5.2 PRELIMINARY DESIGN

5.2.1 General

This clause describes the results of the preliminary design prepared for the project roads based on the results of the traffic demand forecast, the topographic survey (1/10,000 scale topographic maps were prepared by the JICA Study Team), the soil and material investigations, as well as the hydrological investigation, which cover the following:

- Geometric design
- Pavement design
- Drainage design
- Bridge design
- Other structural design

5.2.2 Geometric Design

(1) Typical Cross Sections

Considering the established design criteria, the typical cross sections shown in Figure 5-1 are recommended.

(2) Sidewalk

As stated in 5.1.1, Basic Policies, installing sidewalks with the structure shown in Figure 5-1 was considered. It is recommended that sidewalks be installed for each Project Road at the locations shown in Table 5-5.

(3) Busbays

As stated in 5.1.1, Basic Policies, installing busbays with the structure shown in Figure 5-2 was considered. It is recommended that busbays be installed for each Project Road at the locations shown in Table 5-6. The existing locations and recommendations on the revised design in 1992 were also referred for the Managua-Masaya Road.

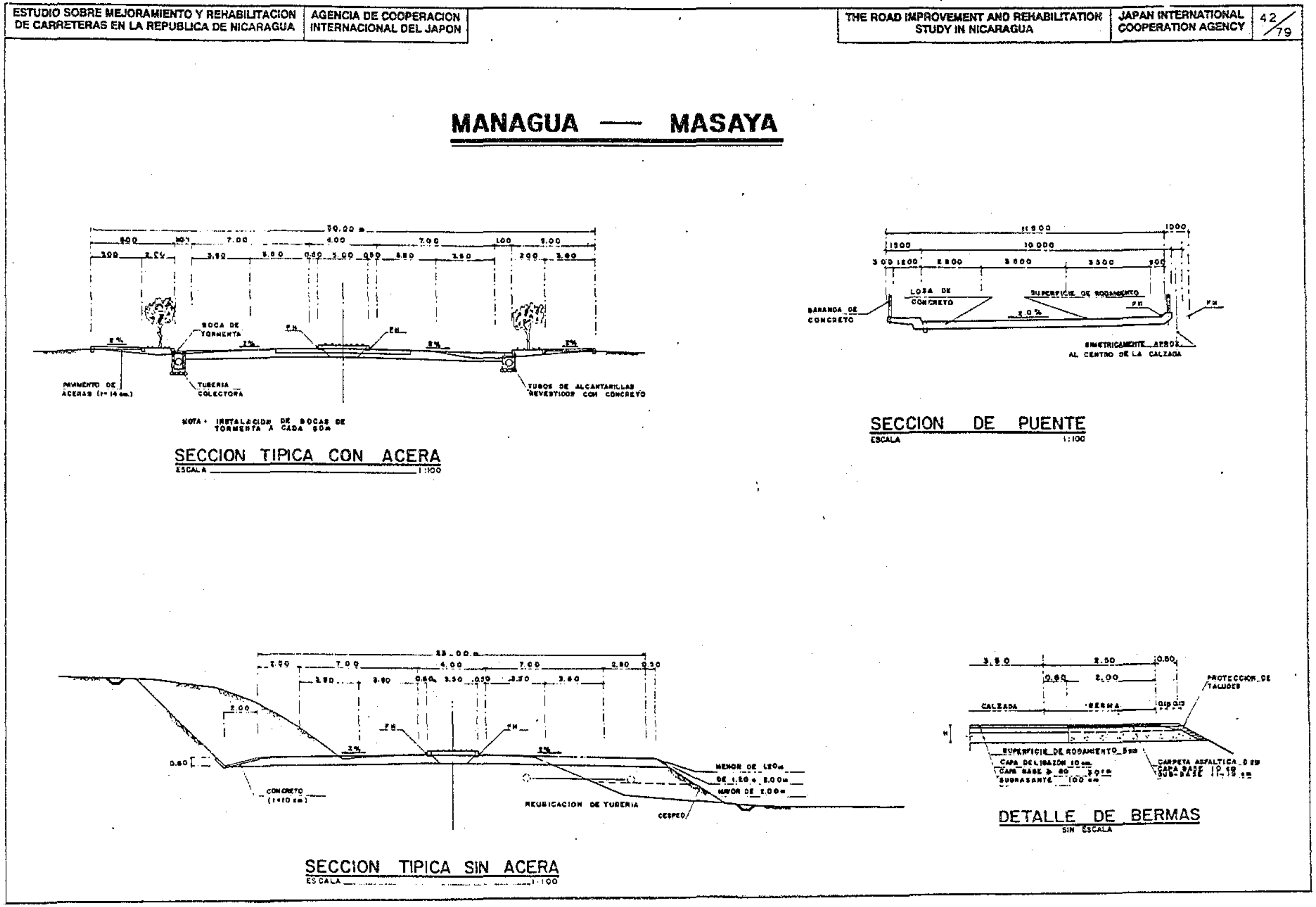


Figure 5-1 Proposed Typical Cross Sections (1)

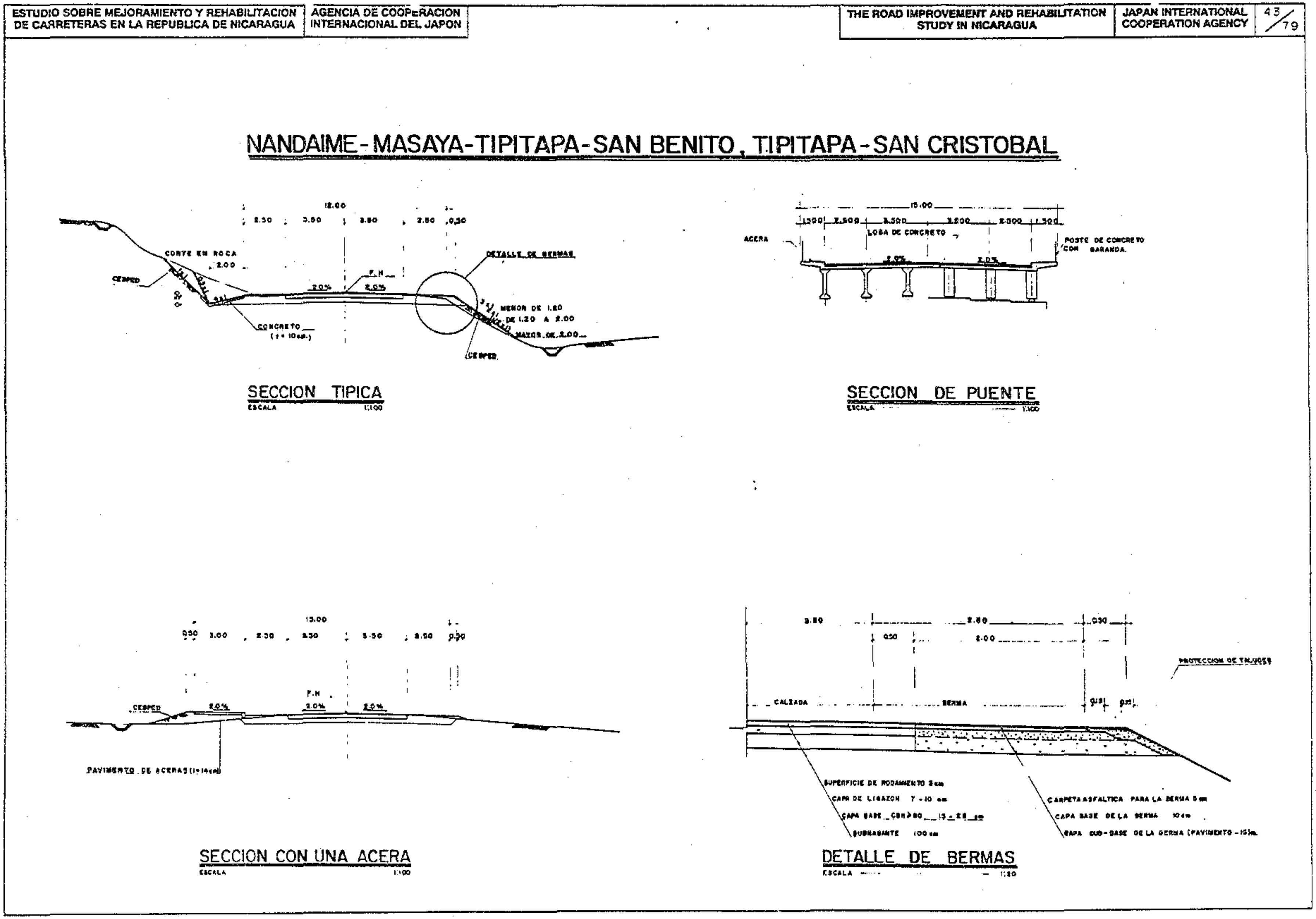


Figure 5-1 Proposed Typical Cross Sections (2)

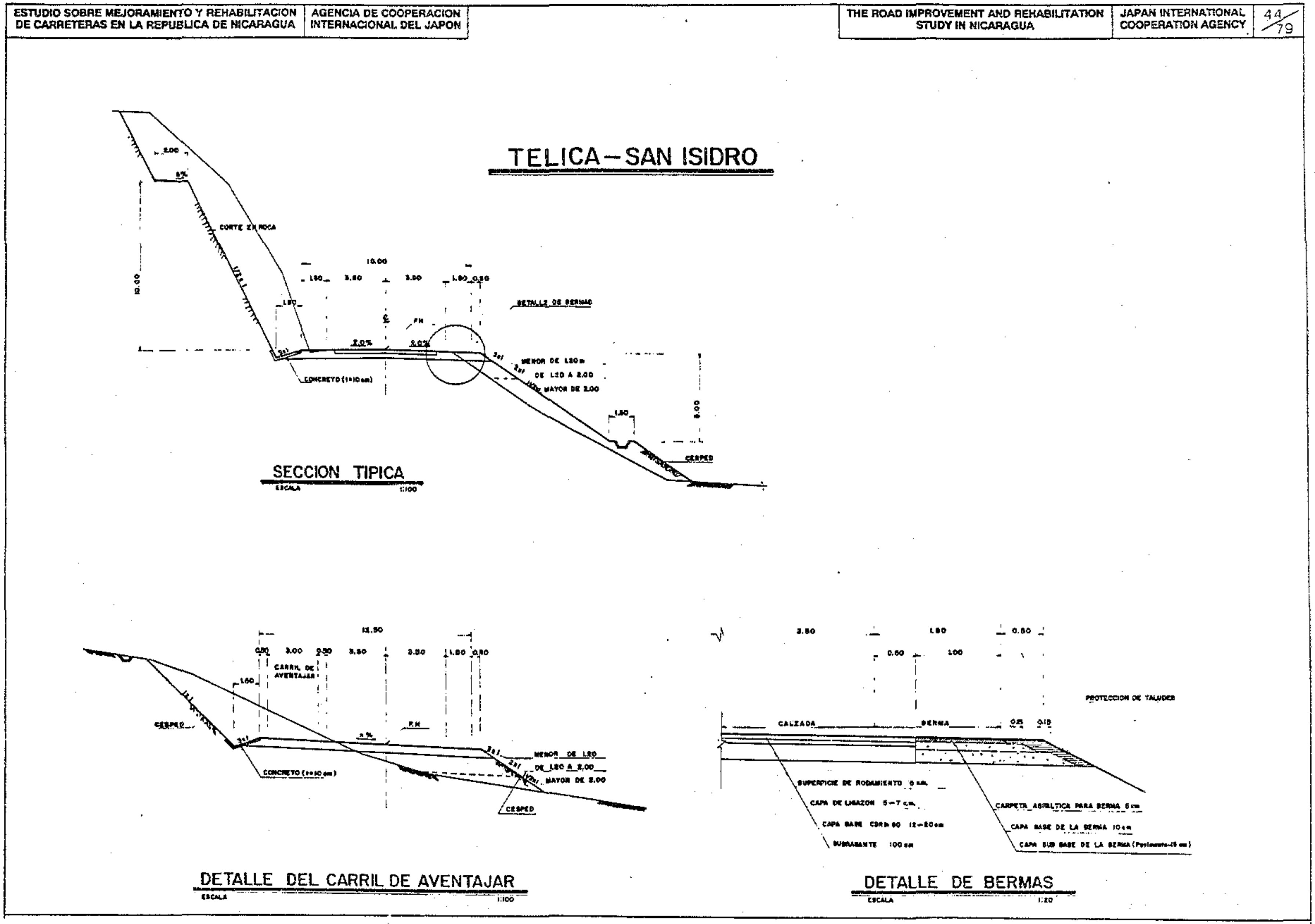


Figure 5-1 Proposed Typical Cross Sections (3)

Table 5-5 Installation of Sidewalks

Project Road	Location	Length	Remarks
Managua-Masaya	Intersection Colonia Centro América	3,220 m	W= 5.0 m
	Est.0+480 -1+000	520 m	W= 5.0 m, left side
	Est.13+200-14+800	3,200 m	W= 5.0 m
	Est.19+680-21+020	1,340 m	W= 5.0 m, left side
	Est.22+130-24+950	2,820 m	W= 5.0 m, left side
	Est.22+130-25+470	3,340 m	W= 5.0 m, right side
	Subtotal	14,440 m	
Managua-Tipitapa	-	-	-
Nandaime-San Benito (Masaya-Nandaime)	Est.0+550 -1+430	880 m	Right side
	Est.8+600 -9+250	650 m	Left side
	Est.9+250 -9+600	350 m	Right side
	Est.12+100-13+000	900 m	Left side
	Est.12+780-15+800	3,020 m	Right side
(El Coyotepe-Río Panamá)	Est.5+750 -6+720	970 m	Left side
	Est.5+800 -6+800	1,000 m	Right side
	Est.8+800 -10+800	4,000 m	
	Est.16+700-17+850	2,300 m	
(Río Panamá-San Benito)	Est.2+600 -2+820	220 m	Left side
	Est.2+530 -2+820	290 m	Right side
	Est.12+350-14+000	1,650 m	Right side
	Est.15+300-16+000	700 m	Right side
	Subtotal	16,930 m	
Telica-San Isidro	Est.11+800-12+900	1,100 m	Left side
	Est.23+330-23+680	350 m	Right side
	Est.23+680-23+830	150 m	Right side
	Est.49+050-49+350	300 m	Left side
	Est.50+100-50+700	600 m	Right side
	Est.59+670-60+750	1,080 m	Right side
	Est.72+650-73+000	350 m	Right side
	Est.86+500-86+800	300 m	Right side
	Subtotal	4,230 m	
Total		35,600 m	

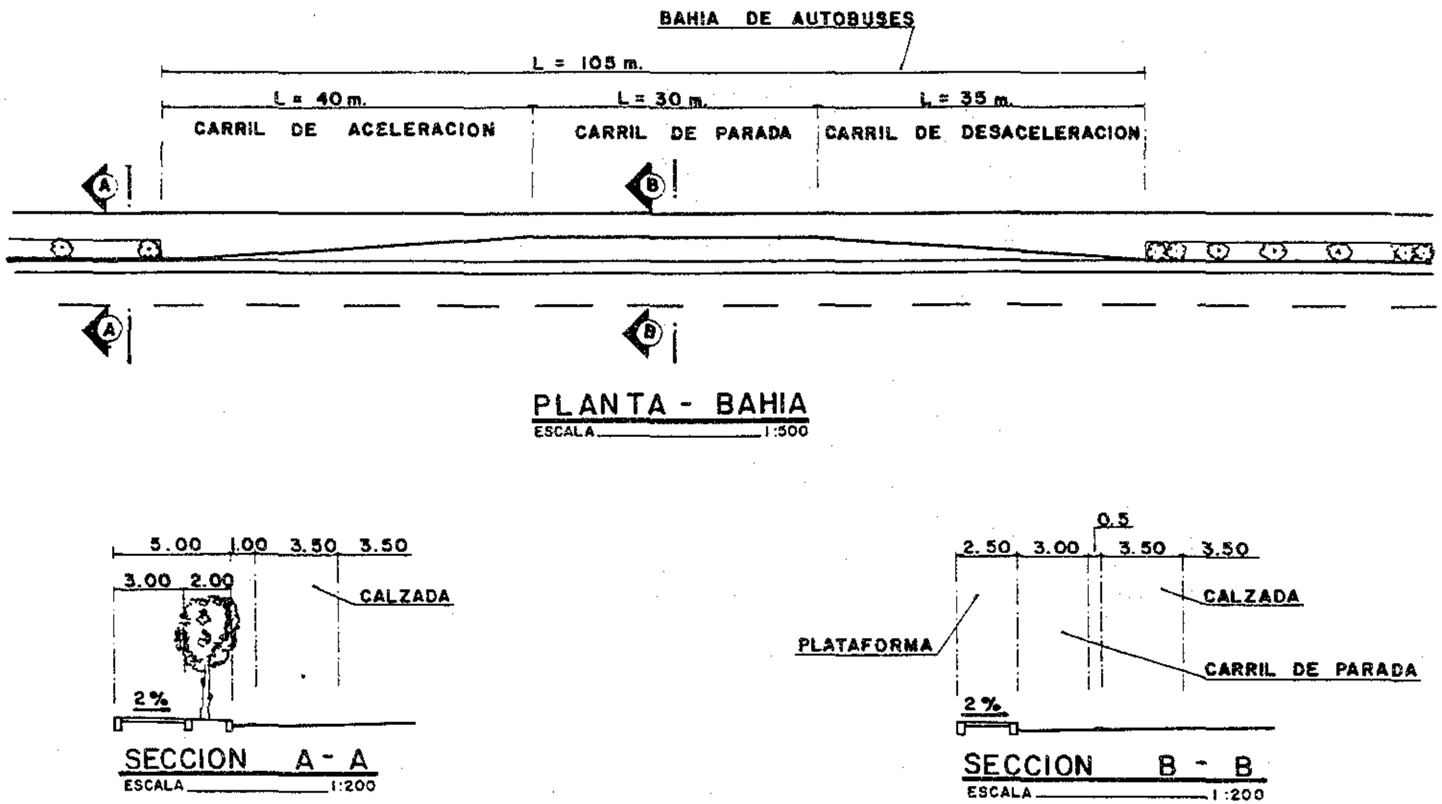


Figure 5-2 Proposed Busbays (with Sidewalk) (1)

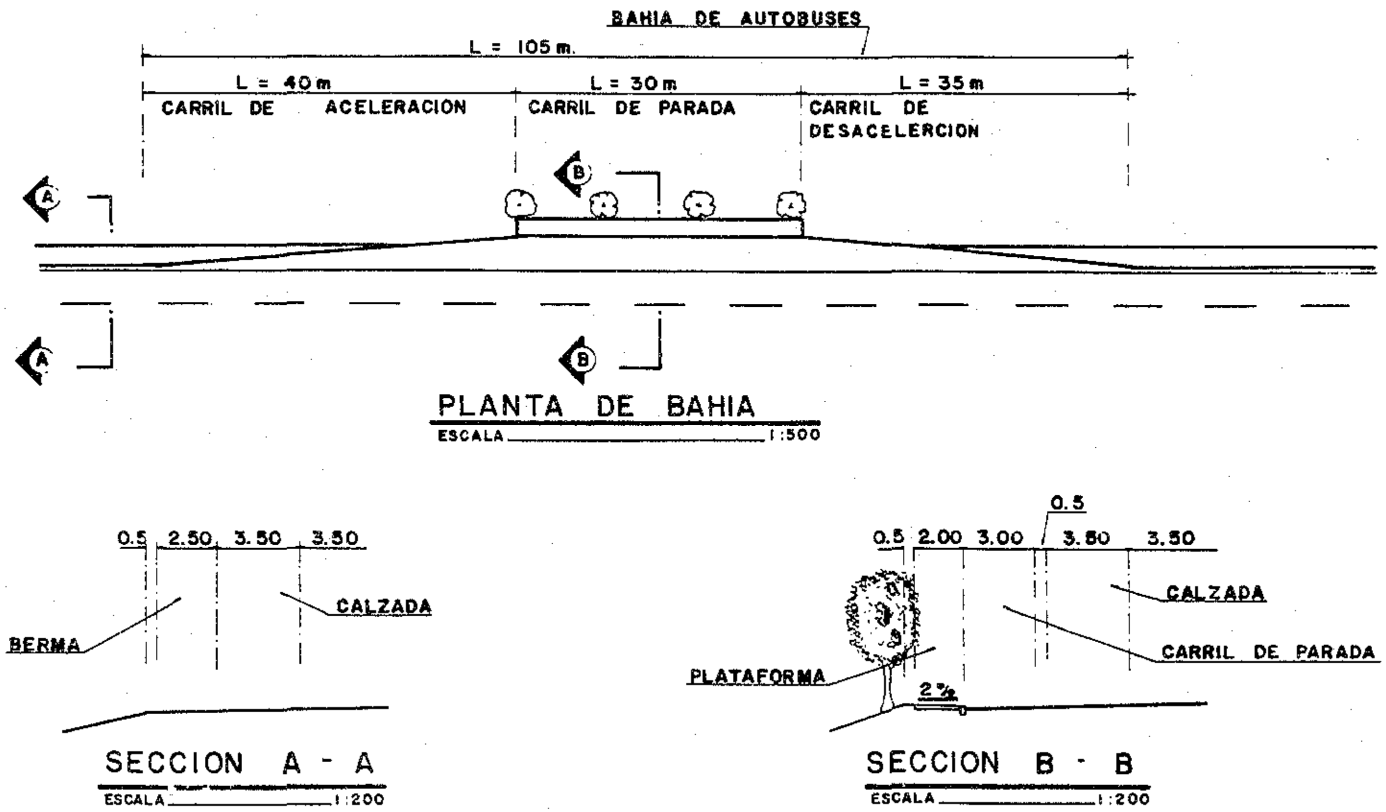


Figure 5-2 Proposed Busbays (without Sidewalk) (2)

Table 5-6 Installation of Busbays

Project Road	Section	Location
Managua-Masaya	Managua-Entrada a Ticuantepe	0+400, 2+400, 3+300,4+700, 5+500, 6+500, 7+400 7 locations
	Entrada a Ticuantepe- El Coyotepe	8+600, 10+600, 11+400, 13+000, 14+500, 15+500, 17+100, 19+700, 20+700 9 locations
	El Coyotepe-Masaya	22+200, 24+000, 25+800 3 locations
	Subtotal	19 locations
Managua-Tipitapa		0+000, 4+200 2 locations
	Subtotal	2 locations
Nandaime-San Benito	Masaya-Catarina	*0+100, 1+400, 3+200, 8+600* 4 locations
	Catarina-El Guanacaste	9+800, 12+800, 13+700, 15+600, 17+600 5 locations
	El Guanacaste-Nandaime	18+000,20+200,23+300,27+000 4 locations
	El Coyotepe-Río Panamá	0+600,6+400,10+000, 14+000,17+000,19+200,21+050 7 locations
	Río Panamá-San Benito	2+600, 7+900, 10+700, 12+800, 13+800, 16+000 6 locations
	Subtotal	26 locations
Telica-San Isidro	Telica-Malpaisillo	0+100, 2+300, 4+250, 10+400, 12+500, 15+800, 16+800, 19+200, 23+600 9 locations
	Malpaisillo-El Jicaral	27+200, 29+400, 32+700, 34+900, 37+400, 38+700, 40+600, 42+600, 47+700, 49+000, 50+500, 52+000, 56+000, 59+100, 60+600 15 locations
	El Jicaral-La Unión	66+800, 68+100, 70+400, 73+000, 77+400, 79+800 6 locations
	Subtotal	35 locations
Total		82 locations

(4) Horizontal and Vertical Alignment

a) Managua-Masaya Road

A check of the compiled 1/10,000 scale topographic maps confirmed that the horizontal alignment of the Project Road conformed to the proposed design criteria. A check of the proposed height of bridges and box culverts that will act as control points also confirmed that the proposed vertical alignment conformed to design criteria. However, the following items were pointed out as requiring improvement:

- Intersection Colonia Centro América (Est.00+000)
- Horizontal alignment on La Morita Bridge (Est.00+490)

- Horizontal and vertical alignment on El Arroyo Bridge to protect the tower support of the transmission line in the vicinity of the Bridge (Est.08+100/08+170).
- At-grade railway crossing at Est.21+860 and vertical alignment at the intersection with NIC-11 (El Coyotepe, Est.22+120).

These items are described below:

① Intersection of Colonia Centro América

Two alternatives were considered:

- Improve the existing at-grade intersection by upgrading signalization while ensuring sufficient lanes and storage length corresponding to the future traffic volume (Alternative-1).
- Construct a flyover for through traffic from/to Tiscapa/Masaya (Alternative-2).

These alternatives were assessed according to the flowchart illustrated in Figure 5-3.

