3.2.2 Road Collapsing

1. Classification of Features

Road features are classified into three categories as shown in Fig. 3.2.3. Cut slopes are excluded and described in the slope damage section of this report (Section 3.2.4).

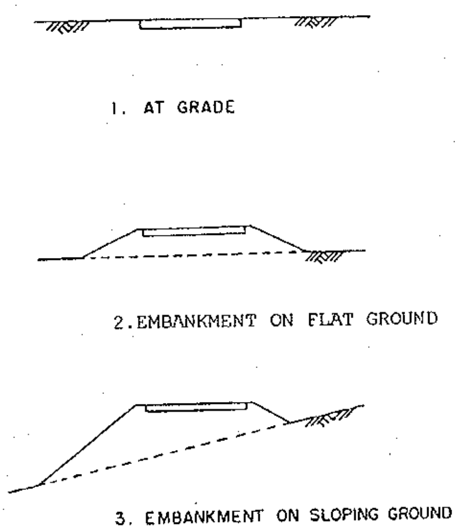


Fig. 3.2.3 Classification of Road Features

The above system is codified by using the letters and numbers of each subgroup. For example, the collapse of a road on an embankment on flat ground from the washing out of a shoulder is represented by RC-2-2.

2. Damage Classification

1) Scouring of Embankment

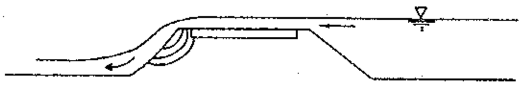
Scouring can affect a road embankment when rapidly moving flood waters flow parallel with the side slopes (as in side drainage ditches). If such a flow continues for a sustained period, the resultant scouring would produce major damage and eventually the whole embankment would collapse.

2) Washing Out of Embankment Shoulder

When flood waters overflow an embankment, the high velocity of the flow on the downstream side can wash out the road shoulder. The downstream side of a road embankment edge experiences maximum water velocity and is the most vulnerable.

The damage classification system is illustrated in Fig. 3.2.4.

1. SCOURING OF EMBANKMENT SLOPE



2. WASHING OUT OF SHOULDER AND EMBANKMENT

Fig. 3.2.4 Classification of Road Collapsing

3.2.3 Road Flooding

1. Classification of Features

The classification of features for road flooding is the same as that used in the Road Collapsing section (refer to Fig. 3.2.3).

2. Damage Classification

1) Inundation (sheet flooding)

This classification is used when there is no damage to a road embankment and the interruption to traffic is entirely due to the submergence of the road's surface. Here, water velocities are generally low but they may be of significant duration.

2) Overflows (channel flooding)

An overflow is potentially more destructive to an embankment than inundation, but this classification is used when there is no damage to a road embankment by an overflow.

3) Road Burial by Debris Flows

This classification is used when a road's surface is buried by the mass of material transported by debris flows. The damage classification is illustrated in Fig. 3.2.5.

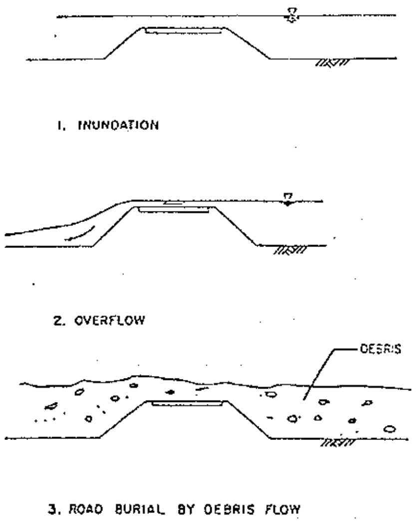


Fig. 3.2.5 Classification of Road Flooding

3.2.4 Slope Damage

1. Classification of Features

Slope damage can be subdivided based on the mechanism of failure and the nature of the features affected. The failure mechanisms are erosion, landslides and rockfalls. The features that are affected are natural slopes, cut slopes, fill slopes and embankments. The different types of features are illustrated in Fig. 3.2.6.

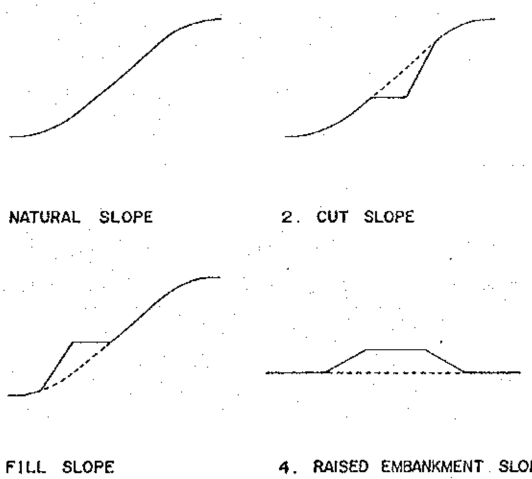


Fig. 3.2.6 Classification of Slope Features

1) Natural Slope

This classification is used if a failure has occurred on natural ground that has neither been cut nor filled.

2) Cut Slope

This classification is used only when a failure occurs in areas that have been excavated and material removed.

3) Fill Slope

This classification applies to failures that occur primarily at fills on sloping ground. There should be only one primary sloping fill face at the cross section.

4) Raised Embankments

This classification is used for raised mounds or embankments placed on gently sloping or flat ground that have two sloping fill faces.

2. Classification of Slope Damage

The principal causes for slope failure are divided into erosion, landslides, and rockfalls. They can further be subdivided into ten damage types as below.

1) Sheet Erosion

Sheet erosion is the sheet-like wearing away of surface material that leaves no individual channels. It is relatively uncommon as most natural materials have minor variations that result in local concentrations of erosion.

2) Rill Erosion

This form of erosion is characterized by numerous small parallel shallow channelways across a surface. This is common in a newly exposed surface.

3) Gully Erosion

This form of erosion is most common and typically consists of deeply incised channels. These may merge and result in a large cavity in the ground's surface.

4) Tunnel Erosion

This form of erosion occurs in ground with a large volume of groundwater flow. Frequently, this type of erosion is initiated by the roots of dead trees or piping of embankments that are ponding water upstream due to inadequate or blocked drainage facilities. It can also occur naturally in permeable friable material that has high groundwater pressure gradients. Tunnel erosion progresses from the surface back into a slope.

5) Scouring by an Incident Stream

This type of erosion is induced by water flows from external sources. High velocity flows from streams and rivers incident to engineering features such as the toes of fills or natural slopes or the sides of embankments are examples. Wave action is also included in this class.

6) Rotational Landslide

This classification is used when the movement of a mass is about a center of rotation resulting in an accurate sliding surface. This occurs most frequently in relatively homogeneous materials, such as alluvial and marine soils and fill slope.

7) Two-Dimensional (2D) Landslide

When a sliding surface is essentially planar, the movement is considered to be a two-dimensional translation. The crest and toe sections may be curved, but should not constitute more than 10% of the slip length. Rock slopes sliding on a single plane of weakness are examples. In fill slopes, the original ground surface may act as a 2D sliding surface if the top soil and vegetation were not first removed.

8) Three-Dimensional (3D) Landslide

When two planes of weakness intersect, they form a wedge. Sliding can occur down the direction of the intersection to form a three-dimensional translational mass. This kind of failure is usually restricted to cut and natural rock slopes with inclined intersecting joint sets.

9) Rockfalls by Toppling

This classification is used when individual rock blocks are dispatched by rotation about a plane inclined towards a roadway. The dispatching force can occur from a build up of water pressure in the back-face joint boundary. Steeply cut rock slopes with near vertical and horizontal orthogonal joint sets have the highest potential for this type of failure.

10) Rockfalls by Undercutting

Localized erosion can remove the matrix of soil that is supporting a block of rock. This is the most common form of rockfall as many natural slopes have quasi-stable blocks of rocks supported by loose soil and vegetation.

Classifications for erosion, landslides and rockfalls are illustrated in Fig. 3.2.7, Fig. 3.2.8 and Fig. 3.2.9, respectively.

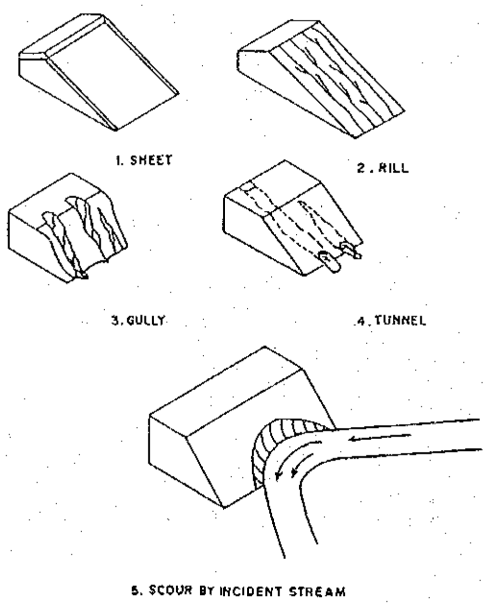
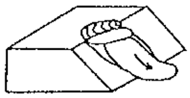
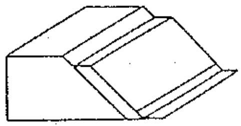


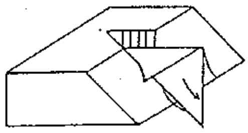
Fig. 3.2.7 Classification of Erosion



6. ROTATIONAL LANDSLIDE

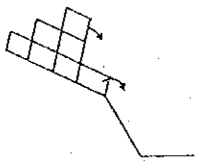


7. 2 DIMENSIONAL LANDSLIDE

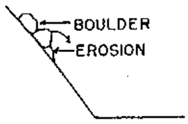


8. 3 DIMENSIONAL LANDSLIDE

Fig. 3.2.8 Classification of Landslides



9. ROCKFALLS BY TOPPLING



10. ROCKFALLS BY UNDERCUTTING

Fig. 3.2.9 Classification of Rockfalls

3.3 Selection of Project Roads

3.3.1 Selection Criteria for Project Roads

In order to identify project roads, a set of criteria has been established. These factors have been subdivided into technical criteria and socioeconomic criteria as shown below:

1. Criteria with respect to the development of a road disaster prevention and restoration plan (technical)

   1) Posses a high potential for future disasters

   2) Exhibit a past history of frequent and long traffic interruptions due to natural causes

   3) Exhibit a wide variety of different types of road disasters

   4) Have a wide variety of physical conditions

2. Criteria with respect to the importance of a road as part of the highway network (socioeconomic)

   1) Ensure uninterrupted traffic along a trunk road with high traffic volume

   2) Effect improvements to communications between urban centers

   3) Ensure access in emergencies

   4) Provide access to areas of interest to tourists

   5) Serve the interests of minorities

   6) Conform to the priorities of the 7th National Highway Development Plan

3.3.2 Selection Procedure

Project roads have been selected in accordance with the following procedures.

1. Identification of disaster-prone routes and areas through the analysis of past disaster records

Past disaster records covering all of Thailand for the last 10 years have been collected and plotted on the route maps. They enable the visual identification of disaster-prone areas.

2. Ascertaining of disaster-prone spots through site reconnaissances and interviews with DOH district office staff

Reconnaissance of disaster spots and interviews with district office staff responsible for the area were conducted in order to confirm the reported locations and to identify any unrecorded disaster-prone locations.

3. Selection of candidate project roads

Prior to the selection of project roads, candidate project roads were selected. They mainly conformed to the technical selection criteria, while socioeconomic factors were not considered at this stage.

4. Selection of project roads

Project roads were selected from a short-list of project roads via systematic screening, based on disaster potential assessment, the rigorous evaluation of technical and socioeconomic criteria, etc.

3.3.3 Identification of Disaster-Prone Routes

Past disaster records for DOH highways were collected for fiscal years 1983 to 1994 as shown in Table 3.3.1.

Table 3.3.1 Disaster Records for DOH Highways

Fiscal Year	North	Northeast	Central	South
1983	C			
1984	C	C		
1985	C	C		
1986	C	C		
1987	C	P	C	
1988	P	C	C	P
1989	P	P	P	P
1990	P	P	C	P
1991	P	P	P	P
1992	P	P	P	P
1993	P	P	P	P
1994				P

Note C: Records are collected but not plotted on a route map
P: Records are collected and plotted on a route map

The incidence of road disasters is closely related to the occurrence of natural disasters such as typhoons, depressions, monsoon troughs, etc. According to the statistical data from the Meteorological Department, the incidence ratio of natural disasters in Thailand varies from 1.64 to 1.18 times/year by region. With regard to the incidence of serious damage being sustained, the ratio varies from 0.55 to 0.36 times/year as shown in Table 3.3.2. This means that every region is hit by a natural disaster that causes serious damage approximately once every two years.

Table 3.3.2 History of Natural Disasters

	North	Northeast	Central	South
1983	"Sarah" (Jun)		*"Herbert"(Oct) *"Kim" (Oct)	NE Mon.(Dec)
1984	"Vernon"(Jun) SW Mon.(Aug) Trough (Sep)	"Vernon"(Jun) SW Mon.(Aug) Trough (Sep)	"Susan"(Oct) "Agnes"(Nov)	NE Mon.(Nov) *NE Mon.(Dec)
1985	Trough (Aug) Dep.(Sep) Dep.(Oct) "Cecil"(Oct)	Trough (Aug) Dep.(Sep) Dep.(Oct) "Cecil"(Oct)	Dep.(Oct) "Cecil"(Oct)	NE Mon.(Nov)
1986	Dep.(May) "Wayne"(Sep)	"Wayne"(Sep) Trough(Oct)	Dep.(May) "Wayne"(Sep) Trough(Oct)	"Wayne"(Sep) Trough(Oct) Trough(Oct)
1987	*"Betty"(Aug)	*"Betty"(Aug)	NE Mon.(Nov)	"Cary"(Aug) *"NE Mon.(Dec)
1988	*Dep.(Oct)	*Dep.(Oct)	Dep.(Sep) *Dep.(Oct)	Dep.(Sep) *Dep.(Nov)
1989	"Cecil"(May) "Dan"(Oct)	"Cecil"(May) "Dan"(Oct)		
1990	"Becky"(Aug) *"Ira" (Oct) *"Lola"(Oct)	"Becky"(Oct) *"Ira" (Oct) *"Lola"(Oct)	*"Ira" (Oct) *"Lola"(Oct)	
1991	*"Fred"(Aug)	*"Fred"(Aug)	*"Fred"(Aug) Dep.(Oct)	Dep.(Oct)
1992		"Colleen"(Oct)		
1993				*Dep.(Dec)
Incidence Ratio	1.64 (0.55)	1.64 (0.45)	1.45 (0.45)	1.18 (0.36)

Note: * : Serious damage sustained
" " : Typhoon
Dep.: Depression
( ) : Incidence ratio for serious damage

Source: The Civil Defense Div. The Local Administration Dep. Ministry of the Interior

Disaster-prone routes were carefully identified from a map on which disaster spots were plotted according to damage type. The disaster-prone route maps are shown in Appendix 2.1.

3.3.4 Identification of Disaster-Prone Spots

Site reconnaissance and interviews with DOH district office staff via a survey by the Study's team members and DOH counterparts were planned and carried out based on information from the disaster-prone maps as discussed in the previous section.

The survey covered the whole of Thailand, i.e., the North, Northeast, Central and South regions for a total of around 8,130 kilometers (refer to Appendix 2.2 and 2.3).

In order to identify disaster-prone spots, physical conditions, types of damage, potential for damage and other related matters were assessed in the field at reported locations.

3.3.5 Candidates for Project Roads

Project roads were selected based on the selection criteria established in Section 3.3.1. The list of these roads is shown in Table 3.3.3 and their location in Fig. 3.3.1 (1) - (2).

Table 3.3.3 Conformity to Selection Criteria

Candidate Route	Technical Criteria	Socioeconomic Criteria	Traffic Volume(ADT)
109	-High potential for slope damage	-Strengthens communications between urban centers -Supports minorities -High traffic volume in future	220
113	-High potential for slope damage and a bridge (culvert) collapsing	-High traffic volume in future -Strengthens communications between urban centers	948
1089	-High potential for slope(cut and fill) damage	-Strengthens communications between urban centers -Tourism promotion -Support minorities	253
1095	-High frequency of cut slope damage	-Strengthens communications between urban centers -Access in emergencies	1,073
1149	-Potential of cut slope damage	-Access in emergencies -Tourism promotion	1,435
1234	-Frequent fill slope damage and cut slope damage	-Tourism promotion -Support minorities	760

Table 3.3.3 Conformity to Selection Criteria (continued)

Candidate Route	Technical Criteria	Socioeconomic Criteria	Traffic Volume(ADT)
1237	-High potential for cut-and fill-slope damage	-Supports minorities	171
1256	-High potential for cut-and fill-slope damage -Potential for a bridge or road collapsing -Wide variety of disaster type	-Tourism promotion -Supports minorities	844
2215	-Long traffic interruptions -Potential for a bridge collapsing	-Rural development	357
4	-Potential for cut-slope damage -Potential for a bridge collapsing -Frequency=0.064/Km/Y	-Trunk road with high traffic volume	6,008
410	-High potential for cut-slope damage -Frequent traffic interruptions	-International trunk road -Supports religious minorities -High traffic volume in future	481
4015	-High potential for a bridge or road collapsing -Long traffic interruptions	-Strengthens communications between urban centers -Access in emergencies	2,167
4090	-Frequent traffic interruptions -High potential for a bridge collapsing	-Strengthens communications between urban centers	738
4107	-High potential for a bridge collapsing	-Rural development -Supports religious minorities	1,469
4115	-Potential for a bridge or road collapsing -Potential for a cut-or fill-slope collapsing	-Rural development -Supports religious minorities	967

3.3.6 Project Roads for Feasibility Studies

1. Conformity to the Technical Selection Criteria for the Candidate Roads

All candidate roads have been evaluated for their conformity to the technical selection criteria and the results of the evaluation are tabulated in Table 3.3.4.

The evaluation is based on a ranking system. Each evaluation item is ranked from 1 to 4.

1) Disaster Potential

The potential for disaster has been decided by experienced engineering judgment based on site reconnaissance and interviews with DOH district office staff.

2) Past Disaster Frequency

The frequency of disasters over the last 10 years mentioned above is calculated based on past disaster records as a disaster potential index of and shown in Table 3.3.5.

Table 3.3.4 Disaster Frequency

Route No.	No. of Disaster Spots (10 years)	Route Length (km)	Frequency (spots/100km/year)
109	NA		
113	27	30	9.00
1089	NA		
1095	NA		
1149	NA		
1234	NA		
1237	NA		
1256	17	42	3.68
2215	NA		
4	34	53	5.35
410	49	80	6.12
4015	33	28	11.78
4090	13	31	4.19
4107	39	33	11.82
4115	62	55	10.25
Total (All of Thailand)	7,344	47,100	1.56

Evaluation criteria for disaster frequency are as follows:

Rank	Disaster Frequency in the Past (spots/100km/year)
4	10 or more
3	10 - 5
2	5 - 1.56
1	1.56 or less

3) Physical and Meteorological Conditions

The assessment of physical and meteorological conditions is based on the results of the assessment for road damage potential (refer to Fig. 2.1.13 and Appendix 2.4).

The evaluation criteria for meteorological conditions are as follows:

Rank	Rainfall Intensity (24 hr. rainfall in mm, 50 year return period)
4	300 or more
3	225 - 300
2	150 - 225
1	150 or less

4) Results of Evaluation

As summarized below, the candidate routes in the northernmost and southernmost areas are mostly ranked high.

Table 3.3.5 Conformity to the Technical Selection Criteria

Route No.	Disaster Potential	Past Disaster Frequency	Physical Conditions	Meteoro-logical Conditions	Total Points
109	4	(4)	4	2	14
113	2	3	2	1	8
1089	3	(3)	3	2	11
1095	4	4	4	2	14
1149	3	(3)	3	2	11
1234	3	(3)	3	2	11
1237	3	(3)	3	3	12
1256	3	(3)	3	3	12
2215	1	1	2	1	5
4	3	3	3	3	12
410	3	4	4	4	15
4015	4	4	4	4	16
4090	4	2	4	3	13
4107	3	4	3	4	14
4115	3	4	3	4	14

Note : ( ) is based on interviews with DOH district office staff.

2. Conformity to the Socioeconomic Selection Criteria

All candidate roads have been evaluated for their conformity to the socioeconomic selection criteria and tabulated in Table 3.3.6.

Table 3.3.6 Conformity to the Socioeconomic Criteria

Route	Road Class (1)	Connects Urban Centers (2)	Access for Emergencies (3)	Tourism Promotion (4)	Supports Minorities (5)	Traffic Volume (6)	Total Points
109	2	1			1	1	5
113	3	1				1	5
1089	2			1	1	1	5
1095	2	1	1	1		3	8
1149	2		1	1		3	7
1234	1			1	1	2	5
1237	1				1	1	3
1256	1			1	1	2	5
2215	1					1	2
4	4	1				4	8
410	3	1	1		1	1	7
4015	3	1	1			4	9
4090	2	1				2	5
4107	2				1	3	6
4115	1				1	2	4

Note : Items (2) to (5) are evaluated as either 1 or 0, with 1 signifying the existence and 0 the nonexistence of an item.

The evaluation criteria for traffic volume is as follows:

Rank	Traffic Volume (ADT)
4	2000 or more
3	1000 - 2000
2	500 - 1000
1	500 or less

3. Total Evaluation of Candidate Roads

The technical and socioeconomic evaluation points discussed above are simply summed up and tabulated in descending order in Table 3.3.7.

Table 3.3.7 Total Evaluation

Route	Technical Points	Socioeconomic Points	Total Points
4015	16	9	25
410	15	7	22
1095	14	8	22
4	12	8	20
4107	14	6	20
109	14	5	19
4115	14	4	18
4090	13	5	18
1149	11	7	18
1256	12	5	17
1234	11	5	16
1089	11	5	16
1237	12	3	15
113	8	5	13
2215	5	2	7

Note : Boldface indicates project roads.

Eight project roads were selected primarily in accordance with the point system mentioned above. Two routes, however, were excluded from the top eight and the ninth and the tenth were selected in place of them.

Route 4115, which was ranked seventh by the point system, was eliminated as a project road to avoid the concentration of project roads in the southernmost area.

Route 4090 has been experiencing frequent flooding for the last few years. The main cause of this is the choking of the river beds with sediment resulting in a raising of the stream bed levels relative to bridges and culverts. The solution to this problem, however, requires consideration of areas that are not within the jurisdiction of DOH, as the entire river catchment needs erosion management. Due to the need to involve other agencies, this route has been eliminated from the list of project roads. However, recommendations on how to deal with this kind of problem and some examples of countermeasures for river choking with sediment is presented in Appendices.

Besides the candidate roads, some sections of Route 4013 have been experiencing coastal erosion. Although this type of damage is not considered in this study, study procedures and some examples of countermeasures for coastal erosion is also presented in Appendices.

