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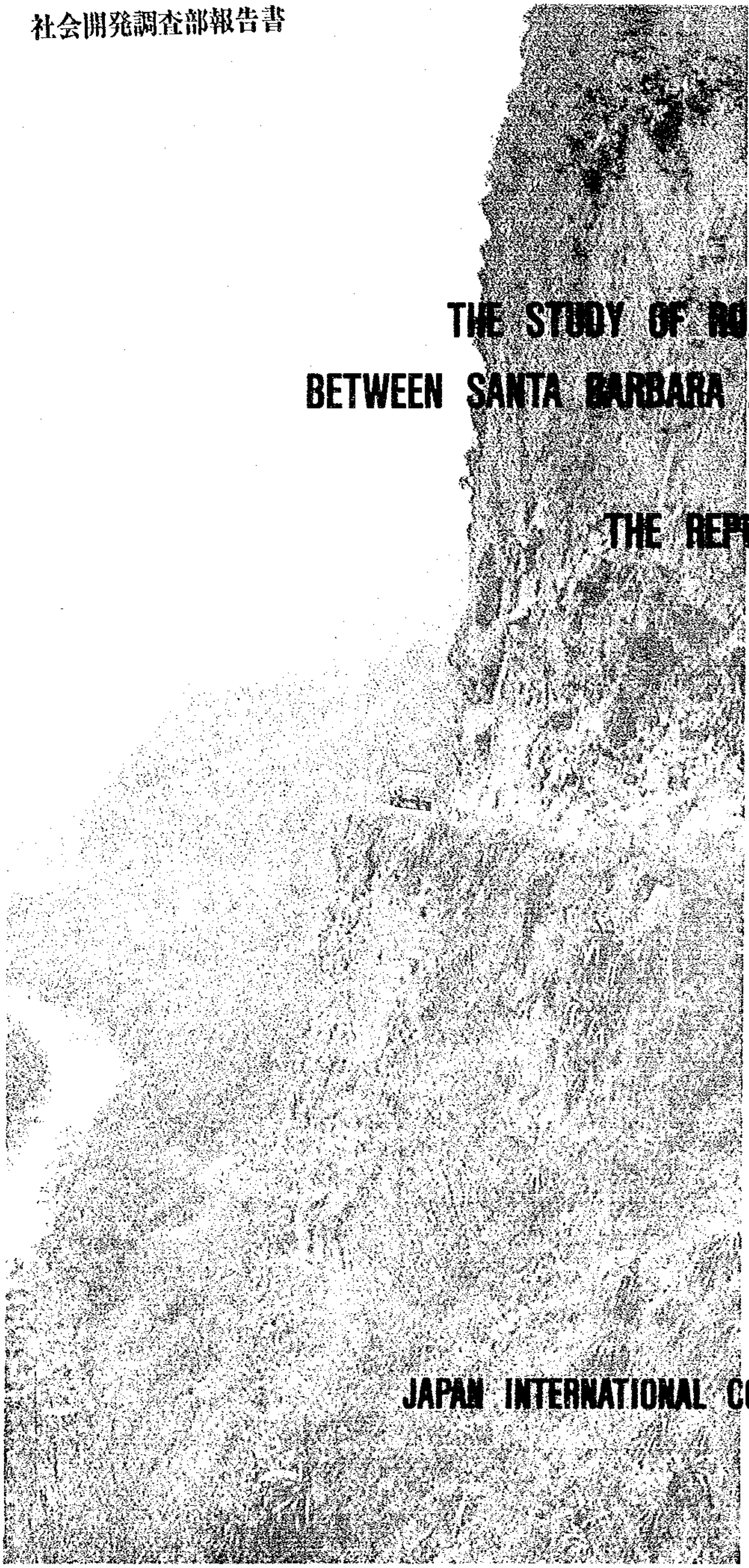

THE STUDY OF ROAD IMPROVEMENT BETWEEN SANTA BARBARA AND BELLA VISTA IN THE REPUBLIC OF BOLIVIA

FINAL REPORT

SUMMARY

MARCH 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of Bolivia, the Japanese Government decided to conduct a Study of Road Improvement between Santa Barbara and Bella Vista and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bolivia a study team headed by Mr. Takashi Tachikawa, and composed of members from Central Consultant Inc., Nippon Koei Co., Ltd. and Kokusai Kogyo Co., Ltd., from August 1989 to December 1990.

The team held discussions with the officials concerned of the Government of the Republic of Bolivia, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the road development and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Bolivia for their close cooperation extended to the team.

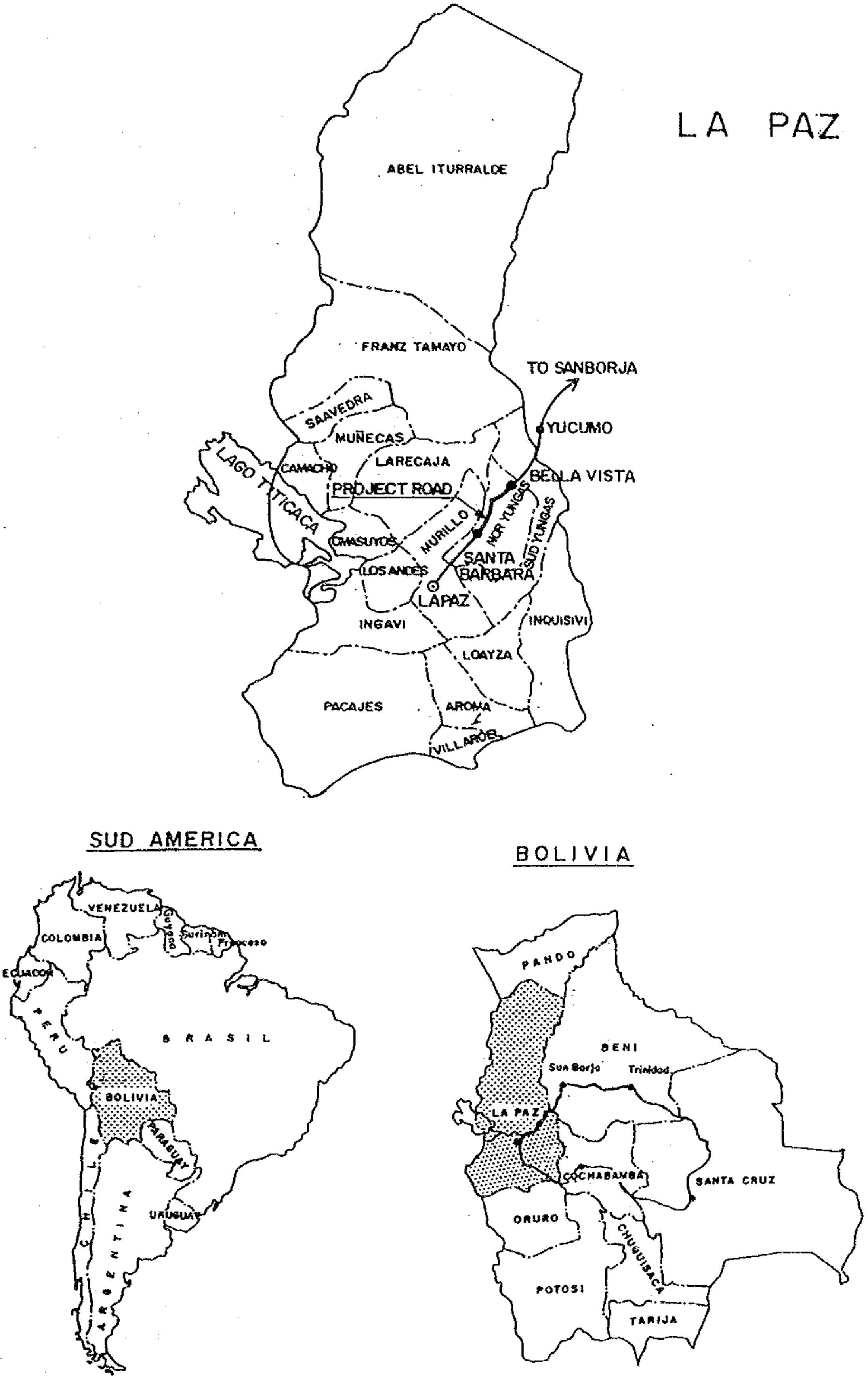
March 1991

Kensuke Yanagiya

Kensuke Yanagiya

President

Japan International Cooperation Agency



The Study of Rord Improvement between Santa Barbara and Bella Vista

Location Map

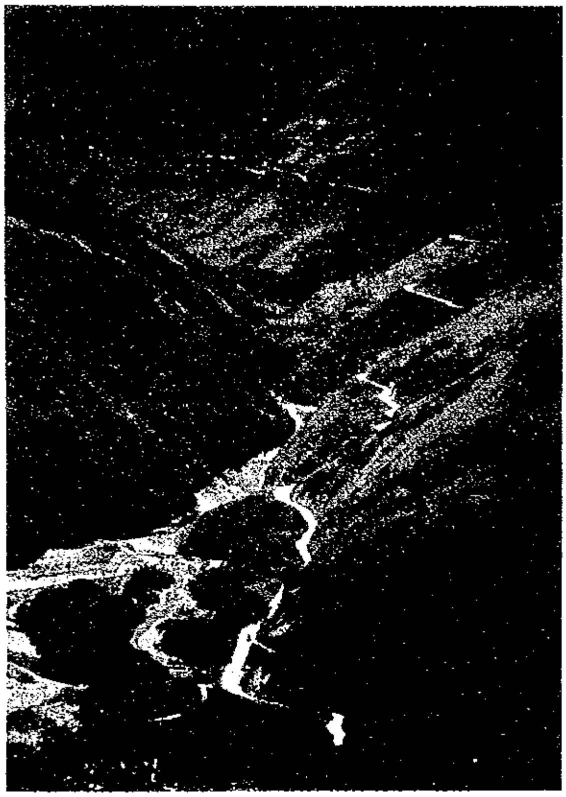


Photo-1
Scene of the present road from Santa Bárbara Bridge (foreground of photo) in the direction of Choro.

Photo-2
Scene of damage due to a landslide near Point A (about 2.2 km from the point of origin; Santa Bárbara Bridge). The Landslide extends about 1 km alongside the road.

Photo-3
Scene of the present road near Challa about 10 km from the point of origin. The road passes a point of change in geographical gradient.

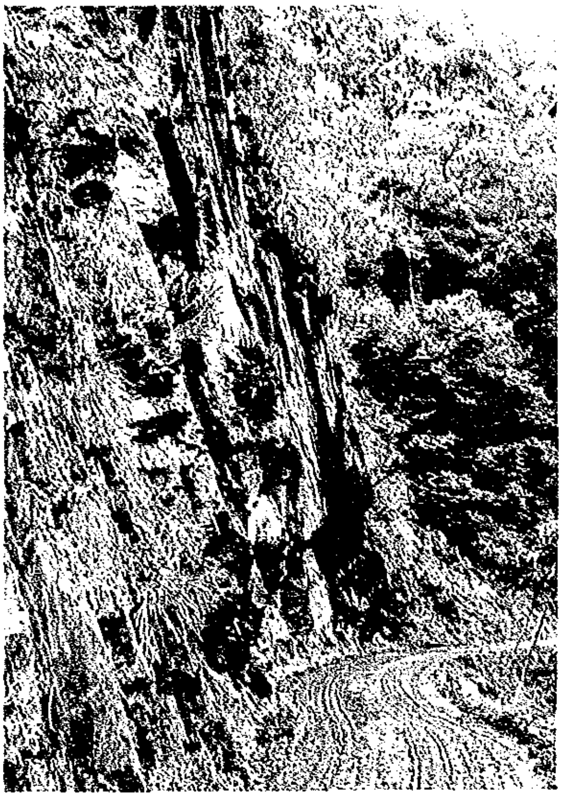


Photo-4
Aspect showing the narrow width and insufficient drainage facility on the present road at a location about 14 km from the point of origin.

Photo-5
Aspect showing overhang by the road near Puerto León about 35 km from the point of origin. One of the dangerous points for traffic on the study section.

Photo-6
Scene of the present truss bridge near Puerto León. The bridge is old and rotten and wooden slabs have been used in temporary treatment.

Photo-7
Scene of the present tunnel excavated without timber shoring at a location 35 km from the point of origin. The length of the tunnel is about 25 m with on-lane.

Photo-8
Scene of the present road and surrounding steep cliff 38 km from the point of origin. The section is located in an area having one of the most severe conditions of the whole extension.

Photo-9
Scene of the same location as Photo-8 taken from a far.

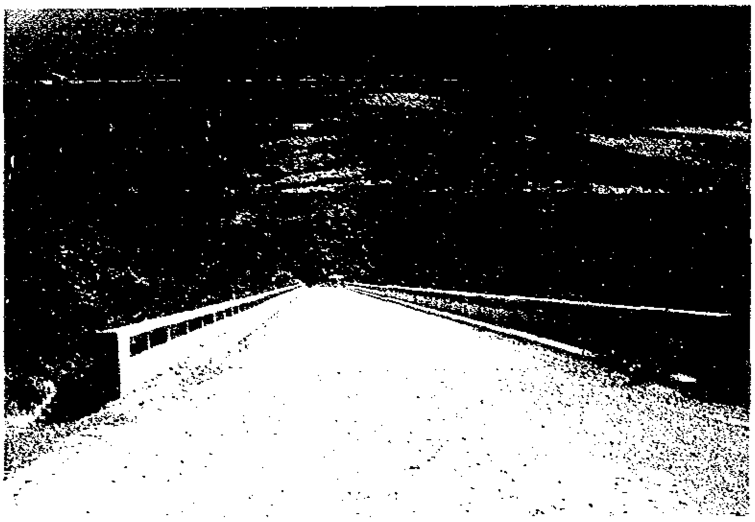


Photo-10
Yara Bridge constructed near the village of Yara. Only this bridge does not require reconstruction or improvement in the whole extension of the Study Road.

Photo-11
Scene of the location 116 km from the point of origin, where landslides occur now and then.

Photo-12
Scene of the present road condition at Bella Vista (terminal point of the Study Road). The road in the foreground of this photo has been already improved by the SNC.