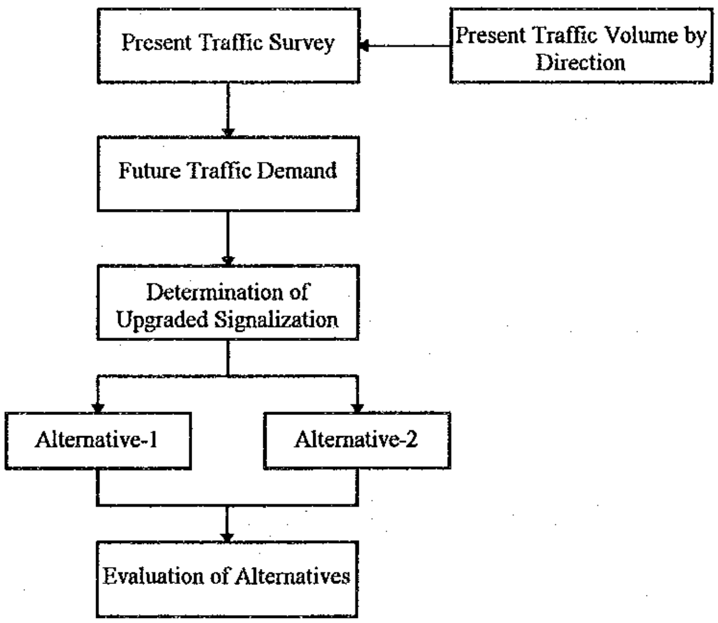


Figure 5-3 Study of Alternatives

The following conditions were assumed:

- According to the results of the future traffic demand forecast, the peak hour was considered to be 7:00 a.m. to 8:00 a.m. Therefore, the traffic volume was established as the directional design hour volume.
- The saturation rate of intersection should be less than 0.9.
- The saturation flow rates were assumed to be as follows:
  - Straight : 2,000 PCU
  - Right-turn : 1,800 PCU
  - Left-turn : 1,800 PCU

Detailed results are described in Appendix A5.1

Following case studies for each alternative, optimum plans for each alternative were determined. These plans are shown in Figures 5-4 and 5-5. These plans call for accommodating traffic flow an upgrading signalization (the saturation rate < 0.9) and by minimizing congestion degree.

Evaluation results are summarized in Table 5-7. The plans for the two alternatives are shown in Figures 5-6 and 5-7, respectively.

Table 5-7 Evaluation of Alternatives for Improving the Intersection Colonia Centro América

Evaluation Item	Alternative-1 (At-grade intersection)	Alternative-2 (Flyover)
Major Considerations	Improve the existing at-grade intersection by upgrading signalization while ensuring sufficient lanes and a storage length corresponding to the future traffic volume	Construction of a flyover for through traffic from/to Tiscapa/Masaya
Traffic Operation	Operation is disadvantageous because all vehicles are controlled by signals	Traffic from/to Tiscapa/Masaya is freely operated
Difficulty of Construction	Advantageous because of stage construction	Slightly difficult to ensure a detour during the construction of a flyover. Long-term construction will be required for the flyover
Cost	Advantageous (C$22,500,000)	Disadvantageous (C$43,200,000)
Overall Evaluation	Alternative-1 is advantageous from economical and constructional viewpoints	Alternative-2 should be considered as a way of handling further increase in future traffic

Under the plan proposed as Alternative-2, bridge structures will be constructed using steel box girder viaducts at intersections and prestressed concrete hollow slabs on the approach ramp as shown in Figure 5-7.

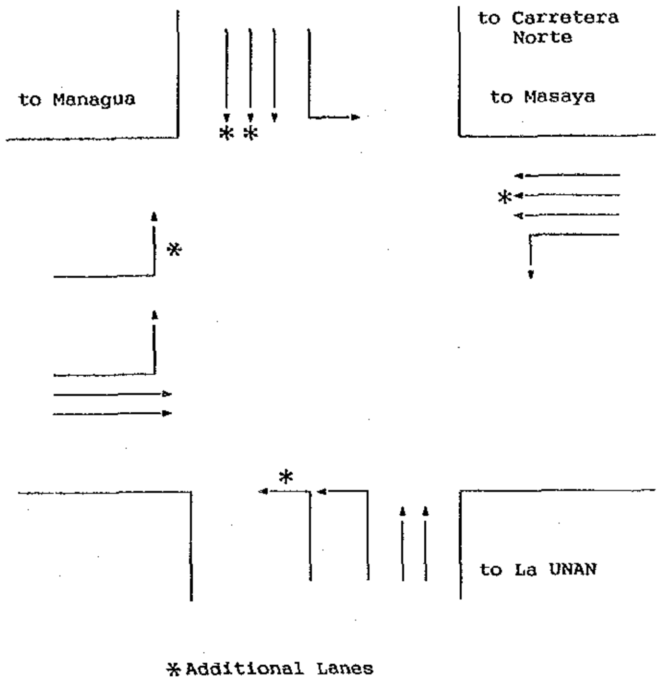


Figure 5-4 Optimum Plan for Alternative-1

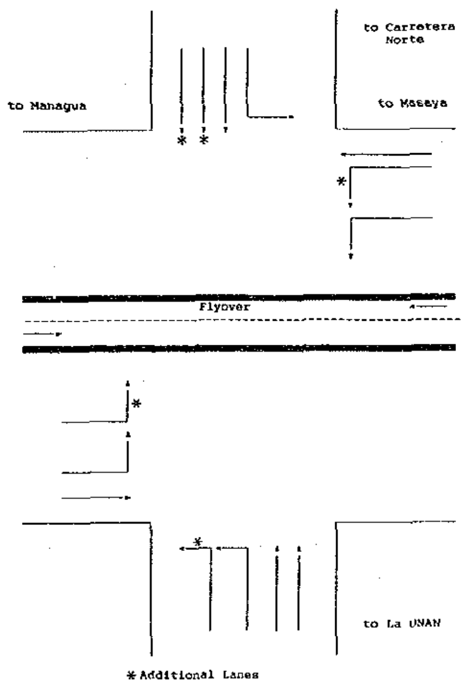


Figure 5-5 Optimum Plan for Alternative-2

INTERSECCION "COLONIA CENTROAMERICA"

(V= 60 km/h)

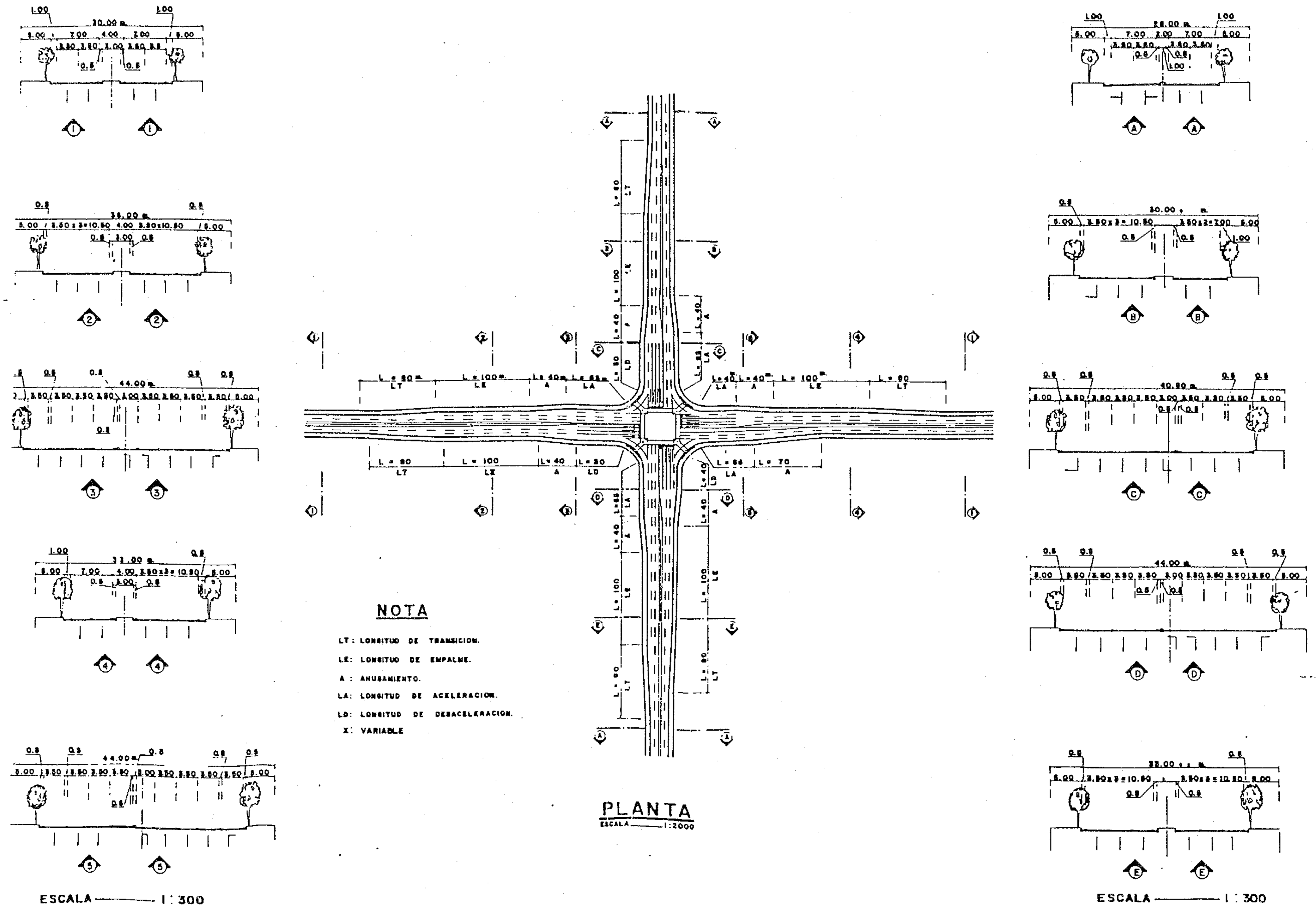


Figure 5-6 Alternative-1 (At-grade Intersection)

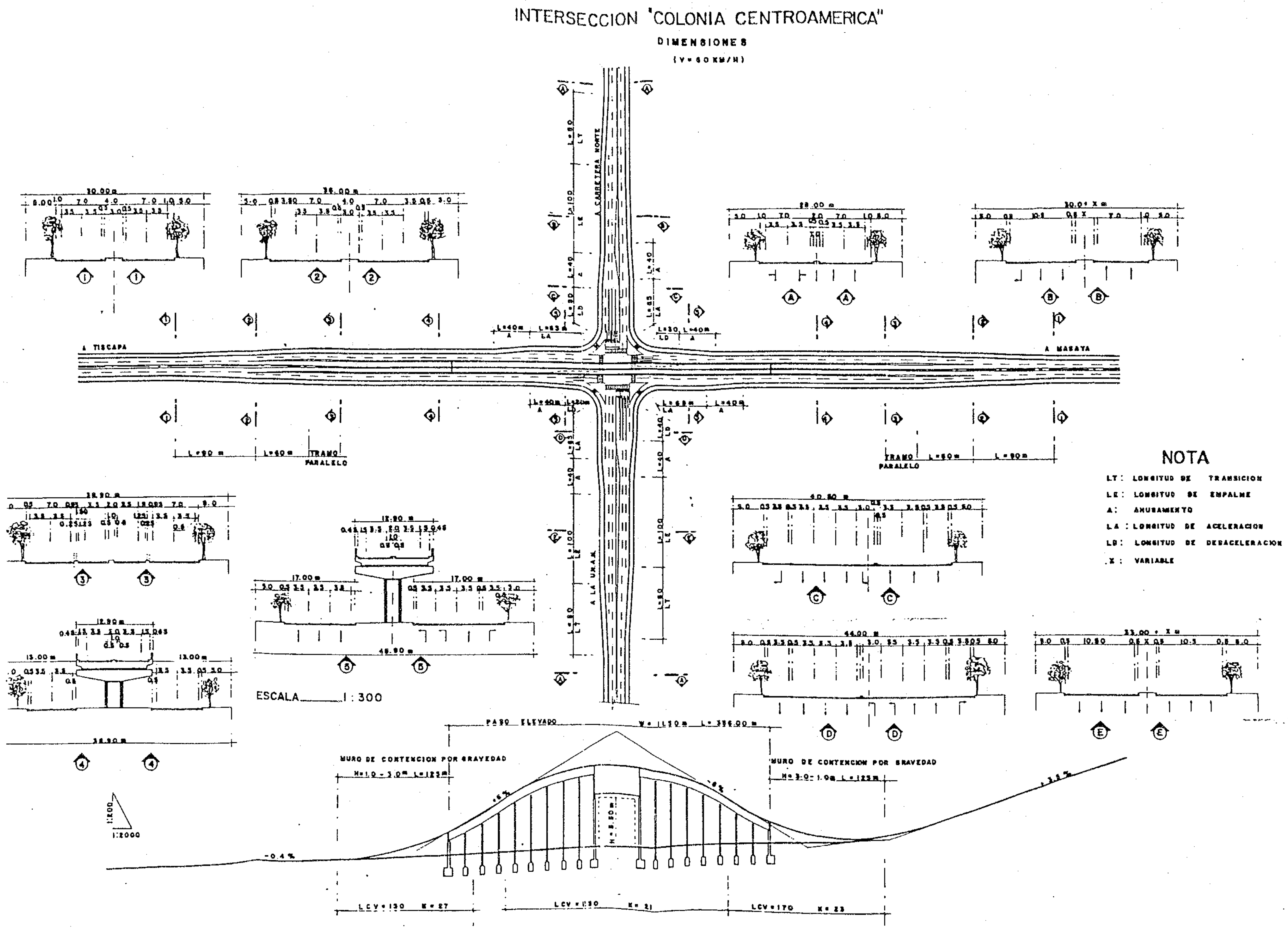


Figure 5-7 Alternative-2 (Grade Separation)

Alternative-1 was considered to be preferable on the basis of the evaluation presented in Table 5-7. A final recommendation will be given after presentation of the economic study in Chapter 6.

② Horizontal Alignment on La Morita Bridge

To ensure the flow of traffic during bridge construction, to avoid having to remove houses in the vicinity of the bridge, and to improve river flow left-hand side, moving the center line 5.0 m to the right was considered. A transition length of 200 m was considered sufficient to ensure smooth traffic flow (refer to Figure 5-8).

The median width on the bridge section should be reduced up to 2.0 m to ensure installation of a grade separation structure. The sidewalk width should also be reduced up to 1.5 m to give pedestrians sufficient room to pass.

③ Horizontal and Vertical Alignment on El Arroyo and for Prevention of Tower Support of the Transmission Line

To ensure the unobstructed flow of traffic during the construction of the bridge, and to avoid the need to remove the tower support located on the top of the right slope (Est. 08+100), a 4.0 m shift to the left of the center line was considered. (Refer to Figures 5-9 and 5-10).

Figure 5-10 is an enlarged drawing of cross section B-B in Figure 5-9, where conditions are critical due to the existence of the tower support and a large-scale cut slope.

The median and sidewalk width should be reduced to 2.0 m and 1.5 m respectively, just like in the case of the La Morita Bridge. Although there is now no sidewalk before and after the bridge, sidewalks should be installed on both sides of the bridge to ensure the safety of pedestrians.

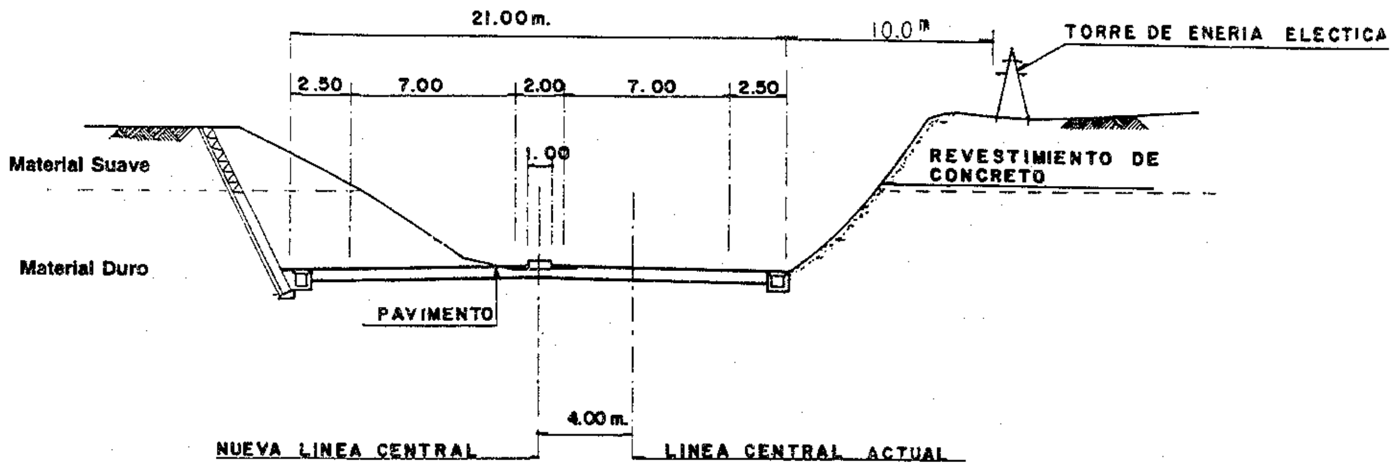


Figure 5-8 Improvement of Alignment at La Morita Bridge

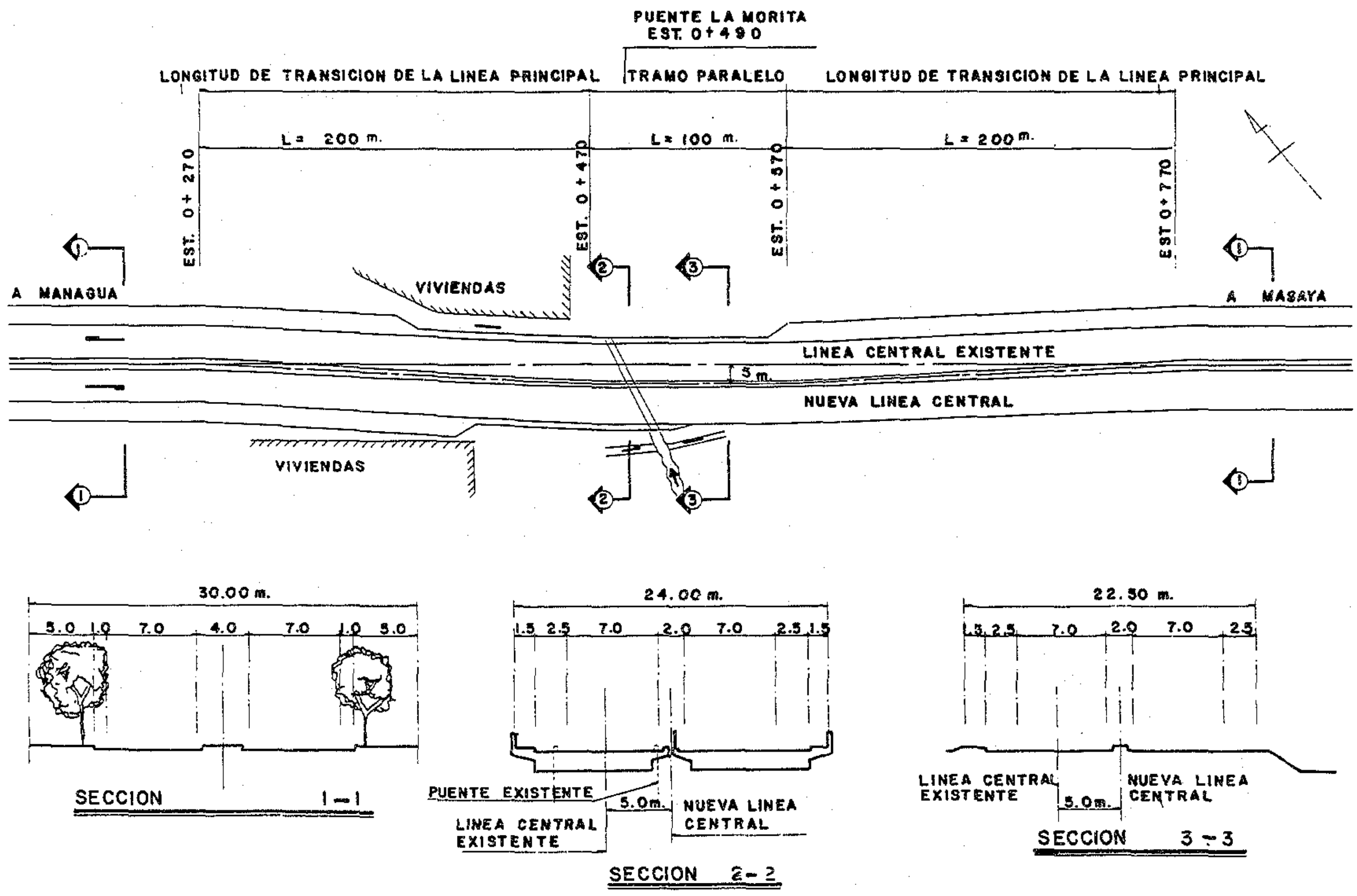


Figure 5-9 Improvement of Alignment at El Arroyo Bridge (Plan)

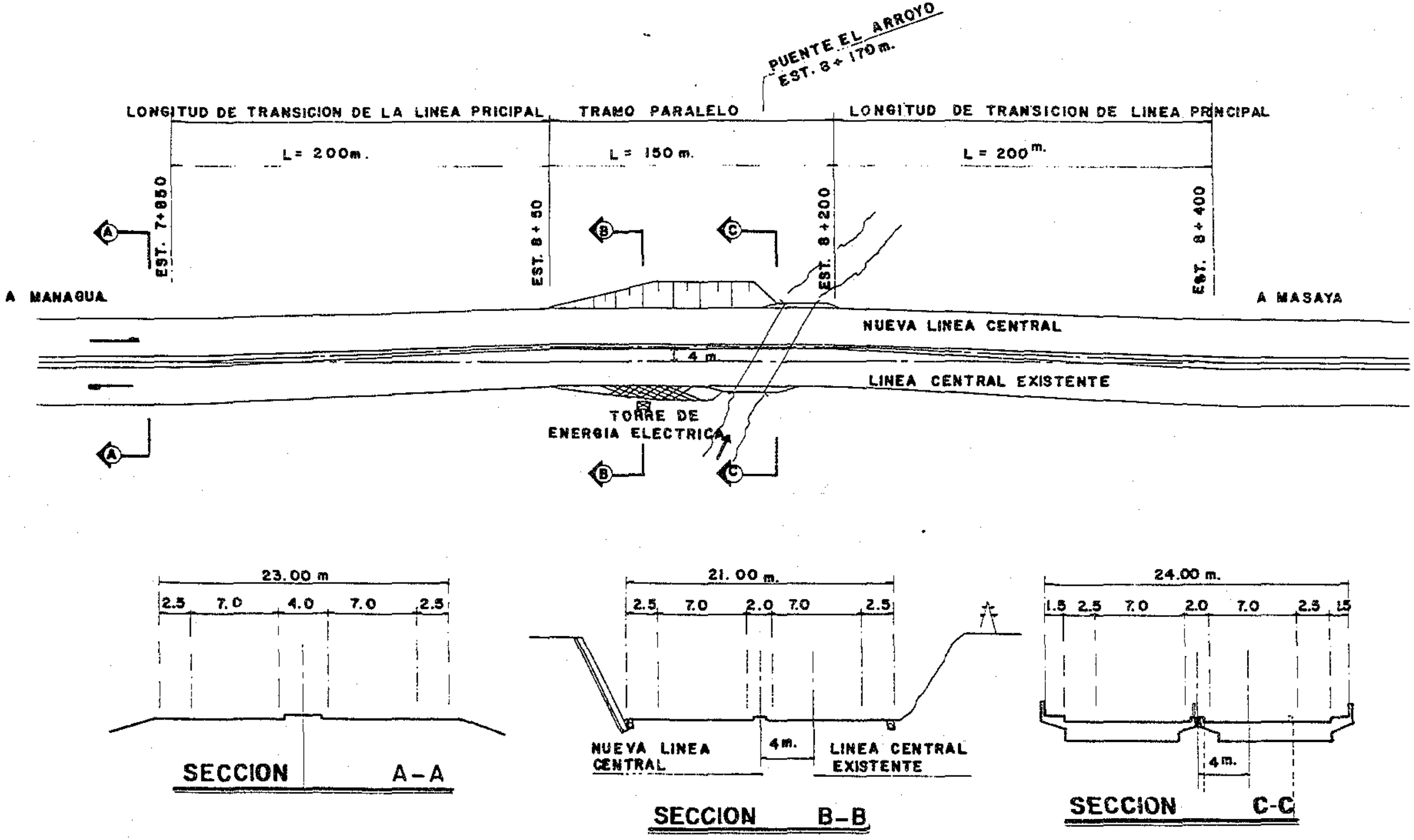


Figure 5-10 Improvement of Alignment at El Arroyo Bridge (Cross Section)

④ Improvement of the At-Grade Railway Crossing at Est.21+860, and Vertical Alignment at the Intersection with NIC-11

Three improvement alternatives were considered. At first, improvement with the at-grade crossing maintaining the present conditions was considered (Alternative-1). Then, improvement by means of grade separation as a possibility in technical view point was considered (Alternative-2). In the case of the latter alternative, an approach road to the flyover without structures (Alternative-2A), and an approach road with structures (Alternative-2B) were also considered.

The alternatives are evaluated in Table 5-8. The plans for each alternative are shown in Figures 5-11 and 5-12, respectively.

