5.3 EXISTING CONDITIONS OF ROAD DISASTERS

A total of 123 potential disaster spots, 38 in Section M-10 (Lucena-Calauag Section in Region IV-A), 41 in Section M-16 (Allen-Calbayog Section in Region VIII) and 44 in Section B-3 (Naguilian Road in Region I) were identified.

Table 5.3-1 gives the number of disaster spots by Section, type of disaster and degree of disaster potential. Summary information and locations of spots are presented in Appendix 5.3-1.

The following observaton can be concluded from Table 5.3-1, Figures 3.2-2, 3.3-2 and 3.4-2, and Figures 5.3-1, 2 and 3.

5.3.1 Lucena-Calauag Section, M-10 along Maharlika Highway

The section with a length of approximately 95.72 kilometers lies between Lucena (km. 136 + 407) and Calauag (km. 232 + 130) or from the southern end of the Sierra Madre Range to the Bondoc Peninsula.

Since the opening of the Pagbilao—Atimonan Sub-section in 1979, substantial damages on the section were attributed not only to pavement deteriorations but failures of cut and embankment slopes and falls of severely weathered limestones resulting in interrupted traffic for quite sometime. The average number of traffic interruption is reported to be about 8 days a year.

The topography of this section is generally flat with the exception of rolling or mountainous terrain from Pagbilao to Atimonan. The geologic formation is of sandstone and limestone and occasionally andesite and mudstone. These bedrocks, especially limestone are severely weathered and feared to collapse in the future.

All of the 38 disaster spots identified in this section are located between Pagbilao (about km. 150) and the point just after Atimonan (about km. 180). The disaster spots density (the number of disaster spots per kilometer) in this sub-section is 1.27 spots per kilometer.

Moreover, of the 38 disaster spots, eight (8) spots were evaluated as disaster potential of Heavy (H) and Medium (M) requiring the urgent implementation of countermeasures and are concentrated within the old zigzag road section which extends only for about 9.6 kilometers. The disaster density of H and M in this particular sub-section is 0.83 spots per kilometer.

Of the 8 disaster spots of categories H and M, fall is dominant with 4 spots, followed by embankment slope failures with 2 spots and cut slope failure and landslide with 1 spot, respectively.

TABLE 5.3-1 SUMMARY OF DISASTER SPOTS BY TYPE OF DISASTER, DISASTER POTENTIAL AND REGION

Road	Region	Section	Disaster Potential	C-S.F, D.F	E-S.F, D.F	C-F	L.S	D.F	Others	T o t a l
Maharlika Highway	IV-A	M - 10	H	1	-	2	-	-	-	3
			M	-	2	2	1	-	-	5
			S	16	4	10	-	-	-	30
			Total	17	6	14	1	-	-	38
	VIII	M - 16	H	-	2	2	-	-	-	4
			M	1	3	7	-	2	-	13
			S	3	2	19	-	-	-	24
			Total	4	7	28	-	2	-	41
	Total	M - 10 M - 16	H	1	2	4	-	-	-	7
			M	1	5	9	1	2	-	18
			S	19	6	29	-	-	-	54
			Total	21	13	42	1	2	-	79
Naguilian	IN	B - 3	H	2	-	1	-	-	-	3
			M	3	8	4	-	-	-	15
			S	13	6	7	-	-	-	26
			Total	18	14	12	-	-	-	44
Grand Total			H	3	2	5	-	-	-	10
			M	4	13	13	1	2	-	33
			S	32	12	36	-	-	-	80
			Grand Total	39	27	54	1	2	-	123

Type of Disaster

(1) Cut Slope Failure
C - S.F = Surface Failure
C - D.F = Deep Failure

(2) Embankment Slope Failure
E - S.F = Surface Failure
E - D.F = Deep Failure

(3) Fall
C - F

(4) Landslide
L.S

(5) Debris Flow
D.F

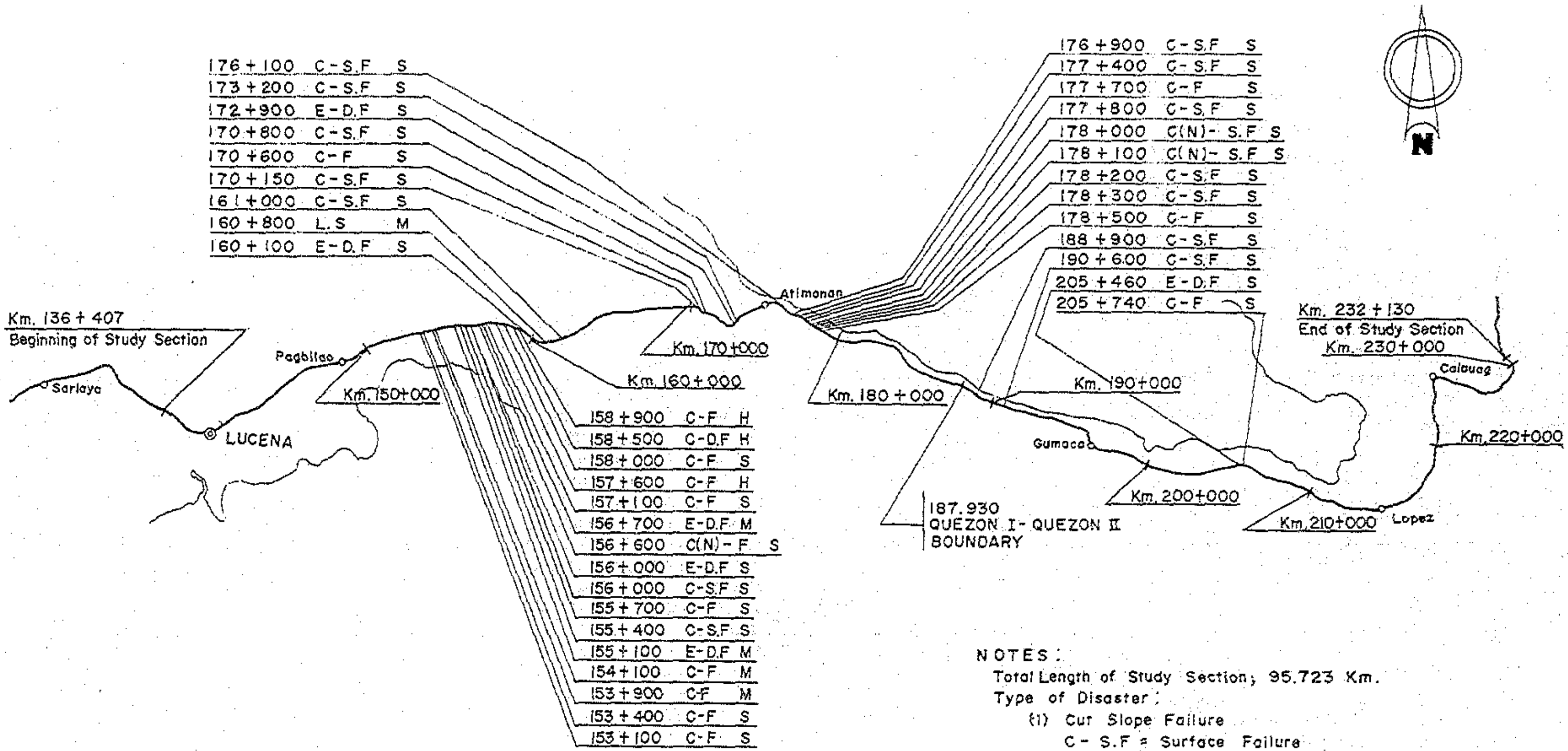
(6) Others

Disaster Potential

H ; Heavy
M ; Medium
S ; Light

Note:

Figure show number of spots.



NOTES :
Total Length of Study Section; 95.723 Km.
Type of Disaster ;
(1) Cut Slope Failure
C - S.F = Surface Failure
E - D.F = Deep Failure
(2) Embankment Slope Failure
E - S.F = Surface Failure
E - D.F = Deep Failure
(3) Fall
C - F
(4) Landslide
L - S
(5) Debris Flow
D - F

FIGURE 5.3-1 LOCATION MAP OF DISASTER SPOTS
LUCENA-CALAUAG SECTION (M-10)

Occurrence of a large number of falls is mainly due to severely weathered limestone with developed cracks. The sizes of fallen rocks are 1.5 to 2.5 meters. These failures are feared to occur in the future.

Embankment slope failures were mainly caused by scouring due to the concentration of road surface water, particularly at inner curves of roads with steep vertical gradients. Side ditches are recommended to be adequately constructed.

5.3-2 Allen-Calbayog Section, M-16 along Maharlika Highway

The section extends for approximately 72.94 kilometers from Allen (km. 663 + 814) in Northern Samar to Calbayog City (km. 736 + 750) in Western Samar.

After the improvement of the section in 1978, the section has been exposed to danger of rock falls and closed to traffic for an average of 9 days a year after heavy rains and typhoons. The majority of slopes seem to be still in unstable condition.

This section can be divided into the moderately hilly segment that passes through the foot of Samar's central range and the flat coastal terrace segment passing along the coast. The geology is of sandstone, shale, andesite, and limestone with folds and faults. These rocks have many developed cracks and are highly weathered. The sandstone is prone to fall in large pieces.

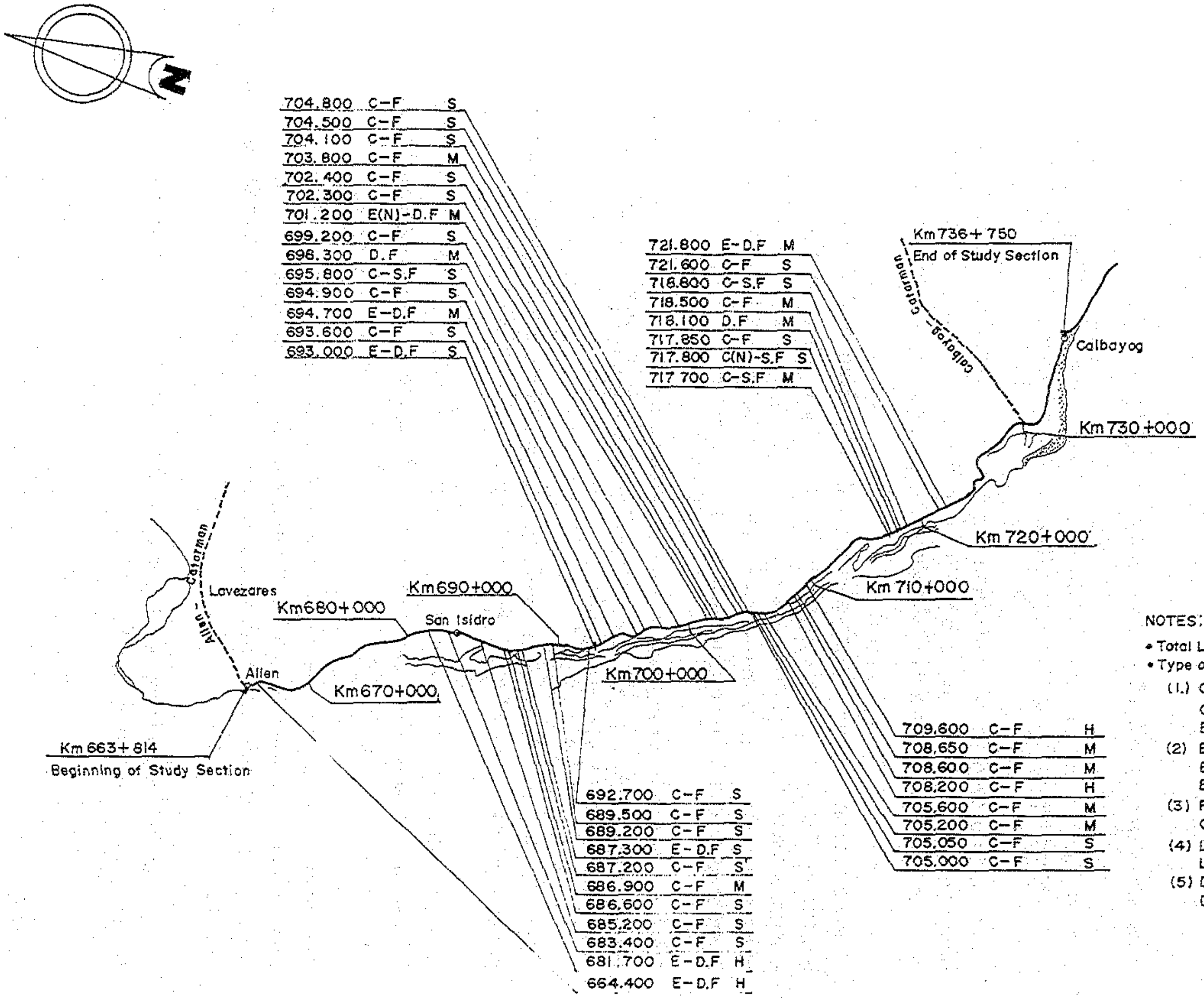
The disaster spots counting 41 in the total are almost equally scattered between San Isidro (km. 686 + 500) and Tinambacan (km. 723 + 300) with the disaster spot density of 1.11 spots per kilometer.

Of the 41 spots identified, a total number of 17 spots were evaluated as disaster potential of Heavy and Medium which are subject to the study.

By type of disaster among H and M, fall is the greatest in number with 9 spots, followed by embankment slope failure, debris flow and cut slope failure with 5, 2 and 1 spots, respectively.

The majority of fall occurred on cut slopes of highly weathered sandstones with developed cracks. Most of fallen rocks are 30 to 50 centimeters in size but occasionally over 3 meters. These falls may continue if no countermeasures are adopted.

Almost all embankment slope failures were observed along the coastline, caused by scouring due to waves and flood water.



NOTES:

- Total Length of Study Section; 72.936 Km
- Type of Disaster:
  - (1.) Cut Slope Failure
    - C-S.F = Surface Failure
    - E-D.F = Deep Failure
  - (2) Embankment Slope Failure
    - E-S.F = Surface Failure
    - E-D.F = Deep Failure
  - (3) Fall
    - C-F
  - (4) Landslide
    - L-S
  - (5) Debris Flow
    - D-F

FIGURE 5.3-2 LOCATION MAP OF DISASTER SPOTS ALLEN-CALBAYOG SECTION (M-16)

5.3.3 Nagulilan Road

The road extends for about 47.2 kilometers from Bauang along the Manila North Road (km. 259 + 220) to Baguio (km 306 + 445).

Disasters along this road must have occurred many times during the last 64 years since its completion in 1919. Although no accurate records are available, it is predicted that disasters occurred at an average of two times a year causing traffic interruption for 4 days.

The road runs in rolling areas for about 17 kilometers from the town of Bauang, then proceeds towards Baguio City through steep mountainous terrain. The geology of this road is chiefly tuff, tuff brecciea, conglomerate, limestone and sandstone.

Of the total of 44 disaster spots recorded, there are only 4 disaster spots in the rolling area with a length of 17 kilometers, while 40 spots exist in the remaining mountainous section with approximately 30 kilometers. The disaster density is 0.24 in the former and 1.33 in the latter.

A number of disaster spots with the disaster potential of Heavy and Medium is 18, among which embankment failure is dominant accounting for 8 spots, followed by 5 spots for cut slope failure and fall, respectively.

In this road, embankment slope failures means the collapse of stone masonry applied to embankment slopes at valley side. These collapses were observed at the considerable number of spots and are feared to occur at other spots in the future.

Cut slope failures and falls were seen on slopes composed of hard rocks such as tuff, tuff brecciea and conglomerate. Since these are relatively hard with many open cracks, fall is likely to occur.

Shown in Figure 5.3-4 is the number of cut slope failures and fall with the disaster potentials of Heavy and Medium in relation to the kind of rocks. The numbers do not tally with the number of disaster spots because slope has more than two kinds of rock.

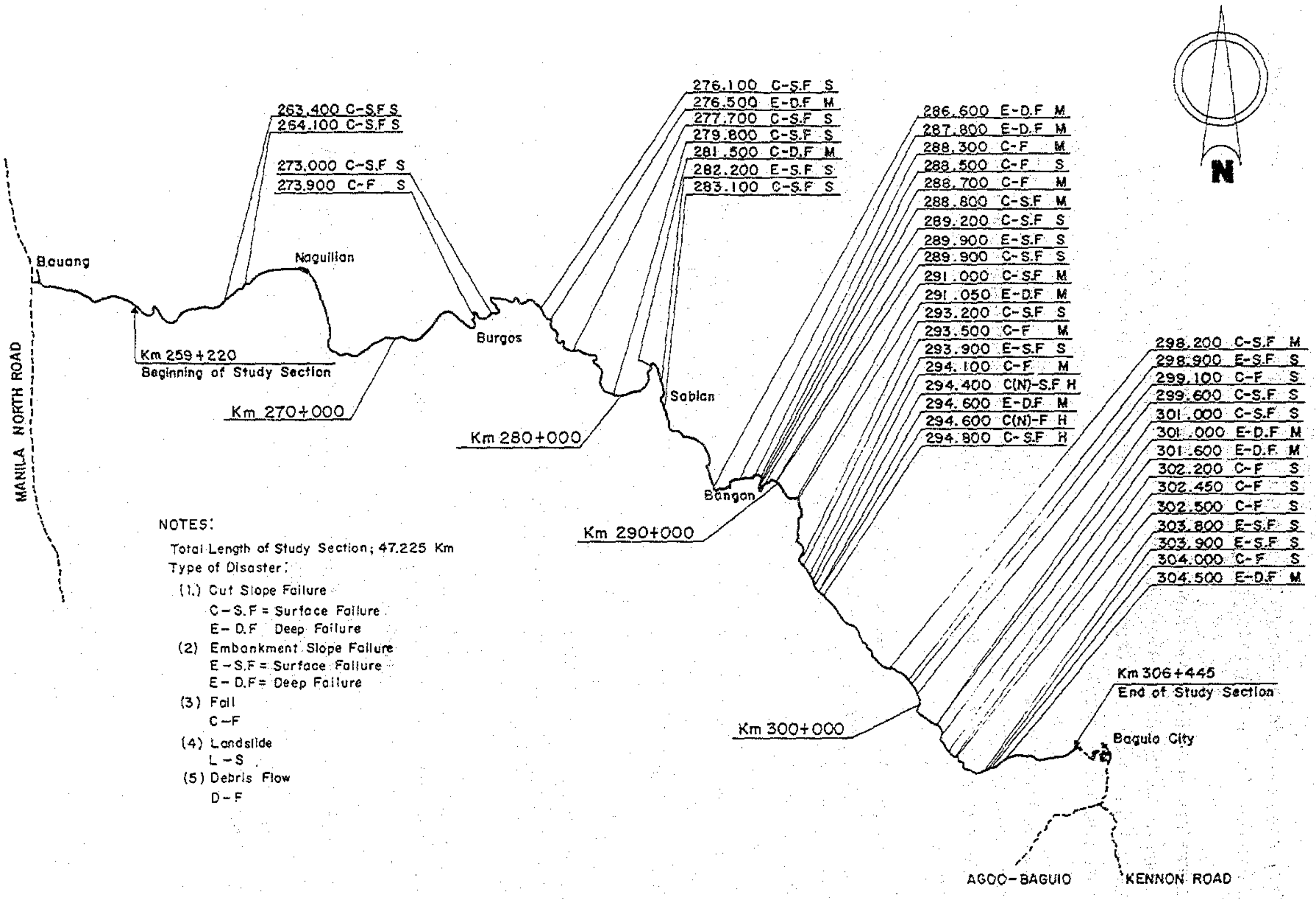


FIGURE 5.3-3 LOCATION MAP OF DISASTER SPOTS
NAGUILIAN ROAD (B-3)

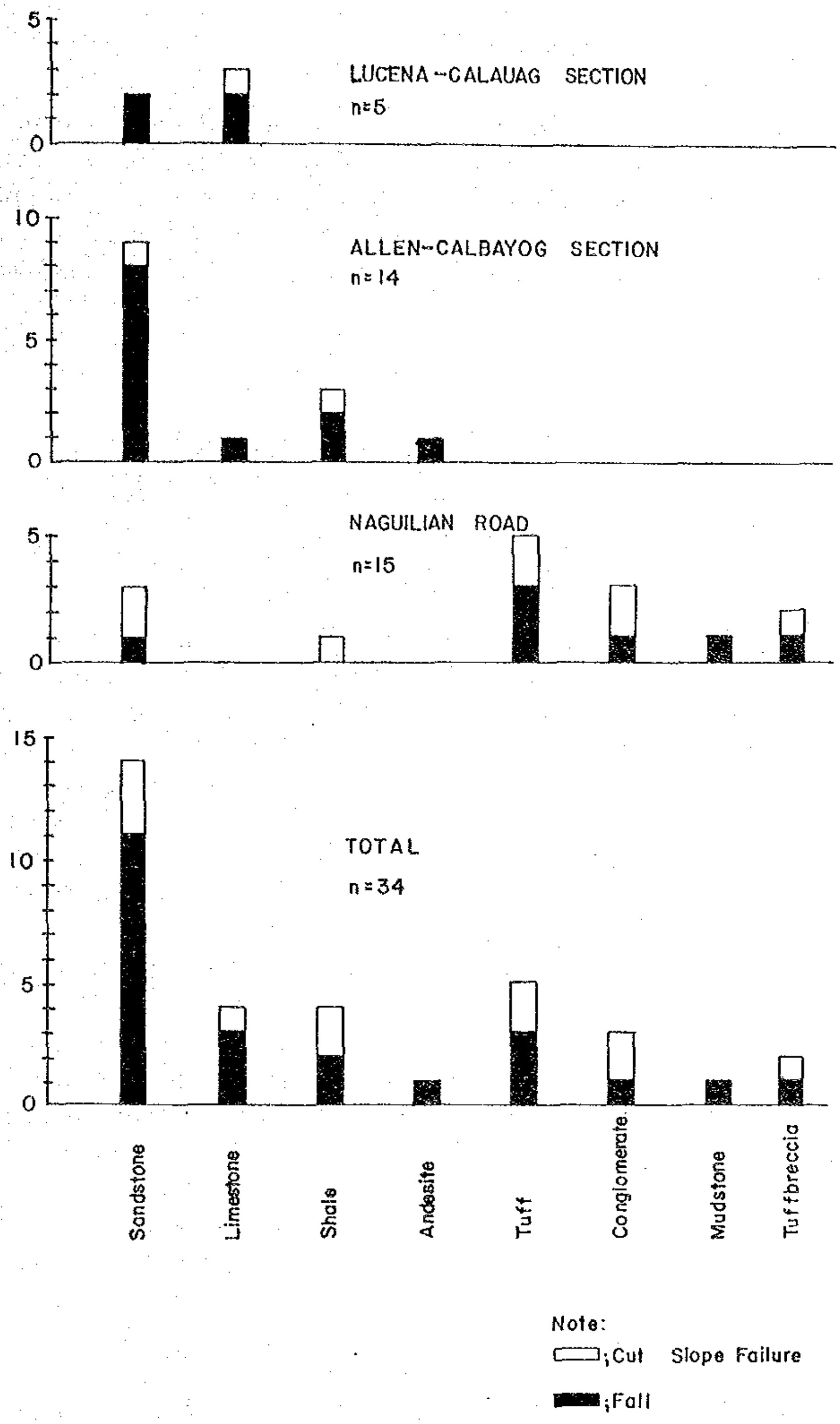


FIGURE 5.3-4 NUMBER OF CUT SLOPE FAILURES AND FALLS AND KINDS OF ROCKS

5.4 CAUSES OF ROAD DISASTER

From Table 5.3-1, it could be noted that the number of spots of falls, cut slope failures, and embankment slope failures is of large magnitude at 54, 39, and 27, respectively. They represent 44, 31 and 22 percent share of the total, respectively. The said three types of disaster account for about 97 percent of the total. Of the remaining types of disasters, there are 2 spots of debris flows and one of landslide.

1) Cut Slopes Failures

Cut slope failures were observed in all the mountainous sections of the three Study Sections, especially in the Lucena-Calauag Section (M-10) and the Naguilian Road inasmuch as these sections have many high cut slopes with the rocks highly weathered and fractured due to faults.

