CHAPTER 5

IDENTIFICATION OF DISASTER PREVENTION SPOTS

CHAPTER 5 IDENTIFICATION OF DISASTER PREVENTION SPOTS

5.1 Natural Condition Survey

5.1.1 Objectives

Fifty-five (55) disaster critical spots identified in Chapter 4 should be carried out more detailed survey for grasping each characteristic of the river condition and the geological condition. Table 5.1.1 is arranged the ID No and the type of disaster.

Table 5.1.1 Serial Number Code of Part (Disaster Critical Spots) for Investigation

Route No. Nic.1

Sireal Number of Disaster Critical spots	ID.No	Kilometer from Managua (km)	Type of Boring
1	N001A290	60.9	R.F.
2	N001A280	73.2	R.F.
3	Junquillal	113.19	Bridge
4	San Nicolas	135.64	Bridge
5	Las Chanillas (R.Esteli)	150.33	Bridge
6	San Ramón	151.85	Bridge
7	N001A240	168.4	R.F.
8	N001B230	168.6	R.C.
9	N001B200	169.8	R.C.
10	N001B190	170.7	R.C.
11	N001B170	171.3	R.C.
12	N001B150	175.0	R.C.
13	N001B120	176.2	R.C.
14	N001A110	178.7	R.F.
15	N001B100	187.3	R.C.
16	N001B070	204.7	R.C.
17	N001A050	214.7	R.F.
18	Rio Inali	226.89	Bridge
19	RioTapacali	233.245	Bridge
20	N001B030	232.5	R.C.
21	N001A020	233.7	R.F.
22	N001A010	235.6	R.F.

Route No. Nic..3

Sireal Number of Disaster Critical spots	ID.No	Distance from Sebaco(km) (*Bridge: from Managua)	Type of Boring
23	003B420	3.9	R.C.
24	003B400	6.9	R.C.
25	003B370	7.4	R.C.
26	El Guayacan	119.05	Bridge
27	N003B320	22.1	R.C.
28	N003B240	32.7	R.C.
29	N003C230	32.9	S.S.
30	N003E170	35.2	D.F.
31	N003C160	35.9	S.S.
32	N003C150	38.9	S.S.
33	N003C140	39.4	S.S.
34	N003B120	40	R.C.

Route No. NIC.5

Sireal Number of Disaster Critical spots	ID.No	Distance from Matagalupa (km)	Type of disaster
35	N005A010	24.6	R.F.

Route No. Nic.15

Sireal Number of Disaster Critical spots	ID.No	Distance from Las Manos (km)	Type of Boring
36	N015E010	9.9	D.F.
37	N015E020	11.1	D.F.
38	N015E050	11.7	D.F.
39	N015E060	13.6	D.F.

Route No. Nic.26

Sireal Number of Disaster Critical spots	ID.No	Distance from I.C. between San Ishidoro & Sebaco (km) (*Bridge:from Managua)	Type of Boring
40	N026A010	9.0	R.F.
41	N026A020	12.7	R.F.
42	N026A030	19.9	R.F.
43	N026A040	20.9	R.F.
44	N026A060	24.7	R.F.
45	La Banderita	170+952	Bridge
46	N026A100	29.3	R.F.
47	N026B110	29.8	R.C.
48	N026A130	33.6	R.F.
49	N026B140	34.0	R.C.
50	N026A150	34.2	R.F.
51	N026B160	37.0	R.C.
52	San Juan de Dios	156+785	Bridge
53	N026B210	45.5	R.C.
54	Papalón	108+154	Bridge
55	Solis	107+533	Bridge

R.F. :Rock Falling
R.C. :Rock Collapsing
S.S. :Slop slide
D.F. :Debris Flow
Bridge :Scoring of fundation

5.1.2 Hydrological Survey

1) Objectives

The hydrological survey targeted the river where the bridge, which had been selected by 11 spots, spanned among the object 55 disaster critical spots of the target for this plan. Each basic data is presented in Appendix – 3.

The purpose of the main investigation does the hydrological survey to the river where the bridge in which the scour under the bridge is worried exists, and verifies a proper scale the influence of the scour by the assumed stream flow velocity and flowing quantity. The bridge for the investigation is shown in Table 5.1.2.

Table 5.1.2 Bridges to be Surveyed

Route	Serial No.	Point from Managua (km)	Land Mark (Bridge name)	Remark
NIC.1	3	113.19	El Junquillal	Via Sebaco
	4	135.64	San Nicolas	-Ditto-
	5	150.33	Las Chanillas	-Ditto-
	6	151.85	San Ramón	-Ditto-
	18	226.89	Río Inalí	-Ditto-
	19	223.25	RíoTapacalí	-Ditto-
NIC.3	26	119.05	El Guayacan	Via Sebaco
NIC.26	45	170.952	La Banderita	Via Leon
	52	156.785	San Juan de Dios	-Ditto-
	54	108.154	Papalón	-Ditto-
	55	107.533	Solís	-Ditto-

2) Survey methodologies

a) Velocity measurement

It is a principal object to obtain the mean velocity in each section in the river. The flow velocity is measured in the straight-line part where the width of a river and depth are constant. The research methodology has the method with a surface float and a stick float and the method with a current-meter. It will measure it in two days different with a current-meter in the main investigation.

b) Hydrological analysis

The opinion decided to the method of the hydrological survey concerning the design of the bridge of MTI etc. is not, and has been decided according to each situation usually.
Establishment is most generally adopted for 50 years as for probable flood peck runoff year's setting but; It is likely to be set importantly in the route by establishment for return period for

100 years and 25 years.

The methodology is applied combination of common hydrological analysis techniques and hydrological model simulation to reach the study goal. It explains the most general setting of the amount of the flood according to the method done in a Nicaragua and the method of setting the plan flood title as follows.

Firstly, the watershed is decided by using the topographical map, which the contour line enters. The topographical map of 1:50,000 are used usually. After the decision of the watershed, the condition for the selection of the condition of the valley and the river, the geographical features conditions, and flood concentration times and conditions of the altitude, the river inclination, and the run-off coefficient, etc. are decided.

To evade the extreme contradiction between the stations to the data of the weather and the rainfall, a double mass-haul curve etc. are used and analyzed. It examines by using a general establishment method for the parameter. The calculation of the establishment rainfall is calculated by the IDF curve by a regional rainfall's of each watershed using the Isohyeteal method in a different year of establishment (establishment for 25, 50 and100 years).
The amount of the flood peck runoff is calculated by using the rational type in a different year of establishment (return period for 25,50 and 100 years).
It is calculated in year of establishment (establishment for 25, 50 and 100 years) when the calculation of the flood stage of each river was inevitably different.
The HEC-RAS model is used for the analysis.

3) The survey results (Flow velocity investigation)

The result of the flow velocity investigation is as following Table 5.1.3. An enough measurement result was not obtained because it was a rainy season but there was little flowing quantity. This seems to have become such a result because rain concentrates in May and October as a trait in a Nicaragua country in the rainy season. Therefore, it stops it in the reference data only.

Table 5.1.3 The Result of Flow Velocity Investigation Result

Serial No.	Bridge	Velocity min (m/s)	Velocity max (m/s)	Q (m3/s) (for Velocity max)
3	Tapacalí	0.036	0.048	0.0348
4	Inalí	0.186	0.271	0.255
5	San Ramón	0.091	0.175	0.009
6	Las Chanillas	0.204	0.431	0.431
18	San Nicólas	0.010	0.037	0.037
19	El Guayacán	N/A	N/A	N/A
26	El Junquillal	0.037	0.061	0.445
45	Las Banderitas	0.162	0.192	0.047
52	San Juan Dios	0.103	0.186	0.017
54	Solís	N/A	N/A	N/A
55	Papalón	N/A	N/A	N/A

4) The survey results (Hydrological Analysis)

a) Grasp of regional characteristic

It has already been described that the hydrological watershed in Nicaragua are divided two directions in the Pacific watershed and the Atlantic watershed, and subdivided into the watershed of 8 in Pacific one and 13 in Atlantic one respectively in Chapter 2.

Moreover, the characteristic classification by the weather is divided into the Pacific plane area, central mountains range area (It is divided into the northern part and central part), and the Atlantic coast plane area. Two small bridges (Papalon and Solis) enter the Pacific plane area, at the position of the object bridge, and nine bridges of the remainder belong to the northern part of central mountains range area.

b) Slope and Hydrology parameters

Table 5.1.4 shows the parameter for the condition index on hydrology calculated on each site setting.

Table 5.1.4 Slope and Hydrology Parameters

Watershed	Watershed Code	Area (Km^2)	Perimeter (Km)	Length (Km)	Time of Concentration (Hr)	Watershed Mean Slope (%)	Form Factor
Tapacalí	45– 1	147.1	55.00	24.00	3.00	21	0.26
Inalí	45 – 2	84.80	47.00	17.00	2.00	21	0.29
San Ramón	45 – 3	2.70	7.00	3.00	0.50	28	0.30
Las Chanillas	45 – 4	114.6	59.53	20.52	3.00	16	0.27
San Nicólas	45 – 5	6.10	10.00	3.00	0.50	31	0.68
El Guayacán	55 – 6	28.3	18.00	12.5	2.00	19	0.18
El Junquillal	69 – 7	49.80	34.00	11.00	2.00	18	0.50
Las Banderitas	69 – 8	7.70	12.50	5.00	1.00	30	0.31
San Juan Dios	69 – 9	9.00	14.25	7.00	1.00	29	0.78
Solís	64–10	0.80	5.01	1.80	0.29	19	0.24
Papalón	64–11	0.60	3.41	1.48	0.23	16	0.27
Watershed	Watershed Code	Torrentially Coefficient (River/km2)	Channel Mean Slope (%)	Watershed Mean Elevation (MSL)	Mean Flow Extension. (Km2/km)	Maximum Altitude (MSL)	Minimum Altitude (MSL)
Tapacalí	45 - 1	0.29	4.1	1121.61	0.19	1665	680
Inalí	45 - 2	0.28	3.9	961.69	0.28	1736	640
San Ramón	45 - 3	0.37	6.7	897.96	0.22	1005	813
Las Chanillas	45 - 4	0.27	2.7	1068.5	0.30	1380	819
San Nicólas	45 - 5	0.66	8.7	1070.0	0.22	1300	920
El Guayacán	55 – 6	0.35	4.8	866.63	0.43	1220	620
El Junquillal	69 – 7	0.18	3.3	608.4	0.30	1000	457
Las Banderitas	69 – 8	0.26	8.4	445.09	0.28	660	240
San Juan Dios	69 - 9	0.44	7.1	267.44	0.20	660	100
Solís	64 - 10	3.85	4.4	225	0.07	250	170
Papalón	64- 11	1.69	4.1	238.98	0.10	230	170

In addition, it became the reference point of the watershed of 11, and Meteorological data (1980-2000) from four stations was used to analyze the rainfall.

Those stations were selected based on adjacent, and each control selected the most suitable part for the above-mentioned watershed as the map had announced with INETER near the position of the precipitation line. The station used is shown in Table 5.1.5.