Table 5-8 Evaluation of Alternatives for Improvement of the At-grade Railway Crossing at Est.21+860 on the Managua-Masaya Road

<table>
<tr><th>Item</th><th>Alternative-1</th><th>Alternative-2A</th><th>Alternative-2B</th></tr>
<tr><td rowspan="2">Major Considerations</td><td rowspan="2">At-grade crossing of the railway.
Improvement of vertical alignment of the intersection with NIC-11</td><td colspan="2">Railway crossing with grade separation.
Improve vertical alignment between the railway crossing and the intersection with NIC-11</td></tr>
<tr><td>Approach road to the flyover without structures</td><td>Approach road to the flyover with structures</td></tr>
<tr><td>Traffic Operation</td><td>Operation is disadvantageous due to traffic control at the railway crossing</td><td colspan="2">Operation is advantageous. (Traffic flows freely. Vertical alignment is improved appropriately).</td></tr>
<tr><td>Difficulties</td><td>Vertical alignment is not improved appropriately.
(i=4.9% at the intersection)</td><td>Large land acquisition is required. (approx.9,700 m²)</td><td>Land acquisition is required. (approx.2,500 m²)</td></tr>
<tr><td>Cost</td><td>Advantageous
(C$3,450,000)</td><td>Disadvantageous
(C$9,030,000)</td><td>Disadvantageous
(C$17,100,000)</td></tr>
<tr><td>Overall Evaluation</td><td colspan="3">The present railway operation is extremely limited. Therefore, alternative-1 is advantageous from an economical viewpoint (investment effect).
Alternatives 2A/2B should be considered corresponding to the improvement of railway operations and/or an increase in traffic in the future.</td></tr>
</table>

Alternative-1 was considered to be preferable on the basis of the above evaluations.

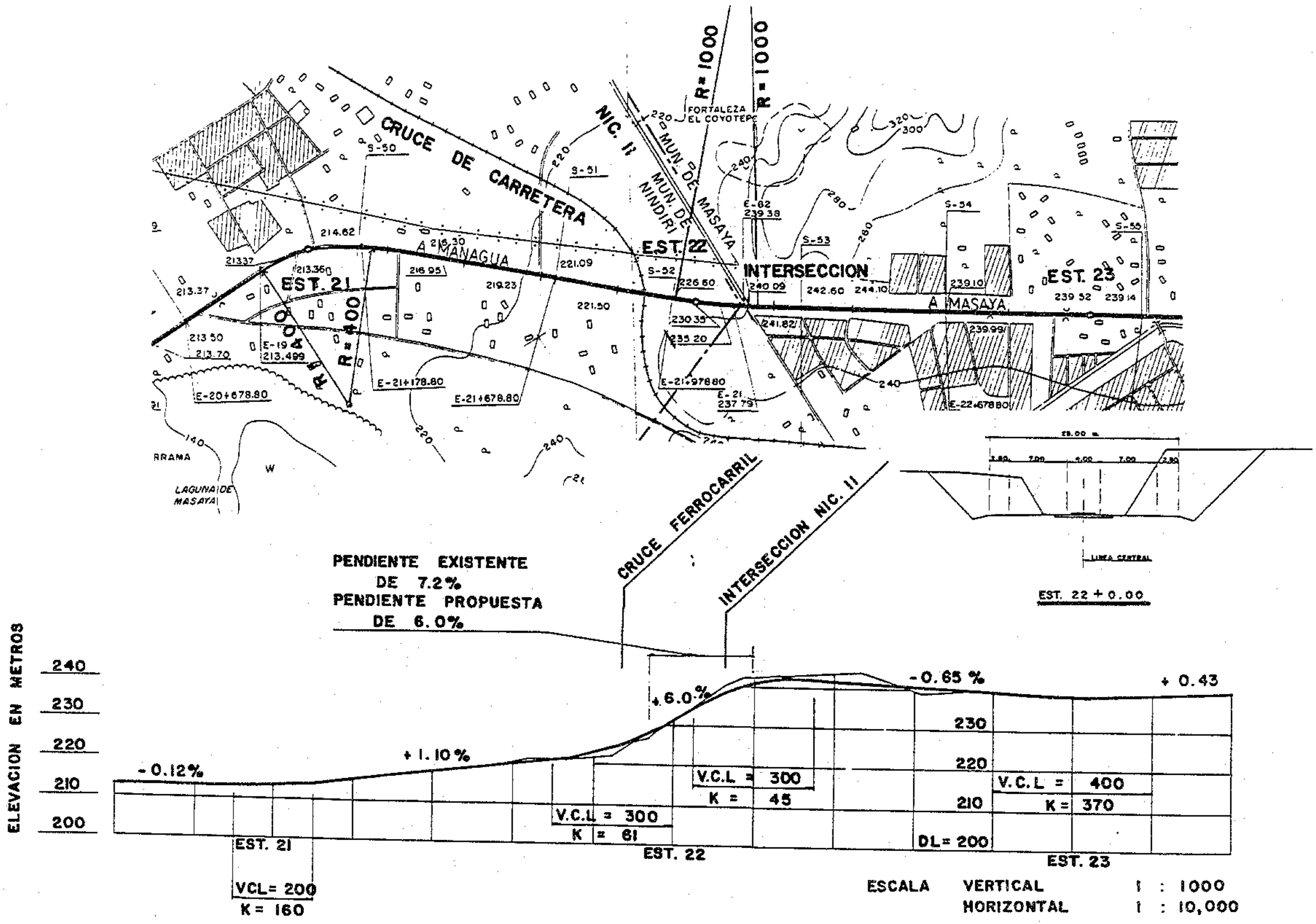


Figure 5-11 Alternative-1 (At-grade Intersection)

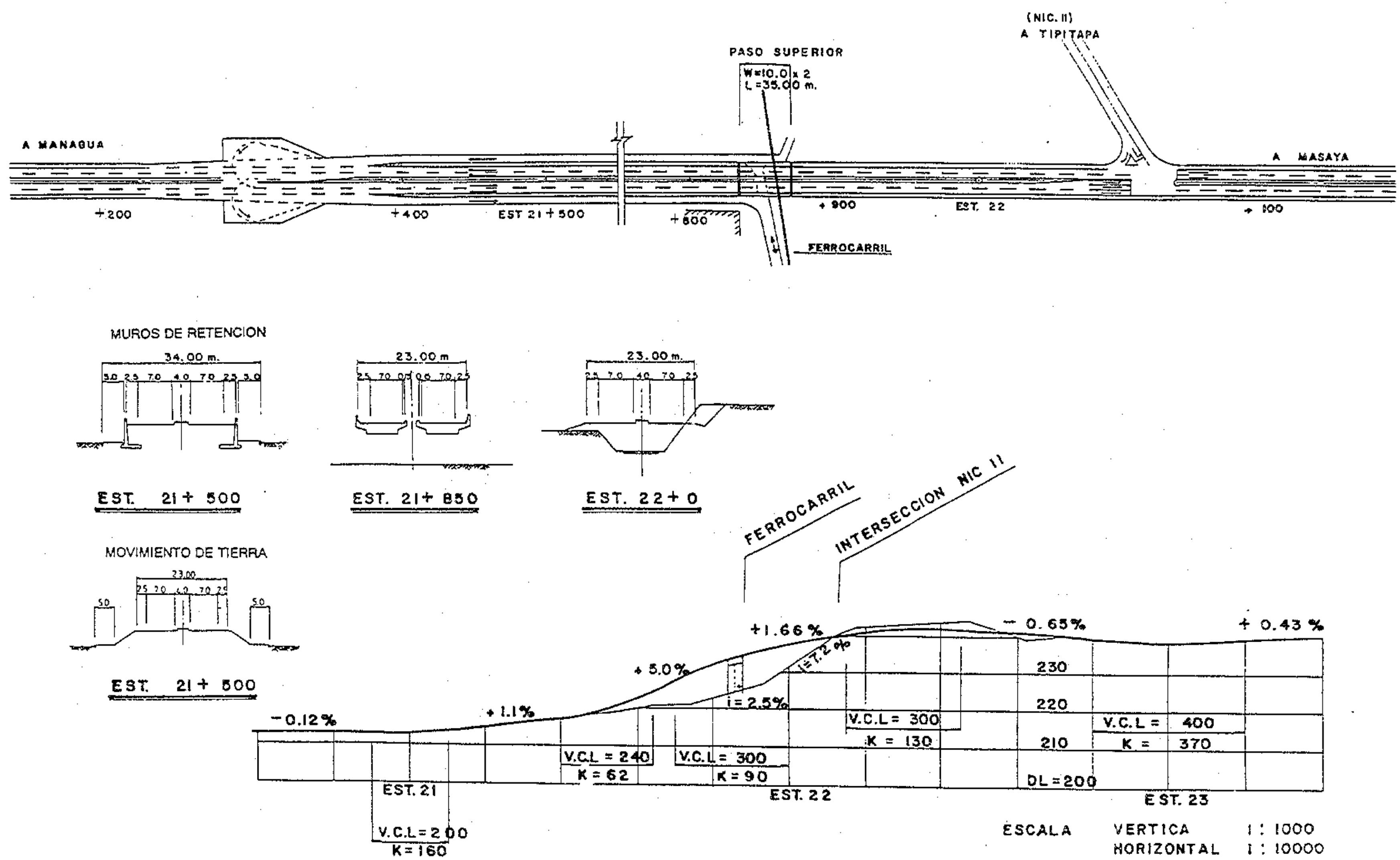


Figure 5-12 Alternative-2 (Grade Separation)

b) Managua-Tipitapa Road

The horizontal and vertical alignment was observed to conform with the proposed/ established design criteria following a check of compiled 1/10,000 scale topographic maps and the proposed height of box culverts that will act control points. Therefore, no improvement in the alignments of the Project Road was considered.

c) Nandaime-San Benito Road

The horizontal alignment of the Project Road was observed to conform with the design criteria after conducting a check using the same method described above. Vertical alignment, however, was observed as requiring the following improvements:

- Masaya-Catarina Section:
  The whole section requires an improvement of alignment.
- Catarina-El Guanacaste Section:
  The section between Est.9+000 and Est.12+400 requires an improvement of alignment.
- El Guanacaste-Nandaime Section, El Coyotepe-Río Panamá Section, and Río Panamá-San Benito Section:
  No improvement is required.

The following items were identified as points to be determined in the geometric design:

- Horizontal alignment of El Arroyo No. 1 Bridge (El Guanacaste-Nandaime)
- River bank along the Agua Agria River (El Guanacaste-Nandaime)
- Bypass to NIC-1 (El Coyotepe-Río Panamá)
- Flooding section before and after Est.3+000 (Río Panamá-San Benito)

The selected plans are described below.

① Horizontal Alignment of El Arroyo No. 1 Bridge (El Guanacaste-Nandaime)

A 14.0 m shift of the center line upstream of the existing bridge was recommended so that replacement work could be done without obstructing traffic.

② River Bank along the Agua Agria River (El Guanacaste-Nandaime)

Several types of structures should be constructed at locations where river bank erosion is expected to be most severe. Stone masonry, which is commonly utilized, was selected from economical and practical viewpoints.

③ Bypass to NIC-1 (El Coyotepe-Río Panamá Section)

A bypass connected to the existing NIC-1 between Managua and Tipitapa was recommended on the El Coyotepe-Río Panamá Section to avoid the need for larger land acquisition in the central area of Tipitapa city.

④ Flood Section Before and After Est.3+000 (Río Panamá-San Benito Section)

The section which is most likely to flood was recommended to be raised to a height of 2.0 m to prevent flood damage.

d) Telica-San Isidro Road

A check using the same method as that used for the Managua-Tipitapa Road confirmed that the horizontal and vertical alignment of the Project Road conformed to the design criteria except for the El Jicaral-La Unión Section.

The following locations were identified as requiring and improvement of alignment on the above El Jicaral-La Unión Section:

- Before and after Est.63+600
- Between Est.68+200 and Est.71+100

① Improvement before and after Est.63+600

It is believed that the center line should be diverted to the mountain side to improve horizontal alignment as shown in Figure 5-13.

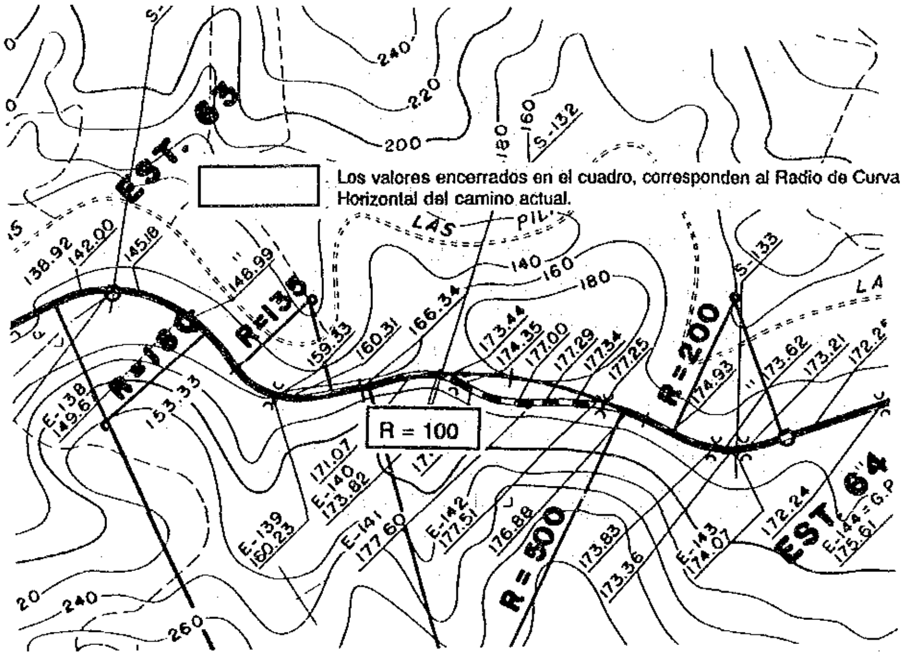


Figure 5-13 Improvement of Alignment before and after Est.63+600

② Improvement between Est.68+200 and Est.71+100

Two alternatives were considered, i.e. Alternative-1 (new route) and Alternative-2 (improvement of the existing road). In the case of alternative-2, a reduction in the of design speed to 40 km/hr is required to conform to the proposed design criteria. On the other hand, in the case of the proposed new alignment (Alternative-1), a 60 km/hr design speed would be possible. Although the cost of Alternative-1 is higher, it is more recommendable from viewpoint of continuity of the design speed, especially considering that an 80 km/hr design speed was adopted before and after the El Jicaral-La Unión Section. The alternatives are summarized in Table 5-9 and a proposed route for Alternative-1 is illustrated in Figure 5-14.

Table 5-9 Consideration of Alternatives for Improvement between Est.68+200 and Est.71+100 on the Telica-San Isidro Road

Item	Alternative-1	Alternative-2
Major Consideration	Establish a new route in order to ensure a 60 km/hr design speed.	Improvement of the existing road
Established design speed	60 km/hr	40 km/hr
Proposed length	2,900 m	3,400 m
Cost	C$29,800,000	C$11,500,000

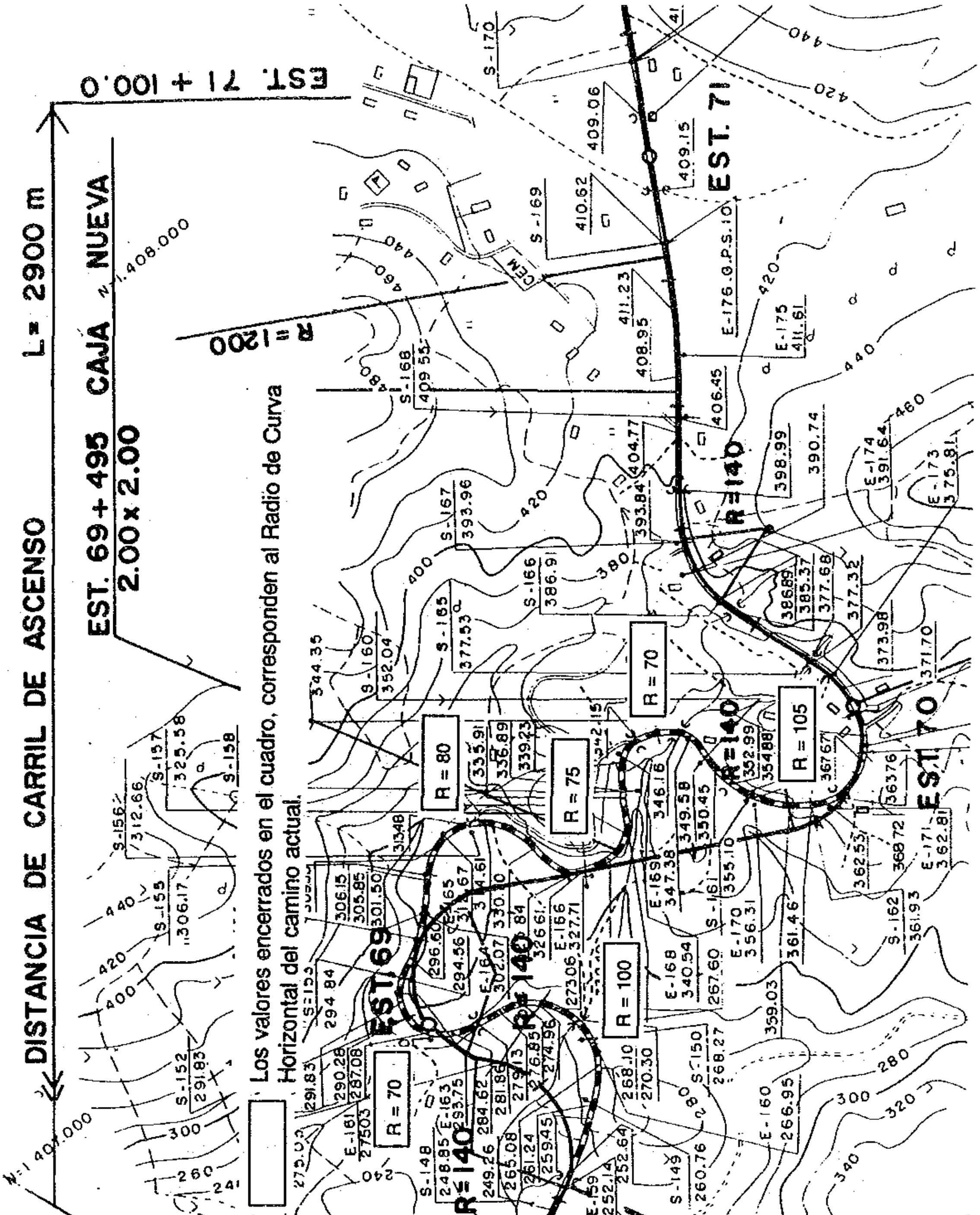


Figure 5-14 Improvement of Alignment between Est.68+200 and Est.71+100

5.2.3 Pavement Design

(1) Pavement Type

Since the Project will require a realized by reconstruction or widening of existing pavement that will only slightly disturb traffic, either flexible pavement or rigid pavement may be applied.

The general characteristics of flexible pavement and rigid pavement are compared in Table 5-10. The major considerations in selecting the pavement type for the new roads are discussed below:

a) Time Constraints

To ensure a total of 20-30 years pavement performance, the use of multistage construction, i.e. initial construction for a 15-year design life with periodic overlays to extend the performance period, is typical in the case of flexible pavement, while single-stage construction is usually used in the case of rigid pavement.

b) Construction Economy

Initial investment costs for rigid pavement are higher than whose for flexible pavement due to the difference in the design life during initial stage construction. However, flexible pavement requires future overlays and higher annual maintenance costs than does rigid pavement. Therefore, if discounted total investment costs consisting of initial construction costs and maintenance costs are compared, rigid pavement is more advantageous than flexible pavement.

c) Design Limitations in Soft Ground

Normally, rigid pavement is not adopted in soft ground and adverse surface soil areas because should structural failure is likely to occur due to the unequal settlement of embankments. As a result, this type of pavement requires costly and troublesome repairs such as the jacking-up of concrete slab, injection with bituminous pavement, etc.

Table 5-10 Comparison of the General Characteristics of Flexible Pavement and Rigid Pavement

Item	Flexible Pavement	Rigid Pavement
Design life	10 years for initial construction. Multistage construction strategy shall be applied to extend the service period with overlays.	20-30 years. Single-stage construction strategy shall be applied.
Resistance to deformation and wear	Deformation in the form of rutting.	Deformation is unlikely. Wear resistance is extremely good.
Sensitivity to overloading	More sensitive than rigid pavement.	
Noise and vibration	Less than rigid pavement.	Noise due to joints, and vibration due to rough surface sometimes cause public nuisance in residential areas.
Brightness	Surface reflection is weak and inferior.	Bright in the dark.
Surface smoothness	Better than rigid pavement, providing more comfortable riding conditions.	
Construction operation	Less construction constraints than rigid pavement.	The following constraints shall be taken into account for continuous and effective operation since the equipment fleet is generally larger than that for flexible pavement. 1) Subgrade construction is smooth and continuous during the embankment construction. 2) Fewer bridge/viaduct structures.
Maintenance	Frequent but simple maintenance is required.	Once damage occurs, rather more difficult repairs are required. Rigid pavement is less suitable for soft ground and adverse soil areas.
Construction economy	Initial stage construction costs are lower than those of rigid pavement.	Initial stage construction costs are higher than those of flexible pavement because of the longer design life. The cost of alterations/repairs are higher than for flexible pavement.

According to the results of a geological investigation (refer to Chapter 2), no soft ground areas were founded in the project area.

d) Local Material Utilization

Bituminous material for the construction of high standard pavement is always imported, and Portland cement is manufactured in Nicaragua. In view of the availability of local materials, it would be preferable to adopt rigid pavement.

e) Overloaded Vehicles

Flexible pavement is more sensitive to overloading than rigid pavement. If it is difficult to control the axle load of trucks, rigid pavement is preferable. However, strict axle load control should be implemented on the roads in any case.

f)Recommendations

Stressing lower initial investment costs, a shorter construction period, better riding conditions, and focusing on the present economic situation of Nicaragua, it is recommended that flexible pavement be used on the Project Roads, on the condition that axle load shall be strictly controlled.

(2) Asphalt Treatment Surface

Taking into account that most of Nicaraguan roads have tinny asphalt surface treatments, the following facts about asphalt surface treatments appearing in the Basic Asphalt Emulsion Manual of the Asphalt Institute of the U.S.A. (a, b, c) and the Japan Road Association (d, e, f) should be emphasized:

a) General

When an asphalt surface treatment is properly constructed, it is economical and easy to place, and will extend the life of the road surface. It will resist traffic abrasion and provide a waterproof cover over the underlying structure; however it does not constitute pavement in itself.

Although an asphalt surface treatment adds little load-carrying strength to a pavement structure, its design is not affected by traffic volume or pavement load limits and it need not consider the pavement design either.

Although surface treatment can result in an excellent surface if properly used, it cannot solve all pavement problems.

A clear understanding of the advantages and limitations of asphalt surface treatments is essential to achieve the best results. It is vital to conduct a careful study of traffic requirements, by evaluating the existing conditions of materials and pavement layers.

b) Uses

Surface treatments primarily serve the following purposes:

- To provide a low-cost, all-weather surface to accommodate light to medium traffic.
- To provide a waterproof layer to prevent the penetration of moisture into the underlying course.
- To provide a skid-resistant surface. Pavements that have become slippery as a result of the bleeding, wearing and polishing of surface aggregates may be treated with sharp, hard aggregates to restore skid resistance.
- To give new life to dry, weathered surfaces. Pavement that has become weathered due to raveling can be restored to useful service by the application of a single or multiple surface treatment layer.
- To provide a temporary cover for a new base course. Surface treatment can provide an appropriate temporary cover for a new base course that will be subject to winter, or for a course that is undergoing multi-stage construction. Basically, surface treatment provides an excellent temporary surface until the final asphalt courses can be placed.
- To salvage old pavement that has deteriorated because of age, shrinkage cracking or stress cracking. Although surface treatment provides little or no structural strength, it can serve as an adequate stop-gap measure until more permanent upgrading can be completed.

c) General Surface Treatment Defects

Generally, the following asphalt surface treatments defects may be observed:

- Intrusion of unstable materials
- Faulty compaction
- Poor aggregate grading
- Lack of drainage
- Insufficient strength for the expected traffic load

d) Traffic Conditions Considerations

Basically, asphalt treatment surfaces can be properly applied to roads with a road width of less than 5.5 m and a traffic volume of less than 150 heavy trucks per day (total for both directions).

e) Drainage Conditions Considerations

Because the water content of "asphalt-emulsions" during and after construction is of fundamental importance to the durability and service life of asphalt treatment surfaces, optimum drainage conditions should be provided for the project road.

f) Maintenance Administration

Compared with normal flexible pavement structures, asphalt treatment surfaces have a very weak structure. As a result, deformations such as cracks, potholes, etc. may easily appear within a short time. For this reason, if an asphalt treatment surface is used, the implementation of an adequate and effective maintenance administration plan should be considered in advance.

Generally, the service life of an asphalt treatment surface is approximately 10 years when optimal and very good maintenance is provided, 5 years when regular maintenance is provided, and 2 or 3 years when maintenance is deficient. The maintenance or rehabilitation costs, in the latter case, would seriously increase if no permanent pavement is set down quickly or if the asphalt surface is improperly used as a flexible pavement.