Cut slope failures were observed on slopes of soil and rock such as diabase, andesite, limestone, sandstone, mudstone, tuff, tuff breccia, conglomerate, etc. Nearly all of the cut slope failures observed were caused by the effect of water. Many were brought about by erosion or scouring resulting from the flow of surface water during rainfalls, and some by groundwater seepage. There is a large failure at km. 158 + 500, in the Lucena-Calauag Section and at km. 294 + 400, and km 294 + 800 along the Naguilian Road, where a slope of over 50 meters in height was drastically scoured by the flow of surface water and groundwater seepage.

It is measured that cut slope failures could not be prevented from recurrence because of the following deficiencies:

—*Drainage facilities are inadequate. None of the following have been provided:* top slope ditch which prevents surface water flowing into the slope, berm ditch which collects surface water on the slope, and vertical ditch which drains surface water collected in the above ditches.

—No berms are provided. Berms not only increase the stability of a slope, but they also decrease the speed of surface water flow, so that they are effective in preventing erosion and scouring.

—No appropriate slope protection is provided. There are some slopes which are covered naturally with vegetation, however, there are no slopes which are protected artificially.

2) Embankment Slope Failures

Embankment slope failures were mainly caused by scouring and were mainly observed at the following sites:

—At inner curves of roads with steep vertical gradients. Surface water on the road concentrates and flows down the embankment slope, causing erosion and scouring. Large-scale examples of this type of failure were seen at km. 155 + 100 and km. 156 + 700 in the Lucena-Calauag Section (M-10), and at km. 286 + 600 and km. 287 + 800 in the Naguilian Road.

—Sections along rivers and coastlines. Waves and flood water scoured embankment in such sections. Large-scale examples of this type of failure are seen at km. 664 + 400, km. 681 + 700 and km. 721 + 800 in the Allen-Calbayog Section.

It is thought that embankment slope failures could not be prevented, because of the following deficiencies:

—Insufficient number and capacity of side ditches and cross drainage facilities especially in mountain sections where surface water was often seen flowing down on the road surface as if it is a river, during field reconnaissance. This was caused by a lack of side ditches and cross drainage facilities which brings about the embankment slope failures.

—No slope protection or protection with unsatisfactory structure. There are slopes covered naturally with vegetation but very rarely protected artificially. At considerable number of spots, collapsed stone masonries applied to embankment slopes were seen. It is presumed that they may be insufficient to resist to the external forces such as earth pressure, force of river flow, etc.

3) Falls

As stated above, the most numerous type of disaster is fall. Falls are categorized into debris falls and rock falls, but all falls in the study sections are rock falls. Falls mainly occur in slopes composed of debris or diorite, andesite, sandstone, conglomerates, limestone, etc. Slopes of highly weathered or fractured rocks usually produce cut slope failures, while falls mainly occur on slopes of hard rock with developed open cracks or on slopes with alternations of different rock layers.

The Allen-Calbayog Section (M-16) has the greatest number of falls with 28 spots, followed by the Lucena-Calauag Section (M-10) with 14 and the Naguilian Road with 12. Large-scale examples of this type were seen at km. 157 + 600 and km. 158 + 900 in the Lucena-Calauag Section, at km. 708 + 200 and km. 709 + 600 in the Allen-Calbayog Section and at km. 293 + 500 along the Naguilian Road.

Most of the fallen rocks are 30 to 50 centimeters in size, but occasionally rocks over 3.0meters in size were seen on the Allen-Calbayog Section and the Lucena-Calauag Section.

Falls were caused by the same deficiencies in design or construction as described in cut slope failures.

4) Landslide

Landslides are classified into soil and rock landslide. Only soil landslide at one spot was seen in the Study Sections. The spot is located at km. 160 + 800 in the Lucena-Calauag Section (M-10). The landslide at this spot is a movement of a thick layer of soil covering the bedrock. Judging from the land form in which surface water easily concentrates, the landslide was caused due to the effect of the water.

5) Debris Flows

Debris flows are classified into debris flow and mud flow. A total number of two spots of debris flows was identified in the Study Sections and both are debris flow type. These were seen at km. 698 + 300 and km. 718 + 100 in the Allen-Calbayog Section.

The former, which is a medium scale of debris flow, is reported to have crushed houses across the road causing a few deaths, and the materials that flowed down covered about a length of 100 meters of the road. According to nearby residents, the flows have recurred every year. A large quantity of spring water was observed at the toe of the slope. Thus, the debris flow is speculated to have been caused by the high level of groundwater.

Debris flow at km. 718 + 100 was caused by torrents, due to non-existence of countermeasures such as cross drains, water ways, small scale sabo dam etc. Materials flow over the road surface every time it rains which interrupt traffic.

5.5 ROAD DISASTER AND RAINFALL

Rainfall is, in most cases, the primary inducer of road disasters among the various causes such as topographical, geological and vegetative conditions. If the interrelation between road disaster occurrence and rainfall intensity is developed based on the past disaster records, the probability of disaster occurrence will be predicted by estimating maximum rainfall intensify for a given period. This relationship can be used to inform road users of possible occurrence of disaster and possible temporary closure of a road to traffic necessary in preventing any accidents whenever rainfall reaches a critical level.

The Study Team's intention of finding out the critical level of rainfall which induces a certain type of disaster such as cut slope failure or rock fall, had to be given up due mainly to the lack of enough samples by type of disaster. Instead, the relationship between disaster (whatever they are) occurrence and rainfall was developed.

24-hour rainfalls of various tropical cyclones at weather stations nearest to the Study Sections is shown in Appendix 5.5-1.

Lucena-Calauag Section

Minimum rainfall height which caused road disaster was 66 millimeters, whereas, maximum rainfall height which did not cause any road disaster was 113 millimeters at the Lucena weather station. These rainfall heihts at the Daet weather station were 71 millimeters and 222 millimeters, respectively. The critical rainfall height which induces road disaster at this section appears to be 70 millimeters.

Allen-Calbayog Section

At the Catbalogan weather station, the minimum rainfall height caused road disasters was 88 millimeters and maximum rainfall which did not cause road disasters was 134 millimeters. These rainfall heights at the Catarman Weather Station were 72 millimeters and 215 millimeters, respectively. As the rainfall pattern of the section is judged to be more or less similar at the Catbalogan weather station than at the Catarman weather station, rainfall height of 90 millimeters appears to be the critical height at this section.

Naguilian Road

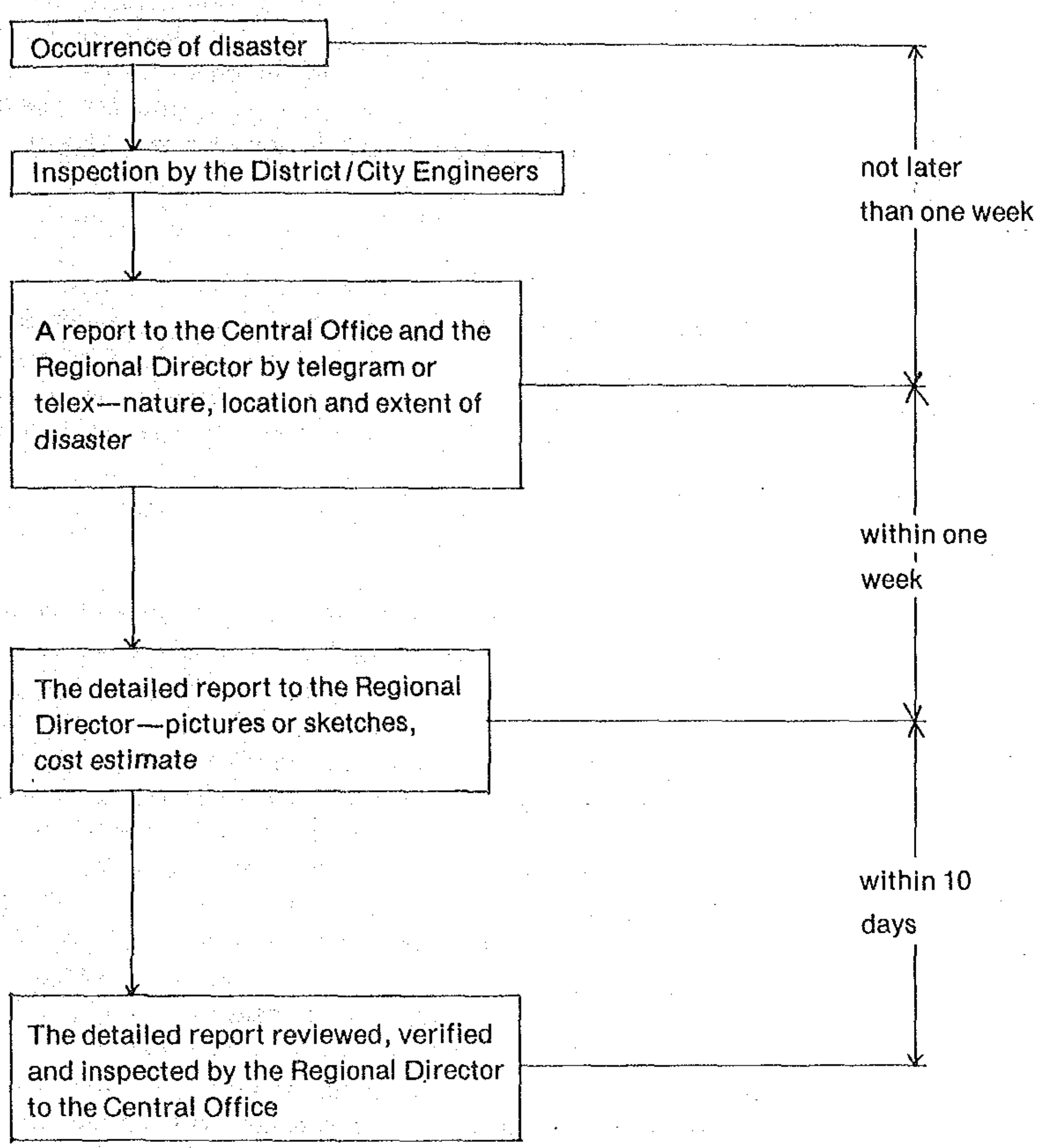
Minimum rainfall height which caused road disasters was 88 millimeters, whereas maximum rainfall height which did not cause any road disaster was 103 millimeters. The critical rainfall height at the Naguilian Road appears to be 90 millimeters.

The relationship between 24-hour rainfall and occurrence of road disaster mentioned above was developed based on a small number of samples available, therefore, accuracy can not be assured. To develop a more accurate relationship, disaster records as well as rainfall data should be compiled more comprehensively.

5.6 RESTORATION OF ROAD DISASTER

5.6.1 Procedure to Restore Road Disasters

The guideline on what measures to take when disaster occurs on national roads was issued as a ministry order in August 1982. When road disaster occurs, the following reports must be made:



For urgent restoration of road disasters interrupting or greatly hindering traffic, the Regional Director's discretionary fund, which represents five (5) percent of the Highway Maintenance Fund, is used. When the discretionary fund is spent, the Highway Maintenance Fund is used until the road is made passable. Further restoration work is conducted only after the contingent or calamity fund has been released. The work is planned by the District/City Engineers and implemented in accordance with the work schedule submitted to the Regional Director. The highway maintenance crew generally conducts restoration work, but when this disrupts regular maintenance work, an emergency crew is employed instead. Each District/City Engineer submits monthly progress reports to the Regional Director, and the Regional Director submits a consolidated report to the Central Office.

5.6.2 Current Restoration Work

Disaster restoration work currently being conducted are all temporary measures, and countermeasures which prevent the disaster from recurring are hardly applied. Descriptions of the kind of restoration work by type of disaster currently being implemented, are given below:

1) Cut Slope Failures

Restoration work is limited to removing fallen soil mass from the road surface by pushing the soil mass off the valley-side slope with a bulldozer. Drainage facilities to drain surface or ground water, slope protection, and the like are hardly applied. Therefore, everytime there is a typhoon or intensive rainfall, failures occur again.

2) Embankment Slope Failures

Stone masonry work is usually adopted to restore embankment slope. There are, however, many cases of repeated failures because: i) no berms were provided on stone masonry over 10 meters high,. ii) concentration of road surface water on shoulder was not solved, iii) no consideration was given to groundwater drainage, and iv) back-filling was not compacted well enough. Among embankment slopes running parallel to a river, there are many in danger of failing because the foundation of the stone masonry is not embedded deep enough and/or foot protection has not been provided, causing scouring. There are also many cases of failures caused by surface water overflowing the side ditch on the mountain side and running over the road surface, thus causing the road shoulder on the valley side to be eroded. If no measures are undertaken to drain surface water, the section adjacent to the restored section may be affected next.

Of restoration methods currently being used, stone masonry is the most expensive. It takes a while for funds to be released, correspondingly restoration work is not implemented immediately and the road is left in its damaged state for long periods of time (often over six months).

3) Falls

Restoration work is limited to removing rocks which fall on the road surface. When the fallen rock is very large, dynamite is used to break the rock into little pieces. No protection work is done on the slope causing the fall.

4) Landslide

Overlay is usually applied when a landslide causes the road surface to sink, while removal is usually applied when a landslide causes the road surface to rise.

5) Debris Flow

Restoration work is limited to removing earth and sand which has flowed onto the road surface.

5.6.3 Fund for Restoration Work

There are five (5) sources of restoration funds, as follows:

—*Regional Director's discretionary fund:* Represents five (5)% of the Highway Maintenance Fund. Mainly used to effect urgent restoration work.

—Highway Maintenance Fund: Made available only when the Regional Director's discretionary fund is expended for urgent restoration work.

—Contingent Fund: Kept as a reserve maintenance fund but also, used for restoration work. Requires the President's approval on use.

—Calamity Fund: Fund amount depends on the scale of disaster, and the President's approval is also required for use.

—BBKN Fund (Baguio-Bontoc, Kennon, Naguilian Road): The source of the fund is toll collected on Kennon and Baguio-Bontoc Roads. Most of the toll income is used for maintenance of Kennon, Naguilian, Agoo-Baguio and Baguio-Bontoc Roads, and some are used for restoration work.

The Regional director's discretionary fund is the only fund that can be used immediately when disaster breaks out. It usually takes four to six months for the calamity fund to be released.

Allocations of the above funds from 1983 to 1984 are shown in Table 5.6-1.

5.6.4 Problems on Disaster Restoration

Restoration work currently being conducted are temporary measures. Since no appropriate and lasting countermeasures aimed at removing the cause of the disaster are undertaken, disasters keep recurring. One reason for this situation is the insufficiency of restoration funds. Since the total amount of restoration work estimated by the District/City engineering office is hardly released, even currently adopted restoration work cannot be implemented sufficiently. The delay in the release of contingent or calamity funds remains the damanged spot without being restored for several months. In the event that another typhoon, for example, strikes the area, the damage will only become more aggravated. Another factor delaying disaster restoration work is the amount of time required to mobilize necessary construction equipment.

TABLE 5.6-1 MAINTENANCE FUND

Unit : Million ₱

FUNDS	1983	1984
Amount Appropriated by General Appropriations Act		
—Maintenance Fund for National Road	565.07	434.60
—Contingent Fund	250.00	136.35
—BBKN Fund	3.19	2.71
—Operational Support Fund	—	22.13
Maintenance Fund Allocated to Regional Offices		
—Region I	47.18	34.20
—Region IV-A	34.07	35.66
—Region VIII	46.86	39.12
Maintenance Fund Allocated to District Engineering Offices		
—Benguet	5.05	5.54
—La Union	3.61	3.20
—Baguio City	1.03	1.09
—Quezon First	3.91	4.92
—Quezon Second	5.86	5.19
—Northern Samar	4.52	4.71
—Calbayog City	1.41	1.36
Regional Director's Discretional Fund (5% of Maintenance Fund)		
—Region I	2.36	1.71
—Region IV-A	1.70	1.78
—Region VIII	2.34	1.96
Estimated Maintenance Fund Allocated to Subject Sections		
—Lucena-Calauag (10-15%)	0.98-1.47	1.01-1.52
—Allen-Calbayog (15-20%)	0.89-1.19	0.91-1.21
—Naguilian Road (5-10%)	0.48-0.97	0.49-0.98

5.7 PREDICTION OF DISASTER

5.7.1 Disaster Prediction Method

Prediction of road disaster and accompanying restoration costs and traffic interruption periods are extremely difficult to make, since nature is the subject matter. Moreover, factors which cause road disaster change as time passes. Main factors which cause road disaster are as follows:

a) Weather conditions (typhoon frequency, rainfall intensity, rotation of dry and rainy season, etc).

b) Slope conditions (geological formation, gradient, height, vegetation, degree of surface water concentration, ground water conditions, degree of weathering, cracks and joints, spread of land behind slope, etc).

c) Change in the shape of slope due to passage of time (from the time of its construction to the time it takes to attain its stable gradient and thereafter, the failured slope expands year by year and becomes more easily affected by rainfall.)

To predict road disasters by taking into account all the above factors is close to impossible because of the limited amount of data available.

In the Study, available past records and data were analyzed to obtain the relationship between typhoons and road disasters. Based mainly on the assumption that the relationship will hold true in the future, road disaster predictions were made. The frequency and scale of typhoon attacks were first predicted. Based on this typhoon scale, restoration cost and traffic interruption period were predicted. A flow chart of road disaster prediction procedure is given in Figure 5.7-1.

Typhoon records prepared by PAGASA listing date of outbreak, course, maximum 24-hour rainfall, total cost of damages and total number of casualties are available from 1948 onwards. Based on these records, typhoons which affected the study sections, were categorized by scale, and then the frequency of typhoon attack was predicted by scale. An analysis of typhoon attack frequency by scale in each section shows that large-scale typhoons attack the sections either once every two years or once every four years. The combination of large and small typhoons attacking the sections within this regular interval was established as the typhoon cycle.,

Traffic interruption periods by scale of typhoon were established based on past records. From this, together with the typhoon cycle, traffic interruption period for a single cycle was forecasted. This was then divided by the number of years in that cycle to obtain the average annual traffic interruption period.

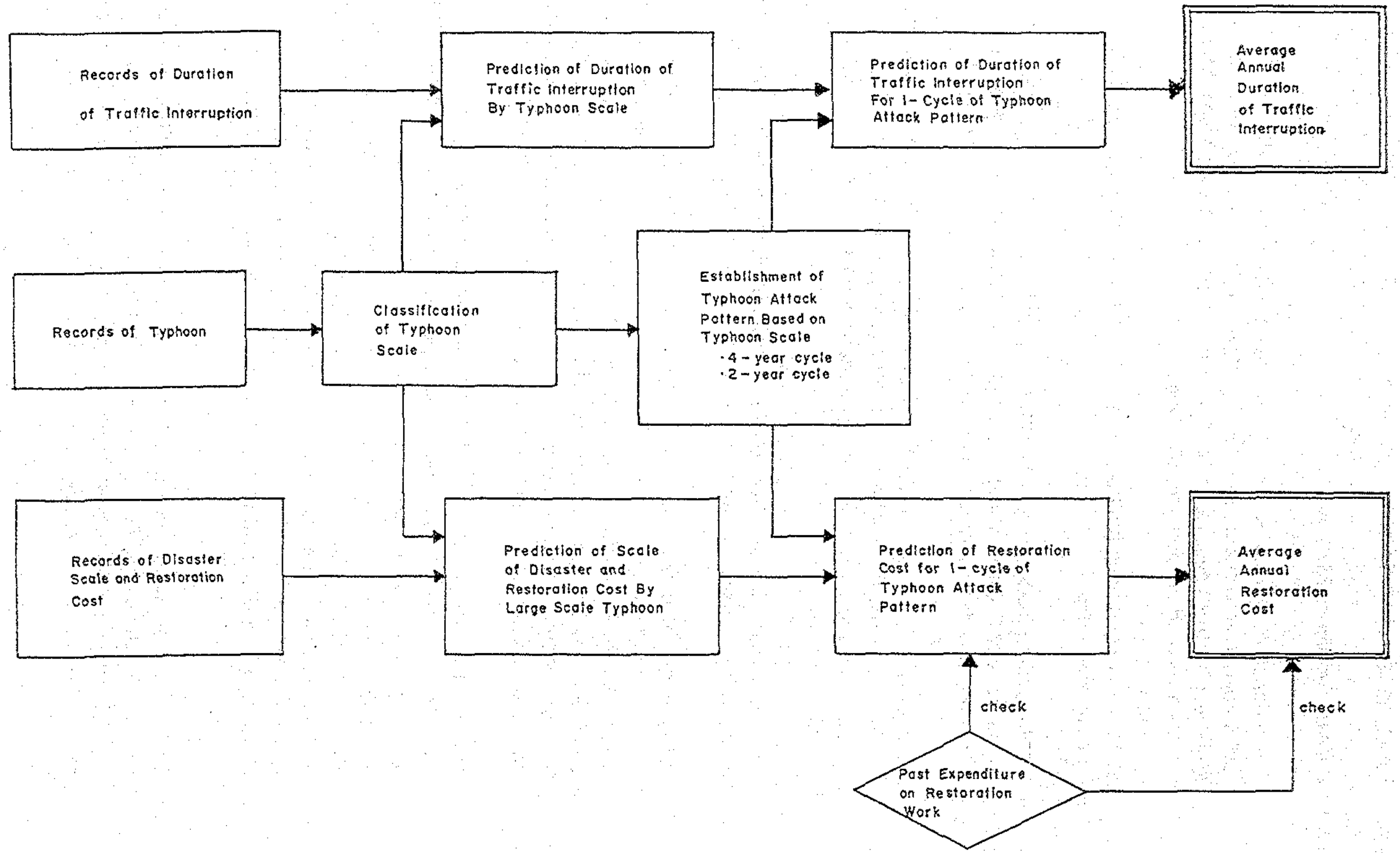


FIGURE 5.7-1 PROCEDURE OF DISASTER PREDICTION

Estimates of the scale of road disaster and the cost of restoration work were made for large-scale typhoons based on past records. The restoration cost of small-scale typhoons was obtained by multiplying a fixed ratio to the restoration cost of large-scale typhoons. Based on the restoration cost estimates by scale of typhoon, together with the typhoon cycle, restoration cost for a single cycle was obtained. This was then divided by the number of years in that cycle in order to obtain the average annual restoration cost. At the same time, average annual expenditures made in the past on restoration work was calculated, and was compared to the predicted value in order to verify the appropriateness of the predicted value.

5.7.2 Number of Typhpoon Attacks

The area affected by tropical cyclones (hereinafter called the cyclone influence zone) was established for each Study Section as follows based on past tropical cyclone records:

Study Section	Cyclone Influence Zone
Lucena-Calauag Section	From 12° 30' to 15° 00' north latitude (from San Bernardino Strait to Bulacan Province in Central Luzon).
Allen-Calbayog Section	From 10° 30' to 13°30' north latitude (from Southern Leyte to Albay Province in the Bicol Region).
Naguilian Road	From 14° 00' to 18° 30' north latitude (from Batangas to Aparri).

The average annual frequency of tropical cyclones passing through their respective zones was obtained from past typhoon records covering 19 years (1965 to 1983) as shown in Table 5.7-1. (also refer to Appendix 5.7-1).

TABLE 5.7-1 AVERAGE ANNUAL FREQUENCY OF TYPHOON ATTACK

Section	Tropical Cyclone		Total
	Typhoon	Tropical Storm & Tropical Depression	
Lucena-Calauag	2.1	2.2	4.3
Allen-Calbayog	2.0	2.2	4.2
Naguilian Road	2.6	2.2	4.8

5.7.3 Scale and Probability of Typhoon Attack

In order to elicit the relationship between typhoon scale and road disaster, typhoons were classified based on criteria shown in Table 5.7-2.

TABLE 5.7-2 TYPHOON CLASSIFICATION CRITERIA

Section	Scale	Criteria (24-hour rainfall)
Lucena-Calauag Section Allen-Calbayog Section	Small (S) Medium (M) Large (L)	Less than 150 mm 150-300 mm More than 300 mm
Naguilian Road	Small (S) Medium (M) Large (L) Super Large (Super-L)	Less than 200 mm 200-400 mm 400-600 mm More than 600 mm

The average annual frequency of typhoons by scale during the period of 19 years (1965 to 1983) is shown in Table 5.7-3. (also refer to Appendix 5.7-2).