The Study of Road Improvement
between Santa Bårbara and Bella Vista

CONTENTS OF THE REPORT

Summary

A. CONCLUSION

From the wide range of engineering and economic studies, undertaken by the Study Team for the Improvement Project of the 115.5Km Road from Santa Barbara to Bella Vista, the following conclusions were drawn:

(1) The total project and construction costs have in this case been estimated to be US$ 188 million and US$ 152 million, respectively.

Attention should be paid to the following points in the Project:

a) The extent of improvement (i.e. widening the existing road and constructing the detour route) is as follows:

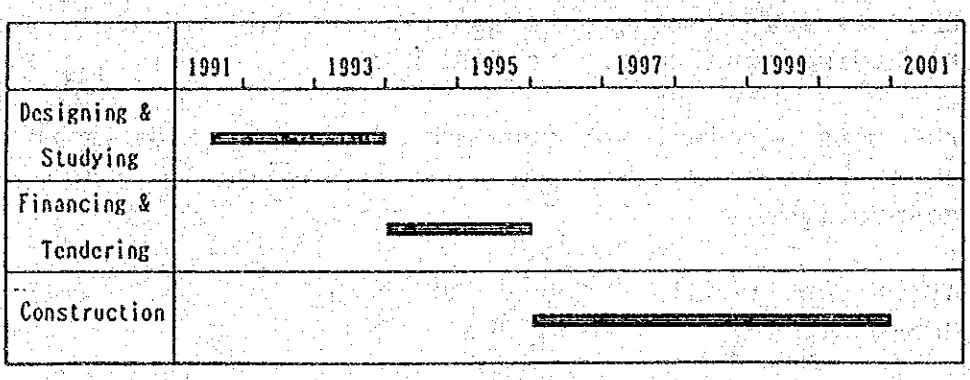
Total length : 108.63Km(existing road : 115.5Km)
by widening : 92.29Km(85%)
by construction : 16.34Km(15%)

b) The earthwork volume will be considerably large and will account for more than 60% of the total. Above all, 8.7 million cubic meters of soil, which is equivalent to 85% of the total volume cut, must be disposed of.

It was confirmed in the Study that it would be possible to locate sufficient spoil banks for disposing of the soil as described above. These would be in the vicinity of the project road and would minimize any environmental disturbance through careful planning and skillful utilization.

c) Since this Project includes large excavation volumes, it is considered that unavoidable disasters such as slope failure may possibly happen after completion of the earthwork operations. Therefore, a period of a few years will be required until the improved road will fully stabilize in this respect.

(2) The construction work for the Project has been assumed to commence in 1996. From the considerations and assumptions made up to this point, the chart below has been derived as the implementation schedule.



(3) The socio-economic effect from the Project has been estimated as follows:

- IRR (Internal Rate of Return) = 19.7%
- NPV (Net Present Value in 1990 price)= US$ 97,625,000

It can be considered that these values represent the significantly high degree of feasibility for this project in this country.

(4) It is recommended from the viewpoint of financial arrangement for the project execution, that the construction work be carried out together with an asphalt concrete surface layer of pavement.

The adoption of an asphalt macadam surface layer for pavement has not been accepted in the investigations:

(5) The Final Design of the Project to be carried out after this Study must include the following studies:

a) Topographic survey
b) Sounding of subsoil conditions
c) Material survey
d) Dividing the Project into sub-sections
e) Determination of spoil bank areas

B. SUMMARY OF VOLUME I

B.1 INTRODUCTION

B.1.1 Study Background

National Road No.3 is the most important road in Bolivia. It is classified as a trunk road in the nation-wide road network system that connects the La Paz area to the northern low flatland, which has a great potential for agricultural and livestock development. However, the actual situation of this road, such as it's surface conditions, drainage facilities, slope conditions and road width is fairly poor for the currently increasing traffic volume.

As a result of successive efforts made by the governments in recent decades, upgrading work on a few sections of this road up to the level of all weather type with 2-lanes, have been carried out or are presently commencing. Viewing these present situation of the road, improvement for the objective road section between Santa Bårbara and Bella Vista can be seen to be certainly required.

In other words, once improvement work between Cotapata and Santa Barbara, between Bella Vista and Yucumo as well as between San Borja and Trinidad are completed in the near future, the section from Santa Barbara to Bella Vista would become a bottle neck for traffic, as it would be the only section where the road width is only one lane and its geometric alignment is very poor.

Due to this situation, the Government of Bolivia intends to improve this section, and has requested the Japanese Government to conduct all necessary studies for this purpose as a bi-national technical cooperation effort. In response to this request, the Japanese Government have decided to carry out a Feasibility Study on the Road Improvement project between Santa Barbara and Bella Vista.

B.1.2 Objectives of the study

The objectives of this Study were to carry out a technical analysis and to examine and evaluate the socio-economic influence of the road improvement work between Santa Bàrbara and Bella Vista, and also to allow transfer of technology to Bolivian technical personnel during the course of the study.

B.1.3 Chronicle of the Study

The following studies were conducted;

1) From August 1989 to September 1989

a) Data collection and analysis
b) Socio-economic analysis
c) Traffic survey and analysis
d) Soil and geological survey
e) Topographic survey

2) From December 1989 to March 1990

a) Determination of design criteria
b) Future traffic forecast
c) Study of alternatives
d) Selection of optimum alternative

3) From July 1990 to December 1990

a) Preliminary design
b) Cost estimation
c) Economic evaluation

B.1.4 Reports

The following reports were submitted to SNC.

a) Inception Report, August 1989
b) Interim Report, March 1990
c) Draft Final Report, December 1990

B.2 PRESENT ROAD CONDITIONS

B.2.1 Road Network System in Bolivia

The existing road network system in Bolivia is illustrated in Fig. B-1, in which the roads are classified as Trunk or First Class National Roads and Sub-trunk or Second Class National Roads.

B.2.2 Road Conditions in the Objective Section

The actual horizontal alignment for the existing road was found not to be very good. There exist many substandard curves with small radii and hardly any straight sections throughout the study section from Santa Barbara to Bella Vista. As a result, the sight distance for drivers is too short, causing serious traffic accidents.

Basically, the vertical alignment of the existing road descends along to the Coroico River from Santa Barbara to Caranavi. However, there are several points where the road keeps away from dangerous cliffs or goes down to cross a valley. These sections have a vertical gradient of more than 7%. In addition, between Caranavi and Bella Vista, there are many places where the vertical gradient of the road is considerably steep as the road has to cross a ridge of more than 1,500 meters in height.

On the other hand, fourteen(14) bridges exist on the study road. A survey of these existing bridges was performed in order to fully understand grasp the actual condition of each structure, the characteristics of the geometric alignment for the approach roads and observe any visual damages in the bridges. As a result, only one bridge (Yara Bridge) is considered to be usable in the future.

With respect to disasters, more than ninety places along the existing road were examined and found to be potential disaster points, where slope failure, rock falls, land slides etc. will probably occur. Out of these potential disaster locations, forty six places were identified as requiring some preventative countermeasures.

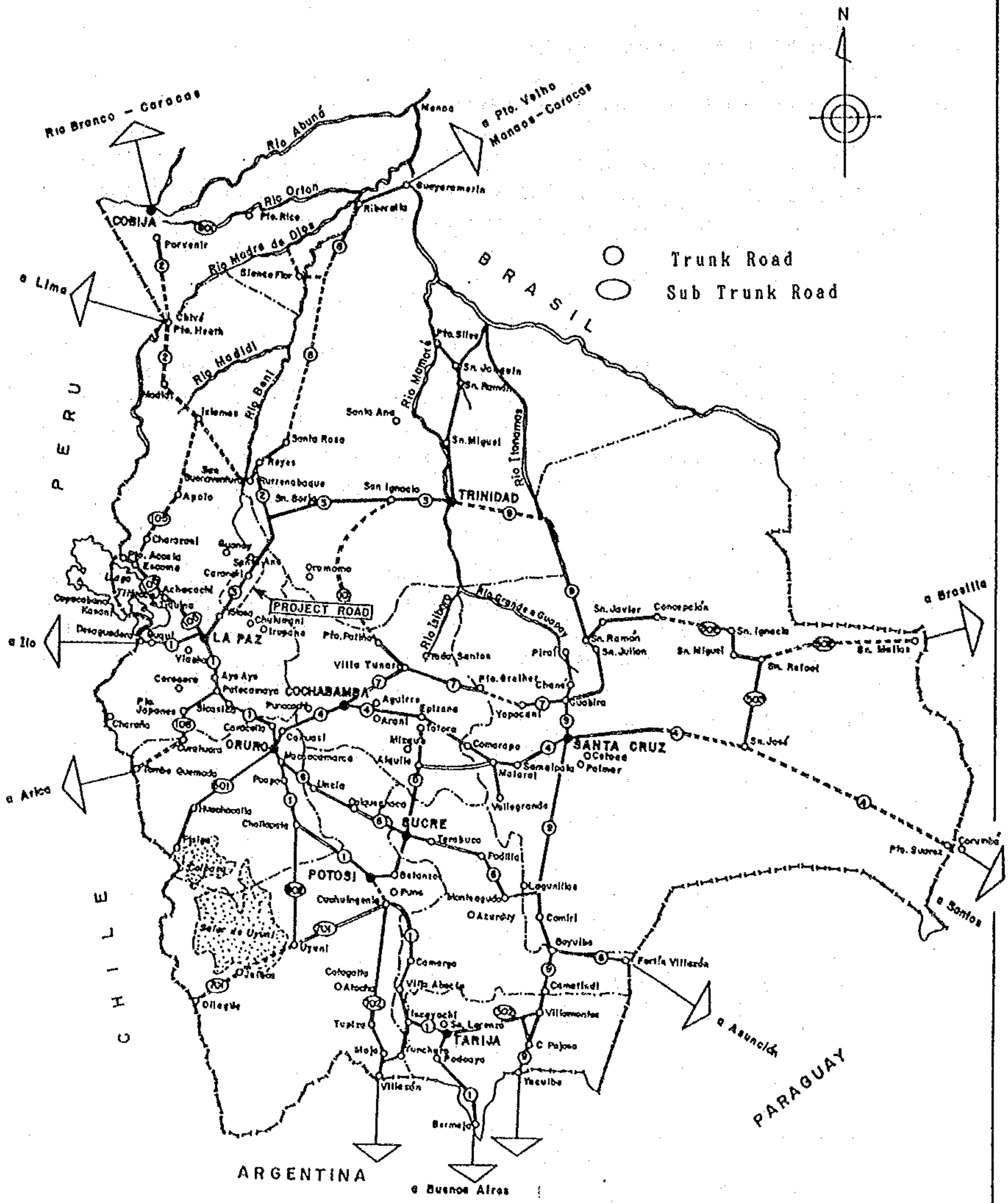


Fig. B-1 Road Network System in Bolivia

B.3 GEOLOGICAL INVESTIGATION

B.3.1 General

A geomorphological map is shown in Fig. B-2 and a geological map of northern Bolivia is shown in Fig. B-3.
Northern Bolivia is divided into six geological provinces stretching in belts from the north west to the south east. These provinces are titled;

(1) The West Andes
(2) Puna Surface (Altiplano)
(3) The East Andes
(4) Sub-Andes Zone
(5) Amazonian Lowland
(6) Brazilian Shield