Moreover, in order to select an adequate pavement type for the Project Roads (from an economical point of view), data on costs and volume of existing asphalt treatment surfaces was collected. This survey was conducted on the construction, maintenance and rehabilitation work on asphalt treatment surfaces treatment carried out by the MCT in order to compare the "cost-performance" of asphalt treatment surfaces with that of flexible pavements.

Unfortunately, the collected data (refer to Appendix A5.3) is not available for this purpose because such data has been collected or processed without applying an appropriate method or technique to establish a Data Base for further technical or economical evaluations. Moreover, in many cases, the data is not complete, or, in the worst case does not exist.

Finally, the following aspects of asphalt treatment surfaces and their application to Project Roads were considered:

- Plans call for Project Roads to function as Troncal Principal roads, accommodating a high to middle traffic volume (i.e. TP-I roads).
- The existing asphalt surface treatments would last up until the expected opening year of the Project Roads.
- The future maintenance requirements for new asphalt surface treatment would be disadvantageous for Nicaragua's economy.

Therefore, asphalt treatment surfaces were not considered an alternative to pavement in the Study.

(3) Thickness Design of Flexible Pavement

The thickness design of flexible pavement was based on the AASHTO Guide for the Design of Pavement Structures 1986.

a) Design Variables and Conditions

The following major design variables and conditions were established for the thickness design.

① Time Constraints

For the 20 years of the analysis period, a two-stage construction was considered. The performance period for the initial stage of the flexible pavement structure was determined to be 15 years. Overlays were designed to extend the pavement life for another 5 years. The presumed opening year of the roads is 2000.

② Traffic Volume Forecast

Since there is no significant difference in the traffic volume forecast for each section, the traffic volumes shown in Table 5-11 were assumed in designing the thickness.

Table 5-11 Traffic Volume Forecast (ADT) for Pavement Design

Section	Year	Passenger Car	Micro-Bus	Large Bus	Pickup	Truck	Trailer	Total
Río Panamá-San Benito	1993	763	99	332	1,562	1,153	312	4,221
	2000	1,095	96	349	1,943	1,526	323	5,332
	2010	1,851	138	562	2,551	2,229	409	7,740
Río Panamá-San Cristobal	1993	1,101	176	370	1,622	1,121	318	4,708
	2000	2,216	219	461	2,425	1,649	379	7,349
	2010	3,104	270	657	2,844	2,227	429	9,531
Managua-Km 8	1993	11,829	636	1,142	5,579	1,628	757	21,571
	2000	16,552	623	1,189	6,771	2,093	609	27,837
	2010	27,811	878	1,906	8,880	3,007	1,034	43,516
Km 8-Entrada a Veracruz	1993	4,673	374	882	3,521	1,394	780	11,624
	2000	6,539	366	918	4,273	1,792	833	14,721
	2010	10,987	516	1,472	5,604	2,575	1,065	22,219
Entrada a Veracruz-El Coyotepe	1993	4,673	374	882	3,521	1,394	780	11,624
	2000	6,539	366	918	4,273	1,792	833	14,721
	2010	10,987	516	1,472	5,604	2,575	1,065	22,219
El Coyotepe-Masaya	1993	4,780	420	894	3,714	1,592	784	12,184
	2000	7,273	451	1,001	4,908	2,165	883	16,681
	2010	11,596	596	1,520	6,148	3,013	1,088	23,961
Masaya-Catarina	1993	1,066	81	299	826	673	390	3,335
	2000	1,504	76	305	1,044	852	412	4,193
	2010	3,046	136	548	1,646	1,403	542	7,321
Catarina-Guanacaste	1993	702	29	127	474	413	245	1,990
	2000	982	29	126	618	516	253	2,524
	2010	1,941	74	251	1,099	884	347	4,596
Guanacaste-Nandaime	1993	731	29	127	499	427	245	2,058
	2000	1,010	26	126	632	523	250	2,567
	2010	1,707	38	202	861	790	309	3,907
El Coyotepe-Río Panamá	1993	107	46	12	193	198	4	560
	2000	609	80	48	544	373	23	1,677
	2010	734	85	83	635	438	50	2,025
Telica-San Isidro	1993	59	17	50	97	51	3	277
	2000	147	19	81	267	150	34	698
	2010	262	25	130	375	241	40	1,073

③ Axle Load Model

Many trucks in Nicaragua are overloaded, exceeding the permitted maximum load of 8 tons for single-axle load and 15 tons for tandem-axle load. Such overloading greatly affects the durability of pavement. The results of the truck load survey carried out by the MCT at the Sapoa, Mateare and Chilamatillo weighing stations (1993 February) indicated that 33% of all C2 trucks (12.0 tons), 38% of all C3 trucks (15.4 tons) and 28% of all T3-S2 trucks (33.0 tons) were overloaded.

The Axle Load Model shown in Figure 5-15 was applied to calculate the Equivalent Single-Axle Load (ESAL) for pavement design based on the AASHTO Guide for the Design of Pavement Structures 1986. The results of this calculation are summarized in Table 5-12.

Table 5-12 Calculation of ESAL Applications

Section	Unit	Year			
		2000	2010	2015	2020
(a) Managua-Masaya	veh/day	27,837	43,516	43,516	43,516
	10^6ESAL	2.14	29.80	46.30	62.70
(b) Masaya-Nandaime	veh/day	2,567	3,907	3,907	3,907
	10^6ESAL	0.56	7.38	11.30	15.20
(c) Masaya-Tipitapa	veh/day	1,677	2,025	2,025	2,025
	10^6ESAL	0.25	3.13	4.74	6.34
(d) Tipitapa-San Benito	veh/day	5,332	7,740	7,740	7,740
	10^6ESAL	1.27	17.00	26.10	35.20
(e) Tipitapa-Managua	veh/day	7,349	9,531	9,531	9,531
	10^6ESAL	1.42	18.10	27.40	36.80
(f) Telica-San Isidro	veh/day	698	1,093	1,093	1,093
	10^6ESAL	0.14	1.98	3.07	4.16

④ Alignment Improvements

Taking into account the alignment improvements considered in the geometric design (refer to Section 5.2.2), a new pavement structure was designed for the following sections:

- Masaya-Nandaime :Est 0+000 - Est 15+300
- Masaya-Tipitapa :Est 19+500 - Est 21+925

⑤ Roadbed Soil Characteristics and Design Sections

As described in the preceding section, the length of the cutting sections is limited when constructing roads. Pavement structures will have to be constructed on embankments over longer stretches.

No.	Vehicle	Axle Load Model (ton)
1	Passenger Cars	1 1
2	Microbus	1 1
3	Bus	4 8
4	Pick Up	1 1
5	Truck	4.5 9
6	Trailer	5 16 16

Figure 5-15 Axle Load Model

Managua-Masaya Road:

The embankment and subgrade materials will be obtained from borrow pits located in San Luis (km 1+050 on the Masaya-Tipitapa Road), except for the stretch in the hilly areas near the El Arroyo Bridge (km 8+100 - km 8+490), km 17+950, and the El Coyotepe intersection (km 21+950 - km 22+630) which have cutting sections. In the latter cases, the embankment materials will be obtained from road excavation sites and nearby borrow pits in the hilly areas.

The embankment and subgrade materials obtained from the borrow pits of San Luis north of the El Coyotepe intersection are composed of a sandy material (A-2-3[0]) with a CBR ranging from 27 to 40. Taking into account the above embankment material conditions, the thickness design was prepared assuming a design CBR of 20% of the subgrade existing material, (obtained from the average of CBR test results carried out by the MCT in 1992), that is almost uniform in each section.

Other Road Sections:

For the Masaya-Nandaime, Masaya-Tipitapa, Tipitapa-San Benito and Río Panamá-San Cristobal Roads, the embankment and subgrade materials will be obtained from the borrow pit located in San Luis (km 1+050 on the Masaya-Tipitapa Road), while for the Telica-San Isidro Road these materials will be obtained from the borrow pit located in San Jacinto (km 14+700 on the Telica-San Isidro Road).

The embankment and subgrade materials obtained from the borrow pits of San Jacinto located between Telica and La Cruz de La India are composed of a sandy material (A-1-a[0], A-1-b[0]) with a CBR ranging from 28 to 37.

Taking into account the above embankment material conditions, the thickness design was prepared assuming that the design CBRs of Table 5-13, which are based on the CBR test results (Refer to Chapter 2), are almost uniform in each section. Design CBRs for the design sections were calculated based on the Japanese design method. Special design cases were considered for some low CBR values (Refer to Appendix A5.2).

Table 5-13 Design CBR for Pavement Design

Project Road	Design Section	Design CBR (%)
Masaya - Nandaime	0+000 - 15+300	25
	15+300 - 27+200	12
Masaya - Tipitapa	0+000 - 21+925	13
Tipitapa - San Benito	0+000 - 16+000	20
Tipitapa - Managua	0+000 - 4+300	36
Telica - San Isidro	0+000 - 16+800	54
	16+800 - 30+400	34
	30+400 - 32+500	40
	32+500 - 41+800	31
	41+800 - 56+400	25
	56+400 - 92+500	14
	92+500 - 95+760	37

b) Thickness Design Results

The thickness design results are summarized as shown in Table 5-14 (details are shown in Appendix A-5.2). Sub-base is omitted for sections where the design CBR is over 20%, since the material quality is considered to be good or the design traffic volume is believed to be low.

Table 5-14 Results of Thickness Design

Design Section	Existing Pavement	Subgrade CBR (%)	New Pavement Thickness (cm)			
			Wearing Course		Base Course	Overlay (after
			Surface	Binder	(CBR>80%)	15 years)
Managua-Masaya Road 00+000-25+900	Asphalt Concrete	20	5	10	30	5
Masaya-Nandaime Road 00+000-15+300	Asphalt Concrete	25	5	10	15	5
15+300-27+200	A. Double Treatment	12	5	10	20	5
Masaya-Tipitapa Road 00+000-21+925	Asphalt Treatment	13	5	7	20	6
Tipitapa-San Benito Road 00+000-16+000	A. Double Treatment	20	5	10	25	5
Tipitapa-Managua Road 00+000-04+300	Asphalt Concrete	36	5	10	25	5
Telica-San Ishidro Road 00+000-16+800	Asphalt Treatment	54	5	5	15	5
16+800-30+400	Asphalt Treatment	34	5	5	20	5
30+400-32+500	Asphalt Treatment	40	5	5	20	5
32+500-41+800	Asphalt Treatment	31	5	5	20	5
41+800-56+400	Asphalt Treatment	25	5	5	25	6
56+400-92+500	Asphalt Treatment	14	5	5	25	6
92+500-95+760	Asphalt Treatment	37	5	5	20	5

(4) Shoulder Design

Shoulders were designed based on the Japanese standards. Figure 5-16 shows a detail of the shoulder pavement and its geometric design.

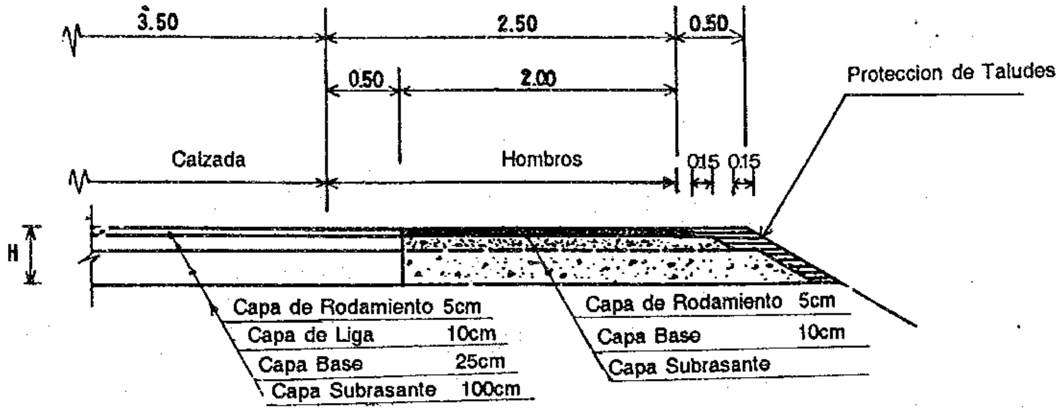


Figure 5-16 Shoulder Design

(5) Recommendations

Taking into account the results obtained from an investigation of existing conditions and the flexible pavement design, the following recommendations can be made.

a) Subgrade

Since embankment settlements and depressions were observed during an investigation of existing conditions (refer to Chapters 3 and 6), the subgrade for the newly designed pavement structure should be improved in the following sections:

- Tipitapa-San Benito :Est 2+000 - Est 3+100
- Telica-San Isidro :Est 30+400 - Est 32+500
  :Est 45+000 - Est 46+700
  :Est 89+900 - Est 95+750

Therefore, in order to stabilize the above subgrade courses, the roadbed material should be replaced by a properly selected material, and should be compacted to 90 percent of the maximum laboratory density (or higher), based on AASHTO Test T180, Method D or the equivalent. However, it is recommended that a detailed soil investigation be conducted on these sections to ensure even greater improvement.

b) Sub-base Course

Since most of the roadbed soil in the designed sections is considered to be of good quality, a sub-base course can be omitted for the respective pavement structures. However, in order to assure a good performance by the new pavement, a layer of compacted (untreated) soil should be provided instead of a sub-base course (CBR>20) for each section of the project, and especially for the sections mentioned in a). If a high embankment is required, this layer should be extended to a thickness of t=100 cm.

This untreated aggregate course should be compacted to 95 % of the maximum laboratory density (or higher) based on AASHTO Test T180, Method D or the equivalent. Moreover, in order to prevent the accumulation of free water within or below the pavement structure in wet areas, the fraction passing the No.8 sieve should be reduced to a very small percent (about 5 to 10%, t=40 cm).

c) Base Course

Untreated graded aggregate consisting of crushed stones from quarries (Cosmapa quarry, 6 km SW of Chinandega for the Telica-San Isidro Road, and Veracruz quarry for the other sections) that have been mechanically stabilized should be used as the base course (CBR>80).

Although no specific quality requirements for base courses are given, the specifications included in AASHTO's Manual for Highway Construction, ASTM Specification D2940, or Japan International Standards (JIS) (M-40 aggregate) can be used.

The untreated aggregate base shall be compacted to 95 % of the maximum laboratory density (or higher), based on AASHTO Test T180, Method D or the equivalent.

d) Flexible Course

The specifications included in ASTM Specification D3515, or the Japan International Standards (JIS) related to quality control of materials and construction methods for flexible courses will be used.

e) Removing the Earthworks of Existing Pavement

Any material that remains after the removal of existing pavement and base courses could be used as embankment or subgrade material, but never as a new base or sub-base course material.

5.2.4 Drainage Design

(1) General

Existing roads on the proposed routes have insufficient drainage. Drainage facilities maintenance work has not yet been conducted. Therefore, such structures are inadequate for discharging rainfall into daylight from carriageways. As a result, substantial improvement of the existing drainage structures for the project roads is required.

In order to maintain the road in good condition in all-weather, the drainage structure is one of the most important factors of the road design.

Data, which is related to precipitation and used to elaborate the rainfall intensity duration curve was obtained from the Hydrology Department of INETER.

There are three observation stations on the objective roads, i.e. A. C. Sandíno, Nandaime and Estelí, and data from those stations is applied to the study routes and divided into the following three groups.

Table 5-15 Division of Rainfall Data for Project Roads

Station	Project Road	NIC No.
A. C. Sandíno	Managua-Masaya Road Masaya-Tipitapa Road Tipitapa-San Benito Road	No.1 and No.4
Nandaime	Masaya-Nandaime Road	No.4 and No.11
Estelí	Telica-San Isidro Road	No.26

For application of the Rainfall Intensity Duration Curve, refer to Figures 2-25 to 2-27 in Section 2.5 "Hydrological Considerations".

(2) Discharge Calculation

Discharge corresponding to each drainage area was calculated by using the Rational Formula, which is as follows

$$Q = \frac{1}{(3.6 \times 10^{-6})} \times C \times I \times A$$

where;

Q : Runoff Maximum Discharge of the watershed (m^3/sec)
C : Runoff Coefficient (0.5)
I : Rainfall Intensity (mm/h)
A : Catchment Area (m^2)

A runoff coefficient is determined for each different soil surface corresponding to the rainfall intensity and topographical characteristics of the drainage area.

In the Study, a runoff value of C = 0.5 was taken as an average. The general values of C were decided according to the ground topography. These values are shown in the following table.

Table 5-16 Runoff Coefficient

Topography	C Values
Steep, arid lands, and impermeable surfaces	0.7 - 0.9
Steep forests and meadows	0.4 - 0.7
Forest lands with moderate to steep slopes	0.2 - 0.4
Flat pervious surfaces	0.1 - 0.2

The rainfall intensity was determined based on a Intensity Duration Curve prepared for a frequency of 20 years. It was applied to pipe culverts and culvert boxes. For bridges, the frequency was calculated for 50 years.

In order to calculate the concentration time, the correction values shown in Figure 5-17 and the following equations were used:

Average Velocity of the flow in the drainage area is:

$$V = 72\ (H/L)^{0.6}$$

where;

V : Average Flow Velocity (Km/h)
L : Longest Overland Flow Distance (Km)
H : Difference of elevation between the highest flow point to the discharge point for L(m).

Concentration Time

$$T = (L/V) \times 60$$

where;
T : Concentration Time (min.)

The Correction Value (K), multiplies the rainfall intensity based on the T value obtained in advance.

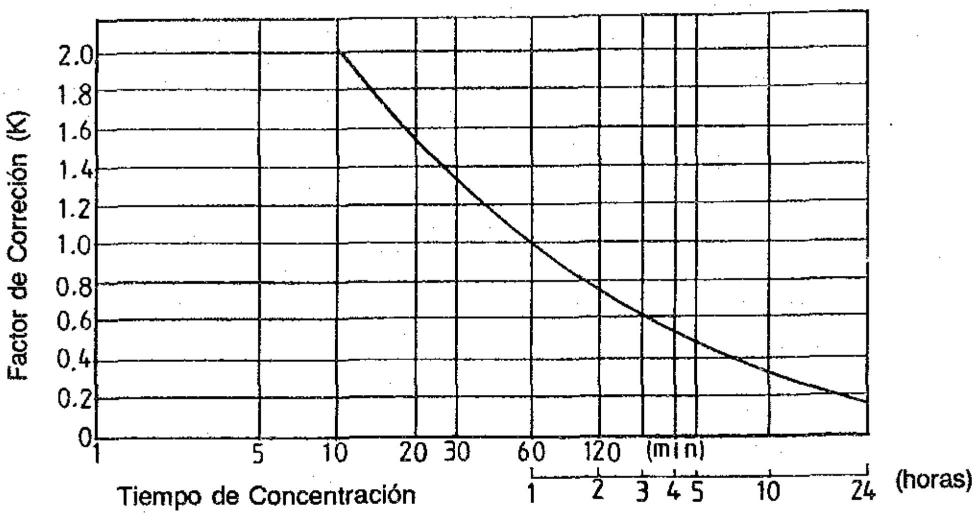


Figure 5-17 Correction Factor for Rainfall Intensity

The maximum discharges on each existing bridge/culvert along the project road are shown in Table 5-17.

Table 5-17 Rainfall Discharges (1)

Managua-Masaya Road

Location	Catchment Area (km²)	Length of Flow (km)	Difference of Elevation (m)	Coefficient C	Time of Concentration (hr)	Rainfall Intensity (mm/hr)	Maximum Run Off (m³/sec)	Remarks
La Morita Bridge at Sta.0+490	23.0	15.0	300	0.5	2.18	42.87	136.9	Existing bridge
Bridge at Sta.2+250	10.0	10.5	400	0.5	1.04	93.97	130.5	Existing bridge
El Arroyo Bridge at Sta.8+170	10.4	22.0	690	0.5	2.44	38.60	557.6	Existing bridge
At Sta.9+350	10.0	8.5	110	0.5	1.60	61.50	85.4	Existing culvert
At Sta.10+630	8.0	7.0	85	0.5	1.37	69.70	77.4	Existing culvert

Masaya-Catarina-Nandaime Section

Location	Catchment Area (km²)	Length of Flow (km)	Difference of Elevation (m)	Coefficient C	Time of Concentration (hr)	Rainfall Intensity (mm/hr)	Maximum Run Off (m³/sec)	Remarks
Mayari Bridge at Sta.58+960	35.0	11.5	280	0.5	1.48	60.01	291.7	Existing bridge
El Arroyo No. 2 Bridge at Sta.61+380	20.0	12.5	190	0.5	2.14	32.00	88.9	Existing bridge
El Arroyo No. 1 Bridge at Sta.62+750	98.0	23.0	470	0.5	3.30	28.91	393.5	Existing bridge

El Coyotepe-Río Panamá Section

Location	Catchment Area (km²)	Length of Flow (km)	Difference of Elevation (m)	Coefficient C	Time of Concentration (hr)	Rainfall Intensity (mm/hr)	Maximum Run Off (m³/sec)	Remarks
At Sta.12+370	6.0	5.0	70	0.5	0.90	125.00	104.2	Existing box culvert 2-3.0×3.0

Río Panamá-San Benito Section

Location	Catchment Area (km²)	Length of Flow (km)	Difference of Elevation (m)	Coefficient C	Time of Concentration (hr)	Rainfall Intensity (mm/hr)	Maximum Run Off (m³/sec)	Remarks
At Sta.7+000	16.0	7.5	28	0.5	2.98	29.76	66.1	Existing box culvert 2-3.7×3.0

Managua-Tipitapa Road

Location	Catchment Area (km²)	Length of Flow (km)	Difference of Elevation (m)	Coefficient C	Time of Concentration (hr)	Rainfall Intensity (mm/hr)	Maximum Run Off (m³/sec)	Remarks
At Sta.0+550	27.0	9.0	60	0.5	3.56	22.42	84.1	Existing box culvert 1-3.7×3.0

Table 5-17 Rainfall Discharges (2)

Terica-San Isidro Road

Location	Catchment Area (km²)	Length of Flow (km)	Difference of Elevation (m)	Coeffi-cient C	Time of Concent-ration (hr)	Rainfall Intensity (mm/hr)	Maximum Run Off (m³/sec)	Remarks
Bridge at Sta.2+970	14.0	9.5	580	0.5	0.71	99.98	194.2	Existing bridge
Bridge at Sta.1+750	8.5	5.0	291	0.5	0.53	140.77	166.2	Existing bridge
Bridge at Sta.20+520	6.0	7.0	592.5	0.5	0.42	172.80	144.0	Existing bridge
Santa Amalia Bridge at Sta.23+200	13.0	12.0	420	0.5	1.24	61.23	110.6	Existing bridge
Bridge at Sta.33+860	7.0	5.5	125	0.5	0.83	85.56	83.2	Existing bridge
Negarote Bridge at Sta.43+050	230.0	26.0	300	0.5	5.25	11.65	369.0	Existing bridge
Bridge at Sta.45+970	49.0	10.0	205	0.5	1.43	51.83	352.7	Existing bridge
Bridge at Sta.54+480	15.0	8.0	570	0.5	0.54	141.96	285.7	Existing bridge
El Arenal Bridge at Sta.61+430	427.0	43.0	1,120	0.5	5.33	11.45	678.3	Existing bridge
Los Cabros Bridge at Sta. 68+180	7.0	10.0	500	0.5	0.84	91.06	88.5	Existing bridge
Bridge at Sta.86+810	66.0	18.0	780	0.5	1.64	47.49	435.3	Existing bridge
Bridge at Sta.94+205	76.0	22.0	820	0.5	2.20	32.63	344.6	Existing bridge

(3) Hydraulic Calculations

The flow capacity of culverts and culvert boxes was calculated by applying the Manning Formula, which is as follows:

$$Q = A \times V$$

$$V = 1/n\ R^{2/3}\ S^{1/2}$$

where;

- Q : Flow capacity of the culvert or channel (m³/sec)
- A : Area of the cross section of the channel (m²)
- V : Average velocity (m/sec)
- n : Coefficient of roughness of Manning 0.02 for culvert boxes, 0.05 for bridge sites
- R : Hydraulic Radius (m)
- S : Slope of the Hydraulic Gradient

(4) Drainage Structures

Any drainage structure to be constructed along the project roads should be designed according to the discharge capacity on the basis of the present runoff.

Economical drainage structures can be selected for sites where the flow is moderate. This does not include sites selected for bridge construction.

a) Pipe Culverts

Considering the proposed widening of the Managua-Masaya Road and given the need for easy maintenance of the drainage structures, the Study planned the replacement of the existing corrugated steel pipes with 42" diameter concrete pipes.

The standard culvert design is shown in drawing No.69

For flat lands, the location of construction sites for new culverts is determined along the following interval of lateral drainage.

Table 5-18 Standard Interval of Pipe Culverts in Flat Areas

Condition	Interval (m)
Grass and flood areas	200
Others	500

In mountainous as well as in hilly areas, culverts are located at the selected sag points based on the results of topographical surveys.

For the improvement sections, existing steel culverts are in suitable condition. However, their interiors and in their intake and outflow/intake aprons are filled with sadiment. Therefore, such structures must be cleaned.

