At Paraguarí (see, Figure 6.4.7)

The study road should first be united with the road from Paraguarí to Piribebuy at the north-eastern edge of Paraguarí city, then turn south-west passing along the last street on the north-western side of the city, and joining together with National Road No.1.

Because the present traffic on the existing study road includes the heavy vehicles encountered on National Road No.1, the street passing through the center of the city would surely be unable to bear the future traffic volume estimated at more than 2,000 vehicles per day in 2005. Moreover, the negative environmental impact upon the road-side area in this such case would not be negligible.

2) At Villarrica (see, Figure 6.4.5)

The only route that can connect the study road, coming from the north-west, with National Road No.8 in the city of Villarrica is that passing along the last street at the north edge of the city. However, to date this street has only been partially developed. For the exactly same reason as in the Paraguarí case, it will not be possible to use the street of the present route in the city after development of the study road.

3) At La Colmena

For the branch section connecting the city of La Colmena and the principal study road, between Paraguarí and Villarrica, three alternative routes were set out as shown in Figure 6.4.6. In case of Alternatived-1 and -2, which run toward the east, there is no idea except the route shown in Fig. 6.4.6, detouring around the city, mainly because of the difficulty of acquiring land.

In the same sense, the only way to connect the 3rd alternative route with the existing Acahay-La Colmena Road would be to allow through traffic to pass the right center and central plaza of the city. Although it was apparent that Alternative-3 was the most disadvantageous of the three alternatives for this reason, this part is examined in more detail in the next section, 6-4-4.

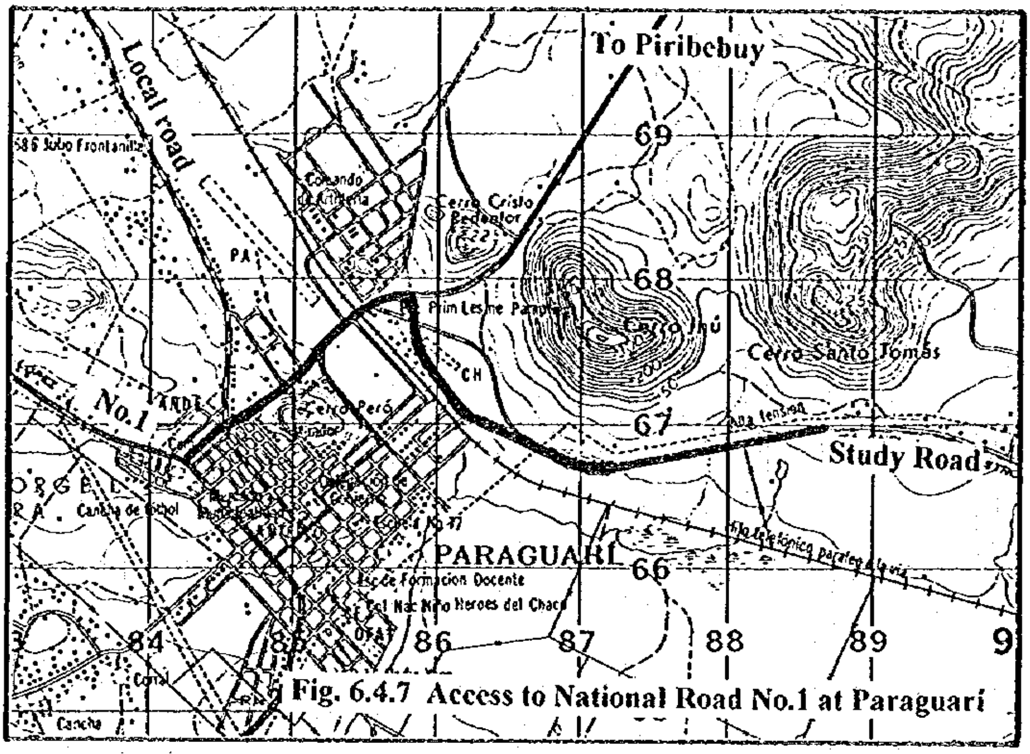


Figure 6.4.7 Access to National Road No.1 at Paraguarí

6-4-3 Preparatory Study for the Evaluation of Alternative Routes

(1) Possible Borrow Pits and Quarry Sites

As described later, it is apparent that it will be impossible to complete the required earthwork by using the "side borrow pit system" for every segment of the study road. In other words, some borrow pits outside of the right of way will be required along almost every segment of the road to obtain material for embankment .

This Study assumed that subgrade layer of the entire objective road must be constructed using material from such borrow pits. That is, the core or lower layer of the embankment could be constructed of material obtained by excavation between the road and the boundary of the right of way (i.e. side borrow); however, considering the quality of material from side borrow, it might be usable for subgrade construction, except on limited parts of the road.

The results of investigations to find borrow pits near the study road carried out during this Study are summarized in Figure 6.4.8. During the preliminary design of this Study, the results of which are described in Chapter 7, the balance of the required volume for subgrade construction, and the potentially available quantity from candidate borrow pits has been analyzed, and the ability to obtain the required quantity of material nearby has been confirmed .

Moreover, stone and rock quarry sites will also be necessary to permit paving and the construction of cement concrete structures in certain locations. The candidate quarry sites found in the Study are also shown in Figure 6.4.8, as C1, C2 and C3. In addition to these three candidate places, "Cerro Acahay", located between Carapeguá and Acahay, had been considered as an alternative quarry. However, the Government of Paraguay has recently designated the area including "Cerro Acahay" as a National Reserve, and hence it is impossible to continue using this site to obtain necessary rock material.

The principal characteristics of the rock obtained from the candidate quarry sites are summarized below:

Table 6.4.3 Principal Characteristics of the Rock Materials

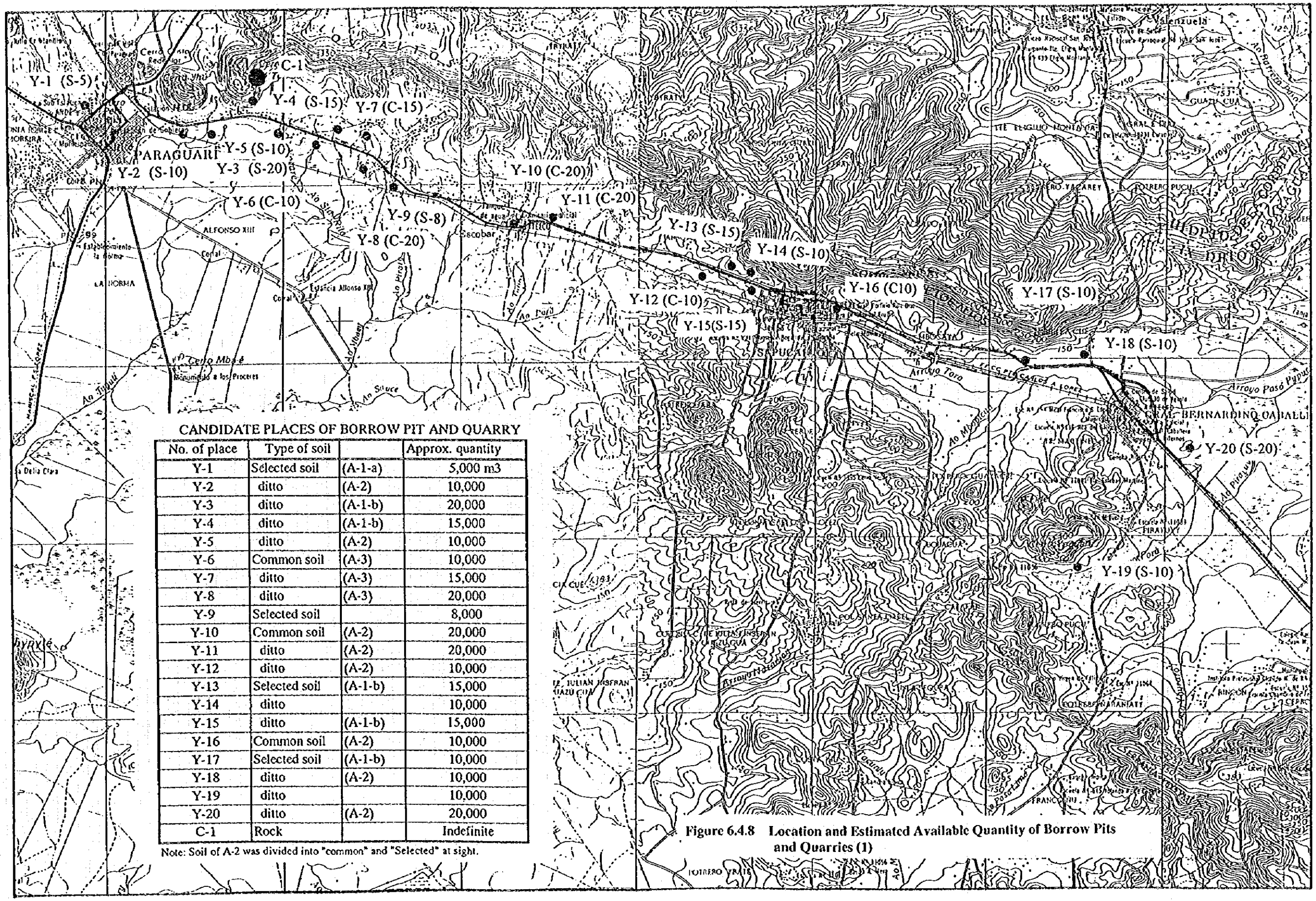
Quarry site	Cerro Santo Tomás at Paraguarí (C1)	Hector Vera (C2)	Cerro Itapé (C3)
Rock type	Granite	Basalt family	Basalt
Present condition	Exploited	Not exploited	Not exploited
Available quantity	Indefinite	Unknown	Indefinite
Abrasion	(A) : 19.0% (B) : 18.9%	Unknown	(B) : 16% * (C) : 19% *
Absorption	0.07%	Unknown	
Specific Gravity	2.84 gs/cm³	Unknown	
CBR	128 (soaked) 170 (unsoaked)	Unknown	
Observation	• Rock material is white gray granite, heavy and hard. • Abrasion is limited in the range complying with the specifications for pavement material. • Further tests of this rock in the final design stage are recommended. (see, the following description.) • Quarry is now being exploited by hand chisels and hammers .	• Rock looks to be a kind of basalt with a reddish color, fairly breakable and not adequate for base and surface course material. • It is worth studying in detail in the final design stage to evaluate if useful for subbase.	• Rock material is a black and heavy basalt. • It looks to be good material for the pavement structure.

Note : 1) * : Those data were obtained in the study of Plan Triánglo in 1977.
2) A, B and C in the abrasion test indicate the gradation of specimen according to AASHTO.
3) The results of the tests conducted in this study on C1 material are included in Annex D.
4) The material of the CBR test is a composite material: (crushed stone: sand: A-2-4)=82:8:10.
The value corresponds to 100% density of the Proctor test.

Regarding the granite rock of C1, execution of more detailed tests in the final design stage are recommended to evaluate more definitely if this rock will be available for pavement material. This recommendation was made by reason of that the following two problems are sometimes pointed out when granite is used as aggregate for asphalt concrete; ① change of grain gradation of crushed granite stone between before and after

heating in asphalt concrete plant is not negligible, and ② bond between granite aggregate and asphalt cement is insufficient.
However, it is considered that the problem of bond can easily be solved, because a lot of cases, in which the similar problem had been solved by adding some agent or by replacing some portion of filler for asphalt mix with slacked lime, were reported.
By executing grain size tests to compare the gradation of crushed stone before and after heating it up to 170 - 200°C, it must finally be evaluated if this granite material can be used for asphalt concrete aggregate.

On such understanding, it was assumed in this feasibility study that quarry sites C1 and C3 would be available for the Project, and hence those two quarries were taken into consideration in the road design, construction planning, and cost estimation of the Project.