TABLE 5.7-3 FREQUENCY OF TYPHOON BY SCALE

Section	Scale	No. of Frequency (1965-1983)	Frequency Per Year
Lucena-Calauag	Small	9	0.47
	Medium	21	1.11
	Large	9	0.47
	Total	39	2.1
Allen-Calbayog	Small	10	0.53
	Medium	22	1.16
	Large	6	0.31
	Total	38	2.0
Naguilian Road	Small	10	0.53
	Medium	25	1.32
	Large	7	0.37
	Super-Large	7	0.376
	Total	49	2.6

5.7.4 Typhoon Attack Pattern

Based on frequency of typhoons by scale, typhoon attack patterns were assumed as follows:

a) Lucena-Calauag Section: 2-year cycle

Year	Pattern	No. of Typhoons
(n)	Small + Medium	2
(n + 1)	Medium + Large	2
Total		4 (2-typhoons per year)

b) Allen-Calbayog Section: 2-year cycle

Year	Pattern	No. of Typhoons
(n)	Small + Medium	2
(n + 1)	Medium + Large	2
Total		4 (2-typhoons per year)

c) Naguilian Road: 3- year cycle

Year	Pattern	No. of Typhoon
(n)	Super-L + Medium + Small	3
(n + 1)	Large + Medium + Medium	3
(n + 2)	Medium + Small	2
Total		(2.67 -typhoon per year)

5.7.5 Traffic Interruption Period

When a road disaster causes traffic interruption, the MPWH releases the Regional Director's discretionary fund and/or maintenance fund for effecting urgent restoration work, in which opening to traffic is given emphasis. Complete restoration work is effected after the contingent fund or calamity fund is made available.

The period required for urgent restoration work, which is equivalent to the traffic interruption period, depends not only on the number of spots damaged, their locations and the types and scales of disasters, but also on the availability of construction equipment and the number of days required to mobilize those equipment. To forecast traffic interruption periods after first predicting all the above factors is quite difficult because of the limited available data. Therefore, prediction of traffic interruption periods in this Study were made mainly on the basis of past traffic interruption periods, under the assumption that past tendencies would continue in the future.

Because there were little recorded data on past traffic interruption periods, such data were collected for the Study Section by interviewing maintenance engineers foremen and nearby residents.

1) Lucena-Calauag Section

The relationship between traffic interruption period and a typhoon scale in the past is as shown in Table 5.7-4.

TABLE 5.7-4 TRAFFIC INTERRUPTION PERIOD AND TYPHOON SCALE LUCENA-CALAUAG SECTION

Year	Name of Typhoon	Max. 24-Hour Rainfall (mm)	Typhoon Scale	Interruption Periods (days)
1984	Paring	152	Medium	6
1983	Bebeng	254	Medium	3
1982	Ruping	201	Medium	1

The past traffic interruption records indicate that number of days of traffic interruption caused by a medium scale typhoon was about 4 days. There was no traffic interruption record for large and small scale of typhoons. Based on maximum 24-hour rainfall height of typhoon scales and slope conditions in this Section, number of days of traffic interruption for large and small scale typhoons were assumed to be 6 days and 1 day, respectively. Average annual traffic interruption was computed as follows:

Year	Typhoon Scale	Traffic Interruption Periods (days)
n	Small + Medium	1 + 4 = 5
n + 1	Medium + Large	4 + 6 = 10
Total	4 Typhoons	15 days
Average	2 Typhoons	7.5 days

Traffic interruptions in the Lucena-Calauag Section were predicted to occur on an average of twice a year for a total of 7.5 days per year.

2) Allen-Calbayog Section

The past traffic interruption records are shown in Table 5.7-5.

TABLE 5.7-2 TRAFFIC INTERRUPTION PERIOD AND TYPHOON SCALE

Year	Name of Typhoon	Max. 24-Hour Rainfall (mm)	Typhoon Scale	Traffic Interruption Period (days)
1983	Bebeng	166	Medium	3
1983	Warling	218	Medium	1
1981	Dinang	133	Medium	5

The number of days of traffic interruption caused by a medium scale typhoon was about 4 days. For large and small scale typhoons, no data was available, therefore, in consideration of 24-hour rainfall heights for large and small scale typhoons as well as geological and other conditions of slopes in this Section, the number of traffic interruption periods of large and small scale typhoons were predicted to be 8 days and 1 day, respectively. Average annual traffic interruption was computed as follows:

Year	Typhoon Scale	Traffic Interruption Period (days)
n	Small + Medium	1 + 4 = 5
n + 1	Medium + Large	4 + 8 = 12
Total	4 Typhoons	17 days
Average	2 Typhoons	8.5 days

An average two traffic interruptions were predicted to occur on this Section annually for a total period of 8.5 days per year.

3) Naguilian Road

Only two samples of past traffic interruption were available, as shown in Table 5.7-6.

TABLE 5.7-6 TRAFFIC INTERRUPTION PERIOD AND TYPHOON SCALE

Year	Name of Typhoon	Max. 24-Hour Rainfall (mm)	Typhoon Scale	Traffic Interruption Period (days)
1984	Maring	382	Medium	1
1982	Norming	88	Small	4

It is quite difficult to predict traffic interruption based on the past records. The number of days of traffic interruption for each scale of typhoon was assumed mainly based on 24-hour rainfall height of each typhoon scale. Traffic interruption periods for super-large, large, medium and small scale typhoon were assumed to be 5,3, 1 and 0 days, respectively. Average annual traffic interruption was computed as follows:

Year	Typhoon Scale	Traffic Interruption Period (days)
n	Super + Medium + Small	5 + 1 + 0 = 6
n + 1	Large + Medium + Medium	3 + 1 + 1 = 1
n + 2	Medium + Small	1 + 0 = 1
Total	8 Typhoons	12
Average	2.67 Typhoons	4

Two traffic interruptions per year were predicted to occur on the Naguilian Road for a total period of 4 days per year.

CHAPTER 6 COUNTERMEASURE SELECTION

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CHAPTER 6 COUNTERMEASURE SELECTION

6.1 DESIGN SPOTS

6.1.1 Spots Subject to Design

Spots urgently requiring the countermeasure work hereinafter called as design spots which will be discussed in detail in section 6.1.2 below. These design spots have been selected and are shown by the road section and by the type of disaster in Table 6.1-1.

TABLE 6.1-1 DESIGN SPOTS

Type of Disaster	Lucena-Calauag Section	Calbayog-Allen Section	Naguilian Road	Total
Cut Slope Failure	1	1	5	7
Embankment Slope Failure	1	2	5	8
Fall	4	9	5	18
Landslide	1	—	—	1
Debris Flow	—	2	—	2
Total	7	14	15	36

The 95.72 kilometer Lucena-Calauag Section has a total of seven (7) design spots, for an average density of 0.07 spots per kilometer. In the Pagbilao-Atimonan Sub-section where disaster spots are concentrated, the density is 0.7 spots per kilometer. The most frequent type of disasters is rock fall, which accounts for 57 percent (or 4 out of 7) of the total design spots.

Average disaster spot density is 0.2 spots per kilometer in the Allen-Calbayog Section, with an extension of 72.94 kilometers, has a total of 14 spots and an average disaster spot density is 0.2 spots per kilometer. The most frequent disaster type is rock fall (9 out of 14) which accounts for 64 percent.

The highest density of 0.3 spots per kilometer of road is recorded in the Naguilian Road, whose extension is 47.23 kilometers and which has a total of 15 disaster spots. In this section, an equal frequency is shown by cut slope failure, embankment slope failure, and rock fall (5 each out of 15).

6.1.2 Criteria for Selection of Design Spots

Disaster types, locations, and the degree of impacts to the road are reported for each study section In4.2 "Disasters in Study Sections" and are summarized in Table 4.3-1. The design spots listed in Table 6.1-1 have been selected in view of the following considerations:

1) Impact on Road

Of the three (heavy, medium and small) disaster impact levels on road discussed in section 4.2-3 "Evaluation of Disaster Potentials" it is deemed more rational and justified to limit countermeasure work to spots where such impact is either heavy or medium, considering the traffic volume, the quality of road facilities, and the amount of past investments for disaster damage restoration. Heavy or medium impact means traffic obstruction by failured materials onto the road, pavement structure collapse, and other causes. Presently small impact can be aggravated to medium or even heavy impact in the future therefore, road disaster prevention project should be a continuous effort, but countermeasure work even after such aggravation is still believed timely. Thus, only spots with heavy or medium impact have been included in design spots.

2) Large-scale Reparian and Sabo Work

In accordance with the Scope of Work of the Study, spots requiring large scale of reparian works, sabo works or hillside works which are considered beyond scope of highway projects have been excluded from design spots.

Three disaster spots in the Allen-Calbayog Section, where sea water washes and flows over the road, thereby damaging it, have been excluded from design spots, because it is believed that to correct such damage, the construction of a revetment adequate against the wave and a facility to protect the road from the broken waves is needed under a revetment project rather than a road project. These spots are Spot No. VIII-1 (km. 664 + 400), No. VIII-2 (km. 681 + 700), and No. VIII-39-1 (km. 721 + 800).

3) Ordinary Earth Failures

Ordinary earth failures, which frequently occur due to the flow of water-saturated slope surface soil on bedrocks have been also excluded from design spots, because countermeasure work involving either the removal of surface soil, cutttng down to stable soil, and/or the installation of complete draining facility will require a relatively large amount of funds, and considering that impact of such earth failures on the road is limited and damage can be restored quickly and inexpensively by cleaning off the earth with a bulldozer, for instance.

In the low portions of Naguilian Road, sporadic spots have such ordinary earth failures, while other spots show possibility of such failures in the future.

4) Valley Side Embankment Failures

"Rip-rap" stone masonry covering the valley side slope surface of embankment has been excluded from design spots, except spots where rip-rap is actually damaged, because it is deemed irrational to demolish existing rip-rap for replacement with a stable retaining wall, even though rip-rap has a limited earth pressure resistance and is weak particularly where rainwater converges. Particularly old rip-rap work is weak. It should be noted that the disaster potential of all spots with rip-rap stone masonry must be rated at least "small". Many spots with rip-rap which were excluded from design spots were seen in the Naguilian Road and the Lucena-Calauag Section.

6.2 POLICIES FOR COUNTERMEASURE SELECTION

Countermeasures appropriate to the cause and type of disaster at each disaster spot, as revealed through topographic, geological, surface and subsurface water and other investigations, must be selected, taking into full consideration the work condition, cost, maintenance, and environment.

In addition, countermeasures selection should aim at the achievement of:

—Introduction of new techniques and work methods

—Minimum traffic interruption during work

—Harmony of work with the environment.

1) Introduction of New Techniques/Work Methods

Although many of the slope failures were caused by weathering, erosion and scouring of slope surface by surface water flow, no slope protection work has been applied to almost all of the slopes. The lack of slope protection work is believed to be related to the Philippines' local conditions such as the existing level of design techniques, non-availability of equipment and materials for slope protection work and economical considerations. In spite of these facts, introduction of new techniques was actively considered in selecting countermeasures, in order to achieve the objectives of the Study which is to "develop techniques of road disaster prevention." New techniques such as seed mud spraying of mechanized and non-manual vegetation work, anchor bolt work to retain rocks from falling and anchor wire net work to minimize the energy of falling rocks were often selected. These work methods are relatively new to the Philippines.

2) Harmony with Environment

Whenever soil condition allows, slope protection by vegetation, which will harmonize with surrounding natural environment, was preferred to artificial structural protections.

3) Minimum Traffic Interruption

Allowing traffic to flow without obstruction and maintaining its safety during work is an important consideration in selecting countermeasures. In general, re-cutting works produce a large amount of excavated materials, which may seriously affect traffic. Therefore, whenever possible, applicable of re-cutting should be avoided. In the Study, for example, a slope protection method such as sprayed concrete was selected even for slopes with gradients of slightly steeper than standard, which ordinarily would be corrected by re-cutting.

However, there are still some slopes which will require re-cutting or removal of unstable materials on the slope. In cases where slopes are low, re-cutting will be done by providing a protection fence at the center of the carriageway so that one-way traffic could be possible. However, majority of the slopes in the Study are so high that a protection fence is deemed not safe to traffic since falling rocks and other materials may go over the fence. In such cases, a temporary structure covering the carriageway such as a rock shed may be necessary to assure perfect traffic safety, but this will cost even more than the countermeasure work itself. Hence, in the Study, as the next best method, re-cutting and removing of unstable materials at night and regulating traffic to certain hours were adopted.

6.3 COUNTERMEASURES FOR EACH TYPE OF ROAD DISASTERS

There are countermeasures commonly applied correspondingly to the type or the cause of disasters. The countermeasures which can be effectively used for the road disaster in the Philippines are listed up based on past experiences in various countries as shown in Figure 6.3-1 to 6.3-5.

The most appropriate countermeasure in relation to the cause of disaster assumed based on investigations of topography, geology, surface water, subsurface water and other conditions was selected among the countermeasures listed up.

In the selection of countermeasures, natural conditions related to the road disasters in the Philippines, especially severe weather involving extremely high rainfall intensity, were taken fully into consideration. However, there are somewhat misgivings about design criteria and durability of countermeasures, especially, slope protection works. Although, all slope protection works applied in the Study were practically used in Japan, they are not yet used in the Philippines. Therefore, their durabilities under such a severe natural condition as in the Philippines are yet to be proven. Pilot application of slope protection works is desirable to confirm their durability and to establish design criteria for countermeasures. The main countermeasures applied for each type of road disasters are discussed herein.

6.3.1 Cut Slope Failure

Table 6.3-1 gives the main countermeasures which are generally applied to cut slope failures, while the following works were adopted in the Study.

a) Drainage Work

The causes of cut slope failures by water maybe divided into two: first, erosion and scouring due to surface water running down on slope surface; and second, sliding of the slope due to decrease of shearing strength and increase of pore water pressure because of elevation of groundwater. In this study, the causes of failures are mostly on the first case. Thus, drainage work (especially surface drainage) is considered vital for slope protection. The following drainage ditches were planned and adopted:

—Top Slope Ditch. This type of ditch is usually placed at the top of the slope when running water from adjacent area is expected. The water accumulated from the ditch was directed outside the slope but, when this is not possible, is drained to the vertical ditches constructed on the slopes.

—Berm Ditch. For wider and higher slopes, a considerable amount of surface water flows down the slope surface causing erosion and scouring. To prevent this, the berm ditch was proposed on the berm of the slopes, however, existing slopes are seldom provided with berms. For slopes where re-cutting was required, berm ditches were proposed on all berms considering the high rainfall intensity in the Philippines.

—Vertical Ditch. Deep scourings due to surface water were often observed for concave-shaped cut slopes. In these causes, vertical ditches were provided. This type of ditches were also used to drain water collected from top slope ditch and berm ditch. At the bottom of the ditch, a catch basin was designed and connected to the existing drainage system. When there are no existing side ditches, new side ditches were provided and connected with available cross drain structures.

The surface drainage system was designed for all spots with cut slope failures.

b) Vegetation

Protection work by vegetation is planting grass on a slope to prevent erosion and scouring. The vegetation prevents rainfall from falling directly to the slope and its roots bind the slope surface. Since this requires relatively low cost and greens the slopes, it was applied whenever possible as a favorable protection work. When vegetation is not applicable on the following types of slopes, protection by structure is applied.

—Slope with gradients steeper than 0.8:1;
—Slopes of hard rock, slopes of soft rock with slight weathering or with few cracks and slopes of highly acid soil; and
—Slopes with a large amount of spring water

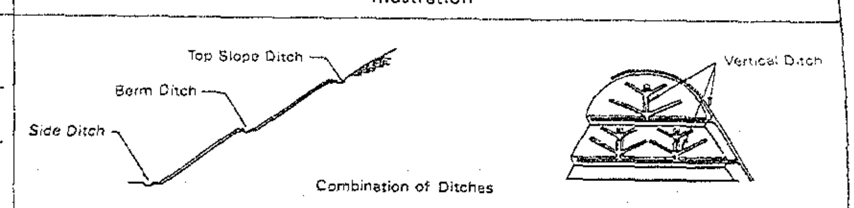
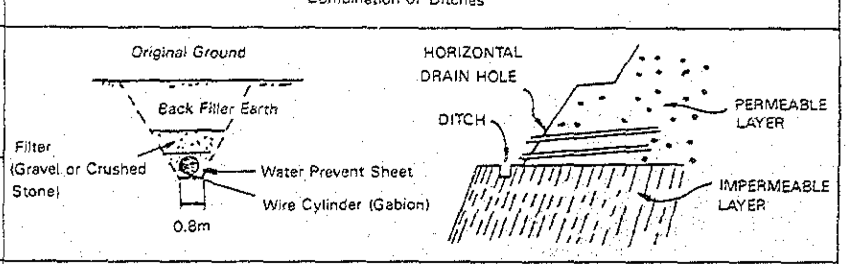
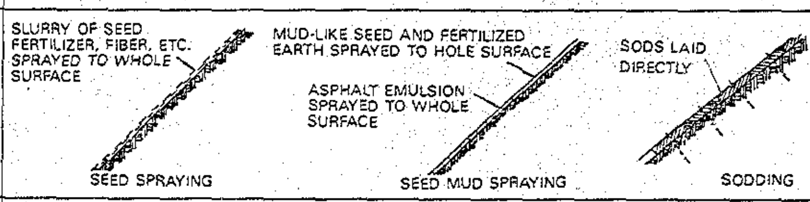
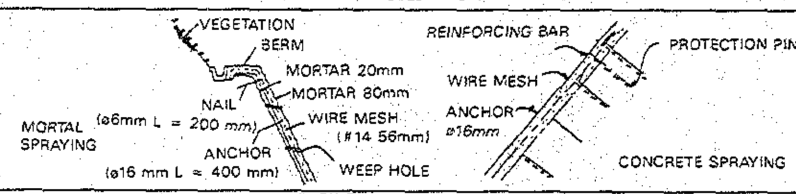
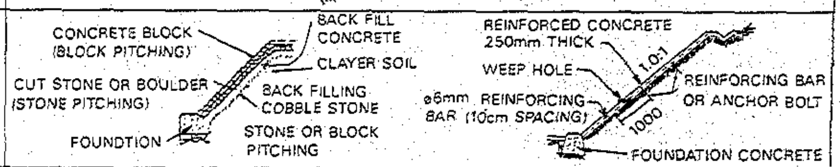
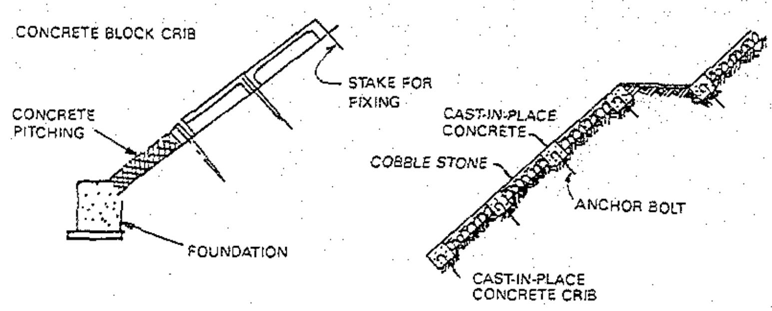
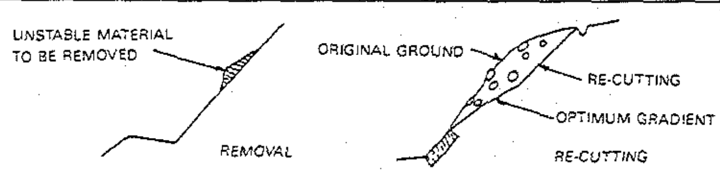
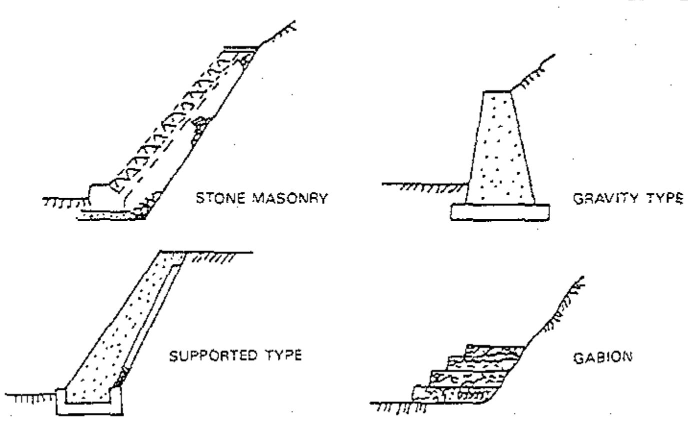
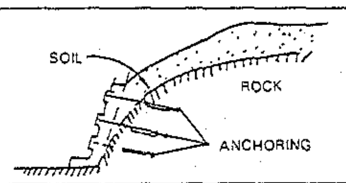
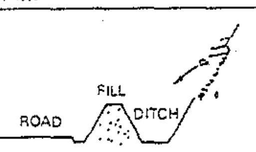
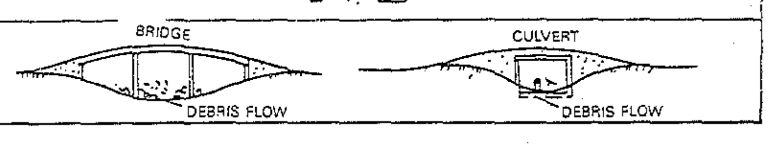
There are two main types of construction methods for slope protection by vegetation: by hand and by equipment. Although the method by hand such as sodding and planting of some kind of shrub is used in the Philippines, the method by equipment, especially seed mud spraying, was applied as a main slope protection work by vegetation in consideration of its prompt and economical construction. Seed mud spraying is to spray mixture of seeds, soil, fertilizer and water onto the slope by pump or spray gun.

This work was applied at two spots, Spot No. IN 4-1 and IN-16 in Naguilian Road.

c) Earth Work

Earth work consists of removal and re-cutting works. Removing unstable soil and rock mass on slope is called removal work. No matter what other countermeasures were applied, it is always necessary to remove first the unstable soil and rocks on the slopes, hence this was applied mostly in the Study.