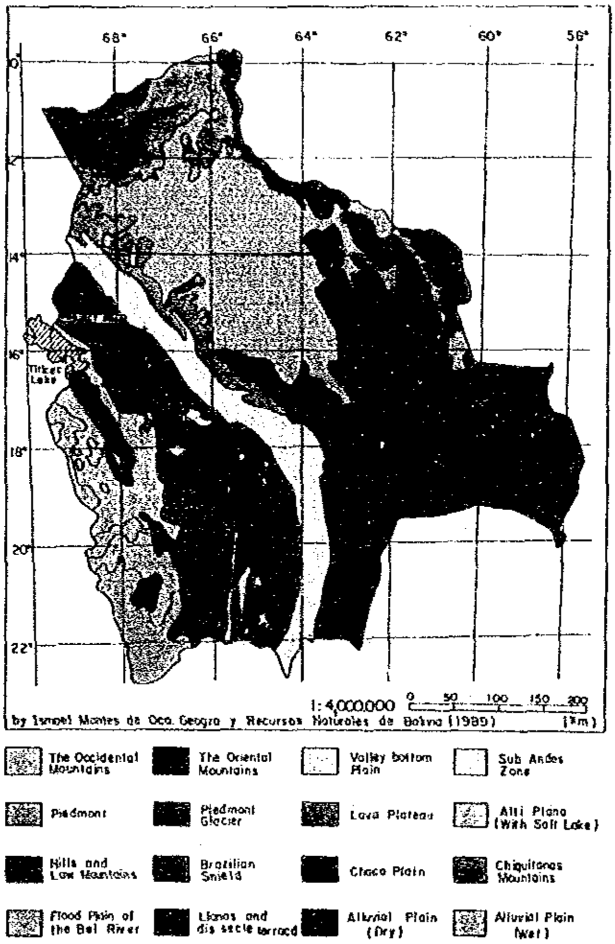


Fig. B-2 Geomorphological Map of the Bolivia

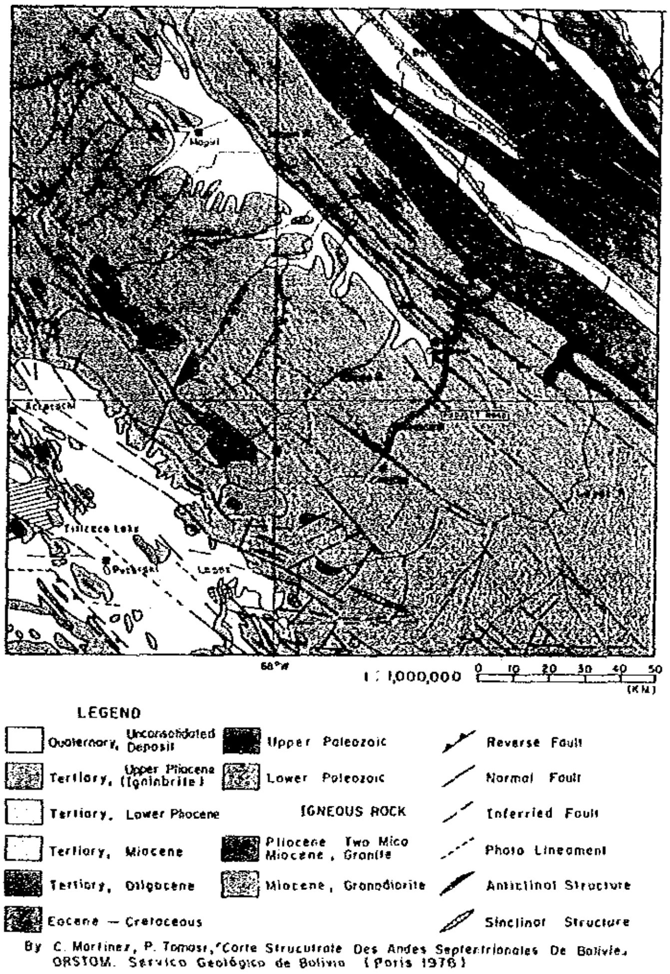


Fig. B-3 Geological Map of the Northern Bolivia

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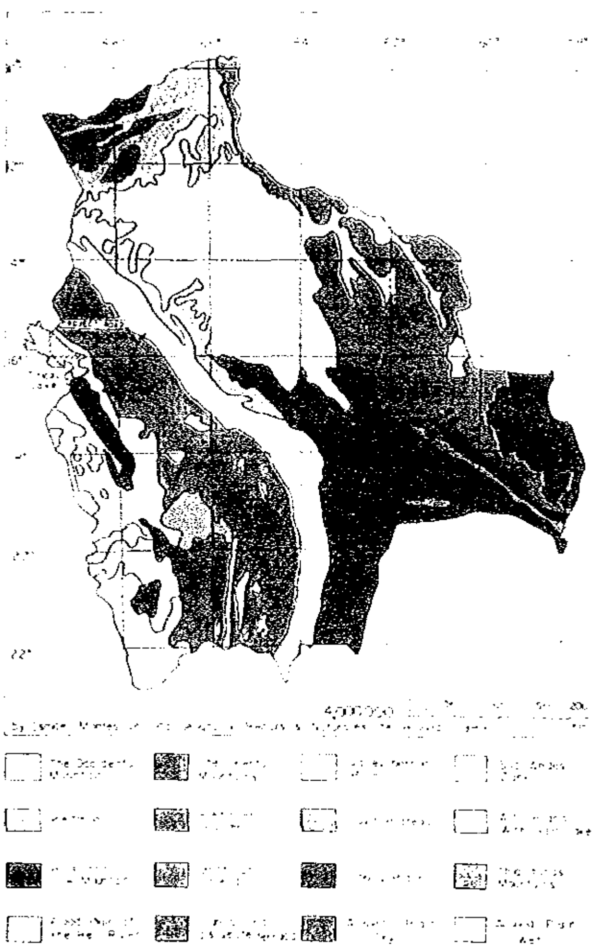


Fig.B-2 Geomorphological Map of the Bolivia

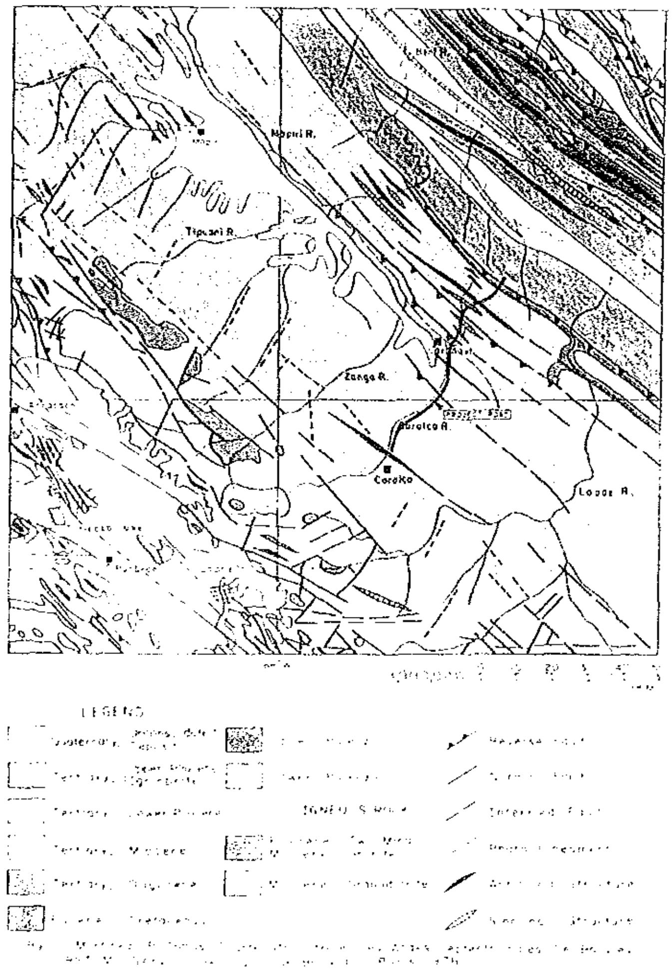


Fig.B-3 Geological Map of the Northern Bolivia

B.3.2 Description of Geological Formations

The area of geological investigation for the Study is located in the East Andes Range and the Sub-Andes Zone. Palaeozoic, Mesozoic and Cenozoic sedimentary rocks are found in this area. A geological map and its profile are shown in the "Geological Drawings" in the report titled "Drawings".

B.3.3 Geomorphological and Geological Problems for the Improvement of the Road

The disasters such as slope failure which were found in the Project area were categorized into the following 6 types:

(a) Slope failure (cut slope or natural slope)
(b) Embankment failure
(c) Rock falls
(d) Landslides
(e) Debris flow or earth flow
(f) Fractured zone along fault lines

At the same time, the stability of each place was also evaluated according to the following classification:

Grade I stable
Grade II unstable when it rains
Grade III unstable

The number of slopes investigated are shown by failure type and by stability grade in Table B-1.

Table B-1 Number of Failures by Type and Stability Grade

Type	a	b	c	d	e	f	Total
Grade							
I	22(20)	3(1)	6(5)	0(0)	3(3)	11(8)	45(37)
II	31(28)	3(2)	3(2)	0(0)	9(9)	5(0)	51(41) ┐*
III	12(12)	2(1)	2(1)	4(4)	2(1)	3(0)	25(19) ┘(60)
Total	65(60)	8(4)	11(8)	4(4)	14(13)	19(8)	121(97)

Note : Slope failures in some places out of the 97 locations were considered to occur as the complex failures of more than two types. The number of failures counted separately are shown without parentheses, and those in parentheses indicate the number of slope failure locations. That is, 121 failures have been observed in 97 spots in total. The number with an asterisk, 60, coincides with that in Table 2.3-12 in Chapter 2 of Volume I.

B.3.4 Drilling Survey

Drilling surveys and laboratory tests on the rocks obtained, were carried out at six locations in the Study area. The total length of boring was 87.2 m.
Standard Penetration Tests (SPT) were conducted for the soft ground of talus deposits and very weathered Tertiary rock. Core samples of hard rock obtained by drilling were transported to the SNC Laboratory to undergo Unconfined Compression Tests (UCT).

Results of the survey and tests are tabulated in Table B-2.

Table B-2 Summary of Drilling and Tests

Boring No.	Location (Km.)	Geological Type	Length of Drilling (m)	Standard Penetration Test (Times)	Unconfined Compression Test (Piece)	Specific Gravity Test (Piece)
P1	0.9	Talus (Quaternary)	10.6	10	-	-
P2	8.9	Slate (Paleozoic)	15.0	-	2	2
P3	37.8	Slate (Paleozoic)	15.5	-	26	26
P4	81.8	Weathered Mudstone (Paleozoic)	15.5	-	-	-
P5	105.2	Sandstone (Mesozoic)	15.5	-	5	5
P6	112.2	Weathered Mudstone (Tertiary)	15.1	15	-	-
Total	-	-	87.2	25	33	33

B.4 BASIC STUDY ON ROAD IMPROVEMENT

B.4.1 Fundamental Problems with the Existing Road

Actual Problems

(1) Excessive transportation costs.

Due to poor road conditions, the practical running speed of vehicles is fairly slow, and hence, it takes a lot of time to pass along this section. Coupled with the fact that the rate of wear and tear on vehicles is higher here than that on a road with normal conditions (due to the irregular, rough road surface), passing along this road is much more costly, compared with other roads.

(2) Driver exhaustion.

The presence of dilapidated bridges, narrow road sections with numerous small curves and short sight distances make drivers and passengers physically and mentally exhausted.

(3) Frequent road closure.

Disasters such as slope failure, rock fall and shoulder displacement often force the road to be closed. Due to the lack of an efficient information system, in many cases of road closure caused by the above-mentioned disasters, vehicles have to wait for the completion of repair work at the disaster site, after arriving without previous notice of that road closure. Repair of these disasters is not always efficient or effective and this frequently prolongs the closure period.

(4) Source of severe traffic accidents.

Once traffic accidents occur on the road , the damage usually becomes seriously severe since the vehicles often plummet over the edge into the valley.

Causes of the Problems

(a) Poor geometric (horizontal and vertical) alignment
(b) Insufficient cross sectional width and composition

(c) Poor road surface treatment
(d) Presence of dangerous structures
(e) Insufficient disaster prevention and drainage facilities
(f) Absence of traffic safety facilities and sign boards

B.4.2 Design Standard and Criteria

Road classification and geometric design criteria adopted in the Study are tabulated in Table B-3. A typical Cross Section is indicated in Fig. B-4.

Table B-3 Geometric Design Criteria for Study

Road classification		Class I.B, very mountainous	
Design vehicle		semi-trailer truck (WB-40)	*1
Design speed		40 km/h	
Stopping sight distance		45 m	
Passing sight distance		160 m	
Radius of horizontal alignment	desirable :	> 50 m	*2
	minimum :	= 45 m	
Superelevation rates	desirable :	< 8 %	*2
	maximum :	= 10 %	
Minimum radius for 2% superelevation of	(minimum)	300 m	*3
Minimum radius without superelevation		1400 m	
Grades for vertical alignment	desirable :	< 6 %	
	maximum :	= 8 %	*4
K-value : concave vertical curves	desirable :	12	
	minimum	11	
: convex vertical curves	desirable :	10	
	minimum :	9	
Normal cross slope		2 %	
Lane widths		3.50 m	
Widening on curves for two lanes	250 m<R<300 m :	0.4 m	*2
(R = Radius of horizontal curves)	145 <R<250 :	0.7 m	
	100 <R<145 :	1.0 m	
	80 <R<100 :	1.3 m	
	65 <R< 80 :	1.6 m	
	55 <R< 65 :	1.9 m	
	45 <R< 55 :	2.2 m	
Shoulder width	normal :	1.0 m	*2
	exceptional :	0.6 m	*2
Total width of cross section		>10.4 m	*2
Width of side ditch		1.0 m	
Clearance Height		>5.5 m	

Note: *1 "Norma" has a category of SR (Semi-trailer), which is equivalent to WB-50 in AASHTO Specification, but one equal to WB-40 in AASHTO's. "(3) *Items out of "Norma"" in this section.*
*2 See, "(3) Items out of "Norma"".
*3 Minimum superelevation 2 % coincides to normal cross slope.
*4 A continuous length of road with a7-8% grade must be less than 400 m.

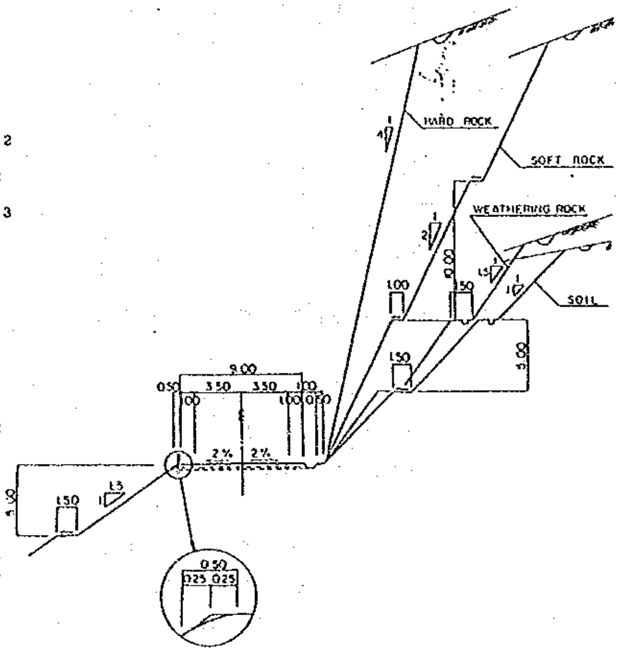


Fig. B-4 Typical Cross Section

B.4.3 Geometric Alignment Alternatives

It can be said that the existing road alignment almost follows the shortest route between Santa Barbara and Bella Vista. Viewing the surrounding topography, it is impossible to find a more advantageous route to construct the new alignment than the existing route. Therefore, the alignment for improvement must basically be similar to that of the existing road.

For road improvement in this case, widening of the road up to two lanes is one of the primary study items. It has been confirmed in the Study that the widening of the existing road is apparently the most favorable, especially from an economic viewpoint, comparing with other ideas such as construction of a separate pavement for a dual carriage way.

Based on this understanding, a geometric improvement has been made mainly for limited sub-sections below where;

1) The horizontal or vertical alignment of the existing road does not comply with the targets criteria in the Study.
2) It is considered better to change the road alignment so as to avoid damage, since a disaster is likely to occur in the future.

As the result of the Study, the following places have been selected for new alignment upgrade.

<u>New Alignments</u>

- Around Point A	L= 0.13 km (0.1%)
- From Point H+2.5 km to I+0.35 km	L= 0.83 km (0.8%)
- Around Point L	L= 2.41 km (2.2%)
- Around Point O+1.8 km	L= 0.50 km (0.5%)
- Around Point Q+5.0 km	L= 1.20 km (1.1%)
- From Point S to V	L= 11.27 km (10.3%)
Sub-Total	L= 16.34 km (15.0%)
<u>Improvement along the Existing Alignment</u>	L= 92.29 Km (85.0%)
Total	L=108.63 km (100%)

B.4.4 Study of the Bridges

A study of bridge construction has been carried out according to the flow chart given in Fig. B-5.