Table 5.1.5 Meteorological Stations

Station Name	ID Code	Record Length	Basin Number
Condega	45003	1958-2001	45
Ocotal	45017	1985-2000	45
Leon	64043	1974-2002	64
San Isidro de Barbacoa	69029	1958-2000	69

Source: INETER

Next, the relation between the object site and the adoption each station is described.

Tapascali and Inali Sites

Tapacali and Inali of the site are between the rainfalls of the equal precipitation line 800mm and 1000mm the site and have had the rainfall 900mm mean during year.

The Ocotal station was naturally selected from this analysis. The Octotal station indicates the rainfall value of the annual mean 870.2mm. The amount of the average rainfall is 158.6mm a month in September, and 74.4mm in July during month of the rainy season (May - October).

The maximum vale is 1717.1mm(1998) in the past of the rainfall during year. Minimum value is 439.5(2000).

San Ramon, Las Chanillas and San Nicolas Sites

The similar condition of Tapacali and Inali has been done to these sites. It is in same Rio CoCo watershed (45) in the rainfall diagram and it has the mean of the provinces of the rainfall 900mm a year. However, the Condega station used the site instead of the Ocotal station to be nearer. Nearest meteorological observatory Esteli station was dismissed by the process of the review and the assessment because of lacking and the contradiction of a lot of data. The Condega station shows the amount of the rainfall of the annual mean 840.7mm. It is 146.1mm of the average rainfall in September and 72.6mm in July.

The maximum value is 1360.8mm(1998) in the past of the rainfall during year. Minimum value is 490.5mm(1985).

El Guayacan Site

Site El Guayacan exists in Rio Grande de Matagalpa watershed (55). There is a site between the precipitation line of 800mm and 1000mm and it has had the rainfall 900mm mean during year. The San Ishidorode Barbacoa station was adopted as data besides Rio Grande de Matagalpa waters (55) though was because it was near the El Guayacan site along the watershed in the Sebaco valley. The San Ishidorode Barbacoa station shows the amount of the rainfall of the annual mean 923.7mm. It is 177.1mm of the average rainfall in September and 80.3mm in July. The maximum value is 1567.4mm(1995) in the past of the rainfall during year. Minimum value is 521.2mm(1986).

Papalon and Solis Sites

Papalon and Solis exist in Cosiguina Volcano-RioTamarindo watershed (64). Naturally, the Leon station located in outskirts was adopted here.

The Leon station indicates the rainfall value of the annual mean 1606.1mm. The amount of the average rainfall is 397.9mm a month in September, and 107.8mm in July. The maximum is 2547mm(1997) in the past of the rainfall during year. Minimum value is 863.9mm(1992).

Junquillal, Las Banderitas, and San Juan de Dios Sites

El Junquillal, Las Banderitas, and San Juan de Dios are located in the upper side of Rio San Juan watershed (69). It is also in the equal rainfall line curve 1000mm about the RioViejo drainage basin. The San Ishidorode Barbacoa station was used for the analysis.

The monthly means rainfall of 20 years record in each nominated stations is shown in Figure 5.1.1.

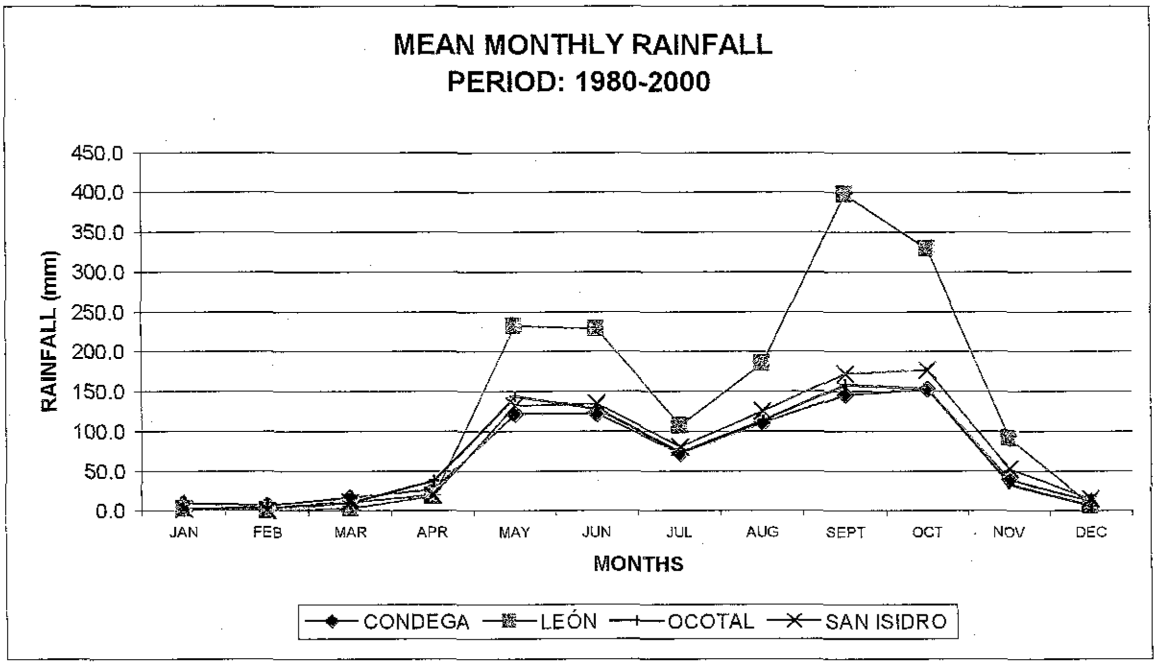


Figure 5.1.1 Rainfall Data in Object Observatory Stations

Source: INETER

c) Intensity Duration Frequency (IDF) Curves

IDF (Rainfall Intensity-Duration-Frequency) Curves for the meteorological station at León, San Isidro and Octal as the national network operated by Instituto Nicaragüense de Estudios Territoriales (INETER), were prepared with data from annual maximum rainfall intensity, these values were read from the rain gage chart.

The common record period established for the analysis was 20 years (1980 – 2000), daily lectures from the rain gage chart to get the maximum rainfall intensity values for 5, 10, 15, 30, 60, 120 and 360 minutes. From these, monthly maximum values are chosen and from them annual maximum values are selected.

Upon data consistency analysis by double mass method, computation of mean or average value, standard deviation and all the Gumbel functions parameters α y β for each duration. Annual maximum values for each meteorological station were arranged in increasing order of magnitude to be able to apply the adjustment test; Applying Gumbel method (Theoretical probability), frequency analysis (Empirical probability) and using the statistic Kolmogorov-Smirnov. After that maximum rainfall intensity for 5, 10, 15, 30, 60, 120 and 360 minutes were computes for 25, 50 and 100 years. The IDF curves are shown in Figure 5.1.2 to 5.1.5.

