# CHAPTER 17 DETAILED EXAMINATION OF COUNTERMEASURES

## 17.1 General

The objectives of this chapter are to review the examination of Part A, and to confirm the stability of cut/ or embankment slopes and bridge foundation scouring in more detail. And most suitable countermeasures are to be selected against the each damage.

## 17.2 Review of the Status of Disaster Prevention Spots

### 17.2.1 Measures to the Seeped Water and Weathered Rocks in Rainy and Dry seasons

Just after rainy season, surface water, spring water with some hydraulic gradient and water film oozing were found to contain on wet conditions of slope surface. These wet conditions affect principally weathered layers consisting of a tuff group. The review of such as phenomenon for countermeasures is shown in Table 17.2.1.

**Table 17.2.1 Influence Level of Slope Surface by Seeped Water and Weathering in Rainy and Dry Season**

Route No. Nic.1

| Serial Number of Disaster Critical spots | Score of first Phase | Score of Second Phase | ID.No | Kilometer from Managua (km) | Type of disaster | Natural Condition Evaluation | Natural Condition Score |
|---|---|---|---|---|---|---|---|
| 1 | 70 | 78 | N001A290 | 60.9 | R.F. | A | 10 |
| 2 | 78 | 84 | N001A280 | 73.2 | R.F. | A | 10 |
| 3 | 90 | 90 | [illegible] | 113.19 | Bridge | B | 6 |
| 4 | 100 | 100 | San Nicolas | 135.64 | Bridge | C | 2 |
| 5 | 90 | 90 | [illegible] | 150.33 | Bridge | B | 6 |
| 6 | 100 | 100 | San Ramón | 151.85 | Bridge | C | 2 |
| 7 | 84 | 84 | N001A240 | 168.4 | R.F. | B | 6 |
| 8 | 72 | 75 | N001B230 | 168.6 | R.C. | B+ | 8 |
| 9 | 72 | 72 | N001B200 | 169.8 | R.C. | C | 2 |
| 10 | 72 | 72 | N001B190 | 170.7 | R.C. | B- | 4 |
| 11 | 78 | 81 | N001B170 | 171.3 | R.C. | B | 6 |
| 12 | 76 | 79 | N001B150 | 175.0 | R.C. | A | 10 |
| 13 | 74 | 76 | N001B120 | 176.2 | R.C. | A | 10 |
| 14 | 76 | 76 | N001A110 | 176.7 | R.F. | B+ | 8 |
| 15 | 73 | 73 | N001B100 | 187.3 | R.C. | B- | 4 |
| 16 | 73 | 76 | N001B070 | 204.7 | R.C. | B+ | 8 |
| 17 | 70 | 70 | N001A050 | 214.7 | R.F. | A | 10 |
| 18 | 100 | 100 | [illegible] | 225.89 | Bridge | B- | 4 |
| 19 | 100 | 100 | [illegible] | 233.245 | Bridge | C | 2 |
| 20 | 75 | 75 | N001B020 | 232.5 | R.C. | B | 6 |
| 21 | 73 | 73 | N001A020 | 233.7 | R.F. | C | 2 |
| 22 | 73 | 73 | N001A010 | 255.6 | R.F. | B- | 4 |
| Sub-total | | | 22spots | | | | |

Route No Nic.3

| Serial Number of Disaster Critical spots | Score of first Phase | Score of Second Phase | ID.No | Distance from Sebaco(km) (*Bridge, from Managua) | Type of disaster | Natural Condition Evaluation | Natural Condition Score |
|---|---|---|---|---|---|---|---|
| 23 | 74 | 74 | 003B420 | 3.9 | R.C. | C | 2 |
| 24 | 72 | 75 | 003B400 | 6.9 | R.C. | B+ | 8 |
| 25 | 80 | 80 | 003B370 | 7.4 | R.C. | B+ | 8 |
| 26 | 100 | 100 | El Guayacan | 119.65 | Bridge | A | 10 |
| 27 | 74 | 76 | N003B320 | 22.1 | R.C. | B+ | 8 |
| 28 | 70 | 72 | N003B240 | 32.7 | R.C. | B- | 4 |
| 29 | 73 | 73 | [illegible] | 32.9 | S.S. | A | 10 |
| 30 | 83 | 83 | N003E170 | 35.2 | D.F. | A | 10 |
| 31 | [illegible] | [illegible] | [illegible] | [illegible] | S.S. | A | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | S.S. | [illegible] | [illegible] |
| [illegible] | 90 | 90 | [illegible] | [illegible] | S.S. | A | [illegible] |
| 34 | 81 | 83 | N003B120 | 40 | R.C. | B | 6 |
| Sub-total | | | 12spots | | | | |

Route No. NIC.5

| Serial Number of Disaster Critical spots | Score of first Phase | Score of Second Phase | ID.No | Distance from Matagalpa (km) | Type of disaster | Natural Condition Evaluation | Natural Condition Score |
|---|---|---|---|---|---|---|---|
| 35 | 76 | 80 | N005A010 | 24.6 | R.F. | A | 10 |
| Sub-total | | | 1spots | | | | |

Route No Nic.15

| Serial Number of Disaster Critical spots | Score of first Phase | Score of Second Phase | ID.No | Distance from Las Manos (km) | Type of disaster | Natural Condition Evaluation | Natural Condition Score |
|---|---|---|---|---|---|---|---|
| 36 | 70 | 70 | N015B010 | 9.8 | D.F. | A | 10 |
| 37 | 70 | 70 | N015B020 | 11.1 | D.F. | A | 10 |
| 38 | 70 | 70 | N015B050 | 11.7 | D.F. | B- | 4 |
| 39 | 70 | 70 | N015B060 | 13.6 | D.F. | B- | 4 |
| Sub-total | | | 4spots | | | | 28 |

Route No. Nic.26

| Serial Number of Disaster Critical spots | Score of first Phase | Score of Second Phase | ID.No | Distance from I.C. between San Ishidoro & Sebaco (km) (*Bridge from Managua) | Type of disaster | Natural Condition Evaluation | Natural Condition Score |
|---|---|---|---|---|---|---|---|
| 40 | 71 | 71 | N026A010 | 9.0 | R.F. | B | 6 |
| 41 | 70 | 70 | N026A020 | 12.7 | R.F. | B | 6 |
| 42 | 71 | 71 | N026A030 | 19.9 | R.F. | C | 2 |
| 43 | 72 | 72 | N026A040 | 20.9 | R.F. | C | 2 |
| 44 | 70 | 78 | N026A060 | 24.7 | R.F. | A | 10 |
| 45 | 100 | 100 | La Pendiente | 170+952 | Bridge | C | 2 |
| 46 | 76 | 78 | N026A100 | 29.5 | R.F. | B | 6 |
| 47 | 73 | 73 | N026B110 | 29.8 | R.C. | C | 2 |
| 48 | 72 | 72 | N026A130 | 33.6 | R.F. | B | 6 |
| 49 | 80 | 80 | N026B140 | 34.0 | R.C. | A | 10 |
| 50 | 85 | 87 | N026A150 | 34.2 | R.F. | A | 10 |
| 51 | 86 | 86 | N026B160 | 37.0 | R.C. | A | 10 |
| 52 | 90 | 90 | San Juan de Dios | 156+785 | Bridge | B- | 4 |
| 53 | 71 | 71 | N026B210 | 45.5 | R.C. | B | 6 |
| 54 | 90 | 90 | Papalón | 106+154 | Bridge | C | 2 |
| 55 | 100 | 100 | Sofía | 107+530 | Bridge | C | 2 |
| Sub-total | | | 16spots | | | | |
| Total | | | Nic1,3,5,15,26 | | | | |

| | |
|---|---|
| R.F. | Rock Falling |
| R.C. | Rock Collapsing |
| S.S. | [illegible] |
| D.F. | Debris Flow |
| Bridge | Scoring of fundation |

### 17.2.2 Measures to the Jumping and Rolling of Unstable Rocks

The wet conditions of slope surface induce new fall of rocks due to repeated dry and wet conditions, reduce bearing capacity due to hair crack-based spalling promotion or collapse due to increasing pore water pressure. This weathering process of the tuff group shifts much-cracked andesite rocks overlaid to overhanging blocks or generates toppling, which will soon lead to falling of the andesite rocks as shown in Figure 17.2.1 and Table 7.2.2. In addition, since the andesite rocks were originally produced by lava flow, they include vertical cooling joints (generates shrinkage cracks generated from lava cooling), the development of their weathering provides a causative factor to cause rock fall. The result of calculation for jumping height and rolling distance, and examination of shifting for road alignment are presented in Sub-section 17.3.7.

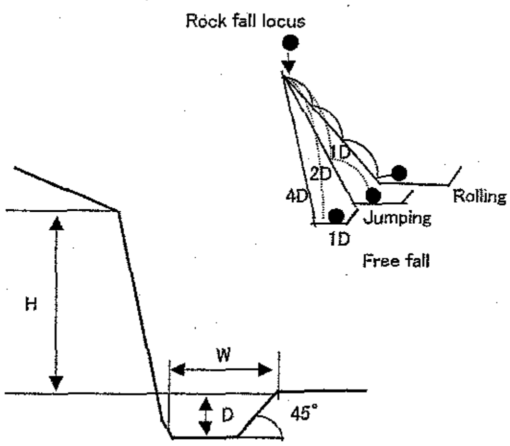



**Table 7.2.2 Calculation Result of Rock Fall Analysis**

| This survey-based calculation and Ritchie's design case for rock fall prevention groove works (1998) | | | | | | |
|---|---|---|---|---|---|---|
| | Slope gradient (°) | Slope height (m) | This calculation example | | Ritchie's design case | |
| | | | Rolling quantity | Jumping quantity | Groove width | Groove depth |
| Bedrock slope | 80 | 5~10 | 2.0 | 5.0 | 3.7 | 1.0 |
| | | 10~20 | 2.5 | 8.0 | 4.6 | 1.2 |
| | | >20 | 3.0 | 10.0 | 6.1 | 1.2 |
| | 70 | 0~10 | 1.5 | 2.8 | 3.7 | 1.0 |
| | | 10~20 | 1.6 | 3.9 | 4.6 | 1.2 |
| | | >20 | 1.7 | 5.8 | 6.1 | 1.8' |
| | | >30 | 2.0 | 6.5 | 7.6 | 1.8' |
| | 60 | 5~10 | 1.2 | 2.8 | 3.7 | 1.2 |
| | | 10~20 | 1.3 | 3.1 | 4.6 | 1.8' |
| | | 20~30 | 1.4 | 3.8 | 6.1 | 1.8' |
| | | >30 | 1.7 | 3.9 | 7.6 | 2.7' |
| | 50 | 0~10 | 0.4 | 0.0 | 3.7 | 1.0 |
| | | 10~20 | 0.7 | 1.0 | 4.6 | 1.2 |
| | | >20 | 0.8 | 1.3 | 4.6 | 1.8' |
| | 40 | 0~10 | 0.3 | 0.0 | 3.7 | 1.0 |
| | | 10~20 | 0.3 | 0.0 | 3.7 | 1.5' |
| | | >20 | 0.7 | 0.5 | 4.6 | 1.8' |

( ° ): In case of using prevention fences, 1.2m shall be applied.

In this calculation case, a block diameter shall be 1m.

## 17.3 Preliminary Engineering Design for Slope Stability

### 17.3.1 General

Based on the result of geological observation, how to determine weathered and loosened slope gradients by height and by rock type is shown in Figure 17.3.1.

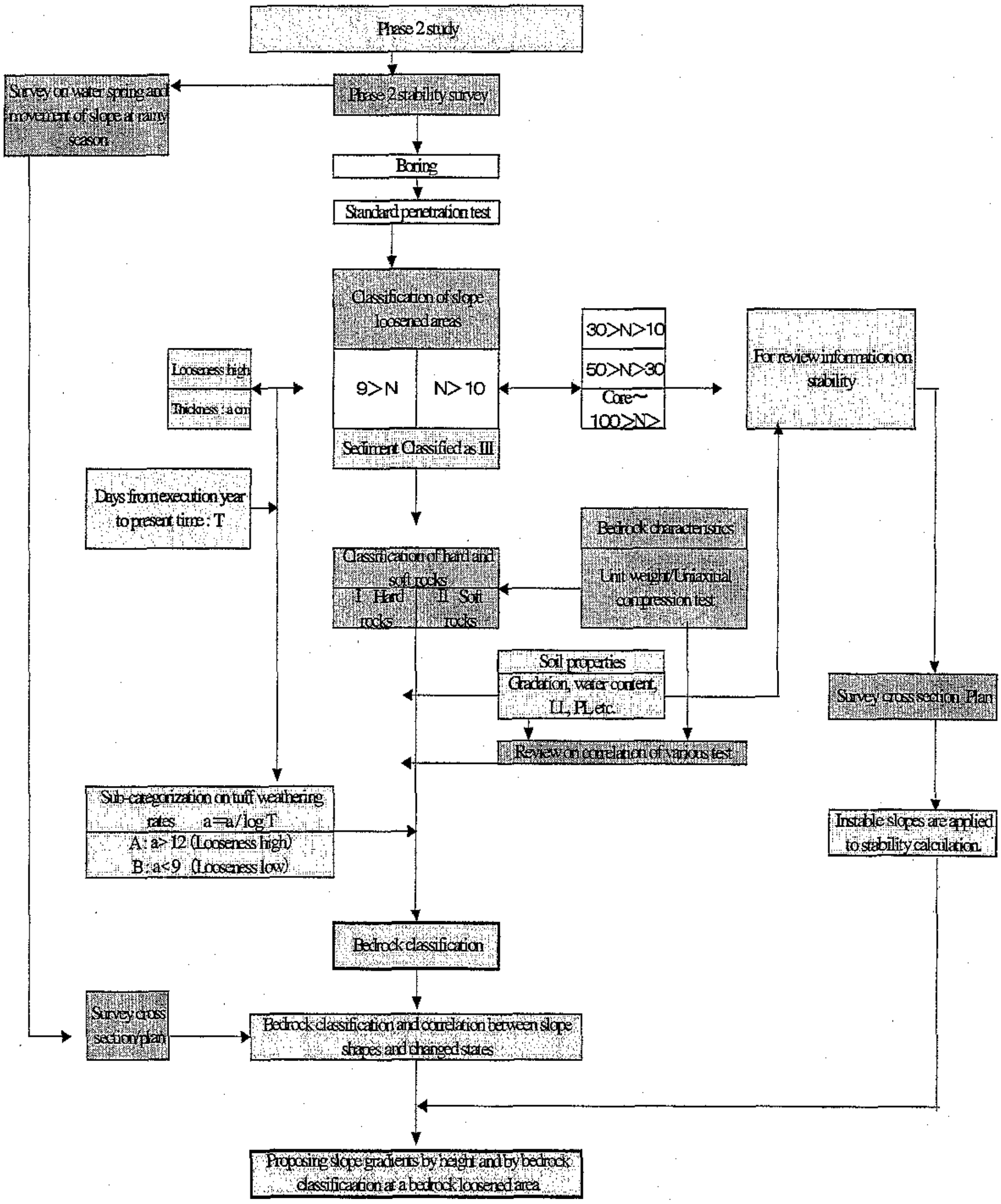



**Figure 17.3.1 Analysis Method for Slope Gradient in a Bedrock Loosening Area**

### 17.3.2 Analysis of Tuff and Andesite Groups

When incorporating slope condition where test samples were collected into the following correlation diagram of unit weight and uniaxial compression strength, the clear difference between slope collapses was considered on reaching uniaxial compression strength of 100kg/cm$^2$and unit weight of 2.5t/cm$^3$ as shown in Figure 17.3.2.

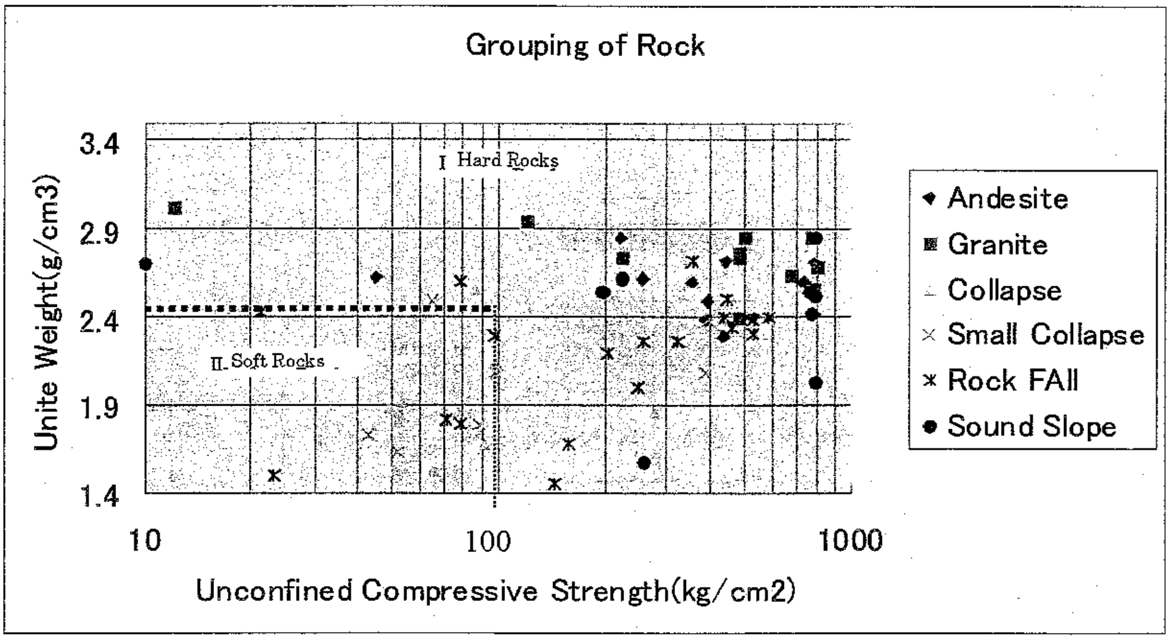



**Figure 17.3.2 Grouping of Rock**

Based on this figure, it was determined as follows;

<u>**Group I**</u> Andesite, Granite, Welded tuff, Qquartz sandstone, and Paleozoic/ Mesozoic stratums, Solider mudstone, Shale

<u>**Group II**</u> Terteary tuff/mudstone/shale including metamorphic rock.

<u>**Group III**</u> (Sediment) Granite weathered soil, talus deposits.

### 17.3.3 Analysis of Loosening Rate in a weathered Layer

Focusing on the existence of very loose weathered layers with N＜10 in N-values based on the standard penetration test, it was determined that the layers were determined to be probably part of a weathered layer of stress released at least with cut. Information for those judgments are based on N-values resulting from boring conducted at a slope toe.

The loosening rate in a weathered layer,

$\alpha$ = a / log T

$\alpha$ : Loosening rate

a : N<10 in thickness (cm)

T : Days from completion to the present time

These calculation conditions were summarized in Table 17.3.1 Analysis on loosening rate. This result is shown as followed:

$\alpha > 12$ Fast loosening group

$\alpha < 9$ Slow loosening group

**Table 17.3.1 Secondary Alteration-Based Lithology Category**

| Category | Descriptions | Loosing rate |
|---|---|---|
| A | Without any protection, it always causes secondary strength reduction after cutting. | $\alpha > 12$ |
| B | Under normal conditions, its secondary strength reduction is low and does not damage slope stability. | $\alpha < 9$ |

Based on this category, local bedrocks were classified into four groups, I B, II B, I A and II A as shown in Table 17.3.2.