It will be necessary to provide the side ditches along the road with riprap aprons to prevent sedimentation and scouring of the aprons.

b) Box Culverts

For the Managua-Masaya Road, new box culverts will be necessary because the traffic lanes will be widened.

In the Study, various types of concrete box culverts with a head wall and aprons were used. The box culverts comply with the MCT standards established for this kind of facility in Nicaragua. In the case of great flow volumes, double-cell box culverts will be necessary.

The locations and types of culvert boxes were determined by comparing the discharge with the flow capacity as shown in Table 5-19. A standard box culvert is shown in Drawing No.10

(5) Other Drainage Structures

The failure of earthwork structures (landslides) is usually caused by rainfall on the slope and the infiltration of water into the ground. Drainage structures are planned to avoid landslides in the cutting sections and to secure the works. The following drainage structures are planned in the Study:

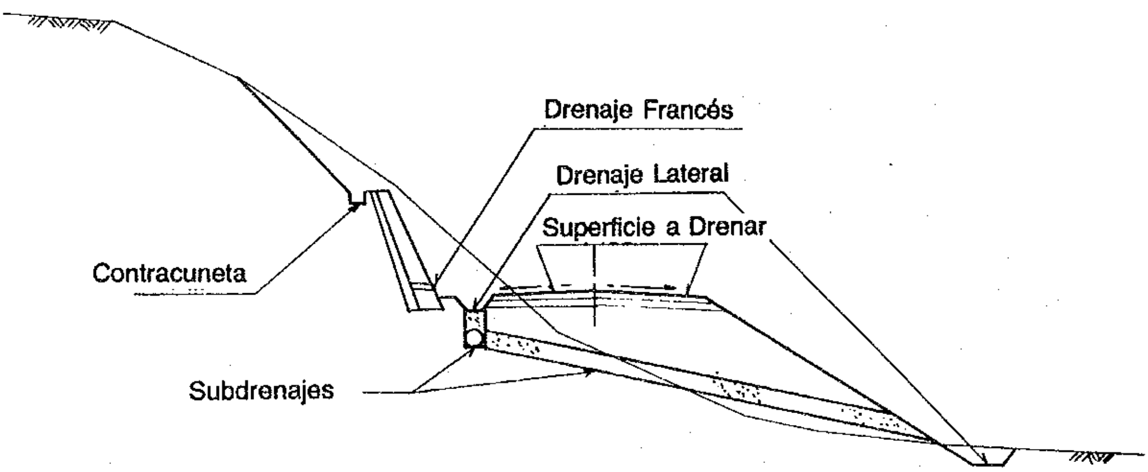


Figure 5-18 Road Drainage Structure

Table 5-19 Hydraulic Calculations (1)

Managua-Masaya Road

Location	Channel Section Height and Width (m)	Channel Area (m^2)	Hydraulic Gradient (%)	Coefficient n	Average Velocity (m/sec)	Discharge Capacity (m^3)	Maximum Runoff (m^3/sec)	Remarks
La Morita Bridge at Sta.0+490	3.0 × 7.0	16.8	2.0	0.02	8.94	150.40	136.9	Bridge reconstruction
Bridge at Sta.2+250	2 - 3.5 × 3.5	19.6	2.0	0.02	7.43	145.60	130.5	New box culvert
El Arroyo Bridge at Sta.8+170	8.0 × 17.0	108.8	1.5	0.05	5.81	623.20	557.6	Bridge reconstruction
At Sta.9+350	2-3.0 × 3.0	14.4	1.6	0.02	5.99	86.30	85.4	New box culvert
At Sta.10+630	2 - 2.5 × 2.5	10.0	3.5	0.02	7.85	78.50	77.4	New box culvert

Masaya-Catarina-Nandaime Section

Location	Channel Section Height and Width (m)	Channel Area (m^2)	Hydraulic Gradient (%)	Coefficient n	Average Velocity (m/sec)	Discharge Capacity (m^3)	Maximum Runoff (m^3/sec)	Remarks
Mayari Bridge at Sta.58+960	5.0 × 15	60.0	1.7	0.05	4.94	296.60	291.7	Existing bridge
El Arroyo No. 2 Bridge at Sta.61+380	2.5 × 9.0	18.0	4.5	0.05	5.27	94.90	88.9	Existing bridge
El Arroyo No. 1 Bridge at Sta.62+750	3.5 × 23.0	73.6	2.2	0.05	5.52	402.70	393.0	Bridge reconstruction

El Coyotepe-Río Panamá Section

Location	Channel Section Height and Width (m)	Channel Area (m^2)	Hydraulic Gradient (%)	Coefficient n	Average Velocity (m/sec)	Discharge Capacity (m^3)	Maximum Runoff (m^3/sec)	Remarks
At Sta.12+370	2 - 3.0 × 3.0	14.4	2.5	0.02	7.49	107.90	104.2	Existing box culvert 2-3.0×3.0

Río Panamá-San Benito Section

Location	Channel Section Height and Width (m)	Channel Area (m^2)	Hydraulic Gradient (%)	Coefficient n	Average Velocity (m/sec)	Discharge Capacity (m^3)	Maximum Runoff (m^3/sec)	Remarks
At Sta.7+000	2 - 3.7 × 3.7	15.4	3.0	0.02	5.48	84.40	66.1	Existing box culvert Corrugated metal culvert 2-3.7×3.0

Table 5-19 Hydraulic Calculations (2)

Managua-Tipitapa Road

Location	Channel Section Height and Width (m)	Area (m^2)	Hydraulic Gradient (%)	Coefficient n	Average Velocity (m/sec)	Discharge Capacity (m^3)	Maximum Runoff (m^3/sec)	Remarks
At Sta.0+550	2 - 3.0 × 3.0	14.4	1.6	0.02	5.99	86.30	84.1	New box culvert

Telica-San Isidro Road

Location	Channel Section Height and Width (m)	Area (m^2)	Hydraulic Gradient (%)	Coefficient n	Average Velocity (m/sec)	Discharge Capacity (m^3)	Maximum Runoff (m^3/sec)	Remarks
Bridge at Sta.2+970	8.0 × 4.5	28.8	5.0	0.05	6.84	197.30	194.2	Existing bridge
Bridge at Sta.1+750	9.0 × 4.5	32.4	3.0	0.05	5.50	178.20	166.2	Existing bridge
Bridge at Sta.20+520	8.0 × 4.0	25.6	4.5	0.05	6.22	159.40	144.0	Existing bridge
Santa Amalia Bridge at Sta.23+200	15.0 × 4.0	48.0	2.6	0.05	5.42	260.20	255.0	Existing bridge
At Sta.24+830	3 - 3.0 × 1.85	13.3	4.0	0.02	9.43	125.80	110.6	Existing triple box culvert
Bridge at Sta.33+860	2 - 3.0 × 2.5	12.0	3.0	0.02	7.81	93.80	83.2	Existing bridge
Negarote Bridge at Sta.43+050	28.0 × 3.5	78.4	2.0	0.05	4.98	390.20	369.0	Existing bridge
Bridge at Sta.45+970	17.0 × 5.0	68.0	2.5	0.05	6.10	419.10	352.7	Existing bridge
Bridge at Sta.54+480	16.6 × 3.5	46.2	4.0	0.05	6.54	302.20	295.7	Existing bridge
El Arenal Bridge at Sta.61+430	50.0 × 4.5	180.0	1.0	0.05	4.29	773.40	678.3	Existing bridge
Los Cabros Bridge at Sta. 68+180	9.5 × 4.0	30.4	1.5	0.05	3.77	470.20	435.3	Existing bridge
Bridge at Sta.86+810	23.0 × 4.0	73.6	3.0	0.05	6.39	470.20	435.3	Existing bridge
Bridge at Sta.94+205	16.0 × 4.0	51.2	4.0	0.05	6.94	355.60	344.6	Existing bridge

a) Side Ditches

The channels of side ditches collect water discharged from road surface cuttings, as well as seepage to prevent erosion from scouring the cuttings.

Road side ditches are also constructed to prevent infiltration into the base and subgrade, thereby maintaining good pavement conditions.

b) Ditches on the Berm

Ditches are also constructed in the slope to prevent the failure of slopes or cuttings, as well as avoid seepage into the lower slopes.

c) Subdrainage

When an embankment is constructed in a swampy area or on soft foundation ground, sub-drainage structures such as sand filters are required in cases where the ground water level is high.

Depressions and settlement of the road surface base, sub-base and sub-grades are caused by the drying out of water in the soil, the reduction of the bearing bower of the soil due to a weakening of the shearing strength caused by soil pressure.

d) Drainage from the Backfill of Structures

The accumulation of ground water and other infiltration water behind retaining walls might endanger the safety of such structures. Therefore, these structures should be provided with drainholes.

5.2.5 Bridge Design

(1) General

Existing bridges can be classified as concrete slab, cast-in-place T beam, and composite steel girder bridges with widths ranging from 7.0 m to 9.5 m for their superstructures. Most existing bridges have a rubble masonry structure with abutments. Some of them have a concrete substructure. In general, the existing bridges on the Project Roads are in good condition.

Nevertheless, these bridges must be replaced and reconstructed due to road widening and a desire for improvements aimed at dealing the future traffic volume increases. There are three bridges on the existing Managua-Masaya Road, i.e. STA 0+490 La Morita Bridge, 2+250 and 8+170 El Arroyo Bridge.

Moreover, El Arroyo No. 1 Bridge, on the Guanacaste-Nandaime Section must be reconstructed because the river bed of the bridge has been scoured. In this respect, the MCT had already taken measures to reinforce the existing bridge. The location of the bridge is inappropriate for dealing with the present conditions of the intersection of El Arroyo River and Agua Agria River. Therefore, a new bridge will be constructed upstream of the existing bridge, as shown in the drawings.

(2) Bridge Width

The bridge will be as wide as the approach roadway section including shoulders and sidewalks. The standard bridge width is indicated in the drawings.

(3) Load

The bridges to be reconstructed must have a design load of HS-20, and will therefore be replaced by permanent concrete bridges or concrete box culverts. The HS loadings will be strong enough to bear the load of a tractor trailer or the corresponding lane load.

(4) Earthquakes

The anticipation for earthquakes in large scale might not be cleared due to the following two reasons: ① The area including Managua itself is on the most unstable fault line between the Western and Eastern parts of Nicaragua, which means that large-scale earthquakes are likely in the future, and ② There were two record large-scale earthquakes in Managua in 1931 and 1972. The 1972 earthquake measured 5.6 on the Richter scale and had a surface-wave magnitude of 6.2.

Hence, the structures are to be designed must consider the locations of assumed active faults, the seismic response of the soil at the site and the dynamic response characteristics of the total structure.

(5) Substructures

a) Sub-soil Conditions

Drilling observations based on the sub-soil geological survey and the soil penetration test are described in Section 2.4, Geological and Soil Mechanical Investigation. At the study sites, outcrops or near-surface bedrock layers were observed. Therefore, sufficient soil bearing capacity near the ground can be obtained.

b) Types of Foundations

It was found that the combined footings and spread with wall were commonly used as part of the foundation design, and are suitable for the sub-soil conditions. The abutment height has to be determined based on the soil profile below the foundation and the boring logs. A typical section is shown in Figure 5-19.

c) Design Conditions

The reinforced concrete structure for abutment which conforms to the AASHTO "Standard Specification for Highway Bridges" is to be designed taking into consideration the following design conditions:

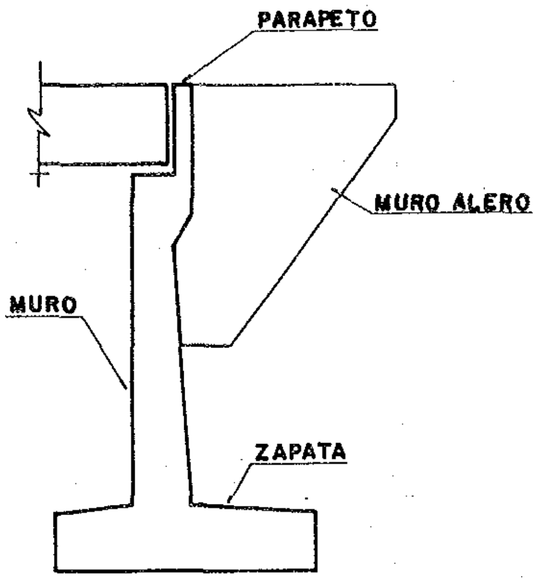


Figure 5-19 Typical Abutment Section

- Type of foundations : Spread foundations
- Materials :
  - Concrete : Specified design compression strength at 28 days (f'c) 210 kg/cm² (3,000 psi)
  - Reinforcing bars : Yield strength, fy in excess of 4,200 kg/cm² (60,000 psi)

The applied design is based on the "Service Load Design Method" (Allowable stress design)

Concrete stress in concrete shall conform the followings:

- Extreme fiber stress in compression is 0.4 f'c
- Bearing stress is 0.3 f'c
- Shear stress is 0.95 f'c

The reinforcement tensible stress shall conform the followings:

- Grade 40 reinforcement is 1,400 kg/cm² (20,000 psi)
- Grade 60 reinforcement is 1,600 kg/cm² (24,000 psi)

d) Wing Wall

Wing walls should be long enough to retain the roadway embankment to the required extent and to furnish protection against erosion. The wing wall length will be computed using the required roadway slopes.

e) Drainage

The filling material behind abutments should be drained via weep holes with french drains placed at suitable intervals.

f) Mortar Rubble Masonry

Where scouring is likely to occur, protection against damage from scouring should be provided in the design of bridge abutments. Embankment slopes and river beds adjacent to structures subject to erosion should be adequately protected by rip-rap or mortar rubble masonry. The masonry should be laid in a line and along a course roughly leveled up for decrease of flow velocity. The location is shown in the drawings.

(6) Superstructures

① The length of bridges will be determined through a hydrologic analysis of the discharge and a hydraulic analysis of the flow capacity, as described in Section 5.2.4, Drainage Design.

② Nicaraguan standard design superstructures are usually either reinforced concrete slab cast-in-place T-beam or composite girders. Table 5-20 shows the results of the comparison study of various types of superstructures, relative span length based on their own structural characteristics, and an economic assessment of construction costs. In addition, the following matters should be considered:

- Materials to be used are locally available
- Budget plan
- Experience with the method of construction and maintenance in Nicaragua
- The use of innovative construction method

Table 5-20 Standard Span of Bridges and Estimated Approximate Costs

Type	Span Length							Unit Cost (C$/m)
		20 m			50 m			
Concrete Bridges								
RC Slab	═							20,000 - 30,000
RC T-Beam	═	═						17,000 - 25,000
PC Hollow Slab		═	═					23,000 - 30,000
PC Composite Girder			═	═				28,000 - 45,000
Steel Bridge								
Simple Composite		═	═					30,000 - 40,000
Continuous I Sharp Girder			═	═	═			35,000 - 55,000
Simple Box Girder				═	═	═		50,000 - 80,000

Notes - RC: Reinforced Concrete
PC: Prestressed Concrete

c) Types of Superstructures

As shown in Table 5-21, the major types of superstructures and applicable relative span lengths are as follows:

Table 5-21 Major Types of Superstructure

Types of Superstructure	Applicable Span length (m)	Remarks
Reinforced Concrete Slab (RC-Slab)	5 - 10	Slab thickness 30-47 cm
Simple Composite Beam	18 - 30	Beam height 76-91 cm
Prestressed Concrete Girder (PC-Girder)	20 - 35	I-shaped

Both RC-Slab and Simple Composite Beams are suitable for short bridges which shows no salient difference in construction costs per unit length. Many such bridges have already been constructed in Nicaragua. On the other hand, PC-Girders are most appropriate for longer bridges.

Hence, the following three types of bridges were applied in the Study.

① STA 0+480 La Morita Bridge : Reinforced Concrete Slab bridge, L = 7.77m

② STA 8+170 El Arroyo Bridge : Composite Beam bridge, L = 20.00m

③ El Arroyo No.1 Bridge in Nandaime : Prestressed Concrete Girder, L = 24.40m

The typical superstructure sections of these bridges are shown in Figures 5-20 to 5-22.

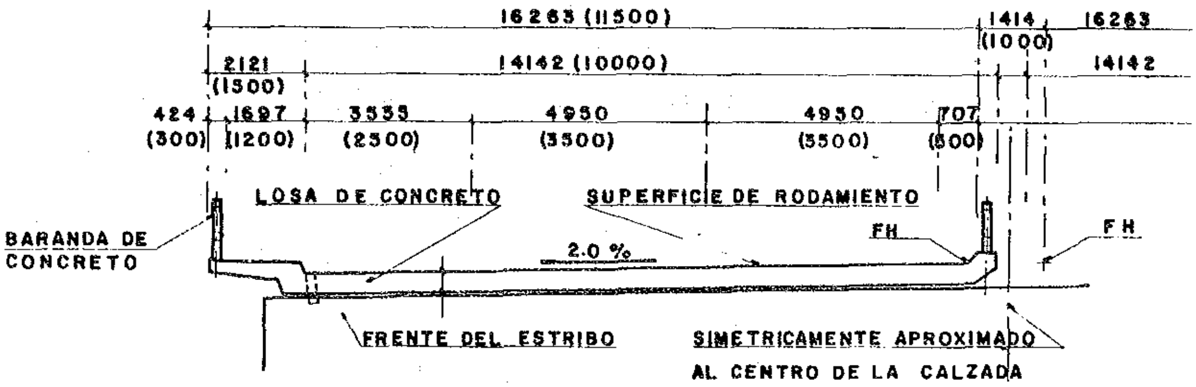


Figure 5-20 Typical Superstructure Section of La Morita Bridge, RC-Slab

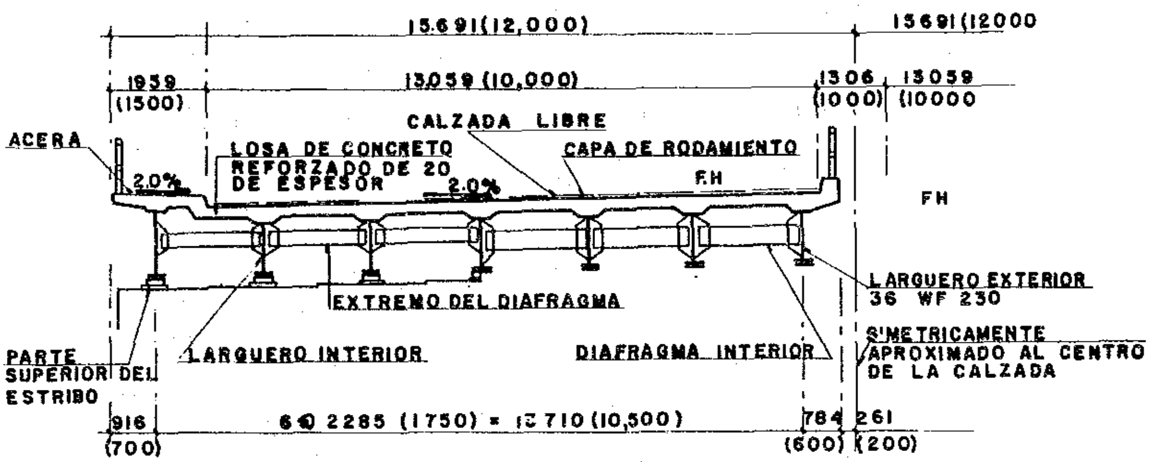


Figure 5-21 Typical Superstructure Section of El Arroyo Bridge, Composite Beam

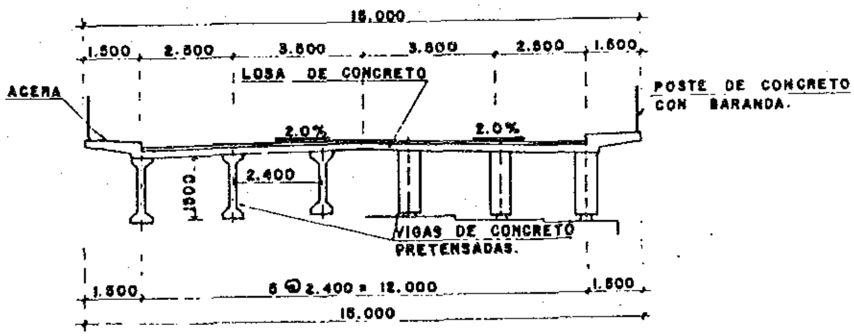


Figure 5-22 Typical Superstructure Section of El Arroyo No.1 Bridge, PC Girder

d) Design Conditions

Each type of bridge superstructure conforming to the AASHTO "Standard Specification for Highway Bridges" is to be designed under the following conditions:

① Type of Superstructure

- Reinforced Concrete Slab (RC-Slab)
- Composite Beam
- Prestressed Concrete Girder

② Materials

- Concrete : Specified design compression strength at 28 days $f'c$
  - RC Slab and Composite Beam are each 280 kg/cm^2 (4,000 psi)
  - Prestressed Concrete Girder is 400 kg/cm^2 (5,700 psi)
- Reinforcing bars : Yield strength, fy in excess of 4,200 kg/cm^2 (60,000 psi)
- Structural Steel : As shown in Table 5-22

Table 5-22 Structural Steel

Minimum Material Properties, Structural Steel (kg/cm^2)					
Type	**Structural *Steel***	***High-Strength Low-Alloy Steel***		***High Yield Strength, Quenched and Tempered Alloy Steel***	
AASHTO Designation	M 183	M 223	M 222	M 244	
Equivalent ASTM Designation	A 36	A 572 Grade 50	A 588	A 514	A 517
Minimum Tensile Strength	4,000 *(58,000)*	4,600 *(65,000)*	4,900 *(70,000)*	7,700 *(110,000)*	7,000 *(100,000)*
Minimum Yield Point or Minimum Yield Strength	2,500 (36,000)	3,500 (50,000)	3,500 (50,000)	7,000 (100,000)	6,300 (90,000)
Pins, Rollers, and Rockers					
AASHTO Designation with Size Limitations	M 16 4" in dia. or less	M 102 To 20" in dia.	M 102 To 20" in dia.	M 102 To 10" in dia.	M 102 To 20" in dia.
ASTM Designation Grade or Class	A 108 Grades 1016	A 668	A 668	A 668	A 668
Minimum Yield Point, psi	2,530 (36,000)	2,300 (33,000)	2,600 (37,500)	3500 (50,000)	3,500 (50,000)

Note : kg/cm^2, ( ) are in pounds per square inch.

③ Prestressed Reinforcement

Prestressed reinforcement shall consists of a high-strength steel wire, a high-strength seven-wire strand, or high-strength alloy bars as required by the plans or by the special provisions. The high-strength steel wire shall conform to AASHTO M 204 (ASTM A 421). The high-strength seven-wire strand shall conform to the requirements of AASHTO M 203 (ASTM A 416). The high-strength alloy bars shall conform to the requirements of AASHTO M 275 (ASTM A 722). Bars with a greater minimum ultimate strength, but otherwise produced and tested in accordance with AASHTO M 275 (ASTM A 722), may be used provided they have no properties that make them less satisfactory than the specified material.

e) Design for Allowable Stress

① Concrete : Reinforced Concrete Slab

- Extreme fiber stress in compression : 0.40 f'c
- Extreme fiber stress in tension for plain concrete : 0.21 f'c
- Bearing stress at service load : 0.95 √f'c

② Prestressed concrete

- Temporary stress before losses due to creep and shrinkage : 0.55 √f'c
- Stress at service load after losses : 0.40 f'c
- Bearing stress at service load : 0.45 f'c

③ Reinforcing Steels Bars Allowable

- Stress as shown in Table 5-23.

④ Structural Steel and High-Strength Bolts

- Allowable stress as shown in Table 5-24.

⑤ Prestressed Steel

- Temporary stress before losses due to creep and shrinkage : 0.70 f'c
- Stress at service load after losses : 0.80 fy

Table 5-23 Allowable Stresses of Reinforcing Steel Bars

Type	Structural Steel	High-Strength Low-Alloy Steel		High Yield Strength, Quenched and Tempered Alloy Steel	
AASHTO Designation with Size Limitations	M169	M102	M102	M102	M102
ASTM Designation Grade or Class	A108 Grades 1016 1030 incl.	A668 Class C	A668 Class D	A668 Class F	A668 Class G
Stress in Extreme Fiber, kg/cm²	2,000 (29,000)	1,800 (26,000)	2,100 (30,000)	2,600 (40,000)	2,600 (40,000)
Shear, kg/cm²	1,000 (14,000)	900 (13,000)	1,050 (15,000)	1,400 (20,000)	1,400 (20,000)

Note : kg/cm², ( ) are in pounds per square inch.