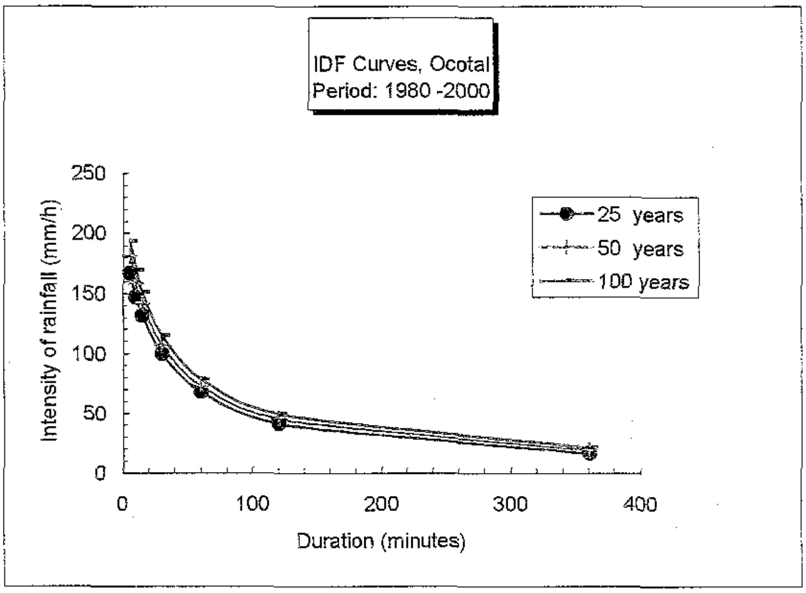


Figure 5.1.2 IDF Curve in Ocotal Station

Source: INETER

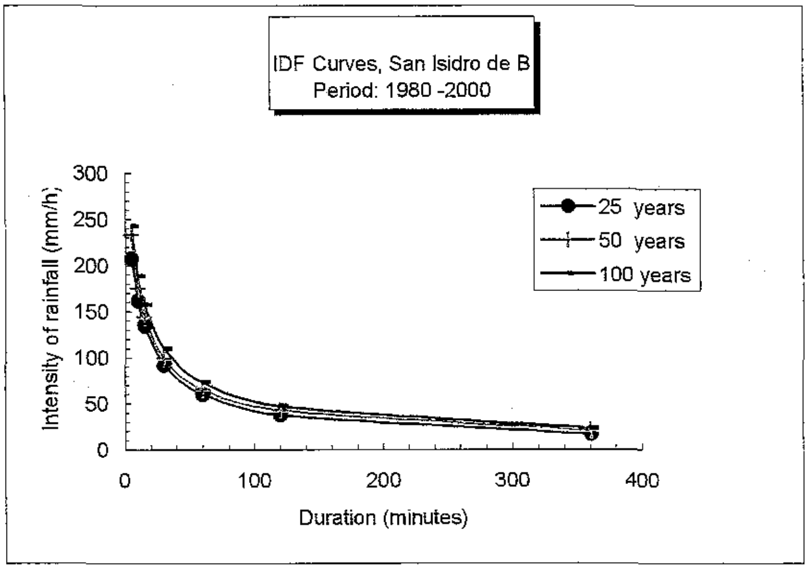


Figure 5.1.3 IDF Curve in San Ishidorode Barbacoa Station

Source: INETER

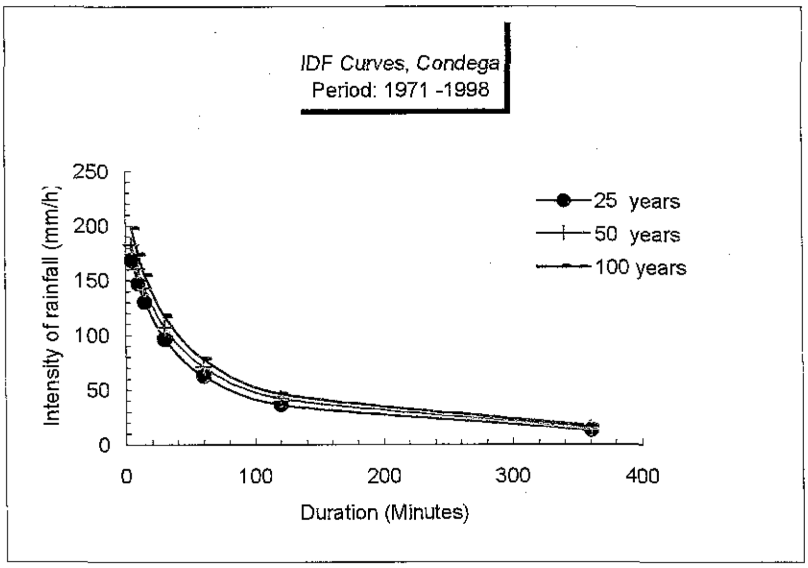


Figure 5.1.4 IDF Curve in Condega Station

Source: INETER

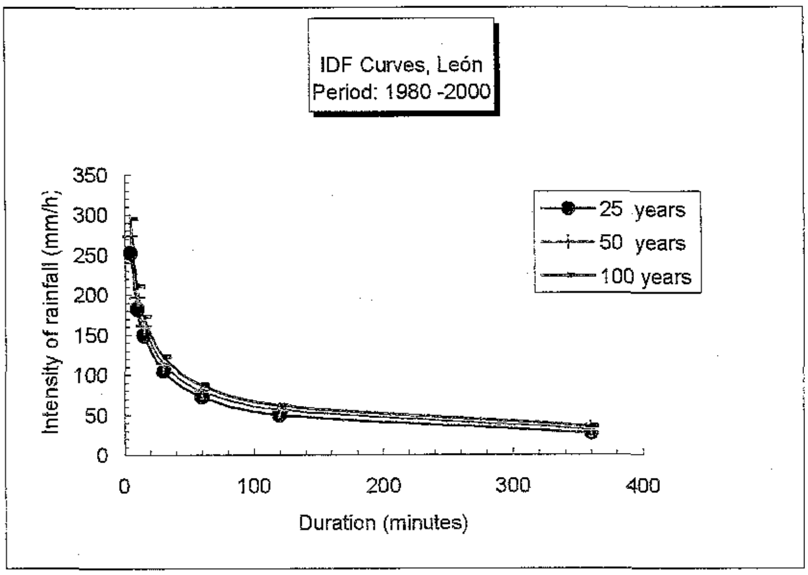


Figure 5.1.5 IDF Curve in Leon Station

Source: INETER

c) Peak Flow Estimation

Peak flow estimation from Rational method approach is basically depending of the rainfall intensity, which were read from the IDF curves (Figure 8-2-2 to 8-2-5) for different return period (25, 50 and 100 years) and used to estimate peak flow for all the watersheds.

The parameters needed in the Rational method such as drainage area, time of concentration is in Table 5.1.4 Slope and Hydrology parameters.

The estimation of runoff coefficient (C) is basically from Table 5.1.6 where values are chosen regarding to some specifics characteristics.

Table 5.1.6 Runoff Coefficients

Land Cover	Soil Type	Terrain Slope				
		Steep 50%	High 20%	Medium 5%	Smooth 1%	Negligible 0%
No Vegetation	Impermeable	0.8	0.75	0.70	0.65	0.6
	Semipermeable	0.70	0.65	0.60	0.55	0.50
	Permeable	0.50	0.45	0.40	0.35	0.30
Crops	Impermeable	0.70	0.65	0.60	0.55	0.50
	Semipermeable	0.60	0.55	0.50	0.45	0.40
	Permeable	0.40	0.35	0.30	0.25	0.20
Pasture, Light Vegetation	Impermeable	0.65	0.60	0.55	0.50	0.45
	Semipermeable	0.55	0.50	0.45	0.40	0.35
	Permeable	0.35	0.30	0.25	0.20	0.15
Grass	Impermeable	0.60	0.55	0.50	0.45	0.40
	Semipermeable	0.50	0.45	0.40	0.35	0.30
	Permeable	0.30	0.25	0.20	0.15	0.10
Forest, Dense Vegetation	Impermeable	0.55	0.50	0.45	0.40	0.35
	Semipermeable	0.44	0.40	0.35	0.30	0.25
	Permeable	0.25	0.20	0.15	0.10	0.05

Source: Ministerio de Obras Publicas de Venezuela

Land use for each of the watershed is from the Soil Use map sheets scale 1: 250,000 (published by INETER) corresponding to the map sheets: Estelí and Managua. The information from this maps together with fieldtrip to the study sites produced updated information about land cover changes not in the used map, for example historical croplands at the Western shifted today into grassland and very little croplands.

Soil type for each of the watersheds is from the Soil type map sheets scale 1: 250,000 (published by INETER) corresponding the map sheets: to Estelí and Managua. The most important characteristic is the soil grade permeability and the slope phase for each zone. In the hydrological study is assumed that soils are semi permeable because there is no information about infiltration values showing a detail classification. Table 5.1.7 shows the computed runoff coefficients for each of the watershed.

Table 5.1.7 Runoff Coefficients for the Watersheds

Watershed	Time of Concentra (Hours)	Run of Coefficient
Tapacalí	3.0	0.62
Inalí	2.0	0.59
San Ramón	0.5	0.48
Las Chanillas	3.0	0.60
San Nicolás	0.5	0.42
El Guayacán	2.0	0.49
El junquillal	2.0	0.46
Las Banderitas	1.0	0.46
San Juan de Dios	1.0	0.44
Solís	0.3	0.45
Papalón	0.3	0.46

The Rational method of Approach is widely used around the world for flood estimation on small rural drainage basins and is the most widely used method for urban drainage design. Peak flow estimation is shown in Table 5.1.8.

The rational formula is Qp=0.278CIA

Qp= Peak discharge (m3/s)
0.278 is a unit conversion factor to SI units.
C=Runoff coefficient(dimensionless)
I =Rainfall intensity (mm/hr), is estimated from the rainfall intensity-duration-frequency (IDF) curves.
A =drainage basin area (km^2)
Tc = (Lc^3 /(Hmax-Hmin))^ 0.385 (California formula)

Table 5.1.8 Peak Flow Estimation

Watershed	A	TC	I(mm/h)			C	Qp(m^3/s)		
Return Period T (Years)	(km^2)	(hours)	25	50	100		25	50	100
Tapacalí	147.11	3.0	35	40	45	0.62	886.75	1013.4	1266.8
Inalí	84.80	2.0	41.7	45.7	50.0	0.59	579.58	635.18	694.94
San Ramón	2.7	0.5	96.8	107.7	117.7	0.48	34.85	38.78	42.38
Las Chanillas	114.61	3.0	35	38	42	0.6	668.61	725.92	802.33
San Nicolás	6.10	0.5	96.8	107.7	117.7	0.42	68.89	69.94	83.77
El Guayacan	28.3	2.0	38.7	43.1	48.1	0.49	149.08	166.03	185.29
El Junquillal	49.8	2.0	38.7	43.1	48.1	0.46	246.28	274.28	306.10
Las Banderitas	7.70	1.0	61.1	66.1	73.8	0.46	60.12	65.04	72.62
San Juan de Dios	9.00	1.0	61.1	66.1	73.8	0.44	67.22	72.72	81.19
Solís	0.80	0.5*	105.9	114.7	123.4	0.45	10.59	11.47	12.34
Papalón	0.60	0.5*	105.9	114.7	123.4	0.46	8.12	8.79	9.46

*For Solis and Papalon the intensity values from IDF are rounded to nearest value (30 minutes)

e) Water Levels Estimation

Generally, Water levels of each watershed of study sites are estimated by HEC-RAS simulation. Before giving the results of the hydraulic simulation by using HEC-RAS model, is necessary to state the particular situation considered to carry out the simulation:

- **Group 1**, in this group were considered the study sites with drainage areas smaller than 10 km^2: Solís, Papalón, La Banderita, San Nicolás, San Juan de Dios and San Ramón (see Table 5.1.7).
  The main characteristics of these sites are:
  Channels walls are almost vertical, moderate depth (5 to 9 m)
  Widths are between 40 and 100 m
  Peak flow estimates lower than 100 m^3/s being the highest estimated magnitude for a 100 years return period.

- **Group 2:** in this group were considered the study sites with bigger drainage areas between 28.3 and 147.11 km^2: El Guayacán, El Junquillal, Las Chanillas, Inalí and Tapacalí (see Table 5.1.7).
  The main characteristics of these sites are:
  Channels depths are less than 6 m
  Widths are between 40 and 120 m.
  The sites Las Chanillas, Inalí and Tapacalí are with channel width bigger than 100 m.

- **Topographic Data:** The cross section are numbered in ascendant order being the first downstream and the last upstream. Cross section - 1 correspond to the road profile at the bridge height, where water levels are estimated in this analysis.

- **Flow Data**: In the steady flow analysis considered for the channel sites an approximation of the critical depth slope is considered, which is the first input data and is the level change between the lowest point in the main channel at the most upstream section and the bridge section difference. Under sub critical regime three profiles were analysed for 25, 50 and 100 years return period. In the case that peak flow for the lower return period (25 years) overtop the bridge section, a lower peak flow value was estimated.

- **Manning roughness coefficients (n)**: The selection of a roughness coefficient value for each of the studied channels is based on the characteristic of the channel bed material. The chosen value is by comparing the pictures taken during the fieldtrip and the pictures on the reference book "Roughness Characteristics of New Zealand Rivers del Water Resources Survey (by D M Hicks and P D Mason, a handbook for assigning hydraulic roughness coefficients to river reaches by the "visual comparison approach", based on physical and hydraulic characteristics for 78 New Zeeland river). The information shall be given for each river includes photographs, cross-section data, bed and bank descriptions, bed surface material size grading, and Manning and Chezy roughness coefficients.

<Pictures of each study site with Manning roughness coefficients>

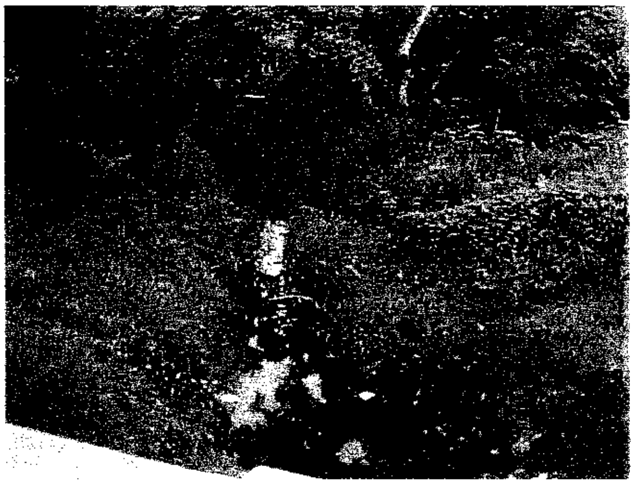
Solís main channel upstream the bridge n = 0.016

Papalón main channel upstream the bridge n = 0.016

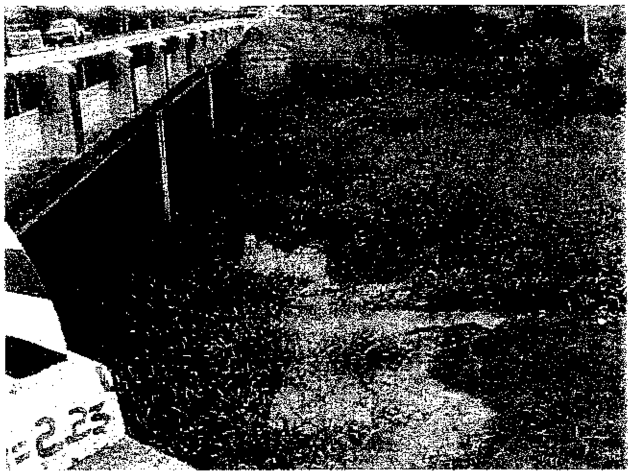
La Banderita main channel upstream the bridge n = 0.027