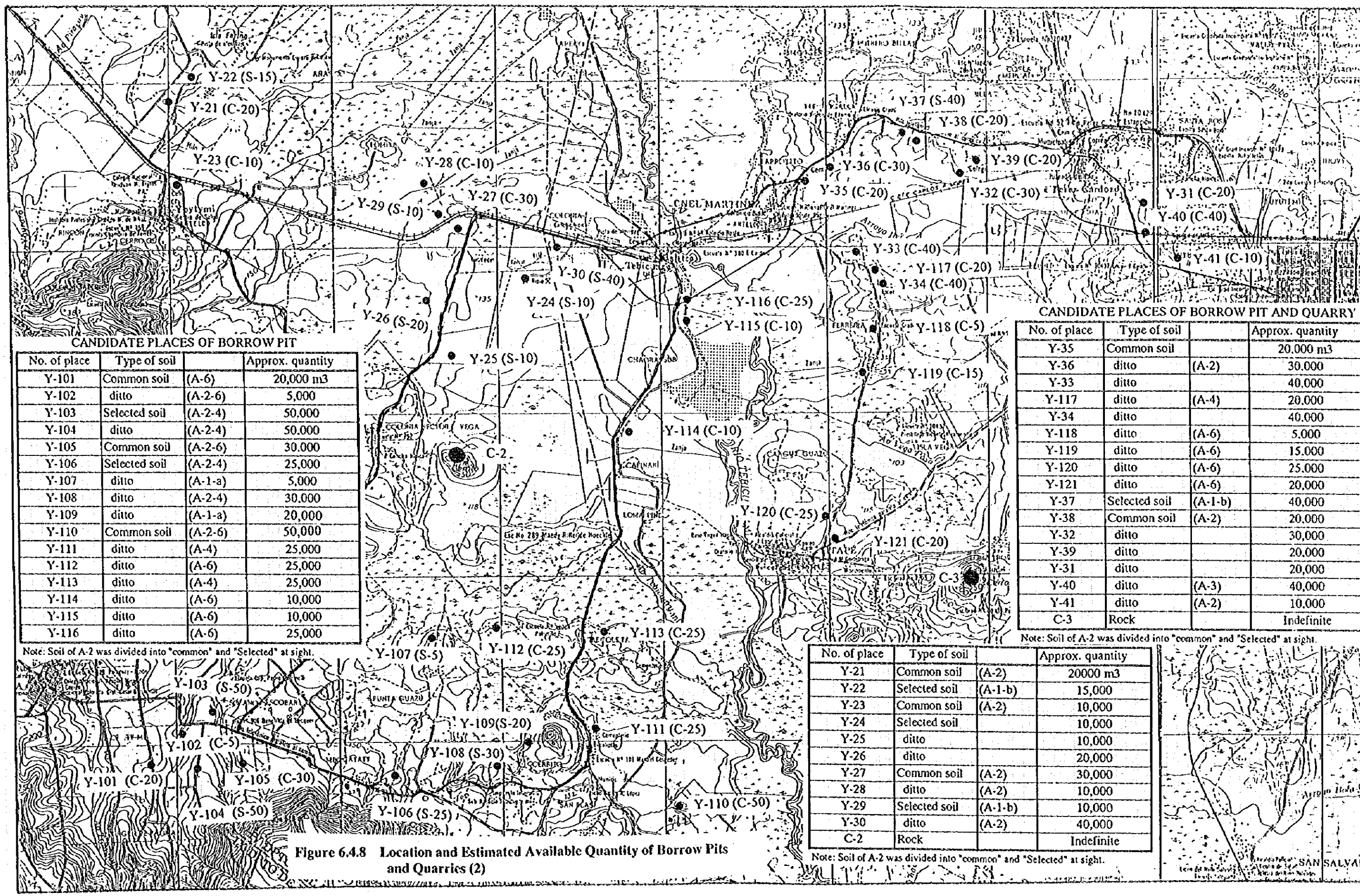


CANDIDATE PLACES OF BORROW PIT AND QUARRY

No. of place	Type of soil		Approx. quantity
Y-1	Selected soil	(A-1-a)	5,000 m3
Y-2	ditto	(A-2)	10,000
Y-3	ditto	(A-1-b)	20,000
Y-4	ditto	(A-1-b)	15,000
Y-5	ditto	(A-2)	10,000
Y-6	Common soil	(A-3)	10,000
Y-7	ditto	(A-3)	15,000
Y-8	ditto	(A-3)	20,000
Y-9	Selected soil		8,000
Y-10	Common soil	(A-2)	20,000
Y-11	ditto	(A-2)	20,000
Y-12	ditto	(A-2)	10,000
Y-13	Selected soil	(A-1-b)	15,000
Y-14	ditto		10,000
Y-15	ditto	(A-1-b)	15,000
Y-16	Common soil	(A-2)	10,000
Y-17	Selected soil	(A-1-b)	10,000
Y-18	ditto	(A-2)	10,000
Y-19	ditto		10,000
Y-20	ditto	(A-2)	20,000
C-1	Rock		Indefinite

Note: Soil of A-2 was divided into "common" and "Selected" at sight.

Figure 6.4.8 Location and Estimated Available Quantity of Borrow Pits and Quarries (1)



CANDIDATE PLACES OF BORROW PIT

No. of place	Type of soil		Approx. quantity
Y-101	Common soil	(A-6)	20,000 m3
Y-102	ditto	(A-2-6)	5,000
Y-103	Selected soil	(A-2-4)	50,000
Y-104	ditto	(A-2-4)	50,000
Y-105	Common soil	(A-2-6)	30,000
Y-106	Selected soil	(A-2-4)	25,000
Y-107	ditto	(A-1-a)	5,000
Y-108	ditto	(A-2-4)	30,000
Y-109	ditto	(A-1-a)	20,000
Y-110	Common soil	(A-2-6)	50,000
Y-111	ditto	(A-4)	25,000
Y-112	ditto	(A-6)	25,000
Y-113	ditto	(A-4)	25,000
Y-114	ditto	(A-6)	10,000
Y-115	ditto	(A-6)	10,000
Y-116	ditto	(A-6)	25,000

Note: Soil of A-2 was divided into "common" and "Selected" at sight.

CANDIDATE PLACES OF BORROW PIT AND QUARRY

No. of place	Type of soil		Approx. quantity
Y-35	Common soil		20,000 m3
Y-36	ditto	(A-2)	30,000
Y-33	ditto		40,000
Y-117	ditto	(A-4)	20,000
Y-34	ditto		40,000
Y-118	ditto	(A-6)	5,000
Y-119	ditto	(A-6)	15,000
Y-120	ditto	(A-6)	25,000
Y-121	ditto	(A-6)	20,000
Y-37	Selected soil	(A-1-b)	40,000
Y-38	Common soil	(A-2)	20,000
Y-32	ditto		30,000
Y-39	ditto		20,000
Y-31	ditto		20,000
Y-40	ditto	(A-3)	40,000
Y-41	ditto	(A-2)	10,000
C-3	Rock		Indefinite

Note: Soil of A-2 was divided into "common" and "Selected" at sight.

No. of place	Type of soil		Approx. quantity
Y-21	Common soil	(A-2)	20000 m3
Y-22	Selected soil	(A-1-b)	15,000
Y-23	Common soil	(A-2)	10,000
Y-24	Selected soil		10,000
Y-25	ditto		10,000
Y-26	ditto		20,000
Y-27	Common soil	(A-2)	30,000
Y-28	ditto	(A-2)	10,000
Y-29	Selected soil	(A-1-b)	10,000
Y-30	ditto	(A-2)	40,000
C-2	Rock		Indefinite

Note: Soil of A-2 was divided into "common" and "Selected" at sight.

Figure 6.4.8 Location and Estimated Available Quantity of Borrow Pits and Quarries (2)

(2) Comparative Analysis of Construction Work Unit Prices

To select the optimum route among the available alternatives, construction cost of each route is one of the most important factors. To estimate the cost, unit price of the work items included in the job to complete the road must be determined, and their quantities must be calculated.

Because there are no standard unit prices for works except those for small building construction published in this country and because MOPC has no authorized cost estimation system for road construction, unit price analysis, except that dealing with bridge construction, was carried out based on or with reference to the results of the cost (budget) estimation of the following eight road construction projects:

① Project Limpio - Emboscada			: 19 km
② Project Emboscada - San Estanislao Section I			: 61 km
③	ditto	Section II	: 70 km
④ Project Tacuara - Salto del Guaira Section I			: 62 km
⑤	ditto	Section II	: 60 km
⑥	ditto	Section III	: 59 km
⑦ Project San Ignacio - Pilar Section I			: 52 km
⑧	ditto Section II		: 53 km

The estimates for projects ① to ⑥ were made in 1995, while the remainder were made in 1994. Analysis was carried out in the manner described below:

i) First, principal work items in the construction of the study road were selected.

ii) Work items similar to the selected ones and their prices were selected from the data of the referred projects, i.e., the above-mentioned eight projects.

iii) The contents and specific characteristics of the work items of each project were examined, that is, estimated quantity, geographical features of the site, assumed quarry and asphalt-plant sites, required distance of transport of embankment material, etc.

iv) Then, by eliminating the partial costs borne by the special or local conditions of the unit price of each work item of the referred project, the representative and proper unit prices for the selected work items of the study road were obtained.

The method of estimation and the definition of work items in each project were not the same. Therefore, the above described analysis was carefully conducted. The results are summarized below:

Table 6.4.4 Unit Prices to be Applied to the Alternative Study

Description	Unit	Unit Price ($)
1. Mobilization	Gl	A×3% *
2. Earthworks		
- Site clearing	km	2,592.0
- Site clearing (Heavy)	km	10,369.0
-Embankment (DMT<2 km)	m^3	4.4
- Selected soil (DMT<2 km)	m^3	4.9
- Soil transport	km-m^3	0.2
3. Pavement		
- Sub/Base, crushed stone	m^3	40.4
- Asphalt concrete	m^3	119.6
- Prime/seal coat, etc.	m^3	581.0
4. Auxiliary drainage facilities		
- Pipe culvert=1.0 - 1.5 m	m	8,806.0
- Box culvert 3.0×3.0	m	25,718.0
5. Concrete for structures	m^3	135.0
6. Others		
- Others	Gl	B×12% **

Note : * A means total costs including the cost of bridge construction.
** B means total costs excluding the cost of bridge construction.

With respect to the cost of bridge construction, the same manner of analysis as described above could not be applied due to the great much difference in the scale of structure and the local conditions of the bridges included in the projects. Therefore, relative construction costs must be considered in a comparative study, in order to that only select the optimum route, the following prices were applied, assuming that all bridges would have a width of 12m.

i) US$7,200/m for bridges with a length between 5 m and 10 m (Reinforced concrete)

ii) US$9,600/m for bridges greater than 10m long (Pre-stressed concrete)

The price of the bridge on the Río Tebicuary-mí will not influence the results of the comparative study because the necessity, type and scale of the bridge in both cases (Alternative-1 and Alternative-2) are identical.

The prices of i) and ii) were obtained from the engineers in the MOPC Bridge Section of MOPC and some experienced consulting engineers as reasonable for Paraguay. The bridge spanning the Río Tebicuary-mí would surely require preparatory work for construction, such as preparation of an access road to the site and site clearance. Therefore, a higher price than for the other bridges was adopted. However, in reality, this price is irrelevant for the alternative study, because both of the two alternative routes, Alternative-1 and Alternative-2 in Figure 6.4.4, would entail construction of size and scale over the River, which means that the two alternatives would basically entail the same construction costs.