Route 4233, which stretches along the coast of the Phuket resort area, is under construction and some sections are already open to traffic. The route, which involves a large scale cut and fill slope, is structurally stable but is aesthetically unsound. From this standpoint, some examples of measures for scenery improvement is also presented in Appendices.

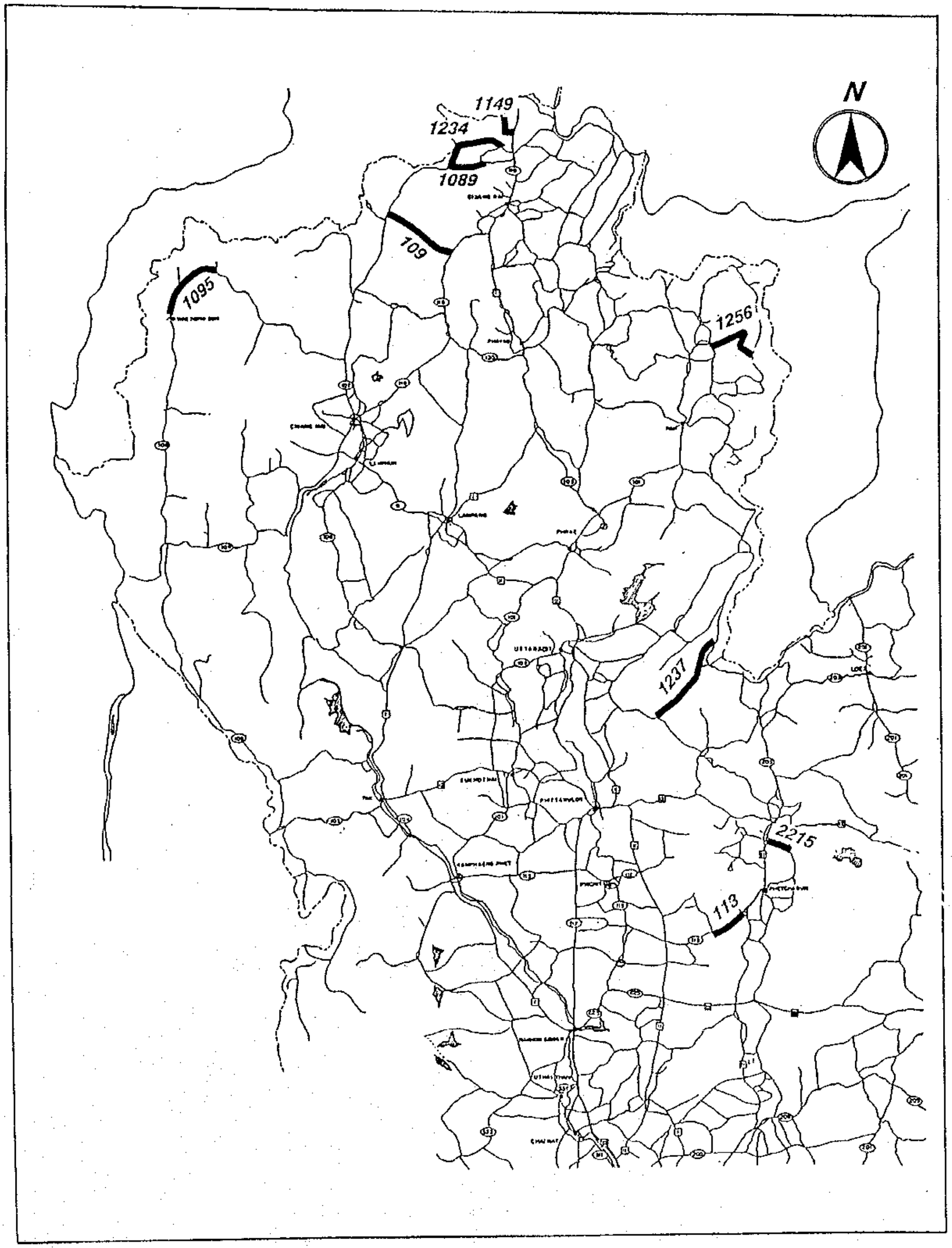


Fig. 3.3.1 (1) Candidate Project Roads in the North Region

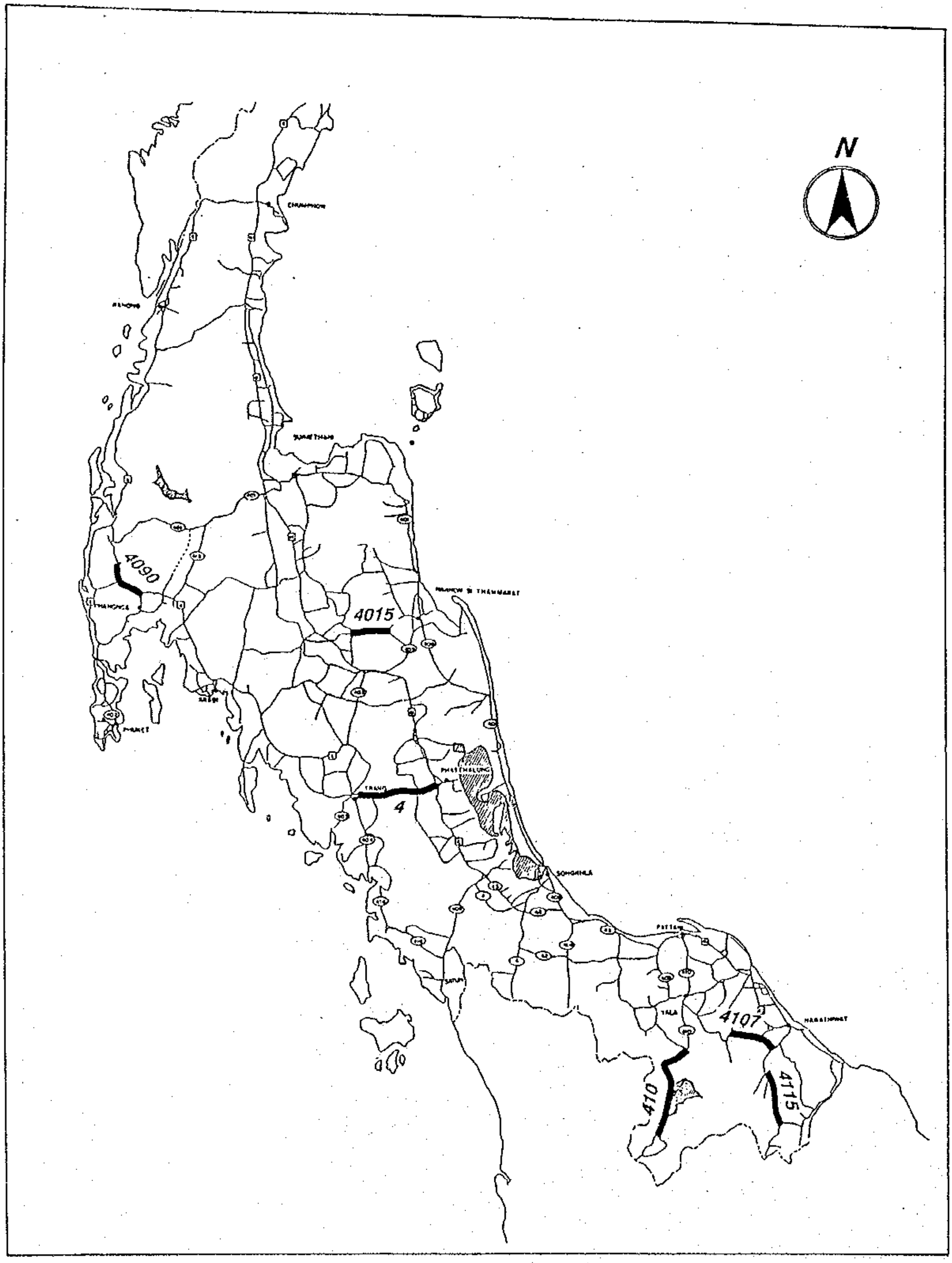


Fig. 3.3.1 (2) Candidate Project Roads in the South Region

3.4 Disaster Spots for the Study

Table 3.4.1 shows the list of 192 disaster spots for the Study. Preliminary design and cost estimation will be carried out for 38 of the spots and the cost for countermeasures will be estimated for the remaining 154 spots. Fig. 3.4.1 and Fig. 3.4.2 show the location of project roads in the North and the South regions, respectively.

Table 3.4.1 Disaster Spots for the Study (1)

SPOT No.	ROUTE No.	CONTROL No.	CHAINAGE No.	DAMAGE TYPE	SURVEY GEO.	SURVEY TOPO.	COST	PRE-DESIGN
109/1	109	0100	14.500	SD-2-10			*	*
109/2	109	0100	16.500	SD-2-3			*	*
109/c1	109	0100	19.100	SD-2-10			*	
109/c2	109	0100	21.950	SD-3-3			*	
109/3	109	0100	24.650	SD-2-6	*	*	*	*
109/c3	109	0100	25.200	SD-2-6			*	
109/c4	109	0100	26.600	SD-3-3			*	
109/c5	109	0100	30.640	SD-2-10			*	
109/c6	109	0100	31.620	RF-1-3			*	
109/c7	109	0100	33.420	SD-2-10			*	
109/c8	109	0200	35.100	SD-3-3			*	
109/c9	109	0200	35.900	SD-3-3			*	
109/c10	109	0200	15.5 - 43.6	SD-2-3			*	
1095/c1	1095	0500	154.250	SD-3-6			*	
1095/c2	1095	0500	156.050	SD-2-6			*	
1095/c3	1095	0500	156.150	SD-2-3			*	
1095/c4	1095	0500	157.000	SD-2-10			*	
1095/c5	1095	0500	157.500	SD-2-6			*	
1095/c6	1095	0500	157.700	SD-2-8			*	
1095/c7	1095	0500	157.900	SD-2-3			*	
1095/c8	1095	0500	158.800	SD-2-7			*	
1095/c9	1095	0500	159.000	SD-2-2			*	
1095/c10	1095	0500	159.450	SD-2-3			*	
1095/c11	1095	0500	159.900	SD-2-6			*	
*1095/c12	1095	0500	160.000	SD-2-7			*	

Note : Route No./1, 2, ... represent spots receiving preliminary design and cost estimates.
Route No./c1, c2, ... represent spots receiving cost estimate.

*About eighty percent of the section (from 15.5 km to 43.6 km) is damaged by gully erosions on cut slopes. All this damage is expressed as 109/c10.

Table 3.4.1 Disaster Spots for the Study (2)

SPOT No.	ROUTE No.	CONTROL No.	CHAINAGE No.	DAMAGE TYPE	SURVEY GEO.	SURVEY TOPO.	COST	PRE-DESIGN
1095/c13	1095	0500	160.500	SD-2-8			*	
1095/c14	1095	0500	160.600	SD-2-7			*	
1095/c15	1095	0500	160.800	SD-2-6			*	
1095/c16	1095	0500	160.850	SD-2-7			*	
1095/1	1095	0500	161.350	SD-2-7	*	*	*	*
1095/c17	1095	0500	161.600	SD-2-3			*	
1095/2	1095	0500	161.700	SD-2-9			*	*
1095/c18	1095	0500	162.350	SD-2-6			*	
1095/c19	1095	0500	162.600	SD-2-7			*	
1095/c20	1095	0500	162.800	SD-2-7			*	
1095/c21	1095	0500	163.450	SD-2-6			*	
1095/c22	1095	0500	163.500	SD-2-6			*	
1095/c23	1095	0500	164.000	SD-2-2			*	
1095/c24	1095	0500	166.800	SD-2-6			*	
1095/c25	1095	0500	167.400	SD-2-6			*	
1095/c26	1095	0500	167.800	SD-2-6			*	
1095/c27	1095	0500	168.000	SD-2-6			*	
1095/c28	1095	0500	168.400	SD-2-7			*	
1095/c29	1095	0500	168.500	SD-2-6			*	
1095/3	1095	0500	168.650	SD-2-6			*	*
1095/4	1095	0500	168.900	SD-2-8			*	*
1095/c30	1095	0500	169.000	SD-2-6			*	
1095/c31	1095	0500	170.000	SD-1-10			*	
1095/c32	1095	0500	170.250	SD-1-10			*	
1095/c33	1095	0500	172.000	SD-1-10			*	
1095/c34	1095	0500	177.100	SD-2-7			*	
1095/c35	1095	0500	177.800	SD-2-3			*	
1095/c36	1095	0500	178.900	SD-2-6			*	
1095/c37	1095	0500	179.100	SD-2-6			*	
1095/c38	1095	0500	179.200	SD-2-7			*	
1095/c39	1095	0500	179.400	SD-2-6			*	
1095/c40	1095	0500	179.500	SD-2-6			*	
1095/c41	1095	0500	180.200	SD-2-6			*	
1149/c1	1149	0100	4.200	SD-2-3			*	
1149/c2	1149	0100	4.500	SD-2-3			*	
1149/c3	1149	0100	4.600	SD-2-3			*	

Table 3.4.1 Disaster Spots for the Study (3)

SPOT No.	ROUTE No.	CONTROL No.	CHAINAGE No.	DAMAGE TYPE	SURVEY GEO.	SURVEY TOPO.	COST	PRE-DESIGN
1149/1	1149	0100	5.200	SD-2-6	*	*	*	*
1149/c4	1149	0100	5.450	SD-2-3			*	
1149/c5	1149	0100	6.700	SD-2-3			*	
1149/c6	1149	0100	8.700	SD-2-3			*	
1149/c7	1149	0100	9.350	SD-2-3			*	
1149/c8	1149	0100	9.500	SD-2-3			*	
1149/c9	1149	0100	9.700	SD-2-3			*	
1149/2	1149	0100	10.472	SD-2-3			*	*
1149/c10	1149	0100	11.700	SD-2-6			*	
1256/1	1256	0101	1.100	RF-1-2			*	*
1256/2/3	1256	0101	5.963	BC-1-5/9		*	*	**
1256/c1	1256	0101	6.900	SD-2-6			*	
1256/c2	1256	0101	9.100	SD-2-9			*	
1256/c3	1256	0101	10.100	SD-2-6/3			*	
1256/c4	1256	0101	12.750	SD-2-7			*	
1256/4	1256	0101	22.000	SD-2-3			*	*
1256/c5	1256	0101	22.200	SD-2-3			*	
1256/5	1256	0101	22.650	SD-3-6			*	*
1256/c6	1256	0101	24.200	SD-2-3			*	
1256/6	1256	0101	25.650	SD-2-6	*	*	*	*
1256/7	1256	0101	27.500	SD-2-7			*	*
1256/c7	1256	0101	28.800	SD-2-8			*	
1256/c8	1256	0101	31.100	SD-2-6			*	
1256/c9	1256	0101	31.800	SD-2-6			*	
1256/c10	1256	0101	31.900	SD-2-6			*	
1256/c11	1256	0101	31.950	SD-2-7			*	
1256/c12	1256	0101	33.640	SD-2-8			*	
1256/c13	1256	0101	33.675	SD-2-10			*	
1256/c14	1256	0101	33.950	SD-3-3			*	
1256/c15	1256	0101	34.200	SD-2-10			*	
1256/c16	1256	0101	35.800	SD-2-6			*	
1256/c17	1256	0101	36.200	SD-2-6			*	
1256/c18	1256	0101	36.400	SD-3-6			*	
1256/c19	1256	0101	36.900	SD-2-6			*	
1256/c20	1256	0101	39.100	SD-2-7			*	
1256/c21	1256	0101	39.300	SD-2-7			*	

Table 3.4.1 Disaster Spots for the Study (4)

SPOT No.	ROUTE No.	CONTROL No.	CHAINAGE No.	DAMAGE TYPE	SURVEY GEO.	SURVEY TOPO.	COST	PRE-DESIGN
1256/c22	1256	0101	39.500	SD-2-1			*	
1256/c23	1256	0101	39.700	SD-2-8			*	
1256/c24	1256	0101	39.900	SD-2-8			*	
1256/8	1256	0101	40.150	SD-3-7	*	*	*	*
1256/c25	1256	0101	40.800	SD-2-8			*	
1256/c26	1256	0101	41.200	SD-2-6			*	
1256/c27	1256	0101	41.800	SD-2-6			*	
1256/c28	1256	0101	42.200	SD-2-6			*	
1256/c29	1256	0101	42.250	SD-3-6			*	
1256/9	1256	0101	43.000	SD-2-1			*	*
1256/c30	1256	0101	43.300	SD-2-1			*	
1256/c31	1256	0101	43.600	SD-2-1			*	
1256/c32	1256	0101	43.700	SD-2-1			*	
1256/c33	1256	0101	44.100	SD-2-6			*	
1256/c34	1256	0101	44.500	SD-2-8			*	
1256/10	1256	0101	44.600	SD-2-10			*	*
1256/c35	1256	0101	45.500	SD-2-7			*	
1256/11/12	1256	0101	45.675	SD-2-8/3-7	*	*	*	**
4/c1	4	3800	37.100	SD-2-3			*	
4/c2	4	3800	37.800	SD-3-6			*	
4/c3	4	3800	41.800	SD-2-3			*	
4/c4	4	3800	43.900	SD-2-6			*	
4/1	4	3800	44.700	SD-2-6	*	*	*	*
4/c5	4	3800	45.030	SD-2-6			*	
4/2/3	4	3900	16.970	BC-1-5/9		*	*	**
410/c1	410	0302	70.500	SD-2-6			*	
410/c2	410	0401	75.550	SD-2-6			*	
410/c3	410	0401	75.850	SD-2-7			*	
410/1	410	0401	75.950	RF-3-3			*	*
410/2	410	0401	76.420	SD-2-7	*	*	*	*
410/c4	410	0401	76.550	SD-2-6/3			*	
410/c5	410	0401	76.850	SD-2-6			*	
410/c6	410	0401	77.500	SD-2-6			*	
410/c7	410	0401	78.100	SD-2-7			*	
410/c8	410	0401	78.400	SD-2-7			*	

Table 3.4.1 Disaster Spots for the Study (5)

SPOT No.	ROUTE No.	CONTROL No.	CHAINAGE No.	DAMAGE TYPE	SURVEY GEO.	SURVEY TOPO.	COST	PRE-DESIGN
410/c9	410	0401	79.000	SD-2-6			*	
410/c10	410	0401	81.750	SD-2-6			*	
410/c11	410	0401	81.870	SD-2-8			*	
410/c12	410	0401	82.000	SD-2-6			*	
410/3	410	0401	82.100	SD-2-6			*	*
410/c13	410	0401	82.500	SD-2-6			*	
410/c14	410	0401	82.750	SD-2-6			*	
410/c15	410	0401	82.780	SD-2-6			*	
410/c16	410	0401	83.400	SD-2-6/7			*	
410/c17	410	0401	83.750	SD-2-7			*	
410/c18	410	0401	83.950	SD-2-7			*	
410/c19	410	0401	84.500	SD-2-7			*	
410/c20	410	0401	85.100	SD-2-6/7			*	
410/c21	410	0401	85.400	SD-2-7			*	
410/4	410	0401	85.700	SD-2-9			*	*
410/c22	410	0401	86.700	SD-2-6			*	
410/c23	410	0401	87.500	SD-2-8			*	
410/c24	410	0401	89.800	SD-2-6			*	
410/c25	410	0401	90.700	SD-2-7			*	
410/c26	410	0401	91.000	SD-2-7			*	
410/c27	410	0401	91.900	SD-2-7			*	
410/c28	410	0401	96.150	SD-2-8			*	
410/5	410	0401	96.300	SD-2-3			*	*
410/c29	410	0401	97.300	SD-2-9			*	
410/6	410	0401	97.800	SD-2-8	*	*	*	*
410/c30	410	0401	100.400	SD-2-7			*	
410/c31	410	0401	101.750	SD-2-7			*	
410/c32	410	0401	103.200	SD-2-6			*	
410/c33	410	0401	105.700	SD-2-6			*	
410/c34	410	0402	106.950	SD-2-6			*	
410/c35	410	0402	106.950	SD-3-6			*	
410/c36	410	0402	107.200	SD-2-6			*	
410/c37	410	0402	109.250	SD-2-6			*	
410/c38	410	0402	109.600	SD-3-6			*	
410/c39	410	0402	109.950	SD-2-6			*	
410/c40	410	0402	110.200	SD-2-8			*	
410/c41	410	0402	110.400	SD-2-6			*	
410/c42	410	0402	110.400	SD-3-5			*	

Table 3.4.1 Disaster Spots for the Study (6)

SPOT No.	ROUTE No.	CONTROL No.	CHAINAGE No.	DAMAGE TYPE	SURVEY GEO.	SURVEY TOPO.	COST	PRE-DESIGN
410/c43	410	0402	110.800	SD-2-6			*	
410/c44	410	0402	111.150	SD-2-6			*	
410/c45	410	0402	114.100	SD-2-6			*	
410/c46	410	0402	114.900	SD-2-6			*	
410/c47	410	0402	116.100	SD-2-6			*	
410/c48	410	0402	116.400	SD-2-6			*	
410/c49	410	0402	118.050	SD-2-6			*	
410/c50	410	0402	118.500	SD-2-6			*	
410/c51	410	0402	119.000	SD-3-6			*	
4015/1	4015	0201	20.125	BC-1-5			*	*
4015/2	4015	0201	21.337	RC-3-2		*	*	*
4015/c1	4015	0201	22.957	BC-1-5			*	
4015/3	4015	0201	26.850	RC-3-1			*	*
4015/4	4015	0201	26.965	BC-1-6			*	*
4015/5	4015	0201	29.390	BC-1-7		*	*	*
4015/c2	4015	0201	35.957	BC-1-5			*	
4107/1/2	4107	0200	7.594	BC-1-5/6		*	*	**
4058/1	4058	0100	8.624	BC-1-8			*	*
				Total	9	13	192	38