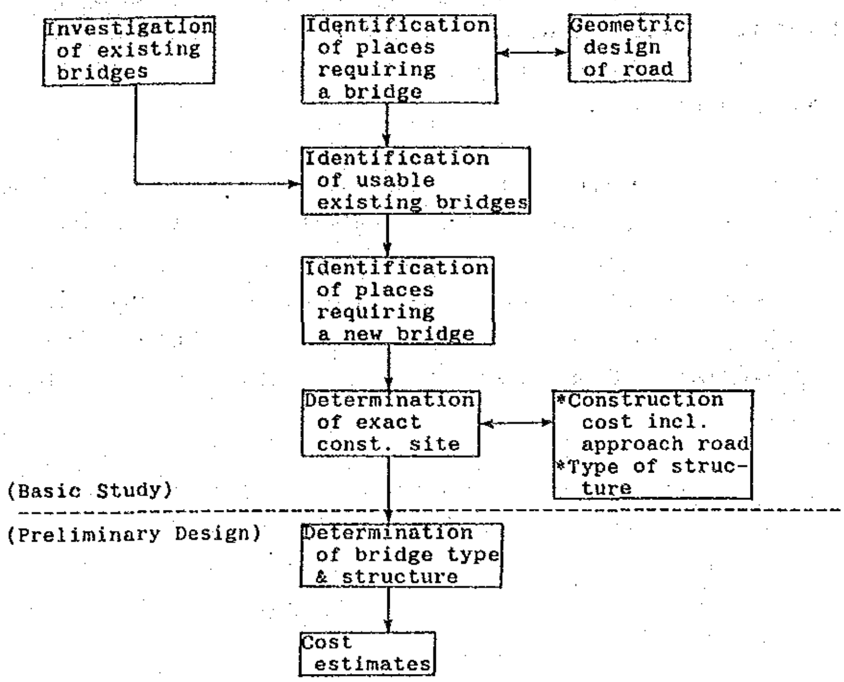


Fig.B-5 Flow Chart for the Study on Bridges

The Study on bridges identified that none of the existing bridges except for the Yara Bridge could be used in the future. Therefore, the bridges shown in Table B-4 should be reconstructed during the improvement work of the project road.

There is no existing bridges at Point A, but it has been considered that a new bridge will be necessary at this location.

Table B.4 Summary of Required New Bridges

Name of Bridge	Name of River	Location of Bridge	Length of Bridge	Horizontal Curvature
Point (A)	---	250 m downstream from exist. brid.	L=132.5 m	R=50- -50 m
Patuni	Patuni	45 m downstream from exist. brid.	L=40 m	R=50 m
Challa	Challa	15 m downstream from exist. brid.	L=20 m	R=50 m
Cascada	Cala Cala	the same location as exist. brid.	L=18.5 m	R=1200 m
Alto Choro	Choro	20 m downstream from exist. brid.	L=50 m	R=50 m
Pto. Leon	Quitacarzon	30 m downstream from exist. brid.	L=75 m	straight
Cajones	Cajones	the same location as exist. brid.	L=25 m	R=400 m
Chojña	Chojña	the same location as exist. brid.	L=22 m	straight
San Silverio	San Silverio	30 m downstream from exist. brid.	L=50 m	R=50 m
San Lorenzo	San Lorenzo	50 m downstream from exist. brid.	L=52 m	R=50 m
Espiritu	Espiritu	40 m downstream from exist. brid.	L=52 m	R=50 m
Carrasco	Carrasco	20 m upstream from exist. brid.	L=30 m	R=60 m S-curve
Avaroa	Mula Jihuata	15 m downstream from exist. brid.	L=25 m	R=50 m

B.4.5 Facilities Required for Disaster Prevention

A study on disaster prevention has been carried out according to the flow chart given in Fig. B-6.

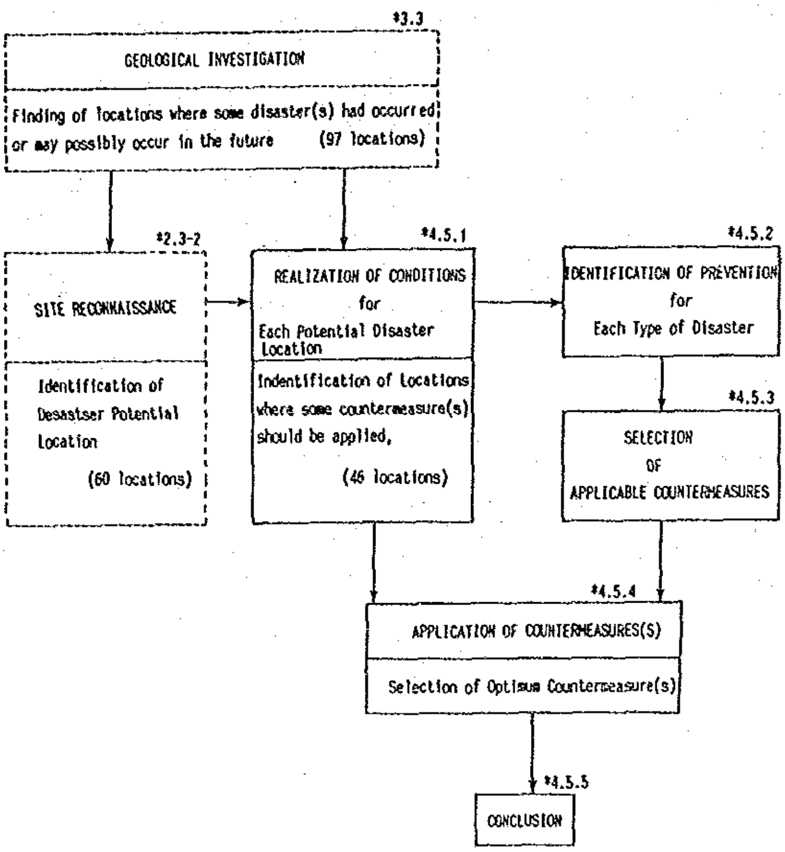


Fig. B-6 Countermeasure Selection Methodology

1) Determination of Conditions for Each Potential Disaster Point

In the disaster prevention study, it was shown that an improvement in road alignment could avoid damage resulting from disasters at several points out of the specified 60 potential disaster locations. Consequently, disaster prevention countermeasures have been set up at 46 locations.

2) Identification of Prevention for Each Type of Disaster

46 disaster locations have been categorized into the following 4 types, and countermeasures for each type of disaster are proposed as follows;

Type A : Slope failure	Slope Protection Works (incl. Retaining wall)
Type C : Rock fall	Catch works
Type D : Landslide	Prevent permeation of ground water into sub-soil
Type E : Debris/earth flow	Catch works for debris

3) Selection of Applicable Countermeasures

Applicable countermeasures were selected against each type of disaster, considering the topographical and geological conditions at each location.

4) Application of Countermeasures for each spot

The optimum countermeasure for each spot was selected through comparison of countermeasures derived from the view point of cost and/or the site condition. As a result, 11 types of optimum countermeasures were selected as shown in Table B-5.

Table B-5 Adopted Countermeasure

Adopted Countermeasure	Number of Countermeasures		
	Grade II location	Grade III location	Total
Type 1 Concrete Spraying	8	1*	9
Type 2 Stone Masonry Retaining Wall	3	-	3
Type 3 Concrete Crib with Concrete Spraying and Anchoring	7	6	13
Type 5 Concrete Pitching and Anchoring	1	2	3
Type 6 Grid Type Concrete Retaining Wall	3	3	6
Type 9 Catch Netting	3	0	3
Type 10 Gabion Catch Wall	2	0	2
Type 11 Catch Fence installed at road side	2	1	3
Type 14 Sub-surface Drainage for Landslide	0	4	4
Type 15 Gabion Dam for Debris/earth Flow	5	-	5
Type 17 Debris/earth Flow Shed	0	1	1
Total number of Countermeasures	34	18	52
Number of Locations having two countermeasures	5	1	6
Total number of Spots requiring countermeasures	29	17	46

* It was adopted to a peculiar location.(Refer to Table 4.5-3(1))

B.5 PRELIMINARY DESIGN

B.5.1 Preliminary Road Design

(1) Horizontal and Vertical Alignment Design :

Horizontal and vertical alignment design were carried out, on the basis of the results gained from precise field investigations and topographical and geological surveys on existing structures. As for the fundamental design conditions, the design criteria established in Section B.4.2 have been employed.

(2) Cross Sectional Design

Typical cross sections of the road for several sites with representative topographical and geological conditions were

established in Section B.4.2. Furthermore, cross sectional profiles at about 100 meters intervals along the proposed road alignment were prepared for the purpose of calculation of earthwork volume in the Project.
In preparing these profiles, the results of geological survey and disaster prevention study were closely referred.

(3) Pavement Design

The pavement structure was designed according to the Guide for Design of Pavement Structure (AASHTO, 1986). As it was considered that bearing strength of roadbed (subgrade) material at a few sub-sections in the Project area was not insufficient, replacement of roadbed soil with better material was recommended to solve this problem.
The result of design is shown in Fig. B-7.

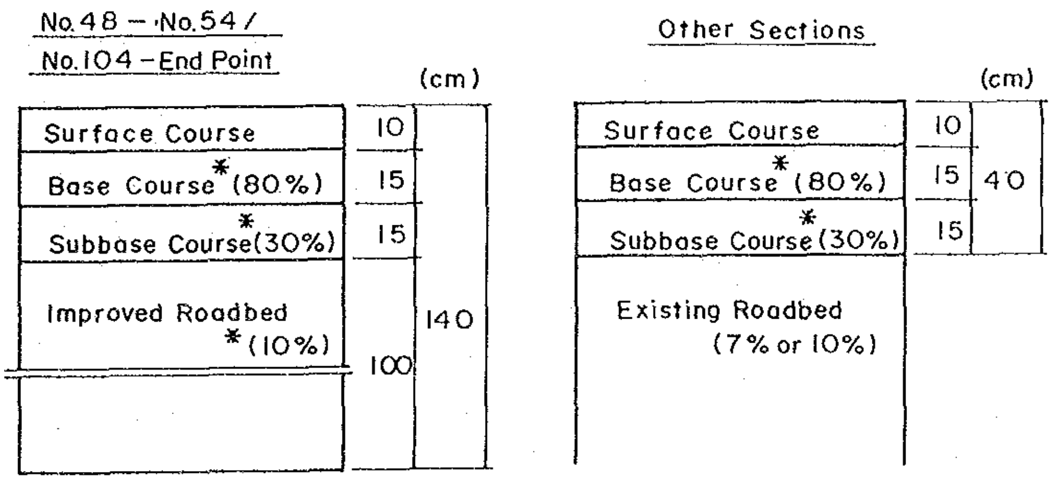


Fig. B-7 Recommended Design of Pavement Structures

(4) Drainage Design

As a result of analysis of data collected, an hourly rainfall intensity of a_0=65 mm/hr has been adopted for the design of drainage facilities in the Study.

A typical drainage system of the road is shown in Fig. B-8.

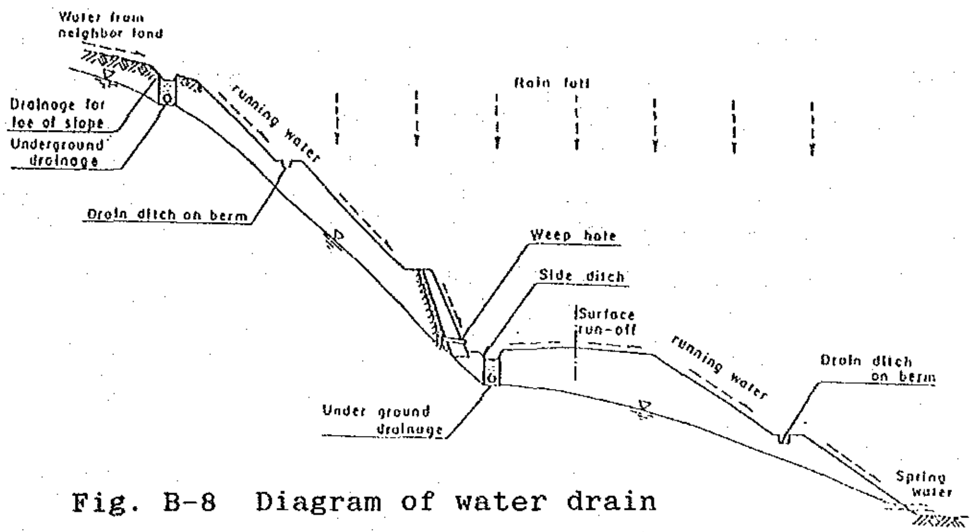


Fig. B-8 Diagram of water drain

In order to drain collected water using side ditches and under ground drainage as shown in Fig. B-8, some lateral drainage must be installed.

Places with a considerably large rain water catchment area on the upstream side of the road requires lateral drainage with a large discharge capacity, such as concrete box culverts. Eleven such places along the Project road were identified.

- 9 places : concrete box culvert (3 x 3 meters)
- 2 places : " " " (4 x 4 meters)

In remaining areas, the amount of run-off water was not so great. Therefore, it was considered that installation of 100cm dia. pipe culverts every 250 m interval along the road would sufficiently cope with water collected by the side ditches and other collection points.

- 429 places : concrete pipe culverts (dia.= 100 cm)

The final design stage of the project will require a more detailed study on the use of pipe culverts and other longitudinal ditches. This will be done to determine the exact location for placement and to find the most appropriate diameter of pipe for each location.

B.5.2 Preliminary Bridge Design

Length, combination of span, effective width and type of structure for each bridge to be constructed in the Project were determined as shown below in Table B-6.