On the other hand, when bids for similar types of road construction were examined, it was discovered that the successful bids, in almost all cases, were 20 to 30% higher than the budgets estimated by MOPC. For instance, tenders for the two road construction projects between San Ignacio and Pilar, of the above-mentioned eight projects, were already finished by 1995, and the contracted amounts for Section I and Section II were 26,498 thousand dollars and 26,289 thousand dollars, respectively. Those amounts are 25% and 29% higher than the respective budget calculated in 1994, i.e., one year before the tenders.

However, considering the purpose of the alternative study, it was believed that the above-listed prices deduced from the budgets of other projects could be used meaningfully for the comparison of the alternative routes.

(3) Pavement Design

Pavement was designed according to the "AASHTO - Guide for the Design of Pavement Structure (1986)" in both cases of flexible and rigid pavement. Then, the cost results were compared to determine which structure should be applied.

1) Flexible pavement (Asphalt concrete pavement)

The design method stipulated in the Guide and the detailed calculation process are shown in Annex C. The principal conditions and the design results are summarized here.

a) Analysis period

The analysis period in the design of initial pavement structure was considered to be ten (10) years from the commencement of use of the developed roads. Assuming an overlay 10 years after the initial development, the overlay design is also discussed.

b) Design traffic

The design traffic is the cumulative traffic volume during the analysis period, and it is expressed by type of vehicle. In this case, the design traffic was calculated for the period from 2005 to 2015, although development of the study roads was estimated to be completed in 2002, as described later. This modification came from the target year in the future traffic demand estimation described in Chapter 5, and its influence on the results pavement design are somewhat on the safe side. The calculated design traffic, based on the estimated traffic volume for the years 2005 and 2015 summarized in Table 5.5.1, is shown in Table 6.4.5.

Table 6.4.5 Design Traffic

(unit: vehicles)

Road Section	Passenger Cars	Buses	Trucks
Paraguarí - Río Tebicuary-mí	5,288,850	1,153,400	4,387,300
Río Tebicuary-mí - Villarrica	3,878,125	1,084,050	3,221,125
La Colmena - Tebicuary	1,036,600	740,950	417,925

Note: 1) Division of the road section coincides with that by the CBR value of the sub-grade described later.
2) Design traffic for each road section has been calculated for the road segment where the estimated traffic volume is greatest.

c) Cumulative 18-kip Equivalent Single Axle Load (E.S.A.L.)

Table 6.4.6 Design ESAL and Cumulative 18-kip ESAL by Road Section

Road Section	Vehicle Type	Design Traffic (A)	ESAL Factor (B)	Design ESAL (A×B)	Cumulative 18-kip ESAL
Paraguarí	P. Car	5,288,850	0.0004	2,116	
-	Bus	1,153,400	1.5980	1,843,133	
Río Tebicuary-mí	Truck	4,387,300	0.9170	4,023,154	
	Total			5,868,403	2,934,202
Río Tebicuary-mí	P. Car	3,878,125	0.0004	1,551	
-	Bus	1,084,050	1.5980	1,732,312	
Villarrica	Truck	3,221,125	0.9170	2,953,772	
	Total			4,687,635	2,343,818
La Colmena	P. Car	1,036,600	0.0004	415	
-	Bus	740,950	1.5980	1,184,038	
Tebicuary	Truck	417,925	0.9170	383,237	
	Total			1,567,690	783,845

Note: (Cumulative 18-kip ESAL) = (Design ESAL) $\times D_D \times D_L$
where, D_D = Directional Distribution Factor = 0.5, D_L = Lane Distribution Factor = 1.0

d) CBR of sub-grade

As for the construction method used for earthworks, a sub-grade layer between 50 and 100 cm thick will be constructed using soil from borrow pits. Referring to the study results on the candidate borrow areas along the study road described in the section, 6-4-3 (1), the values of sub-grade CBR were predicted. That is, soil classified as A-1, A3 and A-2-4, in other words, soil indicated with a symbol "S" in Figure 6.4.8, was predicted to have a CBR value of 6, while the other type of soil from borrow pits was considered to have a CBR value of only 4. Examining, each segment of the road, the balance of required volume of sub-grade and the obtainable volume from the borrow pits in the vicinity, the type of sub-grade material was forecast and its CBR value was determined per segment as below:

Table 6.4.7 CBR of Sub-grade

Road Segment	CBR
Paraguarí - Río Tebicuary-mí	6
- Villarrica	4
La Colmena - Tebicuary	4

Note : Between the alternative routes, the condition above is considered to be the same.

e) Determination of layer thickness

Calculation results are schematically shown in Figure 6.4.9 below.

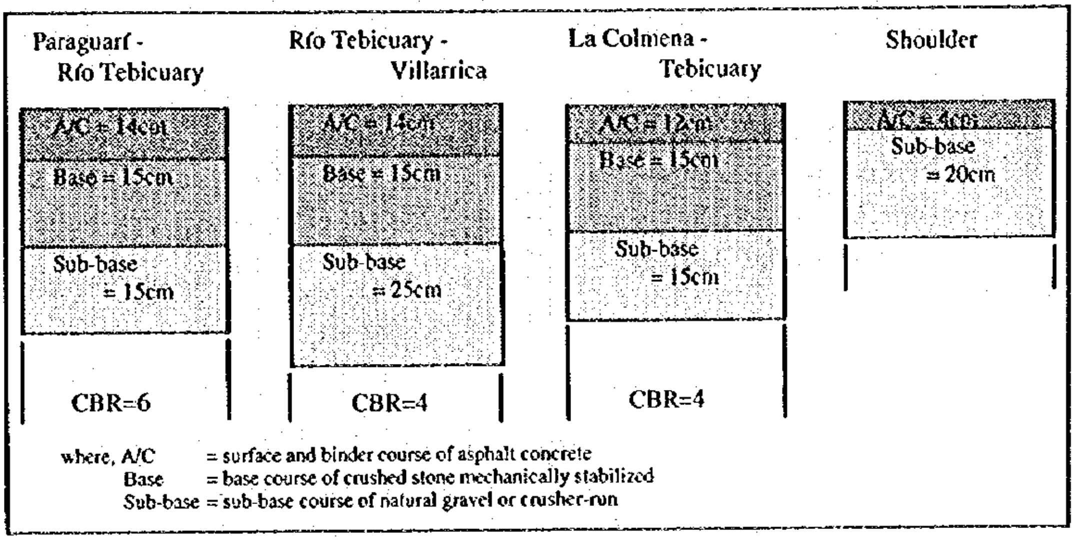


Figure 6.4.9 Result of Flexible Pavement Design

2) Required thickness of overlay

Assuming that overlay pavement would be put down 10 years after the original pavement construction, and assuming that the design period of this overlay would be 15 years after the overlay year, the required thickness of the overlay was calculated. The results are summarized in Table 6.4.8. The detailed calculation process is described in Annex C.

Table 6.4.8 Required Thickness of Overlay

Road Section	Overlay Thickness	
	inches	cm
Paraguarí - Río Tebicuary-mí	3.1	8.0
Río Tebicuary-mí - Villarrica	4.2	11.0
La Colmena - Tebicuary	3.2	8.0

Note: 1) Time of overlay : 10 years after original construction.
2) Design period of overlay : 15 years.

3) Rigid pavement design

Rigid pavement (Concrete pavement) was designed for a period of 25 years and the detailed calculations are given in Annex C (3). The design results are shown in Table 6.4.9.

Table 6.4.9 Required Thickness of Rigid Pavement Layers

Road Section	Thickness of Sub-base		Thickness of Concrete Slab	
	(inches)	cm	(inches)	cm
Paraguarí - Río Tebicuary-mí	(6.0)	16	(11.0)	28
Río Tebicuary-mí - Villarrica	(6.0)	16	(11.0)	28
La Colmena - Tebicuary	(6.0)	16	(9.0)	23

4) Comparison of the construction costs of both pavement types

The cost of flexible pavement including an overlay in 10 years time, and the cost of rigid pavement were compared using the unit prices in Table 6.4.4. In order to convert the cost for an overlay on the original asphalt concrete pavement into present values, the amount was discounted for 9 years with a discount rate of 8 %, which was considered to be fairly optimistic. The comparison results shown in Table 6.4.10 indicate that flexible pavement is considerably more advantageous. Therefore, flexible pavement was applied in this Study.

Table 6.4.10 Cost Comparison of Rigid and Flexible Pavements

Rigid Pavement	Unit Price ($/m3)	Paraguari - Rio Teb. (58.5km) Thick(cm)	Vol. (m3)	1,000$/m²	Rio Teb. - Villarrica (24.5km) Thick(cm)	Vol. (m3)	1,000$/m²	La Colmena - Teb. (38.1km) Thick(cm)	Vol. (m3)	1,000$/m²	Total(121.1km) 1,000 $
Cement Concrete	135	28	114,660	15,479	28	48,020	6,483	23	61,341	8,281	30,243
Subbase	40.4	16	65,520	2,647	16	27,440	1,109	16	42,672	1,724	5,480
Total ($/m²)=R				18,126			7,591			10,005	35,722

Flexible Pavement

Flexible Pavement	Unit Price ($/m3)	Paraguari - Rio Teb. Thick(cm)	Vol. (m3)	1,000$/m²	Rio Teb. - Villarrica Thick(cm)	Vol. (m3)	1,000$/m²	La Colmena - Teb. Thick(cm)	Vol. (m3)	1,000$/m²	Total 1,000 $
Asphalt Concrete	119.6	14	57,330	6,857	14	24,010	2,872	12	32,004	3,828	13,556
Base	40.4	15	61,425	2,482	15	25,725	1,039	15	40,005	1,616	5,137
Subbase	40.4	15	61,425	2,482	25	42,875	1,732	15	40,005	1,616	5,830
Prime Coat	581	0.15	614	357	0.15	257	149	0.15	400	232	739
Sub-total ($/m²)=A				12,177			5,792			7,293	25,262
Overlay (A/C)=B	119.6	8	32,760	3,918	11	18,865	2,256	8	21,336	2,552	8,726
discounted B=C	8 % x 9years			1,960			1,129			1,276	4,365
Total ($/m²)=F=A+C				14,137			6,921			8,569	29,627
R - F ($/m²)				3,990			670			1,436	6,096

6-4-4 Evaluation of the Selected Alternative Routes and the Optimum Route

The alternative routes along the study road selected in sub-section 6.4.2 were examined and evaluated in detail and the optimum route was selected for each part. The results are summarized in this sub-section item by item as follows.

(1) Small-scale Alternative at Sapucaí and G.F. Caballero

1) Sapucaí (see, Figure 6.4.2)

The case of Sapucai has several unique features, making it different from other towns. They are:

i) The town of Sapucaí, where the study road passes through, is spread out on considerably high terrain with more than 2% of the gradient of land surface from north to south inclining downward.

ii) The entrance to the town along the existing road from Paraguarí to Villarrica is located at the north-west end of the town, which is built in a gridiron pattern, while the exit is at the opposite end of the town. Therefore, the existing road has six right-angle turns in the town.

As described in sub-section 6.4.2, it was considered reasonable that the study road have a bypass to detour around the town of Sapucaí, given the size of the town and the forecast traffic volume of the road. At the same time, regarding the route of the bypass, the only option suggested was to make it pass along the northern edge of the town, the best plan from a geographical and engineering viewpoint. Given this, two alternative bypass routes were suggested in 6.4.2 (see, Figure 6.4.2).

Alternative-1 is a north route, passing through an area reserved for a future north-end street of the town, almost the entire stretch of the bypass section. Alternative-2 is along the second street on the north edge, i.e., the street next to that of Alternative-1.

The results of the comparison obtained from this detailed examination are summarized in Table 6.4.11.

In the end, Alternative-2 was selected as the optimum bypass route. The major reason was "Obstacles", i.e., the water tower and well, present along the route of Alternative-1. These are not only very important facilities, but would also be fairly difficult or expensive to relocate.