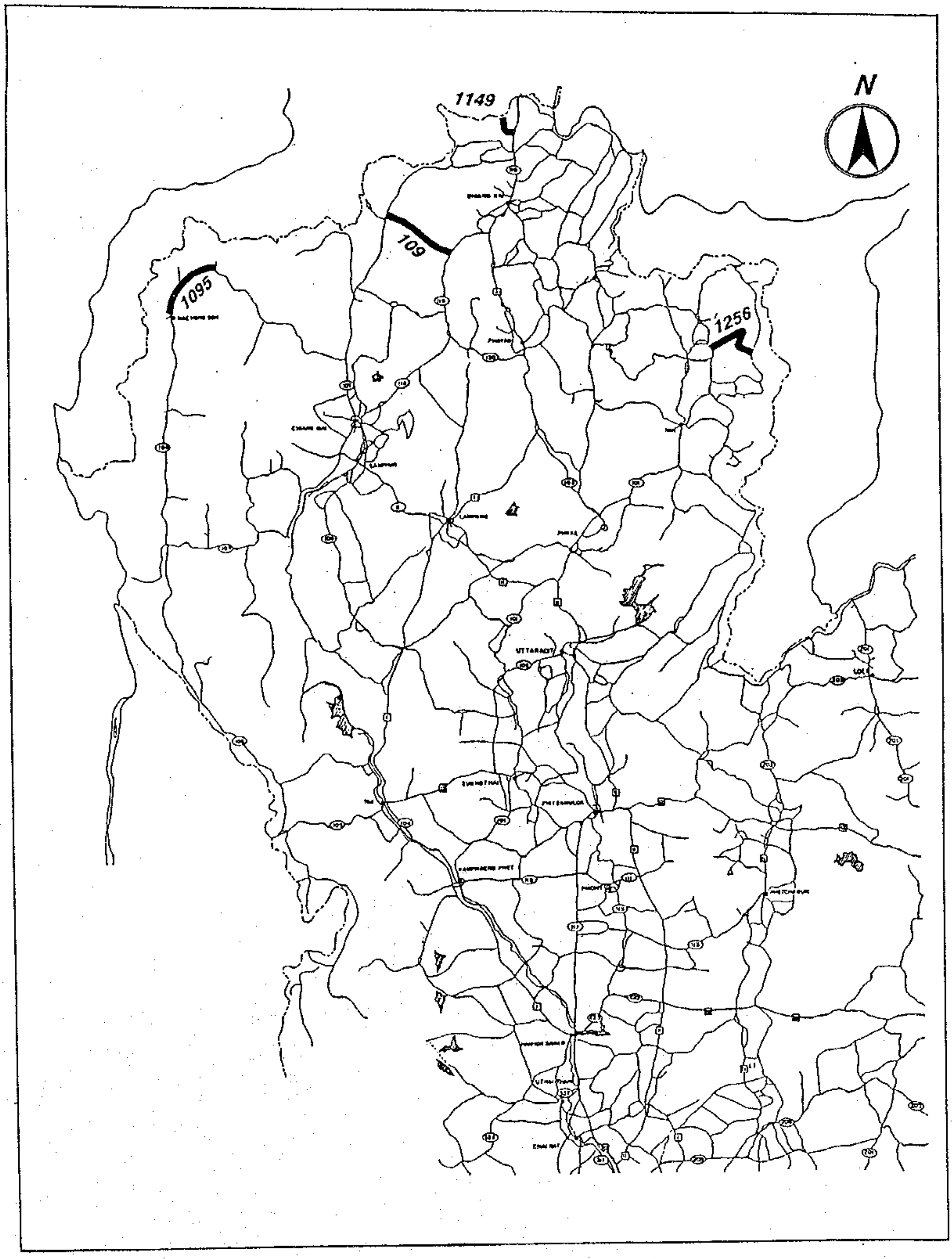


Fig. 3.4.1 Project Roads in the North Region

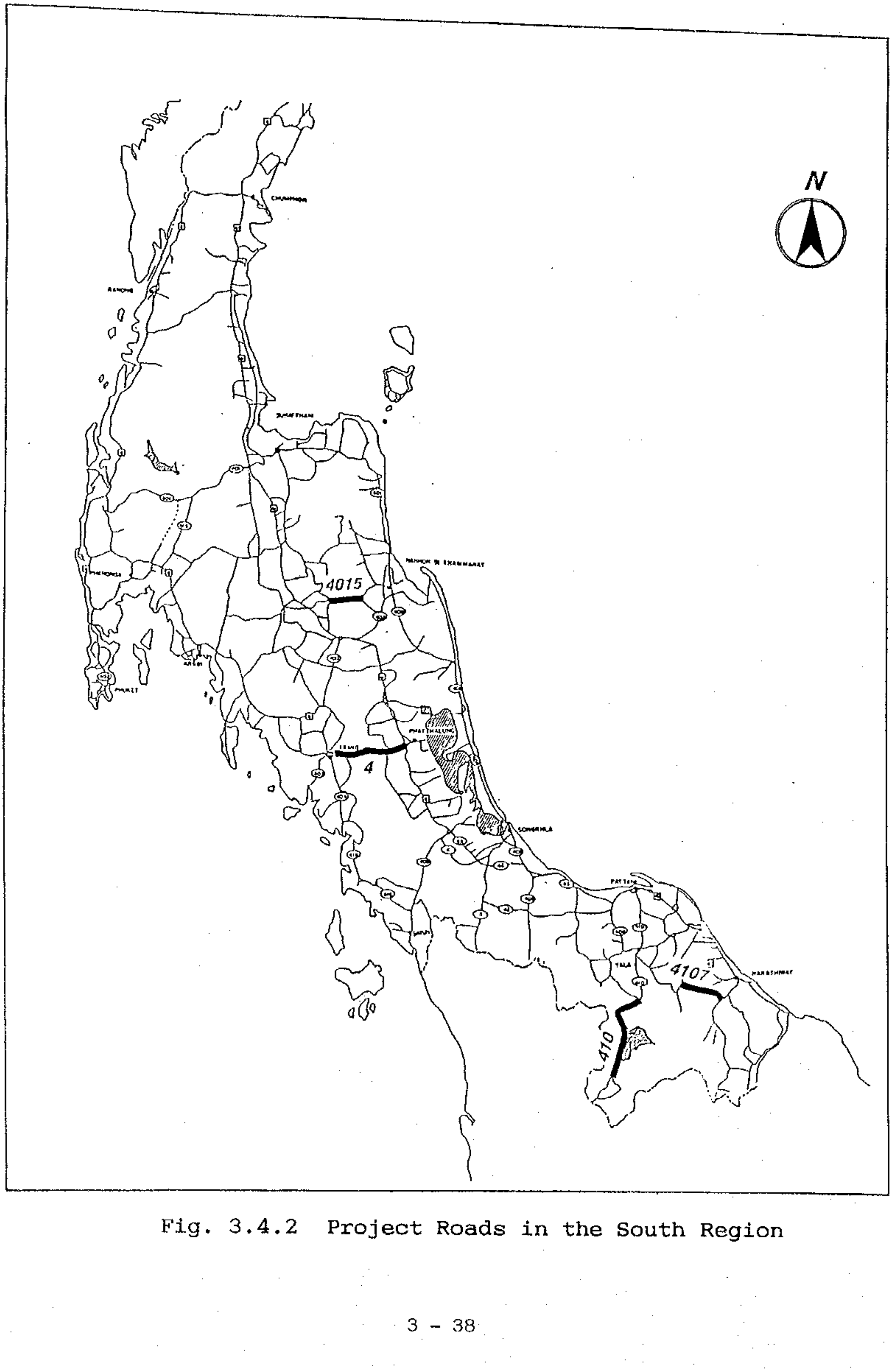


Fig. 3.4.2 Project Roads in the South Region

Chapter 4

Information on Project Roads

Chapter 4 Evaluation of Present Conditions on the Project Roads

4.1 Project Road 109

4.1.1 Natural Conditions

1. Meteorology

The nearest meteorological station to Route 109 is situated at Chiang Rai. The rainfall pattern is illustrated in Fig. 4.1.1 and has a 24hr rainfall intensity of 169.5mm for a fifty-year return period. The overall average annual rainfall is 1801.4 mm. There is a high probability that the magnitude and intensity of rainfall on the road is considerably higher than that recorded at Chiang Rai. As the road is in the far north, it is not affected significantly by typhoons or tropical storm systems, but is influenced more by monsoons or depleted storms passing through from Vietnam and Laos.

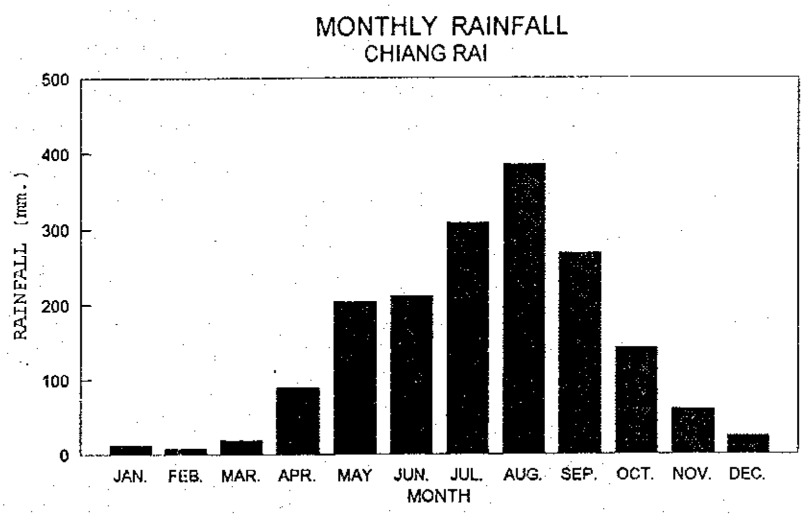


Fig. 4.1.1 Monthly Rainfall at Chiang Rai

2. Geology

Route 109 connects Route 1089 with Route 118 to the east and passes over recent unconsolidated alluvium up to Km. 9.2. There are some older terraces on the periphery at the foot of some slopes and they could be dissected alluvial fans. The road crosses one of these from Km. 9.2 to Km. 9.8.

At approximately Km. 9.8, the geology changes to deeply weathered granites. The complex batholith contains variations of the local mineralogy that results in varying depths and compositions of weathering products.

The weathered granite is friable and erodable. The lack of any slope protection in the construction of the road has led to very extensive slope erosion. At about Km. 37, the incidence of erosion reduces significantly. This may be due to a change in the mineralogy of the granite, but it may also be due to the slopes having been exposed for a shorter period of time. The change is approximately coincident with the boundary between two construction packages. A narrow fluvial valley approximately 200 m wide occurs at Km. 43.6, and the road passes along the valley to the north of a stream. The alluvium narrows to a few tens of metres at Km. 50.5 but widens again at Km. 51.2. The road then continues along the southern side of the stream.

3. Topography

The road passes over flat lying terrain for the first 9 km. and then enters the foot hills of granite mountains. The side slopes of valleys heading north west are generally followed. The angles of natural slopes in the mountainous sections are about 25 to 35 degrees. The hill formations are generally round with smooth transitions between the crests, side slopes and foot slopes. This is typical of granitic terrain. The valley floors are round, but they are now becoming filled with sediment from the large amounts of erosion induced by the road and its exposed surfaces and fill mounds.

4. Past Disaster Records

In the DOH files there are no records of damage on this road. During a survey of the route, numerous locations of severe erosion on both cut and fill slopes were seen along with three landslides. The actual dates of these occurrences is not known, but they are estimated to have happened in the last 2-5 years.

4.1.2 Socioeconomic Conditions

1. General

Rt. 109 connects the two changwats of Chiang Mai and Chiang Rai in the northern areas of the North Region. In Chiang Rai, it starts at A. Mai Suai from Rt. 118 and ends at Rt. 107 in Chiang Mai at A. Fang and at K. A. Chai Prakan to the north, which was separated from A. Fang in 1987. The route was constructed stepwise between 1949 and 1960 to be used only during the dry season. At present, the Chiang Rai section is paved, while the pavement of the Chiang Mai section is expected to be completed by 1995.

2. Function

In addition to being one of the routes connecting the two municipality centers of Chiang Rai and Chiang Mai, about sixteen villages are directly served by this route, which supports the many socioeconomic activities of schools, resorts, oil refineries, small factories and agricultural areas in areas with flat terrain. The route also supports the life of northern tribal people, and it is in a strategic location near the northern territories of the country.

3. Population

As this route passes through the two changwats of Chiang Rai and Chiang Mai, and is located in and used as a direct access by A. Mai Suai, A. Fang and K.A. Chai Prakan, the area and population the route influences can be considered to be as shown in Table 4.1.1.

Table 4.1.1 Area and Population Influenced by Rt. 109

	Population - 1991	Area (km^2)	Density
Changwat:			
Chiang Rai	1,048,200	11,678.3	89.76
Chiang Mai	1,386,000	20,099.1	68.96
Amphoe:			
A. Mai Suai	56,100	1,428.6	39.27
A. Fang	83,600	829.0	100.84
K.A. Chai Prakan	34,500	572.0	60.31

4. Economy

The function of the route and its traffic demand are greatly influenced by the economic indicators of the two changwats of Chiang Mai and Chiang Rai. Table 4.1.2 gives the sectoral GPP for the two changwats at constant 1988 prices, which shows that agriculture in Chiang Rai accounts for about 30% of its GPP, while this share is about 15% in Chiang Mai. On the other hand, Chiang Mai has considerably higher shares in the industrial and services sub-sectors.

Table 4.1.2 Economic Indicators for Rt. 109 ('000 baht)

	1986	1991
Chiang Rai:		
Agriculture	5,341,298	4,879,708
Crops	4,224,539	3,938,229
Livestock	460,742	495,598
Fisheries	16,819	25,679
Forestry	199,658	126
Agricultural services	178,129	166,894
Processed agri. products	261,411	253,182
Mining and quarrying	37,970	60,703
Manufacturing	494,627	617,441
Construction	713,186	1,089,844
Electricity and water supply	117,636	238,821
Transportation and communications	671,253	1,104,333
Wholesale and retail trade	2,119,197	3,338,232
Banking, insurance and real estate	353,093	760,656
Ownership of dwellings	1,031,324	1,200,758
Public administration and defense	629,836	789,003
Services	1,656,603	2,258,239
GPP	13,166,023	16,337,738
Chiang Mai:		
Agriculture	5,048,612	6,181,745
Crops	3,838,669	4,574,645
Livestock	683,347	1,114,437
Fisheries	18,389	49,225
Forestry	77,877	1,201
Agricultural services	123,242	110,703
Processed agri. products	307,088	331,534
Mining and quarrying	309,579	274,994
Manufacturing	1,846,618	3,790,165
Construction	1,770,089	2,921,890
Electricity and water supply	481,978	741,697
Transportation and communications	1,821,698	3,204,251
Wholesale and retail trade	3,254,831	5,166,102
Banking, insurance and real estate	874,351	3,287,018
Ownership of dwellings	1,355,253	1,663,843
Public administration and defense	1,539,240	1,962,982
Services	6,532,553	10,826,963
GPP	24,834,802	40,021,650

5. Traffic

Traffic volume on the route has been continuously increasing during the last few years and it is expected to increase even more after the completion of construction. At both ends of the route, higher traffic volumes have been observed, and past ADT figures for the mid-section of the route are presented in Table 4.1.3.

Table 4.1.3 Traffic Volume on Rt. 109

Average Daily Traffic (ADT):

C-Sec	Km	1985	1987	1989	1991	1993
200	72+819	-	-	-	2175	1724
300	100+250	687	1852	1001	-	-

Traffic Composition - 1993:

Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
1037	113	45	174	247	108	1724

Table 4.1.4 gives the Vehicle registrations between 1988 and 1990 in the two changwats.

Table 4.1.4 Vehicle Registration for Rt. 109

	1988	1989	1990
Chiang Rai:			
Passenger Car	4,174	5,054	5,296
Van & Truck	13,490	14,273	17,149
Motorcycle	65,279	83,885	116,866
Chiang Mai:			
Passenger Car	19,946	21,606	25,444
Van & Truck	27,812	30,074	38,011
Motorcycle	207,300	237,765	236,486

4.1.3 Existing Status of Damages

1. Spot 109/1: Rockfall on a Cut Slope due to Undercutting (SD-2-10)

At Km. 14.50, an eroded section of cut slope in completely weathered granite contains embedded core stone boulders of fresh granite. The eroding matrix of silty sand, which comprises the weathered residual soil, is being washed out and exposing the boulders to the risk of falling onto the road's surface. This is relatively common along this route, but it is generally not that hazardous as falling boulders get trapped in the deep erosion gullies. At this site, the erosion gullies are not large enough to prevent the 3m diameter boulders balanced at the slope's crest from falling onto the road.

This section of slope is only about 15m high, with 1.5m wide berms spaced vertically every 5m. The interberm angle is 0.5/1.; and the overall slope average is about 47 degrees. There is very little vegetation on the exposed surfaces. The existing conditions are shown in Fig. 4.1.2.

2. Spot 109/2 - Gully Erosion on a Cut Slope (SD-2-3)

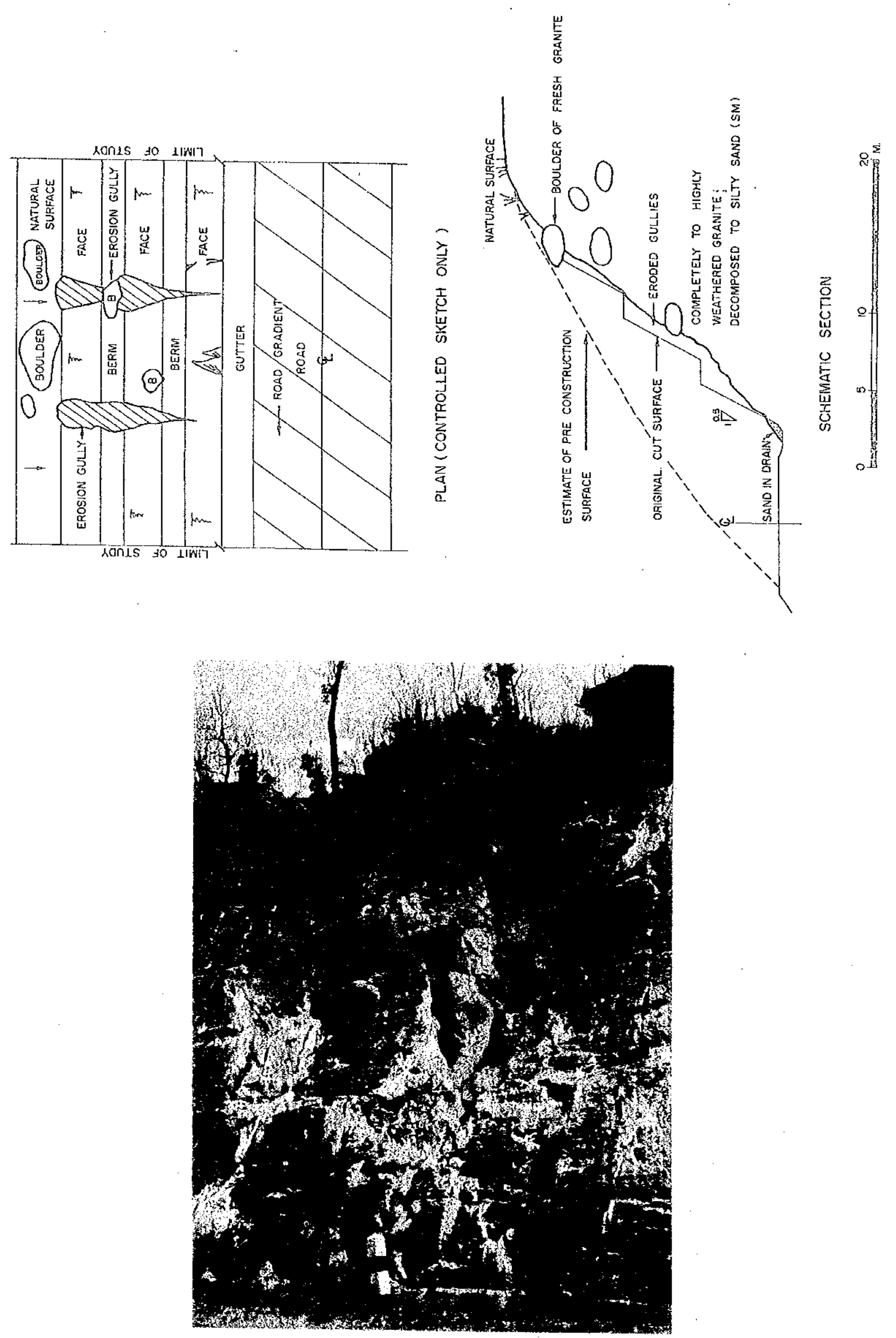
Although there are many examples of severe gully erosion, only one site was selected for study due to the practical constraints of the scope of the Study. A typical section of a severely eroded cut slope at Km 16.5 was chosen. It is approximately 100m long, 40m high and consists of medium-to coarse-grained granite that is completely or highly weathered. The thickness of the completely weathered Zone A is about 10 m with Zone B extending to an unknown depth. The formed cut slope has an average slope of about 47 degrees with 1.5 - 2.0 m wide berms at a vertical spacing of 5 meters. The inter-berm angle is 0.5/1 or 62 degrees. It is deeply eroded with some gullies extending up to 10m into the slope. Masses of eroded sand have accumulated on the berms and at the foot of the slope. The existing conditions are shown in Fig. 4.1.3.

The very high rate of erosion removes any nutrients from the surface of this very poor leached soil, undercuts any seedlings and generally prevents the establishment of vegetation. Natural vegetation progression can not get started under these conditions.

3. Spot 109/3: Cut Slope Rotational Landslide (SD-2-6)

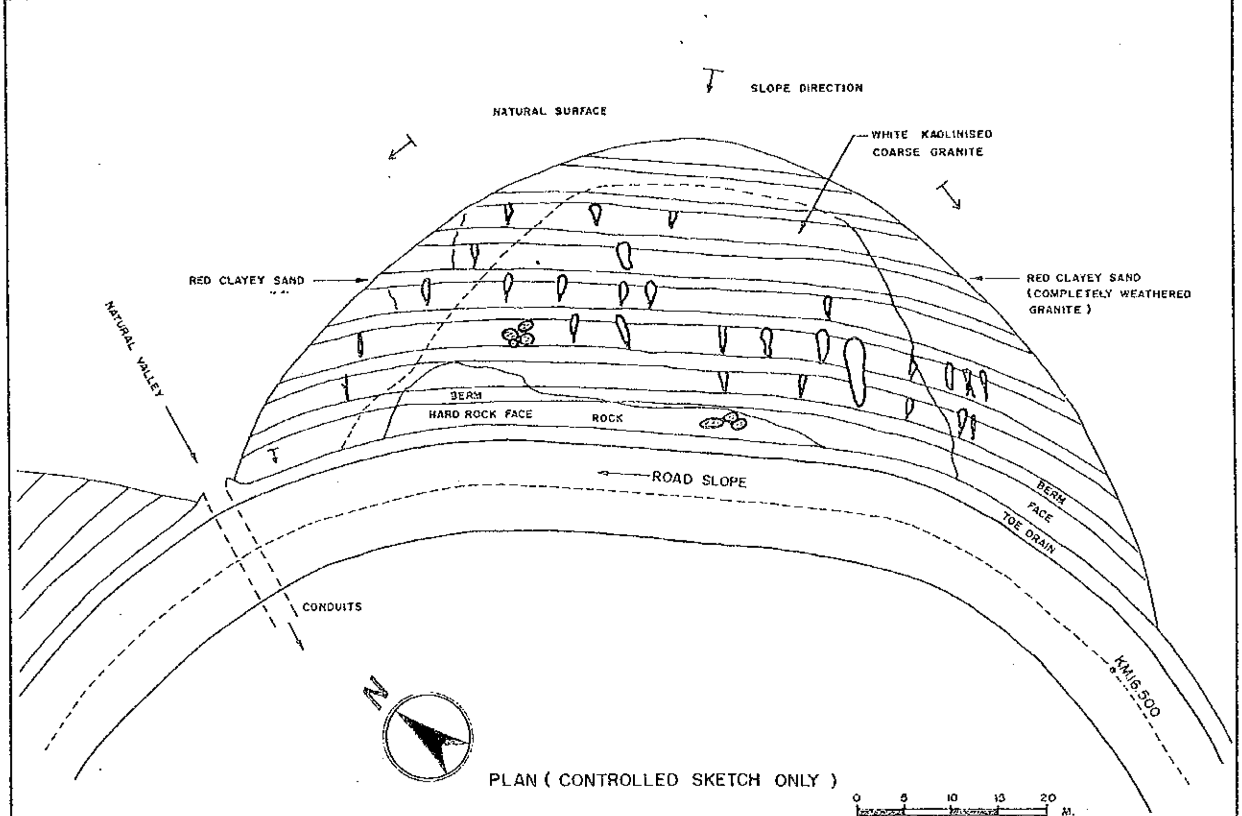
At Km. 24.65, a very large rotational landslide can be seen that affects the natural slope as well as the cut-slope face. The original cut slope was only 20m high with an interberm slope angle of 62 degrees. Berms were 1.5m in width and vertically spaced every 5m. The area around the landslide has been surveyed and the map of the site and the cross section are presented in Fig. 4.1.4.