Table B-6 List of Bridges

Name of Bridge	Bridge Length (m)	Span (m)	Effective Width (m)	Type of Bridge
Point A	132.5	25.6 + 80.0 + 26.1	7.3~9.5	PC Box Girder (Ununiform)
Patuni	40.0	19.65 + 19.65	10.4	PC Box Composite Girder
Challa	20.0	19.3	10.4	PC Box Composite Girder
Cascada	18.5	17.7	9.0	PC Box Composite Girder
Alto Choro	50.0	24.60 + 24.60	9.5	PC Box Girder (Uniform)
Pto. Leon	75.0	24.65 + 25.0 + 24.65	7.3	PC Composite Girder
Cajones	25.0	24.3	9.0	PC Composite Girder
Chojña	22.0	21.3	9.0	PC Composite Girder
San Sirverio	50.0	24.60 + 24.60	9.5	PC Box Girder (Uniform)
San Lorenzo	52.0	25.60 + 25.60	9.5	PC Box Girder (Uniform)
Espiritu	52.0	25.60 + 25.60	9.5	PC Box Girder (Uniform)
Carrasco	30.0	29.3	12.0	PC Composite Girder
Avaroa	25.0	24.3	10.4	PC Box Girder (Uniform)

B.5.3 Other Structural Design

(1) Design of Tunnels

As a result of the road design, the construction of two tunnels was recommended for the Project. Since these two tunnels are very close to each other, the site conditions for both are exactly the same.

1) Geological Conditions

The geological structure of the tunnel site indicates a composition of Paleozoic layers of slate, which is gray colored, well-compacted and fresh with few cracks and seems to have an unconfined compression strength of 530 kg/cm^2.

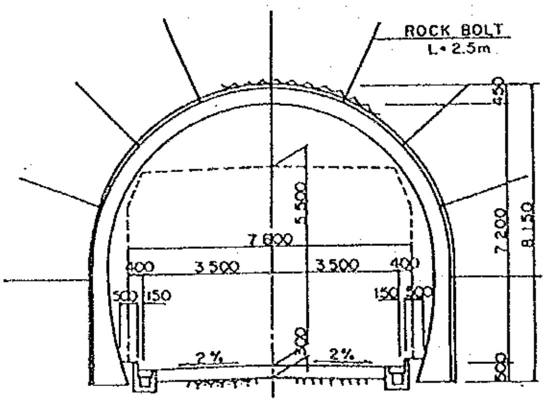
2) Alignment Design

In this project, straight tunnels have been selected for the following reasons:

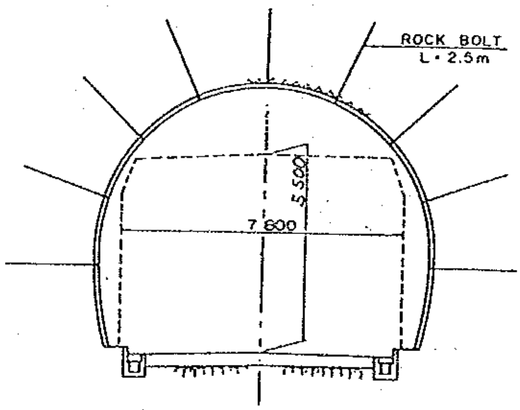
a) Straight tunnels minimize the length, thus reducing the construction cost.

b) Since no electric power is supplied in this area, it will be impossible to install lighting inside the tunnels. Under such a situation, the tunnels should be straight to ensure visual safety.

The dimension and structure of the tunnel are proposed as shown in Fig. B-9.



Structure at Tunnel Entrance

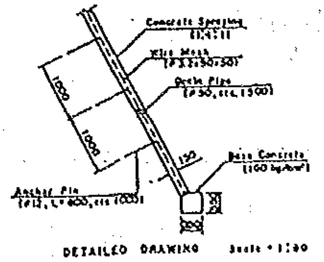


Internal Structure of the Tunnels

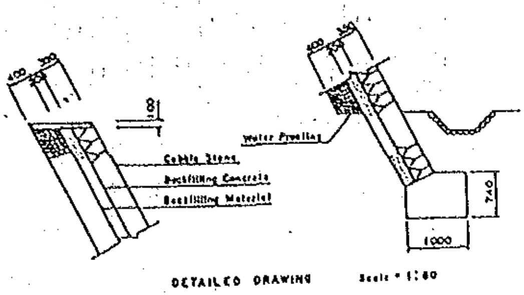
Fig. B-9 Cross Section and Structural Design

(2) Design of Disaster Prevention Facilities

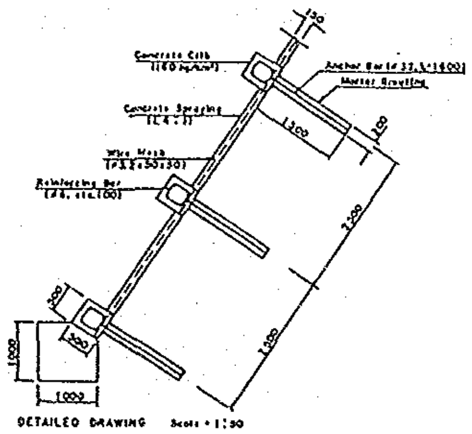
The recommended optimum countermeasures to prevent the expected disasters are shown in Fig. B-10.



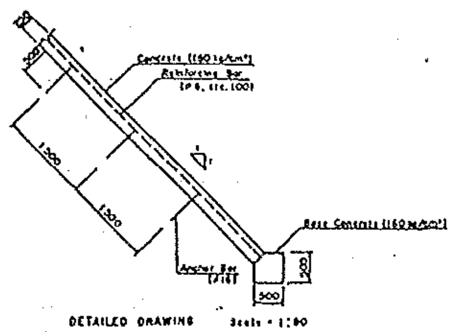
TYPICAL APPLICATION OF TYPE 1
COUNTERMEASURE (CONCRETE SPRAYING)



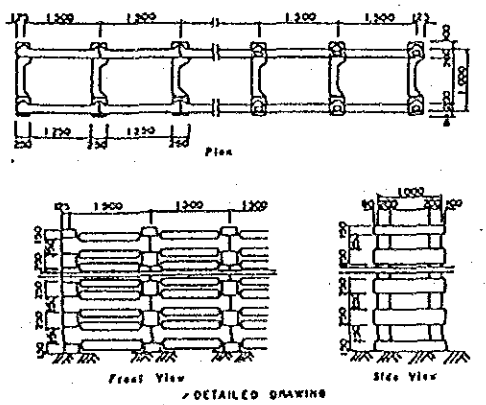
TYPICAL APPLICATION OF TYPE 2
COUNTERMEASURE (STONE MASONRY RETAINING WALL)



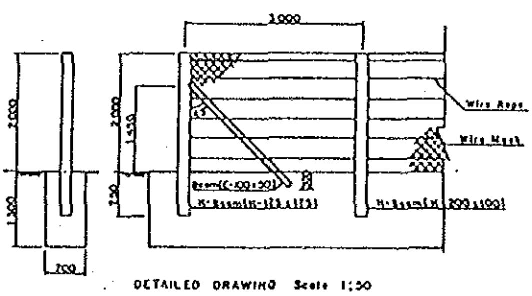
TYPICAL APPLICATION OF TYPE 3 COUNTERMEASURE
(CONCRETE CRIB WITH CONCRETE SPRAYING
AND ANCHORING)



TYPICAL APPLICATION OF TYPE 5 COUNTERMEASURE
(CONCRETE PITCHING AND ANCHORING)

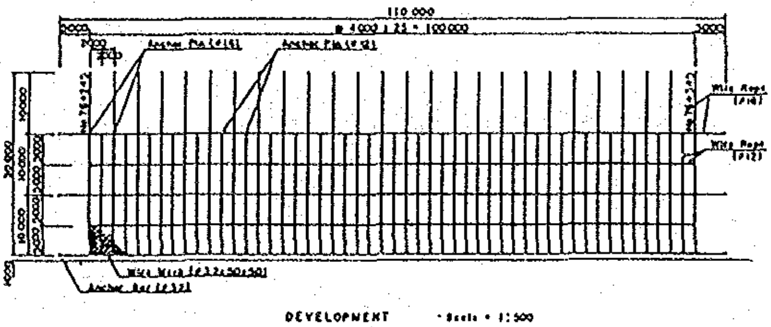


TYPICAL APPLICATION OF TYPE 6 COUNTERMEASURE
(GRID TYPE CONCRETE RETAINING WALL)

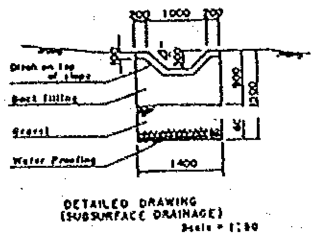


TYPICAL APPLICATION OF TYPE 9/11 COUNTERMEASURE
(CATCH NETTING+CATCH FENCE)

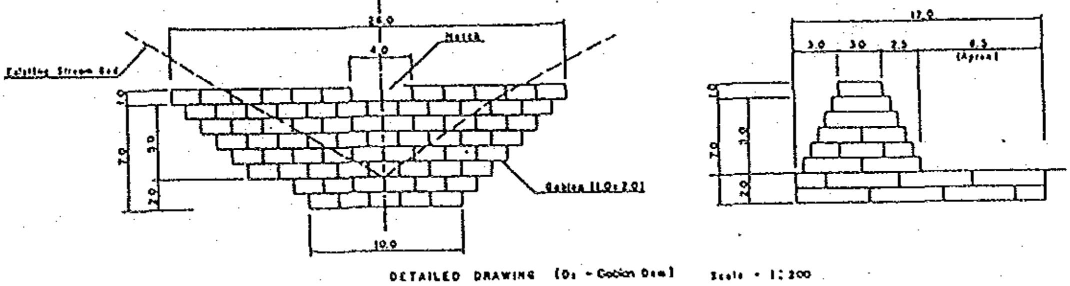
Fig. B-10(1) Disaster Prevention (1)



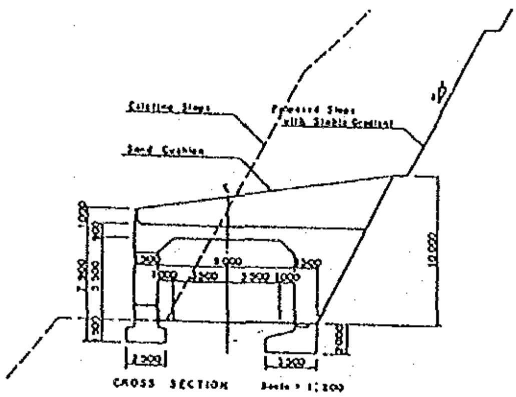
TYPICAL APPLICATION OF TYPE 9/10 COUNTERMEASURE (CATCHNETTING + GABION CATCH WALL)



TYPICAL APPLICATION OF TYPE 14 COUNTERMEASURE
(SUBSURFACE DRAINAGE FOR LANDSLIDE)



TYPICAL APPLICATION OF TYPE 15 COUNTERMEASURE (GABION DAM FOR DEBLIS/EARTH FLOW)-(2)



TYPICAL APPLICATION OF TYPE 17 COUNTERMEASURE (DEBLIS/EARTH FLOW SHED)

Fig. B-10(2) Disaster Prevention (1)

(3) Retaining Walls

Retaining walls were selected where they proved superior in safety and economy to earth work construction. The types of retaining walls employed were determined according to factors such as the intended individual site as shown in Fig. B-11.

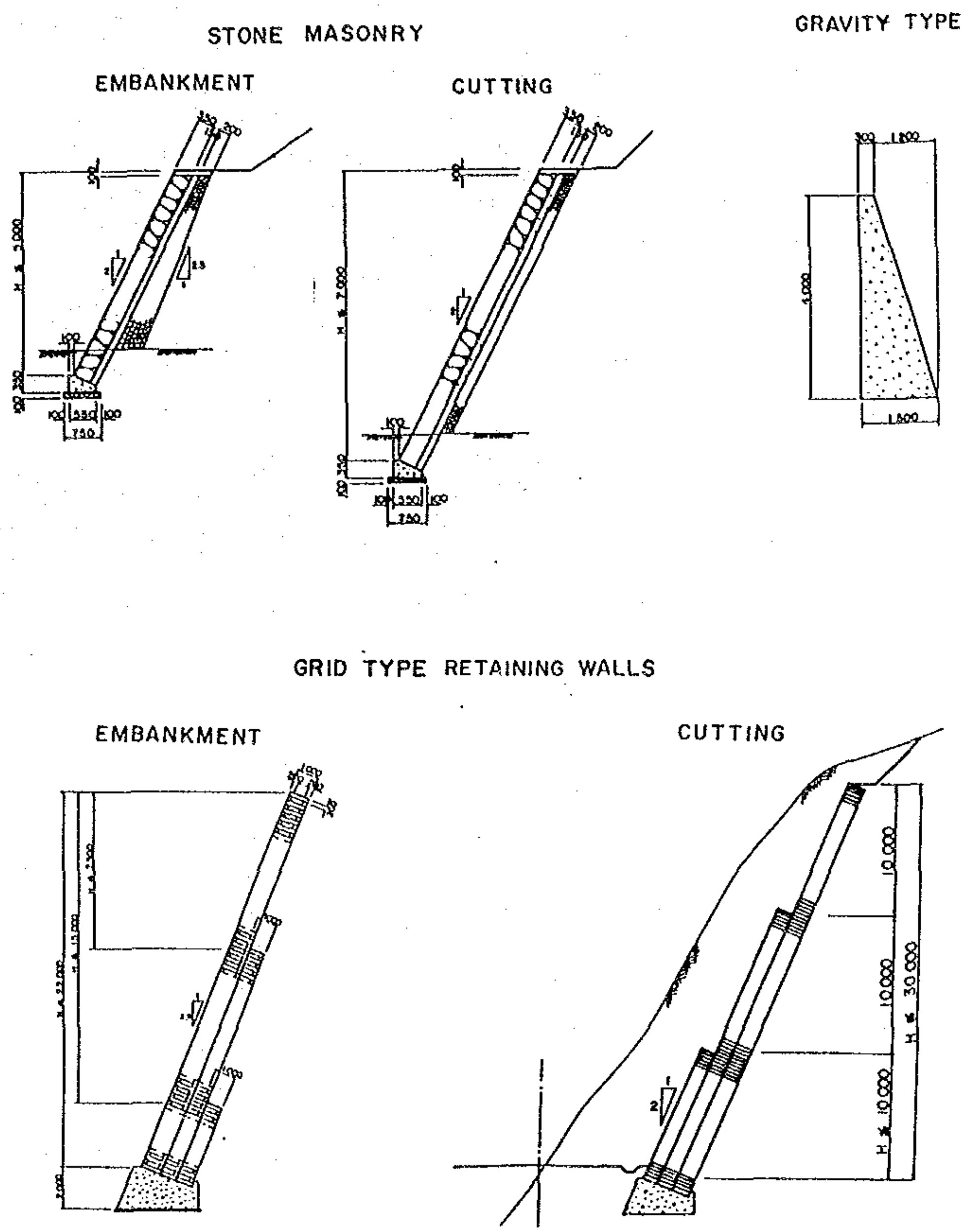


Fig. B-11 Retaining Walls

B.5.4 Earthmoving Plan

The volume for earthworks to be executed in the Project are shown in Fig. B-13.