**Table 17.3.2 Hardness-Based on Lithology Classification**

| Lithology Class | Rock Appearance | Hammer Approach | Representative Rock Types |
|---|---|---|---|
| I | It is hard and dense, and has fresh colors, hardly including weathered brown portinos. Rock structure can be perfectly found. | It has clear sound or dull sound. The head of a hammer cannot penetrate into it due to its hardness. Mudstone and siltstone can be broken only with difficult by hand. Block rock samples can be obtanied. | Plutonic rocks such as granite, fresh metamorphic rocks such as schist group, volcanic rocks such as andesite, rhyolite, agglomerate and basalt, hard sedimentary rocks such as sandstone |
| II | Softened rocks by weathering, low consolidation rocks. Fine structure of the rocks is difficult to identify. | It sounds dull when being struck. The head of a hammer is struck into it. It is easily broken, and its small pieces are broken with fingers. Large samples are difficult to take. | Terteary mudstone, shell, siltstone, and tuff. Weathered parts of the Class I rocks |
| III | Rocks strongly exposed to weathering and alteration, or they show no rock feature. They should be treated as sediment. | When being struck by a hammer, it will be broken as if being collapsed, or the hammer will stick into it. The head of a hammer is easily struck into it. A piece of rock is crushed with figures. | Unconsolidated layers, bedrocks weathered into soil, and talus |

### 17.3.4 Analysis of Slope Gradients

Figure 17.3.3 shows the results of analysis on slope gradients of a loosened area in a weathered layer. tuff rocks, which alternately co-exist with andesite rocks and are partially by weathering force, increase their slope stability. So, this geologic structure could be reflected in measures against slope surfaces.

A step-wise line in the chart shows a proposed value that around 5 ° can be added to, when tuff rocks alternately co-exist with andesite rocks and when tuff spalling little occurs.

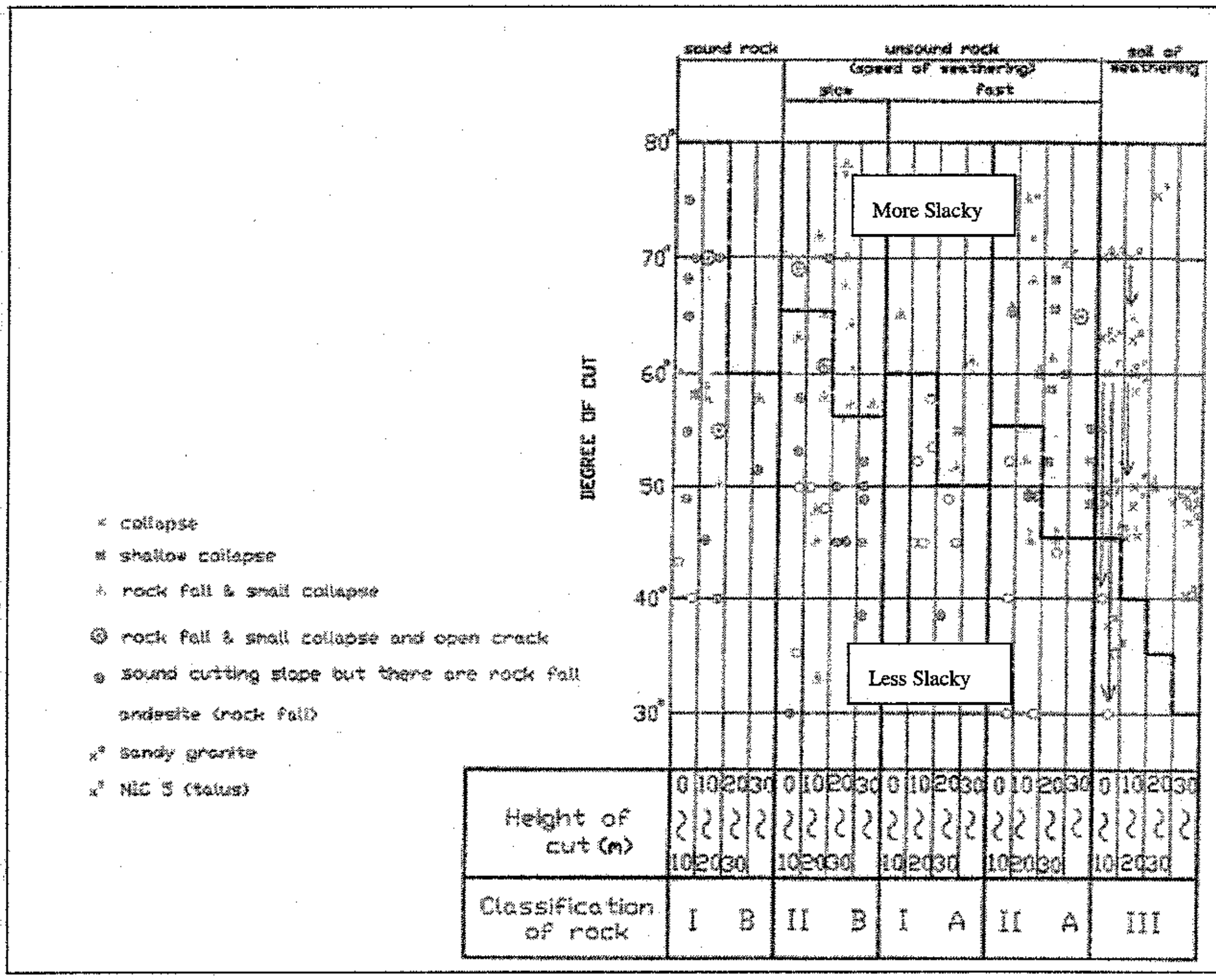



**Figure 17.3.3 Analysis on Slope Gradients of a Loosened Area in a Weathering Layer**

### 17.3.5 Results of Slope Stability Analysis

Stability analysis for circular failure is conducted, generally using the slice method assuming a circular sliding surface shown in Figure 17.3.4.

**Calculate formula**

$$Fs = \Sigma \{ C \cdot L + (W - u \cdot b) \cos \alpha \cdot \tan \Phi \} / \Sigma W \cdot \sin \alpha$$

| | | |
|---|---|---|
| F | : | Factor of Safety |
| C | : | Cohesion |
| $\phi$ | : | Internal friction angle ( °) |
| l | : | Sliding surface length cut by a slice (m) |
| W | : | Total weight of slices |
| U | : | Pore water pressure |
| b | : | Slice width |
| $\alpha$ | : | Angle between a line-linking a middle point and a center of a sliding surface and a plumb line |

The methods for stability calculation include total stress and effective stress methods. Experience shows that the two methods are currently used appropriately according to drainage environments such as ground materials, structure and target grounds due to easy selection of a strength constant and a pore water pressure.

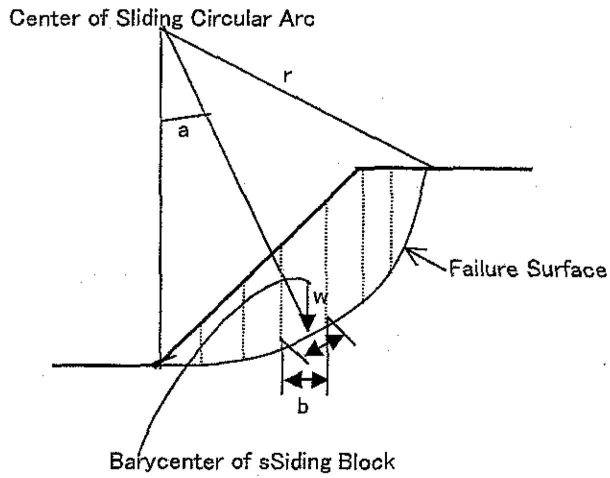



**Figure 17.3.4 Stability Analysis by SlidingCircular Arc Method at Non-earthquake Condition**

If a landslide type is identified from local topographical and geological features and if it is determined on the basis of a field survey whether landslide is active or not, lands with current safety factor shown in Table17.3.3 can be roughly identified.

**Table 17.3.3 Current Factor of Safety**

| | Bedrock landslide | Weathered rock landslide | Colluvial deposit landslide | Clayer soil landslide |
|---|---|---|---|---|
| Unmoving | 1.10 | 1.05～1.10 | 1.03～1.05 | 1.0～1.03 |
| Sliding | 0.99 | 0.95～0.99 | 0.93～0.95 | 0.9～0.93 |

The stability results of disaster prevention spots are shown in Table 17.3.10 in the main text. However because the safety factors of some spots exceed the value of above-mentioned table, it is necessary to take countermeasures certainly.

### 17.3.6 Versatility of Slope Gradient in a Loosened Bedrock in Nicaragua

Table 17.3.4 shows a list of stratums to which these analysis results can be applied. In addition, these bedrocks spread two-dimensionally as shown in Figure 17.3.5. It was found that these results could be used very widely.

**Table 17.3.4 Slope Gradient Applicable Stratums**

<table>
<tr><th colspan="2">Era</th><th colspan="2">West</th><th>Center</th><th>East</th><th>North East</th></tr>
<tr><td rowspan="2">Quaternary</td><td>Holocene</td><td colspan="2">Volcanic and Alluvium</td><td>Alluvium</td><td colspan="2" rowspan="2">Alluvial and Deposits Residuals</td></tr>
<tr><td>Pleistocene</td><td colspan="2">Group Las Sierras</td><td>Indistinct</td></tr>
<tr><td rowspan="5">Tertiary</td><td>Pliocene</td><td colspan="2">Fm.El Salto</td><td>Group Coyol</td><td>Fm.Bluefields</td><td>Group Coyol</td></tr>
<tr><td>Miocene</td><td>Fm. El Fraile</td><td>Fm. Tamarindo</td><td rowspan="3">Group Matagalpa</td><td rowspan="3">Fm.Cukra</td><td rowspan="3">Group Matagalpa</td></tr>
<tr><td>Oligocene</td><td colspan="2">Fm.Masachopa</td></tr>
<tr><td>Eocene</td><td colspan="2">Fm.Brito</td></tr>
<tr><td>Paleocene</td><td colspan="2" rowspan="2">Fm.Rivas</td><td colspan="3" rowspan="2">Group Pre—Matagalpa</td></tr>
<tr><td rowspan="3">Cretaceous</td><td>Superior</td></tr>
<tr><td></td><td colspan="2" rowspan="2">Completo Nicola en Costa Rica</td><td colspan="2" rowspan="2"></td><td rowspan="2">Fm.Metapan</td></tr>
<tr><td>Inferior</td></tr>
</table>

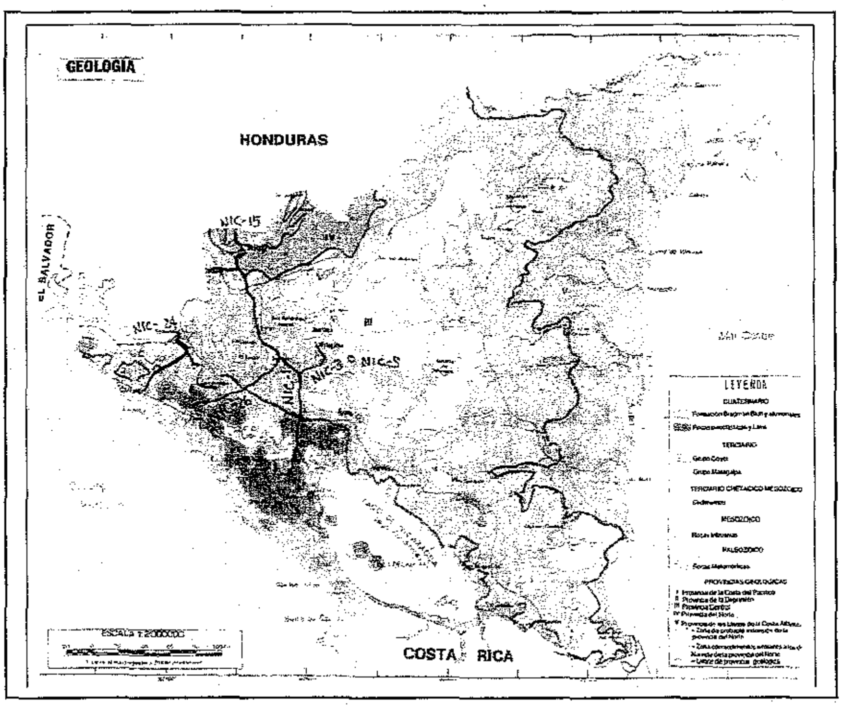



**Figure 17.3.5 Geological Area**

### 17.3.7 Selection of Countermeasure for Slope Disaster

#### 1) Calculation of Jumping Height and Rolling Distance

Based on geological characteristics of the above-mentioned results, conditions of falling stones are shown in Table 17.3.5. And calculation result of jumping height and rolling distance, and size of protection wall and prevention net are shown in Table 17.3.6, 17.3.7 and 17.3.8. However spots that need to shift the road alignment for rockfallings exists at only N003E170 on NIC.3.

Final countermeasures are presented in Table 17.4.9 in the main text.

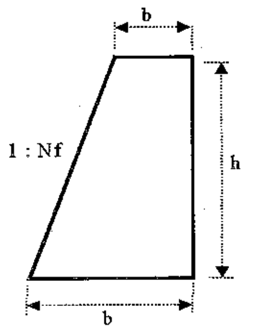
**Table17.3.5 Condition of Fallen Stone**

| ID No. | Slope Gradient (degree) | Condition of Fallen Rock | | | | | Conversion to the Volume | |
|---|---|---|---|---|---|---|---|---|
| | | Slope Height (m) | Slope Gradient (degree) | Size of Rock | Kind of Rock | Density(t/m3) | Density (t/m3) | $\phi$ (m) |
| N001A290 | 45~52 | 40 | 50 | 1.0m*1.0m*0.8m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N001A240 | 45~57 | 20 | 50 | 1.0m*1.0m*0.8m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N001B230 | 40~65 | 30 | 70 | 2.0m*1.5m*0.5m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N001B170 | 42~70 | 40 | 70 | 2.0m*1.5m*0.5m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N001B150 | 50~90 | 20 | 70 | 2.0m*1.5m*0.5m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N001B120 | 50~70 | 50 | 70 | 2.0m*1.5m*0.5m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N003B400 | 33~90 | 20 | 60 | 2.0m*1.5m*0.5m | Tuff ⅡB | 1.7 | 2.6 | 1.50 |
| N003B370 | 45~90 | 20 | 60 | 2.0m*1.5m*0.5m | Tuff ⅡB | 1.7 | 2.6 | 1.50 |
| N003E170 | 45~62 | 20 | 60 | 2.0m*1.5m*0.5m | Tuff ⅡB | 1.7 | 2.6 | 1.50 |
| N005A010 | 41~48 | 40 | 50 | 2.0m*1.5m*0.5m | Andesite ⅡB | 2.5 | 2.6 | 1.50 |
| N026A060 | 53~63 | 20 | 70 | 1.0m*1.0m*0.8m | Tuff ⅡB | 1.7 | 2.6 | 1.00 |
| N026B140 | 50~60 | 40 | 60 | 2.0m*1.5m*0.5m | Tuff ⅡB | 1.7 | 2.6 | 1.50 |
| N026A150 | 48~70 | 50 | 70 | 2.0m*1.5m*0.5m | Tuff ⅡB | 1.7 | 2.6 | 1.50 |
| N026B160 | 53~70 | 20 | 70 | 1.0m*1.0m*0.8m | Tuff ⅡB | 1.7 | 2.6 | 1.00 |

## Table 17.3.6 Jumping Height and Rolling Distance Calculations

| ID No. | Range of Jumping qt | The ninth value | Range of Rolling qt. | The ninth value | f (m) | Slope H (m) | Slope G (deg.) |
|---|---|---|---|---|---|---|---|
| N026A060<br>N026A160 | 0.73 - 2.88m | 2.85m | 0.40 - 2.68m | 2.61m | 1.00 | 20.0 | 70.0 |
| N001A240 | 1.05 -3.44m | 2.72m | 0.38 -3.97m | 0.95m | 1.50 | 20.0 | 50.0 |
| N001A290<br>N005A010 | 1.08 -3.62m | 2.98m | 0.40 - 2.67m | 0.97m | 1.50 | 40.0 | 50.0 |
| N003B400<br>N003B370<br>N003E170 | 1.16 - 4.33m | 3.27m | 0.39 - 4.50m | 3.04m | 1.50 | 20.0 | 60.0 |
| N026B140 | 1.28 - 4.45m | 3.78m | 0.45 - 4.00m | 3.20m | 1.50 | 40.0 | 60.0 |
| N001B150 | 1.67 - 6.14m | 5.08m | 0.73 - 5.12m | 4.77m | 1.50 | 20.0 | 70.0 |
| N001B230 | 1.54 - 7.70m | 6.31m | 0.52 - 7.80m | 6.88m | 1.50 | 30.0 | 70.0 |
| N001B170 | 1.57 - 14.56m | 6.77m | 1.05 - 14.17m | 7.43m | 1.50 | 40.0 | 70.0 |
| N001B120<br>N026A150 | 1.89 - 14.65m | 10.82m | 0.56 - 12.13m | 6.97m | 1.50 | 50.0 | 70.0 |

**Table 17.3.6 Structure Required for Protection Wall**




| Type | Size (m) h | b1 | b2 | Nf | Em (KJ) |
|---|---|---|---|---|---|
| A | 2.00 | 0.50 | 1.50 | 0.50 | 8.94 |
| B | 2.50 | 0.75 | 2.00 | 0.50 | 21.01 |
| C | 3.00 | 1.00 | 2.50 | 0.50 | 40.90 |
| D | 3.50 | 1.25 | 3.00 | 0.50 | 70.21 |
| E | 4.00 | 1.50 | 3.50 | 0.50 | 110.41 |
| F | 4.50 | 1.75 | 4.00 | 0.50 | 163.21 |
| G | 5.00 | 2.00 | 4.50 | 0.50 | 229.76 |
| H | 5.50 | 2.25 | 5.00 | 0.50 | 310.77 |
| I | 6.00 | 2.50 | 5.50 | 0.50 | 406.73 |
| J | 6.50 | 2.75 | 6.00 | 0.50 | 518.11 |

Em: Allowable Absorable Energy

**Table 17.3.8 Relationship between Type of Protection Wall & Natural Conditions**

| Boulder Weight | Slope Height | Slope Gradient (degree) | | | | | |
|---|---|---|---|---|---|---|---|
| (kN) | (m) | 30 | 40 | 50 | 60 | 70 | 80 |
| 1.7 ( $\phi$ =0.5m) | 10 | | | | | | |
| | 20 | | | | | | |
| | 30 | | | | | | |
| | 40 | | | | | | |
| | 50 | | | | | | |
| (kN) | (m) | 30 | 40 | 50 | 60 | 70 | 80 |
| 13.6 ( $\phi$ =1.0m) | 10 | | | | | | |
| | 20 | | | | | N026A060<br>N026B160 | |
| | 30 | | | | | | |
| | 40 | | | | | | |
| | 50 | | | | | | |
| (kN) | (m) | 30 | 40 | 50 | 60 | 70 | 80 |
| 45.9 ( $\phi$ =1.5m) | 10 | | | | | | |
| | 20 | | | N001A240 | N003B400<br>N003B370<br>N003E170 | N001B150 | |
| | 30 | | | | | N001B230 | |
| | 40 | | | N001A290<br>N005A010 | N026B140 | N001B170 | |
| | 50 | | | | | N001B120<br>N026A150 | |
| (kN) | (m) | 30 | 40 | 50 | 60 | 70 | 80 |
| 108.9 ( $\phi$ =2.0m) | 10 | | | | | | |
| | 20 | | | | | | |
| | 30 | | | | | | |
| | 40 | | | | | | |
| | 50 | | | | | | |