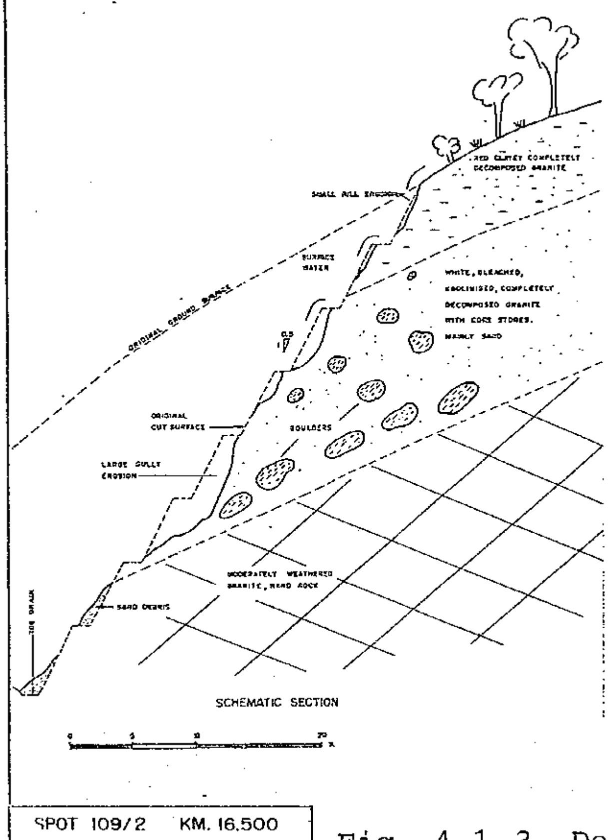
The geology of the site consists of highly to completely weathered granite with core stones up to 2m in diameter. Groundwater can be seen seeping from the face of the damaged area approximately 10m above the slope base. Drilling results indicate loose fine granitic colluvium with imbedded boulders of granite. The drilling was terminated at a depth of 13.80m, and groundwater was hit at about 3m below the surface. The base of the slip surface was not found.

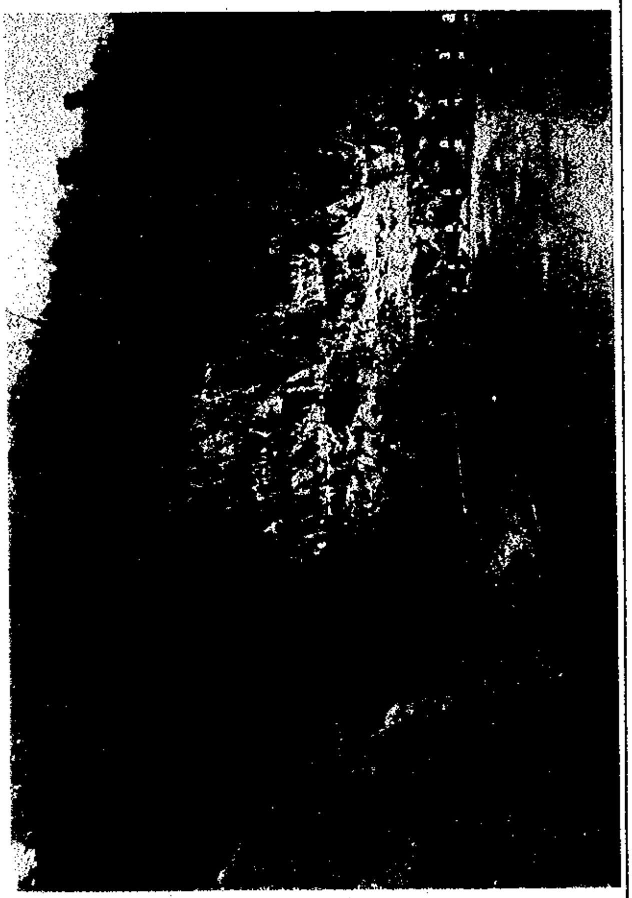


SPOT 109/1 KM. 14.50
EXISTING CONDITIONS

Fig. 4.1.2 Details of Disaster Spot

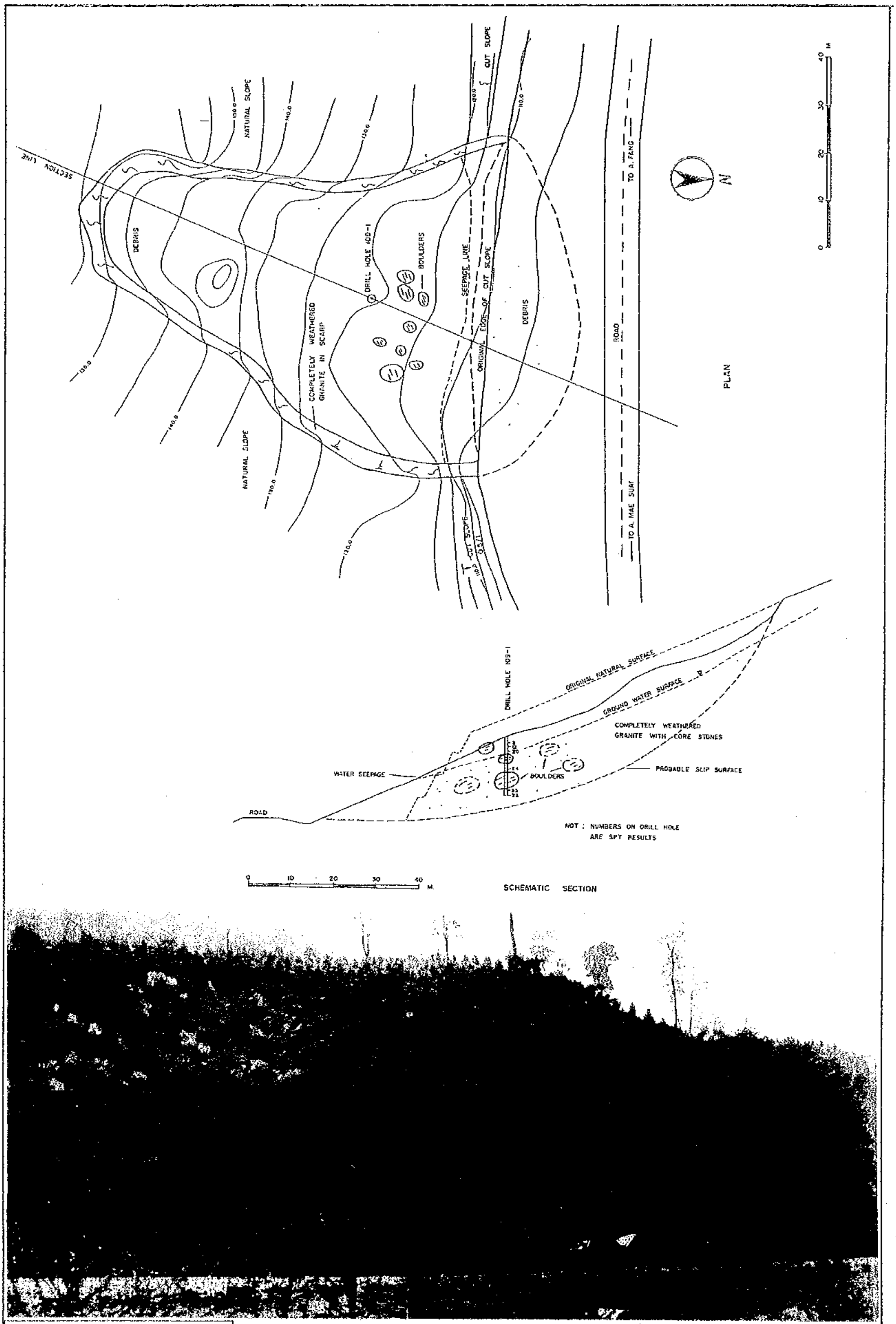






SPOT 109/2 KM. 16.500
EXISTING CONDITIONS

Fig. 4.1.3 Details of Disaster Spot



SPOT 109/3 KM. 24.65 EXISTING CONDITIONS	Fig. 4.1.4 Details of Disaster Spot

4.2 Project Road 1095

4.2.1 Natural Conditions

1. Meteorology

The nearest meteorological station to Route 1095 is situated at Mae Hong Son. The rainfall pattern is illustrated in Fig. 4.2.1 and has a 24hr rainfall intensity of 145.2mm for a fifty-year return period. The overall average annual rainfall is 1262.4 mm. Mae Hong Son is about 50 km from the study spots on Route 1095, and the topography is distinctly different. There is a high probability that the magnitude and intensity of rainfall on the road is considerably greater than that recorded at Mae Hong Son. As the road is in the far north, it is not affected significantly by typhoons or tropical storm systems, but is influenced more by monsoons or depleted storms passing through from Vietnam and Laos.

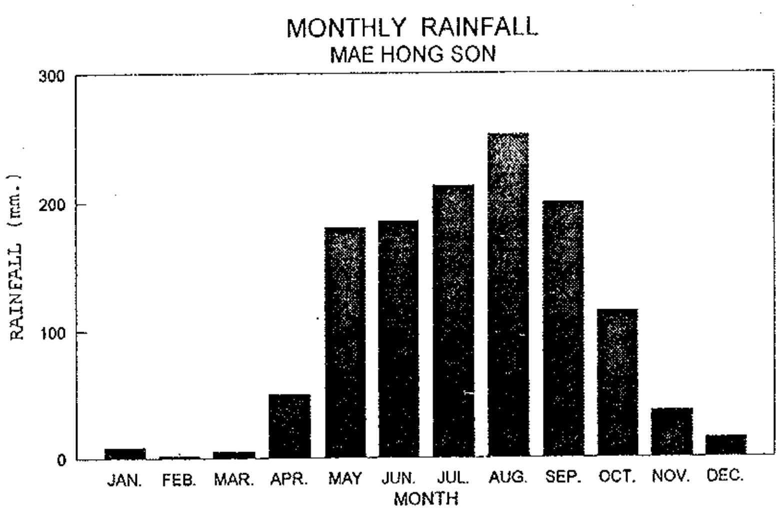


Fig. 4.2.1 Monthly Rainfall at Mae Hong Son

2. Geology

The geology of the section of Route 1095 subject to study consists of interbedded sedimentary rock typical of shallow marine environments. The units mapped by the Geological Survey of Thailand have been divided on the basis of age. However,for engineering purposes, only two major lithological units are generally recognized. These are the older interbedded sandstone and shale Carboniferous sequences and the younger Permian massive limestones. The limestone terrain extends from Km. 152 to Km. 157.5, from Km.165 to Km. 167,from Km. 170 to Km. 173, and from Km. 192 to Km. 194. Except for the section of alluvial soil in the valley of the Mae Sa Nga river, from Km. 200 to Mae Hong Son, the rest of the route is underlain by bedded sandstones and shales.

The sedimentary rock mainly consists of thickly bedded coarse-to medium-grained quartz sandstones with interbeds of laminated shale and massive mudstone. These units are folded but not intensively sheared and are not significantly metamorphosed. The most common cause of landslides in these rocks is a geometric coincidence of bedding dipping towards the road at an angle of 35 - 50 degrees with the face alignment roughly parallel to the strike of the bedding.

3. Topography

The topography of the route is closely associated with the underlying geology. The limestone areas have very steep precipitous cliffs of limestone with scree slopes and residual clay in between mountains. Some of the peaks are over 1400m high. The road follows the base of these scree slopes. In the folded sedimentary areas the terrain has slopes in the order of 25 to 35 degrees with fold and fracture patterns controlling the distribution of ridge and valley orientations. Resistant beds of sandstone stand out as lines of high relief and the valleys often follow shale beds. The general altitude ranges from 500 to 900m above sea level. The section of road that follows the valley of the Mae Sa Nga River has a low relief with high river terraces of gravel and sand. The altitude along this sector is about 350m above sea level.

4. Past Disaster Records

Although it is apparent, from field inspections and discussions with local residents, that this road has a long history of problems, the DOH records do not contain any information of past disasters except for some minor damage to a bridge approach.

4.2.2 Socioeconomic Conditions

1. General

This route is a provincial highway that basically connects the two northern changwats of Chiang Mai, at the junction with Rt. 107, and Mae Hong Son at the end of Rt. 108. It is characterized by its mountainous terrain in most sections, and together with heavy rainfall, landslides are expected. The project route consists of the eastern section of this road, and it is located entirely in Mae Hong Son between its municipality center and K. A. Pang Ma-Pha.

2. Function

The route is considered at present to be the shortest road, in distance, between the two changwats of Chiang Mai and Mae Hong Son. The area along the route has a national park and many tourist spots, as well as different socioeconomic activities near the cities, including police and military camps. Along the project route, there are about seven villages and three schools. In addition, the route is the only connection to the two provincial highways of Rt. 1226 and Rt. 1285, which originate in the northern mountains and serve many hill-tribe villages. These villages come under development programs based on community participation and an integrated crop-livestock development system in order to improve the quality of life. With its location near the northern border, the route is also important from a national security point of view. With future possibilities for access to neighboring countries, the area has a special potential for future tourism development projects that will mainly use this route.

3. Population

The project route connects Chiang Mai with Mae Hong Son, and it is the only road in the area with access to A. Pai and K.A. Pang Ma-Pha. The area and population influenced by the route is shown in Table 4.2.1.

Table 4.2.1 Area and Population Influenced by Rt. 1095

	Population - 1991	Area (km^2)	Density
Changwat:			
Chiang Mai	1,386,000	20,099.1	68.96
Mae Hong Son	175,900	12,672.2	13.88
Amphoe:			
Muang Mae Hong Son	31,600	2,483.1	12.73
A. Pai	22,800	2,244.7	10.16
K.A. Pang Ma-Pha	7,800	789.4	9.88

4. Economy

The sectoral GPP at constant 1988 prices for the two changwats that affect road functions and traffic demand is given in Table 4.1.2 for Chiang Mai and Table 4.2.2 for Mae Hong Son. Mae Hong Son, with the lowest GPP in Thailand, has a higher agricultural share of 27%. Chiang Mai has higher shares for the non-agricultural sub-sectors.

Table 4.2.2 Economic Indicators for Rt. 1095 ('000 baht)

	1986	1991
Mae Hong Son:		
Agriculture	1,088,823	688,289
Crops	379,373	397,299
Livestock	116,980	199,422
Fisheries	3,068	1,302
Forestry	537,703	32,432
Agricultural services	16,944	18,355
Processed agri. products	34,755	39,479
Mining and quarrying	31,576	22,565
Manufacturing	93,834	91,412
Construction	146,128	231,516
Electricity and water supply	15,484	32,148
Transportation and communications	43,176	110,178
Wholesale and retail trade	314,792	507,906
Banking, insurance and real estate	22,741	66,342
Ownership of dwellings	150,359	178,019
Public administration and defense	165,708	237,766
Services	235,554	357,080
GPP	2,308,175	2,523,221

5. Traffic

With recent improvements in the road surface, traffic volumes are sharply increasing as it is the shortest road to Chiang Mai. ADT in 1993 was about 2,000 vehicles compared with less than 300 in 1985. This route is also the only connection with Rt. 1285 (ADT equals 500 vehicles) and Rt. 1226 (ADT equals less than 100 vehicles) as of 1993. Past ADT figures for the project route are presented in Table 4.2.3.

Table 4.2.3 Traffic Volume on Rt. 1095

Average Daily Traffic (ADT):

C-Sec	Km	1985	1987	1989	1991	1993
500	200+750	258	308	169	864	1969

Traffic Composition - 1993:

Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
1306	232	56	143	177	55	1969

Table 4.2.4 gives the vehicle registrations between 1988 and 1990 in the two changwats connected by the project route.

Table 4.2.4 Vehicle Registration for Rt. 1095

	1988	1989	1990
Chiang Mai:			
Passenger Car	19,946	21,606	25,444
Van & Truck	27,812	30,074	38,011
Motorcycle	207,300	237,765	236,486
Mae Hong Son:			
Passenger Car	190	118	146
Van & Truck	761	407	609
Motorcycle	5,809	5,108	6,326

4.2.3 Existing Status of Damages

1. Spot 1095/1: Two-Dimensional Translational Landslide (SD-2-7)

At Km. 161.35, the site contains a very large landslide that has slid on the bedding contacts between sandstones and shales. The on-site geological conditions are complex. An old lobe of colluvium about 12m thick is exposed in the backscarp but the base area has bedded sandstone and shales.

The sedimentary rocks are folded in a gentle syncline with dips varying from 40 degrees near the top of the slide to 15 degrees near the toe. Water was seen seeping from the debris face about 10 m above the toe.

The combination of the geometry of the weak interface between shale and sandstone, the geometry of the original cut face and a high water pressure gradient has produced this slide. The existing conditions are presented in Fig.4.2.2 and 4.2.3.

The direction of movement of the failure was actually about 45 degrees to the road direction. The pre-existing drainage gully on the left side of the slope permitted this direction of sliding.

2. Spot 1095/2: Rockfall on a Cut Slope Due to Toppling (SD-2-9)

At Km. 161.7, a very steep cut slope in strong but jointed sandstone has rocks falling due to toppling. The joints are orientated such that the individual blocks rotate away from the steep face when the back surfaces are filled with water during rain. The resulting falls are not large but they affect the roadway with small boulders and rock fragments when ever heavy rain occurs. The existing conditions are presented in Fig. 4.2.4.

3. Spot 1095/3: Rotational Landslide on a Cut Slope (SD-2-6)

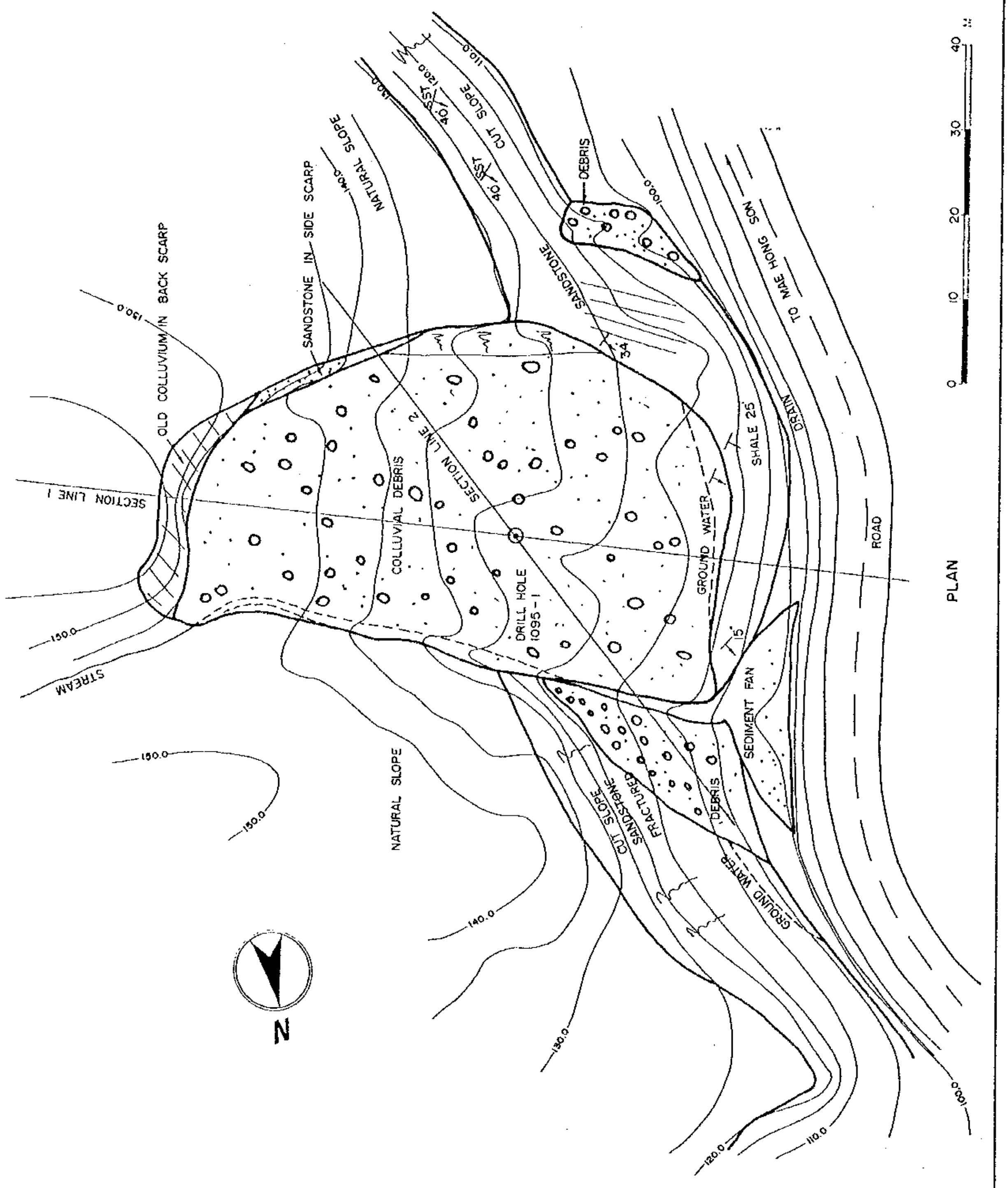
At Km. 168.65 a large, low angle slide has occurred that affects the natural ground and the original cut slope. The damaged surface is curved but probably is controlled to some degree by the bedding of the sandstone and shale. The damage is about 40m wide and around 20m high. The existing conditions are presented in Fig. 4.2.5.