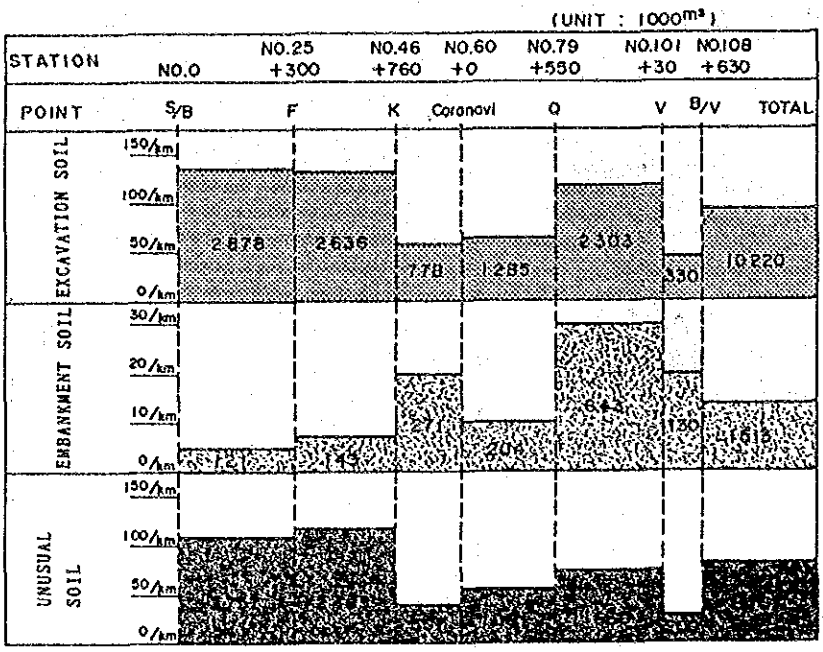


Fig. B-13 Volumes of Excavated Soil

64 areas were selected as candidate locations for spoil banks for soil disposal.

Fig. B-14 shows an idea for an earthmoving plan utilizing those spoil bank locations. It has been confirmed by this chart that it is possible to find spoil banks with sufficient capacity along the road, although the earth volume to be disposed of will be fairly large.

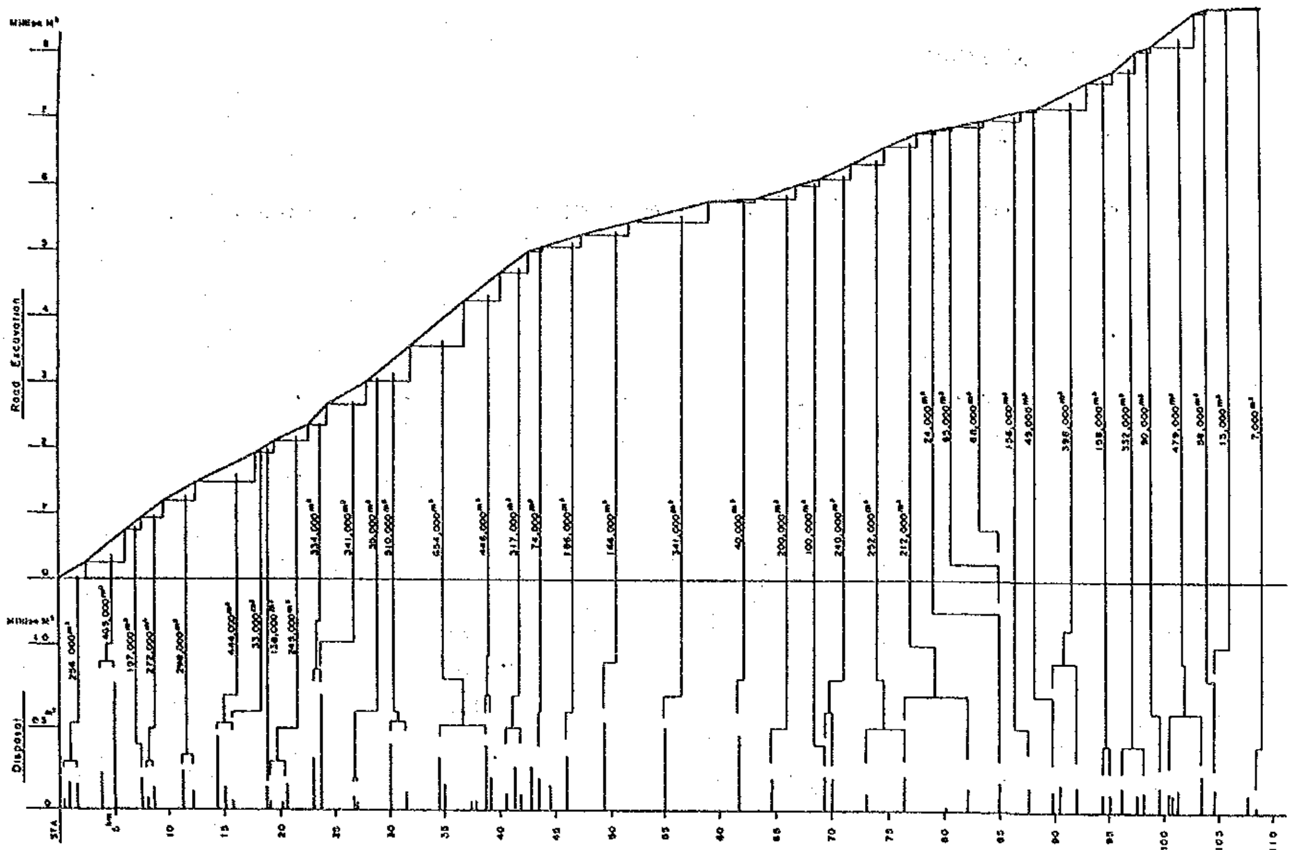


Fig. B-14 Spoil-Bank and Transportation Plan

B.5.5 Maintenance

Like other national roads, this road section will be directly maintained by SNC. The maintenance and repair work for the road include regular inspection, carriageway-related work, slope-related work, cleaning of the drainage facilities, and clearing of the right of way itself.

In order to cope with these tasks for the Project road, it was recommended that the five offices of SNC, i.e., Yorocita, Pto. Leon, Caranavi, Carrasco and Km 53, should be given adequate ties by the time of completion of the improvement work.

B.6 COST ESTIMATES

B.6.1 Cost Breakdown

The overall project cost was broken down as shown in Fig. B-14.

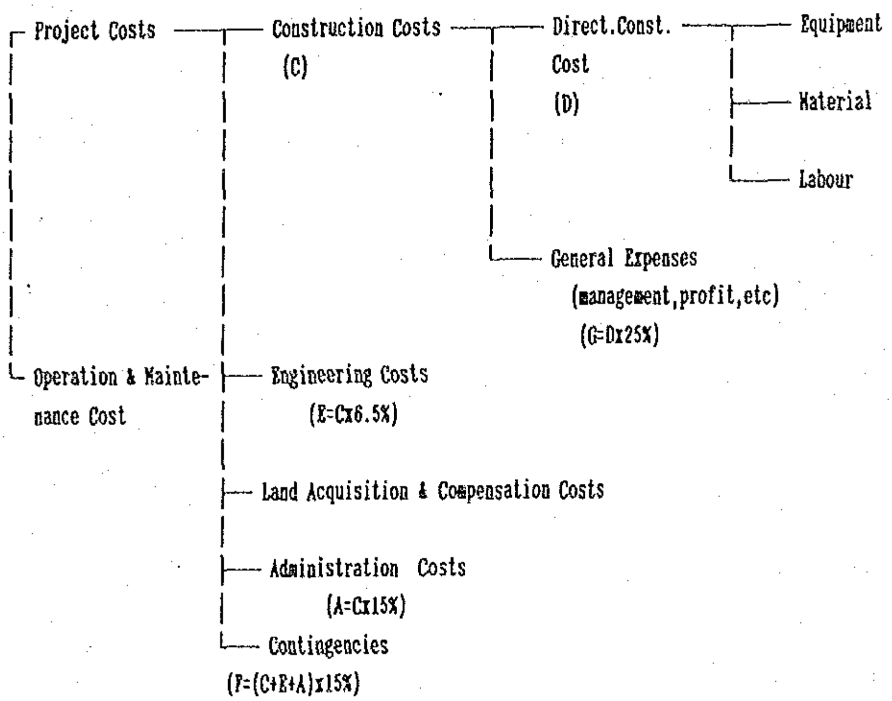


Fig. B-14 Cost Breakdown

B.6.2 Project Cost and Maintenance Cost

The project cost and the maintenance cost were estimated as shown in Table B-7 and Table B-8, respectively.

Table B-7 Project Cost

Items	Cost		Unit	Quantity	Unit Cost (US$) L.C Duties	Unit Cost (US$) L.C Others	Unit Cost (US$) F.C	Cost (1000US$) L.C Duties	Cost (1000US$) L.C Others	Cost (1000US$) L.C SubTotal	Cost (1000US$) F.C	Cost (1000US$) Total	Ratio
Earth Work	Clearing and Grubbing		ha	182.49	2789	2599	9460	509	474	983	1726	2709	
	Excavation A		m^3	1596994	1.4	1.03	2.67	2236	1645	3881	4264	8145	
	Excavation B		m^3	8684325	1.42	1.38	4.72	12332	11984	24316	40990	65306	
	Finished Rolling of Subgrade		m^2	1085401	0.01	0.02	0.04	11	22	33	43	76	
	Slope	Seed Spraying	m^2	233246	0.13	1.13		30	264	294	0	294	
		Concrete Spraying	m^2	95455	3.29	11.97	7.59	314	1143	1457	725	2182	
		Cribworks	m^2	11544	6.95	24.58	15.71	80	284	364	181	545	
		Concrete Pitching	m^2	2210	5.15	13.68	13.12	11	30	41	29	70	
	Retaining Wall	Gravity(4m)	m	50	35.21	224.54	50.02	2	11	13	3	16	
		Stone Masonry	m^2	24754	4.12	27.66	4.69	102	685	787	116	903	
		Grid Type	m^2	45260	17.07	67.07	30.87	773	3036	3809	1397	5206	
	Culvert	Box 3.0×3.0	m	375	202	488	523	76	183	259	196	455	
		Box 4.0×4.0	m	45	282	696	730	13	31	44	33	77	
		Pipe φ1.0	m	8560	17.58	131.21	12.43	150	1123	1273	106	1379	
	Disaster	Catch Netting	m^2	3840	2	1.59	5.95	8	6	14	23	37	
		Gabion	m	144	11.56	25.22	29.94	2	4	6	4	10	
		Catch Fence	m	147	20.48	39.02	53.3	3	6	9	8	17	
		Gabion Dam	m^3	11154	12.78	28.54	35.45	143	318	461	395	856	
		Shed	m	62	1565	2904	4445	97	180	277	276	553	
		French Drain	m	1010	3.54	7.63	10.44	4	8	12	11	23	
	Drainage		km	107.1	4530	29637	5826	485	3174	3659	624	4283	
Payement	Subbase Course		m^2	1065264	0.36	0.3	1.28	383	320	703	1364	2067	
	Base Course		m^2	1025095	0.74	1.17	2.4	759	1199	1958	2460	4418	
	Binder Course		m^2	996281	1.08	0.93	3.67	1076	927	2003	3656	5659	
	Surface Course		m^2	979571	1.28	0.88	4.04	1254	862	2116	3957	6073	
Bridge	L≧50m		Set					387	602	989	1124	2113	
	L<50m		Set					254	474	728	741	1469	
Tunnel	Lining		m	120	1022	3180	2713	123	382	505	326	831	
	Unsupported		m	625	751	2076	2038	469	1298	1767	1274	3041	
	Portal		Pcs	4	2827	9317	7176	11	37	48	29	77	
Others	Gard Rail		km	107.1	5917	1762	14069	634	189	823	1507	2330	
	Marking & Traffic Sign		km	107.1	47.5	427.5		5	46	51	0	51	
Direct Construction Cost				(D)				22736	30947	53683	67588	121271	
General Expenses				(G=Dx25%)				5684	7737	13421	16897	30318	
Total				(C=D+G)				28420	38684	67104	84485	151589	1395/Km
Engineering Cost				(E=Cx6.5%) L.C=40%, F.C=60%				394	3547	3941	5912	9853	
Administration Cost				(A=C.TOTALx1.5%, D=Ax0.1, O=Ax0.9)				227	2047	2274	0	2274	
Land Acquisition & Compensation Cost				(I)				0	146	146	0	146	
Contingencies				(F=(C+E+A)x15%)				4356	6642	10998	13560	24558	
Project Costs	within Duties			(C+E+A+I+F)				33397	51066	84463	103957	188420	1735/Km
	without Duties								51066	51066	103957	155023	1427/Km

Table B-8 Maintenance Cost
(Thousand Dollar in 1990 Levels)

(Unit:1000US$)

	Gravel Road Maintenance				Asphalt Road Maintenance				Macadam Road Maintenance			
Year	L.C		F.C	Total	L.C		F.C	Total	L.C		F.C	Total
	C.D	Other			C.D	Other			C.D	Other		
1st Year	63	124	191	378	26	84	63	173	53	84	140	320
				(315)				(147)				(267)
2nd Year	63	124	191	378	26	84	63	173	53	127	140	320
				(315)				(147)				(267)
3rd Year	63	124	191	378	26	84	63	173	53	127	140	320
				(315)				(147)				(267)
4th Year	127	247	381	755	26	84	63	173	106	254	280	640
				(628)				(147)				(534)
5th Year	127	247	381	755	26	84	63	173	106	254	280	640
				(628)				(147)				(534)
6th Year	127	247	381	755	53	168	126	347	106	254	280	640
				(628)				(294)				(534)
7th Year	127	247	381	755	91	208	243	542	106	254	280	640
				(628)				(451)				(534)
:	:	:	:	:	:	:	:	:	:	:	:	:

Note: ( ): without duties

C SUMMARY OF VOLUME II

C.1 SOCIO-ECONOMIC ANALYSIS

C.1.1 Existing Socio-economic Situation

(i) Population of Bolivia

According to population information from the INE the total population of Bolivia was about 6.4 million in 1985 as shown in Table C.1. This has increased at an average annual growth rate of 2.8 percent since 1980. The annual growth rate of the population in urban areas and rural areas during the same period was 4.3 percent and 1.6 percent, respectively.