San Juan de Dios main channel upstream the bridge n = 0.027

San Nicólas main channel upstream the bridge n = 0.020



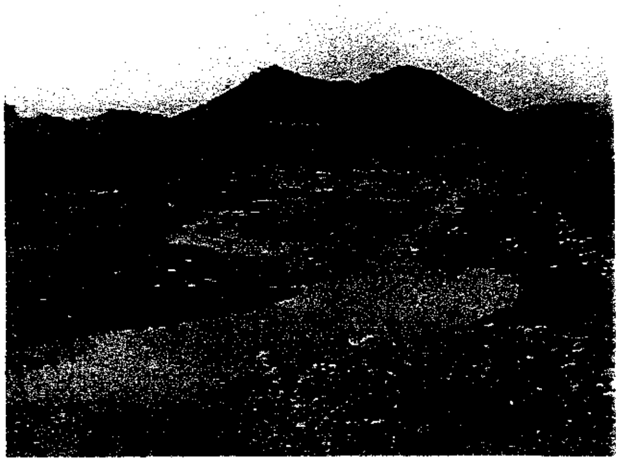
San Ramón main channel upstream the bridge n = 0.045



El Junquillal main channel upstream the bridge n = 0.027

El Guayacán left channel upstream the bridge n = 0.027

Las Chanillas main channel upstream the bridge n = 0.028



Inalí main channel upstream the bridge n =0.028

Tapacalí main channel upstream the bridge n = 0.028

f) Water Level Results: Water levels for each of the cross sections are shown in Table 5.1.9 and 5.1.10 the groups described before and are only estimated for the bridge cross section (bridge structure itself is not considered).

Table 5.1.9 Water Level at the Bridge Cross Section for Group 1

Watershed	Velocity (m/s)			Flow (m³/s)			Water Level at the bridge section (m)			Bridge EL (m)
Return Period	(years) 25	50	100	25	50	100	25	50	100	
Solís	2.28	2.34	2.37	10.59	11.47	12.34	-4.61	-4.58	-4.55	0.28
Papalón	2.47	2.61	2.76	8.12	8.79	9.79	-3.2	-3.14	-3.08	0.30
San Juan de Dios	1.04	1.05	1.07	67.22	72.72	81.19	-0.28	-0.21	-0.11	-0.03
La Banderita	1.19	1.22	1.26	60.12	65.04	72.62	-6.37	-6.25	-6.06	-0.01
San Nicolás	1.72	1.78	1.84	68.89	64.94	83.77	-4.13	-4.22	-3.80	0.40
San Ramón	2.36	2.46	2.54	34.85	38.78	42.3	-3.4	-3.33	-3.26	0.48

Water levels are not tied to a geodesic Benchmark.

Table 5.1.10 Water Level at the Bridge Cross Section for Group 2

Watershed	Velocity (m/s)			Flow (m³/s)			Water Level at the bridge section (m)			Bridge EL (m)
Return Period	(years) 25	50	100	25	50	100	25	50	100	
El Junquillal	1.86	1.89	1.91	246.28	274.28	306.10	0.92	0.98	1.04	0.205
El Guayacán	1.02	1.04	1.07	149.08	166.03	185.29	>0.86*	>0.86 *	>0.86 *	0.86
Ls Chanillas	4.76	4.88	5.03	668.61	725.92	802.33	-4.1	-3.95	-3.75	0.18
Inalí	4.69	4.80	4.92	579.58	635.18	694.94	-3.61	-3.46	-3.3	0.32
Tapacalí	2.65	2.78	2.90	886.75	1013.44	1266.80	295.76	296.06	296.61	299.618

Water levels are not tied to a geodesic Benchmark besides Tapacali

* Road Elevation

g) Result Evaluation

<Group 1>

Two watersheds (Solis and Papalon) are in the western part of the country. Four watersheds (San Juan de Dios, La Banderita, San Nicolás and San Ramón) are in the north. Drainage areas are smaller than 10 km^2 being Solís and Papalón the smallest drainage areas with 0.8 and 0.6 km^2. This is the reason of very low flows estimates (3.76 and 2.51 m^3/s) for 100 years return period.

- **Solís, Papalón, La Banderita, San Nicolás and San Ramón**: water levels at the bridge cross section height are lower than the road line for 100 years return period flows, this is an indication that the analysed channel have hydraulic capacity to withdraw that flow, under the assumption that the bridge structure itself is not considered in the analysis.

- **San Juan de Dios**: The flow for 25, 50 and 100 years return period overtop the bridge line indicating that the channel have not enough hydraulic capacity to withdraw such flows. Surveyed cross sections were extended over the right margin in 3% slope, trying to approximate the hydraulic area.

<Group 2>

The five watersheds (El Junquillal, El Guayacán, Las Chanillas, Inalí and Tapacalí) are in the North of the country. The drainage areas are bigger than group 1 and vary between 28.3 km^2 (El Guayacán) and 147 km^2 (Inalí). Estimates peak flows for 100 years return period are between 185.29 and 1,140.19 m^3/s and are highest values than the group 1.

- **El Junquillal**: estimated water levels overtop the bridge line section. The particular characteristic is that the adjacent areas to the study sites are paddy fields with almost flat and impermeable surfaces completely saturated. Surveyed cross-section for upstream side was extended over the right margin with 3% slope, trying to approximate the hydraulic area. The simulation results indicates the analysed channel have not hydraulic capacity to withdraw the flow.

- **El Guayacán**: The channel is not capable at all to withdraw flows lower than 185.29 m^3/s corresponding to 25 years return period flow. The bridge structure is composed by arcs, such shape produce higher resistance values by contracting the flow section. Therefore the flow resistance of the structure will increase the water levels values given. Considering this situation, a peak flow value supposed to reach the bridge line was estimated, corresponding to a value of 35 m^3/s (<1.5 years return period). The value found could be lower if the bridge structure is considered in the analysis. Water levels for 25, 50 and 100 years return period given as results are not physically right, the reason in giving it is just to illustrate about the magnitude reached for these return periods.

- **Las Chanillas, Inalí and Tapacalí**: Are the sites with biggest drainage areas (114.61, 84.80 and 147.11 km^2) among the study sites, and of course with the biggest peak flow values (657.87, 694.94 and 1,140.19 m^3/s). Channels are quite wide, low slopes, and very flat margins, the bridges section are more depth than the analysed river channels Peak flows reached about 40 – 50% the bridge section height, under the assumption that the bridge structure itself in not considered in the analysis. Surveyed cross sections were extended over the right margin with 3% slope, trying to approximate the hydraulic area. However, Las Chanillas and Inali indicate high velocity each return period even though they contain water Peak Flows. It seems that these phenomena are wide the bank full width on the upstream side, and have the cause in rapidly narrowing in the bridge. It can be said that there is no other way under the present situation but a good influence is not produced on the bridge anyway not doing the river improvement enough. Especially, it can be said that the tendency is remarkable, and it has the factor of the scour of the bridge foundation in the Inali Bridge.

5.1.3 Geological Survey

1) Objective and method of Survey

a) Objective (Boring, Sounding and Sampling)

The boring exploration was executed for the face of slope and the bridge location, which had been selected basing the first phase as disaster critical spots.

The thing to obtain the basic information, which seemed to be necessary for evaluating the stability of the slope or the entire slope, which included the face of it, a slope location was executed aiming.

Moreover, the thing to obtain the basic information which seemed to be necessary for evaluating the stability of the bed-rock considering the bed morphology of the location of bridge, the river sediment, and the forecast bedrock situation, etc. was executed in the bridge location aiming. Moreover, the basic material was sampled, and the standard penetration test was examined also executing at site.

b) Survey method

The investigation method in Nicaragua country was not used the methods other than the ASTM law, and assumed doing by this method to be basic.

Digging did with the oil pressure type rotary boring machine, and executed the standard penetration test within the range, which could be examined.

In the material sampled by sampler, to understand the physical property of the object stratum, grain size analysis, the specific gravity test of soil particle, it examined the moisture content, and LLPL was examined. Moreover, it tried in the rock sample, which had been gathered like the core to examine the unconfined compressive test as a mechanics examination besides the unit weight test and to understand the physical properties value of the bedrock.

c) Selection of boring position

When the position where the boring exploration was executed and the number were decided, the characteristic of the disaster prevention check result of the first phase and the object part was visually investigated closely again. Geographical features which affected stability on that and geological features are considered. At which position of the object part of boring investigated was classified by five stages for the face of slope, and selected for the bridge according to two stages as follows.

The example of the bore arrangement to the object slopes is shown in Table 5.1.11.

Table 5.1.11 Classification Item of Boring Exploration (Slope)

Class	Characteristics	Quantity of Boring
Type-A	Repeatedly because it is a state of the alternation of strata even if it is a single-layer or a combined stratum composition; It is a place where rock faces and weathering are understood easily. When the bore location can be assumed to be one place, and the average stratum composition etc. which affect stabilizing is evaluated.	BH=1
Type-B	The change is seen in the stratum composition and the state of weathering on site. When the average stratum composition etc. which affect stabilizing can be evaluated by the thing to execute the bore by at least two places.	BH≧2
Type-C	The degree of the stratum composition and weathering is complex. When the evaluation of the stability of the entire slope, which includes the face of slope, is needed, and the bore in at least three places or more needed. And, when it set up the erosion and torrent control dam aiming at the thing to assume the riverbed inclination of the road crossing location to be 3° or less in the place where the generation of the avalanche of sand and stone is forecast.	BH≧3
Type-D	For instance, the exposed bedrock omits boring when most information is appreciable in the hard rock etc. by watching for stability.	BH=0
Type-E	The point that the degree of the geological features composition and weathering is extremely complex because of the alteration of the fault and the volcanic. Things except the above-mentioned.	It depends on the situation. Arbitrariness.

Next, the example of the bore arrangement to the object bridges is shown in Table 5.1.12.

Table 5.1.12 Classification Item of Boring Exploration (Bridge)

Class	Characteristics	Quantity of Boring
Type- α	The stratum composition of the point in the bridge: from the distribution of plane geographical features, the crossing geographical features, and the open rock of the river when average geological features and thickness, etc. are appreciable by the bore one place. Especially, when the plain part and the length of bridge were short etc, it applied.	BH=1
Type- β	The change is forecast from the above-mentioned to the fluvial landscape and the stratum composition, and when average geological features and thickness, etc. are appreciable by the bore in two places or more.	BH≧2

The concrete example of the bore arrangement to the object slope is occupied as follows.