In order to precipitate failure in the geometry found at this spot, it is necessary to assume a significant groundwater level or very low friction. The slide is reported to be still active and tends to move every time heavy rain falls.

The cause of the slide is probably a high groundwater pressure combined with low cohesion along the bedding and joint surfaces that combine to produce a curved failure surface.

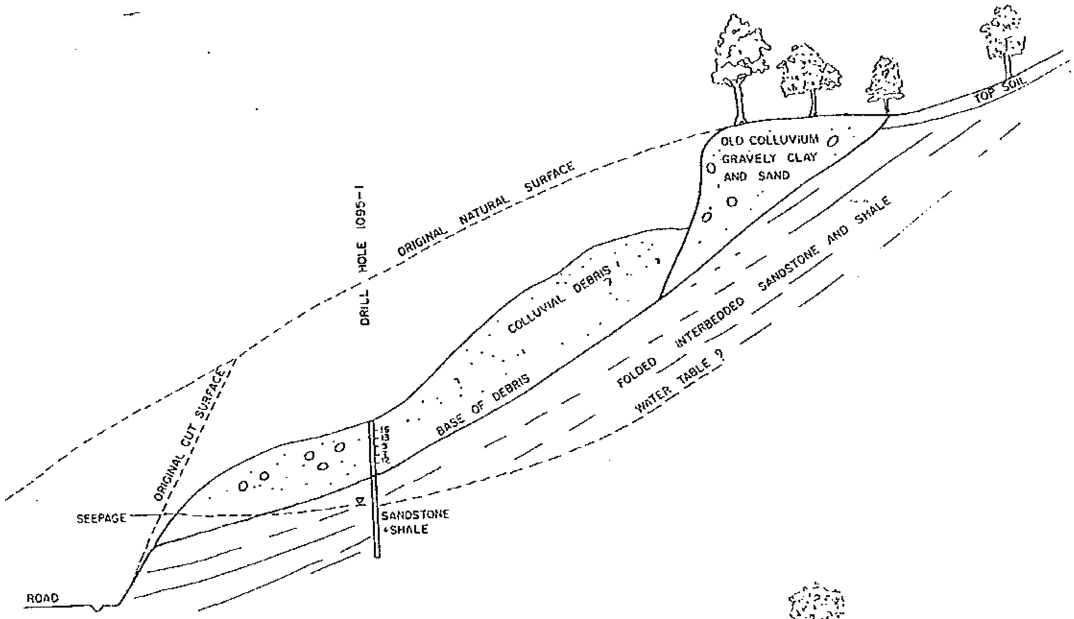
4. Spot 1095/4: Three-Dimensional Translational Landslide in a Cut Slope (SD-2-8)

At Km. 168.900, a three-dimensional wedge type failure has occurred. The sliding mass is bounded by bedding planes and joint surfaces. The underlying rock is sandstone and shale. The failure is about 30m wide and 20 m high. The original cut slope was at 0.5/1 with no berms. The failure debris is thin but contains a number of large intact blocks of sandstone that pose a hazard if they move again. The failure surfaces are exposed. The existing conditions are shown in Fig. 4.2.6.

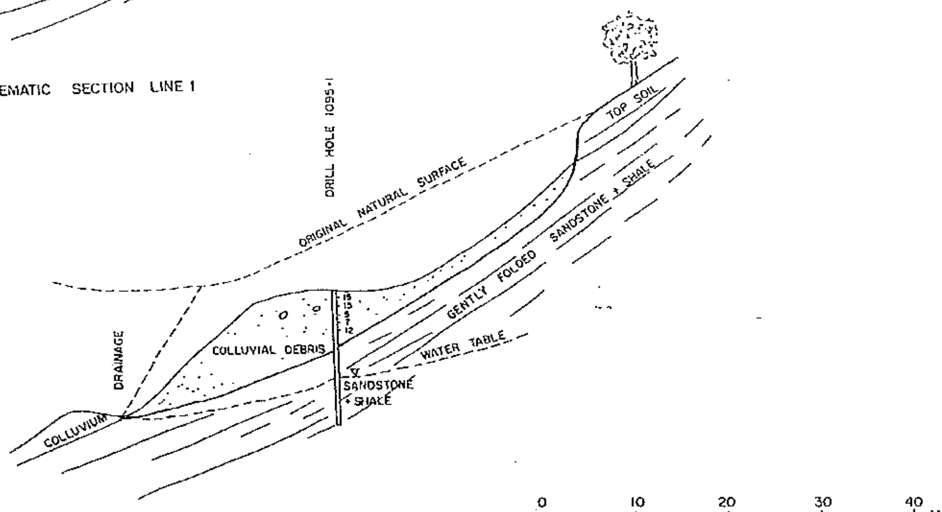


SPOT 1095/1 KM. 161.35
EXISTING CONDITIONS

Fig. 4.2.2 Details of Disaster Spot



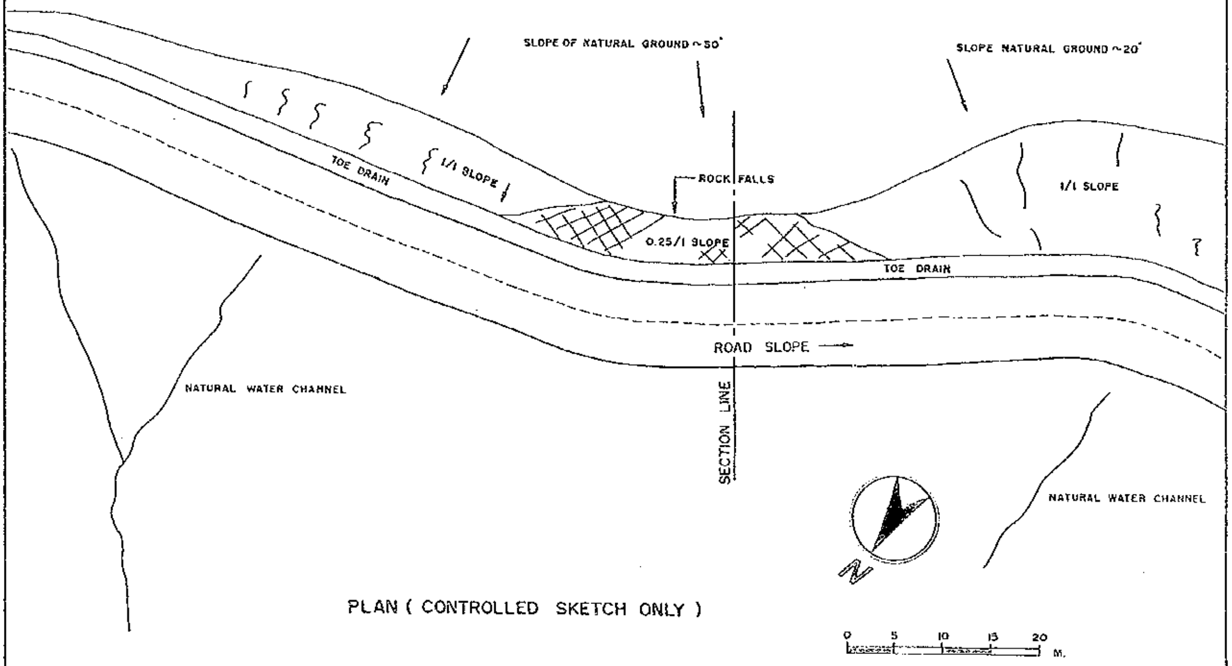
SCHEMATIC SECTION LINE 1

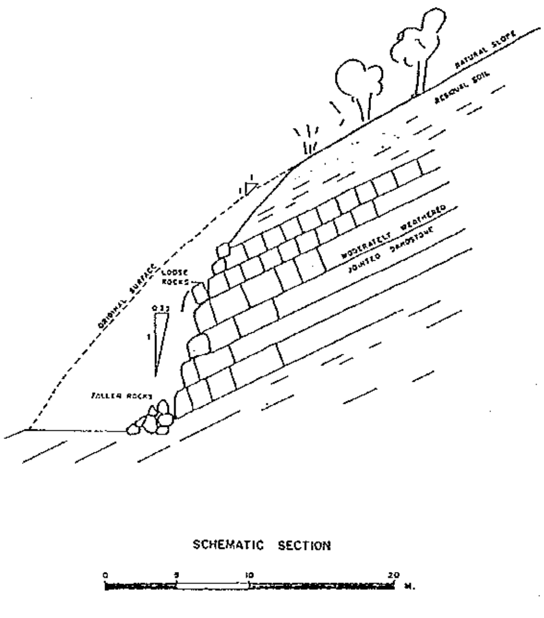


SCHEMATIC SECTION LINE 2

SPOT 1095/1 KM. 161.35
EXISTING CONDITIONS

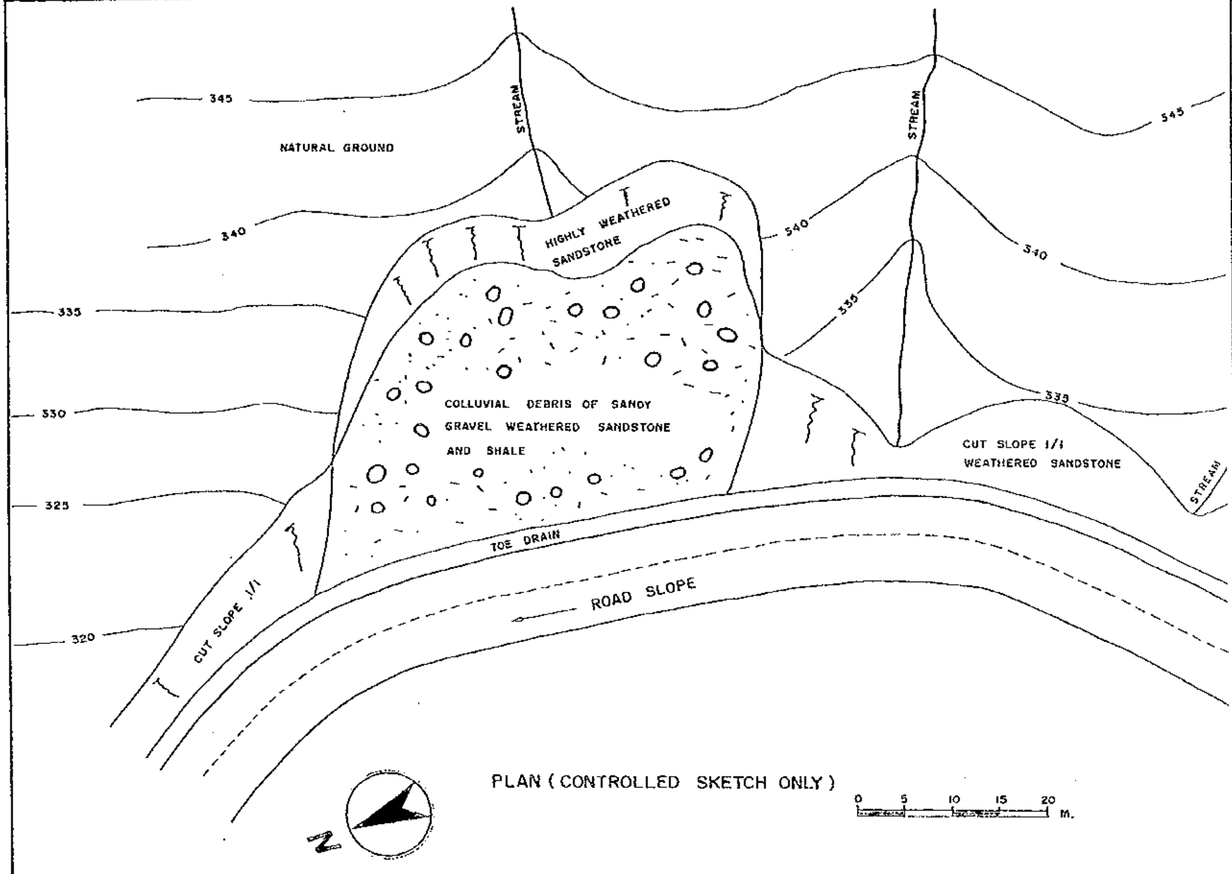
Fig. 4.2.3 Details of Disaster Spot

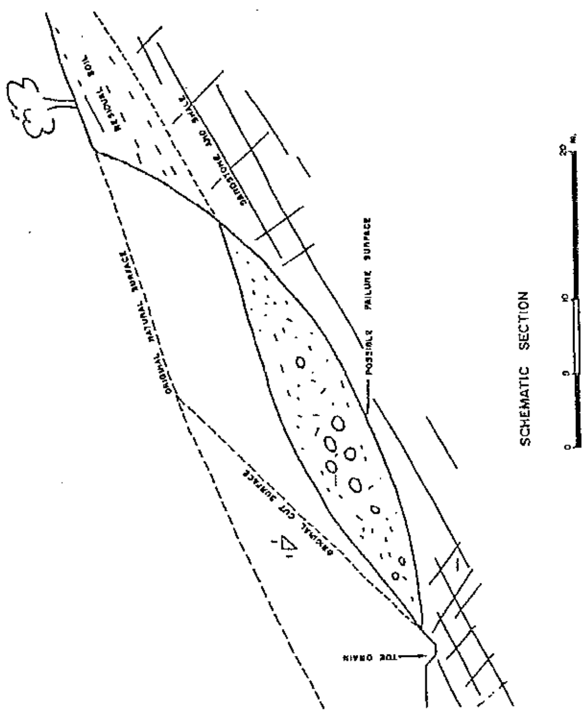




SPOT 1095/2 KM. 161,700
EXISTING CONDITIONS

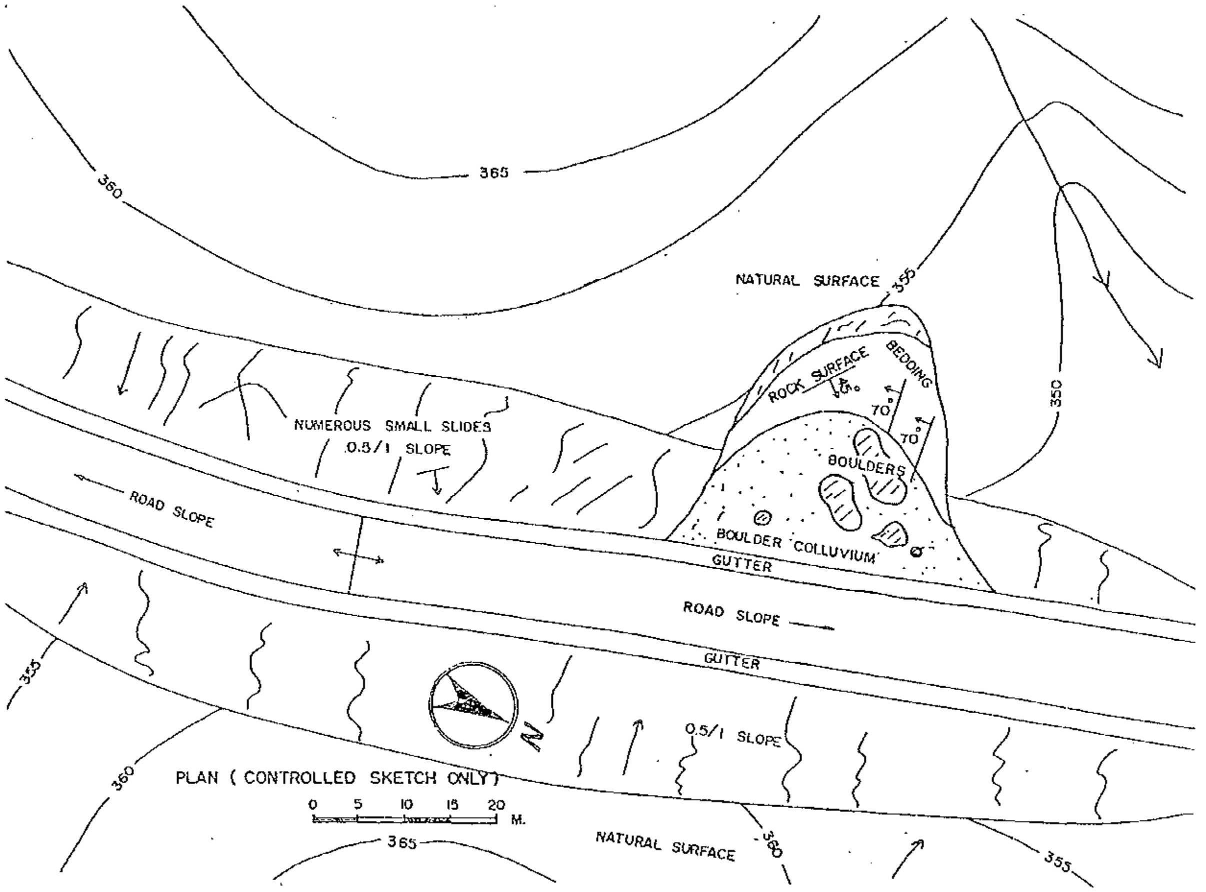
Fig. 4.2.4 Details of Disaster Spot

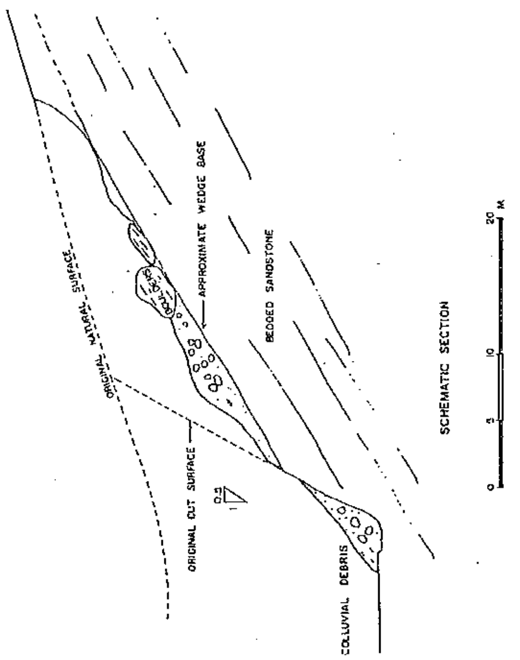




SPOT 1095/3 KM.168.650
EXISTING CONDITIONS

Fig. 4.2.5 Details of Disaster Spot





SPOT 1095/4 KM. 168.900
EXISTING CONDITIONS

Fig. 4.2.6 Details of Disaster Spot

4.3 Project Road 1149

4.3.1 Natural Conditions

1. Meteorology

The nearest meteorological station to Route 1149 is situated at Chiang Rai. The rainfall pattern is shown in Fig. 4.1.1 and has a 24hr rainfall intensity of 169.5mm for a fifty-year return period. The overall average annual rainfall is 1801.4 mm. Chiang Rai is about 40 km from Route 109 and the topography is distinctly different. There is a high probability that the magnitude and intensity of rainfall on the road is considerably higher than that recorded at Chiang Rai.

2. Geology

The first 4 kms of the route pass over recently accumulated sediments of mainly sand and silt. The majority of the route passes over the Doi Tung Igneous Complex, which contains intrusive igneous rocks ranging from acid pegmatites to diorite, hornblendite, gabbro, basalt and dolerite. The depth of weathering of these rocks is large but variable. The acid, quartz rich granitoids have the deepest weathering. There is also evidence of hydrothermal kaolinization.

3. Topography

The initial 4 kilometers of this road pass over flat lying alluvial terrain. The transition to the granitic hills is very marked and slope angles become 25 to 35 degrees. The formation of the hills is rounded. The road continues along side slopes until about Km. 12 where it follows a ridge crest to Km. 14.8.

4. Past Disaster Records

There are no records at the DOH of past disasters on this road for the preceding 10 years.

4.3.2 Socioeconomic Conditions

1. General

This highway originates at the junction with national highway Rt. 1 at Km. 871+173 near the northern border. It was first paved in 1971 as a single-lane roadway 4.0m in width. Due to deterioration, the route is, at present, being improved and its alignment was improved to eliminate steep grades. As a result, the route length became 24km instead of the original length of 17.4km. At the end of the route, and near Wat Prathard Doi Tung, a military earth road extends along the border till A. Mae Sai.

2. Function

The route has a special role in supporting the royal Doi Tung Development Project, which will provide stability and improve the quality of life of the local people in the northern areas. The project is operated and coordinated by many ministries and governmental organizations. The area has developed also as a tourist spot, with many tourism facilities. Six hill-tribe villages are served by the route in addition to a residential area, school and reservoir project. As it runs close to the border, the route is also important for national security. In the case of traffic being interrupted, the route, with its dead end, has no alternatives.

3. Population

The route is located in A. Mae Sai and the area along the route is not heavily populated. The nearest amphoes to the route are A. Mae Chan to the south and A. Mae Sai to the north. The area and population influenced by the route are as follows:

Table 4.3.1 Area and Population Influenced by Rt. 1149

	Population - 1991	Area (km^2)	Density
Changwat:			
Chiang Rai	1,048,200	11,678.3	89.76
Amphoe:			
A. Mae Sai	67,200	285.0	235.79
A. Mae Chan	126,100	1,013.9	124.37

4. Economy

GPP at constant 1988 prices for Chiang Rai is presented in Table 4.1.2.

5. Traffic

Traffic volume on this route is quite high taking into consideration that the route is not a thruway and does not pass through populated areas. Past ADT figures are presented in Table 4.3.2, while vehicle registration figures for Chiang Rai are presented in Table 4.1.4.