Table 6.4.11 Sapucaí Bypass Evaluation Results

Item	Alternative-1		Alternative-2	
Construction Costs	No difference	--	No difference	--
Geography for Const.	A little hard	x	Normal	o
Width of Right of Way	------	o	To be limited by to the street width	x
Obstacles along the Route	1) Water tower 2) Water well	X	-----	O
Land Acquisition	No difference	--	No difference	--
Suggestion of Municipality	There are no problems with either alternative route. The municipality could willingly cope with any land acquisition. If necessary, the municipality can prepare some substitute lands for the land owners.			

2) Gral Fernardino Caballero

The following table shows the items compared and the results obtained for the two alternatives for passing through the town of Gral Fernardino Caballero. In the end, many more points were given to Alternative-2, which was recommended as the optimum route, even though it cannot really be called a "Town bypass route".

Table 6.4.12 R. F. Caballero Bypass Evaluation Results

Item	Alternative-1		Alternative-2	
Construction Costs	A little higher	x	A little lower (additional small bridge needed)	o
Geography for Const.	No difference	--	No difference	--
Width of Right of Way	------	o	To be partially limited by the street width partially	x
Obstacles on the Route	An archaeological research site exists	X	None	O
Land Acquisition	No problem	--	No problem. The section utilizing the existing road has a reserved width of 20 m.	--
Relation to town structure	-----	o	The town is already divided into two by a railway and a wide street, so little influence in splitting the community would be expected. Moreover, a few road service facilities have accumulated along the road.	o
Suggestion of Municipality	Alternative-2 is preferable to Alternative-1, even though there is no special and clear reason to oppose Alternative-1. The people in the town look forward to the early completion of this road development.			

3) Section between Sapucaí and G.F.Caballero

Although no alternative routes were selected for this road section, a simple explanation of the road alignment in this section is provided. For this section, which has a length of about 6 km, a different route from that of the existing road was proposed. The existing road in this section runs through considerably low land along a valley, and is one of the most difficult sections for road maintenance work along the whole stretch of the road, due to its unfavorable topography for drainage. Under these circumstances, if the study road is developed along the existing road in this section, not only would construction costs be higher, but also there would be a problem in the vertical alignment of the road due to the great difference in the land height between the east side of the town of Sapucaí and the junction with the existing road.

A eastern part of the newly proposed road was aligned with the existing rural road, which is 15 m wide, in order to reduce the amount of additional land that would be needed for the study road development. However, there are several houses along this rural road and the southern side area of the road is mainly utilized as pasture land, during the detailed design stage, it might be recommendable to make a small modification and shift the route toward the south in order to leave this rural road as it is.

(2) Large-scale Alternative Route Alignment

The alternative routes selected in 6.4.2 for four sections, which cover a fairly long distance, were examined and compared from various viewpoints to determine the most adequate route.

During this examination and study, all traffic demand forecast results from Chapter 5, regional development potential from Chapter 3, environmental investigation results for the sites, and preparatory studies described in 6.4.3 were carefully mentioned and/or referred to. The results of this study are summarized in the tables provided on the following pages.

This alternative study selected the following routes as the optimum ones for each section:

① Between Ybytymí and Punto Unido (see, Figure 6.4.3)

Alternative - 1 : Short cut parallel to the railway (10.3 km)

② Crossing Río Tebicuary-mí (see, Figure 6.4.4)

Alternative - 1 : Northern route (7.0 km)

③ Between Félix Pérez Cardozo and Villarrica (see, Figure 6.4.5)

Alternative - 1 : Northern route along the railway

④ Branch section to La Colmena (see, Figure 6.4.6)

Alternative - 1 : Western route, almost on the existing road, going north along the Río Tebicuary-mí Basin

Table 6.4.13 Comparison sheet of Alternative Route (1)

Route: **Ybytimi - Punto Unido**

Items for Comparison	Alternative - 1 (Short Cut Route)	Alternative - 2 (Route Along Existing Road)	Comparison 1	Comparison 2
1. Planning Policy	-Short cut parallel to the railway	-Maximum use of the existing road		
2. Total length	10.3 km	18.7 km		
3.Forecast Traffic Vol. (2015)	2,849 vehicles/day	2,076 vehicles/day		
4.Principal Work Items & Volume	1) Road	1) Road		
	-Earth Works 142,800 m3	-Earth Works 133,600 m3		
	-Pavement 72,100 m2	-Pavement 188,490 m2		
	2)Bridge (total length)	2)Bridge (total length)		
	-RC 18.0 m	-RC 12.0 m		
	-PC 53.0 m	-PC 18.0 m		
	-at Tebicuary	-Tebicuary		
5.Total Construction Cost	1.00	1.46	++	
6.Construction Cost (cost/km)	1.00	0.80		+
7. Land Acquisition	length (m) / width (m) / area(ha)	length (m) / width (m) / area(ha)		
-Side expantion	0 / – / 0.0	16,200 / 20 / 32.4		
-New acquisition	10,300 / 40 / 41.2	2,500 / 40 / 10.0		
Total	10,300 / – / 41.2	18,700 / – / 42.4		
8. Geometric Design 1)Horizontal Curve 2)Max.vertical grade	(R > 300.0m) x 6 curves i = 0.80 %	(R > 300.0m) x 21 curves i= 4.45 % (280.0 m long)	+	
9. Running performance	-Very flat -Saving 6 minutes of travelling time compared with Alternative	-Steep slopes -More travelling time than Alternative 1	+ +	
10. Difficulties of construction	-No detour route is required for the present traffic -Necessary to take special measures for low land areas	-Necessary to build a temporary bridge and detour. for the present traffic	++	
11. Connection with surrounding road network	-Separated from existing roads -No service to Hector L. Vera area	-Maintain the present service area		+
12. Impact on socio-economic environment	-Negative impact on Hector L. Vera area -Possibility of agricultural dev't in the new road side area	-Promotion of rural development in the Hector Vera area		+
13. Impact on natural environment	-Impacts of embankment in the low land areas -Risk of inudation over railway (partial section)	-Deforesting, but on a small scale	-	-
14. General opinion of local communities	-Objection (by the inhabitants of Hector L .Vera	-Preferred (by the inhabitants of Hector L. Vera		+
Comprehensive Evaluation	O	X		

Table 6.4.13 Comparison sheet of Alternative Route (2)

Route: Tebicuary - Mrtinez

Items for Comparison	Alternative - 1 (Northern route)	Alternative - 2 (Southern route)	Comparison 1	Comparison 2
1. Planning Policy	-Point with stable river bank & smooth flow in the upperstream	-Point with stable river bank & smooth flow downstream		
2. Total length	7.0 km	8.8 km		
3.Forecast Traffic Vol. (2015)	2,726 vehicles/day	2,726 vehicles/day		
4.Principal Work Items & Volume	1) Road -Earth Works 143,000 m3 -Pavement 49,000 m2 2)Bridge (total length) -RC 0.0m -PC 214.0m -Tebicuary 85.0m	1) Road -Earth Works 180,100 m3 -Pavement 61,600 m2 2)Bridge (total length) -RC 0.0 m -PC 220.0 m -Tebicuary 85.0 m		
5.Total Construction Cost	1.00	1.17	++	
6.Construction Cost (cost/km)	1.00	0.93		+
7. Land Acquisition -Side expantion -New acquisition Total	length (m) / width (m) / area(ha) -Side expantion: 0 / — / 0 -New acquisition: 7,000 / 40 / 28.0 Total: 28.0	length (m) / width (m) / area(ha) -Side expantion: 0 / — / 0 -New acquisition: 8,800 / 40 / 35.2 Total: 35.2	+	
8. Geometric Design 1)Horizontal Curve 2)Max.vertical grade	(R > 400.0 m) x 5 curves i = 4.367 % (300.0 m long)	(R > 500.0 m) x 5 curves i = 3.475 %		+
9. Running performance	-Steeper slope, but smooth horizontal alignment -Less traveling time than Alternative - 2	-Less steep slope -More travelling time than Alternative - 1	+	
10. Difficulties of construction	-Access to bridge site (right bank=0.9km left=0.6km) -Construction length in low land areas : 2.75km -Need for clearance of dense woods in low lands (right)	-Longer access to bridge site (right =1.7km left=1.5km) -Longer length in low land area : 3.15km	+ -	
11. Connection with surrounding road network	-Better connection with the trunk road to San Jose -Bad connection with branch section to La Colmena	-Far from the existing road -Better connection with the branch section to La Colmena		
12. Impact on socio-economic environment	-Negative impact on existing shops (better than alternative 2)	-Negative impact on existing shops	-	-
13. Impact on natural environment	-Need to deforest gallery woods along river -Impact of embankment in low land areas	-Need to deforest gallery woods along river -Risk of inundation of the existing town by bridge const. -Impact on embankment in low land areas	+	
14. General opinion of local communities	-No objection	-No objection	+	+
Comprehensive Evaluation	O	X		

Table 6.4.13 Comparison sheet of Alternative Route (3)

Route: **Cardozo-Villarrica**

Items for Comparison	**Alternative - 1** (Northern route along the rail)	**Alternative - 2** (Southern route crossing hilly land)	Comparison 1	Comparison 2
1. Planning Policy	-Promotion of agricultural dev't along the railway area	-Better service for already developed hilly land		
2. Total length	8.6 km	7.9 km		
3.Forecast Traffic Vol. (2015)	2,785 vehicles/day	2,785 vehicles/day		
4.Principal Work Items & Volume	1)Road -Earth Works 111,000 m3 -Pavement 60,200 m2 2)Bridge (total length) -RC 11.0 m -PC 0.0m -Tebicuary	1) Road -Earth Works 96,000 m3 -Pavement 55,300 m2 2)Bridge (total length) -RC 0.0m -PC 0.0m -Tebicuary		
5.Total Construction Cost	1.00	0.91		
6.Construction Cost (cost/km)	1.00	0.98		
7. Land Acquisition -Side expantion -New acquisition Total	length (m) / width (m) / area (ha) -Side expantion: 8,600 / 10 / 8.6 -New acquisition: 0 / / 0.0 Total: / / 8.6	length (m) / width (m) / area (ha) -Side expantion: 0 / / 0.0 -New acquisition: 7,900 / 40 / 31.6 Total: / / 31.6	++	
8. Geometric Design 1)Horizontal Curve 2)Max.vertical grade	(R > 300.0 m) x 9 curves i = 1.599 %	(R > 700.0 m) x 3 curves i = 4.412 % (915.0 m long)	+	
9. Running performance	-Flat vertical and smooth horizontal alignment	-Smooth horizontal alignment but steep slopes -Many up and down & crossings with a path	+	
10. Difficulties of construction	-Need for detour routes, but very little traffic	-No need for detour route, but many houses exist -Easy to get earth work materials in the vicinity	+	+
11. Connection with surrounding road network	-Far from existing road	-Better connection with the existing road to Itape		+
12. Impact on socio-economic environment		-Loss of cultivated lands and resettlement -Split of communities, but new service to comunity		- +
13. Impact on natural environment		-Impact of cutting earth works -Decrease of forest & cultivated land	++	
14. General opinion of local communities	-Preferred, in order to promote rural dev't along railway area	-Difficulty of land acquisition	++	
Comprehensive Evaluation	O	X		

Table 6.4.13 Comparison sheet of Alternative Route (4)