TABLE 6.3-1 COUNTERMEASURES FOR CUT SLOPE FAILURE

	Classification	Type of Work	Purpose	Application	Illustration
Drainage Work	Surface Drainage	Top slope Ditch	To collect surface water running directly on slope surface and thus prevent erosion and scouring of slope surface.	Required for almost all cases of slope protection, especially for slope with broad area or water concentration. Usually applied together with other countermeasures.	
		Berm Ditch			
		Side Ditch			
		Vertical Ditch			
	Subsurface Drainage	Subsurface Drainer	To drain groundwater, spring water and seepage water and lower pore with pressure and thus stabilize stability of slope.	Effective to drain water near ground surface. Generally used in combination with surface drainage.	
		Horizontal Drain Hole		Effective for slope where ground-water level is higher than plane of failure.	
Protection Work	Vegetation	Seed Spraying	To firmly bind materials of slope surface and thus prevent slope from erosion, scouring and weathering.	Mainly applied to slopes composed of soil or strongly weathered rock. When applied, gradient is preferred to be less than 0.8:1. It improves aesthetics view of the environment.	
		Seed Mud Spraying			
		Sodding			
	Spraying	Mortar Spraying	To cover whole surface of slope with mortar or concrete sprayed by concrete gun and thus prevent slope from erosion, scouring and weathering.	Mainly applied to slope of. . Easily weatherable rock with no spring water or not wet. . Weathered rock which may be stripped off. . Soil not suited for vegetation.	
		Concrete Spraying			
	Pitching	Stone or Block Pitching	To cover slope with stone, or concrete block or cast-in-concrete and thus prevent slope from erosion, scouring, weathering and slight surface failure.	Applied to slope gentler than 45°. Stone pitching is widely adopted.	
		Concrete Pitching			
	Crib	Concrete Block Crib	To prevent slope from erosion, scouring, weathering and slight surface failure. / Resisting force against earth pressure may not be expected.	Applied to slope gentler than 45°. Effective for slope with spring water.	
		Cast-in-place Concrete Crib			
		Sprayed concrete crib	Resisting force against earth pressure may be expected depending on size and space of crib.	Applied to slope steeper than 45°. Effective for weathered rock and large slope with spring water. *1 / *2	
	Earth Work	Removal	To stabilize slope by completely or partially removing unstable materials on slope.	Basic method. Reliable when perfectly enforced. Applied together with drainage, vegetation and other protection works. Application is sometimes limited because of traffic interruption.	
		Re-cutting	To stabilize slope by cutting to optimum gradient.		
Structural Work	Retaining Wall	Stone Masonry Retaining Wall	To protect slope from small size failure, especially, near toe of slope.	Effective only for small earth pressure. Applied to slope with gradient steeper than 45° and with firm soil. Height less than 7 m.	
		Gravity Type Retaining Wall	To directly restraint slope failure or used as a foundation of other works.	Strong bearing ground is required. Height less than 5 m.	
		Supported Type Retaining Wall	To directly restraint slope failure and prevent erosion, scouring and weathering.	Applicable for soil with loose solidification. It can be constructed in limited area. Height less than 8 m.	
		Gabion Retaining Wall	To protect slope from small size failure, especially near toe of slope.	Effective for slope with seepage or spring water.	
	Anchoring	Rock Bolt	To directly restraint slope failure. Usually applied together with concrete pitching crib, etc.	Mainly applied to slope with strongly weathered rock or rock with many cracks and joints. Rock bolt is for small tension against anchoring, while p.c. is for high.	
		P.C. Anchor			
	Catch Work	Catch Fill and Ditch	To prevent spread of damage providing ditch and fill or wall to catch failured materials. Occurance of failure can not be prevented.	Applied when other countermeasures are difficult or costly. Wide space for deposite is required between road edge and toe of slope.	
		Catch Wall			
	Avoiding Problem Work	Route Relocation	To avoid problem by relocating route or pass over disaster site with bridge.	Applied when other countermeasure are difficult or costly.	
		Bridge			

Note: *1. Irregularity of slope surface shall be corrected. Form is required.

*2. Irregularity of slope surface is not necessary to correct. Form is required. Concreting is done by spraying with gun.

Re-cutting is generally applied to correct slopes whose gradients are too steep and unstable. This is one of the most basic measures to improve stability of slopes. However, when applied to very large slopes, a large amount of excavation is required and will affect traffic flow during construction. Therefore, recutting was avoided whenever possible. Instead of adopting re-cutting as a countermeasure to ensure stability of slope, protection works which can resist against earth pressure to a certain extent were applied. However, re-cutting could not be avoided on most soil slopes.

Finally, removal or re-cutting works were applied for almost all slopes of cut slope failures.

d) Catch Work and Avoiding Problem Work

In cases of large-scale cut slope failures where applying countermeasures directly onto the slope is technically difficult or extremely costly, catch work or avoiding problem work is usually applied. Catch work means the construction of a ditch, fill or retaining wall between the toe of slope and the road to prevent fallen materials from extending to the road. In other words, the purpose of this countermeasure is not to prevent cut slope failure from occurring, but to prevent the failure from affecting the road. Avoiding problem work means shifting the route to avoid the disaster potential spots.

As mentioned in 4.3, many of cut slope failures observed in the study sections were caused by either weathering or erosion and scouring due to surface water. Therefore, appropriate slope protection is necessary in order to prevent the extent of failure from growing over the years. The removal of fallen materials within the deposit space will become a major maintenance problem.

For this reason, together with the fact that there are few sections with enough room to allow shifting of the route and construction of catch wall between the toe of slope and road shoulder, re-alignment with catch wall work was recommended only for one spot (Spot No IVA-17) in the Lucena-Calauag Section for cut slope failure.

6.3.2 Embankment Slope Failure

Table 10.3-2 gives the main countermeasures which are generally applied to embankment slope failure. Of these the following works were adopted in the Study.

a) Drainage Work

Almost all slopes observed were damaged by scouring due to concentration of surface water on the roadway. The drainage system was planned with the following considerations:

—Side Ditch. Water on the road surface is generally concentrated at the inner side of curved roads with longitudinal gradient thus creating huge scouring. This failure was created either because there were no side ditches or capacity of ditches was insufficient. The side ditch was planned at many spots.

—Berm Ditch. Berm ditches are not provided on the existing embankment. In this study, berm ditch was designed for all slopes where re-filling was planned.

b) Re-filling

There are many slope failures that remain without any remedial measures. For such slopes, re-filling work was proposed in order to obtain standard gradient of embankment slope.

Since this work aims to fill the washed-out or broken-off portion of the embankment slope with soil, this was always adopted with other protection work such as stone masonry retaining wall.

c) Retaining Wall

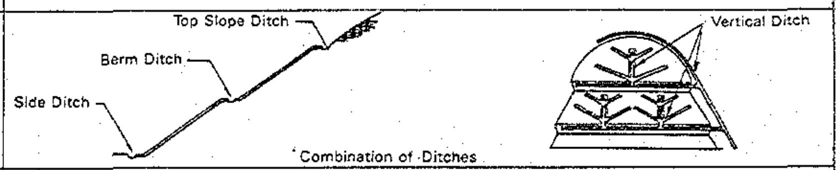
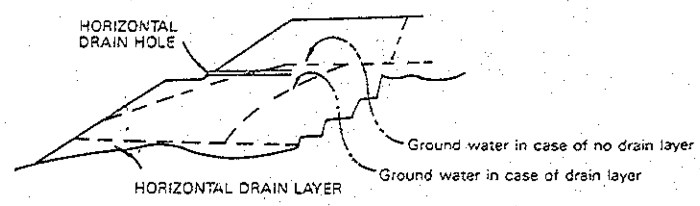
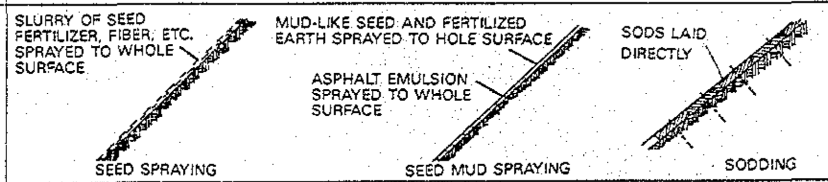
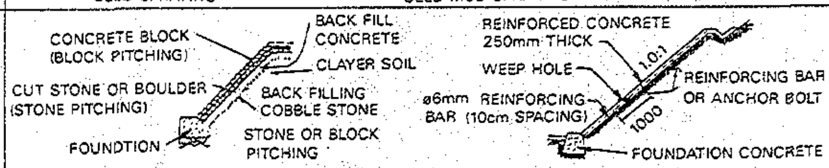
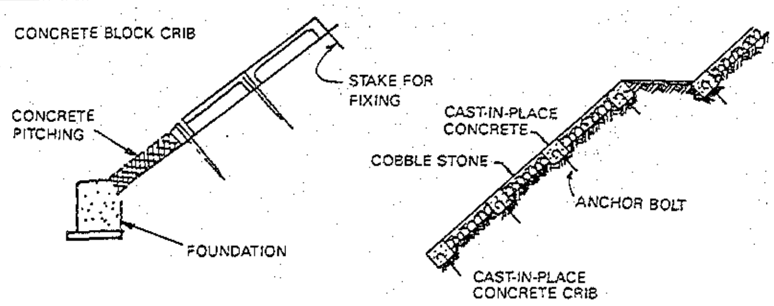
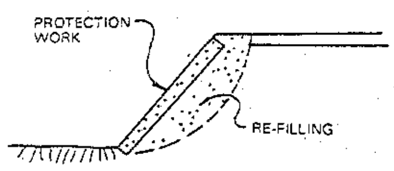
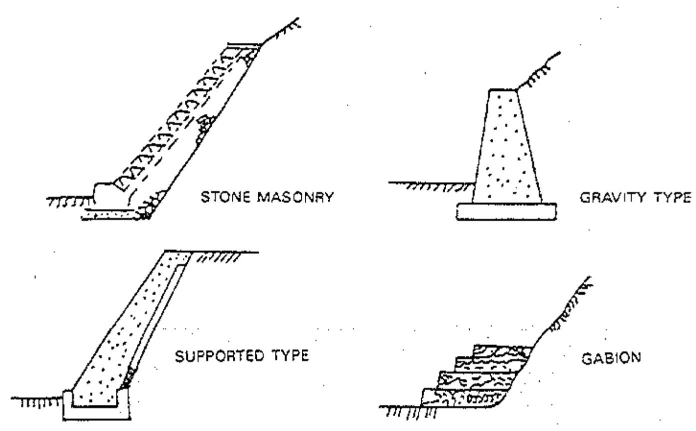
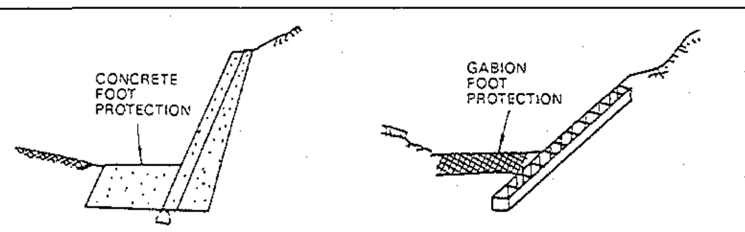
The retaining walls applied were stone masonry and the gravity type. Careful selection was made considering the characteristics of these works. For example, a gabion type retaining wall was adopted for a slope where no firm foundation exists and a big amount of seepage water exists.

Stone masonry retaining walls were adopted for all spots with embankment failure. While gravity types were used at the lower portion of a slope whose height is so tall that stone masonry type cannot resist against earth pressure. These spots are Spot No. VIII-18 in the Allen-Calbayog Section and Spot No. IN-14 in Naguilian Road.

d) Foot Protection

The foot of the embankment slope at Spot No. VIII-18 in the Allen-Calbayog Section was scoured by the river stream. To protect the foot, the gabion foot protection was applied together with the retaining wall which was also newly proposed.

TABLE 6.3-2 COUNTERMEASURES FOR EMBANKMENT SLOPE FAILURE

	Classification	Type of Work	Purpose	Application	Illustration
Drainage Work	Surface Drainage	Berm Ditch	To collect surface water running directly on slope surface and thus prevent erosion and scouring of slope surface.	Required for almost all cases of slope protection, especially for slope with broad area or water concentration. Usually applied together with other countermeasures.	
		Side Ditch			
		Vertical Ditch			
	Subsurface Drainage	Subsurface Drainer	To drain groundwater, spring water and seepage water and lower pore water pressure and thus stabilize stability of slope.	Effective to drain shallow surface water.	
		Horizontal Drain Hole		Mainly applied to high embankment which is already or may be saturated. Effective for slope where groundwater level is higher than plane of failure.	
		Horizontal Drain Layer			
Protection Work	Vegetation	Seed Spraying	To firmly bind materials of slope surface and thus prevent slope from erosion, scouring and weathering.	Should be applied to any slope. It also improves aesthetics view on environmental aspect.	
		Seed Mud Spraying			
		Sodding.			
	Pitching	Stone or Block Pitching	To prevent erosion and scouring slight resisting force to protect surface failure may be expected.	Mainly applied to slope gentler than 45° of high embankment susceptible to scouring.	
	Crib	Concrete Block Crib	To prevent erosion, scouring and slight surface failure. Resisting force against earth pressure may not be expected for block crib, but expected for cast-in-place crib.	Applied to slope with broad area or steeper than 45° where vegetation can not be appied or not effective.	
		Cast-in-place Concrete with form			
	Earth Work	Re-Filling	To fill washed-out and broken-off portion of slope with earth and then, usually cover surface with protection in order to prevent further failure.	Applied to collapsed slope. Usually applied with other measures such as vegetation or pitching.	
				For scouring due to river stream, concrete crib is also used.	
Structural Work	Retaining* Wall	Stone Masonry Retaining Wall	To protect slope from small size failure, especially, near toe of slope.	Effective only for small earth pressure. Applied to slope with gradient steeper than 45° and with firm soil. Height less than 7 m.	
		Gravity Type Retaining Wall	To directly restraint slope failure or used as a foundation of other works.	Strong bearing ground is required. Height less than 5 m.	
		Supported Type Retaining Wall	To directly restraint slope failure and prevent erosion, scouring and weathering.	Applicable for soil with loose solidification. It can be constructed in limited area. Height less than 8 m.	
		Gabion Retaining Wall	To protect slope from small size failure, especially near toe of slope.	Effective for slope with seepage or spring water.	
	Foot Protection	Concrete Foot Protection	To protect foot of retaining wall or other protection work.	Applied to foot which may be scoured by river stream.	
		Gabion Foot Protection			

* Retaining wall is sometimes called as revetment, when it is used to protect scouring of slope due to river stream.

6.3.3 Fall

Table 6.3-3 shows the main countermeasures which are generally used. Of these, the following works were adopted in this Study.

a) Spraying

Spraying consists of mortar and concrete spraying. However, mortar spraying was not adopted because it is not acceptable as a permanent structure under the high temperature and rainfall intensity as in the Philippines. Concrete spraying was positively adopted becaused of its strength against earth pressure and quicker construction. It is also more economical than other structural protection works, notwithstanding the advantage that irregularity of surface of the slope does not need to be corrected.

Concrete spraying of 15 centimeter thickness with reinforced steel net was applied to slopes of drastically weathered rock, slope with loose rock masses of fairly large sizes, and slopes which are expected to have large volume of surface water. These spots are Spot No. IVA-18 in the Lucena-Calauag Section, Spot No. VIII-6 in the Allen-Calbayog Section and Spot No. IN-5 in Naguilian Road.

For the other three spots of fall, concrete spraying of 10 centimeter thickness with wire net was applied. These are Spot No. IVA-7 in the Lucena-Calauag Section, VIII-12 and VIII-30 in the Allen-Calbayog Section.

b) Anchor Wire Net

Anchor wire net aims to restrain unstable rocks by the tension of a net and the friction between rocks and the ground by directly covering a slope with net. But this type cannot provide a complete protection to prevent erosion and scouring of slope surface.

Therefore, this type was adopted on the slopes composed of hard rocks. These are Spot No. IVA-6 in the Lucena-Calauag Section, Spot No. VIII-6 in the Allen-Calbayog Section and Spot No. IN-10, 12, 13, 15 and 15-1 in Naguilian Road.

c) Rock Bolt

Rock bolt work aims to fix unstable rock by anchoring with bedrock. It is generally used on small size of rocks comparing with p.c. anchor. This type was used on slopes that are composed of hard rocks with big cracks. These are Spot No. IN-10 and 15-1 in Naguilian Road.

d) Re-alignment with Catch Wall

The re-alignment method was positively proposed in the Study in order to take advantage of the topographic characteristic whereby terrain is rather flat and there is wide space available to allow shifting of the existing road. Whenever this method was applied, catch wall was always adopted to prevent the spread of damages due to falling rocks.

Among the total of 18 spots of fall, the number of spots where re-alignment with catch work was applied numbers at 7 spots. These are Spot No. IVA-15, 17 and 18 in the Lucena-Calauag Section and Spot No. VIII-27, 28, 29, 32 and 37 in the Allen-Calbayog Section.

6.3.4 Landslide

Table 6.3-4 gives the main countermeasures which are generally applied to landslide.

Earth work as countermeasure for landslide consists of two techniques: Counterweight Fill and Earth Removal. Counterweight fill aims to control movement of landslide force by the weight of the fill. This mettod is simple and therefore widely applied to slopes where there is space for the filling at the toe of embankment. On the other hand, earth removal work is also generally accepted as a reliable and effective method. This is widely used for small and medium size landslides.

For the only one spot of landslide in the Study, Spot No. IVA-20 in the Lucena-Calauag Section, earth removal work was proposed taking into account the size of failure and working space. The analysis of landslide is reported in Appendix 6.3-1.

6.3.5 Debris Flow

Table 6.3-5 gives the main countermeasures which are generally applied to debris flow.

In some cases, avoiding problem work by constructing bridges and culverts proves to be more economical than adopting method to directly prevent occurrence of debris flow.

However, for the two spots (Spot No. VIII-16 and VIII-36) in the Allen-Calbayog Section with rather small sized debris flow, stone pitching waterway was adopted because this proves to be more economical than the construction of bridge and culvert to contain the flow.

TABLE 6.3-3 COUNTERMEASURES FOR FALL

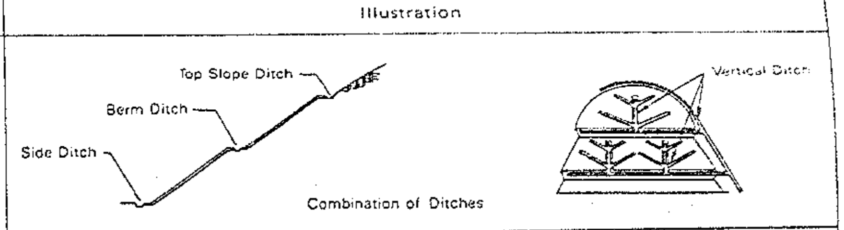
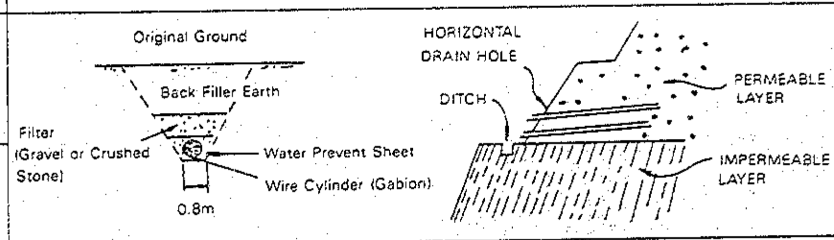
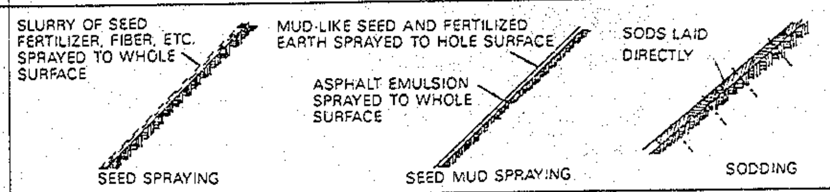
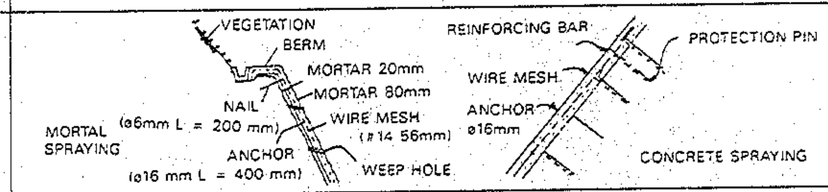
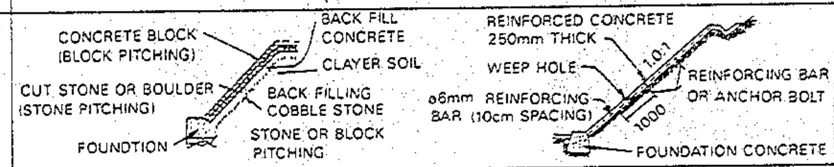
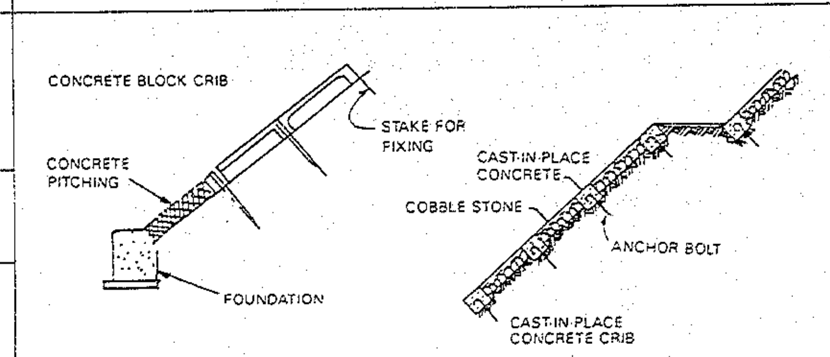
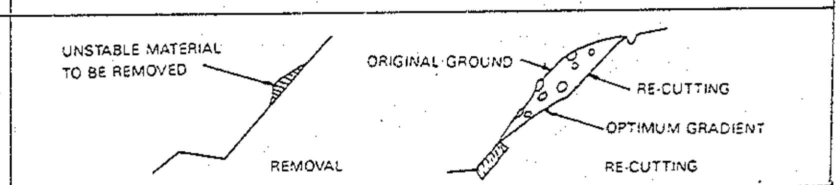
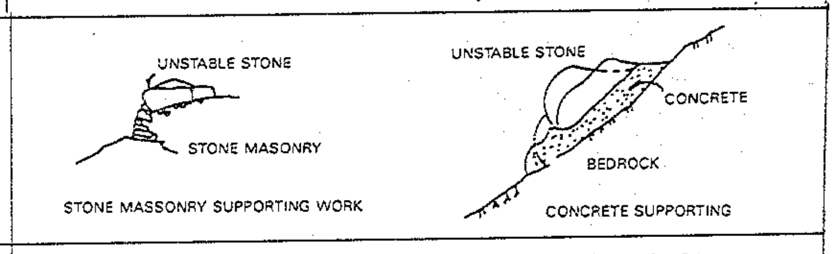
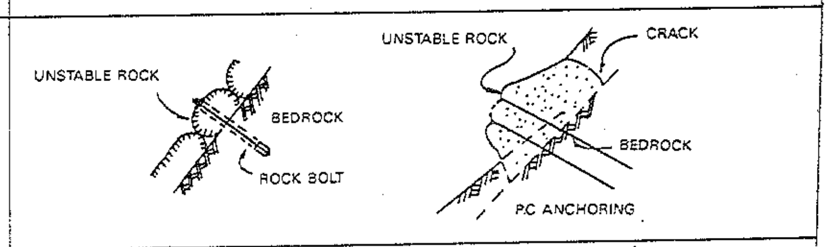
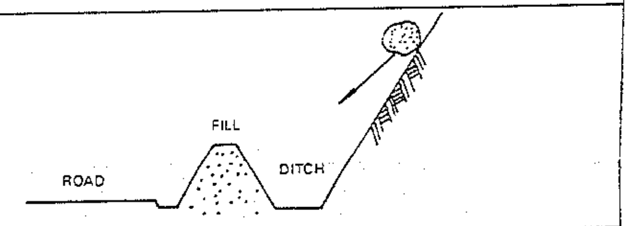
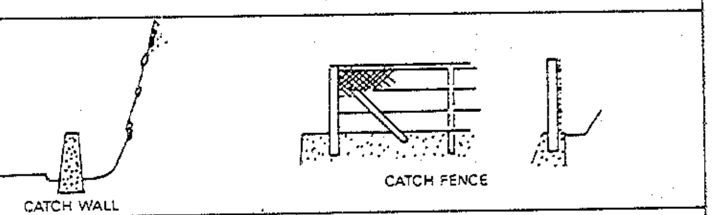
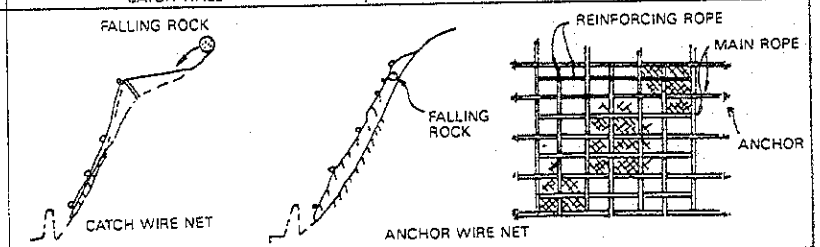
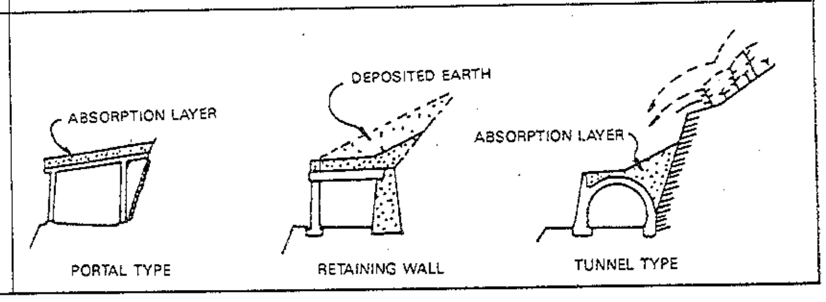
Classification		Type of Work	Purpose	Application	Illustration
Drainage Work	Surface Drainage	Top slope Ditch	To collect surface water running directly on slope surface and thus prevent erosion and scouring of slope surface.	Required for almost all cases of slope protection, especially for slope with broad area or water concentration. Usually applied together with other countermeasures.	
		Berm Ditch			
		Side Ditch			
		Vertical Ditch			
	Subsurface Drainage	Subsurface Drainer	To drain groundwater, spring water and seepage water and lower pore with pressure and thus stabilize stability of slope.	Effective to drain water near ground surface. Generally used in combination with surface drainage.	
		Horizontal Drain Hole		Effective for slope where ground-water level is higher than plane of failure.	
Protection Work	Vegetation	Seed Spraying	To firmly bind materials of slope surface and thus prevent slope from erosion, scouring and weathering.	Mainly applied to slopes composed of soil or strongly weathered rock. When applied, gradient is preferred to be less than 0.8:1. It improves aesthetics view of the environment.	
		Seed Mud Spraying			
		Sodding			
	Spraying	Mortar Spraying	To cover whole surface of slope with mortar or concrete sprayed by concrete gun and thus prevent slope from erosion, scouring and weathering.	Mainly applied to slope of. . Easily weatherable rock with no spring water or not wet. . Weathered rock which may be stripped off. . Soil not suited for vegetation.	
		Concrete Spraying			
	Pitching	Stone or Block Pitching	To cover slope with stone, or concrete block or cast-in-concrete and thus prevent slope from erosion, scouring, weathering and slight surface failure.	Applied to slope gentler than 45°. Stone pitching is widely adopted.	
		Concrete Pitching			
	Crib	Concrete Block Crib	To prevent slope from erosion, scouring, weathering and slight surface failure. Resisting force against earth pressure may not be expected.	Applied to slope gentler than 45°. Effective for slope with spring water.	
		Cast-in-place Concrete Crib			
		Sprayed concrete crib	Resisting force against earth pressure may be expected depending on size and space of crib.	Applied to slope steeper than 45° Effective for weathered rock and large slope with spring water. *1 *2	
Earth Work		Removal	To stabilize slope by completely or partially removing unstable materials on slope.	Basic method. Reliable when perfectly enforced. Applied together with drainage, vegetation and other protection works. Application is sometimes limited because of traffic interruption.	
		Re-cutting	To stabilize slope by cutting to optimum gradient.		
Fixing Work	Supporting	Stone Supporting	To fix unstable rock supporting with stone or concrete.	Mainly applied to big and supportless rock difficult to remove. Base of supporting shall be firmly shored.	
		Concrete Supporting			
	Anchoring	Rock Bolt	To fix unstable rock anchoring to bedrock with rock or p.c. wire.	Mainly applied to big, hard and supportless rock difficult to remove. Anchoring shall be made into firm bedrock. Rock bolt for relatively small rock, while p.c. for boulders.	
		P.C. Anchor			
Catch Work		Catch Fill and Ditch	To prevent spread of damage by providing fill and ditch, wall or fence to catch falling materials. Occurrance of fall can not be prevented.	Wide space for deposite is required between road edge and toe of slope.	
		Catch Wall		A little wide space for deposite is required between road edge and toe of slope. Space for wall or fence is narrower than for fill and ditch.	
		Catch Fence			
		Catch Wire Net	To prevent spread of damage covering slope by net with pocket to catch falling rocks.	Applied where no space for deposite. Unsuitable to soil and rock slope which are easily weathered.	
		Anchor Wire Net	To provide resisting force to fall directly by covering slope with net but inefficient to prevent erosion and scouring.		
Rock Shed		Concrete Rock Shed	To avoid damage by covering whole width of road with shed.	Mainly applied to a large scale of fall. Applied only when other countermeasures are difficult and costly.	
		Steel Rock Shed			