Table 4.3.2 Traffic Volume on Rt. 1149

Average Daily Traffic (ADT):

C-Sec	Km	1985	1987	1989	1991	1993
100	3+150	424	292	1335	1050	1178

Traffic Composition - 1993:

Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
351	585	26	204	32	0	1178

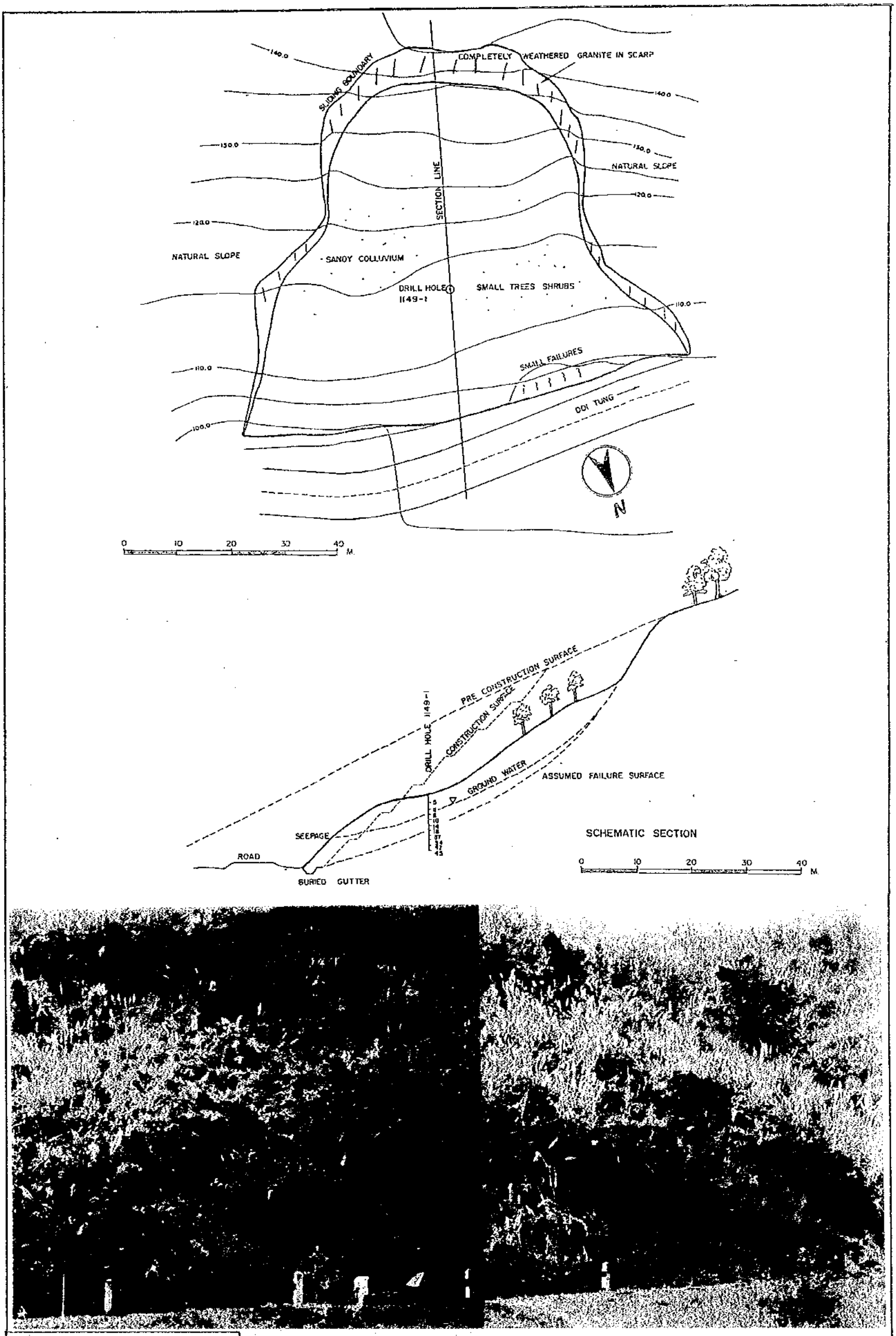
4.3.3 Existing Status of Damages

1. 1149/1 Rotational Landslide on a Cut Slope (SD-2-6)

At Km. 5.2, an 80m wide landslide has been moving over a period of years. The site is underlain by completely weathered granite. The preconstruction natural slope angle was about 25 degrees and the cut was designed at an average of about 42 degrees with 1/1 face angles with 1.5m - 2m wide berms spaced 5m vertically. Groundwater was seen seeping about 3-5 m above the base of the slope. Groundwater was also encountered in drilling at a depth of 2.6m. The existing conditions are illustrated in Fig. 4.3.1.

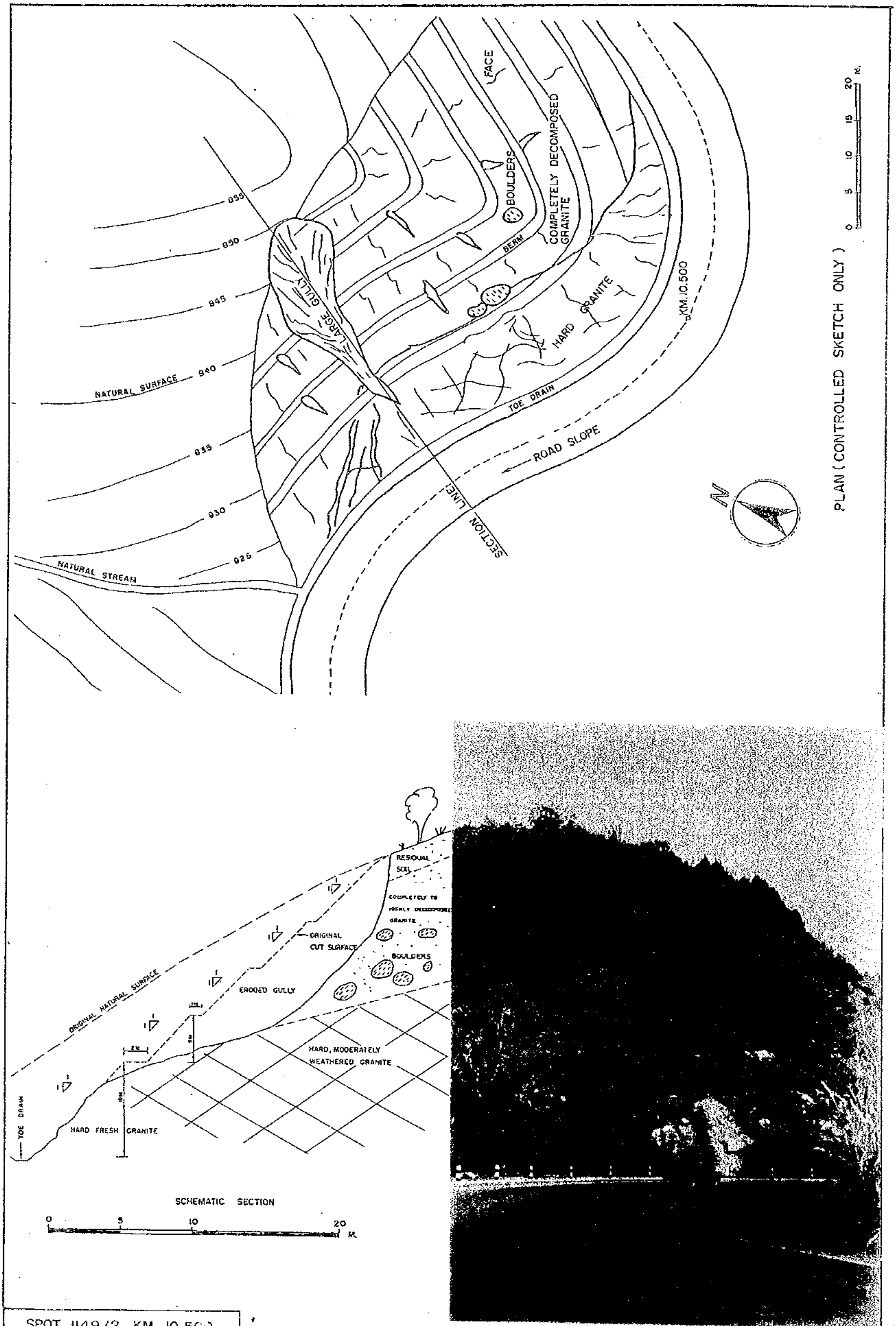
2. 1149/2 Gully Erosion on a Cut Slope (SD-2-3)

At Km. 10.50, a very large erosion gully has developed. The rock is granite with the lower portion of the slope being relatively hard and unweathered. The upper section is, however, highly to completely weathered and surface runoff has produced a gully that is about 10m wide and 15m high. It terminates on contacting hard granite 10m above the toe of the slope. The total cut slope height is about 30m with an angle of 1/1 or 45 degrees. The existing conditions are presented in Fig. 4.3.2.



SPOT 1149/1 KM. 5.200
EXISTING CONDITIONS

Fig. 4.3.1 Details of Disaster Spot



SPOT 1149/2 KM. 10.500
EXISTING CONDITIONS

Fig. 4.3.2 Details of Disaster Spot

4.4 Project Road 1256

4.4.1 Natural Conditions

1. Meteorology

The nearest meteorological station to Route 1256 is situated at Nan. The rainfall pattern is illustrated in Fig. 4.4.1 and has a 24hr rainfall intensity of 177.7mm for a fifty year return period. The overall average annual rainfall is 1801.4 mm. Nan is about 60 to 100 km from Route 1256 and the topography is distinctly different. There is a high probability that the magnitude and intensity of rainfall on the road is considerably higher than that recorded at Nan. As the road is in the far north, it is not affected significantly by typhoons or tropical storm systems, but is influenced more by monsoons or depleted storms passing through from Vietnam and Laos.

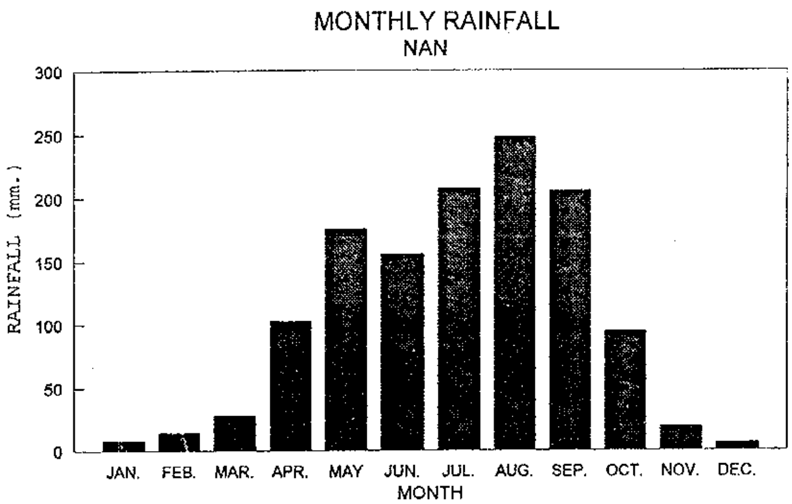


Fig. 4.4.1 Monthly Rainfall at Nan

2. Geology

The geology of this route is complex and contains a wide variety of sedimentary and metamorphic rock and residual soil types. The first 6 km of the road from Pua pass over flat lying recent alluvium. Just before the bridge at Km. 5.96, the geology changes to Upper Permian marine sediments metamorphosed to a foliated schist.

The schist changes to slate at Km. 10.0 and continues to Km 15.5. Massive greywacke and sandstone with no significant foliation are found from Km. 15.5 to Km. 21.0. At Km. 21.0 older Permian metamorphosed marine sediments are again exposed. The marble areas contain some thick layers of red residual clayey soil. These rocks persist till Km. 25 where younger Mesozoic terrestrial sediments are exposed. The depth of weathering in the sediments is not great and rock is usually encountered less than 5m below the surface. Along side slopes and in drainage channels lobes of colluvium can be found up to 10 metres thick.

From Km. 32.0 until the end of the road the rocks are folded red terrestrial sediments that are stratigraphically related to the Khorat Group.

3. Topography

The first 6 km from Pua pass over flat alluvial terrain. The terrain sections have steep scarp slopes and gentler dip slopes. Narrow ridges, shallow soil and structural control of drainage features are common. Very steep natural slopes are found in the sedimentary rocks. The drainage was also structurally controlled with weak beds of shale being a common alignment for stream beds.

4. Past Disaster Records

A total of seven slope failures have been recorded in DOH files over the last 10 years. The total value of the funds used to repair these failures is nearly 5 million baht. Five of the seven reports refer to a fill failure at Km. 45.675. The other two sites can not be located from the records.

4.4.2 Socioeconomic Conditions

1. General

The route is located near to the eastern border in the changwat of Nan in the North Region. It connects the two amphoes of A. Pua and K.A. Boklua through mountainous terrains, designated as a national park, with flat plains at both sides. The flat areas are utilized as agricultural land with many socioeconomic activities near the amphoe centers. The route has a long history in securing the territories of the country due to its strategic location.

2. Function

The route initially served as a security zone for the Third Army near the border with Laos. It helped the military transport services to the area to support national security and integration. Later, it had the important role of promoting rural development, since it connects two amphoe centers and is the only access road for five villages located along its alignment and for another twelve villages located in the nearby mountainous areas. Four schools and a hospital are located along the route, which passes through many scenic areas. At present, the route is used to transport farm products and is an essential road for the daily activities of the local people. Constructing this route has provided many opportunities to the local people and improved the quality of their lives.

Two alternative roads are available in the case that this route is unusable: Rt. 1081, a road to the south that is a paved road in good condition, and Rt. 1080/1081, a road to the north that is partially unpaved and is almost double the length. ARD and PWD roads in the area do not offer any alternatives for this route.

3. Population

The population of the changwat of Nan and the two amphoes of A. Pua and K.A. Boklua, which are directly served by the route, is presented in the following table:

Table 4.4.1 Area and Population Influenced by Rt. 1256

	Population - 1991	Area (km^2)	Density
Changwat:			
Nan	455,100	12,122.0	37.54
Amphoe:			
A. Pua	67,100	657.4	102.07
K.A. Boklua	17,500	1,181.1	14.82

4. Economy

The economic indicators for Nan show that it depends to a large extent on the agricultural sector, which accounts for about 30% of GPP at constant 1988 prices, as shown in Table 4.4.2.

Table 4.4.2 Economic Indicators for Rt. 1256 ('000 baht)

	1986	1991
Nan:		
Agriculture	1,448,844	1,748,408
Crops	886,898	1,212,142
Livestock	205,657	286,862
Fisheries	12,929	15,044
Forestry	121,593	0
Agricultural services	86,334	88,793
Processed agri. products	135,433	145,567
Mining and quarrying	7,726	10,294
Manufacturing	75,889	97,128
Construction	392,949	562,020
Electricity and water supply	45,261	67,185
Transportation and communications	154,578	200,125
Wholesale and retail trade	867,167	1,329,164
Banking, insurance and real estate	84,849	146,326
Ownership of dwellings	400,622	458,429
Public administration and defense	368,784	473,573
Services	617,945	804,217
GPP	4,464,614	5,896,869

5. Traffic

The route has low traffic volumes at its midsection as shown in Table 4.4.3, but it has heavier volumes at sections near the amphoe centers. Due to its mountainous terrain and steep grades, only a small number of heavy trucks and buses use this route.

Table 4.4.3 Traffic Volume on Rt. 1256

Average Daily Traffic (ADT):

C-Sec	Km	1985	1987	1989	1991	1993
101	3+500	102	173	230	624	416

Traffic Composition - 1993:

Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
46	20	0	283	62	5	416

Vehicle registration records between 1988 and 1990 in Nan are presented in Table 4.4.4.

Table 4.4.4 Vehicle Registration for Rt. 1256

	1988	1989	1990
Nan:			
Passenger Car	1,445	955	1,023
Van & Truck	5,793	3,496	4,136
Motorcycle	40,459	36,115	42,258

4.4.3 Existing Status of Damages

1. Spot 1256/1: Inundation of "At-Grade" Road (RF-1-2)

At Km 1.10, a section of the route in this flat terrain has a very low embankment. The length of the road affected by inundation is about 200 metres and the depth of the inundation was reported to be approximately 50 centimeters from the surface of the road. The alignment of this spot is a part of a low section in the vertical curve of this road.

Due to inadequate hydraulic control of the natural drainage patterns, the discharge from the mountains to the south spreads over the flat terrain at times of heavy and sustained rainfall. Floods on this section occur almost every wet season.

It has a number of cross drainage installations consisting of pipe culverts that vary in diameter from 60, 80 to 100 centimeters. The approximate spacing of these culverts is 160 metres. A cross section of this road is presented in Fig. 4.4.2

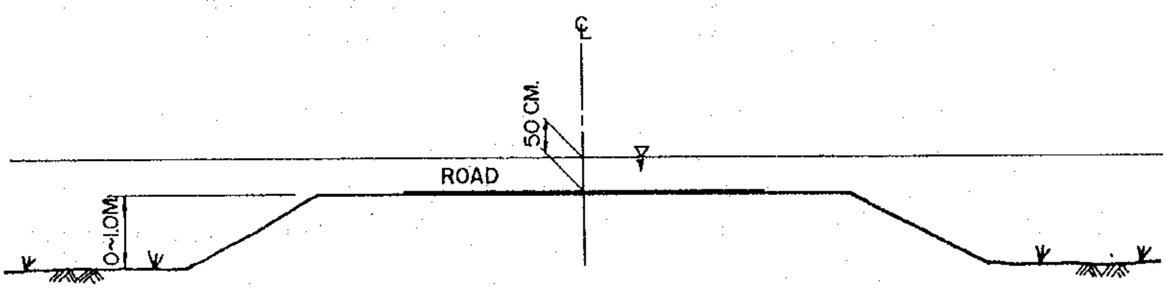


Fig. 4.4.2 Cross Section of Route 1256 at Km. 1.1

2. Spot 1256/2/3: Abutment Scouring (BC-1-5)
Scouring of River Bank (BC-1-9)

The bridge at this site crosses the Nam Yo River at a point where it emerges from steep mountainous terrain. The stream velocities are relatively high. The structure of the bridge consists of 5x10 metre concrete girder spans giving a 50 metre total length. The piers and abutments of the bridge are constructed using bent-pile structures and both abutments are protected with concrete revetments.

The base of the abutment protection revetments are inadequately embedded and have been subject to scouring by the outside curve of the stream on the western side of the bridge.

Although the river banks are protected by natural vegetation and the probability of the river channel shifting is low, a part of the river bank has been eroded a little on the upstream side of the western bank.

About 100 metres downstream of the bridge a weir has been built. This should serve to reduce riverbed degradation. The existing conditions are illustrated in Fig. 4.4.3.

3. Spot 1256/4: Gully Erosion on a Cut Slope (SD-2-3)

At Km. 22.00 an area of cut slope is affected by gully erosion. The slope is about 20m high and the gully is about 15m long, 5m wide and about 10m deep. It has formed along a shear zone dipping 70 degrees.

The original cut slope was at an angle of 45 degrees with berms 1.5m wide at a vertical spacing of 5m. The gully is an isolated feature, as most of the rest of the slope is undamaged. The existing conditions are presented in Fig. 4.4.4.

4. Spot 1256/5: Rotational Landslide on a Fill Slope (SD-3-6)

At Km. 22.650 a 20m high fill slope has recently been repaired by refilling. The failure extended 40m along the edge of the pavement.

The original failure was caused by the erosion of the toe by an incident stream. This resulted in a change in the geometry of the slope. The fill has not been compacted and was of marginal stability in its original form when wet. The fill is comprised of soft sandstone and shale. The existing conditions are illustrated in Fig. 4.4.5.

5. Spot 1256/6: Rotational Landslide on a Cut Slope (SD-2-6)

At Km. 25.650 two large failures have occurred that appear to be combined rotations and translations in weathered sandstone. There are relict joints and bedding surfaces that have contributed to the formation of the failure surfaces.The existing conditions are presented in Fig.4.4.6.

In analyzing the slope stability using computer techniques, it is apparent that the current failed slope debris is even less stable than the original slope for equivalent groundwater conditions and material strengths. The current situation is unsafe as groundwater was found only 2.2m from the surface during drilling.

6. Spot 1256/7: Two-Dimensional Translational Slide on a Cut Slope (SD-2-7)

At Km. 27.500 a slide has occurred in the upper three berms of a 25m high slope. The sliding at this spot is a two-dimensional translation along bedding inclined at about 45 degrees. The presence of berms has allowed the bedding to"daylight" in the interberm faces.

The cohesion along the bedding was insufficient to prevent sliding in the upper 15m of the slope as the rock is more weathered. The existing conditions of the site are illustrated in Fig. 4.4.7.

7. Spot 1256/8: Two-Dimensional Landslide on a Fill Slope (SD-3-7)

At Km. 40.15 a natural saddle has been filled to a depth of 9.5m at the crest. The natural slope is inclined at 30 degrees resulting in a long thin and high fill slope. The contact between the natural surface and the fill is essentially planar and forms a two-dimensional sliding surface.

The edges and base of the fill are being eroded. The slope has failed repeatedly and 9,000 cubic meters of fill has been placed so far in an attempt to stabilize the slope. The route here is still restricted to single lane traffic.

The fill is composed of weak weathered red shale/siltstone and sandstone with elongate shaped particles. The existing conditions are illustrated in Fig 4.4.8.

8. Spot 1256/9: Sheet Erosion on a Cut Slope (SD-2-1)

At Km. 43 the shale is "slaking", which has resulted in a general erosion of the surface with extensive thin sheets of erosion fragments covering the berm benches and toe ditch. The slaking is caused by the swelling and shrinking characteristics of clays contained in the red shale in response to diurnal and seasonal changes in humidity. Fig 4.4.10 illustrates the site at Km. 43.

9. Spot 1256/10: Rockfalls on a Cut Slope due to Undercutting (SD-2-10)

At Km. 44.60 steeply dipping alternating interbedded sandstone and shale are exposed in a steep (70+ degrees) cut slope. The erosion of the weathered soft shale has allowed large blocks of sandstone to fall to the roadway. The existing conditions are illustrated in Fig. 4.4.10.

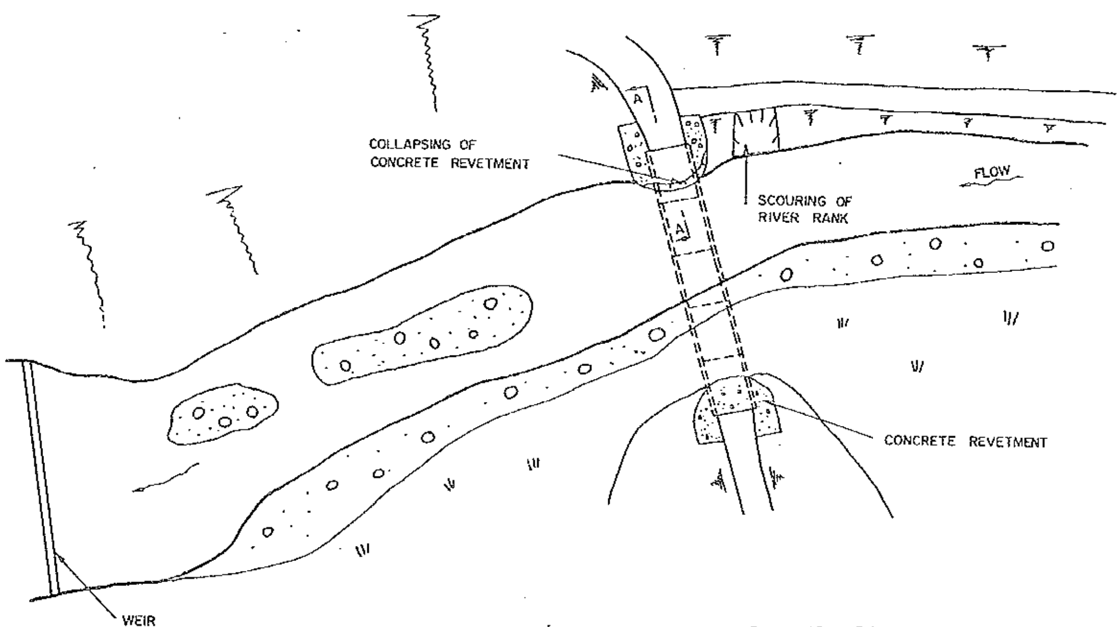
10. Spot 1256/11: Three-Dimensional Wedge failure in a Cut Slope (SD-2-8)
Landslide on fill slope(SD-3-7)

At Km. 45.675 a very large fill failure 55 m high has occurred that has left the road open to only one lane of traffic. The fill toe has been eroded by a stream and the entire fill mass has failed exposing the original natural surface.