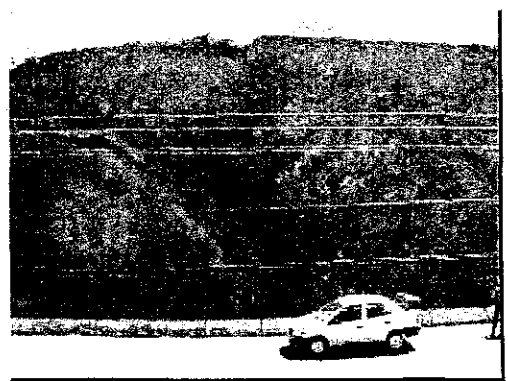
Example of Type-A	Serial-No.8 (ID- No.001B230) Because the composition of the face of slope is large the range where simplicity and the visual investigation can be done, and is also same weathering condition; Especially, the face of slope is not bored. To examine the slope failure, which includes the road, the toe of slope or the road shoulder executes one-place bore.	
Example of Type-B	Serial-No.32 (ID- No.003C150) It is in geographical features of the slope and there are weathering of tuffs, which influence easily and an argillation in a slope movement. And, there is small-scale movement (The flat terrain forms to the leg of the cliff like the belt) in the slope. And, the difference has been generated in the shoulder. The change in the geological features composition is understood by executing the bore in two or more.	
Example of Type-C	Serial-No.35 (ID- No.005A010) Example of inclusion of face of slope collapse shown in Nic-5 of seepage water of stratum composition and lava plateau on back slope and influence on stability of the entire face of slope. Because height the face of slope and width require the examination of stability including the entire road long, plural bores are executed by arrangement to be able to do an overall evaluation.	
Example of Type-D	Serial-No.22 (ID- No.001A010) There is no vegetation and it is a bedrock situation of the entire face of slope and the rock eyes are composed on the mass of agglomerate because of the andesite lava flow of the receiving board. The evaluation of the degree of weathering and stability is possible cases in watching enough.	

Figure 5.1.6 Example for the Classification Item of Boring Exploration (Slope)

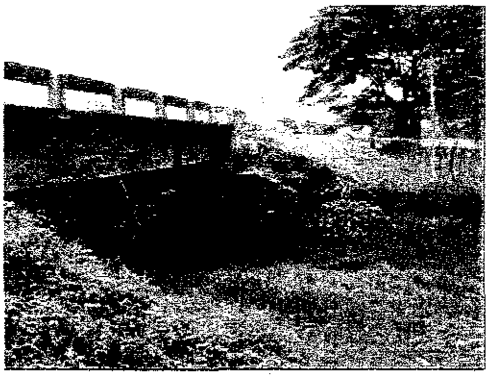
Type- α	Serial-No.4 (ID- San Ramón) It is a bridge in the comparatively short length of bridge laid on geographical features in which the change does not exist in the plain part. As for the stratum composition, a big change need not be assumed in both banks, and a geological features composition and thickness, etc. boring singular average are appreciable.	
Type- β	Serial-No.45 (ID- La Banderita) The bridge exists in sag vertical alignment in the valley of the mountainous area. There is a possibility that there is a change in the stratum composition in the right side shore and left bank in the river. It executes two or more bores and the geological features composition and thickness, etc. are evaluated by doing.	

Figure 5.1.7 Example for the Classification Item of Boring Exploration (Bridge)

Moreover, a technical viewpoint is important, and the safety side of the worker and carrying of the machine is considered enough in the location.

The arrangement of the boring exploration was set as following Table 5.1.13 as a result of such an examination.

Table 5.1.13 Arrangement of Boring Exploration

Route No. Nic.1

Sireal Number of Disaster Critical spots	ID.No	Kilometer from Managua (km)	Type of Boring
1	N001A290	60.9	A
2	N001A280	73.2	C
3	Junquillal	113.19	α
4	San Nicolas	135.64	α
5	Las Chanillas (R.Esteli)	150.33	β
6	San Ramón	151.85	β
7	N001A240	168.4	A
8	N001B230	168.6	A
9	N001B200	169.8	D
10	N001B190	170.7	D
11	N001B170	171.3	A
12	N001B150	175.0	A
13	N001B120	176.2	A
14	N001A110	178.7	A
15	N001B100	187.3	D
16	N001B070	204.7	A
17	N001A050	214.7	A
18	Río Inali	226.89	β
19	RíoTapacali	233.245	β
20	N001B030	232.5	D
21	N001A020	233.7	D
22	N001A010	235.6	D

Route No. Nic..3

Sireal Number of Disaster Critical spots	ID.No	Distance from Sebaco(km) (*Bridge: from Managua)	Type of Boring
23	003B420	3.9	A
24	003B400	6.9	B
25	003B370	7.4	A
26	El Guayacan	119.05	α
27	N003B320	22.1	A
28	N003B240	32.7	A
29	N003C230	32.9	B
30	N003E170	35.2	C
31	N003C160	35.9	B
32	N003C150	38.9	B
33	N003C140	39.4	B
34	N003B120	40	A

Route No. NIC.5

Sireal Number of Disaster Critical spots	ID.No	Distance from Matagalupa (km)	Type of disaster
35	N005A010	24.6	C

Route No. Nic.15

Sireal Number of Disaster Critical spots	ID.No	Distance from Las Manos (km)	Type of Boring
36	N015E010	9.9	C
37	N015E020	11.1	C
38	N015E050	11.7	A
39	N015E060	13.6	A

Route No. Nic.26

Sireal Number of Disaster Critical spots	ID.No	Distance from I.C. between San Ishidoro & Sebaco (km) (*Bridge:from Managua)	Type of Boring
40	N026A010	9.0	D
41	N026A020	12.7	D
42	N026A030	19.9	D
43	N026A040	20.9	D
44	N026A060	24.7	A
45	La Banderita	170+952	β
46	N026A100	29.3	A
47	N026B110	29.8	D
48	N026A130	33.6	A
49	N026B140	34.0	A
50	N026A150	34.2	C
51	N026B160	37.0	A
52	San Juan de Dios	156+785	α
53	N026B210	45.5	A
54	Papaión	108+154	α
55	Solis	107+533	α

R.F. :Rock Falling
R.C. :Rock Collapsing
S.S. :Slop slide
D.F. :Debris Flow
Bridge :Scoring of fundation

2) Survey Result

The survey result of position mentioned above is shown in Table 5.1.14.

Table 5.1.14 The Survey Result

Route: Nic.1

Serial No.	Site situation	Survey result
1 N001A290	Composite bedrocks where welded tuff, tuff, and andesite lava flow constitute alternation of strata. Due to the stress relief, slitting is remarkable. But, because there is weak stratum in tuff, the evaluation of the rock faces and weathering condition of strata, which might be concerned with the whole settlement, is planned. One(1) borehole shall be selected.	According to the boring survey result, the layer from the surface around 1 meter contains hair-cracks and weathered strata. At the level deeper than 1-meter depth, the rock pieces are hard, but there are small cracks. Andesite might not be large-scale decay from the surface strata border, because it part consists of stratified lava flow. However, the cracks have become wider, and it has become rainy season, so the falling stones can't be avoided.
2 N001A280	Gentle slope where tuff is distributing. There is a Power-Transmission Tower on the upper slope. There are two (2) main scarps on this slope, and the range and depth of decay can be estimated from the condition of ground surface change. Several boreholes shall be planned in order to confirm the rock faces, weathering, and existence of weak stratum of tuff in the part deeper than the foot of slope, because confirmation of existence of deep sliding surface, which is concerned with settlement of whole slope, is demanded.	Some part of tuff on the face of slope has been hard weathered up to around 7 meters depth. The level deeper than 7 meters depth is breccia tuff and andesite. Even in the few rain, there is spring water, two main scarps was seen on the slope. The continues observation on the settlement of whole face of slope shall be necessary.
3 Junquillal	The length of bridge is short and the surrounding area is flat. The geological alteration in right and left banks seems to be little. One (1) borehole shall be enough to evaluate.	According to the boring survey result, the weathered belt, most of which has already changed into soil, exists up to 3 meters depth. There is a weathered andesite belt with many cracks at the level deeper than 3 meters depth. Some part of the andeste has changed into soil, but those altered andesite cannot affect the bearing capacity, exsititing size of the bridge.

Serial No.	Site situation	Survey result
4 San Nicolas	The length of bridge is short. The geological alteration in right and left banks seems to be little. One (1) borehole is enough to evaluate.	According to the boring survey result, the welded tuff, most of which has changed into soil, exists up to 3 meters depth. As for the levels deeper than 3 meters depth, the weathering is relatively few.
5 Las Chanillas	The length of bridge is long. The geological alteration in right and left banks seems to exist. Two (2) boreholes are enough to evaluate.	Both 2 boring survey result show that the alteration into soil has reached up to around 5 meters. However the levels deeper than 5 meters depth is a little bit stable, alteration into weathered soil can be seen along the cracks part.
6 San Ramon	It can be judged for condition of Tuff by visual investigation, which mainly distributes in the face of slope. One (1) borehole shall be required to confirm the extent of weathering.	According to the result of boring, tuff, which has become soil up to around 3-meter depth from the surface. Moreover, at the levels deeper than those altered tuff, weathering due to hair-cracks can be seen up to around 12 meters continuously. There is not serious as for N-value.
7 N001A240	As for the geological composition, the tuff and tuff breccia constitute the alteration of strata. Because the rocks are exposed on the face of slope, confirmation by visual observation can be taken on whole face. Only in order to study the stability toward the valley side, confirm the condition of bedrock deeper than the foot of slope. One (1) borehole shall be selected.	The boring survey result shows that tuff contains many hair-cracks up to 3 and 4 meters depth, and that infiltration of rainwater can't be avoided. The andesite can be seen become blocks of dozen cm size due to cracks, and the falling can't be avoided. Tuff under the road part contains many hair-cracks, and those hair-cracks form the water passage to the side surface of road fill and a bad influence for the road banking.
8 N001B230	The tuff and andesite lava flow constitute the alteration of strata. Because the rocks are exposed on the face of slope, confirmation by visual investigation can be taken on whole face. In order to study the stability toward the valley side, the condition of bedrock deeper than the foot of slope shall be confirmed.	According to the boring survey result, tendency of becoming soil can be seen up to around 2 meters depth, and the weathering reached up to around 4 meters. Weak stratum was not identified around the toe of slope to the valley. However, because there are cracks at the interval of 10 – 50 cm on the face of slope, removal of spall shall be required. In general, the weathering reached at least 2 meters depth for tuff

Serial No.	Site situation	Survey result
9 N001B200	Most of the face of slope consists from andesite, and outcrop appears on the whole area. Therefore, the extent of weathering and stability can be judged by the visual investigation.	Although the andesite on the face of slope contains many cracks and open to some extent, the strata are stable as a whole. No change is seen in comparison with the survey result of phase1.
10 N001B190	The tuff and andesite lava flow constitute the alteration of strata. Because the rocks are exposed on the face of slope, confirmation by visual investigation can be taken on whole face. In order to study the stability toward the valley side, the condition of bedrock deeper than the foot of slope shall be confirmed.	Although the exfoliation of face of slope and falling pieces of small rocks can be seen, there are not changes in comparison with the survey result of phase 1. However, because whole face of slope has structure of tuff breccia, the site can be weathered easily. Preventive measure for weathering shall be required.
11 N001B170	Because the white tuff, which is easily affected by weathering, is sandwiched by the hard andesite, overhang can be seen where tuff is exfoliated. In order to confirm the distribution of white tuff, one (1) borehole deeper than the foot of slope shall be selected.	According to the boring survey result, the tendency of becoming soil can be seen up to about 4 meters depth. The firm part is ensured to be around 10 meters depth. The formative condition is bad on the face of slope.
12 N001B150	The self-crashing andesite became breccia, the decay near the foot of slope especially reached an advanced stage. Because the rocks are exposed on the face of slope, in order to confirm the condition of bedrock deeper than the foot of slope, one (1) borehole shall be selected.	The boring survey result shows that hair-cracks are formed up to 2 meters depth. The levels deeper than 2 meters consist of andesite and tuff breccia, and there are no matters. However, the danger of spalls on the overhang part of top of slope is prominent, and early re-cutting shall be required.
13 N001B120	Although the andesite, which appears from the top to the middle of the slope, is hard rock, the weathering and exfoliation of tuff class below them reached an advanced stage. One (1) borehole shall be set to confirm this condition of weathering.	According to the boring survey result, there is no extreme alteration into soil, hair-cracks can be seen to be formed up to 6 meters depth. Not only exfoliation but also wedge-shaped falling down are observed, and, together with the height of face of slope, dangerous falling stones happen often.