Table C.1 Population of Bolivia (1980 - 1985)

(Unit : Person)

Year	Total	Urban	Rural
1980	5,599,592 (100%)	2,488,628 (44.4%)	3,110,964 (55.6%)
1981	5,755,072 (100%)	2,595,237 (45.1%)	3,159,835 (54.9%)
1982	5,915,844 (100%)	2,706,626 (45.8%)	3,209,218 (54.2%)
1983	6,081,722 (100%)	2,822,546 (46.4%)	3,259,176 (53.6%)
1984	6,252,720 (100%)	2,942,944 (47.1%)	3,309,776 (52.9%)
1985	6,429,226 (100%)	3,068,051 (47.7%)	3,361,175 (52.3%)
Average Growth Rate 1980-1985	2.8%	4.3%	1.6%

Source : INE

The population in 1989 was estimated to be about 7.2 millions on the basis of the growth rate indicated in "Estrategia de Desarrollo Econômico y Social 1989 - 2000" (Ministerio de Planeamiento y Coordinaciôn). The estimated population by department in 1989 is shown in Table C.2.

Table C.2 Population by department in 1989

	Population(1988) * (1,000 persons)			Growth Rate ** (1988-2000) (%)			Population(1989) *** (1,000 persons)		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
La Paz	1145.3	1033.9	2179.2	3.7	1.4	2.7	1187.6	1047.9	2235.5
Cochabamba	462.8	599.1	1061.9	4.2	1.6	2.8	482.1	608.5	1090.6
Chuquisaca	130.7	396.5	527.2	3.1	1.7	2.1	134.8	403.3	538.1
Oruro	210.2	181.2	391.4	2.0	1.2	1.6	214.4	183.3	397.7
Potosi	251.5	628.1	879.6	1.8	1.0	1.2	255.9	634.3	890.2
S. Cruz	877.4	457.0	1334.4	6.3	1.5	4.9	932.6	463.7	1396.3
Tarija	124.2	163.4	287.6	4.2	1.3	2.6	129.4	165.5	294.9
Beni	163.8	116.4	280.2	5.2	1.0	3.7	172.3	117.6	289.9
Pando	6.5	44.5	51.0	4.2	0.2	0.8	6.8	44.6	51.4
Total	3372.4	3620.1	6992.5				3515.9	3668.7	7184.6

*,** "Estrategia de Desarrollo Economico y Social 1988-2000" (Ministerio de Planeamiento y Coordinacion)

*** Estimated by Study Team

(2) Employment

The report "Estrategia de Desarrollo Econòmico y social 1989 - 2000" estimated the number of employed from 1980 to 1986, however, compared with the total population, it is understood that the number was assumed to be about 30 percent of the total population as indicated in Table C.3.

Table C.3 Employment and Rate of Employment

Year	Population* (1,000 persons)	Employment** (1,000 persons)	Percentage of total population employed (%)
1980	5599.6	1736.7	31.0
1981	5755.1	1781.3	31.0
1982	5915.8	1805.3	30.5
1983	6081.7	1829.1	30.1
1984	6252.7	1881.4	30.1
1985	6429.2	1928.7	30.0
1986	6609.2	1983.4	30.0

* Source INE
** Source Estrategia de Desarrollo Econòmico y Social (1989 - 2000)

With the growth rate between 1984 - 1986 listed in the far right column of Table A.1-6 of Volume II, the structure of employment by sector in 1989 was estimated as shown in Table C.4 According to this estimation, the share of the primary, secondary, and tertiary sectors were 52.9, 10.2, and 36.9 percent, respectively.

Table C.4 Employment in 1989

Sector	Employment (1,000 persons)	Share (%)
PRIMARY	1140.2	52.9
Agriculture	1070.1	49.7
Mining	58.2	2.7
Petroleum	11.9	5.5
SECONDARY	220.6	10.2
Manufacturing	170.6	7.9
Construction	38.1	1.8
Electricity	11.9	5.5
TERTIARY	794.3	36.9
Transportation	121.7	5.6
Commerce	167.6	7.8
Finance	23.5	1.1
Others	481.8	22.4
TOTAL	2155.1	100.0

Source : "Estrategia de Desarrollo Economico y Social (1989 - 2000)

(3) Gross Domestic Products (GDP)

The Bolivian economy recorded a negative growth through 1981 to 1986 from the viewpoint of gross domestic product (GDP) as shown in Table C.5. However, since 1986 the Bolivian economy has started to recover gradually and recorded a growth rate of 2.1 percent in 1987 and 3 percent in 1988.

Table C.5 shows the per capita GDP, which is seen to decrease by 27 percent to Bs 1,610 in 1988 from Bs 2,196 in 1980. Therefore, the important issue for the government would be to raise not only the GDP but also the per capita income as soon as possible.

Table C.5 Per Capita GDP (in 1980 price)

Year	GDP (Bs 100,000)	Population (Person)	Per Capita GDP (Bs)
1980	122,946	5,599,592	2196
1981	124,083	5,755,072	2156
1982	118,674	5,915,844	2006
1983	110,943	6,081,722	1824
1984	110,611	6,252,721	1638
1985	110,445	6,429,226	1718
1986	107,211	6,611,722	1621
1987	109,479	6,799,397	1610
1988	112,553	6,992,400	1610

Source : Boletin Estadistico No.261
(Banco Central de Bolivia)

C.1.2 Future Socio-economic Framework

(1) Population

The future population was forecast from the growth rate indicated in "Estrategia de Desarrollo Economico y Social 1989-2000" up to the year 2000. The population projection after 2000 was also forecast using the same rate Table C.6 shows the future population by department.

Table C.6 Future Population by Department

(Unit : 1,000 persons)

Department	1989 Urban	1989 Rural	1989 Total	2000 Urban	2000 Rural	2000 Total
La Paz	1187.6	1047.9	2235.5	1769.0	1215.6	2984.6
Cochabamba	482.1	608.5	1090.6	755.4	722.3	1477.7
Chuquisaca	134.8	403.3	538.1	189.4	485.9	675.3
Oruro	214.4	183.3	397.7	265.8	208.4	474.2
Potosi	255.9	634.3	890.2	310.2	706.5	1016.7
Santa Cruz	932.6	463.7	1396.3	1824.4	544.6	2369.0
Tarija	129.4	165.5	294.9	202.6	190.3	392.9
Beni	172.3	117.6	289.9	299.6	131.4	431.0
Pando	6.8	44.6	51.4	10.6	45.4	56.0
Total	3515.7	3668.7	7184.4	5627.0	4250.4	9877.4

Department	2010 Urban	2010 Rural	2010 Total	2020 Urban	2020 Rural	2020 Total
La Paz	2541.4	1391.2	3932.6	3651.0	1592.1	5243.1
Cochabamba	1136.3	844.1	1980.4	1709.3	986.5	2695.8
Chuquisaca	258.0	575.6	833.6	351.5	681.9	1033.4
Oruro	323.2	234.2	557.4	393.0	263.1	656.1
Potosi	369.5	779.3	1148.7	440.0	859.5	1299.5
Santa Cruz	3357.8	630.3	3988.1	6180.0	729.5	6909.5
Tarija	304.6	216.1	520.7	458.0	245.3	703.3
Beni	495.5	145.4	640.9	819.6	160.8	980.4
Pando	15.9	46.2	62.1	23.9	46.9	70.8
Total	8802.2	4862.2	13664.5	14026.3	5565.7	19592.0

(2) Projection of GDP and RGDP

The future gross domestic product by sector was projected on the basis of the growth rate presented in "Estrategia de Desarrollo Economico y Social 1989-2000" until 2000, in which the growth rate was projected by year from 1989 to 2000. The GDP after 2000 is projected with the average growth rate taken from 1998 to 2000. On the other hand, based on the existing RGDP in La Paz, Beni, and Pando, the above estimated GDP was distributed into these three departments to obtain the future RGDP. The results are shown in Table C.7.

Table C.7 RGDP by Sector

(Bs. Million)

Sector	1989	2000	2010	2020
La Paz	30643	50661	84788	139434
Beni	5390	9121	15001	24669
Pando	1056	1785	2934	4828

C.2 TRAFFIC STUDY

C.2.1 Traffic Survey

(1) Survey Procedure

A roadside OD survey was carried out from 8:00 A.M. on September 20 to 8:00 A.M. on September 21 in 1989, at five stations selected by the Study Team, between Santa Barbara and Bella Vista. The location of survey stations for this survey was as follows:

Station	1	In front of the police inspection office at Yolosa
Station	2	In front of the police inspection office at Caranavi on the road to La Paz
Station	3	On the exit from downtown Caranavi to Guanay (near the Market)
Station	4	In front of the Police inspection office on the road to Bella Vista
Station	5	On the road near the SNC office at Bella Vista

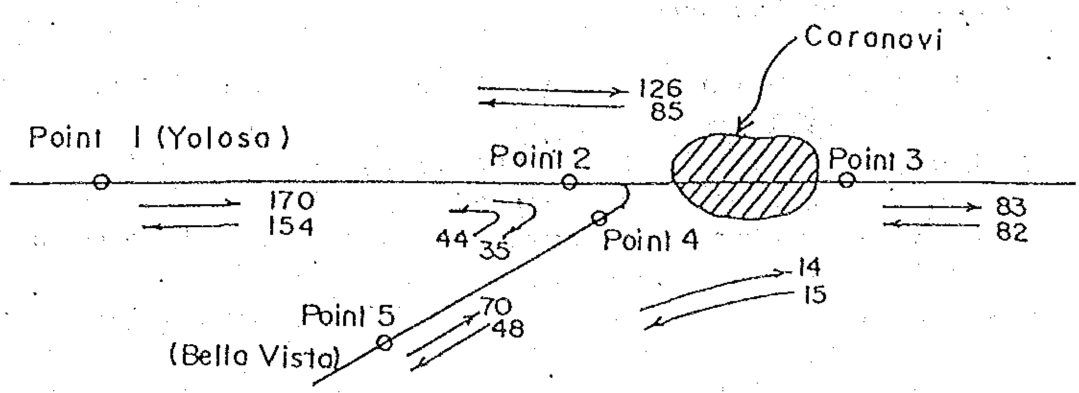
(2) Questionnaire

The interview questions included the following items:

- Trip origin and destination
- Trip purpose
- Type of vehicle
- Number of goods carried
- Volume of goods
- Interview time

(3) Number of Surveyed Vehicles

The vehicles shown in Fig. C.1 were interviewed at the above five survey stations.



(Unit : Vehicle)

Fig. C.1 Number of Surveyed Vehicle

(4) Results of Traffic Survey

The results of the survey are as follows:

Vehicle Composition

	Passenger Car	Bus	Light Truck	Medium Truck	Heavy Truck	Total
Total Vehicles (Vehicle)	72	35	298	75	446	926
Vehicle Composition (%)	7.8	3.8	32.2	8.1	48.2	100.0

Trip Purpose

(Unit : Vehicle)

Purpose	No. of vehicle	share (%)
Business	704	76.02
Go to working place	125	13.50
Go to school	4	0.43
Social intercourse	12	1.30
Tourism & recreation	12	1.30
Shopping	5	0.54
Go back home	9	0.97
Others	14	1.51
No answer	41	4.43
Total	926	100.00

Average Occupancy by Vehicle Type

	Passenger Car	Bus	Light Truck	Medium Truck	Heavy Truck	Total
Total Vehicles1)	72	35	298	75	446	92
Total Passenger2)	291	805	1747	317	2247	5407
Average Occupancy3)	4.04	23.00	5.86	4.23	5.04	5.84

Unit : 1) Vehicle, 2) Person, 3) Person

Average Freight Tonnage Carried

(Unit : Ton)

	Passenger Car	Bus	Small & Medium Truck	Heavy Truck	Total
N←S	0.05	0.0	0.81	1.31	0.75
	0.50	0.0	1.38	4.47	1.60
N→S	0.05	0.0	0.91	2.53	1.04
	0.81	0.0	3.06	6.04	3.86
Average	0.05	0.0	0.85	1.93	0.87
	0.60	0.0	1.78	5.41	2.27

Note : Upper value: Including empty trucks
Lower value: Excluding empty trucks

C.2.2 Present OD Table

Using the weekly and monthly fluctuation, the existing OD table was established, and is shown in Table C.8 below. The total traffic volume generated/attracted was 770 vehicles.

Table C.8 Established OD Table (Vehicles/day)

	La Paz 1	Yolo sa 2	Coloi co 3	Choro 4	Cara navi 5	Bella Vista 6	Alto Beni 7	Beni 8	Guanay 9	Pando 10	Total
1	0	0	0	1	140	8	5	44	98	5	301
2		0	0	0	0	0	0	0	1	0	1
3			0	0	2	1	0	0	0	0	3
4				0	0	0	0	0	0	0	1
5					31	15	3	8	28	4	231
6						0	3	0	1	0	28
7							0	0	6	0	17
8								0	1	0	45
9									0	0	134
10										0	9
Total											770

The traffic volume on the road section between Santa Barbara and Caranavi is shown in Table C.9 along with orevious volumes.