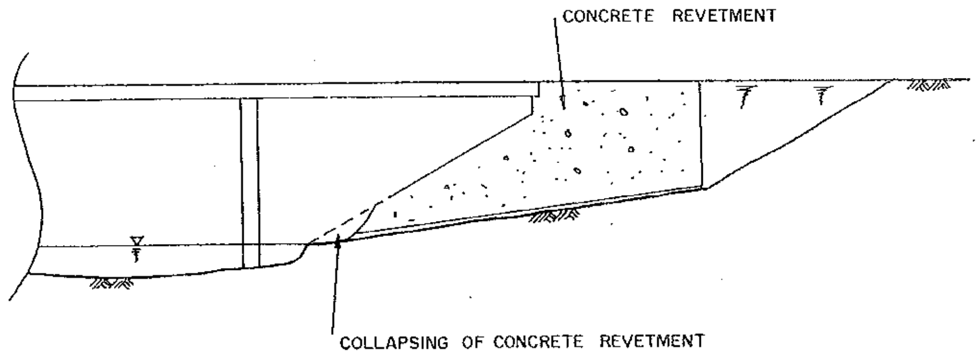
The construction of bank protection works on the stream adjacent to the fill slope has not prevented failure. The natural slope angle is over 45 degrees.

The geology of the site consists of steeply dipping alternating beds of massive red sandstone and thin beds of red shale. The natural conditions of the site are illustrated in Fig. 4.4.11 and Fig. 4.4.12.

SPOT 1256/2/3 KM. 5.963



PLAN



SECTION A-A

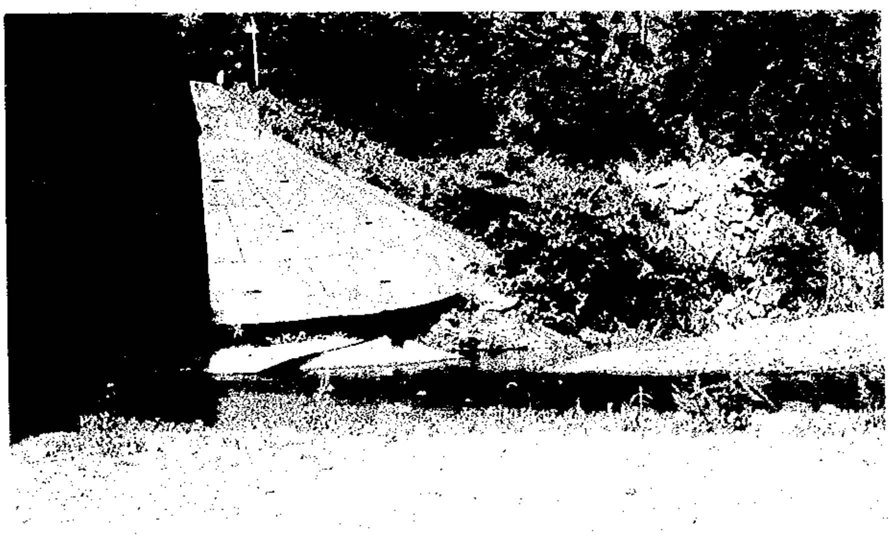
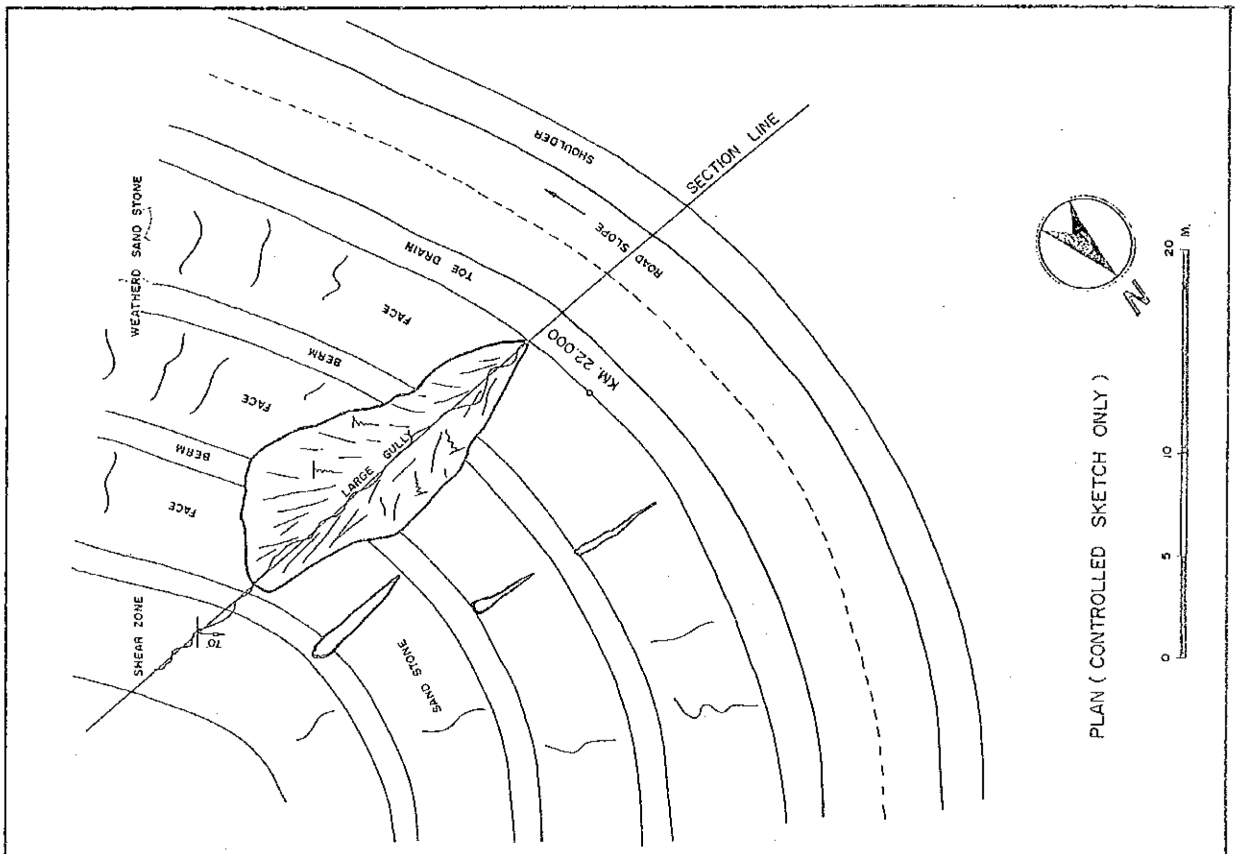
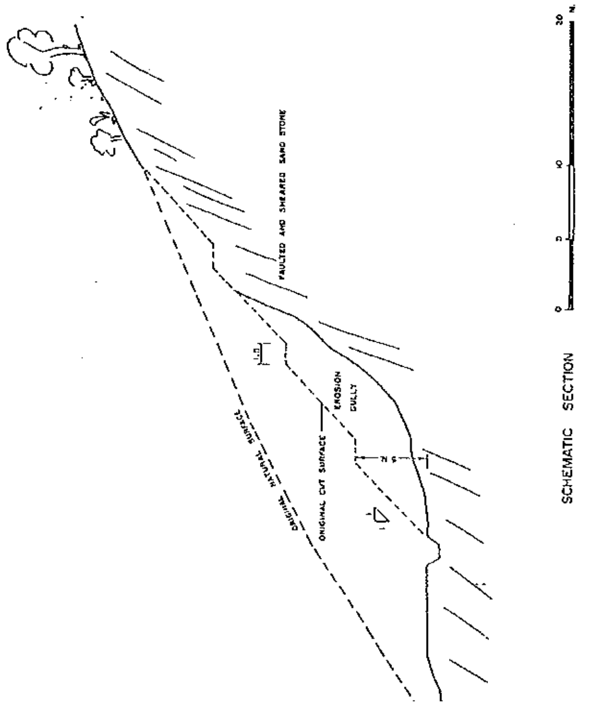