**Table 17.3.8 Required Dimensions for Prevention Nets**

| ID No. | Rope f 12 Mesh f 2.6 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Net Data | | | | Rock Data | | Slope Data | |
| | Main Rope | Auxiliary Rope | Wire Mesh | Maximum Capacity | f (m) | W (kN) | Slope H (m) | Slope G (deg.) |
| N026A060<br>N026A160 | f 12 | f 12 | f 2.6 | n=1.0 | 1.00 | 13.61 | 20.0 | 70.0 |
| N001A240 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 20.0 | 50.0 |
| N001A290<br>N005A010 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 40.0 | 50.0 |
| N003B400<br>N003B370<br>N003E170 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 20.0 | 60.0 |
| N026B140 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 40.0 | 60.0 |
| N001B150 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 20.0 | 70.0 |
| N001B230 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 30.0 | 70.0 |
| N001B170 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 40.0 | 70.0 |
| N001B120<br>N026A150 | f 12 | f 12 | f 2.6 | NG | 1.50 | 45.92 | 50.0 | 70.0 |

| ID No. | Rope f 18 Mesh f 4.2 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Net Data | | | | Rock Data | | Slope Data | |
| | Main Rope | Auxiliary Rope | Wire Mesh | Maximum Capacity | f (m) | W (kN) | Slope H (m) | Slope G (deg.) |
| N026A060<br>N026A160 | f 18 | f 18 | f 4.0 | n=6.0 | 1.00 | 13.61 | 20.0 | 70.0 |
| N001A240 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 20.0 | 50.0 |
| N001A290<br>N005A010 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 40.0 | 50.0 |
| N003B400<br>N003B370<br>N003E170 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 20.0 | 60.0 |
| N026B140 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 40.0 | 60.0 |
| N001B150 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 20.0 | 70.0 |
| N001B230 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 30.0 | 70.0 |
| N001B170 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 40.0 | 70.0 |
| N001B120<br>N026A150 | f 18 | f 18 | f 4.0 | n=1.0 | 1.50 | 45.92 | 50.0 | 70.0 |

## 17.4 Preliminary Engineering Design for Bridge Foundation Scouring

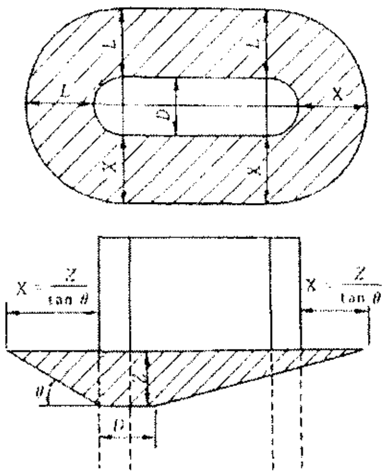
There are many factors for scouring of bridge foundations as follows:

- Change in river flow caused by piers,
- Obstruction ratio of river by piers shape,
- River obstruction ratio by pier width,
- Abutments located in the river flow,
- Lack of the free space under beam, and
- Lack of depth between footing face of bridge foundation and riverbed, etc.

Calculation results of scouring on bridge foundation are shown in Table 17.4.1. The bridges detected with scouring are Junquillal Bridge, LasChanilas Bridge, and Tacapali Bridge.

## Table 17.4.1 Calculation Result of Scouring

| River Name | | UNIT | Junquillal | Las Chanillas | Inali | Tacapari | El Guayacan | San Juan de Dios | La Banderita |
|---|---|---|---|---|---|---|---|---|---|
| Width of river W : | | m | 29.3 | 62 | 64 | 109 | 17.5 | 17.9 | 31.6 |
| Width of pier D : | | m | 0.4 | 0.7 | 0.8 | 1 | 0.9 | 0.4 | 1.1 |
| flow velocity of High water level V : | | m3/s | 246.28 | 668.61 | 579.58 | 886.75 | 149.08 | 67.22 | 60.12 |
| Average level of road surface | | m | 457.3 | 822 | 638.2 | 299.62 | 614 | 96.4 | 226.7 |
| Average level of riverbed | | m | 453.65 | 815 | 631.27 | 292 | 609.6 | 94 | 217.8 |
| of High water level in flood | | m | 458.01 | 817.765 | 634.27 | 295.952 | 614.59 | 96.25 | 220.47 |
| Mean water depth in flood ho : | | m | 4.36 | 2.765 | 3 | 3.952 | 4.99 | 2.25 | 2.67 |
| Average grain diameter of riverbed materials dm : | | mm | 0.5 | 6 | 13 | 10 | 15 | 1 | 3 |
| ho/D | | - | 10.90 | 3.95 | 3.75 | 3.95 | 5.54 | 5.63 | 2.43 |
| Fr = (V/(W·ho))/v(g·ho) = | | - | 0.29 | 0.75 | 0.56 | 0.33 | 0.24 | 0.36 | 0.14 |
| ho/dm | | - | 8720.0 | 460.8 | 230.8 | 395.2 | 332.7 | 2250.0 | 890.0 |
| Z/D | | - | 1.48 | 1.8 | 1.68 | 1.45 | 1.2 | 1.55 | 0.8 |
| Z | | m | 1.776 | 2.16 | 2.016 | 1.74 | 1.44 | 1.86 | 0.96 |
| Angle of repose ? | | Deg | 31.0 | 34.0 | 40.0 | 40.0 | 40.0 | 31.0 | 32.0 |
| tan? | | - | 0.60 | 0.67 | 0.84 | 0.84 | 0.84 | 0.60 | 0.62 |
| X=Z/tan? | | m | 2.96 | 3.20 | 2.40 | 2.07 | 1.72 | 3.10 | 1.54 |
| Result of site survey | Width(X) | m | 3.0 | 3.0 | - | 2.0 | - | - | - |
| | Length(L) | m | 4.0 | 4.0 | - | 2.0 | - | - | - |
| | Depth(Z) | m | 0.7 | 0.8 | - | 1.0 | - | - | - |




X : Horizontal distance of the range of scouring
Z : Maximum depth of scouring
θ : Angle of repose
D : Width of pier

As described in above-mentioned table, expected scouring locations are as follows:

1) Around piers,
2) Around abutments, and
3) Embankment for approaches.

Based on the result of calculation result, a range and a depth of bridge foundation by scouring are protected as shown in Table 17.4.2 and 17.4.3.

**Table 17.4.2 Comparison of Prevention Measures for Foundation Scouring**

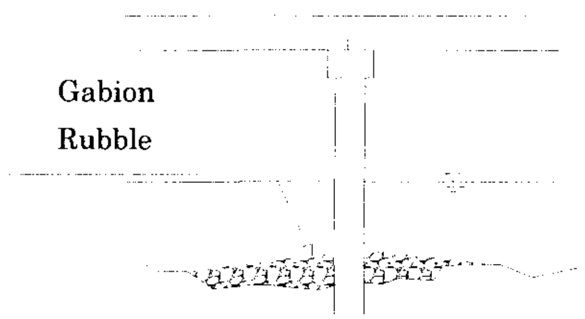
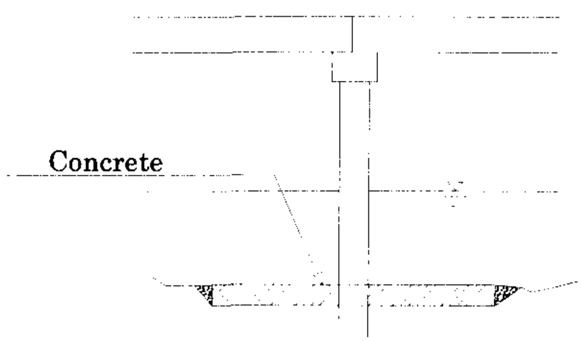
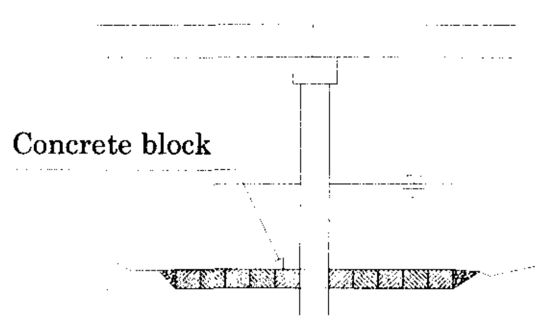
| Material | Illustration | Remarks |
|---|---|---|
| Rubble and gabion |  | This measure is for temporary works and for works in rivers with slow velocity.<br>Economically efficient. Facility for construction is simple and easy (manual labor only is basically sufficient).<br>The advantage of rubble is that it can change its form in response to differential settlement of the riverbed if the foundation is soft.<br>Maintenance is necessary. |
| Protection by the Concrete |  | This measure is applied at sites with fast flows and strong riverbed foundations.<br>This measure is inappropriate for sites with soft riverbed foundations because the structure might collapse due to differential settlement.<br>Because, this measure requires the pouring of concrete on site, it is impossible to execute in the rainy season. |
| Protection by precast concrete block |  | By changing the size of concrete block in accordance with the velocity of water flow, this measure can be applied to all kinds of rivers.<br>Because precast concrete is applied, construction can be implemented at any time except during floods.<br>Maintenance is not necessary.<br>This measure can bear small differential settlement. |

**Table 17.4.3 Countermeasure Applicability by Bridge**

| Name | Rubble Gabion | Concrete | Concrete Block | Explanatory Remarks |
|---|---|---|---|---|
| Junqillal | A | C | C | It is predictable that the settlement will occue due to the soft riverbed.<br>The velocity of water flow is slow.<br>The river always has water flow. |
| San Nicolas | A | C | C | The velocity of water flow is slow.<br>The river always has water flow. |
| Las Chanillas | C | B | A | The velocity of water flow is fast. |
| San Ramon | A | C | C | It is predictable that the settlement will occue due to the soft riverbed. |
| Inali | C | B | A | The velocity of water flow is fast. |
| Tapacali | C | B | A | The velocity of water flow is rather fast.<br>The river always has water flow. |
| El Guayacan | A | A | A | The velocity of water flow is slow.<br>There is a season when the water flow in the river dissapears. |
| Solis | C | A | B | The velocity of water flow is fast.<br>The riverbed is consisted of soft rock.<br>The block is not economical because the width of river is narrow. |
| Papalon | C | A | B | The velocity of water flow is fast.<br>The riverbed is consisted of soft rock.<br>The block is not economical because the width of river is narrow. |
| San Juan de Dios | A | C | C | It is predictable that the settlement will occue due to the soft riverbed.<br>The economical advantage is excellent. |
| La Banderita | A | C | C | The velocity of water flow is relatively fast.<br>The economical advantage is excellent. |

A : Advisable measure
B : Applicable measure
C : Measure difficult to apply

## 17.5 Selection of Spot Specific Countermeasures

The selection of countermeasures for slope damages and bridge foundations are presented in Section 17.6 in the main text. Spot specific countermeasures are in detail selected taking into account the alternative countermeasures against disaster features.

# CHAPTER 18 CONSTRUCTION PLAN AND COST ESTIMATE

## 18. 1 General

The following work items will be taken up in this chapter:

- Clarification of assumptions for making cost estimates,
- Estimate of quantities for each prevention spot,
- Examination of the unit rate for each prevention countermeasure,
- Drawing up of construction costs for each prevention spot, and
- Drawing up of maintenance costs for each Study route.

The lifespan of road disaster prevention measures, which take into account the probability of road-related disasters occurring, are as described below.

- Permanent disaster prevention measure: Effective for 20 years
- Temporary disaster prevention measure: Effective for 10 years

## 18.2 Cost Estimate Assumptions

Construction unit rates obtained from MTI were first reviewed and adjusted as necessary. The Study team then examined unit rates for new work items. As part of this work, the Study team requested unit rate quotations from three general contractors.

Construction costs for each prevention spot are estimated as a direct cost. Note that direct cost includes direct variable cost, which consists of costs for temporary facilities and is greatly dependent on the conditions of a particular spot. Therefore, construction cost is estimated by averaging direct costs.

## 18.3 Unit Rates

Unit rates for different types of work and their corresponding work items are as shown in Table 18.3.1.

Unit rates, which are based on the costs derived in Chapter 7, are revised in the Feasibility Study by considering additional work items and disaster prevention measures. Note that the types of prevention measures are the same as those in Chapter 7. The revised unit rates of the work items, the additional work items and the additional measures are shown in below.

- ■ Work items with a revised unit rate are marked with a ○ and are as follows:
  - (7) Rock-fall prevention device: Net
  - (9) Riverbank protection: Concrete revetment
- ■ Additional work items are marked with a □ and are as follows:
  - (4) Structure: Concrete cribwork
  - (9) Riverbank protection: Concrete cribwork for riverbed
- ■ Additional measures are as follows:
  - (11) Bridge structure
  - (12) Box culvert

**Table 18.3.1 Unit Rates**

| Type of Work | Work Item | Remarks | Unit | Unit Rate | Reason for Modifying Unit Rate |
|---|---|---|---|---|---|
| (4) Structure | Shotcrete | T=10cm | $m^2$ | 48.30 | Vegetation is used to harmonize with a nearby natural park. |
| | Concrete cribwork ? | 0.3×0.3 @2.0m | $m^2$ | 100.00 | |
| | Gabion mat | | $m^3$ | 43.67 | |
| (7) Rock-fall prevention device | Prevention net ? | | $m^2$ | 8.53 | Estimate changed to reflect prices from three local construction companies instead of just |
| | Barrier with gabion mat | | $m^3$ | 97.49 | |
| | Barrier with concrete wall | | $m^3$ | 625.13 | |
| (9) Riverbank protection | Concrete revetments ? | | $m^3$ | 654.95 | Estimate based on prices from two local construction companies was changed to one based on prices from four local construction companies. |
| | Gabion mat | | $m^3$ | 97.49 | |
| | Stone riprap with mortar | | $m^3$ | 66.91 | Concrete cribwork adopted for rapid river flows. |
| | Concrete cribwork for riverbed ? | | $m^2$ | 39.49 | |
| (11) Bridge structure | Steel bridge with concrete slab | | $m^2$ | 406.24 | Bridge is considered as an alternative. |
| | Gravity-type abutment | | $m^3$ | 37.15 | |
| | Reversal T-type abutment(RC) | | $m^3$ | 197.26 | |
| (12) Box culvert | Cast in place | 3m×2m | m | 1740.6 | Box culvert type is considered as an alternative. |

## 18. 4 Spot Specific Construction Plans

The main types of equipment used for construction at each of the disaster prevention spots are as shown in tables 18.4.1 and 18.4.2.

**Table 18.4.1 Main Equipment List for Slope Damage Repair**

| ID. No | Type of Disaster | Type of Countermeasure | Bulldozer | Back hoe | Pick hummer | Shotcrete machine | Truck crane | Vibration roller | Jumbo Breaker | Boring machine |
|---|---|---|---|---|---|---|---|---|---|---|
| N001A290 | R.F | Recutting + Prevention net + Drainage | | ○ | ○ | | ○ | | | |
| N001A280 | R.F | Horizontal drainage | | | | | | | | ○ |
| N001A240 | R.F | Recutting + Prevention net | | ○ | ○ | | ○ | | | |
| N001B230 | R.C | Recutting + Prevention net | | ○ | ○ | | ○ | | | |
| N001B170 | R.C | Recutting + Drainage | | ○ | ○ | | | | ○ | |
| N001B150 | R.C | Recutting + Shotcrete + Drainage | | ○ | ○ | ○ | | | | |
| N001B120 | R.C | Recutting + Drainage | | ○ | ○ | | | | ○ | |
| N003B400 | R.C | Recutting + Drainage | | ○ | ○ | | | | | |
| N003B370 | R.C | Recutting + Drainage | | ○ | ○ | | | | ○ | |
| N003B320 | R.C | Embankment + Concrete retaining wall + Vegetation | ○ | ○ | ○ | | | ○ | ○ | |
| N003C230 | S.S + R.C | Recutting + Cribwork +Drainage<br>Embankment + Vegetation + Drainage | ○ | ○ | ○ | | ○ | ○ | ○ | |
| N003E170 | D.F + R.C | Dam<br>Recutting + Drainage | ○ | ○ | ○ | | ○ | ○ | ○ | |
| N003C150 | S.S + R.C | Recutting + Drainage<br>Embankment +Vegetation | ○ | ○ | ○ | | | ○ | ○ | |
| N003C140 | S.S + R.C | Recutting + Drainage<br>Embankment +Concrete retaining wall + Vegetation + Drainage | ○ | ○ | ○ | | ○ | ○ | ○ | |
| N005A010 | R.F | Recutting + Drainage | | ○ | ○ | | | | ○ | |
| N026A060 | R.F | Recutting + Shotcrete + Drainage | | ○ | ○ | ○ | | | | |
| N026B140 | R.C | Recutting + Horizontal drainage + Drainage | | ○ | ○ | | | | ○ | ○ |
| N026A150 | R.F | Recutting +Drainage | | ○ | ○ | | | | ○ | |
| N026B160 | R.C | Recutting + Prevention net | | ○ | ○ | | ○ | | | |

Note) R.F: Rock-fall/collapsing; R.C: Rock collapsing; S.S: Slope Slide; D.F: Debris flow

**Table 18.4.2 Main Equipment List for Bridge Damage Repair**

| Bridge Name | | Type of Disaster | Type of Countermeasure | Bulldozer | Back hoe | Concrete breaker | Truck crane | Jumbo breaker |
|---|---|---|---|---|---|---|---|---|
| NIC.1 | Junquillal | Bridge | Gabion mat | | ○ | | ○ | |
| | San Nicolas | Bridge | Gabion mat | | ○ | | ○ | |
| | Las Chanillas | Bridge | Concrete block | | ○ | | ○ | |
| | San Ramon | Bridge | Gabion mat | | ○ | ○ | ○ | |
| | Inali | Bridge | Gabion mat<br>Revetment +Stone masonry | | ○ | ○ | ○ | |
| | Tapacali | Bridge | Gabion mat<br>Revetment | | ○ | ○ | ○ | |
| NIC.3 | Guayacan | Bridge | New bridge construction | ○ | ○ | ○ | ○ | ○ |
| NIC.26 | Solis | Bridge | Stone riprap with mortar<br>Gabion mat | | ○ | | ○ | |
| | Papalon | Bridge | Stone riprap with mortar<br>Gabion mat | | ○ | | ○ | |
| | San Juan de Dios | Bridge | Gabion mat | | ○ | | ○ | |
| | La Banderita | Bridge | Stone riprap wall<br>Gabion mat | | ○ | | ○ | |

Note) Bridge: Scouring of foundation

## 18.5 Summary of Spot Specific Work Quantities and Costs

### 18.5.1 NIC.1

Costs for each disaster prevention spot are as shown in Table 18.5.1- Table18.5.7.