Serial No.	Site situation	Survey result
14 N001A110	There is a thin andesite flow lava stratum, whose width is about 0.8 meter, is sandwiched between two tuff strata. The weathering of tuff reached an advanced stage, and exfoliation is remarkable. Especially in order to understand the face of rocks of the middle or lower face of slope, one (1) borehole shall be selected.	According to the boring survey result, andesite is stable as the part of outcrop. So it seems to be no serious, if the spalls are dealt with appropriately. However, although not continuously, the cracks seem to exist up to more than 10 meters depth, and early preventative construction measure for falling stone shall be necessary.
15 N001B100	The black shist is distributed on the steep part of the face of slope. The same rock faces exist continuously in the foot of slope and deeper. So, no borehole shall be required.	Although can be seen the exfoliation of black schist pieces class to some extent on the face of slope, it's no problem with the stability of whole face of slope. However, because the overhang will be generated as the weathering of tuff proceeds, the maintenance of the face of slope shall be necessary
16 N001B070	The andesite and tuff constitute the alteration of strata. The weathering reached an advanced stage, and the exfoliation and losses of rock pieces are remarkable. In order to confirm the depth of weathering of strata and look of strata in the foot of slope, one (1) borehole shall be selected.	According to the boring survey result, the topsoil exist 0.7 – 0.8m depth, and at 2 – 3meters depth is changed into soil. Due to this, the erosion has occurred on the face of slope. There are andesit and tuff class at the levels deeper than those soil, and cracks are remarkable up to 6 - 7 meters depth. So the early preventative measures for falling stones are required.
17 N001A050	The tuff has changed into green color. The extent of weathering, physical characteristics, and strength characteristics are unknown. Although the face of slope is long, same stratum exists continuously. One (1) borehole shall be enough to be done.	According to the boring result, altered tuff has been weathered up to near 7 meters depth, and the weathered degree can be judged large. Under the present condition, the slope is very steep, so the preventative measure for weathering and examination of angle of face of slope shall be required.
18 Rio Inali	The length of bridge is long, and the geological alteration can be assumed. Two (2) boreholes shall be required to evaluate.	According to the boring survey result, although the weathered belt, in which cracks exists at interval of 5 cm on the left bank side, continues up to near 7 meters depth, the foundation sticks closely to the andesite part. So it's not necessary to worry about the differential settlement.

Serial No.	Site situation	Survey result
19 Rio Tapacali	The length of bridge is long, and the geological alteration can be assumed. Two (2) Boring shall be enough to evaluate.	According to the boring survey result, tuff, which has become soil up to near 4 meters depth, exists. There are weathered rock including tuff and breccia tuff at the levels deeper than 4 meters depth.
20 N001B030	The geological composition (alternation of andesite strata and tuff strata) can be judged by visual investigation. The extent of weathering can be assumed by visual investigation on face of neighboring cut slope (Neighboring faces on same hill).	It is anticipated that the andesite on the face of slope becomes overhang as the weathering of tuff proceeds. But there is no special symptom.
21 N001A020	The tuff, which has changed into green, distributes widely, same as place around No. 17(N001A050). The survey could be omitted because it is a face of slope just after construction.	Geological features are tuffs of the same type to the No.17 (N001A050) at all. However, differently from it, because of the gentle cut of angle of slope, no serious progress and alteration of weathering can be observed.
22 N001A010	The andesite lava flow distributes on the agglomerate. There is vestiges of violent volcanic activities, but currently no more than exfoliation can be seen. No borehole shall be selected.	Small exfoliation is seen on the face of slope. Although the tendency to be mild seems to progress in comparison with former survey result, there is no big change.

Route: Nic.3

Serial No.	Site situation	Survey result
23 N003B420	Massive tuff became blocks because of cracks and fell down. For the purpose of comparison, and in order to understand the strength characteristics of fresh rocks, one (1) borehole shall be selected.	According to the boring survey result, massive tuff distributes surface of slope in this site, and it's no serious symptom for the weathering progress from the viewpoint of rock quality. In addition, there is no difference from the phase 1.
24 N003B400	This site consists of tuff (upper part) and volcanic clastic rocks. Because the weathered depth of both two layers seems to be deep, two (2) boreholes shall be selected.	According to the boring survey result, tuff has changed into soil up to 2 meters depth. The weathered belt, part of which has become soil along the hair-cracks, exists at the levels deeper than 2 meters depth. As a whole, hair-cracks seem to occur even inside, and weathering seems to reach an advanced stage.
25 N003B370	There are three (3) strata including andesite(upper part of face of slope), volcanic clastic rocks(lower part of face of slope), and tuff(near the foot of slope). The weathered belt of volcanic clastic rocks caused shallow decay of the face of slope. Because the weathering of tuff at the foot of slope reached an advanced stage, one (1) borehole shall be selected at the foot of slope.	According to the boring result, the toe part of slope face consists of weathered belt containing many cracks. Meanwhile the piece of rock is firm and stable and there is no decay at the deep level. However, whole slope face is observed to be loose. The modification of the angle of slope face and preventative measure for weathering shall be required.
26 El Guayacan	The length of bridge is short, and the geological alteration of right and left banks seems to be little. Evaluation shall be done by one (1) boring.	According to the boring result, topsoil exists up to 1-meter depth, and weathered rocks of tuff breccia exist at the level deeper than 1-meter depth. The later stratum is good in depth as well.
27 N003B320	The whole slope face consists of weathered tuff. The exposed slope face forms 4 – 5 meters weathered belt. Some part has turned into red-color due groundwater. In order to survey the degree of weathering, one (1) boring point shall be selected.	According to the boring result, tuff, which has been weathered to great extent, exists from ground surface up to sixteen (16) meters depth. Especially, the degree of weathering reaches a more advanced stage at the scoria stratum, which begins to appear at the level of 6 meters depth. On the slope face, because tuff has become soil to great extent, the weathering reaches an advanced stage. Because a building is under construction on the slope face, the danger might be increased by its drainage.

Serial No.	Site situation	Survey result
28 N003B240	The face of slope consists from breccia tuff changed in quality. As a part of study of stability measure for face of slope, in order to understand the extent of weathering in deep part, one (1) borehole shall be selected.	The result of boring survey shows that tuff, which has become clod, exists up to 1 meter depth, that tuff, which consists of firm rock pieces, exists at the deeper levels than 1 meter depth, and that there are advanced weathered part in several part of strata. Furthermore, due to alligator cracking, there is concern about the falling debris resulted from exfoliation and wedge-shaped shearing of rocks.
29 N003C230	The exfoliation of surface layer caused by the weathering of tuff class reached an advanced stage, the weathering seems to reach the deep part. In order to study the decay from the deep part, 3 boreholes shall be selected.	The boring result shows that tuff distributes on the surface ground, and that alteration into brown soil reached an advanced stage up to about 6 meters depth. Hair-cracks are formed at the levels deeper than 6 meters depth. It's possible of whole slope face to decay up to a certain level of depth.
30 N003E170	The current road was washed away by the flash flood from the stream and mudslide of slope of mountainside. In order to study the construction measure for the whole site, 5 boreholes shall be selected.	The boring result shows that the relatively firm andesite distributes on the foot part of slope face. However, the weathered belt is formed up to about 2 meters depth on the slope face at middle of the hill. So there is a risk that the slope could decay up to that level of depth. There is a talus cone of about 2 meters size on the foundation of structure, and weathered belt is formed up to 5 meters depth.
31 N003C160	The geographical change and decay are remarkable. In order to study the decay including the current road, 3 boreholes shall be selected.	The boring result shows that the strata around 2 boreholes turned into reddish-brown-color, became soil, and that "water passage" is formed. Tuff with weathering in an advanced stage exists at the level deeper than 7 – 8 meters depth. Around the other one borehole, weathered belt and rocks, which has become soil to some extent, at the levels of 2 – 10 meters depth. In conclusion, this can be said, tuff is weathered and become soil up to 10 meters depth, and contains water passage. The stability of whole slope face shall be required.

Serial No.	Site situation	Survey result
32 N003C150	The geographical change and decay are remarkable to some extent. In order to study the decay including the current road, 2 boreholes shall be selected.	As a result of boring, tuff are weathered and become soil to some extent at the fairly deep level. There is "water passage" at the level of 7 meters or deeper on this site, too. The road surface drainage and seepage water treatment in fill shall be required.
33 N003C140	A decay on the middle section of fill was caused by the penetrating water from mountain side. The decay is remarkable. In order to study the decay including the current road, 2 boreholes shall be selected.	The boring survey result shows that most of tuff has become soil and constitute weathered belt at the fairly deep level. The stability on the whole slope face shall be required.
34 N003B120	There is a face of steep slope consisted of black schist. And there is a dip slope on the schistosity face. The weathering and soundness of hard rocks shall be confirmed. one(1) borehole shall be selected.	The boring result shows that weathered black schist of rocks distribute on the lower part to same extent as on the slope face. There are many cracks. Almost of the schistosity forms are stable directions, but some part of face forms dip slope

Route: Nic.5

Serial No.	Site situation	Survey result
35 N005A010	The face of slope is large, and the width of talus corn is unknown. The border between the face suffering from weathering and bedrock shall be surveyed widely by several borings.	It falls more than Phase 1, and the collapse is generated. However, because there is a thickness layer of the tuff of shade brown near the toe of slope, and a massive, firm tuff is confirmed by the bore besides; It can be judged that the collapse progresses, the main body of the road is rolled, and there is no possibility to collapse. However, there is an old main scarp in 100m interior of the top of slope, and it to expand one by one if it leaves it as it is; It tries to cut, and measures of water discharge treatment etc. are indispensable. The scree was judged to be a tertiary period scree layer.