TABLE 6.3-4 COUNTERMEASURES FOR LANDSLIDE

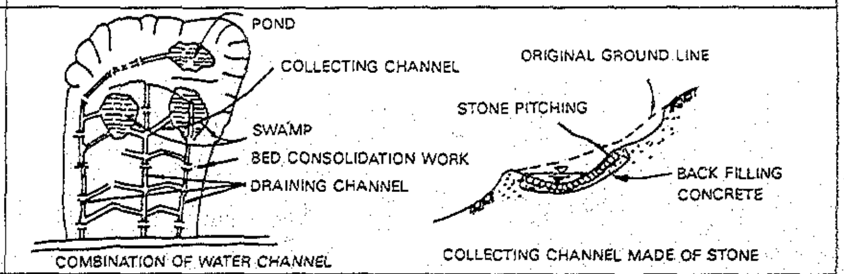
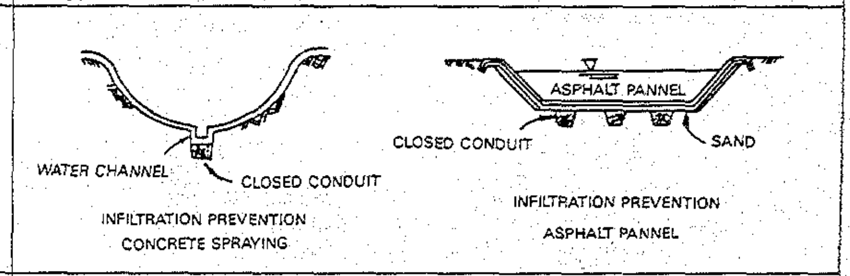
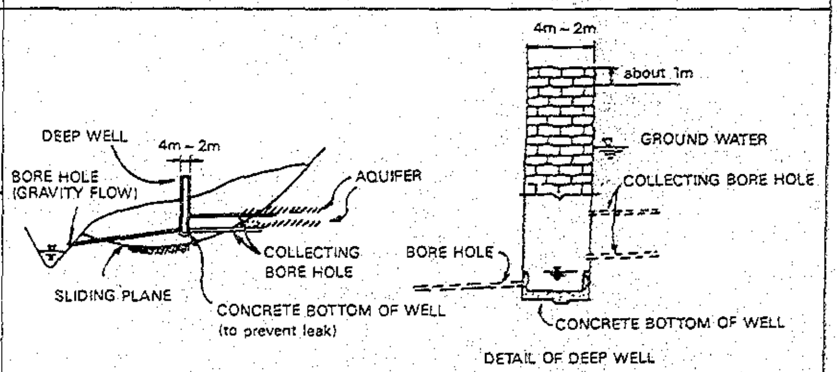
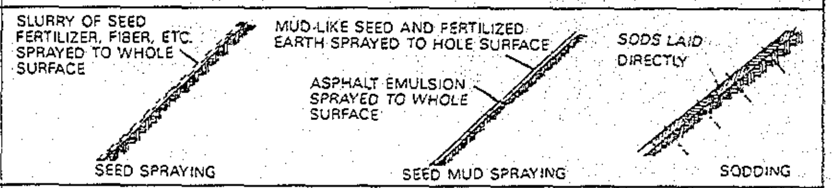
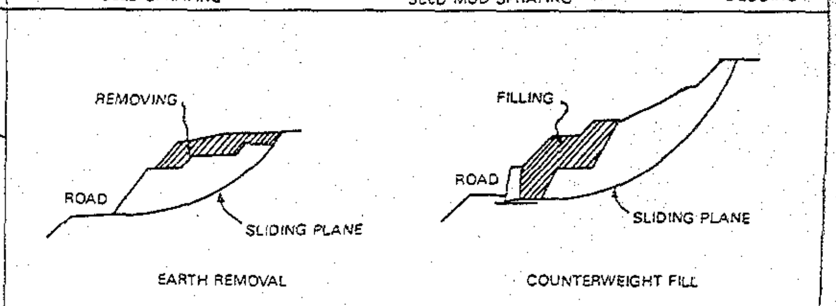
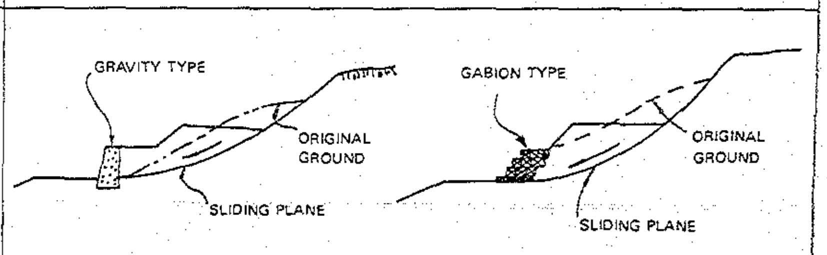
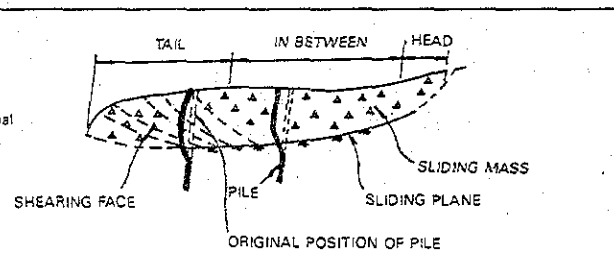
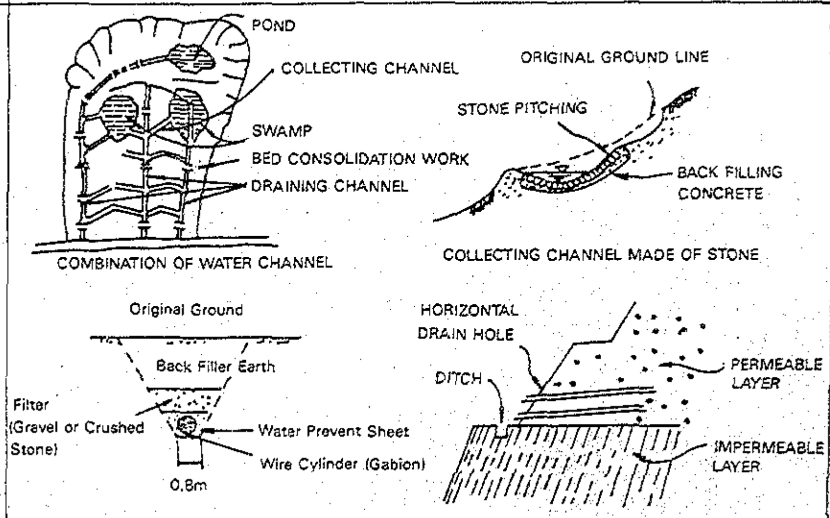
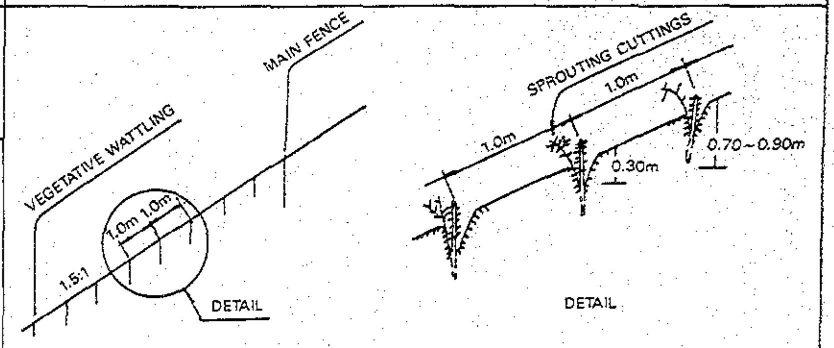
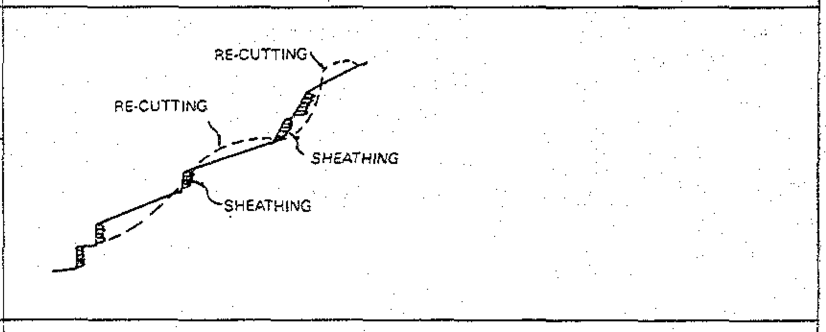
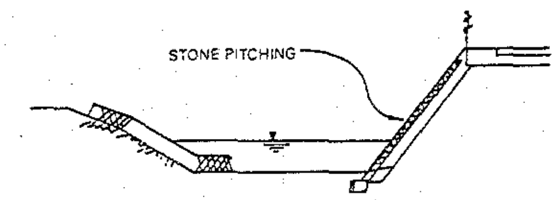
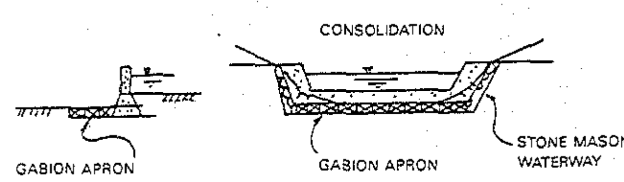
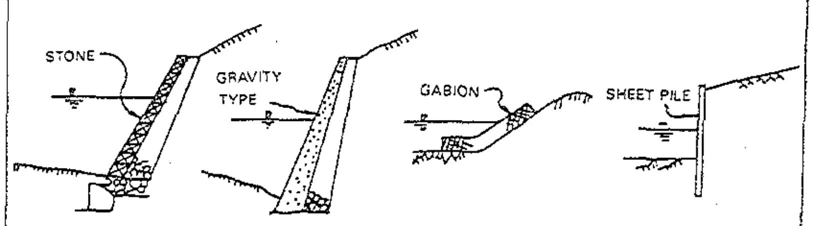
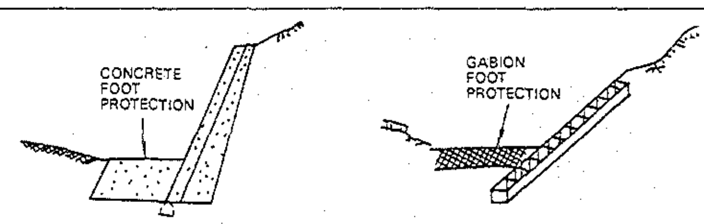
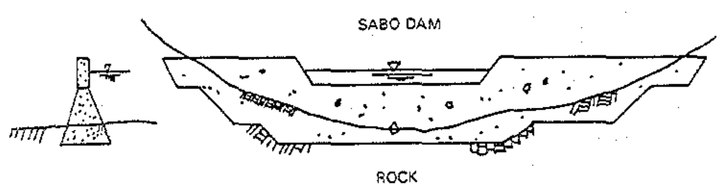
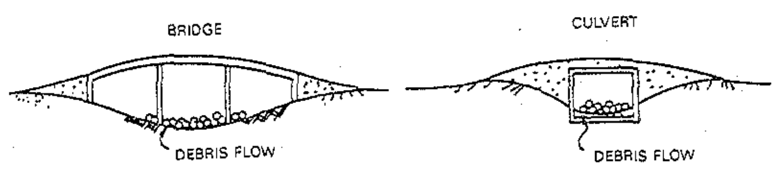
	Classification	Type of Work	Purpose	Application	Illustration
Drainage Work	Surface Drainage	Water Channel	To quickly collect and discharge *precipitated rain inside landslide* area in order to prevent seepage water.	Applied to all cases. Water ~~channel~~ consists of collecting channel and draining. Effective channel network is required.	
		Infiltration Prevention	To cover cracks with cement, clay or other materials in order to prevent seepage of water into cracked portion inside landslide area.	Applied to call cases. Effective for cracked portion where seepage water easily infiltrates and on swamp or water route.	
	Subsurface Drainage	Subsurface Drainer	To drain groundwater and thus lower its level and pore water pressure.	Effective where groundwater level is higher than sliding plane.	
		Horizontal Drain Hole			
		Deep Well		Applied when drain hole is too long or crowdedly placed near *bedrock.*	
Protection Work	Vegetation	Seed Spraying	To prevent seepage of surface water into slide mass and also *to protect slope from erosion* and scouring.	Applied to *all cases, whenever* applicable. Applied to bare area.	
		Seed Mud Spraying			
		Sodding			
Earth Work		Earth Removal	To stabilize slope by removing a partial or whole earth of sliding mass, usually head portion of sliding mass.	*Reliable and effective method.* Applied to many cases.	
		Counterweight. Fill	To control movement force of landslide by weight and *shearing strength of fill.* Filling of earth shall be executed at tail portion of landslide.	Wide area is required at toe of slide for construction. Groundwater shall be completely discharged.	
Structural Work	Retaining Wall	Gravity Type Retaining Wall	To control movement *force of* landslide, increasing resisting force by shear strength and weight of fill and wall. Anchoring is sometimes used to increase resisting force of wall against thrust of landslide.	*Mainly applied to small scale* landslide or secondary failure at tail portion of a large scale landslide. Gabion wall is mainly used as *counterweight for tail portion* of landslide.	
		Gabion Retaining Wall			
	Piling	Precast Concrete Pile	To control movement force of landslide by bending movement *and shearing strength* of pile. Anchoring is sometimes used to increase resisting force of pile against thrust of landslide.	Mainly applied *to landslide* where sliding plane is deep.	Conceptional Diagram of Pile Action 
		Cast-in-Place Concrete Pile			
		Steel Pile			

TABLE 6.3-5 COUNTERMEASURES FOR DEBRIS FLOW

Classification		Type of Work	Purpose	Application	Illustration
Hillside Work	Drainage	Water Channel	To collect surface water on hillside and thus prevent slope from erosion and scouring.	Applied to many cases. Used with other counter-measures.	
		Subsurface			
	Vegetation		To firmly bind materials of slope surface and thus prevent slope from erosion and scouring.	Vegetation is usually applied in combination with protection work such as terracing with stone, net muddling, etc.	
	Afforestation		To cover hillside with tree and shrub and thus prevent slope from erosion and scouring and sometimes to reduce velocity of surface water.	Applied to bare hillside.	
	Re-cutting		To stabilize slope by cutting *unstable portion of hillside* and reforming irregularity of surface of slope.	Applied to hillside with irregularity Used *with vegetation, sheathing* and others.	
	Sheathing		To retain unstable earth with stone or concrete wall or wicker etc.	Applied to a little steep slop where earth shall be retained. Mainly used with other hillside work.	
Torrent Work	Water Way	Stone Pitching Water Way	To smoothly lead flow of water and thus control turbulent flow and prevent scouring *of stream* bed and bank. Also to prevent overflow of flood to adjacent area.	Applied to stream bank composed of erodable soil or to stream bed with steep gradient. Usually used together with consolidation or sabo dam.	
		Concrete Pitching Water Way			
	Consolidation	Stone Consolidation	To control flow of water providing head of water to make gradient of stream bed gentler and to prevent turbulent flow and thus prevent scouring of stream bed and bank. Sometimes only to protect stream bed.	Applied to swift stream, meeting point of flow or stream bed susceptible to scouring. Usually used together with revetment, water way and sabo dam. Concrete consolidation is widely used.	
		Concrete Consulidation			
		Crib Consolidation			
	Revetment	Stone Masonry Revetment	To protect stream bank or hillside from waterclash due to curved flow of stream.	Applied to curved portion of stream.	
		Gravity Type Revetment			
		Gabion Revetment			
		Sheet Pile Revetment			
	Foot Protection	Concrete Foot Protection	*To protect foots of revetment* and water way from scouring.	Applied to foots of revetment and water way.	
		Gabion Foot Protection			
Sabo Works	Sabo Dam	Stone Dam	To control flow of debris and to catch and collect debris and sand, providing space for deposited materials and making gradient stream bed gentler and thus avoid spread of damage and, at the same time, prevent scouring of stream bed and bank.	Mainly applied to large scale of debris flow. Constructed at portion such as narrow stream width, hard bedrock or after meeting of flow.	
		Concrete			
		Concrete Dam			
		Steel Dam			
Avoiding Problem Work		Bridge	To avoid damage. Debris flows passes under bridge or inside of culvert.	Applied when other counter-measures are difficult and costly.	
		Culvert			

* Structural details of revetment may be same as those of retaining wall.

Since the torrent causing debris flow is generally small sized, a stone pitching waterway with a length of 20 to 30 meters upstream measuring from the point where the torrent crosses the road, was deemed sufficient to prevent damage to roads caused by debris flow.

For both spots of debris flow, surface drainage work such as top slope ditches and berm ditches as mentioned in cut slope failures were applied.

For the spot of VIII-16, sub-surface drainage works such as horizontal drain holes and closed conduit drain was applied, because the level of groundwater is known to be high and should be drained.

6.4 CASE STUDIES FOR COUNTERMEASURE SELECTION

In Section 6.3, the general discussion for countermeasure selection was presented based on the conditions and causes of disasters, the advantages and disadvantages of various kinds of countermeasure work, and the basic principle for the selection of such works.

In this section, case studies are presented to show procedures for selection of the most practical countermeasure appropriate for each type of disasters. Spots taken in the studies have been identified to show typical kind of disasters. (See Table 6.4-1). The methodology discussed herein is deemed applicable to other spots of the same type of disaster. It should be, however, pointed out that countermeasure selection is a highly judgemental process requiring a high level of technical competence backed by abundant experiences.

TABLE 6.4-1 SPOTS FOR CASE STUDIES

Case Study Number	Type of Disaster	Spot No.	Km.	Section	Major Countermeasures
1	Cut Slope Failure	IN-4-1	281 + 500	Naguilian Road	Re-cutting Vegetation Water way
2	Embankment Slope Failure	IN-8-5	291 + 050	Naguilian Road	Re-filling Stone Masonry
3	Fall	VIII-21	703 + 800	Allen-Calbayog	Re-cutting Concrete Spraying
4	Fall	VIII-32	709 + 600	Allen-Calbayog	Re-alignment Catch Wall
5	Landslide	IVA-20	160 + 800	Lucena-Calauag	Re-cutting Vegetation Water Way
6	Debris Flow	VIII-16	690 + 300	Allen-Calbayog	Water Way Closed Conduit Horizontal Drain

6.4.1 Case Study 1: Cut Slope Failure

1) Spot

Spot IN-4-1 at Km 281 + 500, in the Naguilian Road has been selected for Case Study I as a typical case of deep failure of a cut slope but, in this case, partly involving natural slope.

Geological Condition;

- Sandstone, Gravelly Soil
- Highly weathered and developed cracks.

Water Condition;

- Concentration of surface water from hinterland.

Considering the fact that this type of slope failure is of common occurence, the criteria, discussed herein may be widely applicable to this type of disaster.

2) Description of Failure

This failure was directly caused by typhoon Maring, which struck the northern part of Luzon Island in August 1984. A mass of approximately 500 cubic meters of the fallen earth and sand slid down and tripped across the road, over the edge of embankment, and down to the bottom of valley below the embankment. An approximately 30 meter high slope with a gradient of partly 12° and partly 30° runs in westerly direction for about 40 meters. See Figure 6.4-1 (a). The slope is of soft sandstone rock or gravelly soil. The rocks had developed cracks and were badly weathered.

3) Cause of Failure

The earth and sand, soaked to saturation under continuous heavy rains and concentration of precipitation because of the ravined topography of the spot, had become unstable thereby causing the earth and sand to fall down the slope. It is presumed that the failure initially occured near the bottom of the slope (near the edge of the road) and gradually extended further upwards. The interface between the bedrock of sandstone and earth of surface was the plane of slide.

4) Proposed Countermeasures

In the report entitled "An Approach on Road Disaster Prevention" prepared in the Stage I Study, countermeasures for cut slope failures were classified into the following six types as shown in Section 6.3 of this report.