**Table 18.5.1 Construction Cost for Countermeasures for Slope Failure**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| N001A290 | R.F | Removal + Prevention net + Drainage | T | $m^2$ | 23,286 | 335 |
| N001A280 | R.F | Horizontal drainage | P | m | 100 | 10 |
| N001A240 | R.F | Removal + Prevention net | T | $m^2$ | 950 | 26 |
| N001B230 | R.C | Removal + Prevention net | T | $m^2$ | 228 | 6 |
| N001B170 | R.C | Recutting + Drainage | P | $m^3$ | 36,028 | 1,590 |
| N001B150 | R.C | Recutting + Shotcrete + Drainage | P | $m^2$ | 252 | 27 |
| N001B120 | R.C | Recutting + Drainage | P | $m^3$ | 10,655 | 814 |
| Total | | | | | | 2,808 |

Note) R.F: Rock fall; R.C: Rock collapsing; P: Permanent countermeasure; T: Temporary countermeasure

**Table 18.5.2 Construction Cost for Countermeasures for Bridge Foundation Scouring**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| Junquillal | Bridge | Gabion mat | T | $m^3$ | 435 | 42 |
| San Nicolas | Bridge | Gabion mat | T | $m^3$ | 114 | 25 |
| Las Chanillas | Bridge | Concrete block | T | $m^3$ | 288 | 189 |
| San Ramon | Bridge | Gabion mat | T | $m^3$ | 86 | 9 |
| Inali | Bridge | Gabion mat<br>Revetment +Stone masonry | T | $m^3$<br>$m^2$ | 1,138<br>1,758 | 828 |
| Tapacali | Bridge | Gabion mat<br>Revetment | T | $m^3$<br>$m^2$ | 238<br>640 | 282 |
| Total | | | | | | 1,375 |

Note) Bridge: Scouring of foundation; T: Temporary countermeasure

## 18.5.2 NIC.3

**Table 18.5.3 Construction Cost for Countermeasures for Slope Failure**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| N003B400 | R.C | Recutting + Drainage | P | $m^3$ | 290 | 40 |
| N003B370 | R.C | Recutting + Drainage | P | $m^3$ | 1,676 | 175 |
| N003B320 | R.C | T-shaped retaining wall +Refilling+ Vegetation+ Drainage | P | $m^3$ | 3,168 | 239 |
| N003C230 | S.S + R.C | Recutting + Cribwork + Vegetation+ Drainage<br>Embankment + Vegetation + Drainage | P | $m^2$<br>$m^3$ | 638<br>4,934 | 328 |
| N003E170 | D.F + R.C | Concrete dam + Box culvert<br>Recutting + Drainage | P | m<br>$m^3$ | 20<br>2,670 | 310 |
| N003C150 | S.S + R.C | Recutting + Drainage<br>Embankment +Vegetation+ Drainage | P | $m^3$ | 9,221<br>16,076 | 918 |
| N003C140 | S.S + R.C | Recutting +Horizontal drainage + Drainage<br>Embankment +T-shaped retaining wall + Vegetation + Drainage | P | $m^3$ | 5,408<br>3,176 | 749 |
| Total | | | | | | 2,759 |

Note) R.C: Rock collapsing; S.S: Slope Slide; D.F: Debris flow; P: Permanent countermeasure

**Table 18.5.4 Construction Cost for Countermeasures for Bridge Foundation Scouring**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| El Guayacan | Bridge | New bridge construction | P | $m^2$ | 500 | 1,379 |

Note) Bridge: Scouring of foundation; P: Permanent countermeasure

### 18.5.3 NIC.5

**Table 18.5.5 Construction Cost for Countermeasures for Slope Failure**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| N005A010 | R.F | Recutting + Drainage | P | $m^3$ | 10,760 | 389 |

Note) R.F: Rock fall; P: Permanent countermeasure

### 18.5.4 NIC.26

**Table 18.5.6 Construction Cost for Countermeasures for Slope Failure**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| N026A060 | R.F | Recutting + Shotcrete + Drainage | P | $m^2$ | 3,604 | 316 |
| N026A140 | R.C | Recutting + Horizontal drainage + Drainage | P | $m^3$ | 11,495 | 904 |
| N026A150 | R.F | Recutting +Drainage | P | $m^3$ | 2,113 | 210 |
| N026B160 | R.C | Removal + Prevention net +Drainage | T | $m^2$ | 1,568 | 13 |
| Total | | | | | | 1,443 |

Note) R.F: Rock fall; R.C: Rock collapsing; P: Permanent countermeasure; T: Temporary countermeasure

**Table 18.5.7 Construction Cost for Countermeasures for Bridge Foundation Scouring**

| ID. No | Type of Disaster | Type of Countermeasure | | Unit | Qty | Cost (US$1000) |
|---|---|---|---|---|---|---|
| Solis | Bridge | Stone riprap with mortar<br>Gabion mat | T | $m^3$ | 72<br>546 | 66 |
| Papalan | Bridge | Stone riprap with mortar<br>Gabion mat | T | $m^3$ | 50<br>408 | 51 |
| San Juan de Dios | Bridge | Gabion mat | T | $m^3$ | 115 | 5 |
| La Banderita | Bridge | Stone riprap wall<br>Gabion mat | T | $m^2$<br>$m^3$ | 162<br>375 | 31 |
| Total | | | | | | 153 |

Note) Bridge: Scouring of foundation; P: Permanent countermeasure

### 18.5.5 Total Cost

Total construction cost for each route is as shown in Table 18.5.8.

**Table 18.5.8 Total Construction Cost by Route**

| Objective Route | Cost (US$1000) | | |
|---|---|---|---|
| | Slope | Bridge | Total |
| NIC.1 | 2,808 | 1,375 | 4,183 |
| NIC.3 | 2,759 | 1,379 | 4,138 |
| NIC.5 | 389 | 0 | 389 |
| NIC.26 | 1,443 | 153 | 1,596 |
| Total | 7,399 | 2,907 | 10,306 |

US$1=C$14.4 (exchange rate as of October 14, 2002)

# CHAPTER 19 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

## 19.1 Method of EIA

The EIA assesses the level of consideration given by countermeasures to the environmental negative factors selected for each spot in Chapter 9. Validity of the method of environmental consideration is judged based on "The summary of general matters for environment observance in the construction stage" (Chapter 5 of NABCV in NIC 2000).

## 19.2 Evaluation of Environmental Consideration

### 19.2.1 Resettlement

Resettlement (a hotel under construction) was originally forecast at one spot (Nic3) among the target spots. However, this was averted by revising works as shown in Table 19.2.1.

**Table19.2.1 Consideration Items for Avoidance of Resettlement**

| Spot No. | Countermeasure | |
|---|---|---|
| | Initial Idea | Final Idea |
| N003B320 | It was forecast that the hotel would fall on in the excavation line due to cutting works. | Cantilever retaining wall was adopted to ensure backfilling at the rear. . |

Land acquisition needs to be carried out at some of objective spots presented in Table 19.2.2 in the main text. However there are no spots where expropriation causes a trouble judging from present conditions of use. Land acquisition is done in accordance with the Nicaraguan law.

### 19.2.2 Economic Activity

Concern was raised over the impact on economic activities at four of the spots; however, measures were taken at each spot to avert this economic impact as indicated in Table 19.2.2.

### 19.2.3 Ground Water

Concern was raised over the impact on three shallow wells that utilize non-artesian ground water. However countermeasures were devised to minimize impact on the water catchment volumes shown in Tables 19.2.3 and 19.2.4.

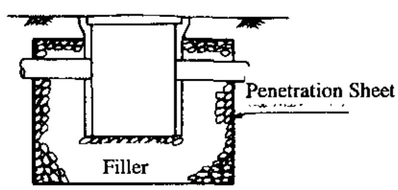
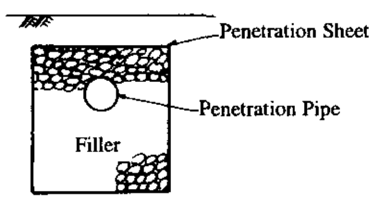
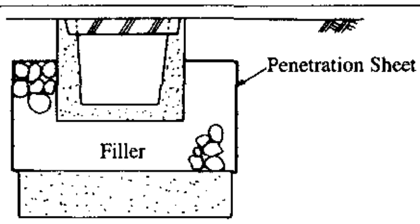
**Table19.2.2 Consideration Items for Economic Activity**

| Spot No. | Countermeasure | |
|---|---|---|
| | **Initial Idea** | **Final Idea** |
| Junquillal (Nic1) | An influence on the service water for rice fields on the downstream side was forecast by the shutoff of water under the construction. | It is the plan to secure the service water by half-section construction. |
| N003B320 | As mentioned in the Table 19-1. | As mentioned in Table 19-1. |
| N003C140 | It was forecast that a coffee field under the embankment will be affected by the construction. | It is the plan to avoid an influence by the wall. |
| N003C150 | A coffee field was confirmed at the top of the slope as a result of the site re-survey. | Influence was minimized by countermeasures matched to the existing slope as much as possible. |

**Table19.2.3 Consideration Items for Ground Water**

| Spot No. | Countermeasure | |
|---|---|---|
| | **Initial Idea** | **Final Idea** |
| N005A010 | Re-cutting + Vegetation + Drainage | Concrete Frame + Vegetation + Drainage (permeation catch pit) |
| N026B140 | Re-cutting | Concrete Frame + Cobble + Drainage (permeation catch pit) |
| N026B160 | Judgment as use of the non-artesian water | Use of confined water. |

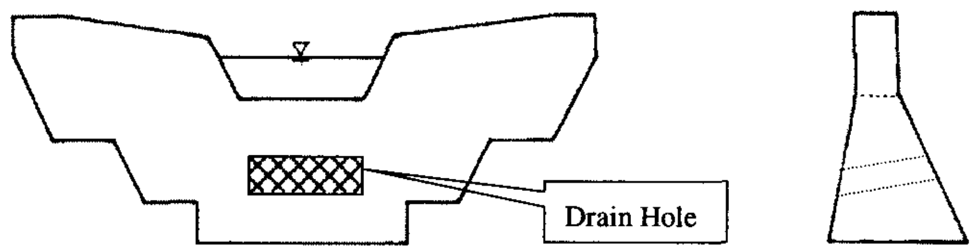
**Table19.2.4 The Drainage Structure in Consideration of the Underground Permeation**

| e.g. Structure | General Outline |
|---|---|
|   | Permeation Catch Pit<br><br>Permeation catch pit is the structure composed of catch pit that it has perforations on the side and the bottom, and filling material on the circumference. And, rainwater is made to permeate from the sides and bottom to the ground. |
|   | Permeation Trench<br><br>Permeation trench is the structure composed of permeation pipe and filling material of the circumference. And, rainwater is made to permeate from the sides and bottom to the ground. |
|   | Permeation Side Ditch<br><br>A permeation side ditch is the structure composed of sides and bottom made from permeable or perforated concrete, and circumference made from filling material. And, rainwater is made to permeate from the sides and bottom to the ground. |

### 19.2.4 Lake and River

Concern was raised over the impact on the river (river use) in one place. However, the structure was revised so that impact on river flow was avoided as shown in Table 19.2.6.

**Table19.2.5 Consideration Item for River Use**

| Spot No. | Dam |
|---|---|
| N003E170 |  |

### 19.2.5 Fauna and Flora

Concern was raised over the direct and indirect impact on the national conservation area (precious animals and plants) in the following two spots. However, it is the plan to avoid any influence as shown in Table 19.2.6.

**Table19.2.6 Consideration Items for Fauna and Flora**

| Spot No. | Pending Issue | Measure |
|---|---|---|
| San Nicolas (Nic1) | There was concern that water supply to the animals will decrease due to shutoff of water by the construction to the Cerro Tomabu national conservation area on the downstream side. | Carry out construction in the dry season without resorting to water shutoff. |
| N003C230 | Because the spot was located in Cerro El Arenal national conservation area, countermeasures had to take vegetation regeneration into consideration. | It is the plan to regenerate vegetation by doing planting in the concrete frame. (Refer to Fig. 19.2.1)<br>The planting is carried out using native species or latent natural seedings. And, the embankment is planted with trees to harmonize with the surrounding landscape. |

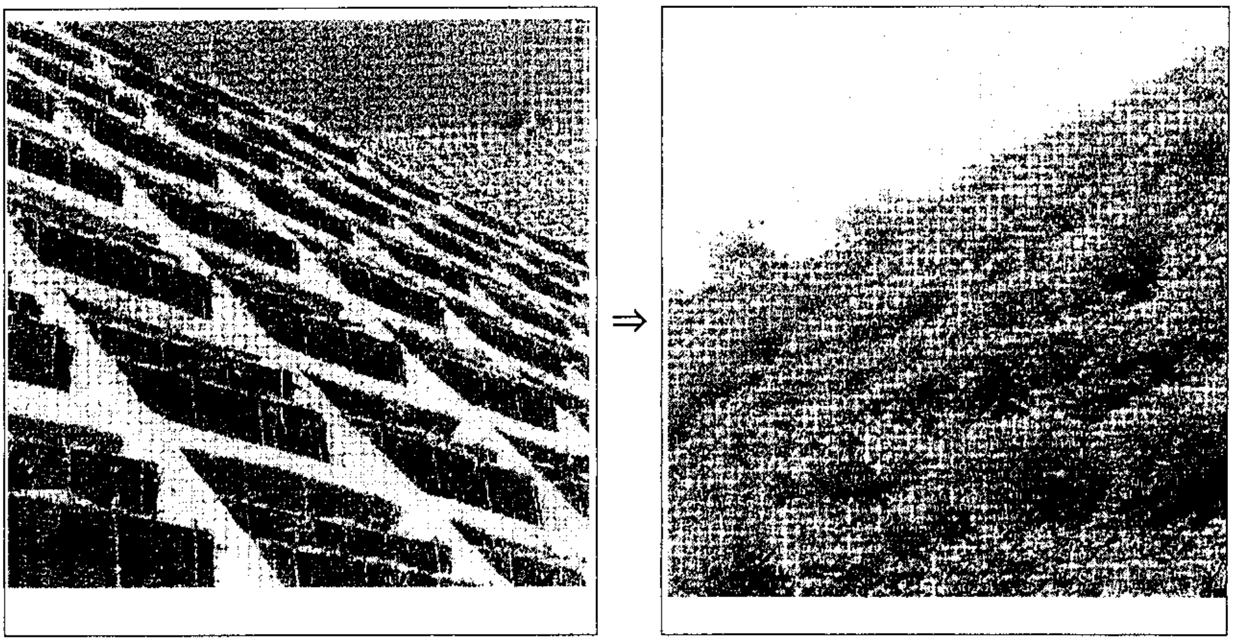


**Figure 19.2.1 e.g. Planting in the Concrete Frame**

### 19.2.6 Landscape

N003C230, where countermeasures are enforced directly in the national conservation area, was made the target for careful consideration to the landscape. As above mentioned, it is planned to take countermeasures here that give careful consideration to vegetation that matches with the surrounding natural landscape.

## 19.3 The Items to Concern for The Next Step

Concerning responsibility to the legal environment must be referred to the section 108 of NIC2000 in the construction contract stage. Furthermore, as for the items of concern with the environment in the stage of the basic design, the detailed design and the construction, it is important to confirm the mentioned items of NABCV fully. Detailed contents are described in the main text.

## 19.4 Evaluation at Present

It is judged that adequate countermeasures are being taken with respect to items that are immediately pertinent to minimization of environmental impact. Final evaluation of all site is shown in Table 19.4.1.

# Table19.4.1 Evaluation of Each Spot for Environmental Impact

| Enviroment Item | | | Stage of IEE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nic.1 | | | | | | | | | | | | | Nic.3 | | | | | | | | 5 | Nic.26 | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| Social Environment | 1 | Inhabitant Transfer | D* | B | D | D | D | D | B | B | B | B | B | D | D | B | B | D | A | B | B | B | B | B | B | D | B | B | B | D | D | D |
| | 2 | Economic Activity | D | D | A | D | D | D | D | D | D | D | D | D | D | D | D | D | A | D | D | D | A | D | D | D | D | D | D | D | D | D |
| | 3 | Facility for Life and Traffic | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B |
| | 4 | Waste | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B |
| Natural Environment | 5 | Ground Water | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | B | D | D | B | D | B | D | D | D |
| | 6 | Lake/Liver | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | B | D | D | D | D | D | D | D | D | D | D | D |
| | 7 | Fauna/Flora | D | D | D | A | D | D | D | D | D | D | D | D | D | D | D | D | D | B | D | D | D | D | D | D | D | D | D | D | D | D |
| | 8 | Landscape | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | B | D | D | D | D | D | D | D | D | D | D | D | D |
| Pollution | 9 | Air Pollution | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| | 10 | Water Pollution | B | B | B | B | B | B* | B | B | B | B | B | B* | B* | B | B | B | B | B | B | B | B | B* | B | B | B | B | B* | B | B | B |
| | 11 | Noise/Vibration | D | D | D | D | B | D | D | D | D | D | D | D | D | D | D | B | B | D | D | D | D | D | D | D | D | D | B | D | D | D |
| Countermeasure by Primary Survey | | | GW | PN | GM | GM | GM | GM | PN | PN | R+S | R+S | R+S | GM | GM | R | R | RW | R | R+R E+C W+V | D | R+R E+C W+V | R+R E+C W+V | R+S D+V | R+S | GM | R | R+S | PN | GM | GM | GM |

*: Existance of Particular Condition.

| Enviroment Item | | | Stage of EIA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nic.1 | | | | | | | | | | | | | Nic.3 | | | | | | | | 5 | Nic.26 | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| Social Environment | 1 | Inhabitant Transfer | B | B | D | D | D | D | D | D | B | B | B | D | D | B | B | B | B | B | B | B | B | B | B | D | B | B | B | D | D | D |
| | 2 | Economic Activity | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | B | D | D | D | D | D | D | D | D | D | D |
| | 3 | Facility for Life and Traffic | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B |
| | 4 | Waste | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B | B |
| Natural Environment | 5 | Ground Water | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| | 6 | Lake/Liver | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| | 7 | Fauna/Flora | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| | 8 | Landscape | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| Pollution | 9 | Air Pollution | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| | 10 | Water Pollution | B | B | B | B | B | B* | B | B | B | B | B | B* | B* | B | B | B | B | B | B | B | B | B* | B | B | B | B | B* | B | B | B |
| | 11 | Noise/Vibration | D | D | D | D | B | D | D | D | D | D | D | D | D | D | D | B | B | D | D | D | D | D | D | D | D | D | B | D | D | D |
| Countermeasure by Fainal Survey | | | CW+ BR+ SD | R+S D+V | GM | GM | GM | GM | BR+ PN | BR+ PN | SF+ CF+ SD+ BR | SF+S +SD | R+C F+S D+G D+B R | GM | GM | R+C F+V +SD | R+C F+V +SD | NB | CW+ GD | R+C F+V +SD +GD +RE | D+R +CF +V+ SD | R+C F+V +SD +GD +RE | R+C F+V +SD +GD +CW | R+C F+V +SF +GD | SF+S +SD | GM | R+C F+S D+G D | R+C F+S D+G D | BR+ PN | GM | GM | GM |

Note : GM (Gabion Mat) CM (Concrete Mat) NB (New Bridge) GW (Gabiaon Wall) CW (Concrete Wall) CF (Concrete Flame) R (Recutting) S (Shotcrete)
PN (Prevention Net) BR (Boulder Removal) CW (Counter Weight) D (Dam) V (Vegitation) C (Culvert) SD (Surface Drainage) GD (Ground Drainage)
RW (Reconstruction Wing Wall) RE (Re-embankment) SF (Slope Fairing) BP (Bank Protection)

NIC.1
1 N001A290
2 N001A280
3 Junquillal
4 San Nicolas
5 Las Chanillas
6 San Ramon
7 N001A240
8 N001B230
9 N001B170
10 N001B150
11 N001B120
12 Rio Inali
13 Rio Tapacali
NIC.3
14 003B400
15 003B370
16 El Guayacan
17 N003B320
18 N003C230
19 N003E170
20 N003C150
21 N003C140
NIC.5
22 N005A001
NIC.26
23 N026A006
24 La Banderita
25 N026B140
26 N026A150
27 N026B160
28 San Juan de Dios
29 Papalon
30 Solis

# CHAPTER 20 PROJECT EVALUATION

## 20.1 General

As noted in Chapter 13 the traffic benefits that would result from disaster prevention measures are evaluated by calculating the dis-benefits to traffic of a disaster occurring. When traffic re-routes to avoid the closed link it potentially incurs two types of dis-benefit;

- increased vehicle operating costs due to additional distance; and
- increased passenger time costs.