Table 5-24 Allowable Stresses-of Structural Steel

Type	Structural Carbon Steel	High-Strength Low-Alloy Steel		High Yield Strength, Quenched and Tempered Alloy Steel	
AASHTO Designation	M 183	M 223	M 222	M 244	
Equivalent ASTM Designation	A 36	A 572 Grade 50	A 588	A 514	A 517
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes girders, and built-up sections subject to bending. Satisfy both Gross and Net Section criterion.	1,400 (20,000)	1,900 (27,000)	1,900 (27,000)	Not Applicable	
Axial tension in members without holes. Axial compression, gross section: stiffeners of plate girders. Compression in splice material, gross section.	1,400 (20,000)	1,900 (27,000)	1,900 (27,000)	3,800 (55,000)	3,400 (49,000)
Shear in girder webs, gross section	850 (12,000)	1,200 (17,000)	1,200 (17,000)	2,300 (33,000)	2,100 (30,000)
Stress in extreme fiber or pins	2,000 (29,000)	2,800 (40,000)	2,800 (40,000)	5,600 (80,000)	5,000 (72,000)
Shear in pins	1,000 (14,000)	1,400 (20,000)	1,400 (20,000)	2,800 (40,000)	2,500 (36,000)
Bearing on pins not subjected to rotation	2,000 (29,000)	2,800 (40,000)	2,800 (40,000)	5,600 (80,000)	5,000 (72,000)
Bearing on power-driven rivets and high-strength bolts (or as limited by the allowable bearing on the fasteners)	1,000 (14,000)	1,400 (20,000)	1,400 (20,000)	2,800 (40,000)	2,500 (36,000)

Note : kg/cm², ( ) are in pounds per square inch.

5.2.6 Other Structures

It is recommended that existing drainage structures be replaced, and new drainage structure has already been described in Section 5.2.4 Drainage Design.

(1) Side Ditches and Catch Basins with Cross Drains

Transverse drainage of the roadway should be provided with a suitable crown on the roadway surface, while longitudinal drainage should be secured by cambers or the gradient. Rainfall will then be accumulated into a side ditch or catch basin with a cross drain of downgrade, and this will prevent the flooding of roadway surfaces and bridges.

Longitudinal drainage at the foot of the slope on either side of roadway should be provided with a sufficient number of ditches, concrete-lining V sharp ditches or riprap ditches that are large enough to adequately drain the pipe culverts or box culverts. Some typical sections are illustrated in the drawings.

(2) Pipe Culvert

The specification sizes, strengths, and dimensions of precast soil-reinforced concrete pipe culverts are available in Nicaragua.

Culverts should be protected by a minimum of 1.2 m of earth cover to prevent damage from heavy construction equipment which may pass over them during construction. If the earth cover is less than 1.2 m at the detailed design stage, a special concrete foundation will be required under the pipe at the bottom of the trench in order to withstand the load of a heavy vehicle.

The drainage structure of the pipe culvert consists of precast reinforced concrete pipes, reinforced concrete wing walls, rubble masonry walls, and riprap aprons with inlets and outlets at both ends. The plan and section are shown in the drawings.

(3) Box Culvert

The specification sizes and dimensions of cast-in-place reinforced concrete box culverts for drainage structures are the same as those in the standard obtained from the MCT in Nicaragua.

The bridge at the station 2+250 between Managua-Masaya on the existing road has a 4.00 m short span, reinforced concrete slab. According to the soil penetration tests described in Chapter 2, Geological and Soil Mechanical Investigation. The depth of the developing point, which has a sufficient bearing capacity, is approximately 10.0 m below the existing riverbed.

An alternative study to select a bridge or culvert for the objective location was also conducted. A box culvert structure was selected as the most economical and easiest to construct because the piling which is required for the bridge structure seems to be difficult in these kinds of formations.

In other improvement sections, some of the existing pipe culverts do not have sufficient flow capacity. In particular, existing triplex or fourfold pipe culverts have accumulated sand and gravel in the inlets and outlets on both ends. These existing pipe culverts should be replaced by the box culverts described in Table 5-25.

Table 5-25 List of Box Culverts

Improvement Section	Station	Size of Box Culvert
Managua-Masaya	9+330	2 - 3.00 × 3.00 (Double)
	10+600	2 - 2.50 × 2.50 (Double)
Masaya-Río Panamá	7+440	2 - 1.50 × 1.50 (Double)
Río Panamá-San Benito	2+970	2.00 × 3.00
	6+430	2.00 × 2.50
San Cristobal-Río Panamá	0+130	2 - 3.00 × 3.00 (Double)
Telica-San Isidro	24+070	1.50 × 2.00
	57+310	1.50 × 2.50
	81+500	2.00 × 3.00
	82+070	1.50 × 2.50
	83+310	1.50 × 2.50
	84+570	2 - 1.50 × 2.00 (Double)

(4) Rubble Masonry and Riprap

Mortar rubble masonry is commonly constructed in roads and bridges in Nicaragua. In the Study, rubble masonry was applied to the required roadways to provide the required slope protection against erosion or landslides and to protect the foundations of bridge structures against scouring or erosion, as well as to reduce scouring problems in the inlet and outlet aprons at both ends of the pipes and box culverts.

5.3 CONSTRUCTION PLAN

5.3.1 General

The construction plan study primarily focus on:

- The establishment of a construction method
- The preparation of a construction time schedule

The results of the study are utilized in the construction cost estimates.

5.3.2 Construction Method

(1) Equipment-Intensive Construction

To ensure economic efficiency and shorten the construction period for the Project Roads, the equipment-intensive construction method should be adopted.

(2) Earthwork

Basically, in the case of partial widening (a widening of the shoulder portion), the side borrow method should be applied to embankments. In the case of full widening (2 lanes to 4 lanes), borrow materials should be considered, and materials obtained from common excavation should be utilized as much as possible. The use of the following borrow pits were considered for the subgrade. (Refer to Table 5-26).

Table 5-26 Location of Borrow-Pits

Location of Borrow-Pits	Type of Soil	Remarks
East San Luis (3.2 km north of El Coyotepe)	Clay Sand	Managua-Masaya Managua-Tipitapa Nandaime-San Benito
San Jacinto (12.5 km east of Telica)	Tuffaceous Clay	Telica-San Isidro

(3) Paving Work

The following sources of paving materials were considered:

- Quality : Subbase Course : Sandy Gravel
  Base Course : Graded Crushed Stone
- Location of: Sources : PROINCO Gravel Quarry at Veracruz
  Managua-Masaya, Managua-Tipitapa, Nandaime-San Benito
  : Cosmapa Quarry
  Telica-San Isidro

Asphalt plants should be established along the Project Roads to provide asphalt mixtures during construction.

(4) Construction Method to Widen the Managua-Masaya Road

The road should be widened over three construction stages.

- The first construction stage should start from separated half way of the road.
- The second construction stage should be reversed the traffic side from using way to the constructed side after completion of the work.
- The last construction stage should mainly deal with the center portion, green belt, and other works, as well as the sidewalk portion after completion of the road work on both sides.

The details of the procedure are provided in Appendix A5.4.

(5) Construction Method for Improving the Intersection of Colonia Centro América on the Managua-Masaya Road

The construction method for the "at-grade intersection" will be the same as the traffic changing method used for the above road widening project.

The construction method for the "Grade Separation" should be applied in three stages as above.

In the first stage, traffic lane will be changed for one side of the road, while the other way area will be widened. This stage should take ten months. After the first stage works have been completed, the traffic lane will be changed to the other way, and the other side of the road will be widened, This is the second stage. Finally in the third stage, flyover construction works will be conducted.

5.3.3 Construction Time Schedule

(1) Scheduling Conditions

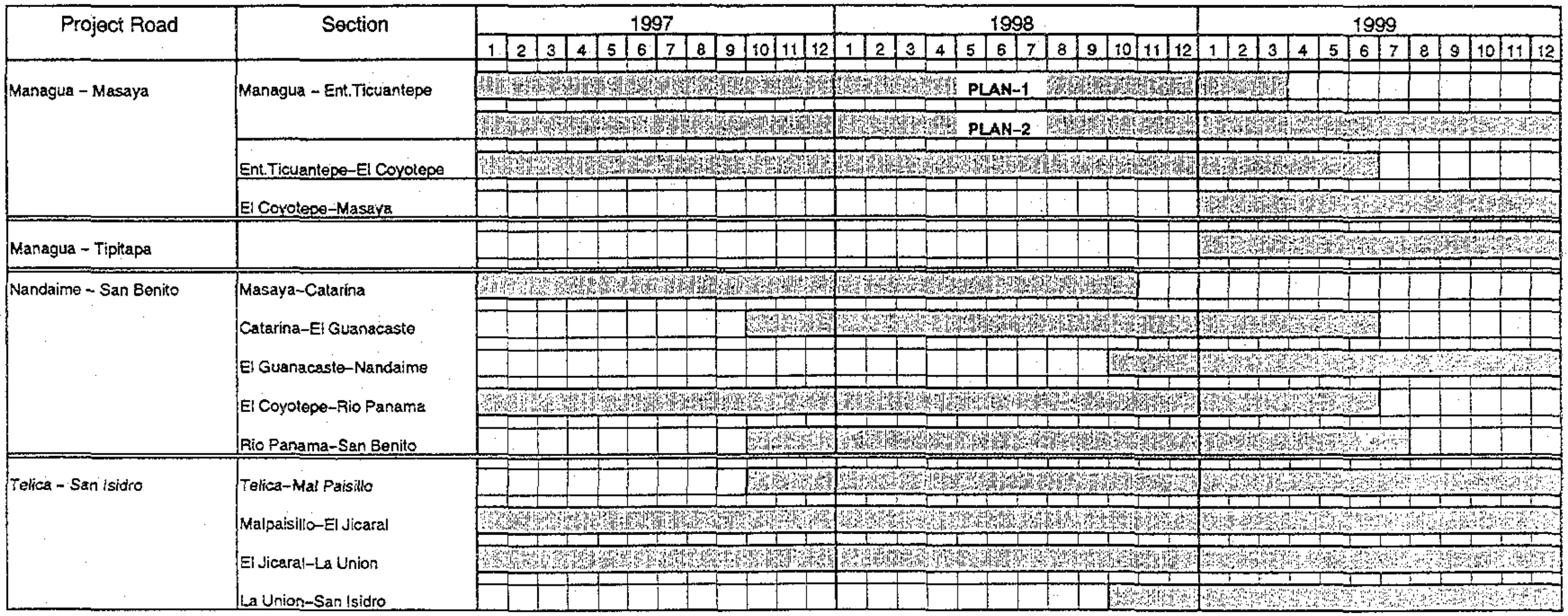
Taking into account the scale of the construction work and the major equipment and plants required, the maximum construction period has been set as 3 years.

The number of working days has been set as follows, on the basis of previous work experience in the objective areas.

- Rainy Season (May-October) :20 days
- Dry Season (November-April) : 25 days

(2) Time Schedule

The construction time schedule for each project road was set on the basis of the above conditions, as shown in Figure 5-23.



Note: Plan-1: Improvement of intersection "Colonia Centroamerica" with at-grade intersection

Plan-2: Improvement of intersection "Colonia Centroamerica" with at-grade intersection

Figure 5-23 Construction Time Schedule

5.4 MAINTENANCE PROGRAM

5.4.1 General

Operation and maintenance works for the whole road network of Nicaragua have been planned and carried out by the Maintenance Office of the Road and Highway General Office.

Basically, maintenance work in Nicaragua is neither classified by implementation period nor scale. As shown in Table 5-27, maintenance work conducted during the years 1992 and 1993, and work planned for 1994, are broadly summarized in a few items, which are estimated annually.

Table 5-27 Summary of the Maintenance Works of 1992-1994

Item	1992 (km)	1993 (km)	1994	
			(km)	(Córdobas)
1. Paved roads				
- Patching	1,138.32	634.48	715.06	3,950.01
- General cleaning	1,193.55	338.04	456.99	1,790.02
- Pavement marking	100.25	137.00	46.00	460.00
2. Unpaved roads				
- Surface repair	673.32	808.28	762.07	17,080.27
- Leveling	1,234.33	1,104.52	580.81	1,219.70

5.4.2 Proposed Maintenance Program

On the basis of maintenance programs typically applied in the U.S.A. and Japan, the following maintenance program has been drawn up for the project roads, dividing the main maintenance activities into routine maintenance, periodic maintenance and incidental maintenance.

(1) Routine Maintenance

Routine maintenance consists of routine (daily) inspections of the conditions of pavements, cut and fill slopes, drainage structures, bridges, and other structures and facilities. The purpose of this type of maintenance is to monitor possible defects or damage.

Inspections should be conducted daily, or at least weekly, by a road patrol team supervised by regional road authorities. The results of these routine inspections should then be promptly reported to the operation head office for any necessary follow-up maintenance work.

(2) Periodic Maintenance

Periodic maintenance consists of detailed inspections to be performed at certain time intervals (for example, weekly, monthly or yearly) depending on the type and kind of facilities. Such maintenance includes the checking and testing of the conditions of various structures and facilities.

These inspections should be conducted by technicians or engineers from the regional office. Defects and damages should be promptly reported, so that the necessary repairs can be effected.

Periodic maintenance also covers such work as the cleaning of pavements, guardrails and traffic sign boards, mowing, and the maintenance of landscape plantation areas, as well as pavement markings and paint.

Depending on the maintenance works items, such work may be carried out every 1, 2 or 3 years. Such work (except for the inspections themselves) should be basically conducted by contractors under the supervision of a regional operation office.

① Annual works

- Cleaning of pavements
- Mowing and maintenance of plantation areas
- Cleaning of ditches and culverts
- Lightly damaged pavement repairs

② Work every 2 or 3 years

- Patching and resurfacing of pavement
- Repair of fill and cutting slopes
- Repair of the expansion joints on bridges and viaducts

③ Work every 15 years

- Improvement work including pavement overlays, widening, construction of additional facilities, etc.

(3) Incidental Maintenance

Incidental maintenance is basically the work carried out to restore the project roads and related facilities to their normal operating conditions after they have been damaged by traffic accidents, or natural disasters or environmental changes.

5.5 PROJECT COST ESTIMATION

5.5.1 Estimation Conditions

Project costs were estimated on the basis of the results of the preliminary design and quantity take-off of each work item, a study of the construction method, and a study on the operation and maintenance of the project roads.

Project costs in this clause consist of the following items:

- Construction Costs
- Engineering Costs
- Operation and Maintenance Costs
- Overlay Costs

The basic premises applied to and estimation of project costs are as follows:

① All the construction work will be conducted by contractor(s) to be employed for the development of the project roads.

② The unit price of each cost component has been determined on the basis of economic conditions prevailing in 1993.

③ Project costs have been divided into local and foreign portions. Equipment and imported materials were assumed to be part of the foreign portion.

④ Taxes will be imposed by the government of Nicaragua on all construction works conducted and engineering services provided.

⑤ Physical contingencies were estimated to be 10% of the total construction costs and engineering costs.

Project costs were estimated in both financial terms and economic terms. Economic project costs for economic analysis were estimated by deducting transfer items such as taxes and duties from the total financial project costs.

5.5.2 Construction Costs

(1) Construction Works Unit Prices

Construction work unit prices were determined on the basis of an analysis of labor costs, material costs, and equipment costs for the major work items.

a) Labor Unit Costs

Table 5-28 shows the labor unit costs applied in the construction cost estimate, which includes taxes, and overhead, etc. These costs are based on an 8-hour working day.

Table 5-28 Labor Unit Cost

Classification	Unit Cost per Day (C$)
Foreman	92.00
Equipment Operator	92.00
Building Labor	92.00
Truck Driver	92.00
Common Labor	74.00
Skilled Labor	92.00

b) Material Unit Costs

Table 5-29 shows major construction material unit costs. These materials were classified as either domestic or imported, as shown in the table.

Table 5-29 Material Unit Costs

Description	Unit	Unit Cost (C$)	Domestic/Imported
Crushed Stone	m^3	167.23	Domestic
Sand	m^3	126.49	Domestic
Portland Cement	50 kg	20.22	Domestic
Reinforcing Bar	kg	4.13	Imported
Concrete	m^3	559.21	Domestic
Timber (2"x4")	m	1.06	Domestic
Steel Structure	kg	11.76	Imported
Gasoline	Gallon	14.60	Imported
Diesel Oil	l	7.14	Imported
Straight Asphalt	l	2.12	Imported
Metallic Pipe (D= 30",L= 1.0 m)	m	707.00	Imported

c) Equipment Unit Costs

Table 5-30 shows the equipment unit costs which apply to the construction of the Project Roads. Daily costs include depreciation costs, operation and maintenance costs (fuel, lubricants, spare parts, etc.) and management costs.

Table 5-30 Equipment Unit Costs

Equipment	Daily Cost (C$)
Aggregate Spreader	416
Bulldozer 200 HP	5,582
Bulldozer 75 HP	1,958
Dump Truck 12 t	2,100
Dump Truck 16 t	2,366
F.E. Loader 2.5 cy	3,084
Motor Grader 30,000 Lbs	5,582
Asphalt Finisher 130 HP	7,680
Tired Roller	1,550
Sheeps-foot Roller 130 HP	3,435
Tandem Roller 10 t	1,500
Flat Truck 3/4 t	760
Flat Truck 3 t	1,045
Flat Truck 10 t	1,524
Vibratory Drum Roller 130 HP	3,740
Water-tank Truck 1200 Gal	1,200

(2) Indirect Costs

Indirect costs consist of general expenses and profits. These costs were estimated as 33% of the total direct construction costs.

(3) Taxes

Taxes consist of fiscal stamp taxes, municipality taxes, and sales tax (IGV). Fiscal stamp taxes and municipality taxes were estimated to be 2% of total construction costs. Sales tax was estimated at 15% of total of the construction costs, fiscal stamp taxes, and municipality taxes.

Estimated construction costs by Project Road are shown in Table 5-31.

Table 5-31 Construction Cost (1)

(Unit : 1,000 Córdobas)

Description		Managua-Masaya Road					
		Managua-Entrada Ticuantepe Section			Entrada Ticuantepe-Masaya Section		
		Local	Foreign	Total	Local	Foreign	Total
Earth Work	Cleaning R/W	25,250	76,760	102,010	51,000	155,040	206,040
	Removal of the existing A/C	15,688	364,216	379,904	27,750	644,250	672,000
	Excavation	53,505	688,518	742,023	87,330	1,123,788	1,211,118
	Filling	2,820	14,655	17,475	118,440	615,510	733,950
	Subgrade	302,120	1,699,880	2,002,000	675,288	3,799,512	4,474,800
Pavement Work	Base Course	4,082,390	3,264,300	7,346,690	6,685,800	5,346,000	12,031,800
	Binder Course	3,463,200	4,195,800	7,659,000	5,890,560	7,136,640	13,027,200
	Surface Course	2,240,100	2,849,250	5,089,350	3,783,660	4,812,550	8,596,210
Drainage Work	Concrete Ditch	3,449,665	-	3,449,665	5,121,516	-	5,121,516
	Pipe Culvert	2,756,610	-	2,756,610	4,476,330	-	4,476,330
	Box Culvert	1,305,500	1,092,500	2,398,000	2,200,000	1,970,000	4,170,000
Bridge Work	River Bridge	3,297,000	4,133,000	7,430,000	-	-	-
	Pedestrian Bridge	1,254,500	1,067,500	2,322,000	-	-	-
	Retaining Wall	360,000	240,000	600,000	-	-	-
Miscellaneous Work	Slope Protection	431,200	-	431,200	614,880	-	614,880
	Marking	102,850	-	102,850	177,990	-	177,990
	Sidewalk	182,790	393,390	576,180	438,696	944,136	1,382,832
	Others Works	2,779,592	2,315,451	5,095,043	2,496,248	1,607,086	4,103,334
Total Direct Cost		26,104,780	22,395,220	48,500,000	32,845,488	28,154,512	61,000,000
Indirect Cost		8,614,577	7,390,423	16,005,000	10,839,011	9,290,989	20,130,000
Stamp/Municipality Tax		1,388,775	1,191,425	2,580,200	1,747,380	1,497,820	3,245,200
IGV		5,416,220	4,646,560	10,062,780	6,814,782	5,841,498	12,656,280
Total Construction Cost		41,524,352	35,623,628	77,147,980	52,246,661	44,784,819	97,031,480

(Unit : 1,000 Córdobas)

Description		Managua-Tipitapa Road			Nandaime-San Benito Road		
		Local	Foreign	Total	Local	Foreign	Total
Earth Work	Cleaning R/W	10,750	32,680	43,430	163,000	495,520	658,520
	Removal of the existing A/C	4,440	103,080	107,520	73,260	1,700,820	1,774,080
	Excavation				270,600	3,482,160	3,752,760
	Filling				981,360	5,099,940	6,081,300
	Subgrade				928,272	5,222,928	6,151,200
Pavement Work	Base Course	809,760	648,000	1,457,760	11,960,420	9,568,800	21,529,220
	Binder Course	624,000	756,000	1,380,000	9,711,800	11,755,800	21,467,600
	Surface Course	513,000	652,500	1,165,500	8,757,480	11,138,900	19,896,380
Drainage Work	Concrete Ditch	1,265,662		1,265,662	19,249,836		19,249,836
	Pipe Culvert	758,700		758,700	11,127,600		11,127,600
	Box Culvert	300,000	300,000	600,000	900,000	600,000	1,500,000
Bridge Work	River Bridge				2,150,000	1,950,000	4,100,000
	Pedestrian Bridge						
	Retaining Wall						
Miscellaneous Work	Slope Protection	28,000		28,000	2,744,000		2,744,000
	Marking	22,100		22,100	332,860		332,860
	Sidewalk				901,764	1,940,724	2,842,488
	Others Works	525,828	853,180	1,379,008	4,360,328	4,414,748	8,775,076
Total Direct Cost		4,862,240	3,345,440	8,207,680	74,612,580	57,370,340	131,982,920
Indirect Cost		1,604,539	1,103,995	2,708,534	24,622,152	18,932,213	43,554,365
Stamp/Municipality Tax		258,671	177,977	436,648	3,969,389	3,052,102	7,021,491
IGV		1,008,818	694,112	1,702,929	15,480,618	11,903,198	27,383,816
Total Construction Cost		7,734,268	5,321,524	13,055,791	118,684,739	91,257,853	209,942,592

Table 5-31 Construction Cost (2)

(Unit : 1,000 Córdobas)

Description		Telica-San Isidro Road Local	Foreign	Total
Earth Work	Cleaning R/W	313,400	1,399,400	1,712,800
	Removal of the existing A/C	96,200	2,233,400	2,329,600
	Excavation	541,200	6,964,320	7,505,520
	Filling	1,274,640	6,621,810	7,896,450
	Subgrade	285,520	1,606,480	1,892,000
Pavement Work	Base Course	16,077,990	12,865,500	28,943,490
	Binder Course	7,768,800	9,374,850	17,143,650
	Surface Course	10,602,000	13,485,000	24,087,000
Drainage Work	Concrete Ditch	28,197,772		28,197,772
	Pipe Culvert	9,761,940		9,761,940
	Box Culvert	1,680,000	1,400,000	3,080,000
Bridge Work	River Bridge			
	Pedestrian Bridge			
	Retaining Wall			
Miscellaneous Work	Slope Protection	2,035,000	2,403,000	4,438,000
	Marking	488,410		488,410
	Sidewalk	171,823	369,787	541,610
	Others Works	3,333,715	3,522,563	6,856,278
Total Direct Cost		82,628,410	62,246,110	144,874,520
Indirect Cost		27,267,375	20,541,217	47,808,592
Stamp/Municipality Tax		4,395,831	3,311,492	7,707,323
IGV		17,143,742	12,914,823	30,058,565
Total Construction Cost		131,435,358	99,013,642	230,449,000

5.5.3 Engineering Costs

Engineering costs consist of detailed design and construction supervision costs. Detailed design costs were assumed to be 5% of direct construction costs, while construction supervision costs were assumed to be 10% of total construction costs. Taxes will also be imposed on all engineering costs in Nicaragua. Fiscal stamp taxes and municipality taxes were estimated to be 2% of the total costs. Sales tax was also estimated at 10% of the total costs, including fiscal stamp taxes and municipality taxes. Table 5-32 shows the estimated engineering costs by Project Road.

5.5.4 Operation and Maintenance Costs

Annual maintenance costs were estimated at 10,000 Córdobas per km on the basis of previous experience in Nicaragua. Annual operation costs, which include administration costs, were also estimated at 2,600 Córdobas per km.