Route: **Branch Section to la Colmena**

Items for Comparison	Alternative - 1 (Eastern route along Tebicuary Mi River basin)	Alternative - 2 (Central route passing H. Vera)	Alternative - 3 (Route proceeding north directly from La Colmena)	comparison 1	comparison 2	comparison 3
1. Planning Policy	-Promotion of much suger cane producing area	-Shorter route to Tebicuary, promoting small scale agri.	-Shortest route to road Paraguari - Villarrica			
2. Total length	38.1 km	27.0 km	26.3 km			
3.Forecast Traffic Vol. (2015)	941 vehicles/day	343 vehicles/day	343 vehicles/day	+		
4.Principal Work Items & Volume	1) Road -Earthworks 470,000 m3 -Pavement 266,700 m2 2)Bridge (total length) -RC 69.0 m -PC 65.0 m -Tebicuary	1) Road -Earthworks 192,000 m3 -Pavement 189,000 m2 2)Bridge (total length) -RC 0m -PC 31.0 m -Tebicuary	1) Road -Earth Work 144,000 m3 -Pavement 184,100 m2 2)Bridge (total length) -RC -PC 15.0 m -Tebicuary			
5.Total Construction Cost	1.00	0.63	0.54		+	++
6.Construction Cost (cost/km)	1.00	0.89	0.78			
7. Land Acquisition	length (m) / width (m) / area (ha)	length (m) / width (m) / area (ha)	length (m) / width (m) / area (ha)			
-Side expantion	36,600 / 20 / 73.2	25,500 / 25 / 63.8	26,300 / 30 / 78.9			
-New acquisition	1,500 / 40 / 6.0	1,500 / 40 / 6.0	0 / / 0.0			
Total	38,100 / / 79.2	27,000 / / 69.8	26,300 / / 78.9			
8. Geometric Design 1)Horizontal Curve 2)Max.vertical grade	(R > 150.0 m) x 35 curves= (0.9 curves/km) i = 4.200% (600.0 m long)	(R > 250.0 m) x 22 curves= (0.8curves/km) i = 4.482 % (560.0 m long)	(R > 250.0 m) x 30 curves= (1.1curves/km) i = 4.435 % (250.0 m long)			
9. Running performance	-Most flat vertical alignment among the 3 alternatives -Limited speed sections exist	-Moderate performance among the 3 alternatives -Passing through the urban area of H. Vera	-Lower performance by up and down & many curves	+	+	
10. Difficulties of construction	-Easy detour route preparation in wide existing ROW -Longer section in lower area	-Difficult detour route preparation in narrow ROW	-Easy detour preparation in mostly pasture area			+
11. Connection with surrounding road network	-Better connection with existing road -Contributes to a future wider road network (toward Iturbe)	-Better connection with local community roads -Will play still local road even in future	-Far from existing roads and communities -Possibly be a part of direct connecting route with #2	+++	+	+
12. Impact on socio-economic environment	-more beneficial (see, traffic volume) -Promotes & supports sugar cane industry directly	-Loss of agricultural lands -Promotes sugar cane industry	-Less beneficiary, surrounded by large scale pastures -Less potential of future development	++	+	
13. Impact on natural environment	-Decrease of gallery forest, but on a small scale -Minimum impacts among three alternatives	-Decrease of gallery forest and roadside forest	-Increase deforestration oppotunities	+		
14. General opinion of local communities	-Preferable -Understood this is the best choice for La Colmena	-Preferred in Vera				
Comprehensive Evaluation	O	X	XX			

Based on the results of the alternative study, the selected routes are shown in Figure 6.4.9, and the length of them can be calculated by section as shown below:

Table 6.4.14 Length of the Road along the Optimum Route

Section		Distance (km)	Accumulated Distance (km)
Paraguarí - Villarrica Section			
Paraguarí	Escobar	14.0	14.0
	Sapucaí	9.0	23.0
	Gral F. Caballero	10.0	33.0
	Ybytymí	9.0	42.0
	Tebicuary	16.0	58.0
	Cnel Martínez	4.0	62.0
	Félix P. Cardozo	10.0	72.0
	Villarrica	11.0	83.0
Tebicuary - La Colmena Section			
Tebicuary	Tebicuary-mí	20.0	20.0
	La Colmena	18.1	38.1
Total Length (km)			121.1

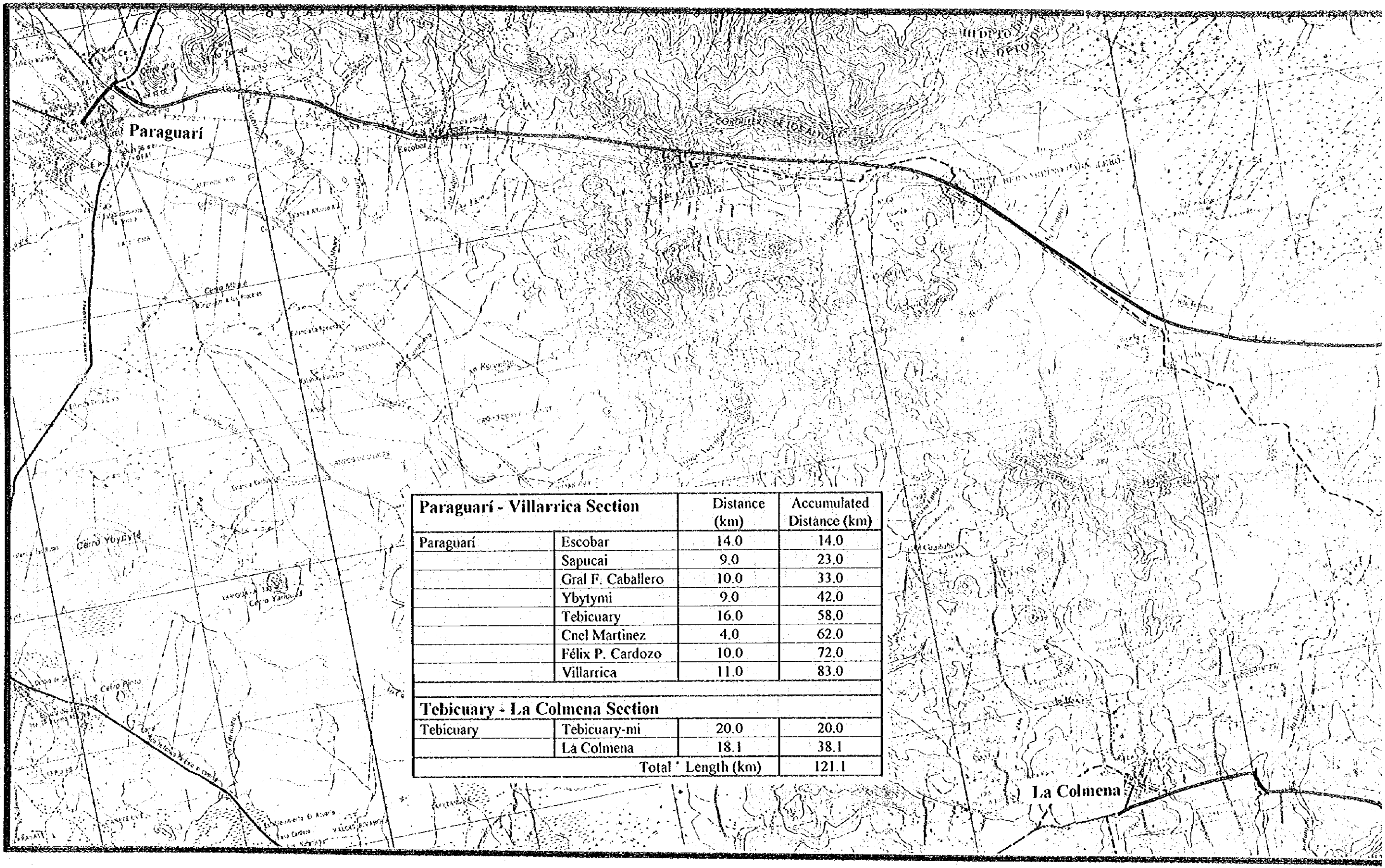
6-4-5 Study of Bridge Structures

(1) Present Conditions of Existing Structures

In order to understand the present conditions of existing structures in the study area, a site investigation was executed. As a result of the site investigation, it was clarified that the majority are wooden bridges and culverts, except the truss bridge at Ao. Tebicuary-mí, which must be replaced by a new bridge as part of the reconstruction of the road. The existing structures and their lengths on the objective road, as investigated during a visit to the site, are shown in Table 6.4.15.

Table 6.4.15 Existing Structural Length of the Objective Road

Section	Segment	From	- To	Length of Existing Structures (m)										Total (m)
1. Paraguarí - Villarrica	Segment 1	Paraguarí	- Sapucai	4.00	4.00	4.00	6.70	2.00	2.00	2.00	2.00			26.70
	Segment 2	Sapucai	- Caballero	2.00	2.00	2.00	24.30							30.30
	Segment 3	Caballero	- Ybytymí	18.40	12.30									30.70
	Segment 4	Ybytymí	- Punto Unido	4.00	13.80	0.70	9.50	8.50	4.96	15.00	13.70	5.35	0.57	76.08
	Segment 5	Punto Unido	- Tebicuary	6.30	4.85	2.20	5.00							18.35
	Segment 6	Tebicuary	- Martínez	213.30	21.90	27.55	33.95							296.70
	Segment 7	Martínez	- Cardozo											0.00
	Segment 8	Cardozo	- Villarrica	4.00										4.00
2. Empalme - Punto Unido	Segment 1	Empalme	- No. 162+00											0.00
	Segment 2	No. 162+00	- No. 178+00	12.50										12.50
	Segment 3	No. 178+00	- Punto Unido											0.00
3. La Colmena - Tebicuary	Segment 1	La Colmena	- No. 253+50	6.00	13.00	1.50	2.00	2.00	2.00	3.00	11.70	17.40		58.60
	Segment 2	No. 253+50	- No. 273+00	10.50	6.30	11.00								27.80
	Segment 3	No. 273+00	- Tebicuary	49.50	1.50	11.00	2.00	2.00						66.00



Paraguarí - Villarrica Section		Distance (km)	Accumulated Distance (km)
Paraguarí	Escobar	14.0	14.0
	Sapucai	9.0	23.0
	Gral F. Caballero	10.0	33.0
	Ybytymi	9.0	42.0
	Tebicuary	16.0	58.0
	Cnel Martinez	4.0	62.0
	Félix P. Cardozo	10.0	72.0
	Villarrica	11.0	83.0
Tebicuary - La Colmena Section			
Tebicuary	Tebicuary-mi	20.0	20.0
	La Colmena	18.1	38.1
		Total Length (km)	121.1