These two parameters are evaluated by the JICA STRADA model by running the model for two cases : with the affected link in place (a common base), and without the link in place. These are converted to monetary benefits using the parameters developed in the Chapter 11 and set out in Table 20.1.1.

**Table 20.1.1 Vehicle Operating Costs and Passenger Costs, Nicaragua 2002**

| *Vehicle type* | *Operating Cost per 1000 km, US $* | *Passenger Costs per vehicle hour* |
|---|---|---|
| Car | 185.5 | 2.84 |
| Utility | 215.1 | 1.09 |
| Average Bus | 529.7 | 14.90 |
| Light Goods | 549.1 | 1.04 |
| Medium Goods | 768.2 | 1.04 |
| Heavy Goods | 878.5 | 0.75 |

Source : NIC2000 Transport Plan and year 2002 prices

Table 20.1.2 lists the parameters used in the economic evaluation.

**Table 20.1.2 Economic Evaluation Parameters**

| *Parameter* | *Value* | *Source* |
|---|---|---|
| Discount Rate | 10% | International Norm |
| Discount period | 18 years | 2003 to 2020 |
| Maintenance cost for works | 2% of capital cost per year | Assumption |
| Implementation of measures | 2003 | Assumption |
| Start year of benefit flow | 2004 | Assumption |

## 20.2 Economic Analysis

Locations of vulnerable sites are shown in Figure 20.2.1.

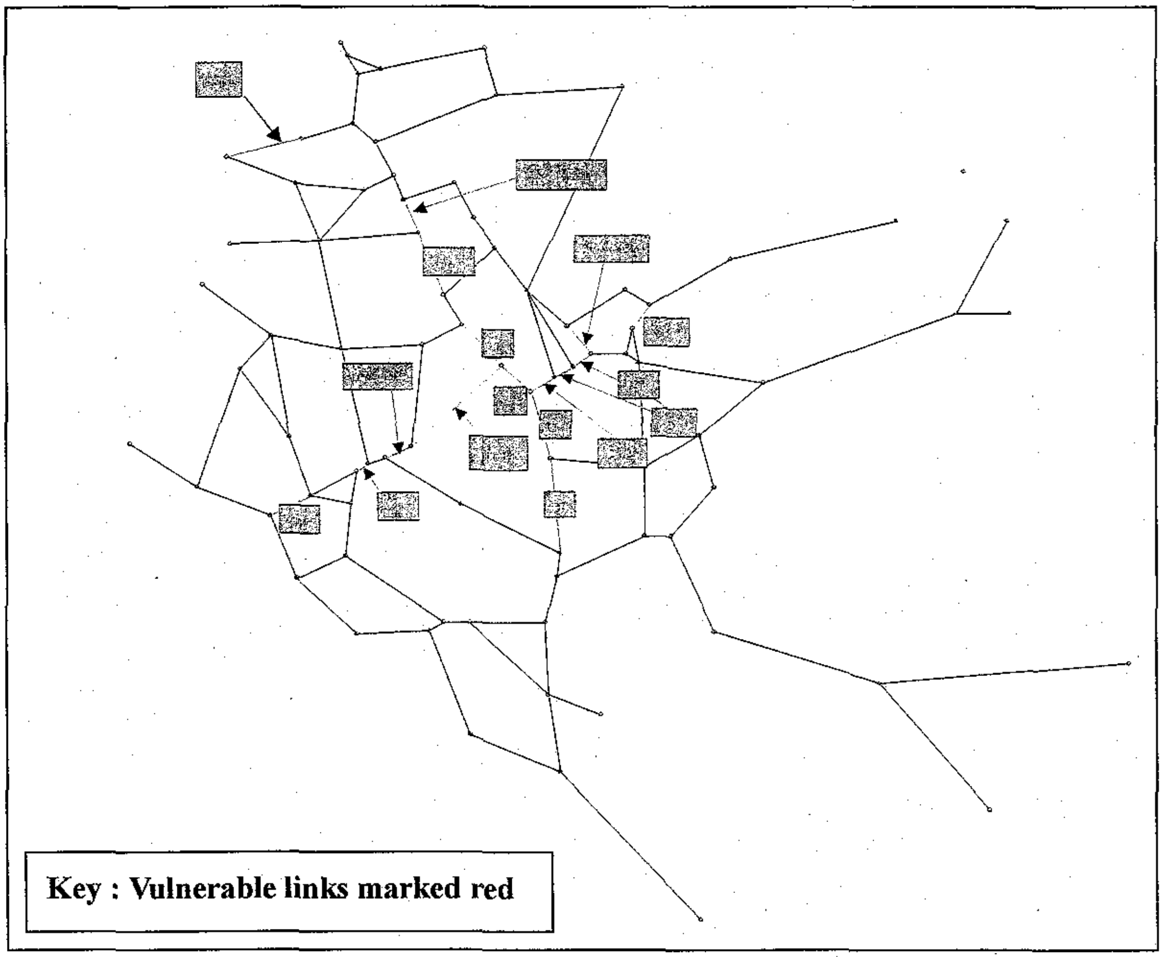



**Figure 20.2.1 Locations of 30 Vulnerable Road Sites for Evaluation**

The economic evaluation relies on quantifying disadvantages that flow from road closures due to a natural disaster. Moreover, the scale of the dis-benefits is a function of the amount of traffic and the length and quality of alternative routes available to traffic.

The Study has selected locations that urgently require the implementation of disaster prevention measures. Note, however, that although these locations recurrently experience disasters, it is difficult to quantify in terms of probability the frequency that disasters will occur. In Nicaragua, the "rainy" season (which includes the onslaught of typhoons) lasts from April to October. As a result of this six-month period of rains, it is unavoidable that some roads will become impassable due to land and rock slides, severe scouring of bridge foundations, etc. For this reason, it has been decided that the frequency of disasters should be derived applying past data that experienced the heaviest rains. Maximum hourly rainfall data for the past 20 years are as shown in Table 20.2.1. As the table indicates, there are variations in the figure. For example, the figure for maximum hourly rainfall in the year that experienced Hurricane Mitch is abnormally large as compared to the figures for the previous and following years. Accordingly, after much consideration, the Study has selected 200 mm/h of rain or more as the figure for when rock foundations experience cracking due to water infiltration, land and rock slides occur, etc. Based on this, it can be seen that there were seven times that this figure was exceeded over the twenty year period from 1980 to 2000, meaning that every three years a road disaster would occur at the locations requiring disaster prevention measures.

Table 20.2.1 Maximum Annual Hourly Rainfall for the Past 20 Years

| Year | Amount of Rainfall (mm/h) | Comments |
|---|---|---|
| 1980 | 283.3 | |
| 1981 | 98.9 | |
| 1982 | 85.1 | |
| 1983 | 37.3 | |
| 1984 | 48.5 | |
| 1985 | 245.9 | |
| 1986 | 50.1 | |
| 1987 | 47.5 | |
| 1988 | 217.1 | |
| 1989 | 50.0 | |
| 1990 | 143.6 | |
| 1991 | 96.3 | |
| 1992 | 57.6 | |
| 1993 | 129.4 | |
| 1994 | 112.4 | |
| 1995 | 324.9 | |
| 1996 | 340.4 | |
| 1997 | 157.7 | |
| 1998 | 888.4 | Hurricane Mitch |
| 1999 | 215.0 | |
| 2000 | 82.6 | |

In addition, as described in Chapter 18, the lifespan of disaster prevention measures shown below are reflected in investment costs.

- Permanent disaster prevention measure: Effective for 20 years
- Temporary disaster prevention measure: Effective for 10 years

The construction period required for implementing road disaster prevention measures (With Project) and the costs for road restoration when no measures are implemented (Without Project) are as shown in Table 20.2.2. Furthermore, note that there are substantial variations in the construction period required for prevention measures depending on the scale and content of the work involved. For example, installation of the netting to prevent rocks from falling on to the surface a road requires little time, while re-cutting a slope or reinforcing embankments at certain locations will require up to two years.

The costs for road restoration for the "Without Project" case consists of the investment needed to restore a road to its previous condition prior to a disaster. In this case, it is assumed that there is no road closure, and the costs and scale for restoration work will vary depending on whether or not one lane of the existing road can be used or if a temporary detour road has to be built. For example, the use of locally available rock to deal with the scouring of bridges is an inexpensive method of restoration.

**Table 20.2.2 Construction Period for Road Disaster Prevention Measures (With Project) & Road Restoration Costs (Without Project)**

| Item No. | Site | Construction Period (Days) | Road Restoration Costs (US$) |
|---|---|---|---|
| 1 | N001A290 | 195 | 2,000 |
| 2 | N001A280 | 449 | 2,000 |
| 3 | Junquillal | 1663 | 1,000 |
| 4 | San Nicolás | 596 | 1,000 |
| 5 | Las Chanillas | 296 | 1,000 |
| 6 | San Ramón | 1023 | 1,000 |
| 7 | N001A240 | 223 | 2,000 |
| 8 | N001B230 | 213 | 2,000 |
| 11 | N001B170 | 26 | 2,000 |
| 12 | N001B150 | 204 | 2,000 |
| 13 | N001B120 | 43 | 7,000 |
| 18 | Rio Inalí | 2 | 5,000 |
| 19 | Rio Tapacalí | 4 | 1,000 |
| 24 | 003B400 | 715 | 2,000 |
| 25 | 003B370 | 351 | 2,000 |
| 26 | El Guayacán | 59 | 1,000 |
| 27 | N003B320 | 309 | 2,000 |
| 29 | N003C230 | 44 | 3,000 |
| 30 | N003E170 | 52 | 2,000 |
| 32 | N003C150 | 22 | 2,000 |
| 33 | N003C140 | 27 | 2,000 |
| 35 | N005A010 | 33 | 2,000 |
| 44 | N026A060 | 32 | 2,000 |
| 45 | La Banderita | 73 | 1,000 |
| 49 | N026B140 | 32 | 2,000 |
| 50 | N026A150 | 92 | 2,000 |
| 51 | N026B160 | 1211 | 2,000 |
| 52 | San Juan de Dios | 198 | 1,000 |
| 54 | Papalón | 357 | 1,000 |
| 55 | Solís | 371 | 1,000 |

It is thought that Nicaragua will continue to gradually increase the size of its arterial and local road network and raise the overall quality of its road infrastructure. Furthermore, with the construction of new roads, it is envisioned that travel times in the case of disasters when alternative routes are used will become shorter. Based on this, the following two future schemes were taken into consideration in the building of the traffic demand model with JICA's STRADA.

- NIC. 7, between San Benito and San Lorenzo (the Managua – Boaco road), will be upgraded to a high-standard road.
- The road between Santa Cruz and San Nicolas in the vicinity of Esteli will be paved.

As for the proposed rehabilitation and improvement of the Guayacan - Jintoega link, this should be taken into consideration in the economic evaluation. On the other hand, at the time of drafting of this report, the status of this scheme, which will have a major effect on the amount of the benefits from the disaster prevention measures for NIC.3 on the Jinotega-Matagalpa-Guayacan section, was not known. At the same time, it is known that the improvement of NIC.3 will affect the economic evaluation of the Jintoga-Guayacan link. Therefore, the evaluation of sites on NIC.3 was undertaken by varying the economic benefits of disaster prevention measures depending on when the improvements to the Jinotega-Guayacan link are completed.

The results of the economic evaluation for each of the Study's links are as shown in Table 20.2.3.

## Table 20.2.3 Results of Economic Evaluation

| Site No | ID No. | Cost (US$) | | Benefits($USM) | | Benefits - Cost ($US) | Net Present Value ($US) | EIRR | B/C | Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Cost (US$) | Total Dis-counted Cost | Total Benefits | Total Dis-counted Benefits | | | | | EIRR | B/C |
| 1 | N001A290 | 959,018 | 616,618 | 6,747,338 | 3,276,470 | 5,788,319 | 2,659,851 | 4% | 5.31 | | |
| 2 | N001A280 | 16,535 | 14,190 | 516,136 | 454,254 | 499,601 | 440,064 | 44% | 32.01 | | |
| 3 | Junquillal | 120,235 | 77,307 | 2,189,560 | 1,091,941 | 2,069,325 | 1,014,634 | 12% | 14.12 | | |
| 4 | San Nicolas | 71,569 | 46,016 | 1,141,730 | 584,712 | 1,070,161 | 538,695 | 12% | 12.71 | | |
| 5 | Las Chanillas | 541,058 | 347,883 | 1,015,448 | 510,686 | 474,390 | 162,803 | 0.4% | 1.47 | | |
| 6 | San Ramon | 25,765 | 16,566 | 1,015,448 | 510,686 | 989,684 | 494,120 | 30% | 30.83 | | |
| 7 | N001A240 | 74,431 | 47,857 | 1,855,991 | 937,770 | 1,781,559 | 889,914 | 19% | 19.60 | | |
| 8 | N001B230 | 17,176 | 11,044 | 472,346 | 241,134 | 455,169 | 230,091 | 24% | 21.83 | | |
| 11 | N001B170 | 2,629,033 | 2,256,222 | 2,670,153 | 2,401,084 | 41,120 | 144,861 | 0.3% | 1.06 | | |
| 12 | N001B150 | 44,644 | 38,313 | 823,606 | 730,977 | 778,962 | 692,664 | 24% | 19.08 | | |
| 13 | N001B120 | 1,345,933 | 1,155,072 | 1,589,184 | 1,394,328 | 243,252 | 239,256 | 0.5% | 1.21 | | |
| 18 | Rio Inali | 2,370,350 | 1,524,059 | 857,206 | 420,114 | -1,513,143 | -1,103,945 | 0% | 0.28 | | |
| 19 | Rio Tapacali | 807,293 | 519,064 | 454,892 | 223,324 | -352,401 | -295,740 | 0% | 0.43 | 13.1% | 12.3 |
| 24 | N003B400 | 66,139 | 56,760 | 2,022,393 | 1,809,886 | 1,956,254 | 1,753,125 | 41% | 31.89 | | |
| 25 | N003B370 | 289,359 | 248,326 | 1,023,196 | 910,609 | 733,837 | 662,283 | 4% | 3.67 | | |
| 26 | El Guayacan | 2,280,149 | 1,956,812 | 10,398,159 | 9,353,209 | 8,118,010 | 7,396,397 | 5% | 4.78 | | |
| 27 | N003B320 | 395,182 | 339,143 | 531,581 | 468,155 | 136,400 | 129,012 | 69% | 1.38 | | |
| 29 | N003C230 | 542,341 | 465,435 | 662,039 | 580,433 | 119,698 | 114,999 | 0.5% | 1.25 | | |
| 30 | N003E170 | 512,579 | 439,892 | 785,681 | 696,845 | 273,102 | 256,952 | 1.0% | 1.58 | | |
| 32 | N003C150 | 1,517,894 | 1,302,649 | 1,547,361 | 1,382,357 | 29,467 | 79,708 | 0.3% | 1.06 | | |
| 33 | N003C140 | 1,238,456 | 1,062,837 | 1,276,078 | 1,138,202 | 37,621 | 75,365 | 0.3% | 1.07 | 15.1% | 5.8 |
| 35 | N005A010 | 643,204 | 551,994 | 1,051,918 | 936,458 | 408,714 | 384,464 | 1.1% | 1.70 | 1.1% | 1.7 |
| 44 | N026A060 | 522,500 | 448,406 | 734,632 | 650,901 | 212,132 | 202,494 | 0.8% | 1.45 | | |
| 45 | La Banderita | 51,258 | 43,989 | 188,552 | 161,995 | 137,294 | 118,006 | 4% | 3.68 | | |
| 49 | N026B140 | 1,494,746 | 1,282,783 | 2,132,684 | 1,909,148 | 637,938 | 626,365 | 0.9% | 1.49 | | |
| 50 | N026A150 | 347,231 | 297,992 | 475,861 | 418,007 | 128,630 | 120,015 | 0.7% | 1.40 | | |
| 51 | N026A160 | 37,216 | 23,928 | 1,528,606 | 774,707 | 1,491,390 | 750,778 | 33% | 32.38 | | |
| 52 | San Juan de Dios | 14,314 | 9,203 | 466,350 | 236,538 | 452,036 | 227,335 | 26% | 25.70 | | |
| 54 | Papalon | 146,000 | 93,873 | 4,004,273 | 2,057,405 | 3,858,273 | 1,963,531 | 21% | 21.92 | | |
| 55 | Solis | 188,941 | 121,483 | 2,008,137 | 1,031,535 | 1,819,196 | 910,052 | 7% | 8.49 | 11.7% | 12.1 |
| | | 19,310,546 | 15,415,719 | 52,186,537 | 37,293,870 | 32,875,991 | 21,878,151 | | | 12.8% | 10.2 |

As the results of the economic evaluation indicate in the above table, the net present value figures for sites 18 and 19 are negative. This is due to the effectiveness of the alternative route, meaning that the existing route is not much more attractive than the alternative route even during normal times.

## 20.3 Budget Priorities

The analysis of a potential budget for the implementation of disaster prevention measures has been carried out in two stages:

i) The creation of prioritized packages of work that maximize benefits, whilst minimizing cost;

ii) Linking the funding packages to potential funding sources.

Table 20.3.1 and 20.3.2 list the links (and their disaster prevention schemes) in the order of largest to smallest in terms of benefit/cost ratio and EIRR, respectively.
It should be noted, however, that in the case where there is an existing road and relatively little new investment is needed, together with benefits occurring soon after project completion, the EIRR, which gives no indication of the size of costs or benefits, tends to overrate a project and is not such an appropriate indicator for comparison. Therefore, prioritization is carried out by grouping projects into three bands of benefit/cost (B/C) ratios: 1) a B/C ratio 10 or above, 2) a B/C ratio 1.5 or above but less than 10, and 3) a B/C ratio less than 1.5.