- Drainage Work — Surface Drainage
  Subsurface Drainage
- Protection Work
- Earth Work
- Structural Work
- Catch Work
- Avoiding Problems Work

The procedure for the selection of countermeasures is shown in the Flow Chart of Figure 6.4-2 in order to arrive at the most appropriate work mentioned above.

For this particular spot, the following factors such as the condition of the slope, geology and water were taken into consideration in accordance with the procedure shown in the Flow Chart.

Flow of Countermeasure Selection

Step 1: Re-alignment of road cannot be done because of the valley at the opposite side.

Step 2: Proper countermeasures can be applied within the areal boundary of the slope, judging from the size of the disaster affected area and the size and shape of slope.

Step 3: Slope is stable judging from the gradient of 30° and 15°.

Step 4: Surface of the slope is eroded or weathered. The surface is composed of earth and sand so that vegetation can grow.
Thus, vegetation was selected as the protection work.

Step 5: No groundwater is anticipated.

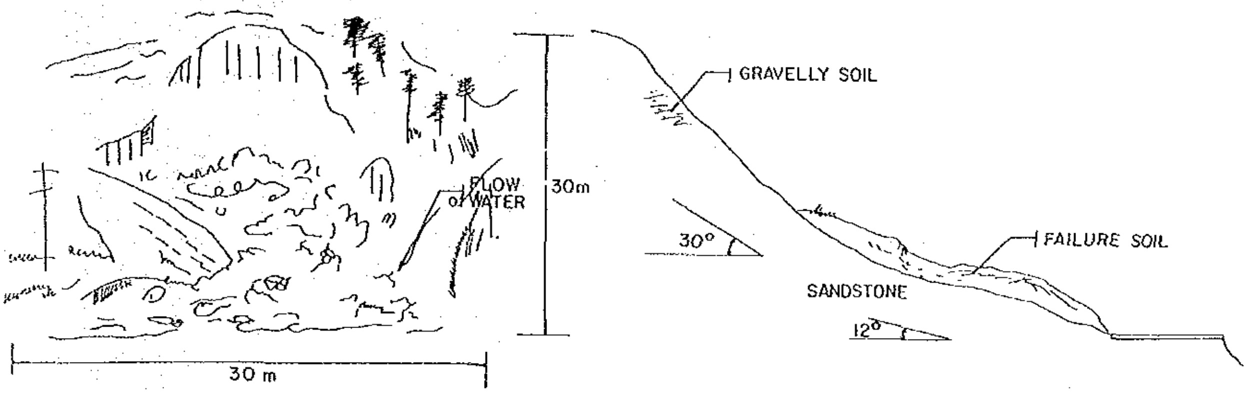
Step 6: Surface or seepage water is anticipated.
Thus, a surface drainage system is required.

Special Condition:
A water way is required because of the convergence of flow of water. Thus, a stone pitching water way and pipe culvert is proposed for this spot.

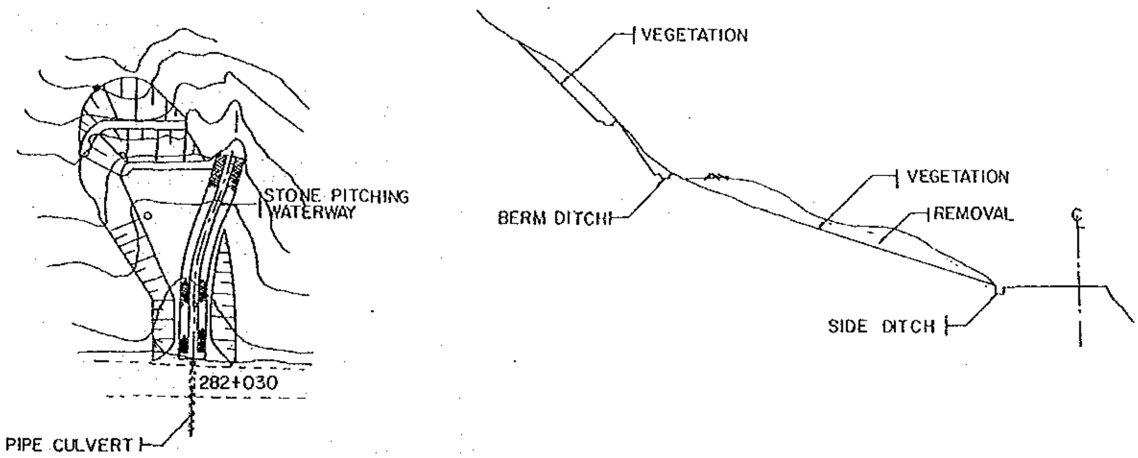
Recapitulation of Proposed Works

- Slope re-shaping . . . . Removal
- Slope protection . . . . Vegetation
- Drainage . . . . .Berm ditch, Side ditch
- Flow of Water . . . . .Stone pitching
  Water way and Pipe Culvert.

See Figure 6.4-1(b).



(a) Present Condition



(b) Proposed Countermeasure

FIGURE 6.4-1 CASE STUDY I CUT SLOPE FAILURE SPOT NO. IN-4-1

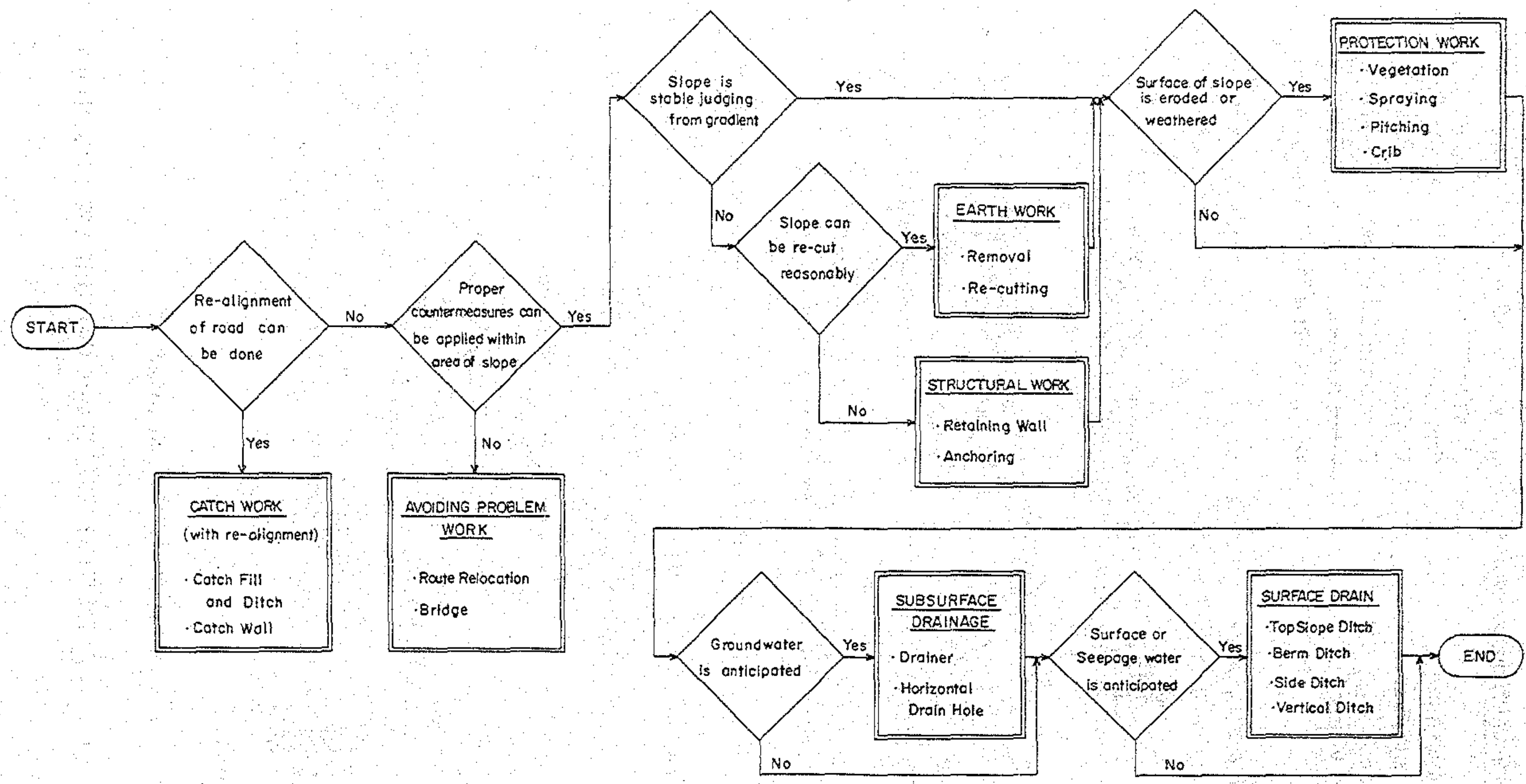


FIGURE 6.4-2 FLOW CHART FOR SELECTION OF COUNTERMEASURES OF CUT SLOPE FAILURE

6.4.2 Case Study 2: Embankment Slope Failure

1) Spot

Spot IN-8-5 at km. 291 + 050, in the Naguilian Road has been selected for Case Study 2 as a typical case of deep failure of an embankment slope. This particular type of disaster has been experienced rather often not only in the Naguilian Road but also in the Lucena-Calauag Section. Because embankment failures generally required a similar countermeasure work, the basics discussed herein may be widely applicable to this type of disaster.

Geological Condition: Embankment with cohesive soil.
Water Condition: Concentration of surface water of road.

2) Description of Failure

During typhoon Maring in August 1984, the embankment shouler of the road failed at the spot where the alignment is convexed. Usually, embankment failure occurs at concaved portion of the embankment where surface water flows and converges. In this case, the small rip-rap of about 3 m high was damaged at first and finally collapsed because of the continuous rain. See Figure 6.4-3(a).

3) Cause of Failure

Although the Naguilian Road is relatively well equipped with ditches of stone pitching, it is assumed that the failure was caused by the rainwater which converged at the point where local damage of the stone pitching was left unrepaired, washed away the stone pitching and then penetrated into the embankment soil. This is an example of a potentially small failure which deteriorated gradually to become a large failure under continuous rainfall.

4) Proposed Countermeasures

In the report entitled "an Approach on Road Disaster Prevention" prepared in the Stage I Study, countermeasures for embankment failures were classified into the followig four types as shown in Section 6.3 of this report.

- Drainage Work — Surface Drainage
  Subsurface Drainage
- Protection Work — Vegetation
  Pitching
  Crib
- Earth Work — Re-filling
- Structural Work — Stone Masonry Retaining Wall
  Gravity Type Retaining Wall
  Supported Type Retaining Wall

The procedure for the selection of countermeasures is shown in the Flow Chart of Figure 6.4-4.

For this spot, the following factors such as the condition of the slopes, geology and water were considered in accordance with the procedure in the Flow Chart.

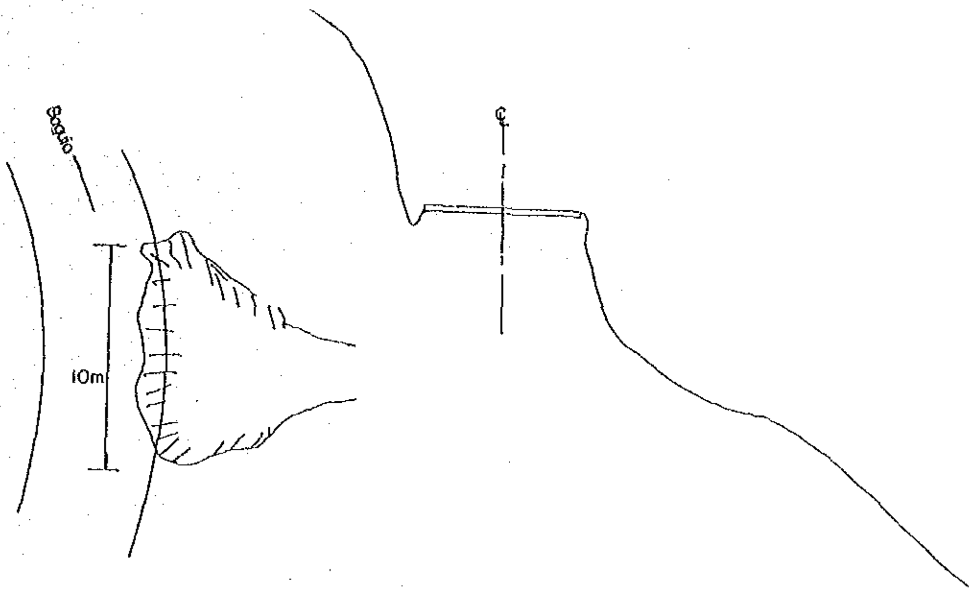
Flow of Countermeasure Selection

Step 1: Re-filling can be applied.
Step 2: Slope is steeper than a standard gradient.
Step 3: Expected earth pressure is at a minimum judging from gradient and height of the slope. Thus, stone masonry retaining wall was selected together with re-filling earth work.
Step 4: No groundwater is anticipated.
Step 5: Surface or seepage water is anticipated. Thus, berm and side ditches are required.

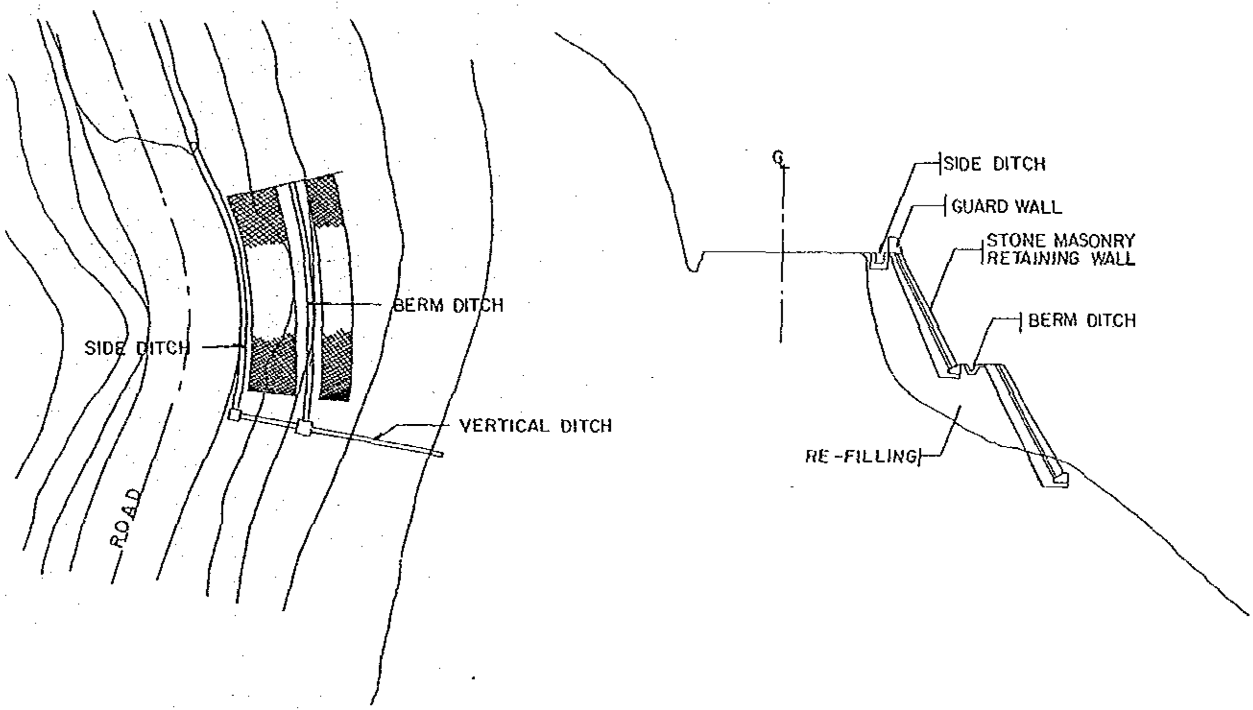
Recapitulation of Proposed Countermeasures

- Slope re-shaping . . . . .Re-filling
- Slope protection . . . . .Stone masonry retaining wall
- Drainage . . . . .Berm ditch, side ditch

See Figure 6.4-3(b).



(a) Present Condition



(b) Proposed Countermeasures

FIGURE 6.4-3 CASE STUDY 2 EMBANKMENT SLOPE FAILURE SPOT NO. IN-8-5

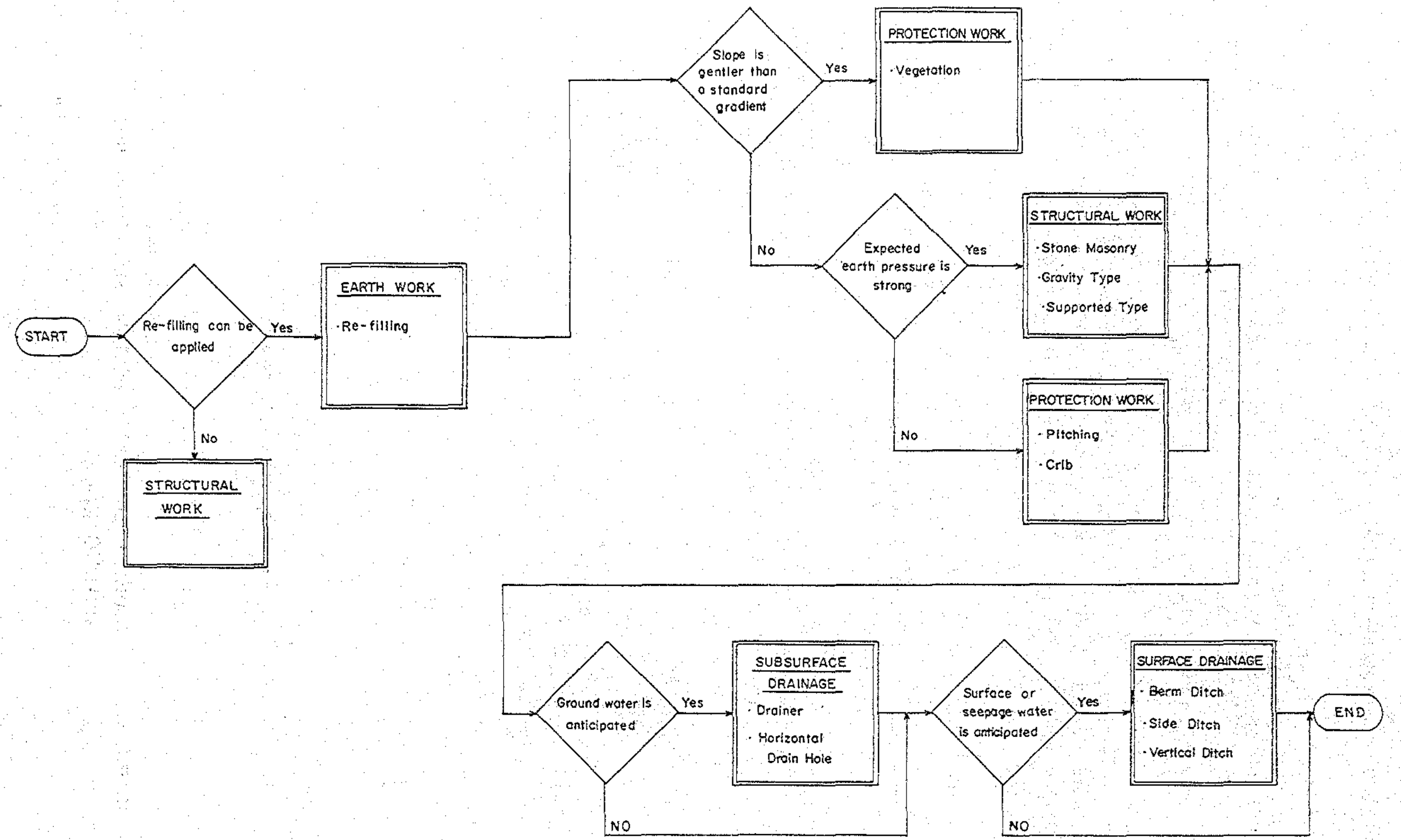


FIGURE 6.4-4 FLOW CHART FOR SELECTION OF COUNTERMEASURES OF EMBANKMENT SLOPE FAILURE

6.4.3 Case Study 3: Fall

1) Spot

Spot VIII-21 at Km. 703 + 800 in the Allen-Calbayog Section of the Maharlika Highway has been selected for Case Study 3. For this spot, discussion is made on concrete spraying which is the common countermeasure against fall as well as cut slope failure.

Geological Condition:
- Sandstone.
- Slightly weathered and regular cracks.

Water Condition:
- Water from hinterland of the slope.

2) Description of Fall

This cut slope is about 30 meters high and 100 meters long. The bedrock of the slope is slightly weathered sandstone with regular degree of cracks, falling in pieces of about 50 to 100 centimeters in diameter. Under heavy and continuous rain, earth and sand fall together with the rocks. See Figure 6.4-5(a).

3) Cause of Fall

Falling rocks were detached from bedrock mass because of loss of combining force between each unit of bedrocks due to seepage of water and erosion.

4) Proposed Countermeasures

Likewise, countermeasures for fall were also classified into the following six types as presented in Section 6.3 of this report:
- Drainage Work — Surface Drainage
- Protection Work
- Earth Work
- Fixing Work
- Catch Work
- Rock Shed

The procedure for the selection of countermeasures is shown in the Flow Chart of Figure 6.4-6.

For this particular spot, the following factors such as the condition of the slope, geology and water were taken into consideration in accordance with the procedure shown in the Flow Chart.

Flow of Countermeasures Selection

Step 1: Re-alignment of the road cannot be done because of the sea at the opposite side.

Step 2: Proper countermeasures can be applied within the areal boundary of the slope, judging from the size of the disaster, affected area and the size and shape of slope.

Step 3: Slope is stable judging from the gradient of 50° and the kind of rock.

Step 4: Detached rocks or supportless stones do not exist on the slope.

Step 5: The surface of slope is eroded or weathered.
Thus, protection work is required.

Among various type of protection works, concrete spraying was chosen because vegetation cannot grow, while pitching and crib work are costly.

Step 6: Surface or seepage water is anticipated.
Thus, the surface drainage, particularly, berm ditch, side ditch were selected.

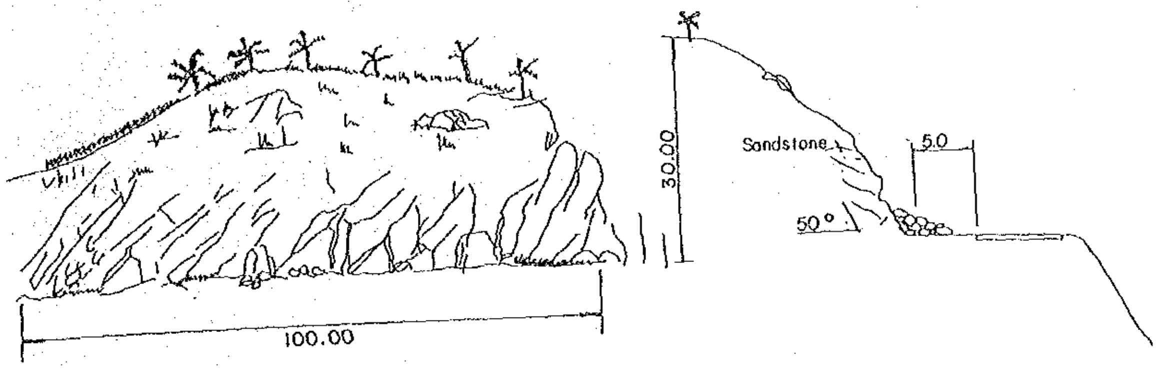
Recapitulation of Proposed Countermeasures

- Slope re-shaping —In case of concrete spraying, the irregularity of surface of slope should be roughly corrected.