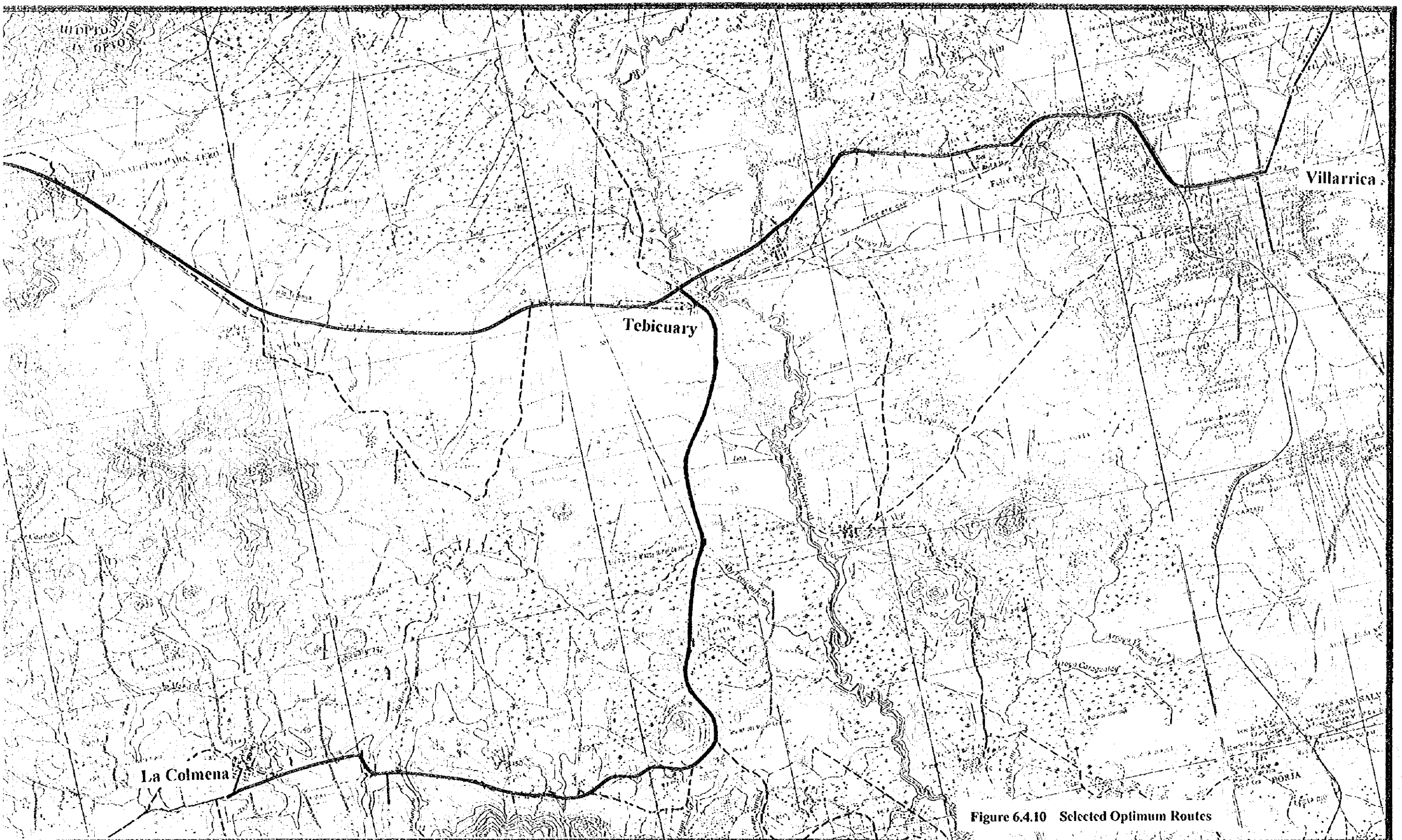


Figure 6.4.10 Selected Optimum Routes

(2) Bridge Categorization of Objective Road

The bridges are categorized by type as shown in Table 6.4.16, except for the bridges at Río Tebicuary-mí and Ao. Tebicuary-mí, which are studied in (4) in detail.

Table 6.4.16 Bridge Categorization of the Objective Road

Bridge length L(m)	Type of Bridge
15 meters < L ≦ 30meters	Prestressed concrete bridge
5 meters ≦ L ≦ 15 meters	Reinforced concrete bridge

(3) Required Structural Length of the Objective Road

In order to decide the types of bridges, the required bridge lengths are determined considering topographical survey and hydrographical analysis results, and are shown in Table 6.4.17.

Table 6.4.17 Required Bridge Length on the Objective Road

Section	Alternative	From - To	Segment	Required Bridge Length (m)							Total (m)
1. Paraguarí - Villarrica		Paraguarí - Sapucai	Segment 1	10.00							10.00
		Sapucai - Caballero	Segment 2	25.00							25.00
		Caballero - Ybytymí	Segment 3	20.00	15.00						35.00
	Alternative-1	Ybytymí - Punto Unido	Segment 4	30.00	10.00	10.00	5.00	15.00	15.00	10.00	95.00
	Alternative-2	Ybytymí - Punto Unido		15.00							15.00
		Punto Unido - Tebicuary	Segment 5	10.00	5.00	5.00					20.00
	Alternative-1	Tebicuary - Martínez	Segment 6	215.00	30.00	30.00	30.00				305.00
	Alternative-2	Tebicuary - Martínez		215.00	30.00	30.00	30.00				305.00
		Martínez - Cardozo	Segment 7								0.00
	Alternative-1	Cardozo - Villarrica	Segment 8								0.00
	Alternative-2	Cardozo - Villarrica									0.00
2. La Colmena - Tebicuary	Alternative-1	La Colmena - No. 253+50	Segment 1	30.00	15.00	15.00	20.00				80.00
		No. 253+50 - No. 273+00	Segment 2	15.00	10.00	15.00					40.00
		No. 273+00 - Tebicuary	Segment 3	50.00	15.00						65.00
3. Empalme - Punto Unido	Alternative-2	Empalme - No. 162+00	Segment 1								0.00
		No. 162+00 - No. 178+00	Segment 2	15.00							15.00
		No. 178+00 - Punto Unido	Segment 3								0.00
4. La Colmena - H.Vera - Pto. Unido	Alternative-3	La Colmena - Héctor Vera		15.00							15.00
		Héctor Vera - Punto Unido									0.00

All the bridges, except the bridges in Río Tebicuary-mí and Ao. Tebicuary-mí, on selected optimum route mentioned in 6-4-4 are shown as Table 6.4.18.

Table 6.4.18 Number of Bridges on the Selected Optimum Route

(Paraguarí - Villarrica)

From	To	Segment	Reinforced Concrete			Prestressed Concrete		
			5 m	10 m	15 m	20 m	25 m	30 m
Paraguarí	- Sapucai	Segment 1	0	1	0	0	0	0
Sapucai	- Caballero	Segment 2	0	0	0	0	1	0
Caballero	- Ybytymí	Segment 3	0	0	1	1	0	0
Ybytymí	- Punto Unido	Segment 4	1	3	2	0	0	1
Punto Unido	- Tebicuary	Segment 5	2	1	0	0	0	0
Tebicuary	- Cnel. Marínez	Segment 6	0	0	0	0	0	3
Cnel. Martínez	- Cardozo	Segment 7	0	0	0	0	0	0
Cardozo	- Villarrica	Segment 8	0	0	0	0	0	0
Total			3	5	3	1	1	4

(La Colmena - Tebicuary)

From	To	Segment	Reinforced Concrete			Prestressed Concrete		
			5 m	10 m	15 m	20 m	25 m	30 m
La Colmena	- No. 253+50	Segment 1	0	0	2	1	0	1
No. 253+50	- No. 273+00	Segment 2	0	1	2	0	0	0
No. 273+00	- Tebicuary	Segment 3	0	0	1	0	0	0
Total			0	1	5	1	0	1

(4) Alternative Study of the Tebicuary-mí Bridge and Detailed Study of the Belly Bridge

1) Alternative study of the Tebicuary-mí Bridge

The formation level of the bridge is determined as a result of hydrographical analysis due to the absence of navigation in Río Tebicuary-mí. Clearance between the bridge structure and the river's water level is determined as one meter against the Design High Water Level. The width of the river is approximately 65 meters on the selected optimum route according to the topographical survey; however, it is recommended to extend the length of the bridge to more than 215 meters given the flood discharge according to the hydrographical analysis based on existing data on the railway located along the selected optimum route.

As the selected optimum route passes through a forest extending approximately 70 meters on the right bank, it is recommendable to extend the length of the bridge on the left bank side, where a plain stretches to Cnel. Martínez for the purpose of flood discharge because the forest on the right bank is also in the flood area, and the dense woods do not allow a smooth water flow, so will surely be ineffective to lengthen the bridge on that side.

It is also recommended to avoid the construction of bridge piers in the river because of the required long construction time, which includes coffering, and because of lack of hydrographical data for an area that does not clarify flows for the rainy and dry seasons of the year.

a) Proposal for alternative bridge types

From the viewpoint of required bridge length, four types of bridges shall be proposed, as shown in Table 6.4.19. The formation level of each type of bridge is determined from the height of the girders and the influence of the earth works.

The conditions for selecting the types of bridges to compare the structural characteristics are as follows:

① The first proposal, metal truss and PC 5 span continuous composite girder (85m+5@26m)

Piers shall not be constructed in the river in the case of a metal-truss bridge. In the flood plain, a PC composite connected girder bridge, which can be constructed quickly and easily, shall be adopted.

② The second proposal, PC 2 span T rigid frame box girder and PC 5 span continuous composite girder(2@42.5m+5@26m)

The bridge type in the flood plain shall be the same as in the first proposal, i.e., a PC 5 span continuous composite girder. However, a pier shall be constructed in the middle of river in the form of a PC T rigid frame box girder.

③ The third proposal, metal 2 span continuous plate girder and PC 5 span continuous composite girder(2@42.5m+5@26m)

The bridge type in the flood plain shall be the same as in the case of the first proposal, i.e., PC 5 span continuous composite girder. However, a pier shall be constructed in the middle of river in the form of a metal 2 span continuous plate girder.

④ The fourth proposal, PC 3 span continuous box girder (60m + 96m + 60m)

A pier shall be constructed in the river and the span length of the bridge shall be adjusted to 60m + 96m + 60m.

⑤ The fifth proposal, PC 4 span continuous box girder(4@54m)

A pier shall be constructed in the river as in the case of the fourth proposal, and the span length of the bridge shall be uniformly adjusted as 4@54m.

⑥ The sixth proposal, PC 7 span continuous composite girder (7@31m)

Two piers shall be constructed in the river and their superstructures shall be a PC 7 span continuous composite girder, which can be constructed quickly and easily.

With respect to the first proposal for the bridge, which shall be constructed in the flood plain on the left side of the bank, three types of bridges such as a PC hollow slab girder, a PC T connected girder, and a PC composite connected girder are compared in Table 6.4.20

Table 6.4.19 Proposal of Alternative Bridge Types

Proposal	Type of Superstructure	Construction Method	Division of Span (m)	Total Length (m)	Height of Girder (m)
1st.	Metal Truss+	Cable erection	85	215	1.55
	PC 5 span continuous composite	Fixed timbering	5 @ 26		
2nd	PC 2 span T rigid frame box	Cantilever erection	2 @ 42.5	215	3.4
	PC 5 span continuous composite	Fixed timbering	5 @ 26		
3rd	Metal 2 span continuous plate	Fixed timbering	2 @ 42.5	215	2.3
	PC 5 span continuous composite		5 @ 26		
4th	PC 3 span continuous box	Cantilever erection	3 @ 72	216	4.1
5th	PC 4 span continuous box	Push out erection	4 @ 54	216	3.4
6th	PC 7 span continuous composite	Fixed timbering	7 @ 31	217	1.85

Table 6.4.20 Comparison of Structure for Continuous 5 Spans in Proposals 1, 2 and 3

Item	Unit	Quantity		
		PC Hollow Slab	PC T Connected Girder	PC Composite Connected Girder
Concrete	m³	1,423.3	742.6	430.0
Slab concrete	m³	-	234.2	349.0
Form	m²	3,134.0	1,092.0	2,496.0
Steel bar	t	156.7	148.5	156.0
PC wire	t	42.7	40.8	24.0
Form for hollow	m	3,120.0	-	-
Erection	t	-	1,856.5	1,310.5
Timbering	m³	8,450.0	-	-
Comparison of cost		1.84	1.09	1.00

According to the economic evaluation shown in Table 6.4.20, the PC composite connected girder is the most economical type of bridge. Therefore, it shall be selected for Río Tebicuary-mí bridge in the flood plain.

b) Comparison of alternative bridge types

A preliminary estimate of alternative bridge types is executed as shown in Table 6.4.21.

Table 6.4.21 Preliminary Estimate of Alternative Bridge Types

Proposal	Type of Superstructure	Construction Method	Cost	Total Cost (m)
1st.	Metal Truss+	Cable erection	2,546,386	3,385,435
	PC 5 span continuous composite	Fixed timbering	839,049	
2nd	PC 2 span T rigid frame box	Cantilever erection	3,108,542	3,947,591
	PC 5 span continuous composite	Fixed timbering	839,049	
3rd	Metal 2 span continuous plate	Fixed timbering	2,829,202	3,668,251
	PC 5 span continuous composite		839,049	
4th	PC 3 span continuous box	Cantilever erection	5,619,822	5,619,822
5th	PC 4 span continuous box	Push out erection	4,942,735	4,942,735
6th	PC 7 span continuous composite	Fixed timbering	3,708,851	3,708,851

According to the preliminary estimate of alternative bridge types, it is clear that the first proposal provides the most economically feasible bridge.