Table C.9 Traffic Volume
(Santa Barbara-Caranavi) (Vehicles/Day)

Year	Passen-ger Car	Bus	Light Truck	Medium Truck	Heavy Truck	To-tal	Growth Rate
1984	18	13	32	31	36	130	
1985	13	50	33	33	66	194	1.49
1986	25	12	52	31	61	181	0.93
1987	32	15	71	20	108	246	1.36
1988	33	17	74	19	115	268	1.09
1989	17	14	105	16	149	301	1.12

C.2.3 Projection of Future Traffic Volume

The future traffic volume was projected for the following three categories:

1) Increase in existing traffic
2) Generation of refrigerated trucks
3) Development Traffic

The normal traffic volume is that traffic growing at a rate parallel to the social and economic growth. The refrigerated truck is considered to be the traffic diverted from airplanes to vehicles, mainly carrying beef from the Beni department to the La Paz department. The development traffic is generated and/or attracted from the newly developed area, (to carry increased products) developed by the influence of the proposed project. The future traffic volumes on the road section between Santa Barbara and Caranavi, and between Caranavi and Bella Vista were projected as shown in Table C.10(1) and Table C.10(2), respectively.

Table C.10(1) Future Traffic Volume Between Santa Barbara-Caranavi

(Unit : Vehicles/Day)

Year	Type of Traffic	Passen-ger Car	Bus	Light Truck	Medium Truck	Heavy Truck	Total	Growth Ratio (1989=1)
1989		17	14	105	16	149	301	1.00
2001	Trend	54	31	239	37	523	884	
	Refrigerated Truck	0	0	0	0	20	20	
	Developed	3	3	2	1	5	14	
	Total	57	34	241	38	548	918	3.0
2010	Trend	88	48	353	54	850	1393	
	Refrigerated Truck	0	0	0	0	24	24	
	Developed	7	4	27	4	57	99	
	Total	95	52	380	58	931	1516	5.0
2020	Trend	130	68	484	74	1230	1986	
	Refrigerated Truck	0	0	0	0	26	26	
	Developed	10	8	30	4	74	126	
	Total	140	76	514	78	1330	2138	7.1

Table C.10(2) Future Traffic Volume
Between Caranavi-Bella Vista
(Unit : Vehicles/Day)

Year	Type of Traffic	Passen-ger Car	Bus	Light Truck	Medium Truck	Heavy Truck	Total	Growth Ratio (1989=1)
1989		3	1	19	3	75	101	1.00
2001	Trend	10	2	44	6	263	325	
	Refrigerated Truck	0	0	0	0	20	20	
	Developed	2	2	1	0	5	10	
	Total	12	4	45	6	288	355	3.5
2010	Trend	16	3	64	10	428	521	
	Refrigerated Truck	0	0	0	0	24	24	
	Developed	5	3	8	2	60	78	
	Total	21	6	72	12	512	623	6.2
2020	Trend	23	5	88	13	619	748	
	Refrigerated Truck	0	0	0	0	26	26	
	Developed	8	6	14	2	79	106	
	Total	31	11	102	15	724	880	8.7

C.3 ECONOMIC ANALYSIS AND EVALUATION

C.3.1 Setting up Alternatives

From the viewpoint of decreasing the initial project cost, alternatives were firstly broken into two categories, the paved surface case (nominated as "P") and the unpaved surface case (nominated as "U"). A paved surface refers to an asphalt concrete or an asphalt macadam. An unpaved surface refers to a gravel surface. Consecutively the foremost category was broken down into seven cases, depending on the year when the project road is paved or whether the pavement is an asphalt concrete or an asphalt macadam. As a result, the alternatives examined here contain a total of the following eight cases:

CASE P-1	Paved asphalt concrete surface from 2001
CASE P-2	Paved asphalt concrete in 2003
CASE P-3	Paved asphalt concrete in 2006
CASE P-4	Paved asphalt concrete in 2011
CASE P-5	Paved asphalt macadam surface from 2001
CASE P-6	Paved asphalt macadam in 2003
CASE P-7	Paved asphalt macadam in 2003 and asphalt concrete in 2008
CASE U	Unpaved surface

C.3.2 Economic Benefit

The completion of the project road is expected to result in many kinds of benefits (whether quantitative or qualitative). In this part the quantitative benefit is estimated for the purpose of calculating the economic indicators, such as the internal rate of return, benefit cost ratio, and so on. The estimated quantitative benefits are as follows:

a) Running time saving benefit
b) Waiting time saving benefit
c) Vehicle operating cost saving benefit
d) Disaster prevention benefit
e) Accident deduction benefit
f) Transportation cost deduction benefit from refrigerated trucks
g) Development Benefit

(1) Running Time Saving Benefit

Running time saving benefit was estimated on the basis of the difference in vehicle running speed between the existing road and the improved road. The estimated benefit is shown in Table C.11.

Table C.11 Time Saving Benefit in 2020
(Unit : Dollar)

Year	Road Surface	Santa Barbara and Caranavi	Caranavi and Bella Vista	Total
CASE P-1 & P-5		12162169	2736719	14898888
CASE P-2, P-6 & P-7		12162169	2736719	14898888
CASE P-3		12162169	2736719	14898888
CASE P-4		12162169	2736719	14898888
CASE U		10026320	2147928	12174248

(2) Waiting time saving benefit

Most of the vehicles driving along the existing road are forced to wait for a while to pass each other on the narrow width of the existing road. Such waiting times are expected to be eliminated completely after the completion of the project road. The estimated waiting time saving benefit is shown in Table C.12.

Table C.12 Total Waiting Time Saving Benefit
(Unit : Dollar)

Year	Santa Barbara and Caranavi	Caranavi and Bella Vista	Total
2001	1464220	62113	1526333
2010	4302858	189656	4492514
2020	10580080	474463	11054543

Note : Benefit is common to every alternative.

(3) Vehicle Operating Cost Saving Benefit

The vehicle operating cost benefit is defined as the difference between the vehicle operating cost on the existing road and that of a newly improved road. The estimation of vehicle operating costs was made by using the "Vehicle Operating Cost Submodel of the HDM-III Model" developed mainly by the World Bank. Table C.13 shows the vehicle operation cast saving benefit.

Table C.13 Vehicle Operating Cost Saving Benefit in 2020

(Unit : Dollar)

	Santa Barbara and Caranavi	Caranavi and Bella Vista	Total
CASE P-1 & P-5	42278120	14981912	57260032
CASE P-2, P-6 & P-7	42278120	14981912	57260032
CASE P-3	42278120	14981912	57260032
CASE P-4	42278120	14981912	57260032
CASE U	30671061	10604575	41275636

(4) Disaster Prevention Benefit

The existing road has repeatedly been subjected to natural disasters such as land slides, debris flow, rock falls, etc. However, The newly improved project road is provided with sufficient disaster prevention countermeasures. Consequently, after the project road is completed, all disaster restoration work is expected to be eliminated. Therefore, in eliminating these disasters it brings about benefit through the reduction of disaster restoration expense. The disaster prevention benefit is shown in Table C.14.

Table C.14 Disaster Prevention Benefit

(Unit : Dollar)

Year	Cost Benefit	Time Benefit	Total
2001	31589	221578	253167
2010	31589	413614	445203
2020	31589	713256	744845

Note : Benefit is common to each alternative.

(5) Accident Reduction Benefit

Some traffic accidents occur on the existing road every year. Most of these accidents have been caused by unfavorable existing road conditions such as numerous sharp and small curves, narrowness, etc. After the completion of the project road, these accidents are expected to be avoided. The reduction of these traffic accidents should decrease damage, which results in a saving of repair cost to damaged vehicles, medical treatment cost for the injured, and loss of the human life. Therefore, the reduction of traffic accidents is one of the benefits accrued from the completion of this project road. Table C.15 shows the benefit from the reducation in traffic accidents.

Table C.15 Benefit from Deduction of Traffic Accidents
(Unit : Dollars)

Item	2001	2010	2020
Vehicle Damage	110385	174102	248217
Reduction in the injured	51969	81862	116355
Reduction in fatalities	333564	631085	1070650
Total	495918	887049	1435222

(6) Transportation Cost Reduction Benefit from Refrigerated Truucks

At present, most beef consumed in La Paz city is transported by airplane from the production site in the Beni department or cows are carried by trucks with alive. After the completion of the project road, beef transportation by airplane from the production site to La Paz city is expected to be diverted into transportation by refrigerated truck, because airplane currently carrying beef are very old and are considered very difficult to continue operating even in the future. Therefore, beef transportation will be transferred into refrigerated trucks whether the project road is completed or not. The vehicle operation cost of the refrigerated trucks can be saved if the project road is completed, compared with the existing road situation. Therefore, this saved cost can be counted as one of the benefits obtained from the completion of the project road. The estimated benefit is shown in Table C.16.

Table C.16 Benefit from Transportation Cost Reduction from Refrigerated Trucks (Unit : US$)

	Case P-1 Case P-5	Case P-2 Case P-6 Case P-7	Case P-3	Case P-4	Case U
2001	998834	772148	772148	772148	772148
2010	1198601	1198601	1198601	926577	926577
2020	1217943	1217943	1217943	1217943	1003791

(7) Developement Benefit

The completion of the project road is expected to increase the amount of agricultural products in the infuluenced area. The increase in production means the expansion of producer's economic activities, which results in an increase of the income. As this increment is brought about by the completion of the project road, it is considered to be benefit of this project. The income from the production of "rice", "maize", "banana", and "yuca" was examined from the available data. Table C.17 shows the income increment benefit derived from the project.

Table C.17 Development Benefit
(Unit : Us$)

		Rice	Banana	Maize	Yuca	Total
2001	La Paz	16837	140	2312	78	19365
	Beni	122296	441	9332	1016	133086
	Pando	30706	139	2291	259	33395
	Total	169840	720	13936	1351	185846
2010	La Paz	221861	1845	30394	881	254981
	Beni	1609918	5817	109807	13333	1738874
	Pando	404275	1846	30104	3465	439690
	Total	2236054	9508	170306	17679	2433546
2020	La Paz	301060	2491	41199	1208	345958
	Beni	2184662	7889	148859	18167	2359577
	Pando	548642	2497	40826	4566	596531
	Total	3034363	12877	230884	23941	3302066

Note : Benefit is common to each alternative.

C.3.3 Economic Costs

The construction and maintenance costs estimated from the engineering study in Chapter 6 of Volume 1 are not the true economic cost, since the financial cost includes transfer items such as taxes. As the financial cost does not represent the real figure for the economic analysis, the economic construction and maintenance costs are obtained by substracting all taxes from their respective financial amounts.

C.3.4 Economic Analysis

(1) Calculation of Economic indicators

In order to assess project viability, the IRR, B/C and NPV were calculated considering the above-mentioned benefit and cost stream. Table C.18 summarized the value of the above three economic indicators by alternative.

Table C.18 Value of Economic Indicators by Alternative

Alternative	B/C	NPV ($)	IRR (%)
CASE P-1	1.890	97625296	19.7
CASE P-2	1.867	91676176	19.4
CASE P-3	1.794	82904640	18.7
CASE P-4	1.700	72061976	18.1
CASE P-5	1.857	94234784	19.8
CASE P-6	1.894	94910936	19.8
CASE P-7	1.877	93097920	19.6
CASE U	1.552	56610392	17.2

(2) Sensitivity Analysis

It must be kept in mind that the estimated benefit and cost be examined from the viewpoint of projection errors and uncertainty. In order to examine the above unexpected and uncertain situations using the economic indicators, a sensitivity analysis was performed on the assumption of a decrease in benefit and an increase in cost (there are no problems for the opposite case since this would make the values of the economic indicators better). In this sensitivity analysis the project benefit is assumed to decrease by 5%, 10%, 15% and 20%. On the other hand, the project cost is assumed to increase by 5%, 10%, 15% and 20%. Table C.19 shows the results of the worst case (cost 20% up and benefit 20% down). CASE P-1, CASE P-6 and CASE P-7 were fesible even in the worst case.

Table C.19 The Worst Case in the Sensitivity Analysis

	IRR (%)	B/C	NPV ($)
CASE P-1	12.1	1.008	1275536
CASE P-2	12.0	0.996	-656064
CASE P-3	11.5	0.957	-6744624
CASE P-4	11.0	0.907	-14426768
CASE P-5	11.9	0.991	-1566016
CASE P-6	12.1	1.010	1602816
CASE P-7	12.0	1.001	154464
CASE U	10.0	0.828	-26467416

(3) Cumulative Financial Cost required until 2020

Even if the project road brings about a large benefit, the project might not be viable in the case where the executing agency of the project (SNC) has difficulty in bearing the financial burden including the project cost and maintenance cost after the completion of the project. Considering the existing SNC financial situation (the SNC desires to have several large scale road projects desired to be completed in a near future), it is requested to minimize the cumulative financial project cost (including the future maintenance cost) as much as possible. Table C.20 shows the cumulative financial cost up until 2020.

Table C.20 Cumulative Financial Cost Up Until 2020

(Unit : Thousand Dollars)

Alternative	Initial Cost	Maintenance Cost	Total Cost
CASE P-1	188422	5020	193442
CASE P-2	166706	27009	193715
CASE P-3	166706	28413	195119
CASE P-4	166706	30753	197459
CASE P-5	178981	26166	205147
CASE P-6	166706	34143	200849
CASE P-7	166706	35937	202643
CASE U	166706	31540	198246

(4) Qualitative benefits

In addition to the quantitative benefits as explained in C.2, the proposed project brings about many qualitative benefits. Especially, the following qualitative benefit is significantly important:

The completion of the project will make driver and passenger comfort and will ensure punctuality between origin and destination. In addition, it is certain that the damage to goods carried by the trucks can be drastically decreased, especially on the asphalt surface road.

C.3.5 Economic Evaluation

In conclusion, CASE U is not recommended from the viewpoint of the sensitivity analysis and qualitative benefit. CASE P-2, CASE P-3 and CASE P-4 are also not recommended from the results of the sensitivity analysis because they are not feasible in the worst case. Moreover, CASE P-5, CASE P-6 and CASE P-7 are not recommended since the cumulative financial cost is high. Therefore, the remaining alternative, CASE P-1, is said to be much superior to other alternativs.

From the above reasons, it is strongly recommended to select CASE P-1 (paved surface from the opening year).

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