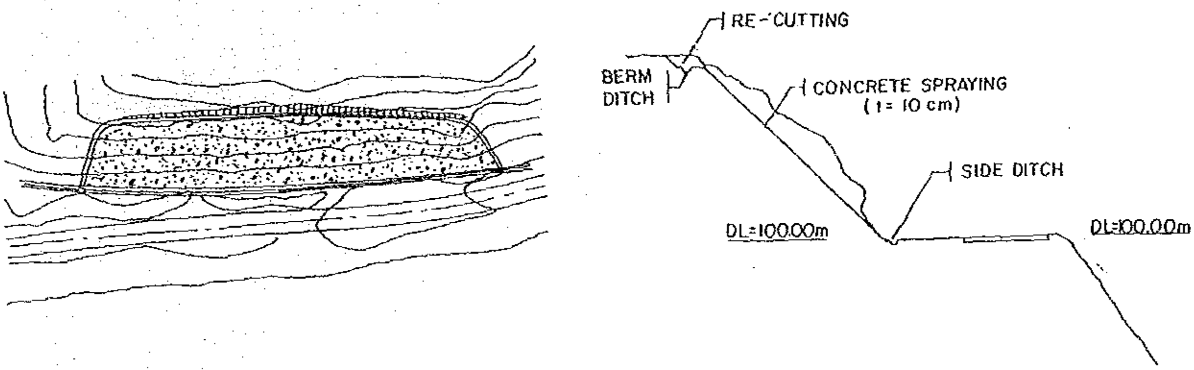
- Slope Protection —Concrete Spraying.
Thickness of concrete is 10 centimeters because cracks are not so deep.

- Drainage —Berm ditch, side ditch.

See Figure 6.4-5(b).



(a) Present Condition



(b) Proposed Countermeasures

FIGURE 6.4-5 CASE STUDY 3 FALL SPOT NO. VIII-21

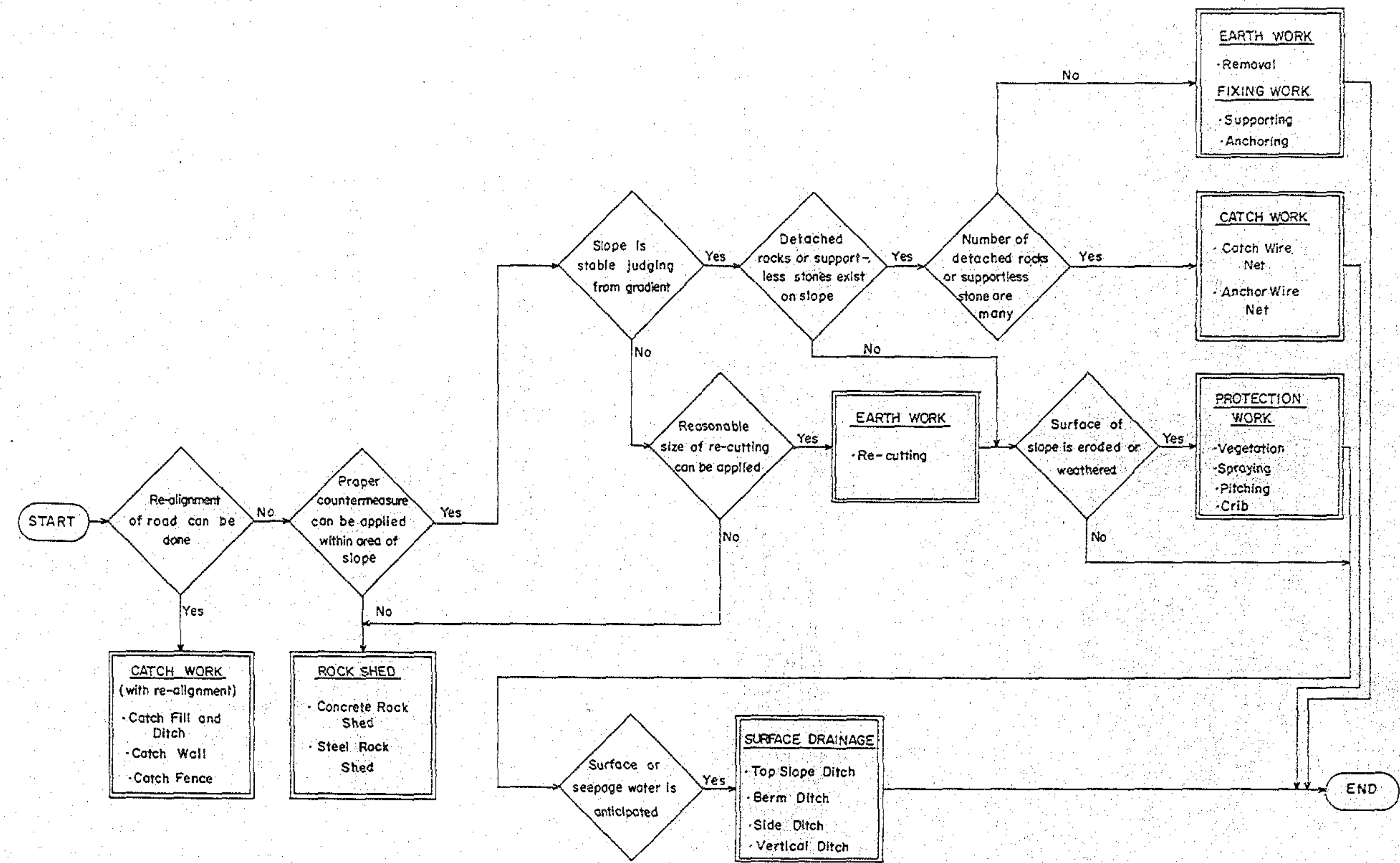


FIGURE 6.4-6 FLOW CHART FOR SELECTION OF COUNTERMEASURES OF FALL

6.4.4. Case Study 4: Fall

1) Spot

Spot VIII-32, km. 709 + 600, in the Allen-Calbayog Section of Maharlika Highway has been identified for Case Study 4. The slope consists of bedrocks with alternate layers. At some portion of the slope, cracks run inclined to the road and at other potion inclined to the mountain. For this particular spot, typical example of fall is discussed.

Geological Condition:
- Alternative layers of sandstone and shale.
- Slightly weathered and developed cracks.
- Cracks inclined to road.

Water Condition:
- Water from hinterland.

2) Description of Fall

This cut slope is about 20 meters high and 120 meters long. This slope consists of alternating sandstone and shale with developed cracks and weathered surface. At the northern portion of the slopes, cracks run inclined to the road where fallen rocks are flat and at the southern portion, cracks run inclined to the mountain where fallen rocks are angular and cubic. See Sigure 6.4-7 (a).

3) Cause of Fall

Generally in the case of alternating layers of rocks, rainwater permeates into the softer layer. This causes the initiation and propagation of its cracks, then gradually makes the harder layer unstable or supportless until the latter starts falling in pieces. In the case of this particular spot, the soft layer of shale was thin and was eroded, while the sandstone layer was the hard layer that falls into pieces.

4) Proposed Countermeasures

The procedure adopted in the Case Study 3 was also applied for this spot.

<u>Flow of Countermeasures Selection</u>

Step 1: Re-alignment of the road is possible because of the flat terrain at the opposite side of the slope. Thus, re-alignment method was selected. It is generally understood that the re-alignment work is more economical than other alternatives as proved by the comparative study shown in Appendix 6.4-1.

The construction cost for this spot is as follows:

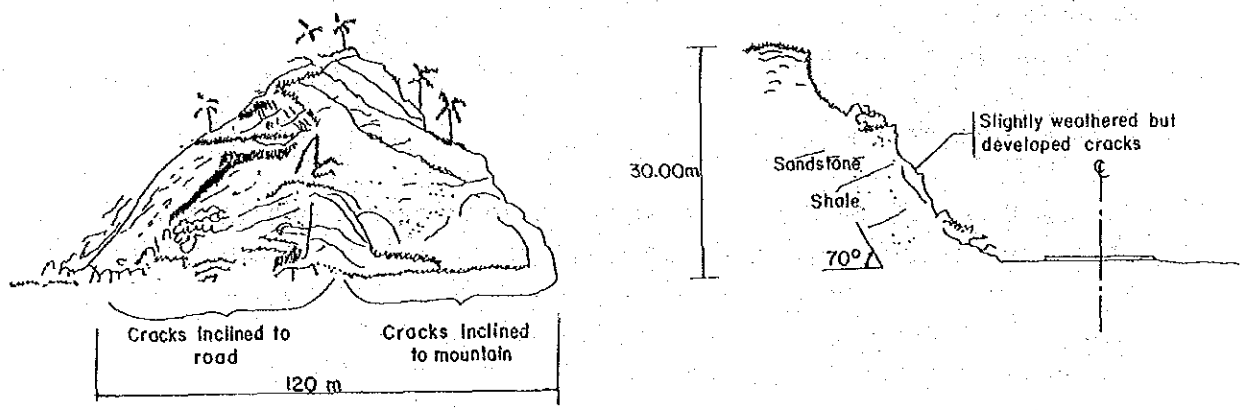
Re-alignment: 720,000 pesos

Concrete Spraying: 11,400,000 pesos

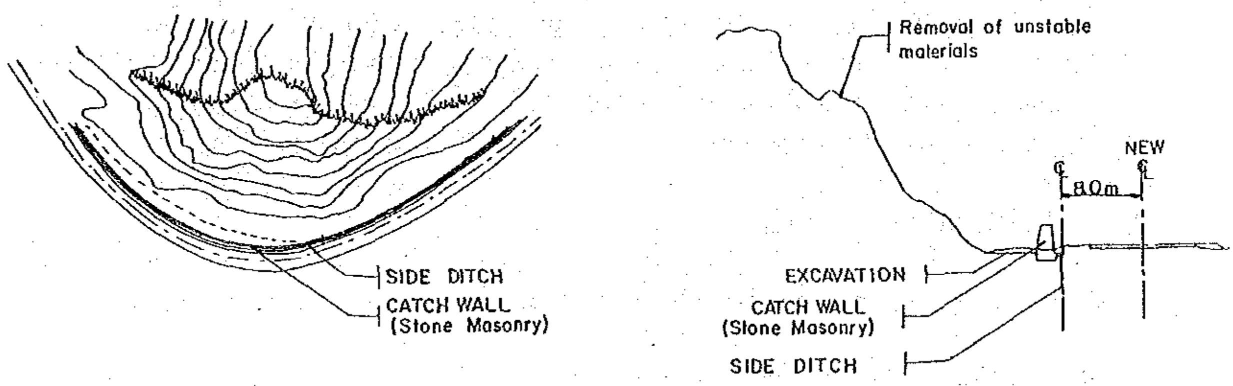
Recapitulation of Proposed Countermeasures

- Slope re-shaping — Unstable material on the slope shall be removed so that the maintenance work involving removal of the deposited material at the designed space can be minimized.
- Re-alignment —
  - Re-alignment of 8 meters
  - Stone Masonry Catch Wall
- Drainage — Side Ditch. Whatever protection work, side ditch should be always provided.

See Figure 6.4-7 (b)



(a) Present Condition



(b) Proposed Countermeasures

FIGURE 6.4-7 CASE STUDY 4 FALL SPOT NO. VIII-32

6.4.5 Case Study 5: Landslide

1) Spot

Spot IVA-20 at Km 160 + 000, in the Lucena-Calauag Section has been selected for Case Study 5 on landslide. The countermeasure work identified is the removal of earth which is the most fundamental countermeasure for landslide.

Geological Condition: Cohesive Soil
Water Condition: Concentration of Water at the left side of slope.

2) Description of Disaster

Found on this spot is a cliff measuring 2 to 4 meters high which is considered the evidence of landslide at hillside along the road. Above the scraped-off cliff is relatively precipitous hills. In view of the fact that the cliff shows the exposure of bedrock, it is believed that the covering earth has slide down on the plane of slide between the rock and the earth. See Figure 4.6-8 (a).

3) Cause of Failure

Rainwater running down the steep hillside saturated the soil of the lower moderate hillside until the soil lost shearing force and slid down over the bedrock. The maximum thickness of the earth/sand layer that slid down was approximately 2 meters as determined by a boring test. The earth/sand that has slid down will possibly flow out further to the road under heavy rain in the future.

4) Proposed Countermeasures

The countermeasures for landslide were also classified into the following four types as presented in Section 6.3 of this Report:

- Drainage — Surface Drainage
  —Subsurface Drainage
- Protection Work
- Earth Work
- Structural Work

The procedure for the selection of countermeasures are shown in the flow chart in Figure 6.4-9.

For this spot, factors such as the condition of the slope, geology and water were considered in accordance with the procedure shown in the flow chart.

Flow of Countermeasures Selection

Step 1: Earth work can be applied.
Since earth work is a practical and economical method as compared with structural work, it should be adopted wherever applicable.
Thus, earth removal work was proposed considering the easiness of construction because of topographical condition.

Step 2: A bare area exists in the landslide area.
Although the slope presently has no bare area, a bare area will be exposed as a result of earth removal.

Step 3: Groundwater is not abundant and its level is not high. Thus, the sub-surface drainage is not required.

Step 4: Surface water seepages into slide mass.
Thus, surface drainage, especially, top ditch, berm ditch and side ditch are necessary.

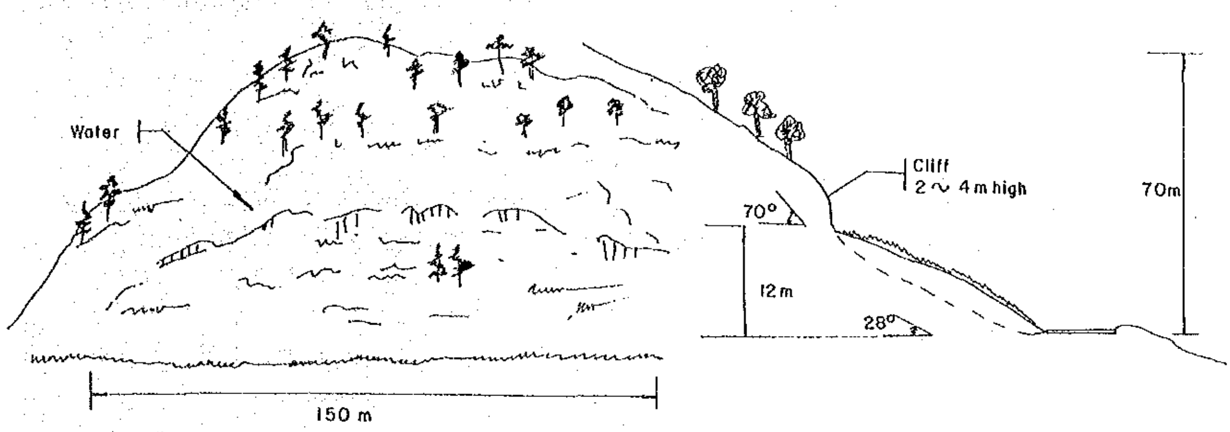
Special Consideration:

A water way is deemed necessary because of the convergence of flow of water at the left side of the slope. As the countermeasures for this water flow, stone pitching water way and pipe culvert are proposed.

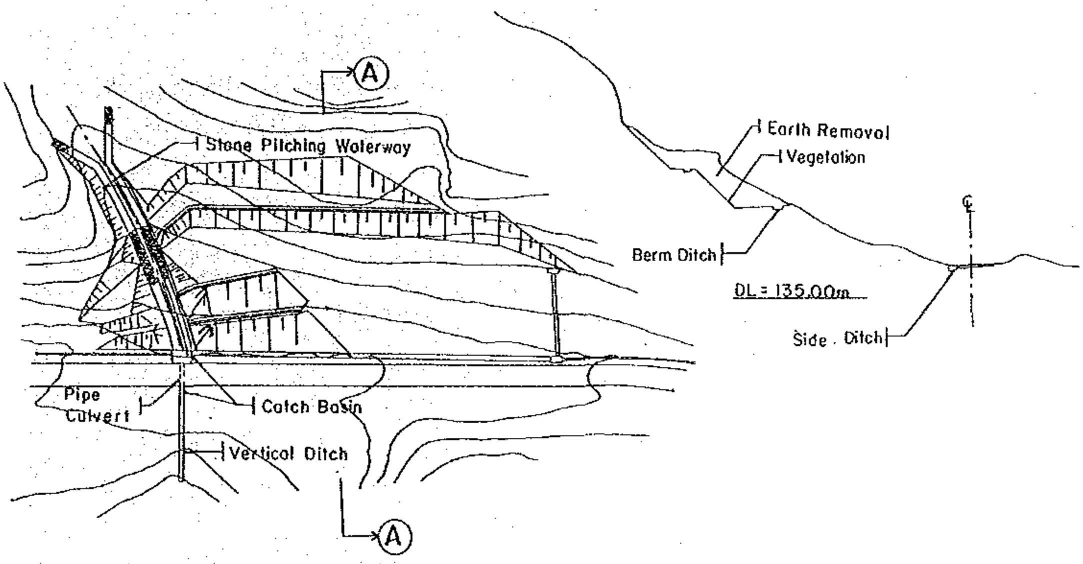
Recapitulation of Proposed Countermeasures

- Countermeasures — Earth Removal of top of slide mass.
- Slope Protection — Vegetation
- Drainage — Top Ditch, Berm Ditch, Side Ditch.
- Flow of Water — Stone Pitching Water Way, Pipe Culvert.

See Figure 4.6-8 (b)



(a) Present Condition



(b) Proposed Countermeasures

FIGURE 6.4-8 CASE STUDY 5 LANDSLIDE SPOT NO. IV-A-20

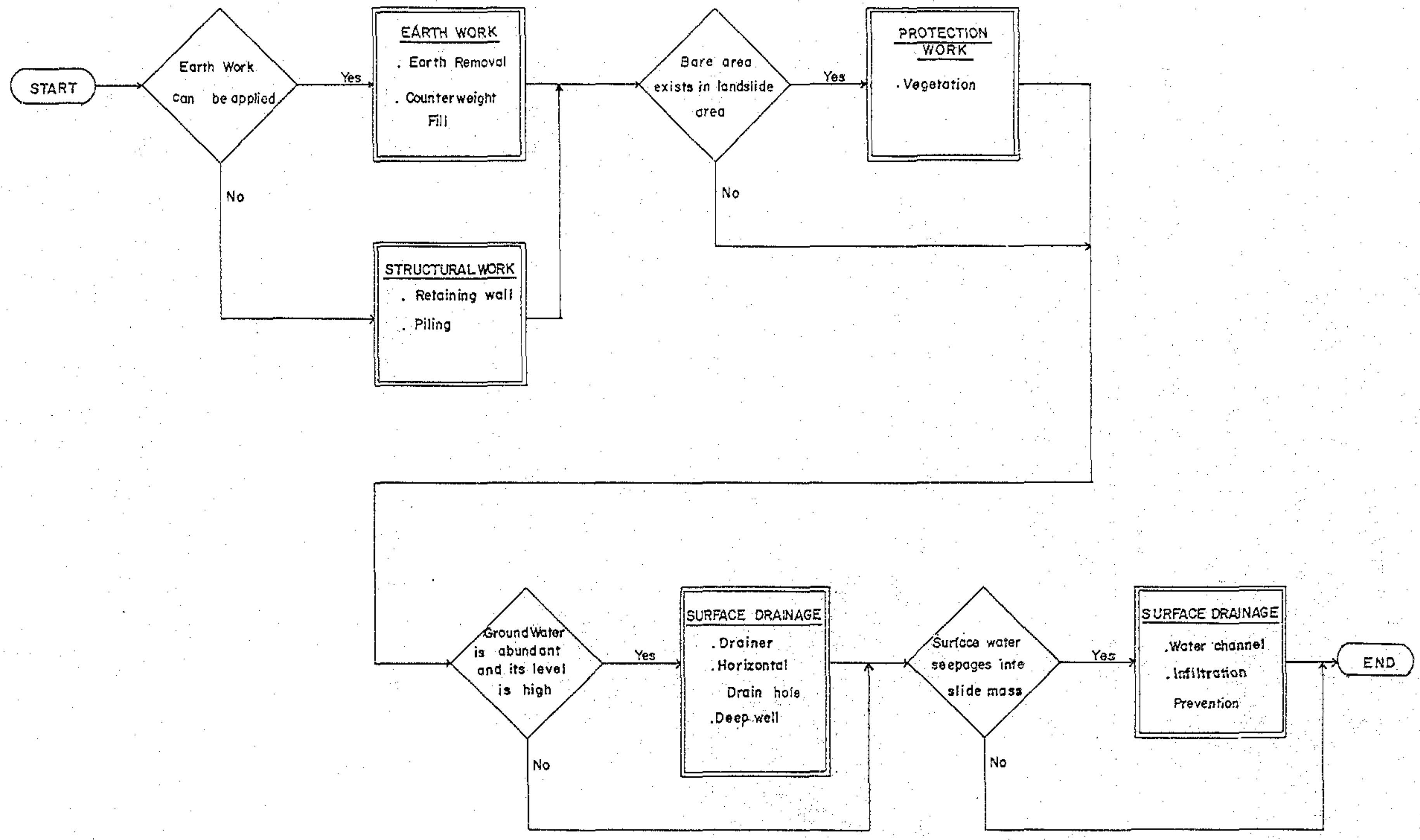


FIGURE 6.4-9 FLOW CHART FOR SELECTION OF COUNTERMEASURES OF LANDSLIDE

6.4.6 Case Study 6: Debris Flow

1) Spot

Spot VIII-16 at km. 698 + 300 in the Allen-Calbayog Section of Maharlika Highway has been selected for Case Study 6, a typical case of debris flow. Discussion herein includes the basics of countermeasure selection against individual cases of minor debris flow which has a rather high incidence.

Geological Condition:
Loose Alluvial earth.

Water Condition:
- Water from hinterland converges at this small valley.
- Level of groundwater is high.

Slope failure observed on the cut slope adjacent to the road is not discussed here as the Case Study.

2) Description of Disaster

The debris flow occured at this spot is reported to have crushed houses across the road, killing some number of people in 1982. According to the local inhabitants, minor debris flows have occured every year. Although the slope is considered relatively stable after the occurence of failure, minor cases of debris flow are likely to happen in the future in view of the spring water found at the foot of the hill. See Figure 6.4-10 (a).

3) Cause of Debris Flow

At this spot, the soil is loose alluvial earth, the groundwater level is high and the topography is such that surface water converges on this spot. Continous heavy rain saturated the soil which caused the debris flow.

4) Proposed Countermeasures

The countermeasures for debris flow were also classified into the following four types as shown in Section 6.3 of this Report.

- Hillside Work
- Torrent Work
- Sabo Work
- Avoiding Problem Work

The procedure for the selection of countermeasures is shown in the Flow Chart of Figure 6.4-11.

For this spot, the following factors such as the condition of hillside slope, torrent and water were taken into consideration in accordance with the procedure shown in the flow chart.

Flow of Countermeasures Selection

Step 1: Reasonable size of countermeasure can be applied since this involves minor debris flow.

Step 2: Failures or waste area exist in the hillside.
Since debris or mud has come from the area, hillside work is necessary. The slope composed of loose alluvial earth is highly eroded so that recutting is recommended. When re-cutting is applied, vegetation and surface drainage system shall be employed.

Step 3: Ground water is abundant and its level is high.
To drain groundwater and lower pore water pressure, horizontal drain holes and closed conduits are proposed.

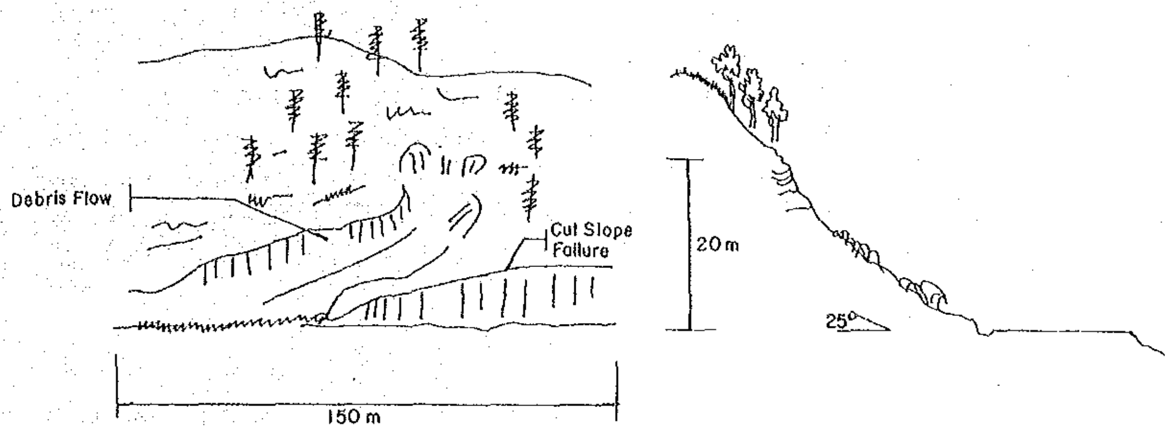
Step 4: Gradient of stream bed is not so steep, therefore a large amount of debris may not be produced. Thus, sabo work may not be necessary.