As mentioned in (4) 1), it is recommended to avoid constructing bridge piers in the river and the first proposal is the only method which allows the constructing of piers on land. Therefore, if this proposal is adopted, it will not be necessary to consider coffering, which is influenced by weather and the rainy season for which hydrographical data is not available for this area. The total period of construction of the bridge will be approximately 25 months, which is shortest construction period for any of the alternative bridge types.

Concerning the height of girders, the first proposal results in the lowest height of 1.55 meters, which influences the earth works. Comparing the height of girders in the first proposal and the fourth proposal using the continuous box cantilever erection method with a girder height of 4.1 meters, the first proposal is approximately three times lower than the fourth proposal. Regarding the earth works, the first proposal is approximately two times less than the fourth proposal.

The first proposal requires painting every 10 years, and it has been ascertained that MOPC is not opposed to the use of a metal bridge, and they would accept painting it every 10 years. A comparison of the structural characteristics of each of the alternative bridge types is shown in Table 6.4.22.

c) Conclusion

The preliminary estimate and the comparison of alternative bridge types confirms that the first proposal, which consists of an 85-meter metal truss bridge over the river section and a PC continuous composite girder bridge on the left bank side, is the most appropriate and recommendable type in terms of economic cost, construction method, and other factors mentioned in Table 6.4.21. It is also clarified that MOPC is not opposed to use of a metal bridge or the painting of this bridge every 10 years.

2) Detailed Study of the Bailey Bridge (Bridge on Arroyo Tebicuary-mí)

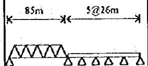
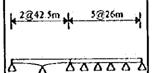
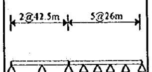
There is an existing Bailey bridge located at Ao.Tebicuary-mí along Alternative-1 route, which is the selected optimum route from La Colmena to Tebicuary. The existing Bailey bridge has a length of 50 meters, and consists of three spans of metal trusses. The bridge width is 4.1 meters, and it has two metal piers in the river.

According to the comparison of these 3 types of bridges, i.e., PC hollow slab girder, PC

T connected girder, and PC composite connected girder, shown in Table 6.4.22, the PC composite connected girder is the most economical type of bridge. Therefore, it shall be selected for Río Tebicuary-mí bridge in the flood plain and for Bailey bridge at Ao. Tebicuary-mí.

As part of the road reconstruction, a two-span PC simple T girder bridge is recommended. A concrete pier will be constructed in the river, to ensure that there will be no problem with the flow discharge.

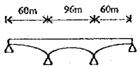
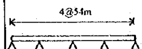
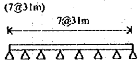
Table 6.4.22 Comparison of the Structural Characteristics of the Tebleuary-mf Bridge (1)

Bridge Type	Construction Method	Division of Span	Level of Economic Cost	Quantity			Possibilities of Construction and Period of Completion	Maintenance Cost	Technology Transfer	Employment Opportunity	Esthetics	Driving Comfort	Period of Construction	Global Evaluation
				Super structure	Sub structure	Earth work								
The 1st proposal Truss + PC 5 span continuous composite girder	Cable erection and Fixed timbering	Bridge total length L=215m (85m+5@26m)  	1.00	**Metal truss** Metal :480t Slab concrete :319m^3 --------------- **PC composite girder** Concrete: 430m^3 Concrete for slab:349 m^3 PC wire:24t Steel bar:156t Form:2496m^2	Concrete :942m^3 Pile in-situ (ϕ 1,000) :1,248m	Selected soil :6,300m^3 Embankment :43,803 m^3	1. Piers can be constructed at the same time. 2. Period of construction is shorter than the 4th proposal. 3. It is possible to construct superstructure without piers in the river. It is suitable for this country considering the time of rainy season .	1. Basically, it is not necessary to consider maintenance. 2. Painting is required for every 10 years and costs US$ 75,000 each time.	1. There are only few truss bridges in this country. Therefore, it is significant for technology transfer. 2. This method is available to use for other projects.	1. Construction work shall be done at the site except superstructure for truss. Therefore, there are many employment opportunities at the site.	1. It is remarkable to see the structure on the road.	1. It is a through bridge and the longitudinal section can be very flat. Completed elevation of the road surface is approximately 2m lower than 2nd 4th and 5th proposal..	25 months --------------- Metal truss :15 months --------------- PC composite girder :17months --------------- Substructure :5 months	◎
			◎			◎	○	○	○	○	○	○	◎	
The 2nd proposal PC 2 span T rigid frame box girder + PC 5 span continuous composite girder	Cantilever erection and Fixed timbering	Bridge total length L=215m 2@42.5m + 5@26m  	1.17	**PC T rigid frame box girder** Concrete :1020m^3 PC wire: 61t Steel bar:122t Form:3264m^2 --------------- **PC composite girder** Same as proposal-1.	Concrete :1,138m^3 Pile in-situ (ϕ 1,000) :1,426m Landing Stage :260m^2 Coffering :480m^2	Selected soil :6,300m^3 Embankment :69,317 m^3	1. There shall be access road to pier until the completion of superstructure construction. 2. Constructing a pier in the river may increase construction cost.	1. Same as 1st proposal-1.	1. There are only a few bridges of this type constructed in this country. Therefore, it is significant for technology transfer. 2. This method is available for other projects.	1. Construction work for both superstructures and substructures shall be done at the site. Therefore, there are many employment opportunities at the site.	1. Variation of girder height for PC T rigid frame box girder is impressive.	1. Because of PC T rigid frame box girder height, longitudinal slope shall be steep.	29 months --------------- PC T rigid frame box girder :14 months --------------- PC composite girder :17months --------------- Substructure :12months)	△
			△			△	△	○	○	○	○	△	△	
The 3rd proposal Metal 2 span continuous plate girder + PC 5 span continuous composite girder	Fixed timbering	Bridge total length L=215m 2@42.5m + 5@26m  	1.08	**Metal 2 span plate girder** Metal girder :265t Slab concrete :357m^3 Steel bar:82t --------------- **PC composite girder** Same as proposal-1.	Concrete :1,156m^3 Pile in-situ (ϕ 1,000) :1,428m Landing Stage :400 m^2 Preparation Yard :400 m^2 Coffering :480 m^2	Selected soil :6,300m^3 Embankment :54,227 m^3	1. It is necessary to construct the superstructure after the completion of piers and abutments. Therefore, period of construction shall be longer. 2. Same as 2nd proposal-2.	1. Same as 1st proposal-1.	1. There are only a few bridges of this type constructed in this country. Therefore, it is significant for technology transfer. 2. This method is available for other projects.	1. Construction work for both superstructures and substructures shall be done at the site. Therefore, there are many employment opportunities at the site.	1. It is a common type of bridge. Therefore, the impression is not so strong.	1. The longitudinal slope shall be gentle.	29 months --------------- Metal 2 span continuous plate girder :14 months --------------- PC composite girder :17months --------------- Substructure :12months)	△
			○			○	△	○	○	○	△	○	△	

Remarks; ◎:Excellent, ○:Good, △:Poor

Period of construction does not include preparatory work and finishing work.

Table 6.4.22 Comparison of the Structural Characteristics of the Tebicuary-mí Bridge (2)

Bridge Type	Construction Method	Division of Span	Level of Economic Cost	Quantity			Possibilities of Construction and Period of Completion	Maintenance Cost	Technology Transfer	Employment Opportunity	Esthetics	Driving Comfort	Period of Construction	Global Evaluation
				Super structure	Sub structure	Earth work								
The 4[th] proposal PC 3 span continuous box girder	Cantilever erection	Bridge total length L=216m (60m+96m+60m) 	1.66	Concrete for PC :2,757m³ PC wire :117t Steel bar :303t Form :15,111 m²	Concrete :2,902m³ Pile in-situ (ϕ 1,000) :5,101m Landing Stage :400 m² Preparation Yard :400 m² Coffering :480 m²	Selected soil :6,300m³ Embankment :79,244 m³	1. There shall be access roads to piers until the completion of superstructure construction. 2. Two piers shall be constructed at the same time. 3. Period of construction shall be shorter due to construct abutments and superstructure at the same time after the completion of piers. 4. Same as 2[nd] proposal-2.	1. Same as 1[st] proposal-1.	1. There are only a few bridges of this type constructed in this country. Therefore, it is significant for technology transfer. 2. This method is available for other projects.	1. Construction work for both superstructures and substructures shall be done at the site. Therefore, there are many employment opportunities at the site.	1. Variation of girder height is impressive.	1. It is a deck bridge, therefore longitudinal slope shall be steep.	26 months (Substructure : 12months)	△
			△			△	△	○	○	○	△	△	○	
The 5[th] proposal PC 4 span continuous box girder	Push out erection	Bridge total length L=216m (4@54m) 	1.46	Concrete for PC :2,359m³ PC wire :78t Steel bar :368t Form :15,111 m²	Concrete :2,475m³ Pile in-situ(ϕ 1,000) :4,350m Landing Stage :352 m² Preparation Yard :400 m² Coffering :480 m²	Selected soil :6,300m³ Embankment :69,317 m³	1. It is necessary to construct the superstructure after the completion of piers and abutments. Therefore, period of construction shall be longer. 2. Same as 2[nd] proposal-2.	1. Same as 1[st] proposal-1.	1. Same as 2[nd] proposal-1. 2. Same as 2[nd] proposal-2	1. Same as 2[nd] proposal-1.	1. It gives keen image due to lineal shape and no variation.	1. Same as 2[nd] proposal-1.	28 months (Substructure : 9 months)	△
			△			△	△	○	○	○	△	△	△	
The 6[th] proposal PC 7 span continuous composite girder	Fixed timbering	Bridge total length L=217m (7@31m) 	1.10	Concrete for PC :971 m³ Concrete for slab :668 m³ PC wire :53t Steel bar :328t Form :6,604 m²	Concrete :2,510m³ Pile in-situ (ϕ 1,000) :1,554m Landing Stage :416 m² Coffering :960 m²	Selected soil :6,300m³ Embankment :67,972 m³	1. Two piers shall be constructed in the river. Therefore, construction cost will be increased for these piers in the river. 2. Constructing two piers in the river may increase construction cost.	1. Same as 1[st] proposal-1.	1. Same as 2[nd] proposal-1 2. Same as 2[nd] proposal-2	1. Same as 2[nd] proposal-1.	1. It is a common type of bridge. Therefore, the impression is not so strong.	1. The longitudinal slope shall be gentle.	28 months (Substructure :9 months)	○
			○			△	△	○	○	○	△	○	△	

Remarks; ◎:Excellent, ○:Good, △:Poor

Period of construction does not include preparatory work and finishing work.