Table 5-32 Engineering Cost

(Unit : 1,000 Córdobas)

Description	Managua-Masaya Road					
	Managua-Entrada Ticuantepe Section			Entrada Ticuantepe-Masaya Section		
	Local	Foreign	Total	Local	Foreign	Total
Supervisiont	3,471,935	2,978,565	6,450,500	4,368,450	3,744,550	8,113,000
Stamp/Municipality Tax	138,877	119,143	258,020	174,738	149,782	324,520
IGV	361,081	309,771	670,852	454,319	389,433	843,752
Sub-total	3,971,893	3,407,479	7,379,372	4,997,507	4,283,765	9,281,272
Detailed Design	1,305,239	1,119,761	2,425,000	1,642,274	1,407,726	3,050,000
Stamp/Municipality Tax	52,210	44,790	97,000	65,691	56,309	122,000
IGV	135,745	116,455	252,200	170,796	146,404	317,200
Sub-total	1,493,194	1,281,006	2,774,200	1,878,761	1,610,439	3,489,200
Total Engineering Cost	5,465,087	4,688,485	10,153,572	6,876,268	5,894,204	12,770,472

(Unit : 1,000 Córdobas)

Description	Managua-Tipitapa Road			Nandaime-San Benito Road		
	Local	Foreign	Total	Local	Foreign	Total
Supervisiont	646,678	444,944	1,091,622	9,923,473	7,630,255	17,553,728
Stamp/Municipality Tax	25,867	17,798	43,665	396,938	305,211	702,149
IGV	67,255	46,274	113,529	1,032,041	793,546	1,825,587
Sub-total	739,800	509,016	1,248,816	11,352,452	8,729,012	20,081,464
Detailed Design	243,112	167,272	410,384	3,730,629	2,868,517	6,599,146
Stamp/Municipality Tax	9,724	6,691	16,415	149,226	114,741	263,967
IGV	25,284	17,396	42,680	387,986	298,326	686,311
Sub-total	278,120	191,359	469,479	4,267,841	3,281,584	7,549,425
Total Engineering Cost	1,017,920	700,375	1,718,295	15,620,293	12,010,596	27,630,889

(Unit : 1,000 Córdobas)

Description	Telica-San Isidro Road		
	Local	Foreign	Total
Supervisiont	10,989,579	8,278,733	19,268,312
Stamp/Municipality Tax	439,583	331,149	770,732
IGV	1,142,916	860,988	2,003,904
Sub-total	12,572,078	9,470,870	22,042,948
Detailed Design	4,131,421	3,112,306	7,243,727
Stamp/Municipality Tax	165,257	124,492	289,749
IGV	429,668	323,680	753,348
Sub-total	4,726,346	3,560,478	8,286,824
Total Engineering Cost	17,298,424	13,031,348	30,329,772

5.5.5 Overlaying Costs

Overlays will be required to ensure the durability of pavements after 15 years (year 2015). Such overlays, measuring 5 cm or 6 cm in thickness, will extend the pavement service life to the 20th year of the economic analysis period. Over the last 5 years, the overlaid structure will support the remaining design traffic. Overlays should be set down in 2014-2015. Overlaying costs consist of the overlaying work itself, pavement markings, and various indirect costs.

5.5.6 Estimated Project Cost

Project costs were determined as shown in Table 5-33 on the basis of the above considerations coupled with individual cost estimations.

An annual cash flow of project costs was also prepared, as shown in Tables 5-34 to 5-38, on the assumption that the project would be implemented from 1997 through 1999.

Table 5-33 Estimated Project Costs

(Unit : 1,000 Córdobas)

Item		Managua-Masaya		Managua-Tipitapa	Nandaime - San Benito	Telica - San Isidro
		1st Section	2nd Section			
Construction Cost	Local	41,524	52,247	7,734	118,685	131,435
	Foreign	35,624	44,785	5,322	91,258	99,014
	Total	77,148	97,032	13,056	209,943	230,449
Engineering Cost	Local	5,465	6,876	1,018	15,620	17,298
	Foreign	4,688	5,894	700	12,011	13,031
	Total	10,153	12,770	1,718	27,631	30,329
Subtotal	Local	46,989	59,123	8,752	134,305	148,733
	Foreign	40,312	50,679	6,022	103,269	112,045
	Total	87,301	109,802	14,774	237,574	260,778
Contingency	Local	4,699	5,912	875	13,431	14,873
	Foreign	4,031	5,068	602	10,327	11,205
	Total	8,730	10,980	1,477	23,758	26,078
Total	Local	51,688	65,035	9,627	147,736	163,606
	Foreign	44,343	55,747	6,624	113,596	123,250
	Total	96,031	120,782	16,251	261,332	286,856
Annual Operation and Maintenace Cost	Local	107	219	54	821	1,207
	Foreign	0	0	0	0	0
	Total	107	219	54	821	1,207
Overlay Cost	Local	3,727	6,302	851	15,421	20,289
	Foreign	4,532	7,655	1,038	18,941	24,818
	Total	8,259	13,957	1,889	34,362	45,107

Note : 1st Section - Managua-Entrada Ticuantepe
2nd Section - Entrada Ticuantepe-Masaya

Table 5-34 Annual Cash Flow of the Project Costs (Managua-Masaya Road : Managua-Entrada Ticuantepe Section)

(Unit : 1,000 Córdobas)

Item		Initial Investment			Additional Investment			Remarks
		1997	1998	1999	2000-2013	2014	2015-2019	
Construction Cost	Local	12,792	20,745	7,987				
	Foreign	10,974	17,797	6,853				
	Total	23,766	38,542	14,840	0	0	0	77,148
Engineering Cost	Local	2,817	1,324	1,324				
	Foreign	2,417	1,136	1,136				
	Total	5,234	2,460	2,460	0	0	0	10,154
Sub-total	Local	15,609	22,069	9,311				
	Foreign	13,391	18,933	7,989				
	Total	29,000	41,002	17,300	0	0	0	87,302
Contingency	Local	1,561	2,207	931				
	Foreign	1,339	1,893	799				
	Total	2,900	4,100	1,730	0	0	0	8,730
Total	Local	17,170	24,276	10,242				
	Foreign	14,730	20,826	8,788				
	Total	31,900	45,102	19,030	0	0	0	96,032
Operation and Maintenance Cost	Local				107	107	107	
	Foreign				0	0	0	
	Total	0	0	0	107	107	107	
Overlay Cost	Local				0	3,727	0	
	Foreign				0	4,532	0	
	Total	0	0	0	0	8,259	0	
Total	Local				107	3,834	107	
	Foreign				0	4,532	0	
	Total	0	0	0	107	8,366	107	

Table 5-35 Annual Cash Flow of the Project Costs (Managua-Masaya Road : Entrada Ticuantepe-Masaya Section)

(Unit : 1,000 Córdobas)

Item		Initial Investment			Additional Investment			Remarks
		1997	1998	1999	2000-2013	2014	2015-2019	
Construction Cost	Local	5,092	26,836	20,319				
	Foreign	6,234	19,089	19,462				
	Total	11,326	45,925	39,781	0	0	0	97,032
Engineering Cost	Local	3,545	1,666	1,666				
	Foreign	3,038	1,428	1,428				
	Total	6,583	3,094	3,094	0	0	0	12,771
Sub-total	Local	8,637	28,502	21,985				
	Foreign	9,272	20,517	20,890				
	Total	17,909	49,019	42,875	0	0	0	109,803
Contingency	Local	864	2,850	2,199				
	Foreign	927	2,052	2,089				
	Total	1,791	4,902	4,288	0	0	0	10,981
Total	Local	9,501	31,352	24,184				
	Foreign	10,199	22,569	22,979				
	Total	19,700	53,921	47,163	0	0	0	120,784
Operation and Maintenance Cost	Local				219	219	219	
	Foreign				0	0	0	
	Total	0	0	0	219	219	219	
Overlay Cost	Local				0	6,302	0	
	Foreign				0	7,655	0	
	Total	0	0	0	0	13,957	0	
Total	Local				219	6,521	219	
	Foreign				0	7,655	0	
	Total	0	0	0	219	14,176	219	

Table 5-36 Yearly Cash Flow of the Project Costs (Managua-Tipitapa Road)

(Unit : 1,000 Córdobas)

Item		Initial Investment			Additional Investment			Remarks
		1997	1998	1999	2000-2013	2014	2015-2019	
Construction Cost	Local			7,734				
	Foreign			5,322				
	Total			13,056	0	0	0	13,056
Engineering Cost	Local			1,018				
	Foreign			700				
	Total			1,718	0	0	0	1,718
Sub-total	Local			8,752				
	Foreign			6,022				
	Total			14,774	0	0	0	14,774
Contingency	Local			875				
	Foreign			602				
	Total			1,477	0	0	0	1,477
Total	Local			9,627				
	Foreign			6,624				
	Total			16,251	0	0	0	16,251
Operation and Maintenance Cost	Local				54	54	54	
	Foreign				0	0	0	
	Total			0	54	54	54	
Overlay Cost	Local				0	851	0	
	Foreign				0	1,038	0	
	Total			0	0	1,889	0	
Total	Local				54	905	54	
	Foreign				0	1,038	0	
	Total			0	54	1,943	54	

Table 5-37 Yearly Cash Flow of the Project Costs (Nandaime-San Benito Road)

(Unit : 1,000 Córdobas)

Item		Initial Investment			Additional Investment			Remarks
		1997	1998	1999	2000-2013	2014	2015-2019	
Construction Cost	Local	12,544	57,595	48,546				
	Foreign	13,487	37,498	40,273				
	Total	26,031	95,093	88,819	0	0	0	209,243
Engineering Cost	Local	8,052	3,784	3,784				
	Foreign	6,191	2,910	2,910				
	Total	14,243	6,694	6,694	0	0	0	27,631
Sub-total	Local	20,596	61,379	52,330				
	Foreign	19,678	40,408	43,183				
	Total	40,274	101,787	95,513	0	0	0	237,574
Contingency	Local	2,060	6,138	5,233				
	Foreign	1,968	4,041	4,318				
	Total	4,028	10,179	9,551	0	0	0	23,758
Total	Local	22,656	67,517	57,563				
	Foreign	21,646	44,449	47,501				
	Total	44,302	111,966	105,064	0	0	0	261,332
Operation and Maintenance Cost	Local				821	821	821	
	Foreign				0	0	0	
	Total	0	0	0	821	821	821	
Overlay Cost	Local				0	15,421	0	
	Foreign				0	18,941	0	
	Total	0	0	0	0	34,362	0	
Total	Local				821	16,242	821	
	Foreign				0	18,941	0	
	Total	0	0	0	821	35,183	821	

Table 5-38 Yearly Cash Flow of the Project Costs (Telica-San Isidro Road)

(Unit : 1,000 Córdobas)

Item		Initial Investment			Additional Investment			Remarks
		1997	1998	1999	2000-2013	2014	2015-2019	
Construction Cost	Local	10,248	60,569	60,618				
	Foreign	9,900	36,914	52,200				
	Total	20,148	97,483	112,818	0	0	0	230,449
Engineering Cost	Local	8,917	4,191	4,191				
	Foreign	6,717	3,157	3,157				
	Total	15,634	7,348	7,348	0	0	0	30,330
Sub-total	Local	19,165	64,760	64,809				
	Foreign	16,617	40,071	55,357				
	Total	35,782	104,831	120,166	0	0	0	260,779
Contingency	Local	1,917	6,476	6,481				
	Foreign	1,662	4,007	5,536				
	Total	3,579	10,483	12,017	0	0	0	26,079
Total	Local	21,082	71,236	71,290				
	Foreign	18,279	44,078	60,893				
	Total	39,361	115,314	132,183	0	0	0	286,858
Operation and Maintenance Cost	Local				1,207	1,207	1,207	
	Foreign				0	0	0	
	Total			0	1,207	1,207	1,207	
Overlay Cost	Local				0	20,289	0	
	Foreign				0	24,818	0	
	Total			0	0	45,107	0	
Total	Local				1,207	21,496	1,207	
	Foreign				0	24,818	0	
	Total			0	1,207	46,314	1,207	

CHAPTER 6

ECONOMIC EVALUATION

CHAPTER 6 ECONOMIC EVALUATION

6.1 METHOD OF ECONOMIC EVALUATION

6.1.1 General

The four Project Roads selected for the feasibility study in the Master Plan stage were economically evaluated. As explained in Chapter 5, the following selected road projects were examined in this Chapter.

Table 6-1 Selected Road Projects

Project Road	Project No.
(1) Managua-Masaya Road	
* Managua-Entrada de Ticuantepe Section	
- At-grade intersection	Project-1
- Grade-separated intersection	Project-2
* Entrada de Ticuantepe-Masaya Section	Project-3
(2) Managua-Tipitapa Road	Project-4
(3) Nandaime-San Benito Road	Project-5
(4) Telica-San Isidro Road	
- Including improvement of alignment	Project-6
- Partial improvement	Project-7

In selecting of the Project Roads, the following conditions were considered.

- To exclude committed projects by donor countries and international lending agencies
- To exclude road sections inside the off-limits Area.
- To include sections which have continuity as trunk road.

Although there might be some economically feasible sections on the roads excluded above, these four sections mentioned above were economically evaluated here.

6.1.2 Basic Assumptions and Evaluation Method

Each project listed in the previous clause was evaluated by comparing its costs and benefits. The project evaluation period was set at 23 years including a construction period of 3 years from 1997 to 1999.

In order to evaluate each project from a national economic viewpoint, it was essential to estimate the economic benefits and economic costs generated by the implementation of the project. The evaluation was based on the conventional discounted cash flow method. Three evaluation indicators , i.e., internal rate of return (IRR), net present value (NPV) and benefit-cost ratio (B/C), were adopted as project indicators. The latter two indicators were evaluated on the basis of a discount rate of 12%, according to the interest rate of major international lending agencies.

The basic assumptions of the evaluation are summarized as follows:

- Construction period : from 1997 to 1999
- Project life : 23 years from 1997 to 2019
- Basic price : 1993 price
- Residual value : None

6.1.3 Concept of With-case and Without-case

It is necessary to define the concepts of "With-case" and "Without-case" to understand the benefits of the project, since some benefit items are defined as the difference between their cost of "Without-case" and "With-case". The concept of "Without-case" means that the same service level as at present will remain in the future. To keep this service level in the future, asphalt surface repairment must be provided periodically. This is the situation of "Without-case". Therefore, under this analysis, it is assumed that asphalt surface repairment will be provided every 5 years.

The following table shows the different road situations for "With-case" and "Without-case".

Table 6-2 Difference in Road Situations for With-case and Without-case

Item	Without-case	With-case
Asphalt Concrete Pavement	-	X
Asphalt Surface repairment every 5 years	X	-
Maintenance Work		
- Periodical Overlay/15 years	-	X
- Annual maintenance	X	X

6.1.4 Benefits of the Project

The transportation project generally promises the following diverse benefits:

① Benefits to users.

② Benefits to the project executing agency.

③ Benefits deriving from an increase in the asset value of land, buildings, etc.

Benefits generated by the road improvement project are described in more detail below:

(1) Benefit to Users

a) Vehicle Operation Cost Savings

Vehicle operation cost (VOC) savings are derived from a reduction in fuel consumption resulting from an increase in running speed, and from a reduction in the fixed cost of VOC resulting from a shortening of vehicular travel time.

b) Travel Time Savings

Travel time will be saved by the increase in running speed made possible by the improvement of the road structure.

c) Improved Driving Comfort

Driving comfort not only for drivers but also for passengers will be improved due to a reduction in vehicular jolting and the need to avoid pot hales, cracks, and other pavement deterioration. Considering that the existing asphalt surfaces of the Project Roads have been deteriorating, this improvement is supposed to be fair-sized.

d) Reduction of Damage to Cargoes

Damage to cargoes caused by shocks and jolts resulting from bad road conditions, especially shoulder conditions, could be reduced by improving the roads.

e) Reduction of Traffic Accidents

According to the projected increase in future traffic volume, the number of traffic accidents will surely increase. Due to the improvement in the road structure, the rate of increase of traffic accidents would decrease compared with the "Without-case" scenario. However, it is difficult to estimate the rate of reduction and to quantify damage caused by accidents since available data is insufficient. Therefore, this benefit was not quantified in this analysis.

(2) Benefits to the Project Executing Agency

The project executing agency, MCT, will benefit because the periodical expenditures for asphalt surface treatment in the "Without-case" scenario would be saved by the implementation of the project ("With-case"). These savings could then be allocated to other investments in Nicaragua's economy.

Asphalt surface treatment expenditure are estimated in the following section 6.2.

6.2 ESTIMATION OF BENEFITS

Several of the project benefits described in the previous section were assessed qualitatively.

6.2.1 Vehicle Operation Cost Savings

Benefits from vehicle operation cost savings are calculated by the difference between VOC of "With-case" and VOC of "Without-case". To estimate VOC, six vehicle types were selected in accordance with the vehicle types adopted in the traffic survey of the Study. Information related to VOC for each vehicle type was collected through an interview survey as shown in the Table 6-3.

Table 6-3 Basic Information of VOC Estimate

Item	Passenger Car TOYOTA EL40L-AEMDS	Microbus TOYOTA BB42L-BRMRS	Bus TOYOTA BLUE BIRD	Pick-up TOYOTA YN85L-PRMRS	Truck TOYOTA DA116L-H3	Traller GM CC7H042
Purchase of Vehicle (C$)	101,835	257,336	465,350	108,776	275,621	298,382
(Second-hand Vehicle)	50,918	128,668	232,675	54,388	137,811	149,191
Annual Mileage (km)	12,000	50,000	75,000	40,000	90,000	90,000
Insurance Cost/Year (C$)	752	1,780	3,341	814	2,237	2,306
No. of Tires/Vehicle	4	6	6	4	6	12
Life Span of Vehicle (Year)	10	12	12	12	12	12
Life Span of Tire (Year)	1.00	0.50	0.50	0.50	0.50	0.50
Salvage Value of Vehicle (% of Market Price)	10	10	10	10	10	10
No. of Crew/Vehicle	0	2	2	2	2	2
Salary of Driver/Year (C$)	0	14,400	19,200	14,400	19,200	19,200
Salary of Assistant/Year (C$)	0	10,800	14,400	10,800	10,800	10,800
Maintenance Cost/Year (C$)	600	1,800	2,500	800	2,500	2,500
Office Admin. Cost/Year (C$)	0	2,460	9,615	0	9,615	9,615
Interest Rate/Year (%)	16	16	16	16	16	16

The collected information for the VOC was expressed in terms of the 1993 market price. To conduct an economic evaluation, it was necessary to convert these prices into economic prices by eliminating diverse taxes such as import tax, sales tax, etc., since taxes are one of transfer items in the nation. The percentage of these taxes, and the converted economic costs are shown in Table 6-4.

The unit cost of the VOC was estimated on the basis of figures in Tables 6-3 and 6-4, and is shown in Table 6-5.

Table 6-4 Economic Price of Vehicle, Fuel, Oil, Tire

(Unit : Córdobas)

Item	Passenger Car TOYOTA EL40L-AEMDS	Microbus TOYOTA BB42L-BRMRS	Bus TOYOTA BLUE BIRD	Pick-up TOYOTA YN85L-PRMRS	Truck TOYOTA DA116L-H3	Trailer GM CC7H042
Market Price and Tax Portion for Market Price						
Purchase of Vehicle	101,835	257,336	465,350	108,776	275,621	298,382
(Second-hand Vehicle)	50,918	128,668	232,675	54,388	137,811	149,191
Percentage of Tax for Vehicle	27	23	23	27	23	23
Fuel (Gasoline, Diesel)	3.17	1.82	1.82	1.82	1.82	1.82
Percentage of Tax for Fuel	51.7%	14.6%	14.6%	14.6%	14.6%	14.6%
Oil	8.85	8.85	8.85	8.85	8.85	8.85
Percentage of Tax for Oil	13%	13%	13%	13%	13%	13%
Tire	354	469	1,581	426	1,662	1,887
Percentage of Tax for Tire	35%	35%	35%	35%	35%	35%
Economic Price						
Purchase of Vehicle	74,645	197,634	360,181	79,842	212,228	229,754
(Second-hand Vehicle)	37,323	98,817	180,090	39,921	106,114	114,877
Fuel (Gasoline, Diesel)	1.53	1.55	1.55	1.55	1.55	1.55
Oil	7.70	7.70	7.70	7.70	7.70	7.70
Tire	230	305	1,028	277	1,080	1,227

Note : Price of second-hand vehicle is estimated in 1/2 of that of new vehicle

VOC savings are calculated by comparing the cost of "With-case" with the cost of "Without-case". It is generally known that some elements of the road characteristics such as surface conditions, geometric alignment, gradient, curvature, etc. affect the VOC; however, in the Study, an increase in running speed and a shortening of travel time were selected as the most important elements, since all other elements will remain relatively unchanged by the road improvement.

The benefits of VOC savings for each case in 2000 and 2010 are shown in Table 6-6. (Information about VOC savings is attached in Annexes A6.4)

VOC savings from 2001 to 2009 will be distributed proportionally with the VOC of 2000 and 2010. After 2010, it is assumed that it will be the same as that of 2010.

6.2.2 Travel Time Cost Savings

The time savings in 2000 and 2010 were determined from the traffic analysis in the Study by project. Applying these time savings made it possible to calculate annual time savings in 2000 and 2010. Time savings from 1991 to 1999 and time savings after 2010 were determined in same way as in the case of VOC.

Table 6-5 Unit Vehicle Operation Costs

Vehicle Operation Cost / km (Unit : Córdobas)

Item	Passenger Car TOYOTA EL40L-AEMDS	Microbus TOYOTA BB42L-BRMRS	Bus TOYOTA BLUE BIRD	Pick-up TOYOTA YN85L-PRMRS	Truck TOYOTA DA116L-H3	Trailer GM CC7H042
Variable Cost						
Fuel Cost	0.1812	0.3419	0.4857	0.1839	0.9037	0.9037
Lubricant Oil	0.0077	0.0226	0.0308	0.0077	0.0570	0.0570
Tire Cost	0.0875	0.0834	0.1874	0.0630	0.1641	0.3728
Fixed Cost						
Maintenance	0.0500	0.0360	0.0333	0.0200	0.0278	0.0278
Depreciation	0.3315	0.1732	0.2098	0.1069	0.1032	0.1117
Insurance	0.0627	0.0356	0.0445	0.0204	0.0249	0.0256
Crew Wage	0.0000	0.5040	0.4480	0.6300	0.3333	0.3333
Administration Cost	0.0000	0.0492	0.1282	0.0000	0.1068	0.1068
Interest of Loan	0.3395	0.2059	0.2482	0.1088	0.1225	0.1326
Total	1.0600	1.4519	1.8160	1.1407	1.8433	2.0713

Vehicle Operation Cost /Hour (Unit : Córdobas)

Item	Passenger Car TOYOTA EL40L-AEMDS	Microbus TOYOTA BB42L-BRMRS	Bus TOYOTA BLUE BIRD	Pick-up TOYOTA YN85L-PRMRS	Truck TOYOTA DA116L-H3	Trailer GM CC7H042
Variable Cost						
Fuel Cost	8.15	15.39	21.86	8.28	40.66	40.66
Lubricant Oil	0.35	1.02	1.39	0.35	2.56	2.56
Tire Cost	3.94	3.75	8.43	2.84	7.39	16.77
Fixed Cost						
Maintenance	0.38	0.58	0.80	0.26	0.80	0.80
Depreciation	3.25	3.43	6.19	1.74	3.67	3.97
Insurance	0.48	0.57	1.07	0.26	0.71	0.74
Crew Wage	0.00	8.05	10.73	8.05	9.58	9.58
Administration Cost	0.00	0.79	3.07	0.00	3.07	3.07
Interest of Loan	2.60	3.29	5.95	1.39	3.52	3.81
Total of Fixed Cost	4.12	13.41	21.87	10.30	17.84	18.16
Total	16.55	33.57	53.54	21.76	68.45	78.17

Note : Estimated in 45 km/h of average speed

Table 6-6 Benefits of Vehicle Operating Cost Savings in 2000 and 2010

(Unit : 1000 Córdobas)

Project No.	Vehicle Operating Cost Saving	
	2000	2010
Project-1	17,518.86	38,986.61
Project-2	19,243.54	28,054.13
Project-3	15,311.06	31,361.84
Project-4	1,625.68	1,985.11
Project-5	15,125.79	27,558.15
Project-6	4,774.48	8,076.73
Project-7	4,774.48	8,076.73

Time value was calculated by using the GDP per one employment. In Nicaragua, GDP in 1992 was 8,426.6 million Córdobas. On the other hand, the number of employment in 1992 was estimated to be 1,225,000 based on SPP-DGNV and MITRAB of Nicaragua. On the assumption of 2,184 working hours per year (Source : Ministry of Labor, 8 hours × (303 days - 30 holidays)), individual productivity per hour was estimated at 3.07 Córdobas.

This time value was then assigned only to trips related to economic activities such as "business", "going to work" and "going home". The average number of passengers, the share of trip purpose related to economic activity and the benefits on travel time savings are shown in the Table 6-7.