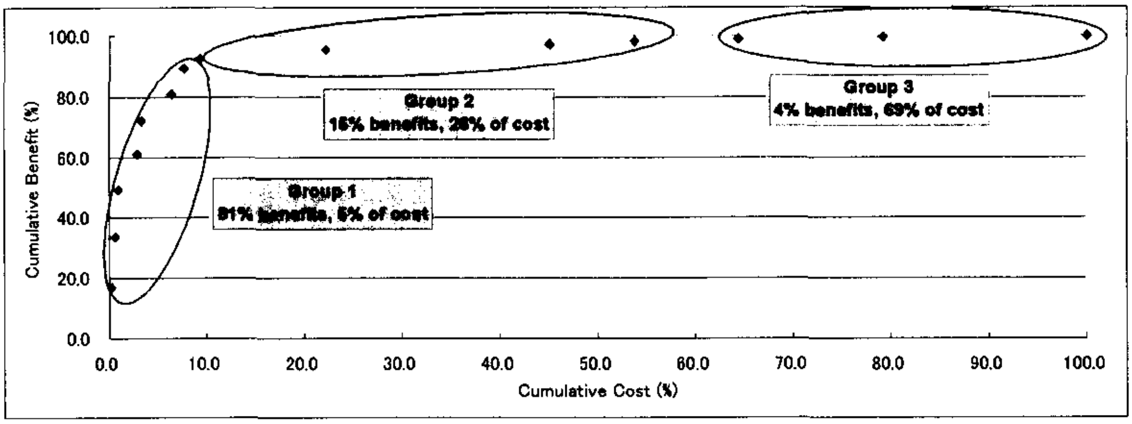
# Table 20.3.1 Ranked Schemes with B/C

| Site No | ID No. | Cost (US$) | | Benefits($USM) | | Benefits - Cost ($US) | Net Present Value ($US) | EIRR | B/C | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Cost (US$) | Total Dis-counted Cost | Total Benefits | Total Dis-counted Benefits | | | | | B/C |
| 51 | N026A160 | 37,216 | 23,928 | 1,528,606 | 774,707 | 1,491,390 | 750,778 | 33% | 32.38 | |
| 2 | N001A280 | 16,535 | 14,190 | 516,136 | 454,254 | 499,601 | 440,064 | 44% | 32.01 | |
| 24 | N003B400 | 66,139 | 56,760 | 2,022,393 | 1,809,886 | 1,956,254 | 1,753,125 | 41% | 31.89 | |
| 6 | San Ramon | 25,765 | 16,566 | 1,015,448 | 510,686 | 989,684 | 494,120 | 30% | 30.83 | |
| 52 | San Juan de Dios | 14,314 | 9,203 | 466,350 | 236,538 | 452,036 | 227,335 | 26% | 25.70 | Priority |
| 8 | N001B230 | 17,176 | 11,044 | 472,346 | 241,134 | 455,169 | 230,091 | 24% | 21.83 | Group1 |
| 54 | Papalon | 146,000 | 93,873 | 4,004,273 | 2,057,405 | 3,858,273 | 1,963,531 | 21% | 21.92 | |
| 7 | N001A240 | 74,431 | 47,857 | 1,855,991 | 937,770 | 1,781,559 | 889,914 | 19% | 19.60 | |
| 12 | N001B150 | 44,644 | 38,313 | 823,606 | 730,977 | 778,962 | 692,664 | 24% | 19.08 | |
| 3 | Junquillal | 120,235 | 77,307 | 2,189,560 | 1,091,941 | 2,069,325 | 1,014,634 | 12% | 14.12 | |
| 4 | San Nicolas | 71,569 | 46,016 | 1,141,730 | 584,712 | 1,070,161 | 538,695 | 12% | 12.71 | |
| 55 | Solis | 188,941 | 121,483 | 2,008,137 | 1,031,535 | 1,819,196 | 910,052 | 7% | 8.49 | 23.8 |
| 1 | N001A290 | 959,018 | 616,618 | 6,747,338 | 3,276,470 | 5,788,319 | 2,659,851 | 4% | 5.31 | |
| 26 | El Guayacan | 2,280,149 | 1,956,812 | 10,398,159 | 9,353,209 | 8,118,010 | 7,396,397 | 5% | 4.78 | Priority |
| 25 | N003B370 | 289,359 | 248,326 | 1,023,196 | 910,609 | 733,837 | 662,283 | 4% | 3.67 | Group2 |
| 45 | La Banderita | 51,258 | 43,989 | 188,552 | 161,995 | 137,294 | 118,006 | 4% | 3.68 | |
| 35 | N005A010 | 643,204 | 551,994 | 1,051,918 | 936,458 | 408,714 | 384,464 | 1.1% | 1.70 | |
| 30 | N003E170 | 512,579 | 439,892 | 785,681 | 696,845 | 273,102 | 256,952 | 1.0% | 1.58 | 4.2 |
| 49 | N026B140 | 1,494,746 | 1,282,783 | 2,132,684 | 1,909,148 | 637,938 | 626,365 | 0.9% | 1.49 | |
| 5 | Las Chanillas | 541,058 | 347,883 | 1,015,448 | 510,686 | 474,390 | 162,803 | 0.4% | 1.47 | |
| 44 | N026A060 | 522,500 | 448,406 | 734,632 | 650,901 | 212,132 | 202,494 | 0.8% | 1.45 | |
| 50 | N026A150 | 347,231 | 297,992 | 475,861 | 418,007 | 128,630 | 120,015 | 0.7% | 1.40 | |
| 27 | N003B320 | 395,182 | 339,143 | 531,581 | 468,155 | 136,400 | 129,012 | 69% | 1.38 | |
| 29 | N003C230 | 542,341 | 465,435 | 662,039 | 580,433 | 119,698 | 114,999 | 0.5% | 1.25 | Priority |
| 13 | N001B120 | 1,345,933 | 1,155,072 | 1,589,184 | 1,394,328 | 243,252 | 239,256 | 0.5% | 1.21 | Group3 |
| 33 | N003C140 | 1,238,456 | 1,062,837 | 1,276,078 | 1,138,202 | 37,621 | 75,365 | 0.3% | 1.07 | |
| 32 | N003C150 | 1,517,894 | 1,302,649 | 1,547,361 | 1,382,357 | 29,467 | 79,708 | 0.3% | 1.06 | |
| 11 | N001B170 | 2,629,033 | 2,256,222 | 2,670,153 | 2,401,084 | 41,120 | 144,861 | 0.3% | 1.06 | |
| 19 | Rio Tapacali | 807,293 | 519,064 | 454,892 | 223,324 | -352,401 | -295,740 | 0% | 0.43 | |
| 18 | Rio Inali | 2,370,350 | 1,524,059 | 857,206 | 420,114 | -1,513,143 | -1,103,945 | 0% | 0.28 | 1.1 |
| | | 19,310,546 | 15,415,719 | 52,186,537 | 37,293,870 | 32,875,991 | 21,878,151 | | | 10.2 |

## Table 20.3.2 Ranked Schemes with EIRR

| Site No | ID No. | Cost (US$) | | Benefits($USM) | | Benefits – Cost ($US) | Net Present Value ($US) | EIRR | B/C | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Cost (US$) | Total Dis-counted Cost | Total Benefits | Total Dis-counted Benefits | | | | | EIRR |
| 27 | N003B320 | 395,182 | 339,143 | 531,581 | 468,155 | 136,400 | 129,012 | 69% | 1.38 | |
| 2 | N001A280 | 16,535 | 14,190 | 516,136 | 454,254 | 499,601 | 440,064 | 44% | 32.01 | |
| 24 | N003B400 | 66,139 | 56,760 | 2,022,393 | 1,809,886 | 1,956,254 | 1,753,125 | 41% | 31.89 | |
| 51 | N026A160 | 37,216 | 23,928 | 1,528,606 | 774,707 | 1,491,390 | 750,778 | 33% | 32.38 | |
| 6 | San Ramon | 25,765 | 16,566 | 1,015,448 | 510,686 | 989,684 | 494,120 | 30% | 30.83 | Priority |
| 52 | San Juan de Dios | 14,314 | 9,203 | 466,350 | 236,538 | 452,036 | 227,335 | 26% | 25.70 | Group1 |
| 8 | N001B230 | 17,176 | 11,044 | 472,346 | 241,134 | 455,169 | 230,091 | 24% | 21.83 | |
| 12 | N001B150 | 44,644 | 38,313 | 823,606 | 730,977 | 778,962 | 692,664 | 24% | 19.08 | |
| 54 | Papalon | 146,000 | 93,873 | 4,004,273 | 2,057,405 | 3,858,273 | 1,963,531 | 21% | 21.92 | |
| 7 | N001A240 | 74,431 | 47,857 | 1,855,991 | 937,770 | 1,781,559 | 889,914 | 19% | 19.60 | |
| 3 | Junquillal | 120,235 | 77,307 | 2,189,560 | 1,091,941 | 2,069,325 | 1,014,634 | 12% | 14.12 | |
| 4 | San Nicolas | 71,569 | 46,016 | 1,141,730 | 584,712 | 1,070,161 | 538,695 | 12% | 12.71 | 30% |
| 55 | Solis | 188,941 | 121,483 | 2,008,137 | 1,031,535 | 1,819,196 | 910,052 | 7% | 8.49 | |
| 26 | El Guayacan | 2,280,149 | 1,956,812 | 10,398,159 | 9,353,209 | 8,118,010 | 7,396,397 | 5% | 4.78 | |
| 1 | N001A290 | 959,018 | 616,618 | 6,747,338 | 3,276,470 | 5,788,319 | 2,659,851 | 4% | 5.31 | Priority |
| 25 | N003B370 | 289,359 | 248,326 | 1,023,196 | 910,609 | 733,837 | 662,283 | 4% | 3.67 | Group2 |
| 45 | La Banderita | 51,258 | 43,989 | 188,552 | 161,995 | 137,294 | 118,006 | 4% | 3.68 | |
| 35 | N005A010 | 643,204 | 551,994 | 1,051,918 | 936,458 | 408,714 | 384,464 | 1.1% | 1.70 | |
| 30 | N003E170 | 512,579 | 439,892 | 785,681 | 696,845 | 273,102 | 256,952 | 1.0% | 1.58 | 4% |
| 49 | N026B140 | 1,494,746 | 1,282,783 | 2,132,684 | 1,909,148 | 637,938 | 626,365 | 0.9% | 1.49 | |
| 44 | N026A060 | 522,500 | 448,406 | 734,632 | 650,901 | 212,132 | 202,494 | 0.8% | 1.45 | |
| 50 | N026A150 | 347,231 | 297,992 | 475,861 | 418,007 | 128,630 | 120,015 | 0.7% | 1.40 | |
| 29 | N003C230 | 542,341 | 465,435 | 662,039 | 580,433 | 119,698 | 114,999 | 0.5% | 1.25 | |
| 13 | N001B120 | 1,345,933 | 1,155,072 | 1,589,184 | 1,394,328 | 243,252 | 239,256 | 0.5% | 1.21 | Priority |
| 5 | Las Chanillas | 541,058 | 347,883 | 1,015,448 | 510,686 | 474,390 | 162,803 | 0.4% | 1.47 | Group3 |
| 33 | N003C140 | 1,238,456 | 1,062,837 | 1,276,078 | 1,138,202 | 37,621 | 75,365 | 0.3% | 1.07 | |
| 11 | N001B170 | 2,629,033 | 2,256,222 | 2,670,153 | 2,401,084 | 41,120 | 144,861 | 0.3% | 1.06 | |
| 32 | N003C150 | 1,517,894 | 1,302,649 | 1,547,361 | 1,382,357 | 29,467 | 79,708 | 0.3% | 1.06 | |
| 19 | Rio Tapacali | 807,293 | 519,064 | 454,892 | 223,324 | -352,401 | -295,740 | 0% | 0.43 | |
| 18 | Rio Inali | 2,370,350 | 1,524,059 | 857,206 | 420,114 | -1,513,143 | -1,103,945 | 0% | 0.28 | 0.4% |
| | | 19,310,546 | 15,415,719 | 52,186,537 | 37,293,870 | 32,875,991 | 21,878,151 | | | 12.8 |

The schemes can be seen to fall into three distinct groups, which indicate the priorities for investment. These groups are shown in Figure 20.3.1. Note that in **Priority Group 1** there are 12 sites on 9 links, which account for 81% of total benefits and 5% of total costs. In **Priority Group 2** there are 7 sites located on 4 different links, which make up 15% and 26% of the total benefits and costs, respectively. As for **Priority Group 3**, it contains 11 sites on 3 links, and accounts for 4% of the total benefits and 69% of the total cost.




The above three priority groups provide the basis for prioritizing investment and creating work packages for disaster prevention. The schemes for each group are as described in Table 20.3.3

As for the assumptions of the economic evaluation for each of the work packages, they are as follows:

- Total disaster prevention facility costs were calculated by work package.
- Benefits accrue from preventing the adverse effects of a single disaster at a particular site for each respective package.
- As an example to illustrate the benefit stream, calculations were carried out for several locations with disaster prevention facilities for each package. That is, Site 51 (NIC.26) for Package 1, Site 26 (NIC.3) for Package 2, and Site 7,8,11,12, and 13 (NIC.1) for Package 3 were taken up.
- Benefits were considered to occur after the completion of construction of the disaster prevention facilities.

## Table 20.3.3 Proposed Work Sub-packages in Priority Order

| Package No. | Sub Package | Link | Site | Road | Cost (US$) |
|---|---|---|---|---|---|
| 1 | 1a | 2 | N001A280 | Nic1 | 12,339 |
| | | 3 | Junquillal | Nic1 | 51,825 |
| | | 4 | San Nicolas | Nic1 | 30,849 |
| | | 6 | San Ramon | Nic1 | 11,105 |
| | | 7 | N001A240 | Nic1 | 32,082 |
| | | 8 | N001B230 | Nic1 | 7,404 |
| | | 12 | N001B150 | Nic1 | 33,316 |
| | Cost | | | | 178,921 |
| | 1b | 24 | N003B400 | Nic3 | 49,358 |
| | | 27 | N003B320 | Nic3 | 294,912 |
| | Cost | | | | 344,269 |
| | 1c | 51 | N026A160 | Nic26 | 16,041 |
| | | 52 | San Juan de Dios | Nic26 | 6,170 |
| | | 54 | Papalon | Nic26 | 62,931 |
| | Cost | | | | 85,142 |
| Package 1 Cost | | | | | **608,333** |

| Package No. | Sub Package | Link | Site | Road | Cost (US$) |
|---|---|---|---|---|---|
| 2 | 2a | 1 | N001A290 | Nic1 | 413,370 |
| | Cost | | | | 413,370 |
| | 2b | 25 | N003B370 | Nic3 | 215,940 |
| | | 26 | El Guayacan | Nic3 | 1,701,604 |
| | | 30 | N003E170 | Nic3 | 382,521 |
| | Cost | | | | 2,300,064 |
| | 2c | 35 | N005A010 | Nic5 | 480,003 |
| | Cost | | | | 480,003 |
| | 2d | 45 | La Banderita | Nic26 | 38,252 |
| | | 55 | Solis | Nic26 | 81,440 |
| | Cost | | | | 119,692 |
| Package 2 Cost | | | | | **3,313,129** |

| Package No. | Sub Package | Link | Site | Road | Cost (US$) |
|---|---|---|---|---|---|
| 3 | 3a | 5 | Las Chanillas | Nic1 | 233,215 |
| | | 11 | N001B170 | Nic1 | 1,961,965 |
| | | 13 | N001B120 | Nic1 | 1,004,427 |
| | | 18 | Rio Inali | Nic1 | 1,021,702 |
| | | 19 | Rio Tapacali | Nic1 | 347,971 |
| | Cost | | | | 4,569,280 |
| | 3b | 29 | N003C230 | Nic3 | 404,732 |
| | | 32 | N003C150 | Nic3 | 1,132,757 |
| | | 33 | N003C140 | Nic3 | 924,221 |
| | Cost | | | | 2,461,711 |
| | 3c | 44 | N026A060 | Nic26 | 389,925 |
| | | 49 | N026B140 | Nic26 | 1,115,482 |
| | | 50 | N026A150 | Nic26 | 259,127 |
| | Cost | | | | 1,764,534 |
| Package 3 Cost | | | | | **8,795,526** |

| | |
|---|---|
| Grand Total | 12,716,988 |

# CHAPTER 21 IMPLEMENTATION PROGRAMME

## 21.1 Execution Agency

The General Division of Planning, Ministry of Transport and Infrastructure (GDP), is the responsible government agency for the execution of the implementation of the Project. The Cooperation and Economic Relationship Office, Ministry of Foreign Affairs, is also the executing agency for supporting the Ministry of Transport and Infrastructure in donor assisted projects.

## 21.2 Project Packaging

As described in Chapter 20, three work packages result from the economic evaluation, and cost-effectiveness considerations. Package One contains disaster spots of NIC.1, NIC.3 and NIIC.26. Package Two contains sites on NIC.3, NIC.5 and NIC.1. Package Three sites are restricted to NIC.1 and NIC.3. The order of implementation is related to the cost effectiveness of the construction works. The relationship of the package groupings and the disaster spots are shown in Table 21.2.1.

**Table 21.2.1 Package Group and Disaster Spots**

| | Nic1 | Nic3 | Nic5 | Nic26 | Total |
|---|---|---|---|---|---|
| Package1 | N001A280<br>Junquillal<br>San Nicolas<br>San Ramon<br>N001A240<br>N001B230<br>N001B150 | N003B400<br>N003B320 | | N026A160<br>San Juan de Dios<br>Papalon | 12 |
| Package2 | N001A290 | N003B370<br>El Guayacan<br>N003E170 | N005A010 | La Banderita<br>Solis | 7 |
| Package3 | Las Chanillas<br>N001B170<br>N001B120<br>Rio Inali<br>Rio Tapacali | N003C230<br>N003C150<br>N003C140 | | N026A060<br>N026B140<br>N026A150 | 11 |

## 21.3 Validity Evaluation to Each Countermeasure

### 21.3.1 Review to Environmental Issue

The four environmental impacts on NIC.3 have been identified. However these issues have been reviewed in consideration of the following countermeasures:

- The hotel of "N003B320 spot" will be safeguarded by constructing a retaining wall without re-cutting the slope,
- The natural park of "N003C230 spot" will be protected by planting vegetation into the cribwork after re-cutting the slope,
- The downstream area of "N003E170 spot", where the mountain stream could be blocked, will be continue to be irrigated through an opening in the dam, and
- The coffee field of "N003C140 spot" will be safeguarded by constructing a retaining wall in order to reduce the embankment reach.

Thus, the issues related to the environment of each disaster spot have been completely settled by appropriate mitigation measures. Therefore each countermeasure is valid in relation to the environment aspects.

### 21.3.2 Validity of the Result of Economic and Financial Analysis

The construction costs, including measures to compensate for environmental impacts, have been included in the economic evaluation (Chapter 20). Most of the schemes will require some maintenance. The costs of maintenance of the permanent schemes were included in the economic evaluation at 2% of capital cost as shown in Table 20.1.4 of the main text. The resultant maintenance cost requirements are summarised in Table 21.3.1.