Route : Nic.15

Serial No.	Site situation	Survey result
36 N015E010	Because the current road crosses the stream which produces avalanche, in order to keep the angle of riverbed where road crosses less than three degrees, the construction countermeasures (dam) shall be studied. In order to confirm the thickness of deposit on the riverbed, weathering condition of bedrock, and so on, several borings shall be necessary. The boreholes shall be arranged in the vertical and horizontal directions.	Many small streams join Pipilis river near this site. So the comprehensive viewpoint shall be required. The boring survey shows that the width of deposit on the riverbed is averagely 2 meters, and that most constituent at the levels under riverbed is hard and small porphyrite. Decomposed granite is not identified.
37 N015E020	The deposit of decomposed granite soil. For the purpose of countermeasure (dam), in order to measure the width of deposit, and to confirm the weathering condition of bedrock, several boring shall be necessary. The boreholes shall be laid in the vertical and horizontal directions.	River terrace of 20 – 400 meters height is formed on the both riversides. Hard rocks including granite and porphyrite are exposed on some part of this terraced cliff. The boring survey made it clear that the width of deposited on current riverbed is around 2 meters, and that the every granite, which can form foundation, is brown and weathered one. Since the part of river terrace, at which the abut will be placed, consists of decomposed granite soil and weathered rocks, the length of bank can be long.
38 N015E050	The deposit of decomposed granite soil. The confirmation of the width of deposit is necessary. Evaluation shall be done by one (1) boring.	Landform characterized by decay of granite turned into spillway, and the decay prevails all over whole spillway. The boring survey result shows that the decomposed granite soil is weathered up to the deep level. The structure that needs foundation is unsuitable for the buffer zone.
39 N015E060	The deposit of decomposed granite soil. The confirmation of the width of deposit is necessary. Evaluation shall be done by one (1) boring.	The cutting of foot of mountain triggered repetition of shallow decay of slope face on side hill and falling stones, taking effect on whole steep slope now. The ground consists of decomposed granite soil, which is originated from weathered granite, and weathered massive rocks. This soil condition extends up to the depth. The boring result shows that hard granite rocks distribute at the level near 14 meters depth.

Route : Nic.26

Serial No.	Site situation	Survey result
40 N026A010	The weathering of volcanic clastic rock on the lower face of slope grows fast, and the blocks of tuff fell down. . It can be confirmed by visual inspection.	Generally, the weathering speed of volcanic clastic rocks is fast, and tuff on the upper part forms overhang. That block in toppling condition is required to be removed. Danger parts can be dealt with easily because they are apparent
41 N026A020	There is an exfoliation in the weathering part of andesite, and falling down of wedge-shaped rock piece. There is a buffer zone. It cane be confirmed by visual inspection.	Although there is an exfoliation of andesite, no change in weathering progress can be seen.
42 N026A030	The extent of weathering of gravel andesite can be confirmed by visual inspection.	No decay of whole slope face occurred. No change in weathering progress can be seen, although there is an exfoliation of tuff caused by weathering,
43 N026A040	The extent of weathering of andesite and gravel tuff can be confirmed enough by visual inspection.	There is no continuity among strata, and andesite and tuff seem to be isolated by fault. Although the exfoliation and falling stones can be identified, weathering progress is not changed
44 N026A060	The face of slope consists of composite of tuff and andesite. In order to confirm the extent of weathering, one (1) boring shall be selected.	According to the boring result, tuff which contains open cracks (through which water passes) in the surface or deeper, exists continuously up to about 9 meters depth. Because open cracks might take effect, there are many spall and falling stones on the current face of slope.
45 La Banderita	The site is located in the valley such as sag alignment. The geological alteration between the right and left banks seems to exist. Evaluation shall be done by two (2) boring.	The width of surface soil is 40 – 50 cm. The weathered belt of tuff exists up to 4 meters depth. The strata, which deeper than it is supposed of hard rocks. As a result, there were almost no differences between the two boring survey results of both banks and it is adopted as bridge foundation without problem. Some measure shall is needed to be taken to that part, because the front of footing crops out.

Serial No.	Site situation	Survey result
46 N026A100	The geological constitution (composite of tuff, andesite, and volcanic clastic rocks) can be confirmed by visual observation. But the confirmation of weathering degree shall be necessary. One (1) borehole shall be selected.	According to the boring survey result, agglomerate with open cracks exists from 0 to 4 meters depth. Agglomerate, which exists from 4 meters to 8 meters depth is composed, even though it has close cracks. As for the 8 meters of deeper, strata was gathered together firmly. Because the weathering of surface reached an advanced stage and there are many exfoliations and falling stones on the current faced of slope, prevention measure for falling stones shall be necessary.
47 N026B110	The extent of weathering of andesite can be confirmed by visual observation.	At this location, there is no continuity among the strata of both andesite and tuff, and this site is isolated. It seems by reason of fault from the circumstance. Although there is exfoliation, it is no difference in weathering progress from the phase 1.
48 N026A130	The tuff which distributes mainly on the face of slope can be confirmed by visual survey, in order to confirm the extent of weathering, one (1) borehole shall be selected.	According to the boring result, the width of topsoil is 40 cm, and there is a weathered tuff belt with hair-cracks from the depth deeper than surface up to around 2 meters. Although, in the level deeper than 2 meters, the number of cracks is increasing, tuff is good condition. Under the present circumstance, the rainy water inflowing from the top of slope generates the gully, and the exfoliations are being repeated. The measure to drainage on the top of slope shall be necessary.
49 N026B140	There is a structural altered belt, whose length is about 30 meter, and which is affected by the fault and the associating volcanic alteration, on the tuff, which distributes mainly on the face of slope. The huge rock, which changed into block, fell down. Because the detailed survey is demanded, one (1) borehole shall be considered for the time being.	According to the boring result, the granulation by hair-cracks reached up to 8 meters depth for the leg of slopes. Under the present conditions, the falling large stones and decoy of altered belt continue with current road involved. This site is in dangerous situation.

Serial No.	Site situation	Survey result
50 N026A150	The face of slope constitute composite of tuff and andesite, and was decolorized by the volcanic gas. There was a case that caused large-scale decay before, and the geology is complicated. The depth of weathering shall be evaluated by several boring.	Because the altered degree by the volcanic gas on the face of slope is weak, there is no more than falling stones under the present conditions. However, because the weathering reached up to around 8 meters depth on some boreholes, the risk on this is so serious that decay from the part of water passage on the halfway of slope can be caused by the penetration of rainy water. Measure is not only to face of slope but also to whole slope shall be required.
51 N026B160	The geological constitution (composite of tuff, andesite, and volcanic clastic rocks) can be confirmed by visual observation. But the confirmation of weathering degree shall be necessary. One (1) borehole shall be selected.	According to the boring survey result, the weathering reached up to about 3 meters depth. The bedrocks deeper than 3 meters is sound. However, this site is still dangerous because the spall fall down on the sidewalk.
52 San Juan de Dios	The bridge length is short, and the circumstance is flatland. The geological alteration seems to be little, and One (1) borehole shall be enough to evaluate.	According to the boring result, the andesite bedrocks exist at the level deeper than topsoil. Although there are many cracks, there in no problematic factor related to the bearing capacity.
53 N026B210	The andesite lava flow with many open cracks distributes on the tuff. A part of the cracks forms the dip slope, and toppling. One (1) borehole shall be selected in order to confirm the extent of weathering of tuff to base of andesite.	According to the boring survey result, the weathering reached up to 4.0 meters depth at the lower tuff. Leaving the tuff weathering cause of falling andesite stones which are located at the unstable position on the upper part of slope.
54 Papalon	The bridge length is short, and the circumstance is flatland. The geological alteration seems to be little, and evaluation shall be done by one (1) boring.	According to the boring survey result, the weathered belt, which has turned into soil, exists from the level deeper than surface soil up to 15 meters. There exists no hard bedrock at all. However, the N-value is fully satisfactory at the level of about 8 meters depth or deeper.
55 Solis	The bridge length is short, and the circumstance is flatland. The geological alteration seems to be little, and evaluation shall be done by one (1) boring.	According to the boring survey result, the weathered belt of tuff and andesite exists from the 4 - 15 meters depth under the topsoil even in the weathered belt. the N-value is fully satisfactory.

3) Factor for selection and evaluation measure

Although the geological evaluation was comprehensively conducted in the survey of phase 1, the evaluation in the survey of the current study shall be based on potentiality of risk, including the confirmation of the condition of progress of weathering and collapsing, and condition of weathering toward inner strata. As for the bridges, the evaluation is based on the impact, of the scouring condition and hydrological analysis result, on the bridges themselves. Following five (5) grades (In case with evaluation item that is not applicable, the indicator shall contain six (6) grades) indicated the result of evaluation.

a) Evaluation of the slopes

A: The weathering and collapsing reached a high advanced stage, and the emergency has increased. The potentiality of risk, including the advanced stage of weathering inside of the slopes, is high (10 points).

B Plus (B+): Approximately medium between A and B (8 points).

B: The weathering and collapsing reached a medium stage. The potentiality of risk, including the medium stage of weathering into inner part, is medium (6 points).

B Minor (B -): Approximately medium between B and C (4 points).

C: The weathering and collapsing didn't progress so much. The weathering didn't reach at inner part of the slope (2 points).

D: Totally decayed completely. Otherwise, countermeasure was totally accomplished. For that reason, this case is to be excluded from the evaluation (0 point).

b) Evaluation of the bridge foundation scouring

A: The scouring reached an advanced stage, and the emergency has been increased. There is a remarkable restriction for the flow velocity and flow volume, including narrow cross section of streamway, and the factor of scouring progress is very remarkable. (10 points)

B Plus (B+): Approximately medium between A and B (8 points).

B: The scouring reached a medium stage. There is a medium restriction for the flow velocity and flow volume on the bridge crossing part (6 points).

B Minor (B -): Approximately medium between B and C (4 points).

C: The scouring didn't progress so much. There is no restriction for the flow velocity and flow volume exists on the bridge crossing part (2 points).

D: The Bridge was totally fell down. Otherwise, countermeasure has been totally accomplished. For those reasons, this case is to be excluded from evaluation (0).

The survey mentioned above resulted as follows Table 5.1.15.

Table 5.1.15 Evaluation of the Natural Conditions Survey

Serial No.	ID No.	Evaluation	Point
1	N001A290	A	10
2	N001A280	A	10
3	Junquillal	B	6
4	San Nicolas	C	2
5	Las Chanillas	B	6
6	San Ramon	C	2
7	N001A240	B	6
8	N00B230	B+	8
9	N001B200	C	2
10	N001B190	B−	4
11	N001B170	B	6
12	N001B150	A	10
13	N001B120	A	10
14	N001A110	B+	8
15	N001B100	B−	4
16	N001B070	B+	8
17	N001A050	A	10
18	Rio Inali	B−	4
19	Rio Tapacali	C	2
20	N001B030	B	6
21	N001A020	C	2
22	N001A010	B−	4
23	003B420	C	2
24	003B400	B+	8
25	003B370	B+	8
26	El Guayacan	A	10
27	N003B320	B+	8
28	N003B240	B−	4
29	N003C230	A	10
30	N003E170	A	10
31	N003C160	A	10
32	N003C150	B+	8
33	N003C140	A	10
34	N003B120	B	6
35	N001A050	A	10
36	N015E010	A	10
37	N015E020	A	10
38	N015E050	B−	4
39	N015E060	B−	4
40	N026A010	B	6
41	N026A020	B	6
42	N026A030	C	2
43	N026A040	C	2
44	N026A060	A	10
45	La Banderita	C	2
46	N026A100	B	6
47	N026B110	C	2
48	N026A130	B	6
49	N026B140	A	10
50	N026A150	A	10
51	N026B160	A	10
52	San Juan de Dios	B−	4
53	N026B210	B	6
54	Papalón	C	2
55	Solís	C	2

5.2 Socio-economic Framework

5.2.1 Review of Improvement/ Development Plan

1) Economy

a) Reference

During from 1960 to 1977 Nicaragua increased Gross Domestic Product (GDP) three times. In 1977 GDP was at its highest, at US$2,934.3 million, with a pr capital income of U$1,169.8. Exports registered US$941.6 million. The fiscal deficit was only 9.8% of GDP, and the payment balance of the current account was 8.1% of GDP, and external Debt was almost 39.0% of GDP.