Table 6-7 Benefits of Travel Time Saving in 2000 and 2010

(Unit : Córdobas)

Item	Passenger Car	Microbus	Bus	Pick-up	Truck	Trailer	Total Benefit on Travel Time Saving
Hourly Time Value (C$)	3.07	3.07	3.07	3.07	3.07	3.07	
Ave. No. of Passengers	3.2	16.3	44.4	3.0	4.4	2.5	
Trip Purpose (Economic Activity)	0.751	0.735	0.574	0.784	0.857	0.896	
Time Saving in 2000							
Project-1	1,226,400	53,290	95,630	536,185	188,340	55,480	
Project-2	1,349,770	57,670	104,390	588,015	203,670	58,400	
Project-3	548,960	36,135	82,855	408,800	207,320	72,270	
Project-4	36,865	4,745	7,665	44,165	33,945	6,935	
Project-5	512,460	32,485	89,060	453,330	275,940	88,330	
Project-6	88,695	730	51,465	152,935	81,395	13,505	
Project-7	88,695	730	51,465	152,935	81,395	13,505	
Time Saving in 2010							
Project-1	1,757,110	77,745	123,005	676,345	303,315	86,140	
Project-2	1,972,095	84,315	136,875	743,870	325,945	89,790	
Project-3	1,366,195	80,665	189,070	751,900	418,290	129,210	
Project-4	41,975	5,475	10,585	45,260	33,945	5,110	
Project-5	1,089,890	62,050	178,485	740,950	506,620	136,510	
Project-6	156,585	17,155	81,760	220,825	133,955	16,425	
Project-7	156,585	17,155	81,760	220,825	133,955	16,425	
Benefit on Travel Time Saving in 2000							
Project-1	9,048,163	1,960,013	7,482,167	3,871,599	2,180,291	381,525	24,923,758
Project-2	9,958,366	2,121,110	8,167,556	4,245,845	2,357,756	401,605	27,252,238
Project-3	4,050,130	1,329,050	6,482,641	2,951,798	2,400,010	496,986	17,710,615
Project-4	271,983	174,522	599,716	318,900	392,959	47,691	1,805,770
Project-5	3,780,840	1,194,803	6,968,125	3,273,333	3,194,380	607,428	19,018,907
Project-6	654,376	26,849	4,026,662	1,104,289	942,257	92,871	6,847,305
Project-7	654,376	26,849	4,026,662	1,104,289	942,257	92,871	6,847,305
Benefit on Travel Time Saving in 2010							
Project-1	12,963,648	2,859,472	9,624,009	4,883,644	3,511,282	592,368	34,434,422
Project-2	14,549,770	3,101,117	10,709,208	5,371,217	3,773,255	617,468	38,122,036
Project-3	10,079,546	2,966,870	14,792,987	5,429,199	4,842,274	888,551	38,999,427
Project-4	309,684	201,371	828,179	326,806	392,959	35,140	2,094,140
Project-5	8,041,017	2,282,207	13,964,808	5,350,133	5,864,813	938,752	36,441,730
Project-6	1,155,257	630,963	6,396,967	1,594,498	1,550,711	112,951	11,441,347
Project-7	1,155,257	630,963	6,396,967	1,594,498	1,550,711	112,951	11,441,347

6.2.3 Maintenance Cost Saving

As mentioned in the Section 6.4, implementing the project would save on maintenance costs. The life of an asphalt pavement on an improved road, as proposed in the Study, is assumed to be about 15 years. Nevertheless, during the service life of the pavement, ordinary maintenance such as revetments, cleaning, and partial rehabilitation must continue to be carried out as at present.

Existing roads will require asphalt surface treatment every 5 years hereafter in order to maintain the same level of traffic movement. Therefore, the difference between the maintenance costs in "Without-case" and those in "With-case" is considered to be a cost saving benefit of the project.

Maintenance costs were estimated on the basis of a unit cost of 11.5 Córdobas/m², which was obtained from 1993 maintenance cost information (Annexes A5.3). These maintenance costs mentioned in Chapter 5 were then converted into economic costs by subtracting taxes as shown in Tables 6-8 and 6-9. (Refer to Annexes A6.7 for the Conversion Factor)

Table 6-8 Financial Maintenance Costs in "Without-case"

Project No.	Unit Cost (Córdobas/m²)	Width (m)	Length (km)	Total Cost (1,000 Córdobas)
Project-1	11.5	23	8.520	2,253.5
Project-2	11.5	23	8.52 0	2,253.5
Project-3	11.5	23	17.380	4,597.0
Project-4	11.5	12	4.300	593.4
Project-5	11.5	12	65.125	8,987.3
Project-6	11.5	10	95.760	11,012.4
Project-7	11.5	10	95.760	11,012.4

Table 6-9 Economic Maintenance Costs Saving

(Unit : 1,000 Córdobas)

Project No.	Financial Cost/Year	Conversion Factor	Economic Cost/Year	Annual Maintenance Cost (With-case)	Economic Maintenance Cost Saving
Project-1	2,254	0.75713	1,706	89	1,617
Project-2	2,254	0.75713	1,706	89	1,617
Project-3	4,597	0.75713	3,481	183	3,298
Project-4	593	0.75713	449	45	404
Project-5	8,987	0.75713	6,804	685	6,119
Project-6	11,012	0.75713	8,338	1,009	7,329
Project-7	11,012	0.75713	8,338	1,009	7,329

6.3 ECONOMIC COST

As explained above, project costs were estimated at market price. Therefore, financial costs must be converted into economic costs to evaluate the project.

In the cost estimation, project costs were divided into two parts, i.e., a local currency portion and a foreign currency portion. About 70% of the foreign currency portion was in the form of imported construction equipment, while 30% was in the form of imported materials such as gasoline, oil, straight asphalt, etc.

Economic costs for the local currency portion were calculated by eliminating taxes such as stamp tax and municipality tax. Furthermore, import tax was eliminated from the foreign currency portion. Although the tax rate varies from item to item, the average tax rate was determined by taking into account the composition of project cost items as shown in Table 6-10.

Table 6-10 Tax Rate

Type of Tax	Tax Rate
Stamp Tax	2%
Municipality Tax	2%
Sales Tax	15%
Import Tax for Equipment	26%
Import Tax for Materials	10%

The project costs, maintenance costs, and periodic overlay costs, which were estimated in Chapter 5, in economic cost terms were calculated as shown in Table 6-11.

Table 6-11 Economic Project Costs, Economic Maintenance Costs and Economic Overlay Costs

(Unit : 1,000 Córdobas)

Project No.	Financial Cost *			Economic	Economic	Economic
	Local Portion	Foreign Portion	Total	Project Cost	Maintenance Cost	Overlay Cost
Project-1	46,989	40,313	87,302	67,563	89	6,255
Project-2	52,389	55,612	108,001	82,754	89	6,225
Project-3	59,124	35,475	109,803	84,981	183	10,571
Project-4	8,752	6,022	14,774	11,549	45	1,431
Project-5	134,305	103,269	237,574	184,787	686	26,012
Project-6	148,734	112,045	260,779	203,027	1,009	34,152
Project-7	77,856	58,651	136,507	106,276	1,009	34,152

Note : * - Financial cost excluding contingency

6.4 ECONOMIC EVALUATION

Using the cash flow of economic cost and economic benefit, the Internal Rate of Return (IRR), Net Present Value (NPV) and Benefit Cost Ratio (B/C) were calculated for each project. With IRR and B/C, the viability of the project and the ability to repay the loan could be determined. At the same time, NPV could be applied to determine the scale of social profit. The results of the estimation of indicators are shown in Table 6-12. A cash flow table is shown for each project in Annexes A6.1.

Table 6-12 Evaluation Results

	Project-1	Project-2	Project-3	Project-4	Project-5	Project-6	Project-7
IRR (%)	46.00	41.97	38.43	31.90	21.07	4.42	12.24
NPV (1000C$)	256,409	235,530	213,505	11,909	120,358	-73,239	1,392
B/C	5.56	4.48	4.10	2.38	1.80	0.53	1.02

High indicators were obtained in the evaluation for each section of Project Roads -- Managua-Masaya Road, Nandaime-San Benito Road, Managua-Tipitapa Road (Project-1 to Project-5). These projects are judged as feasible. For the Telica-San Isidro Road , upgrading of the existing road section including improvement of road alignment (Project-6) was judged as unfeasible by the evaluation. On the other hand, Project-7, which is an alternative for Project-6 and consists of the improvement plan mentioned in Table 6-13, was judged as feasible with high indicators for the evaluation. (See Annexes A6.10 for more details)

Table 6-13 Work Items for Project-6 and Project-7 (Telica-San Isidro Road)

Work Item	Contents of the Implementation	
	Project-6	Project-7
Asphalt Course	95.8 km (Whole Section)	95.8 km (Whole Section)
Base Course	95.8 km (Whole Section)	40.8 km
Shoulder	95.8 km (Whole Section)	20.0 km
Drainage	95.8 km (Whole Section)	66.8 km
Alignment Improvement Section	2 sections	–
Length of Alignment Improvement	Approx. 1.7 km	–

From the results of the evaluation, it is recommended to implement the improvement of the asphalt course for the whole section and partial improvement of the base course, shoulder and drainage for a certain stretch of the Project Road. It is also recommended that the road classification of this Project Road will be upgraded to a level proposed in Chapter 5 in compliance with the increase of traffic volume in the future.

6.5 SENSIBILITY ANALYSIS

Project costs and benefits could be changed by estimation errors, unexpected socio-economic changes, etc.; therefore, a sensitivity analysis was performed. In this analysis, the project costs (only initial costs) and benefits were assumed to change within a range of ±10% and ±30%. As shown in the Table 6-14, all projects except the one for the Telica-San Isidro Road would continue to be feasible even if costs were increased by 20%.

Table 6-14 Sensitivity Analysis Results

Project-1

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	46.00	42.91	39.66	36.21
	NPV	256,409	225,154	193,899	162,643
	B/C	5.56	5.00	4.45	3.89
-10 %	IRR	43.20	40.27	37.18	33.91
	NPV	250,922	219,667	188,412	157,156
	B/C	5.06	4.56	4.05	3.55
-20 %	IRR	40.77	37.97	35.03	31.91
	NPV	245,435	214,180	182,925	151,669
	B/C	4.65	4.19	3.72	3.26
-30 %	IRR	38.64	35.96	33.14	30.16
	NPV	239,948	208,693	177,438	146,182
	B/C	4.30	3.87	3.44	3.01

Project-2

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	41.97	38.95	35.79	32.46
	NPV	235,530	205,212	174,893	144,575
	B/C	4.48	4.03	3.59	3.14
-10 %	IRR	39.24	36.39	33.39	30.23
	NPV	228,892	198,574	168,225	137,937
	B/C	4.08	3.67	3.26	2.86
-20 %	IRR	36.88	34.16	31.31	28.32
	NPV	222,254	191,936	161,617	131,412
	B/C	3.75	3.37	3.00	2.62
-30 %	IRR	34.80	32.21	29.49	26.61
	NPV	215,616	185,298	154,979	124,661
	B/C	3.46	3.12	2.77	2.42

Project-3

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	38.43	35.67	32.78	29.74
	NPV	213,505	185,296	157,087	128,879
	B/C	4.10	3.69	3.28	2.87
-10 %	IRR	35.94	33.33	30.60	27.72
	NPV	206,879	178,670	150,462	122,253
	B/C	3.74	3.37	2.99	2.62
-20 %	IRR	33.78	31.31	28.71	25.97
	NPV	200,253	172,044	143,836	115,627
	B/C	3.44	3.09	2.75	2.41
-30 %	IRR	31.90	29.53	27.06	24.44
	NPV	193,627	165,419	137,210	109,001
	B/C	3.18	2.86	2.54	2.23

Project-4

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	31.90	30.30	28.69	27.07
	NPV	11,909	10,893	9,877	8,861
	B/C	2.38	2.26	2.14	2.03
-10 %	IRR	29.00	27.53	26.06	24.57
	NPV	11,087	10,071	9,055	8,039
	B/C	2.17	2.06	1.96	1.85
-20 %	IRR	26.57	25.21	23.84	22.46
	NPV	10,264	9,249	8,233	7,217
	B/C	2.00	1.90	1.80	1.70
-30 %	IRR	24.49	23.22	21.94	20.65
	NPV	9,442	8,427	7,411	6,395
	B/C	1.85	1.76	1.67	1.58

Project-5

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	21.07	20.25	19.41	18.55
	NPV	120,358	108,108	95,858	83,608
	B/C	1.80	1.72	1.64	1.55
-10 %	IRR	19.45	18.67	17.87	17.06
	NPV	105,958	93,708	81,458	69,209
	B/C	1.65	1.57	1.49	1.42
-20 %	IRR	18.04	17.30	16.54	15.76
	NPV	91,558	79,308	67,058	54,809
	B/C	1.51	1.44	1.37	1.30
-30 %	IRR	16.80	16.09	15.36	14.62
	NPV	77,158	64,908	52,659	40,409
	B/C	1.40	1.33	1.27	1.21

Project-6

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	4.42	3.18	1.82	0.31
	NPV	-73,239	-82,544	-91,849	-101,154
	B/C	0.53	0.48	0.43	0.37
-10 %	IRR	3.45	2.25	0.93	-0.54
	NPV	88,901	-98,206	-107,510	-116,815
	B/C	0.49	0.44	0.39	0.34
-20 %	IRR	2.59	1.43	0.15	-1.29
	NPV	-104,562	-113,867	-123,172	-132,477
	B/C	0.45	0.40	0.36	0.31
-30 %	IRR	1.83	0.69	-0.56	-1.96
	NPV	-120,223	-129,528	-138,833	-148,138
	B/C	0.41	0.37	0.33	0.29

Project-7

Initial Cost		Benefit 0 %	-10 %	-20 %	-30 %
0 %	IRR	12.24	10.53	8.67	6.61
	NPV	1,392	-7,676	-16,676	-25,675
	B/C	1.02	0.91	0.81	0.71
-10 %	IRR	11.22	9.53	7.69	5.63
	NPV	-4,369	-13,369	-22,368	-31,368
	B/C	0.95	0.86	0.76	0.67
-20 %	IRR	10.27	8.60	6.76	4.70
	NPV	-10,062	-19,061	-28,061	-37,060
	B/C	0.90	0.81	0.72	0.63
-30 %	IRR	9.38	7.72	5.88	3.81
	NPV	-15,754	-24,754	-33,753	-42,753
	B/C	0.85	0.77	0.68	0.60

6.6 IMPACT OF THE PROJECT

Besides the above-mentioned effects on selected projects, each project would also have the following impact.

(1) Managua-Masaya Road

① The 4-lane road proposed in the Study would further strengthen its function as a major trunk road in Nicaragua.

② The high grade of the road would be influential in the construction or reconstruction of other trunk roads in the future.

③ Expanding the road capacity would contribute to development of socio-economic activities along the road, such as the opening of restaurants, petrol kiosks, and other shops for road users.

(2) Managua-Tipitapa Road

① Since Tipitapa is becoming a bed town of Managua, improving this section would provide residents with greater commuting convenience, so that they could go shopping to Managua from Tipitapa, San Benito, etc.

② The improvement would make the transport of agricultural products from agricultural area to Managua, the largest consumption area in Nicaragua , much smoother.

(3) Nandaime-San Benito Road

① Improving the Central American Highway in Nicaragua would facilitate international transport, especially by heavy vehicles, on this road.

② The eastern part of Managua would be closer to Masaya as travel time would be shortened.

(4) Telica - San Isidro Road

① East-west transport would become more convenient.

② The transport of agricultural products for export from Region VI would be facilitated.

6.7 PROJECT FINANCE CONSIDERATIONS

It is necessary to prepare finance sources for execution of the project, as the procurement of project capital is a little difficult for the executing agency, MCT.

According to MCT, maintenance expenditures for paved roads in 1992 and 1993 totalled about 3 million Córdobas per year. "Programa de Inversiones de Pública 1993" proved that the MCT budget was 61 million Córdobas, and 27 million Córdobas were allocated to the road sector (not including foreign aid). Considering the above present financial situation of MCT, low-interest-loans should be sought from international lending agencies or foreign donor countries to cover the costs of the project. In such a case, MCT should take into account the repayment of the loan on schedule.

Assuming the lending conditions mentioned below, annual repayment for each project is calculated to be as shown in Table 6-15.

- Repayment period : 20 years
- Grace Period : 3 years
- Interest Rate : 8 %

A repayment schedule for each project is attached in Annex A6.2.

Table 6-15 Annual Repayment Amount

(Unit : 1000 Córdobas))

Project No.	1997	1998	1999	2000-2016
Project-1	2,552	6,160	7,683	10,528
Project-2 *	2,193	5,247	7,282	9,980
Project-3	1,576	5,890	9,663	13,241
Project-4	0	0	1,300	1,782
Project-5	3,544	12,501	20,907	28,650
Project-6 *	3,149	12,374	22,949	31,448
Project-7	2,110	8,291	15,376	21,070

Note : Not recommended in the Study

Road and highway construction and maintenance costs are generally derived from the following sources.

① Increase in the share of the budget for the road sector

② City Planning Tax

③ Development Tax

④ Increase in the Fuel Surcharge Tax

⑤ Introduction or increase of the Automobile Tonnage Tax

Considering the present political and economic conditions of Nicaragua, however, it would be difficult to introduce the sources mentioned above.

Nevertheless, in pace with political and economic stabilization in Nicaragua, the above sources should be introduced as soon as possible.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

7.1.1 Necessity of the Project

The projects, which are to improve section of the national trunk roads, are of great importance for development of Nicaragua, and are expected to play the following important roles.

(1) Managua-Masaya Road

- To directly solve the problem of traffic congestion at the exit of Managua heading towards Masaya, and thereby eliminate one of the main traffic bottlenecks in Managua.
- To improve urban transport in the Managua region, where the increase in the number of vehicles has been remarkable.
- To strengthen and support the urban development of the area between Managua and Masaya, where housing developments have rapidly been cropping up as Managua City continues to expand.
- To partially contribute to the realization of high capacity transport in response to inter-regional and international transport demands.

(2) Managua-Tipitapa Road

- To strengthen and support the transport of agricultural products from the Central Regions, the major area of production, to Managua, the major center of consumption.
- To contribute to the realization of high capacity transport in response to interregional transport demand.

(3) Nandaime-San Benito Road

- To strengthen the trunk road network in the Managua-Masaya Metropolitan Area.
- To strengthen and support the transport of agricultural products from the Central Regions, the major area of production, to Managua, the major center of consumption.

- To contribute to the realization of high capacity transport in response to interregional and international traffic demands.

(4) Telica-San Isidro Road

- To contribute to the strengthening of east-west trunk roads in the nationwide road network.
- To contribute to the promotion of export by corresponding to the expected future increase in the transport of agricultural products from the Central Regions to the major port, Corinto.

7.1.2 Future Traffic

Traffic on national roads in Nicaragua has recently increased remarkably. Under such situation, total vehicular traffic demand along the Project Roads has been forecast as follows.

Table 7-1 Future Traffic Volume Projection

Project Road	Traffic Volume (veh./day)		
	1993	2000	2010
Managua-Masaya Road	22,100	28,500	43,500
Managua-Tipitapa Road	4,700	7,300	9,500
Nandaime-San Benito Road	4,200	5,300	7,700
Telica-San Isidro Road	300	700	1,100

7.1.3 Technical Aspects

The main design features are as follows:

① In implementing the Project, it was considered necessary to reserve two years to make financial arrangements, one year for tendering, and three years for construction. Therefore, in the Study, the above projects are expected to have a span of 20 years from the year 2000.

② The design speed for the project roads was determined on the basis of topographical conditions. The applied design speed for each project road is as follows:

- Managua-Masaya Road : 80 km/hr
- Managua-Tipitapa Road : 100 km/hr
- Nandaime-San Benito Road
  - Nandaime-Masaya Section : 80 km/hr
  - El Coyotepe-San Benito Section : 100 km/hr
- Telica-San Isidro Road
  - Telica-El Jicaral Section : 80 km/hr
  - El Jicaral-La Unión Section : 60 km/hr
  - La Unión-San Isidro Section : 80 km/hr

③ To ensure pedestrian safety, it was decided that sidewalks would be constructed in the densely populated area along the project roads and in the vicinity of schools. It was also proposed that busbays be installed at appropriate locations such as in the town, along the Project Roads, and at major intersections.

④ Flexible pavement was adopted because of the advantages it offered, such as lower initial investment costs and more comfortable riding conditions than rigid pavement. The pavement should be composed of a surface and binder course of asphaltic concrete, and a base course of mechanically stabilized crushed stone.

The shoulder should be composed of a surface course of asphaltic concrete and base course of mechanically stabilized crushed stone. The following thicknesses were determined to be appropriate:

• Carriageway	Surface Course	: 5 cm
	Binder Course	: 5 cm to 10 cm
	Base Course	: 15 cm to 30 cm
• Shoulder	Surface Course	: 5 cm
	Base Course	: 10 cm

⑤ To ensure adequate drainage, longitudinal side ditches should be installed not only in the cut section but also on the toe of the embankment slope. Lateral pipe/box culverts should also be installed at proper intervals.

(1) Managua-Masaya Road

① It will be necessary to widen this road to a 4-lane carriageway with a 4.0 m median to cope with the traffic demand projected for 2010.

② The intersection of Colonia Centro América should be improved by upgrading signalization to ensure adequate channeling of the carriageway and pedestrian bridge.

③ The existing El Coyotepe at-grade railway crossing can be maintained in its present state, since the railway operation was abandoned.

④ The existing La Morita Bridge and El Arroyo Bridge should both be replaced to handle heavier vehicle loads.

(2) Nandaime-San Benito Road

① Where bank erosion is likely along the Agua Agria River, stone masonry should be installed for both economical and practical reasons.

② A bypass connected to the existing NIC-1 between Managua and Tipitapa should be constructed on the El Coyotepe-Río Panamá Section to make it unnecessary to more land acquisition in the central area of Tipitapa City.

③ The existing El Arroyo Nº 1 Bridge should be replaced to handle the present greater vehicle load.

7.1.4 Environmental Aspects

The environmental impact study and its conclusions can be summarized as follows.
Firstly, the ten environmental items to be studied were selected, and their present state was investigated. Secondly, predictions and/or forecasts of how they would change because of the Project by 2000 and 2010 were prepared. Thirdly, the changes, i.e., impact of the Project, were evaluated with reference to the related Standards in Nicaragua, or in the U. S. A. or Japan, when necessary.

- Thirdly, the changes, i.e., impact of the Project, were evaluated with reference to the related Standards in Nicaragua, or in the U. S. A. or Japan, when necessary.

The results of the study can be summarized as follows:

- It is strongly recommended that a monitoring system for air quality, water quality, and noise and vibration, closely interrelated with traffic control, be established.
- A management plan to minimize the influence of the Project on land, soil, flora, landscape and social conditions was proposed.

7.1.5 Project Costs

The project costs were estimated to be as follows. From this, the cost of Managua-Entrada de Ticuantepe Section was estimated, including the cost of improving the Colonia Centro América intersection.

Table 7-2 Project Cost

Project Road	Project Cost (1,000 Córdobas)
Managua-Masaya Road	
- Managua-Entrada de Ticuantepe Section	96,031 *1 (118,801) *2
- Entrada de Ticuantepe-Masaya Section	120,782
Managua-Tipitapa Road	16,251
Nandaime-San Benito Road	261,332
Telica-San Isidro Road	286,856

Note - 1) : Improvement by at-grade for Colonia Centro América Intersection (Plan-1)
2) : Improvement by grade separation for Colonia Centro América Intersection (Plan-2)

7.1.6 Economic Analysis Results

Economic analysis followed the conventional discounted cash flow methodology in determining the EIRR, NPV and B/C ratio. The quantified economic benefits were the savings in vehicle operating costs, time costs, and maintenance costs. The obtained results indicated that the projects are highly feasible, except for the project involving Telica-San Isidro Road.

Managua-Entrada de Ticuantepe Section considered two technical alternatives, as mentioned in the footnote of Table 7-2. Following the economic evaluation, Plan-1 was determined to be the most recommendable.

Table 7-3 Economic Analysis Results

Project Road	IRR (%)	NPV	B/C
Managua-Masaya Road			
- Managua-Entrada de Ticuantepe Section	46.00	256,409	5.56
- Entrada de Ticuantepe-Masaya Section	38.43	213,505	4.10
Managua-Tipitapa Road	31.90	11,909	2.38
Nandaime-San Benito Road	21.07	120,358	1.80
Telica-San Isidro Road	12.24	1,392	1.02

7.2 RECOMMENDATIONS

7.2.1 Implementation of the Projects

The results of the Study indicate that the Project is technically sound (no serious technical difficulties during construction are anticipated) and economically feasible, except for the project involving Telica-San Isidro Road. Taking into account the direct and enormous indirect benefits (intangible benefits) on regional development besides the quantified savings in traveling costs, the Projects should be implemented at the earliest opportunity.

7.2.2 Matters Requiring Further Consideration

(1) Establishment of an Environmental Impact Monitoring System

Monitoring, especially of air pollution, water quality, noise and vibration, is necessary to preserve the environment during and after construction of the Project. Establishment of a system for this purpose in the detailed design stage is strongly recommended.

(2) Removal of Existing Utilities

The removal of utilities, such as underground mains and telephone and electric lines, were not taken into account in the Study. Therefore, detailed investigations and negotiations with the related offices during the detailed design stage of the project would be required.

(3) Necessity of Rehabilitation of the Managua-Masaya Road after 2010

The traffic demand on the Project Road in 2010 was forecast in the Study. Meanwhile, a preliminary engineering study and economic evaluation were carried out based on the predicted traffic volume after 2010. As the result, the Study proposed rehabilitation by overlaying pavement in 2014.

(4) Maintenance Program

Basically, maintenance work in Nicaragua is neither classified by implementation period nor scale. Hence, the maintenance program are required for the project roads, dividing the main maintenance activities into routine maintenance, periodic maintenance and incidental maintenance.

(5) Feasibility of the Project Involving Telica-San Isidro Road

For the Telica-San Isidro Road, upgrading of the existing road section including improvement of road alignment (Project-6) was judged as unfeasible by the evaluation. On the other hand, Project-7, consists of the partial improvement of the asphalt course, base course, shoulder and drainage, was judged as feasible with relatively high indicators for the evaluation.

Therefore, it is recommended to implement the improvement of the asphalt course for the whole section and partial improvement of the base course, shoulder and drainage for a certain stretch of the Project Road. It is also recommended that the road classification of this Project Road will be upgraded to a level proposed in Chapter 5 in compliance with the increase of traffic volume in the future.

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