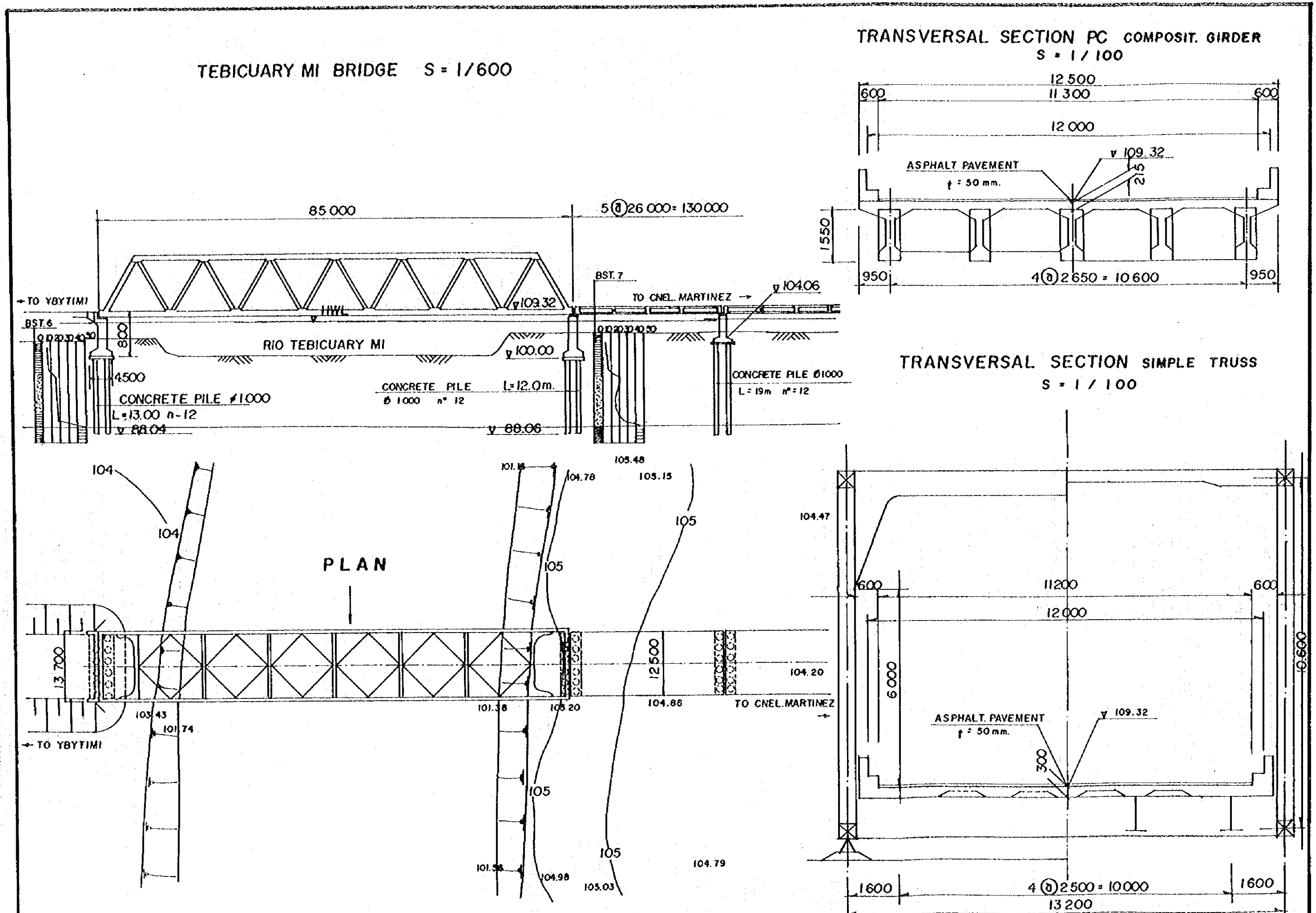


Figure 6.4.11 General View of the Tebecuary-mí Bridge

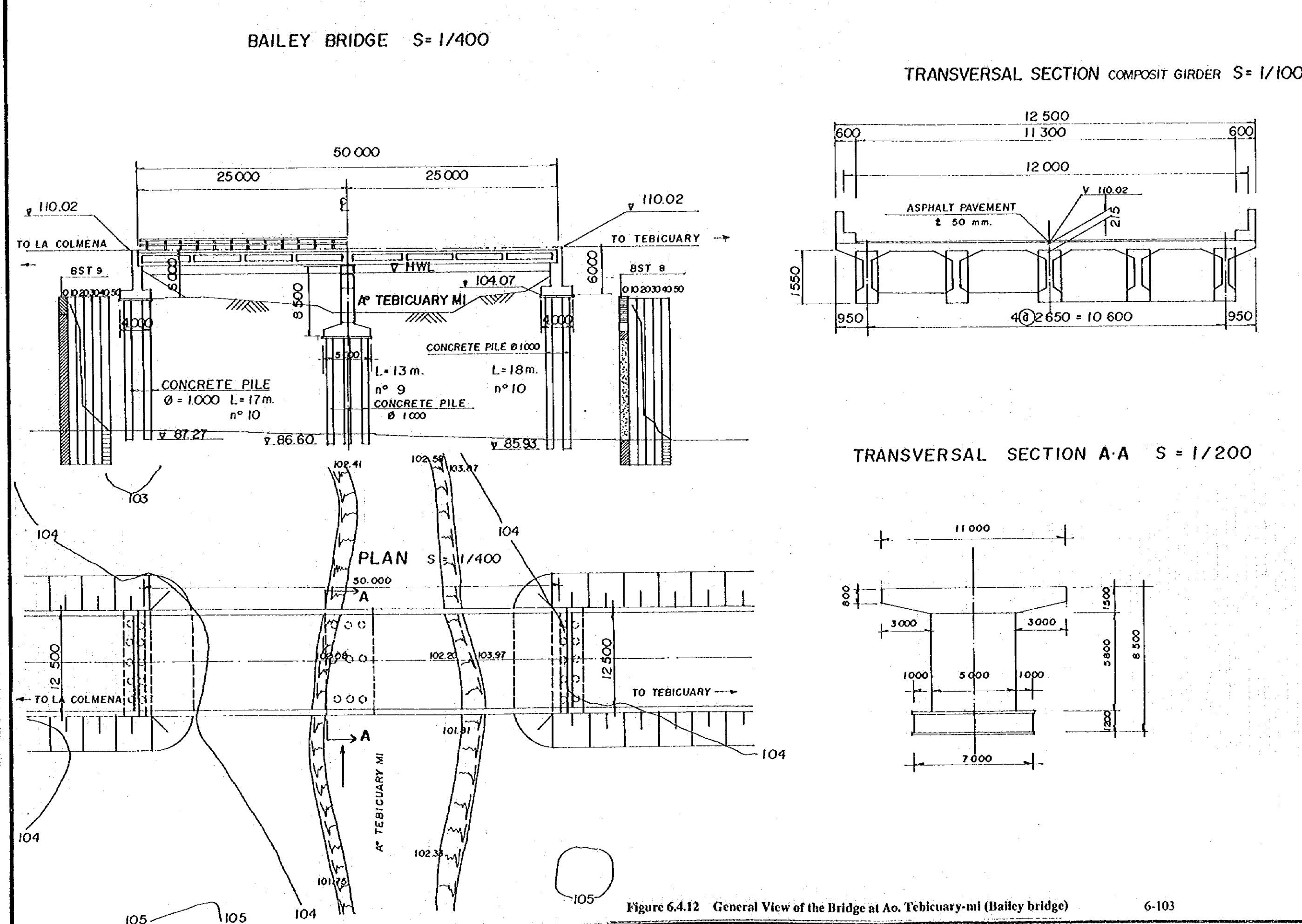
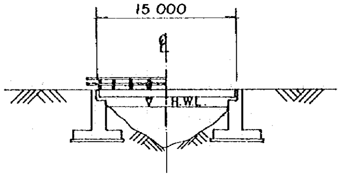
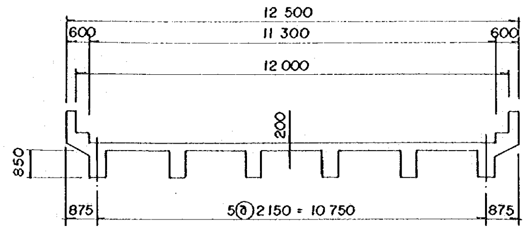


Figure 6.4.12 General View of the Bridge at Ao. Tebicuary-mi (Bailey bridge)

RC BRIDGE S = 1/400



TRANSVERSAL SECTION RC BRIDGE S = 1/100



PLAN S = 1/400

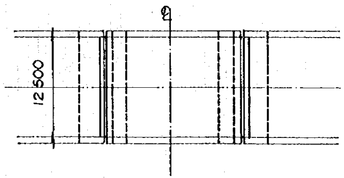
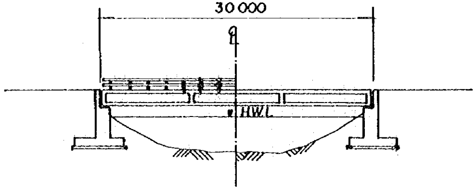
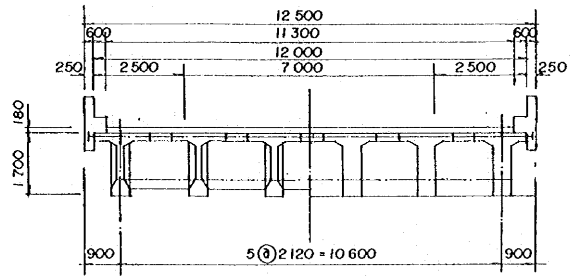


Figure 6.4.13 Typical Plan of RC Bridge

PC SIMPLET GIRDER BRIDGE
S = 1/400



TRANSVERSAL SECTION PC SIMPLET GIRDER
S = 1/100



PLAN S = 1/400

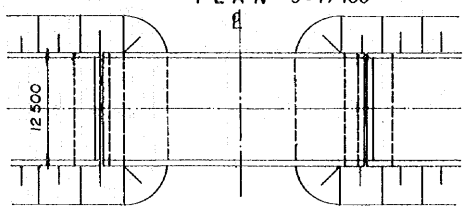


Figure 6.4.14 Typical Plan of PC Simple Girder Bridge

CHAPTER 7

PRELIMINARY DESIGN AND CONSTRUCTION PLAN

CHAPTER 7 PRELIMINARY DESIGN AND CONSTRUCTION PLAN

7-1 Preliminary Design of Road

The preliminary design of the objective road was carried out based on aerial photographs taken in 1994 at a scale of about 1 to 20,000, and 1 to 5,000, which were enlarged photos of the former. Mosaics of these photographs were obtained based on data from the topographic survey, longitudinal leveling survey, and cross sectional survey along the objective road, all of which were conducted in this Study.

Road design here consists of geometric design, earthwork design, minor drainage structure design except bridges, and a study on the method of construction. In the course of the design work, all data obtained from site reconnaissance, the boring survey, the hydraulic survey, the traffic demand forecast, and surveys of existing facilities were referred to and utilized.

7-1-1 Geometric Design

The objective roads are one from Paraguarí to Villarrica, and its branch from La Colmena to Tebicuary. These roads were divided into three sections for the reason given later in 7-3. Then, the sections were divided again into road segments considering topographic features (hilly, flat, low flood land), present land use and human settlement, actual conditions of the existing road (width, surface conditions, alignment), etc. This division is shown in Table 7.1.1 and Figure 7.1.1. In Figure 7.1.1, the locations of the candidate quarries and the assumed locations of asphalt plants, which are mentioned later, are also indicated.

Table 7.1.1 Division of Road into Segments

Segment	From - To -	Distance
Section 1 : Paraguarí-Rio Tebicuary-mí (58.5 km)		
1	Paraguarí - Sapucaí	L=22.5km
2	Sapucaí - Caballero	L=10.5km
3	Caballero - Ybytymí	L= 9.0km
4	Ybytymí - Punto Unido	L=10.0km
5	Puto Unido - Río Tebicuary-mí	L= 6.5km
Section 2 : Río Tebicuary-mí - Villarrica (24.5 km)		
6	Rio Tebicuary-mí - Martínez	L= 4.5km
7	Martínez - Cardozo	L= 8.0km
8	Cardozo - Villarrica	L=12.0km
Section 3 : Branch to La Colmena (38.1 km)		
9	La Colmena - Sta.126+100	L=25.3km
10	Sta.126+100 - Sta.138+100	L= 2.4km
11	Sta.138+100 - Tebicuary	L=10.4km