During the 1980's, the economy of Nicaragua registered the most drastic deterioration in the history. The inflation value in 1988 was 33.0 % and the lowest GDP was registered in 1991 at 62.0% of the GDP value of 1977. Exports and per capital income were 40% of the 1977 value.

The fiscal deficit of the non-financial public sector was 20.3% of GDP. The deficit of the current account of the payment balance increased up to 59.4% in 1992, and the losses of the state financial system increased up to 48% of the GDP. State banks were technically bankrupt at that time.

b) Building the bases for commerce economy

Since 1990, Nicaragua started to fight hyperinflation and to build the bases for the economic development of the country. In order to implement a stability program and structural adjustments, the country embarked on economic increase policies and inflation control, and on important flows of external sources expressed by the support of international community.

Fiscal monetary restorations were implemented to stop the money change run, and to control immediately inflation. The role of the state was reduced, and privatization and financial reforms were implemented to reduce state bureaucracy and to reinforce private sector.

c) Monetary reform and adjustment of the financial system

In February 1991 monetary reform included the change in the value of the currency. The government introduced a golden Cordoba, C$1.0 golden Cordoba = US$1.0 and C$5.0 million of old Cordoba, and a macro devaluation of 400%. Public sector wages were frozen to reduce demand and lower prices.

The reform included strengthening financial markets through liberalization of interest values, reduction and unification of the legal system and severing government interference in credit policy of Central Bank. These reforms support the refinancing of private banks and reduce the role of the state bank in the management of the financial resources.

All these changes were intended to create conditions for a strong economy with price stability. In 1998 total deposits in private banks was 61.0% of GDP, and the deposits in foreign money represented 41.8% of GDP.

5.2.2 Improvement/ Development Potential in Plan

1) Background Data and Forecasts

Figure 5.2.1 shows the growth in population of Nicaragua over the period 1980 to 2002. During this period population grew by 87%, at an average annual growth rate of 2.9%.

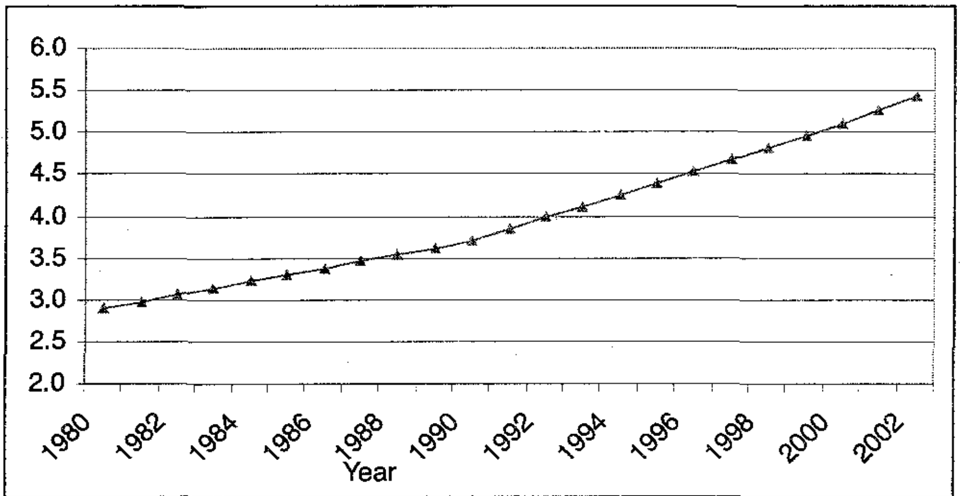


Figure 5.2.1 Nicaragua Population, 1980 to 2002, Millions

The age structure of the population is extremely skewed towards the younger age-groups. As a consequence, population growth in the future is expected to be much higher than in the past. Figure 5.2.2 shows forecast population growth to the year 2020. Growth between 2002 and 2020 is estimated to be 78%, at an annual rate of 3.25%.

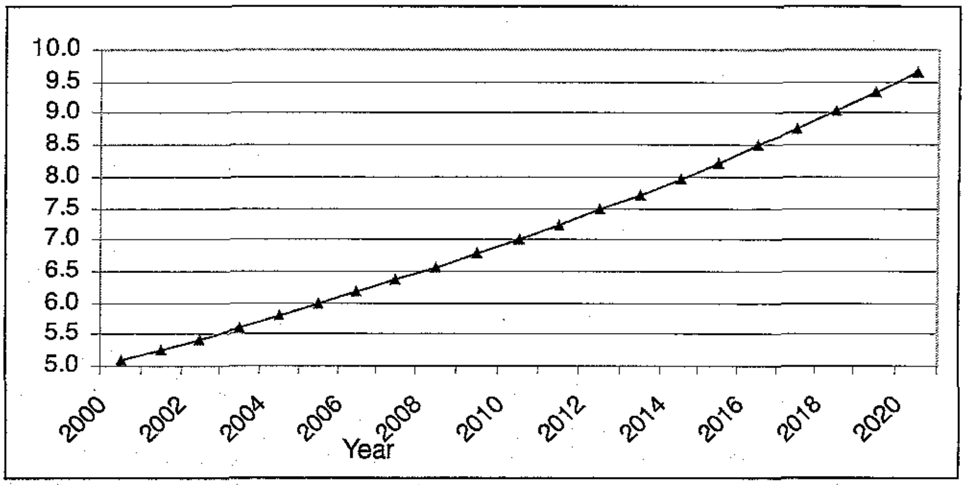


Figure 5.2.2 Forecast Population of Nicaragua to 2020, Millions

Table 5.2.1 shows the quinquennial sector contributions to GDP forecast for the period 2000 to 2020. It shows the importance of agriculture to the national economy and reveals that this is forecast to grow from 27.1% in 2000, to 29.0% in 2020. The total economy is forecast to grow by 6.5% per year between 2000 and 2005, by 6.0% per year between 2005 and 2010, by 5.5% annually between 2010 and 2015 and by 5% per year between 2015 and 2020. Figure 5.2.3 shows the annual growth rates by sector and emphasises the high growth rates of the agricultural, construction, industrial and service sectors.

Table 5.2.1 GDP Forecasts by Sector, Nicaragua, 2000 to 2020, US$ Millions

	2000	2005	2010	2015	2020
Agriculture	681.9	951.5	1301	1718.4	2231.6
Other primary	55.3	62	69.2	84.4	92.4
Industry	503.2	706.7	955	1254.1	1608.3
Construction	130.8	179.3	244.5	331.6	432.2
Other Secondary	42.8	51.7	59.9	72.4	68
Services	1102.2	1496.2	1983.9	2568.6	3262.8
Total	2516.2	3447.4	4613.5	6029.5	7695.3

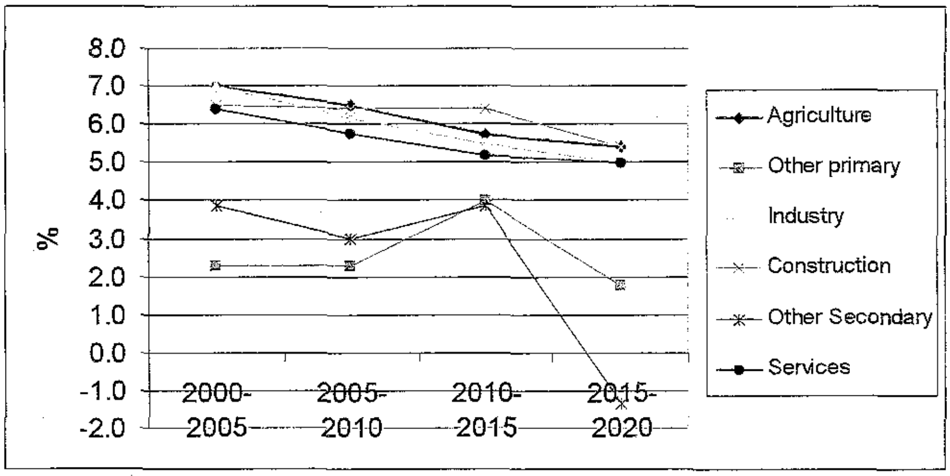


Figure 5.2.3 Annual Growth Rates by Sector of the Economy, 2000 to 2020

Figure 5.2.4 shows GDP per head for the period 1980 to 2000 and forecast from 2000 to 2020. Average GDP per head fell drastically from the mid-1980's over a 15-year period, leading to one of the lowest in the western hemisphere. From 1998 GDP per head began to grow again, and it is now forecast that it will rise by 2.3% per annum until 2020.

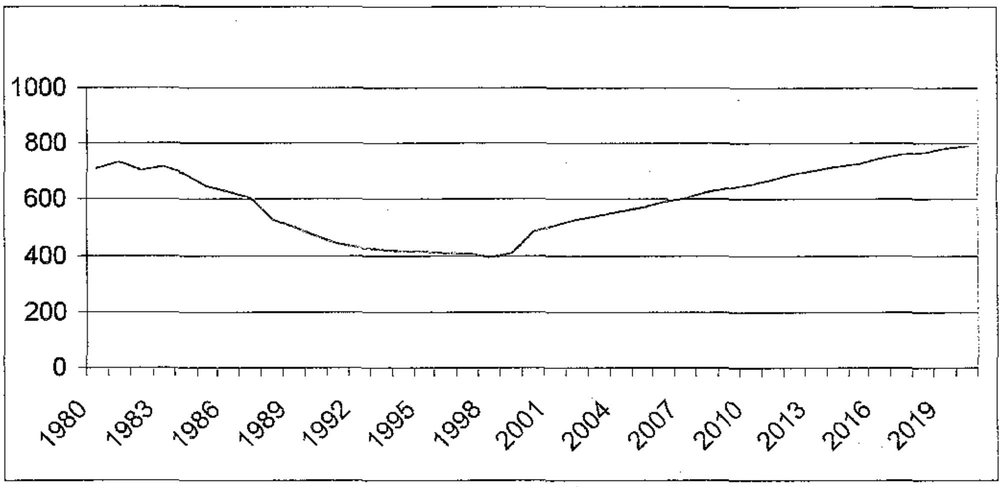


Figure 5.2.4 Average GDP per head (US$), Nicaragua, 1980 to 2020