Step 5: Flow of water shall be controlled whereby overflow of flood to adjacent area shall be prevented. Thus, a water way, more precisely a stone pitching water way, is required.

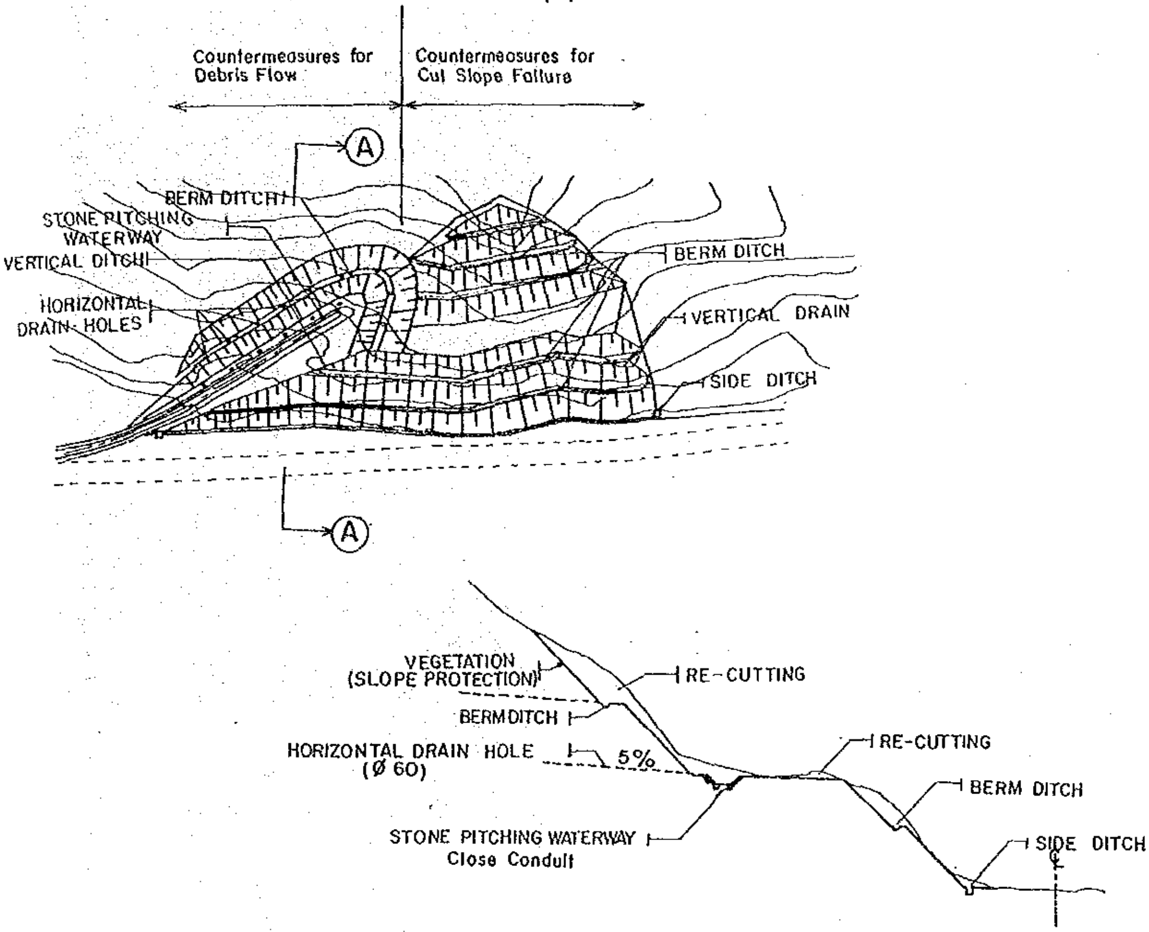
Recapitulation of Proposed Countermeasures

- Hillside Work — Re-cutting, Vegetation, Surface Drainage
- Hillside Work (Subsurface Drainage)
  —Horizontal Drain Hole, Closed Conduit.
- Torrent Work — Stone Pitching Water Way.

See Figure 6.4-10 (b)



(a) Present Condition



SECTION A-A

(b) Proposed Countermeasures

FIGURE 6.4-10 CASE STUDY 6 DEBRIS FLOW SPOT NO. VIII-16

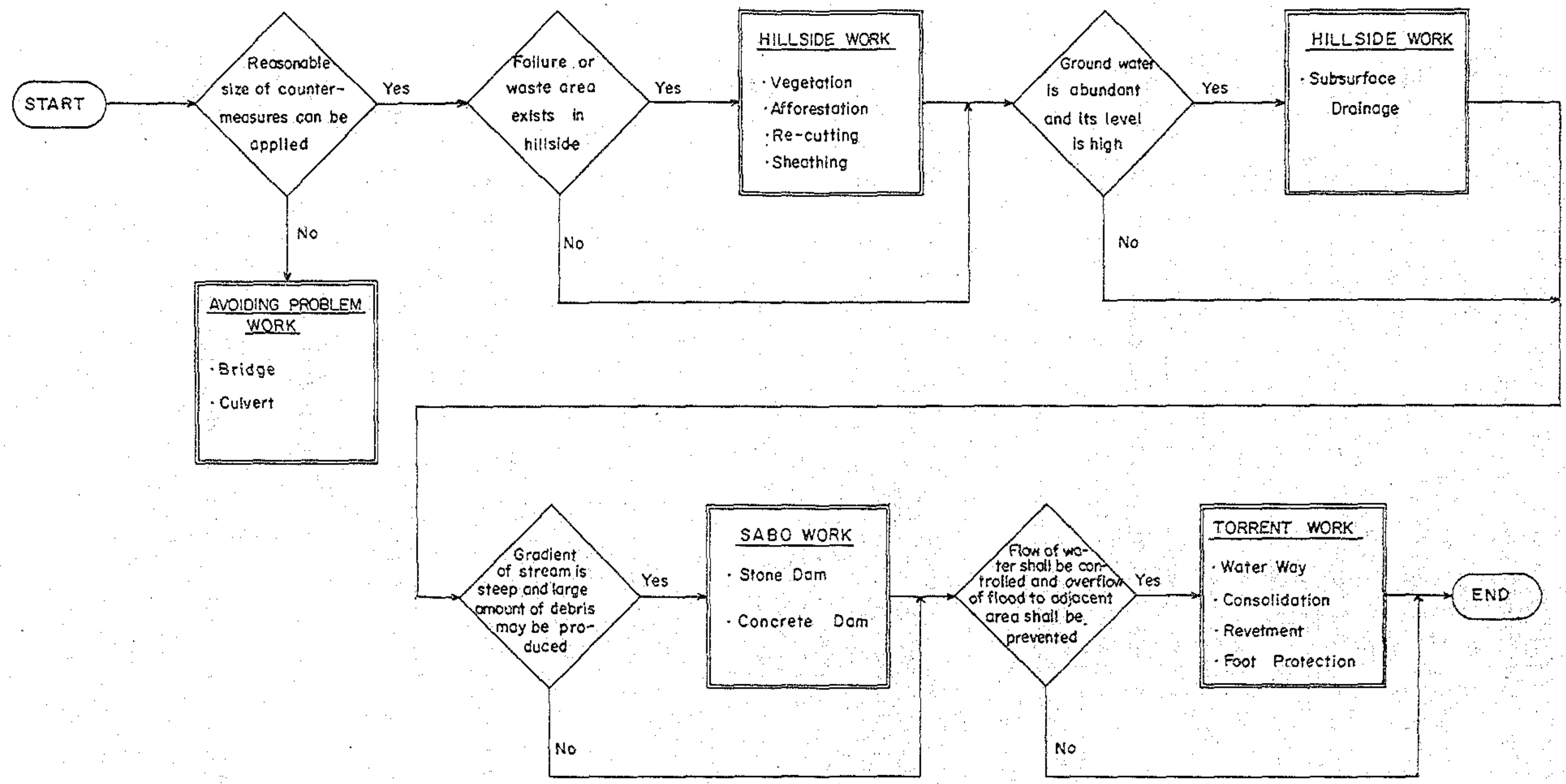


FIGURE 6.4-11 FLOW CHART FOR SELECTION OF COUNTERMEASURES OF DEBRIS FLOW

6.5 APPLIED COUNTERMEASURES

The number of the main countermeasures applied for each design spot of the Study Sections is summarized by types of disasters in Table 6.5-1. The number of the main and secondary countermeasures adopted is shown by type of disasters and by the Study Sections in Table 6.5-2. While, the types of the main and secondary countermeasures applied for each design spot are reported in Table 6.5-3.

Detailed information on applied countermeasures including sketchy illustrations of slopes, geological and water condition and the main factors for the selection of countermeasures are reported in Appendix 6.5-1.

1. Countermeasures of each Study Section

   Of the total 36 design spots which urgently require countermeasures, the Naguilian Road has the largest number amounting to 15 spots, followed by 14 spots for the Allen-Calbayog Section and 7 spots for the Lucena-Calauag Section.

   The largest number of countermeasures with a total of 51 was applied for the Allen-Calbayog Section, followed by the Naguilian Road with 50 and the Lucena-Calauag Section with 26. The average number of countermeasures applied for each spot is 3.9 in the Lucena-Calauag Section, 3.6 in the Allen-Calbayog Section and 3.3 in the Naguilian Road. This indicates that there are relatively large scale disasters in which conjective application of measures was required in the Lucena-Calauag Section as comapred to the other two sections.

   The main countermeasures proposed for each section are the re-alignment method for both the Lucena-Calauag Section and the Allen-Calbayog Section and stone masonry and anchor wire net work for the Naguilian Road.

   Among the countermeasures applied for all types of disaster, excluding earth removal and re-cutting work, surface drain work has the largest number with 34, 18 for rock falls, 7 for cut slope failures, 6 for embankment failures and 3 for others. Surface drainage work was applied in many cases because many slope failures were brought about by erosion or scouring due to the flow of surface water during rainfall.

2. Countermeasures for Cut Slope Failures

   The main countermeasures proposed for the total of 7 spots of cut slope failure are re-cutting and anchor wire net work for 2 spots each and re-alignment, vegetation and stone pitching retaining wall for 1 spot each.

With regards to the countermeasures applied for cut slope failure, surface drain work has the largest number with 7, followed by 6 each for earth removal and re-cutting and 2 each for anchor wire net and catch wall.

This proves that most of cut slope failures were caused by surface water flow on the slopes. Removal work was applied in most cases because unstable materials have to be removed no matter what types of countermeasures were applied.

3. Countermeasures for Embankment Slope Failure

Stone masonry retaining wall with re-filling was adopted as the main countermeasure for all of the 8 spots of embankment slope failures.

Side ditch as one of surface drain works was also applied whenever surface drainage system were inadequate. It should be recognized that measures to drain water is very important to prevent embankment failures.

4. Countermeasures for Fall

Of the total of 18 spots of fall, re-alignment is the largest number of the main countermeasures amounting at 7 spots, followed by concrete spraying at 5, anchor wire net at 4 and re-cutting work at 2.

Re-alignment method with catch wall was proposed at 5 spots in the Allen-Calbayog Section and 2 spots in the Lucena-Calauag Section (plus 1 for cut slope failure). Because the terrain in these sections is rather flat and there is a wide space between the road edges and the toe of slopes to allow for the slight shifting of the alignment of the existing road. In this case, catch wall was always included in the design to prevent the spread of damages of falling rocks.

5. Countermeasures for Landslide

For the only one spot of landslide in the Study Section, earth removal work was applied as the main countermeasure together with surface drain and stone pitching waterway.

6. Countermeasures for Debris Flow

The main countermeasure applied for debris flow was stone pitching waterway and drainage work. Since only small or medium size of debris flow is subject to design in the Study, the above two works were automatically selected as countermeasures.

TABLE 6.5-1 MAIN COUNTERMEASURES FOR EACH TYPE OF DISASTER

Type of Countermeasure / Type of Disaster	Number of Design Spots	Removal	Re-cutting	Vegetation	Concrete Spraying t = 10^{cm}	Concrete Spraying t = 15^{cm}	Anchor Wire Net	Stone Masonry R. W.	Stone Pitching Waterway	Re-alignment	T o t a l
Cut Slope Failure	7		2	1			2	1		1	7
Embankment Slope Failure	8							8			8
Fall	18		2		3	2	4			7	18
Landslide	1	1									1
Debris Flow	2								2		2
T o t a l	36	1	4	1	3	2	6	9	2	8	36

TABLE 6.5-2 NUMBER OF APPLIED COUNTERMEASURES

SECTION	DISASTER TYPE	DISASTER SPOT NUMBER	APPLIED COUNTERMEASURES: EARTH WORK		DRAINAGE WORK		PROTECTION WORK		CATCH WORK		STRUCTURE WORK			TORRENT WORK		AVOIDING WORK	TOTAL
			REMOVAL/ RE-CUTTING	RE-FILLING	SURFACE DRAIN	SUB-SURFACE DRAIN	VEGETATION	CONCRETE SPRAYING	ANCHOR WIRE NET	CATCH WALL	STONE MASONRY R.W.	GRAVITY TYPE R.W.	ANCHORING	STONE PITCHING WATER WAY	GABION F.P.	RE-ALIGNMENT	
LUCENA-CALAUAG SECTION	C-SF, DF	1	1	-	1	-	-	-	-	1	-	-	-	-	-	1	4
	E-SF, DF	1	-	1	1	-	-	-	-	-	1	-	-	-	-	-	3
	C-F	4	4	-	4	-	-	2	-	2	-	-	1	-	-	2	15
	L.S	1	1	-	1	-	1	-	-	-	-	-	-	1	-	-	4
	D.F	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	SUB-TOTAL	7	6	1	7	0	1	2	0	3	1	0	1	1	0	3	26
ALLEN-CALBAYOG SECTION	C-SF, DF	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	2
	E-SF, DF	2	-	2	-	-	-	-	-	-	2	1	-	-	1	-	6
	C-F	9	9	-	9	-	-	3	1	7	-	-	-	-	-	5	34
	L.S	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	D.F	2	2	-	2	1	1	-	-	1	-	-	-	2	-	-	9
	SUB-TOTAL	14	12	2	12	1	1	3	1	8	2	1	-	2	1	5	51
NAGUILIAN ROAD	C-SF, DF	5	4	1	5	-	2	-	2	1	1	1	1	1	-	-	19
	E-SF, DF	5	-	5	5	-	-	-	-	-	5	1	-	-	-	-	16
	C-F	5	5	-	5	-	-	1	3	-	-	-	1	-	-	-	15
	L.S	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	D.F	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	SUB-TOTAL	15	9	6	15	0	2	1	5	1	6	2	2	1	0	0	50
TOTAL	C-SF, DF	7	6	1	7	-	2	-	2	2	1	1	1	1	-	1	25
	E-SF, DF	8	-	6	6	-	-	-	-	-	8	2	-	-	1	-	25
	C-F	18	18	-	18	-	-	6	4	9	-	-	2	-	-	7	64
	L.S	1	1	-	1	-	1	-	-	-	-	-	-	1	-	-	4
	D.F	2	2	-	2	1	1	-	-	1	-	-	-	2	-	-	9
	TOTAL	36	27	9	34	1	4	6	6	12	9	3	3	4	1	8	127

NOTE :

TYPE OF DISASTER

- C-S.F, D.F Cut slope surface failure, deep failure
- E-S.F, D.F Embankment slope surface failure, deep failure
- C-F Cut slope rock fall
- L.S Landslide
- D.F Debris flow

R.W RETAINING WALL

F.P FOOT PROTECTION

TABLE 6.5-3 COUNTERMEASURES APPLIED TO EACH DISASTER SPOTS

NOTE:
●; MAIN COUNTERMEASURE
○; SECONDARY COUNTERMEASURE

SECTION			LUCENA-CALAUAG SECTION							ALLEN-CALBAYOG SECTION														NAGUILIAN ROAD															TOTAL
SPOT NUMBER			IVA-6	IVA-7	IVA-8	IVA-15	IVA-17	IVA-18	IVA-20	VIII-6	VIII-13-1	VIII-16	VIII-18	VIII-21	VIII-27	VIII-28	VIII-29	VIII-30	VIII-31	VIII-32	VIII-33	VIII-36	VIII-37	IN-3-2	IN-4-1	IN-4-4	IN-4-5	IN-5	IN-7	IN-8-4	IN-8-5	IN-10	IN-12	IN-13	IN-14	IN-15	IN-15-1	IN-16	
KM			153+900	154+100	155+100	157+600	158+500	158+900	160+800	686+900	694+700	698+300	701+200	703+800	705+200	705+600	708+200	708+600	708+650	709+600	717+700	718+100	718+500	276+550	281+500	286+600	287+800	288+300	288+700	291+000	291+050	293+500	294+100	294+400	294+600	294+600	294+800	298+200	
TYPE OF DISASTER			C-F	C-F	E-D.F	C-F	C-D.F	C-F	L.S	C-F	E-D.F	D.F	E-D.F	C-F	C-F	C-F	C-F	C-F	C-F	C-F	C-S.F	D.F	C-F	E-D.F	C-D.F	E-D.F	E-D.F	C-F	C-F	C-S.F	E-D.F	C-F	C-F	C(N)-S.F	E-D.F	C(N)-F	C(N)-S.F	C-S.F	
TYPE OF COUNTERMEASURE																																							
EARTH WORK		Removal/Re-cutting	○	○		○	○	○	●	○		○		○	○	○	○	○	●	○	●	○	○		○			○	●			○	○	○		○	○	●	27
EARTH WORK		Re-filling			○						○		○											○		○	○			○	○				○				9
DRAINAGE WORK	SURFACE DRAINAGE	Top Slope Ditch				○		○		○		○		○				○	○		○							○										○	10
DRAINAGE WORK	SURFACE DRAINAGE	Berm Ditch				○		○	○			○						○	○		○	○			○					○	○				○			○	13
DRAINAGE WORK	SURFACE DRAINAGE	Vertical Ditch			○			○		○		○		○														○										○	7
DRAINAGE WORK	SURFACE DRAINAGE	Side Ditch	○	○	○	○	○	○	○	○		○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	34
DRAINAGE WORK	SUB-SURFACE DRAINAGE	Close Conduit Ditch										○																											1
DRAINAGE WORK	SUB-SURFACE DRAINAGE	Horizontal Drain Hole										○																											1
PROTECTION WORK	VEGETATION	Seed Mud Spraying							○			○													●													○	4
PROTECTION WORK	SPRAYING	Concrete Spraying (t=10 cm)		●										●				●																					3
PROTECTION WORK	SPRAYING	Concrete Spraying (t=15 cm)						○		●																		●											3
CATCH WORK		Catch Wall				○	○	○							○	○	○	○		○		○	○						○								○		12
CATCH WORK		Anchor Wire Net	●							○																						●	●	●		●	●		7
STRUCTURAL WORK	RETAINING WALL	Stone Masonry Retaining Wall			●						●		●											●		●	●			●	●				●				9
STRUCTURAL WORK	RETAINING WALL	Gravity Type Retaining Wall											○																	○					○				3
STRUCTURAL WORK	ANCHORING	Rock Bolt																														○					○		2
TORRENT WORK	WATERWAY	Stone Pitching Water Way							○			●										●			○														4
TORRENT WORK	FOOT PROTECTION	Gabion Foot Protection											○																										1
AVOIDING WORK		Re-alignment				●	●	●							●	●	●			●			●																8

CHAPTER 7 PRELIMINARY DESIGN OF COUNTERMEASURES

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CHAPTER 7 PRELIMINARY DESIGN OF COUNTERMEASURES

7.1 LAND AND GEO-TECHNICAL SURVEYS

7.1.1 Land Survey

The following surveys at selected spots were conducted:

—Centerline and Profile surveys of existing road alignment.
—Cross-sectional survey and topography for design of countermeasures.

The volume of surveys conducted is summarized in Table 7.1-1.

TABLE 7.1-1 VOLUME OF SURVEYS

ITEM	Section			Total
	Lucena-Calauag	Allen-Calbayog	Naguilian Road	
Traverse and Profile Surveys	16 km	25 km	26 km	67 km
Cross-sectional surveys and topography	4 spots (16 sections)	11 spots (39 sections)	9 spots (15 sections)	24 spots

The traverse and profile surveys were only done for sections where the disaster spots to be examined exist, and no data on road alignment are available. Table 7.1-2 shows the length of surveys conducted.

TABLE 7.1-2 LENGTH OF CONDUCTED SURVEYS

Section	Total Section Length (km)	Length of Surveys Conducted (km)
Lucena-Calauag (M-10)	95.723	16.00
Allen-Calbayog (M-16)	72.936	25.00
Naguilian Road (M-3)	47.225	26.00

Accuracy of the survey is as follows:

—Traversing 1/10,000
—Profile . . . . 6 + $\sqrt{S}$ (cm)

Where S is horizontal length expressed in km.

Profile is drawn at a vertical scale of 1:200 and a horizontal scale of 1:2,000. Forty-five (45) temporary bench marks were established.

A cross-sectional survey at the disaster spots was conducted at every 50 m. interval for ordinary cases and 20 m. for complicated terrain. Topographical mapping was prepared indicating contourlines of 5 m. interval. Cross sections and topographical maps were made at a scale of 1:200 and 1:500, respectively.

A cross-sectional survey and topographical mapping were conducted only for big scale or typical disaster spots. For the others, sketches were made based on observation during ocular inspection or on available maps. Table 7.1-3 indicates the total number of disaster spots and surveyed spots.

TABLE 7.1-3 NUMBER OF DESIGN SPOTS AND SURVEY SPOTS

Section	Total Number of Spots	Number of Surveyed Spots	Number of Spots Designed Based on Sketch
Lucena-Calauag (M-10)	7	5	2
Allen-Calbayog (M-16)	14	12	2
Naguilian Road (B-3)	15	12	3
Total	36	29	7

7.1.2 Geo-technical Survey

Generally, a geo-technical survey for disaster investigation includes the following:

—survey and recording the topographical condition, kind of soil and rock, condition of slope protection, spring water, shape of failure by field investigation;

—sounding, boring to infer sliding plane of failure or landslide and condition of groundwater;
—for landslide, to survey movement of ground by landslide gauge.

Countermeasures were designed by putting together the results of all the above surveys.

In this study the following surveys were made:

—A check table with a sketch was prepared to show the present condition of disasters and the element which may be considered as cause of disaster. These are shown in the Appendix 7.1-2.

—Surveys to infer sliding plane and condition of groundwater were only conducted for spots of large scale cut slope failures, embankment slope failure and landslide. Details of surveys are shown in Table 7.1-4.

TABLE 7.1-4 QUANTITIES OF GEO-TECHNICAL SURVEY CONDUCTED FOR INVESTIGATION OF SLIDING PLANE AND GROUNDWATER

Spots	Km. Post	Kind of Disaster	Quantities Conducted Boring	Remarks
IVA-17	158 + 500	C-D.F	2 Holes 20 m	Lucena-Calauag
IVa-20	160 + 800	L.S.	3 Holes 60 m	-do-
IN-4-1	281 + 500	C-D.F	2 Holes 20 m	Naguilian Road
IN-4-4	286 + 600	E-D.F	1 Hole 10 m	-do-
IN-8-5	291 — 050	E-D.F.	1 Hole 10 m	-do-
Total			9 Holes 120 m	

Standard penetration tests were made for soil, while core borings were done for rocks. The level of groundwater was also surveyed.