**Table 21.3.1 Annual Maintenance Budget Estimates (US$, 2002 prices)**

| Package | Annual Maintenance Cost ($) |
|---|---|
| 1 | 12,167 |
| 2 | 66,263 |
| 3 | 175,911 |
| Total | 254,340 |

Source : 2% of capital costs of permanent works

The sum total in Table 21.3.1 should be safeguarded for maintenance, to be deployed after the capital works have been undertaken. This sum is accounted for in the economic evaluation and hence the economic evaluation is valid. In addition, the sum in Table 21.3.1 will be sufficient to cover the required maintenance works identified in Table 21.4.2

of the main text. At the spots listed above where there will be a need for single-lane traffic working during construction, it is assumed that this will be controlled by temporary traffic signals, or manually. In both cases, traffic can expect to be delayed, depending on the length of road affected. This length affects the time taken for vehicles to clear when both directions are halted, and increases the disbenefit. Even a relatively long section (150m) should clear in 30 seconds. The maximum resultant disbenefits for each of the sires would be less 30 vehicle-hours per day. In monetary values these will always be much less than 1% of the potential benefits of the works, and the traffic disbenefits can be considered to be negligible. Hence the economic evaluation is valid.

### 21.3.3 Validity Evaluation of the Countermeasures

As above-mentioned, the countermeasures are have been validated from the results of the environmental impacts and the economic analyses. Furthermore, almost all of the construction materials and the construction machines are readily available in Nicaragua.

The benefits from this investment are due to the prevention of disasters at all 30 sites. The Internal Rate of Return of this project in avoiding disasters at each of the following sites over the next 10 years is set out in Table 21.3.2.

**Table 21.3.3 Project Internal Rate of Return (EIRR) in Preventing Disasters on Each Road Link : Full Project Cost in Each Case**

| *Link* | *Road* | *EIRR(%)* |
|---|---|---|
| Malpaisillo | NIC.26 | 27.9 |
| Sebaco to Chagatuillo | NIC.3 | 28.2 |
| La Sirena to Condega | NIC.1 | 15.5 |
| Average | | 23.5 |

Source : Project Evaluation Spreadsheets

The average EIRR for all the sites is 23.5%. This means that the project rate of return for the prevention of just one disaster is 23.5%, and the rate of return for preventing more than disaster will be higher. Therefore, the countermeasures planned through this Study are highly applicable to preventing the road disasters in Nicaragua.

## 21.4 Construction Period of Each Project Packaging

The construction period for each project package was estimated taking account of the work volume, site condition, weather condition, right-of-way situation, etc. The disaster spots have been divided into three categories, described as follows.

◆ **Package 1: Priority Site 1**

The disaster spots of Priority Site 1 are composed of NIC.1, NIC.3 and NIC.26. The main work items are to install gabion mats to prevent scouring of bridge foundations, to cut the weathered and steep slope surfaces, and to installation drainage and retaining walls. The detailed works are shown in Table 21.4.1. The estimated construction period for this package is 2 years.

**Table 21.4.1 Construction Work of Package 1**

| Road No. | ID No. | Countermeasure | Total |
|---|---|---|---|
| Nic.1 | N001AA280 | Horizontal drainage | 7 |
| | Junquillal | Gabion mat | |
| | San Nicolás | Gabion mat | |
| | San Ramón | Gabion mat | |
| | N001A240 | Removal of loose rocks, installation of netting | |
| | N001B230 | Removal of loose rocks, installation of netting | |
| | N001B150 | Cutting, shotcrete and drainage | |
| NIC.3 | N003B400 | Cutting and drainage | 2 |
| | N003B320 | Retaining wall and fill, drainage and re-vegetation | |
| NIC.26 | N026B160 | Removal of loose rocks,<br>Installation of netting and drainage | 3 |
| | San Juan de Dios | Gabion mat | |
| | Papalón | Gabion mat and riprap with mortar | |

◆ **Package 2 : Priority Site 2**

The disaster spots of Priority Site 2 are composed of NIC.3, NIC.5 and NIC.26. The main work items are the construction of a new bridge, to install gabion mats, to cut the weathered and steep slope surfaces, and to install drainage. The detailed works are shown in Table 21.4.2. The estimated construction period for this package is 2 years.

**Table 21.4.2 Construction Work of Package 2**

| Road No. | ID No. | Countermeasure | Total |
|---|---|---|---|
| NIC1 | N001A290 | Removal of loose rocks,<br>Installation of netting and drainage | 1 |
| NIC.3 | N003B370 | Cutting and drainage | 3 |
| | El Guayacán | New bridge | |
| | N003E170 | Cutting and drainage, concrete dam and Box culvert | |
| NIC.5 | N005A010 | Cutting and drainage | 1 |
| NIC.26 | La Banderita | Masonry wall and gabion mat | 2 |
| | Solis | Gabion mat and riprap with mortar | |

◆ **Package 3 : Priority Site 3**

The disaster spots of Priority Site 3 are composed of NIC.1 and NIC.3. The main work items are to install gabion mats to prevent scouring of bridge foundations, to cut the weathered and steep slope surfaces, and to install drainage. The detailed works are shown in Table 21.4.3. The estimated construction period for this package is 2 years.

**Table 21.4.3 Construction Work of Package 3**

| Road No. | ID No. | Countermeasure | Total |
|---|---|---|---|
| NIC.1 | Las Chanillas | Concrete brocks | 5 |
| | N001B170 | Cutting and drainage | |
| | N001B120 | Cutting and drainage | |
| | Rio Inali | Gabion mat and stone masonry | |
| | Rio Tapascali | Gabion mat | |
| NIC.3 | N003C230 | Cutting and concrete protect with vegetation, Lower down embankment with drainage | 3 |
| | N003C150 | Cutting and drainage above road, embankment, Vegetation and drainage below | |
| | N003C140 | Cutting with drainage and horizontal drainage above road, embankment, vegetation and drainage below | |
| NIC.26 | N026A060 | Cutting, shotcrete and drainage | 3 |
| | N026B140 | Cutting, drainage and horizontal drainage | |
| | N026A150 | Cutting and drainage, lateral carriageway drainage | |

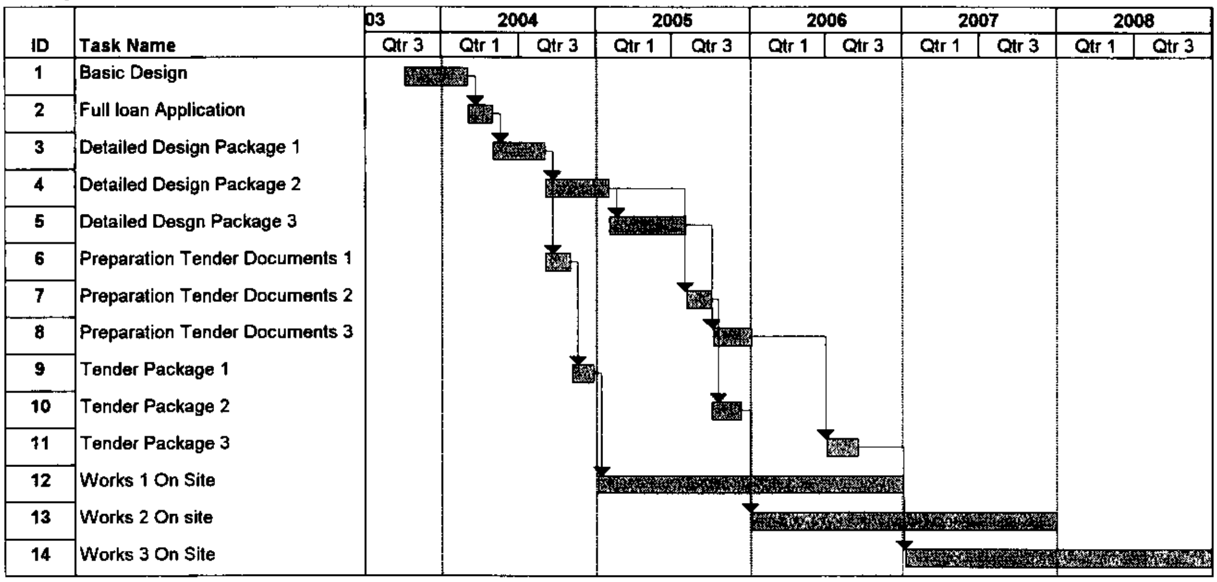
## 21.5 Engineering Services

The proposed Engineering Services comprise two main components, which are included a detailed design and a tendering for the construction works. The total required period of the Engineering Services is 5 years.

## 21.6 Implementation Schedule

The implementation schedule was set up taking account of the construction period estimated for each project package and for the engineering services. The recommended implementation schedule is shown in Figure 21.6.1.

**Figure 21.6.1 Proposed Implementation Schedule for Disaster Prevention Measures**




## 21.7 Investment Programme

The investment programme of the Project has been made on the basis of the implementation schedule. The cost breakdown set out in Table 20.1.2 has been allocated to engineering services and construction works as follows;

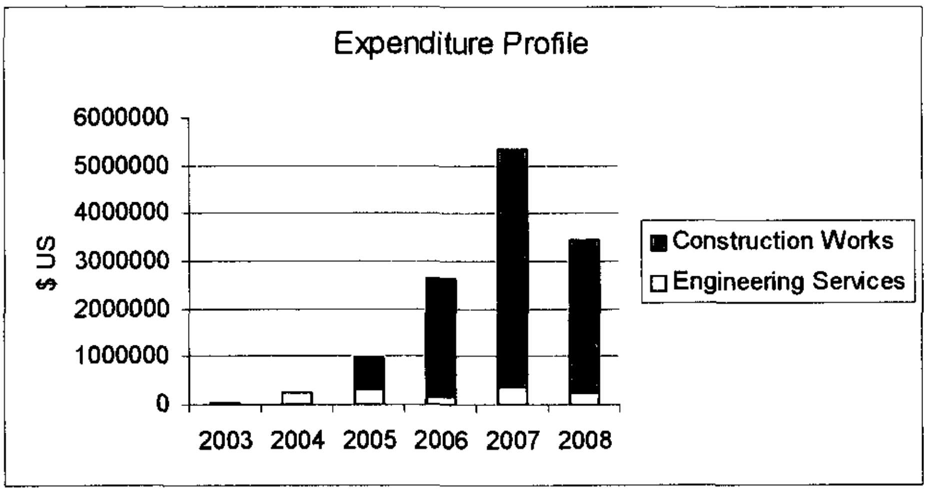
| *Component* | *Allocation* |
|---|---|
| Engineering works | Construction works |
| Design | Engineering Services |
| Construction Supervision | Engineering Services |
| Client Costs | Construction Works |
| Transport of materials | Construction works |
| Contingency | Construction Works |

Table 21.7.1 shows the tentative investment programme for the proposed disaster spots and structural strengthening projects.

**Table 21.7.1 Potential Expenditure Profile for Disaster Prevention Measures (\$US, 2002 prices)**

| *Year* | *Engineering Services* | *Construction Works* | *Total* |
|---|---|---|---|
| 2003 | 30,918 | - | 30,918 |
| 2004 | 235,330 | - | 235,330 |
| 2005 | 293,840 | 672,110 | 965,950 |
| 2006 | 166,100 | 2,466,136 | 2,632,236 |
| 2007 | 341,803 | 5,042,143 | 5,383,945 |
| 2008 | 220,491 | 3,248,117 | 3,468,608 |
| Total | 1,288,482 | 11,428,506 | 12,716,988 |

Source : Allocation of Capital Costs (Table 20.3.3) to Implementation Schedule (Figure 21.7.1) in the main text




Source : Table 21.7.1

**Figure 21.7.1 Potential Expenditure Profile for Disaster Prevention Measures**

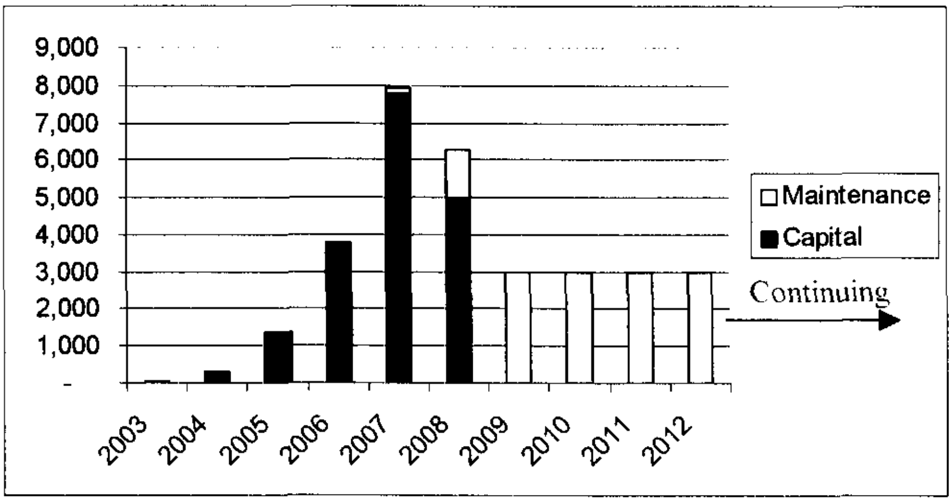
## 21.8 Financing Arrangements

As a result, it is anticipated that the necessary works can be funded by an International Donor, and the proposed implementation plan provides for the processing of an appropriate grant application. Typically, in Nicaragua grant aided highway projects are co-financed by the Government of Nicaragua at an average rate of 10% of the total project cost It is therefore recommended that MTI makes budget provision for the implementation and maintenance of this project in accordance with Table 21.8.1 and Figure 21.8.1

**Table 21.8.1 Proposed MTI Budget Provision for Implementation and Maintenance of Disaster Prevention Measures ('000s Cordoba)**

| Year | Capital | Maintenance |
|---|---|---|
| 2003 | 45 | - |
| 2004 | 339 | - |
| 2005 | 1,391 | - |
| 2006 | 3,790 | - |
| 2007 | 7,753 | 165 |
| 2008 | 4,995 | 1,301 |
| 2009 | - | 2,984 |
| 2010 | - | 2,984 |
| 2011 | - | 2,984 |
| 2012 | - | 2,984 |

Source : Capital budget 10% of total of Table 21.8.1, Maintenance Budget as Table 21.4.1, both converted at $1 = 14.4 Cordoba of the main text




Source : Table 21.8.1

**Figure 21.8.1 Proposed MTI Budget Provision for Implementation and Maintenance of Disaster Prevention Measures ('000s Cordoba)**

# CHAPTER 22 MAINTENANCE AND OPERATIONS SYSTEM

## 22.1 General Flow of Maintenance and Operations System

Taking into consideration the present status of road maintenance in MTI, an overall concept for a system of road maintenance and operations is proposed as shown in Figure 22.1.1.

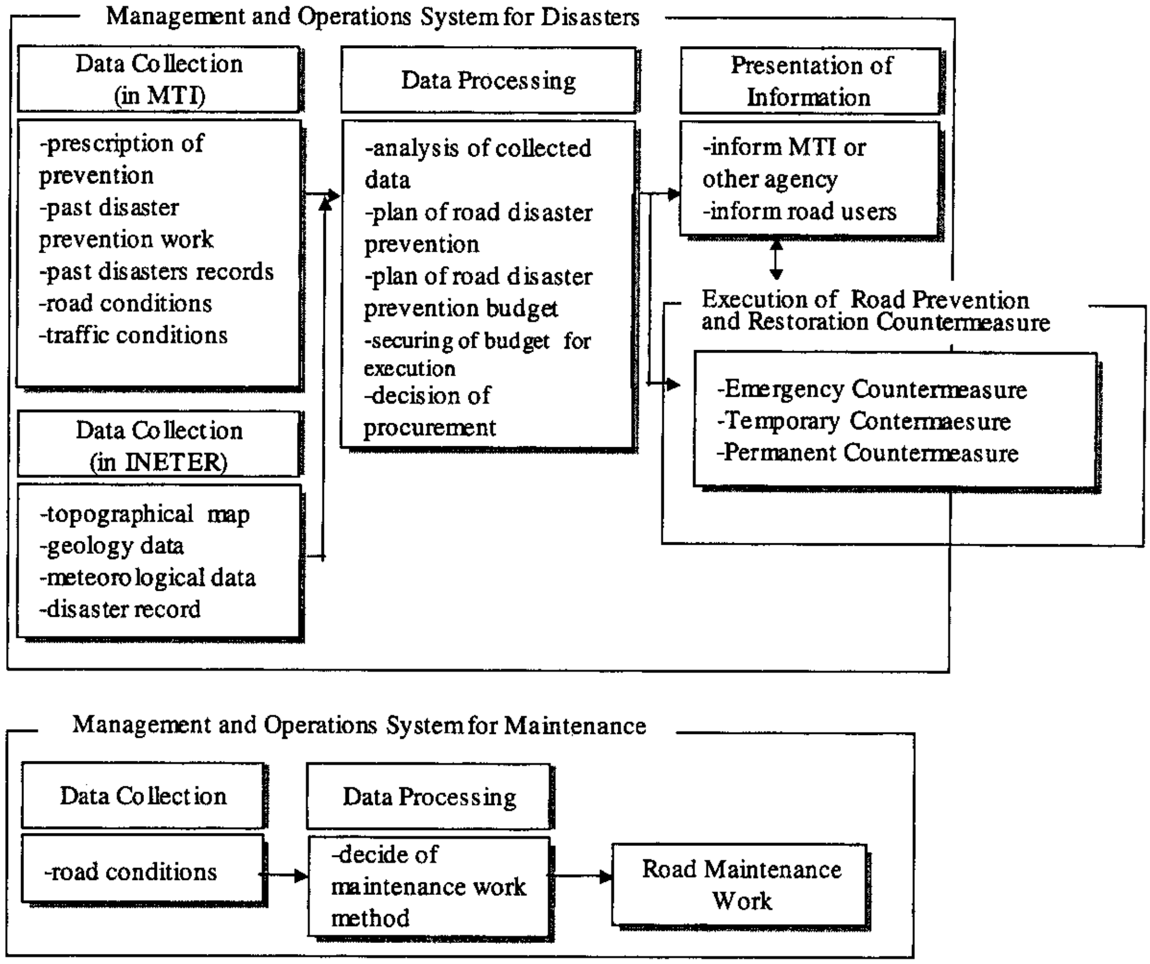



**Figure22.1.1 Concept of Maintenance and Operations System**

## 22.2 Organization of Maintenance Division

### 1) Present Status of General Division of Roads

The General Division of Roads (GDR) is comprised of five departments: 1) Department of Road Construction, 2) Department of Road Maintenance, 3) Department of Road Management, 4) WB Affairs Department, and 5) IDB Affairs Department. Although the Department of Road Maintenance (DORM) is in charge of all aspects of maintenance work, most of the work carried out consists of road surface restoration.

As for when there is damage to road structure, road users and/or local authorities report directly to a Disaster Prevention Technical Unit that comes directly under the MTI, which then reports to the Minister. However, together with many other outstanding issues, GDR receives information too late under this system, resulting in materials and manpower to deal with a disaster being slow and behind schedule. Moreover, as for road inspections in local areas, road inspectors have to be dispatched from the head office, who then return to said office to study the field results and draw up the appropriate response. Given this background, there is insufficient planning overall, an insufficient budget, and a lack of technical capability in the GDR to deal with road disasters. Furthermore, problems continue to pile up as a result of this situation.

2) The Role of GDR

In order to firmly carry out road disaster prevention, it is important for the DORM to plan on how to acquire the necessary information and technologies, to draw up annual plans indicating locations requiring road disaster prevention, to secure a sufficient budget, to plan inspections, to store data, etc., and to report regularly to the GDR.

3) The Role of Local Offices

In order to realize effective road inspections and maintenance, it is proposed that consideration be given to having the responsibility for this work be moved from the head office to the local offices to reduce costs, as well as establishing local offices. The role of local offices is to carry out inspections for their respective jurisdictions, to compile data from their fieldwork, to keep records of disasters, to keep the head office well informed, etc.

In order for the above to be executed without fail, the four personnel described below should be assigned to local offices for road disaster prevention purposes. However, other road maintenance experts can also be assigned to these offices.

? Director: 1 (engineer)

? Engineer: 1 (to establish and confirm locations requiring disaster prevention measures)

? Technicians: 2 (to transport inspection tools and assist the engineer)

Further, it is recommended that local offices be established in the following major cities: Managua, Leon, Matagalpa, Ocotal, Granada, and Juigalpa.

4) The Role of the General Division of Planning

The role of the General Division of Planning is to secure the budget for road disaster prevention, establish an investment plan for this, and to carry out the said plan.

The organizational chart and role of the DORM in MTI to be involved with future road prevention countermeasures is as shown in Figure 22.2.1.

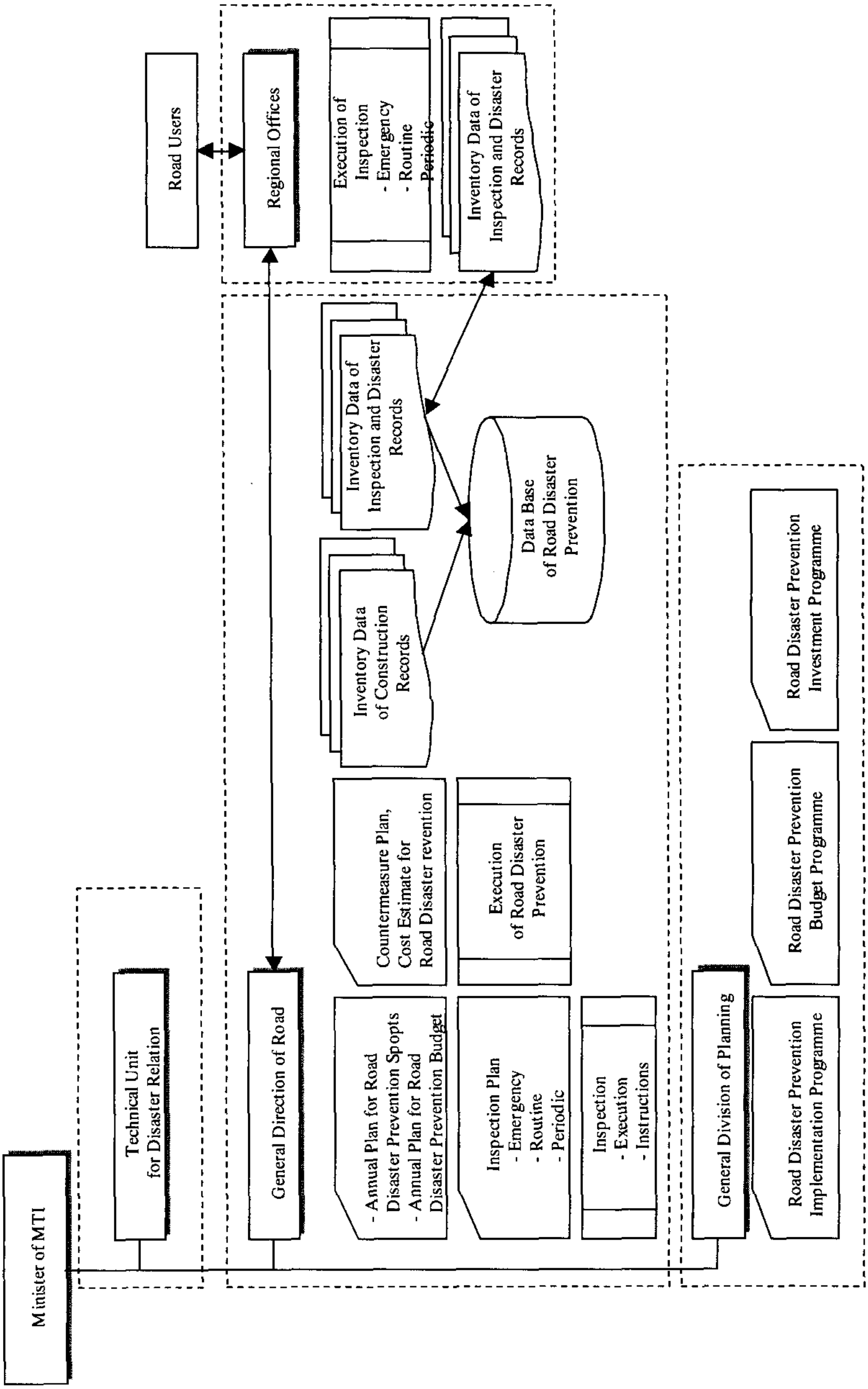



**Figure 22.2.1 Organizational Chart of Maintenance Division**

## 22.3 Inspection and Maintenance Work Methods

### 22.3.1 General

It is important to understand that insufficient maintenance not only affects road facilities such as slopes and bridges, which in turn can affect the flow of road traffic, but can also threaten life and property should they collapse, resulting in large costs being incurred for restoration, etc.

### 22.3.2 Types of Maintenance Inspection

Maintenance inspection consists of the following types:

- Routine inspection
- Periodic inspection
- Urgent inspection

Below, the purpose of each of these types of inspection is explained.

**1) Routine Inspection**

The purpose of routine inspection is to detect at an early stage minor damage and the potential for such damage to become more severe. The main work items in a routine inspection are as follows:

- Confirmation of smooth traffic flows
- Checking for rock and/or debris on roads.
- Inspection of the status of road structures, slopes, and drainage facilities. If damage and/or abnormalities are detected, execution of more detailed inspection and recording and reporting of results.
- In case of emergency, execution of urgent countermeasures.

**2) Periodic Inspection**

The purpose of periodic inspection is to inspect defects or potential defects of slopes, bridges, etc. close up and in detail. The main work items in a periodic inspection are as follows:

- Inspection of slope stability, damage to road facilities, level of damage and/or deterioration
- Check for seepage water from slopes and inspection of drainage system during rainy season to confirm functionality.
- Recording of results in a database.
- Decision on whether or not it is necessary to have further inspection by an engineer, technician, or specialist.

### 3) Urgent Inspection

The purpose of urgent inspection is to check for damage that poses a danger to road users and the surrounding community after the a natural disaster, such as a hurricane or earthquake, or when existing damage threatens to become a danger. The main work items in an urgent inspection are described below.

- More than one expert should do thorough detailed inspections simultaneously.
- Sketches indicating the locations, direction, and widths of cracks, together with present condition photographs and crack distribution charts, should be drawn up. Moreover, measurements should be performed if needed and topographical maps, cross-section sketches, etc. drawn up.
- Urgent inspections should be carried out rapidly after a disaster such as a rainstorm, hurricane, earthquake, etc., since road facilities such as slopes can be easily damaged in such circumstances. Should damage be detected, appropriate measures should be carried out.
- When symptoms of deformation appear, a partial or full detailed inspection of the object facility should be executed. Measurement equipment, such as an extensometer and inclinometer to check for soil movements and the progress of cracking, should be used.
- If soil movement is ongoing, it should be carefully monitored. It is assumed to factor of the stability judgment. From the result of factors, the part with the possibility of the occurrence of the disaster is separately inspected in detail. Strengthening of the countermeasure and observation is examined.
- When slope damage, landslides, etc. occur, boring should be carried out in order to ascertain present conditions. That is, boring should provide data to investigate the direction of soil movement, the existence of slide surface groundwater, soil composition, etc.

### 4) Inspection System

As described above, by executing inspections that are purpose oriented, it is possible to avoid a road disaster from occurring. For this reason, the following inspection team system is recommended:

- Total no. of members per inspection team: 3
- No. of engineers: 1 (to establish and confirm locations requiring disaster prevention measures)
- No. of technicians: 2 (to transport inspection equipment and assist engineer)

## 22.4 Methods of Repair/ Rehabilitation

Priority work items for repair and rehabilitation are listed below:

- The secondary disaster prevention gives priority after confirmation of dread of secondary disaster and work safety,
- Confirmation of detour road,
- Confirmation of appropriate amount of repair and rehabilitation work, and
- Selection of appropriate repair and rehabilitation methods taking into consideration availability of materials.

In determining the cause of road facility deformation or collapse, various inventory data are used.

Each type of repair and rehabilitation methods is presented in Figure 22.4.2 to Figure 22.4.6 of the main text. These types of countermeasures are the cracking of slopes, the boulder stone and loose stones on slopes, defect in drainage facility and weathering of shotcrete, slope damage from road surface water inflow, and landslide.

## 22.5 Procurement

Based on countermeasures, the Study team was able to confirm that all of the materials for the countermeasures could be procured in Nicaragua. As for equipment, everything could be procured except for a shotcrete machine.

As for contractual matters when the countermeasures are executed, two cases are considered. The first case is contracting with a private company and the second case with COERCO (or a public entity). The selection of the contract type is to be decided by MTI and will depend on the amount of construction work required.

## 22.6 Plan of Database System

It is important that the maintenance records, the facility conditions, condition of geological and weather characteristics are grasped in order to achieve the effective road maintenance. And several relative data, which are geology, topography and hydrology, should be arranged to use smoothly. Therefore the various database should be established promptly.

All of the data collected in this Study should be used for near future. The database of road maintenance in MTI is recommended as shown in Figure 22.6.1. The arranged data are as follows;

- Basic data (route number, distance, coordinates, type of structure, photographs),
- Survey records (topography, geology, weather, hydrology, traffic volume,

socio-economic index, etc.),

- Facility, road inventory,
- Construction records (as-built drawings, qualities, applied standards, construction method, etc.),
- Inspection frequency, inspection schedule, and
- Repair/ restoration records and its schedule.

The Bridge Management System (BMS), which was donated to the General Direction of Roads by DANIDA in October 2001, is operated and managed efficiently now. Therefore, in the future, this plan of database system should be managed in cooperation with BMS.

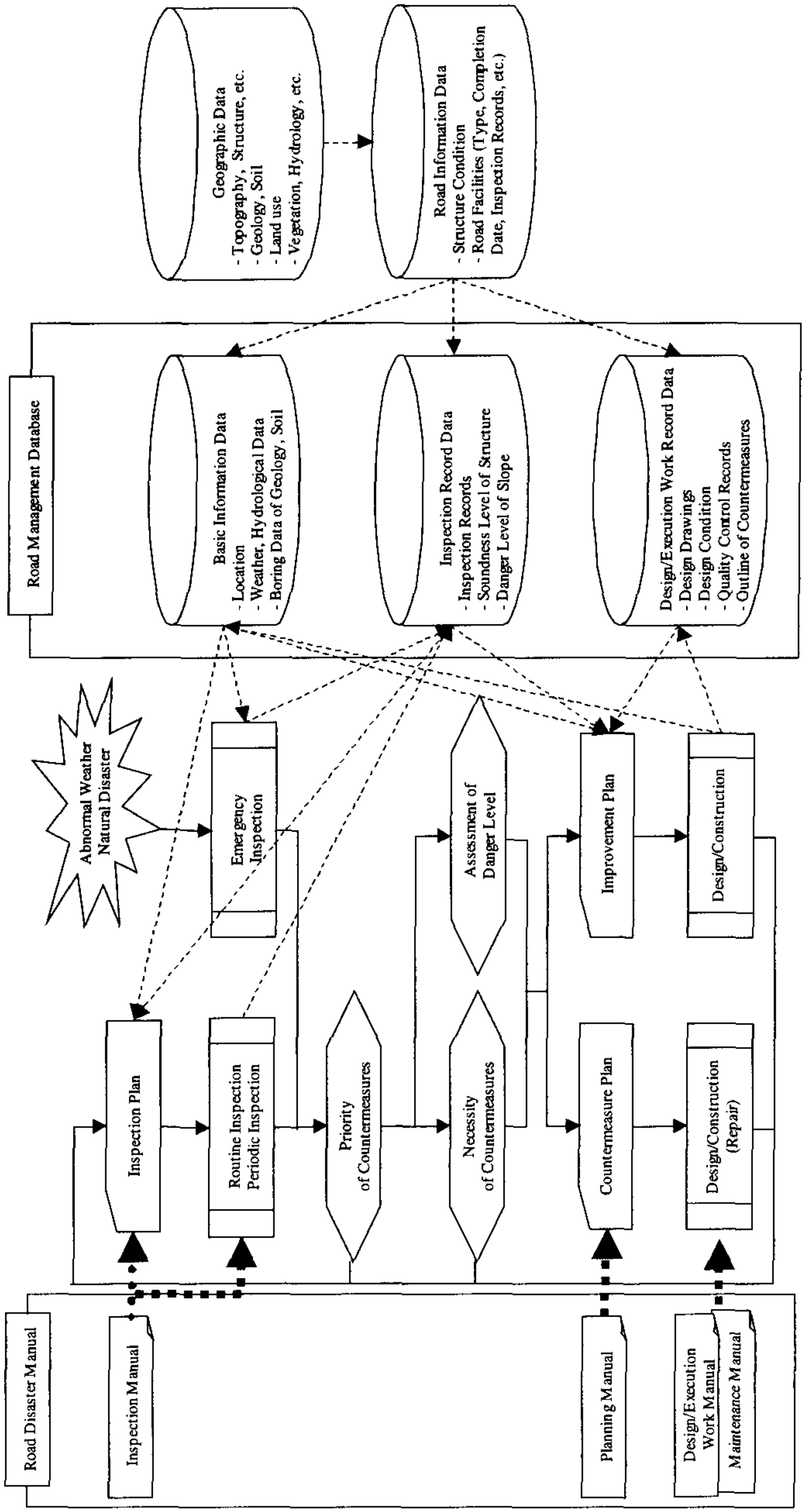



**Figure 22.6.1 Management of Database System for Road Maintenance**

# CHAPTER 23 CONCLUTION AND RECOMMENDATION

The feasibility study proved that project spots of Package 1, 2 and 3 are technically, environmentally and economically feasible. The information and data surveyed in this Study can be finally concluded as follows.

## 23.1 Early execution of the disaster prevention spots

The identified disaster prevention spots are highly critical. Therefore, the disaster prevention work should be executed as early as possible in order to protect the safety of road users and the stability of traffic movement and the economy.

Therefore, the priority order of the project package should be considered as grouped in the following Table 23.1.1.

## Table 23.1.1 Priority Order of Project Packages

| Priority Order | Package No. | Road No. | ID No. | Cuntermeasure | Total |
|---|---|---|---|---|---|
| 1 | 1 | Nic.1 | N001AA280 | Horizontal drainage | 7 |
| | | | Junquillal | Gabion mat | |
| | | | San Nicolás | Gabion mat | |
| | | | San Ramón | Gabion mat | |
| | | | N001A240 | Removal of loose rocks, installation of netting | |
| | | | N001B230 | Removal of loose rocks, installation of netting | |
| | | | N001B150 | Cutting, shotcrete and drainage | |
| | | NIC.3 | N003B400 | Cutting and drainage | 2 |
| | | | N003B320 | Retaining wall and fill, drainage and re-vegetation | |
| | | NIC.26 | N026B160 | Removal of loose rocks, Installation of netting and drainage | 3 |
| | | | San Juan de Dios | Gabion mat | |
| | | | Papalón | Gabion mat and riprap with mortar | |
| 2 | 2 | NIC1 | N001A290 | Removal of loose rocks, Installation of netting and drainage | 1 |
| | | NIC.3 | N003B370 | Cutting and drainage | 3 |
| | | | El Guayacán | New bridge | |
| | | | N003E170 | Cutting and drainage, Concrete dam and Box culvert | |
| | | NIC.5 | N005A010 | Cutting and drainage | 1 |
| | | NIC.26 | La Banderita | Masonry wall and gabion mat | 2 |
| | | | Solis | Gabion mat and riprap with mortar | |
| 3 | 3 | NIC.1 | Las Chanillas | Concrete brocks | 5 |
| | | | N001B170 | Cutting and drainage | |
| | | | N001B120 | Cutting and drainage | |
| | | | Rio Inali | Gabion mat and stone masonry | |
| | | | Rio Tapascali | Gabion mat | |
| | | NIC.3 | N003C230 | Cutting and concrete protect with vegetation, Lower down embankment with drainage | 3 |
| | | | N003C150 | Cutting and drainage above road, embankment, Vegetation and drainage below | |
| | | | N003C140 | Cutting with drainage and horizontal drainage above road, embankment, vegetation and drainage below | |
| | | NIC.26 | N026A060 | Cutting, shotcrete and drainage | 3 |
| | | | N026B140 | Cutting, drainage and horizontal drainage | |
| | | | N026A150 | Cutting and drainage, lateral carriageway drainage | |
| Total Disaster Prevention Sites | | | | | 30 |

## 23.2 Recommendation

In order to execute the projects, the MTI has been recommended to take the following actions.

- **Execution of Screening, Emergency/ Routine/ Periodic Inspection Survey,**

  Approximately 80 over disaster potential spots were identified by the inspection survey on the objective six (6) roads, which are NIC.1, NIC.3, NIC.5, NIC.15, NIC.24 and NIC.26, in this Study. The screening and inspection surveys should be carried out for not only the objective roads but also other major roads and the rural roads.

- **Understanding Manuals and Standard Drawings,**

  The manuals are composed of five (5) parts as below.
  - An Inspection Manual,
  - A Planning Manual,
  - A Design/ Execution Works Manual,
  - A Maintenance Manual, and
  - A Design Standards/ Standard Drawings.

  Each manual is applicable to conditions on Nicaraguan roads, and users must understand the contents of all 5 manuals.

- **Strengthening of Maintenance Division in MTI,**

  The Direction of Road Maintenance is organized in General Division of Roads of MTI. However, its main work is only minor maintenance works of road surfaces on major roads. Almost all of major maintenance works are carried out by donations from the foreign counties.

  In order to build up a strong maintenance organization, the following actions are recommended.
  - Clarification of roles and responsibilities in the range of Direction and Division with a role in road maintenance,
  - Establishment/ management of Database for the maintenance work, and
  - Reorganization of reporting and liaison lines.

- **Establishment of Regional Offices, and**

  In order to get information of disaster quickly, regional offices should be established at main towns on major roads. The roles of regional offices will be to carry out screening, and other inspection surveys for emergency, routine and periodic maintenance. Data collected from inspection surveys should be analysed in regional offices and be reported to the main maintenance division in MTI. Thus the regional offices should take responsibility for major roads in their local areas.

- **Secure the Special Budget for Road Disasters**

  A special budget for roads disaster should be established to a safeguard against possible loss. MTI should take on great responsibility for the management and control of major and rural roads in Nicaragua. If traffic accidents occur within MTI's responsibility, it is likely to be a result of very bad carriageway surfaces, very dangerous slope surfaces, very risky bridge condition, etc.

  Therefore, in order to safeguard road safety and economic development to the road users, MTI should itself secure a special budget for road disasters.

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