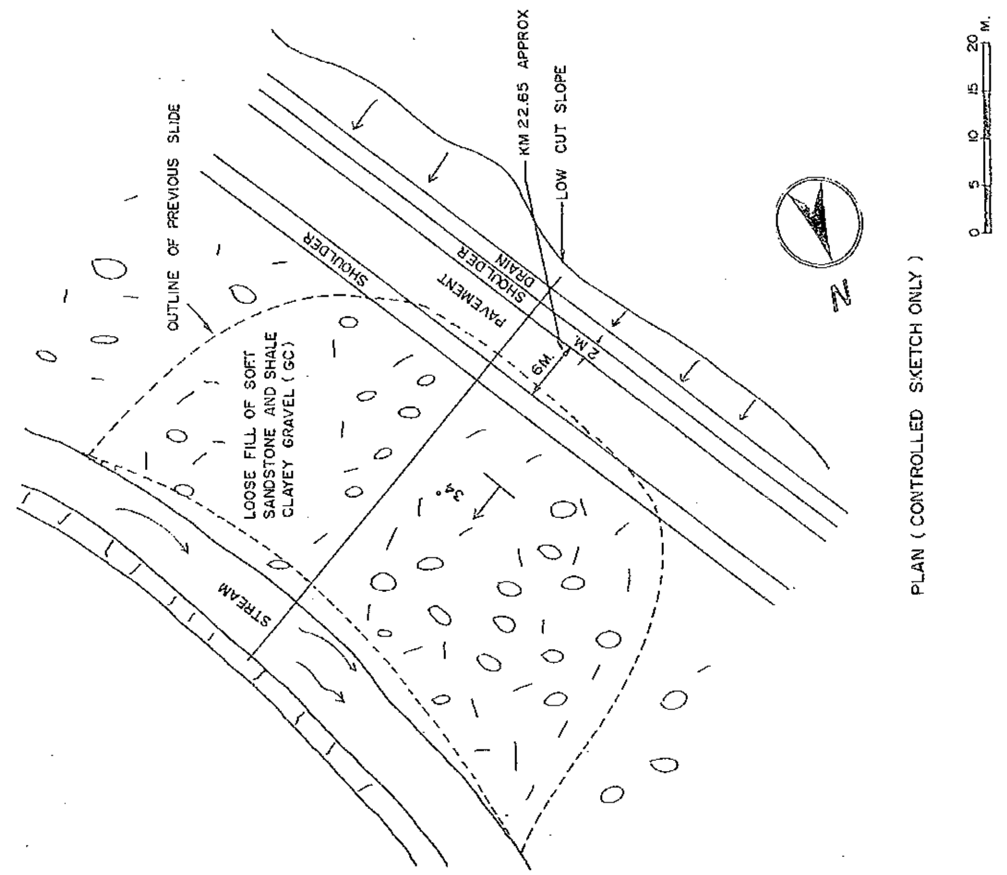
Fig. 4.4.3 Details of Disaster Spot

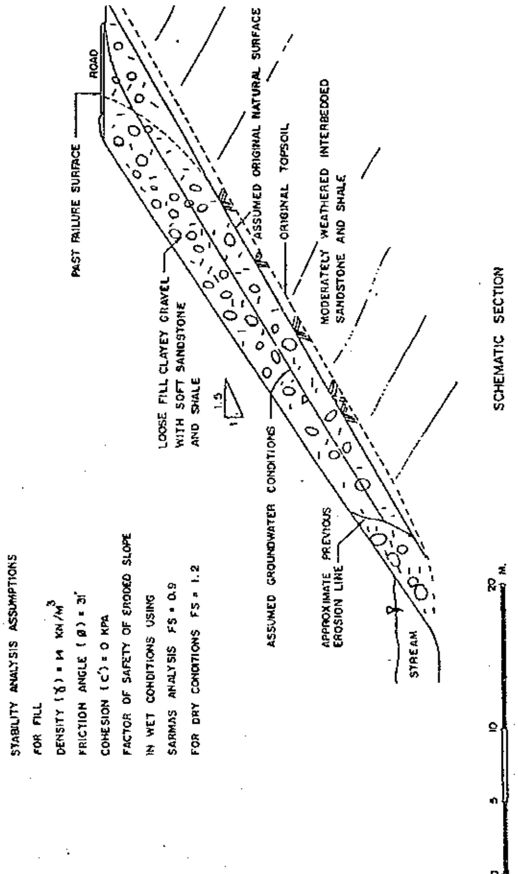


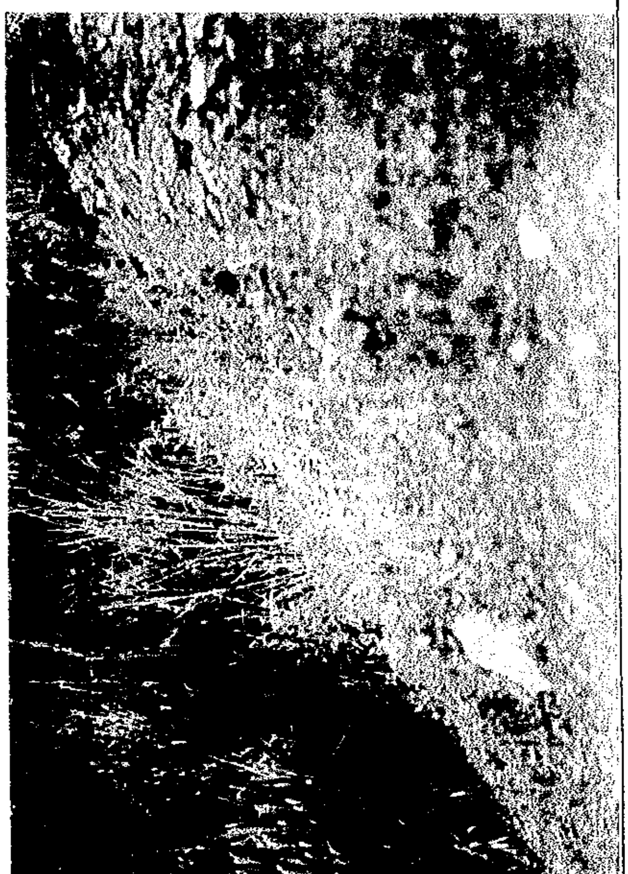


SPOT 1256/4 KM. 22.000
EXISTING CONDITIONS

Fig. 4.4.4 Details of Disaster Spot



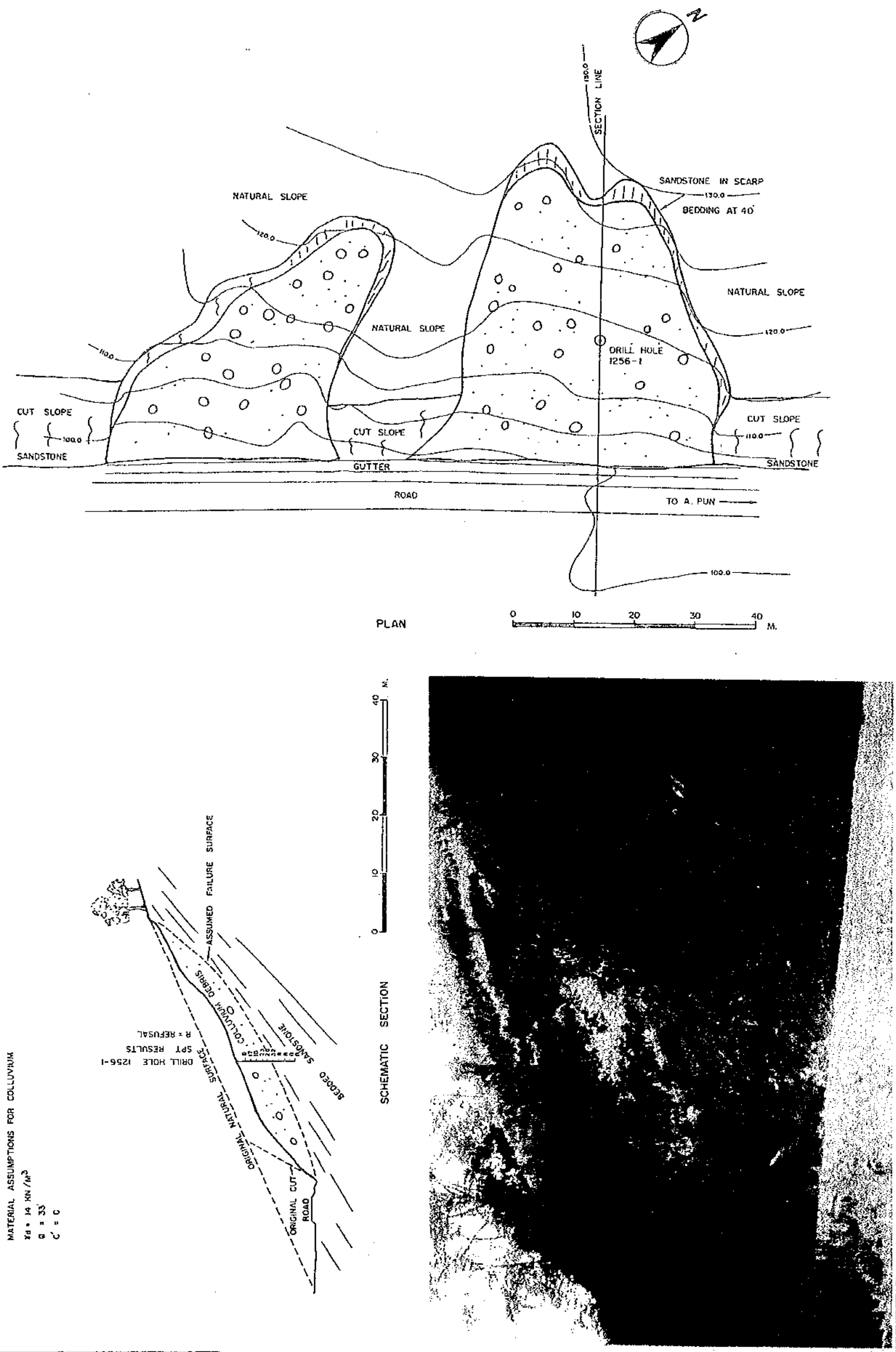




SPOT 1256/5 KM. 22.65

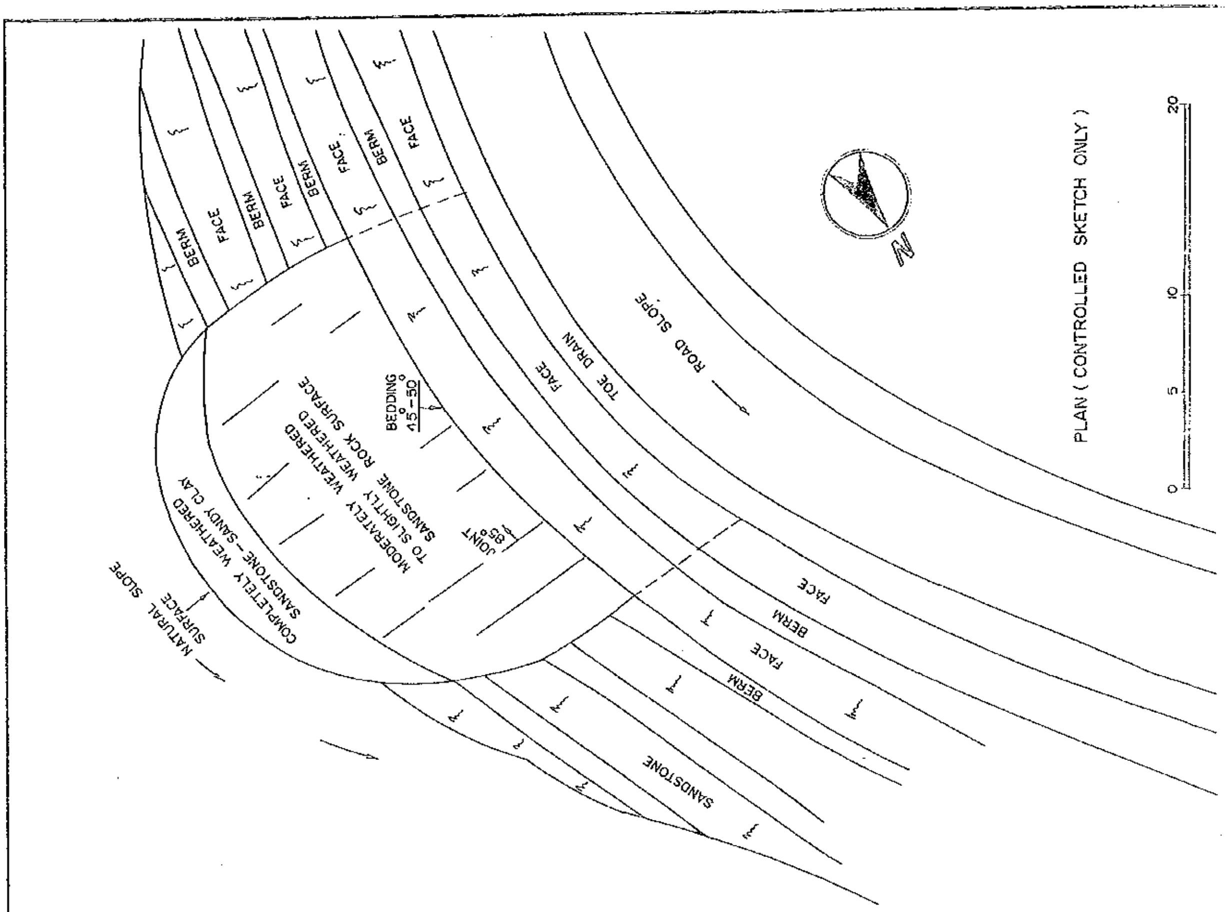
EXISTING CONDITIONS

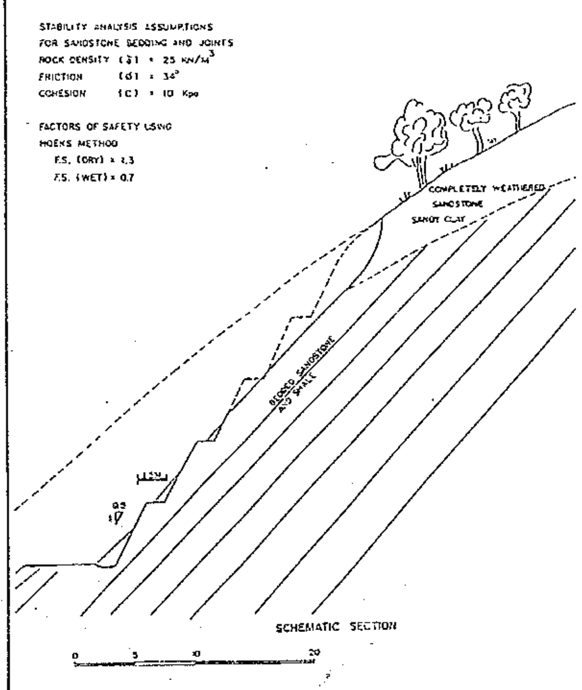
Fig. 4.4.5 Details of Disaster Spot



SPOT 1256/6 KM. 25.65
EXISTING CONDITIONS

Fig. 4.4.6 Details of Disaster Spot





SPOT 1256/7 KM. 27.500
EXISTING CONDITIONS

Fig. 4.4.7 Details of Disaster Spot

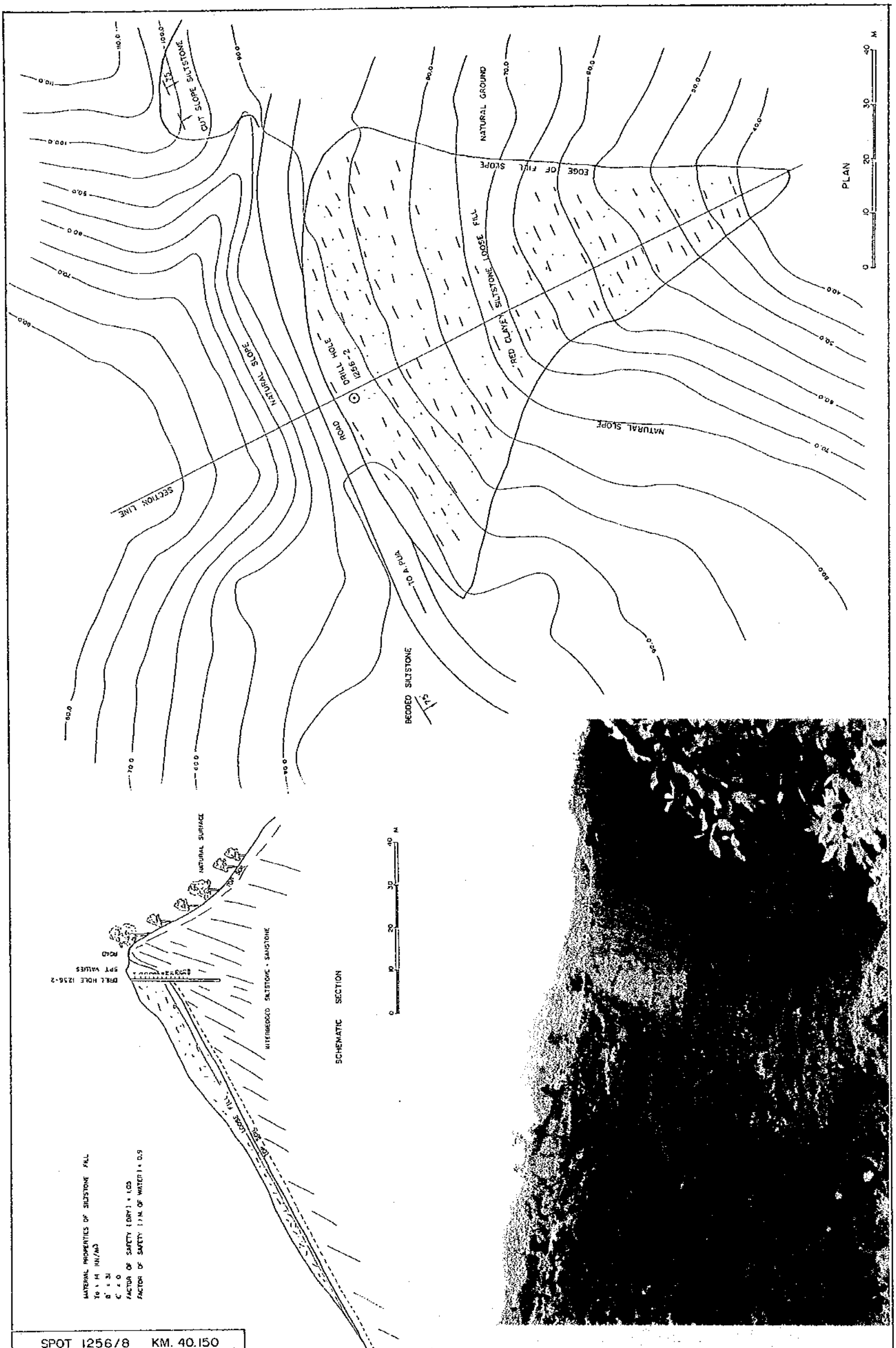
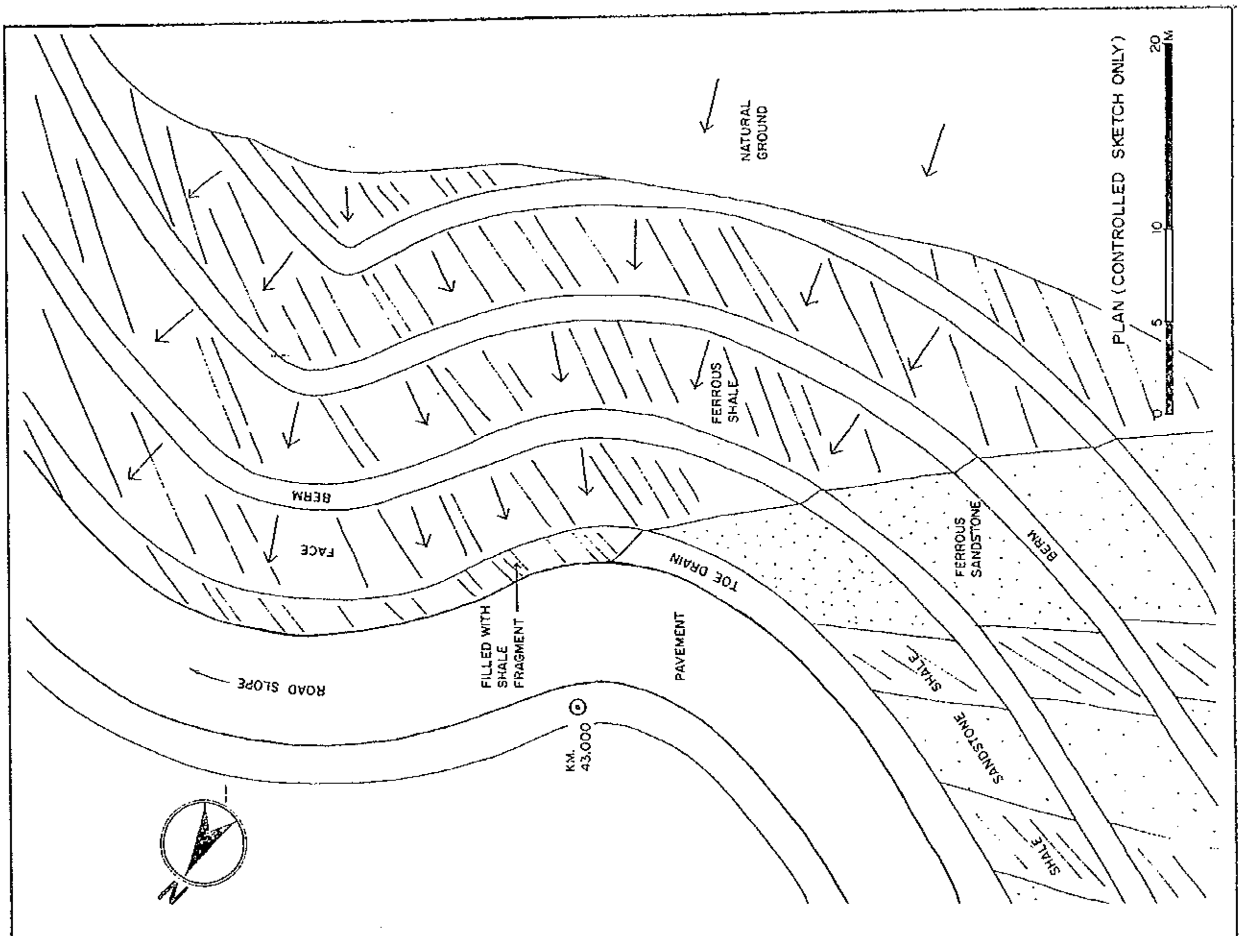
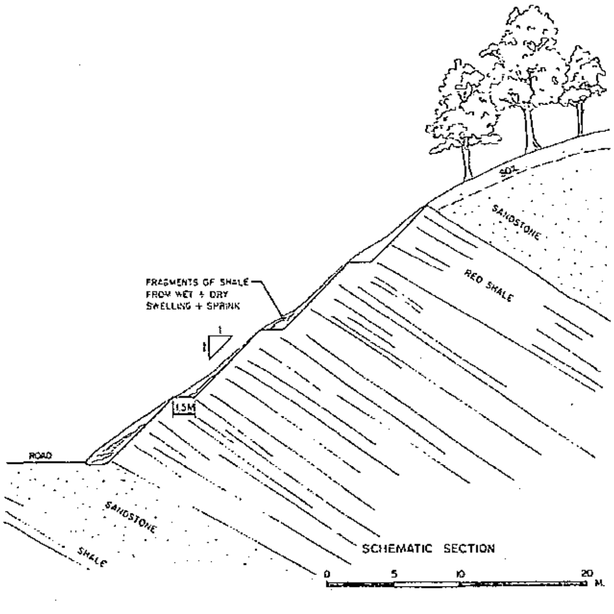


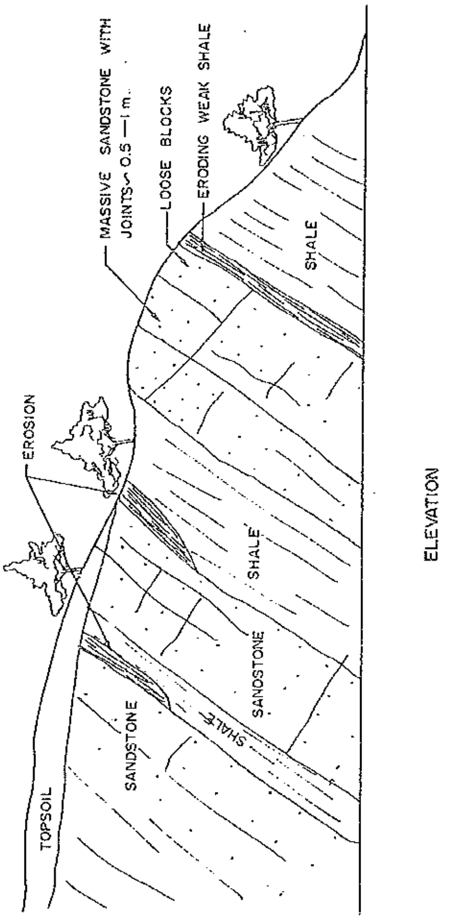
Fig. 4.4.8 Details of Disaster Spot

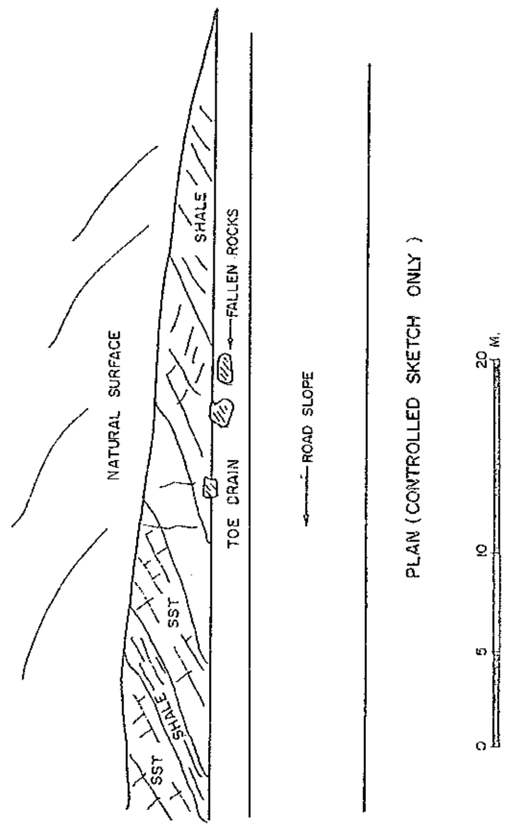


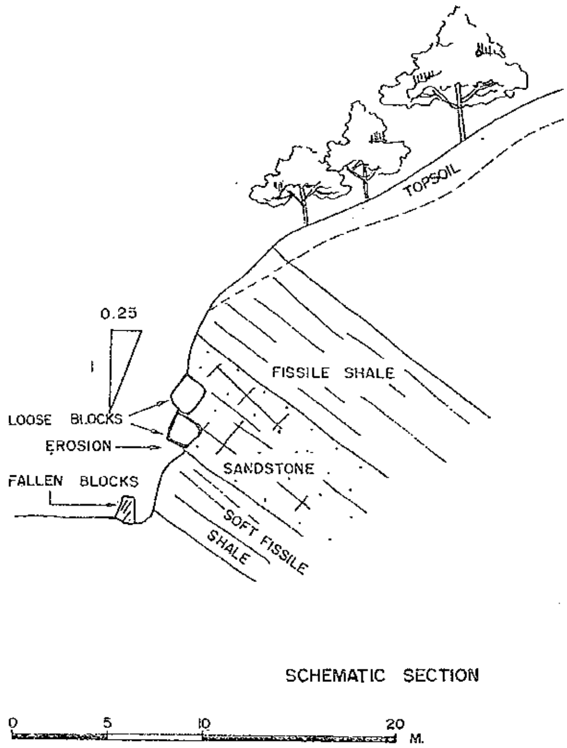


SPOT 1256/9 KM. 43.00
EXISTING CONDITIONS

Fig. 4.4.9 Details of Disaster Spot

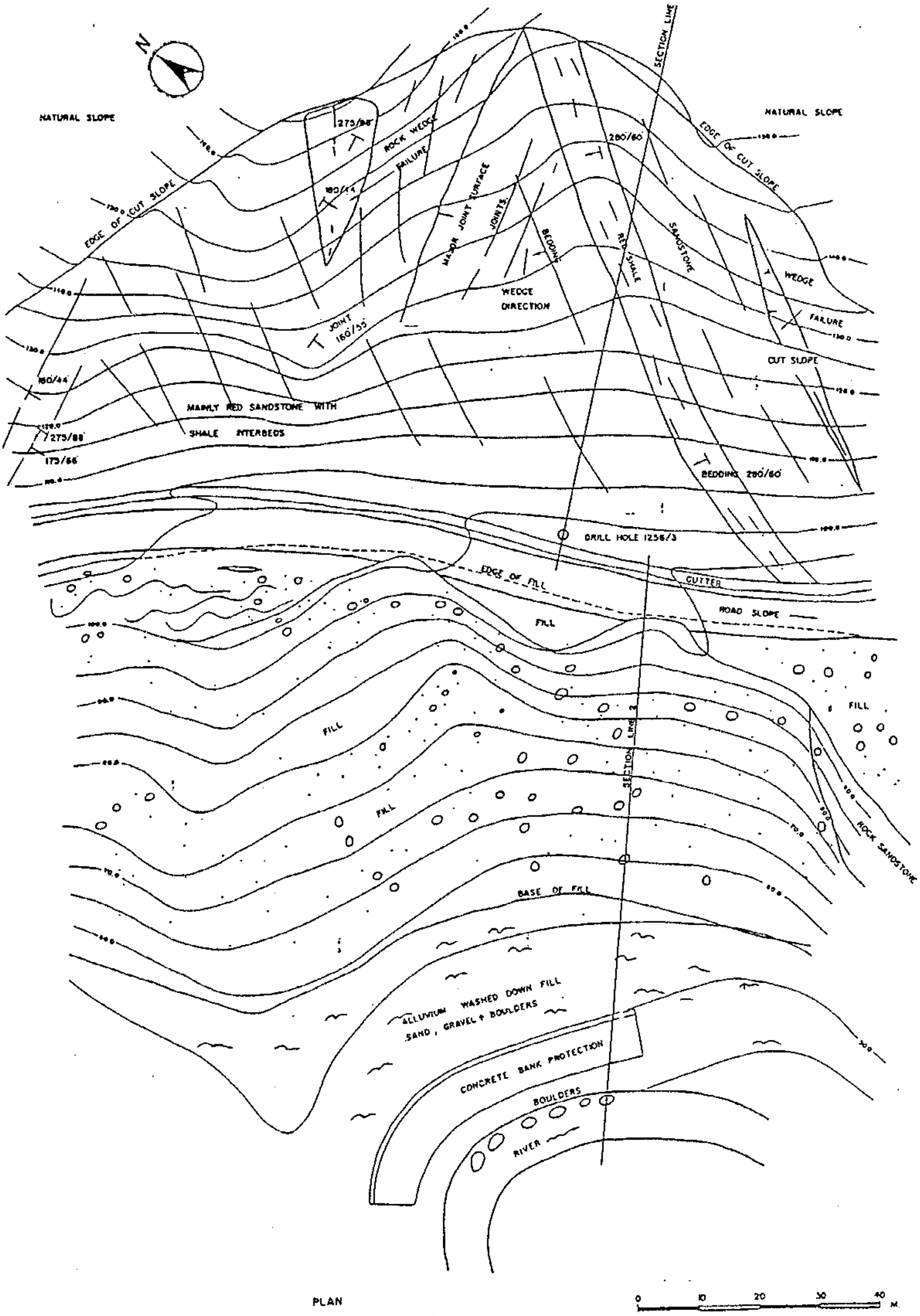






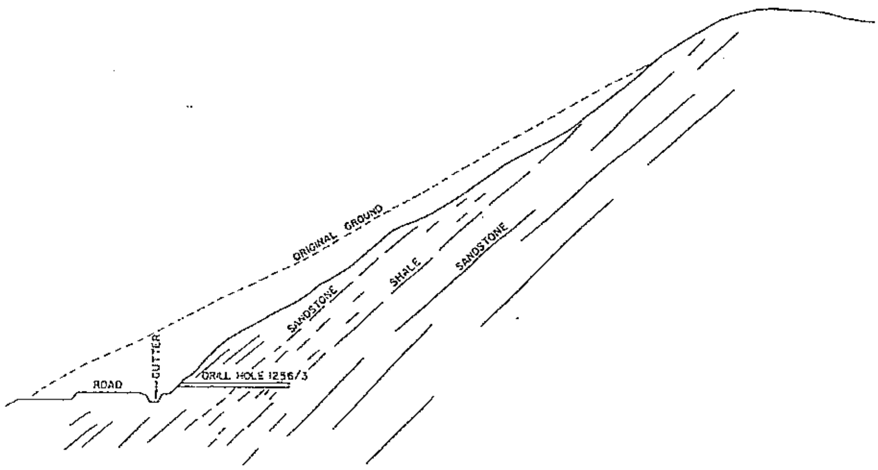
SPOT 1256/10 KM. 44 600
EXISTING CONDITIONS

Fig. 4.4.10 Details of Disaster Spot

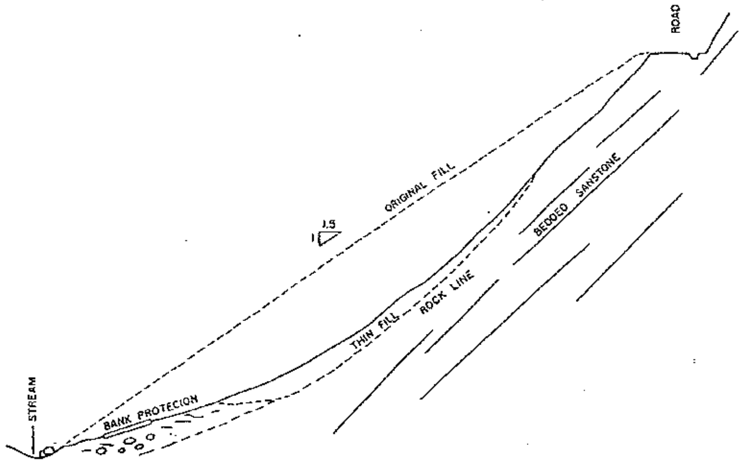


SPOT 1256/II KM. 45.675
EXISTING CONDITIONS

Fig. 4.4.11 Details of Disaster Spot



SCHEMATIC SECTION LINE 1



SCHEMATIC SECTION LINE 2

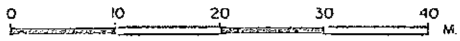


Fig. 4.4.12 Details of Disaster Spot

SPOT 1256/II KM. 45.675
EXISTING CONDITIONS

4.5 Project Road 4

4.5.1 Natural Conditions

1. Meteorology

The closest meteorological station to this route is at Trang. Peak rainfall occurs in September and the annual total rainfall is 2187 mm. Tha annual distribution of rainfall is illustrated in Fig.4.5.1. The maximum 24hr rainfall intensity is 282mm with a return period of 50 years. The mountains along this route are not very high and it is expected that the rainfall patterns recorded at Trang fairly represent conditions at the disaster spots. The area is subject to typhoons in the latter part of the year.

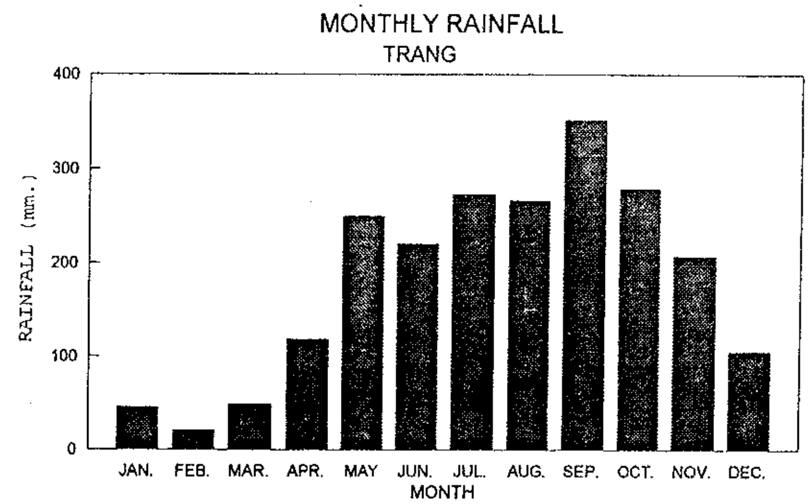


Fig. 4.5.1 Monthly Rainfall at Trang

2. Geology

The first 23 km of this road from Phatthalung to Trang pass over recent alluvium. Tertiary sandstone and siltstone beds with occasional exposures of Carboniferous metasediments are present until Km. 28.4. Limestone of the Ordivician Tung Song Group is found along the northern side of the road until Km. 35. Tertiary sediments continue until the contact with the Mesozoic granite intrusion at Km. 36.7. The granite contains a number of roof pendants of older sedimentary rock and it is deeply weathered. The granite continues until Km. 45.5 where Tertiary sandstones are again encountered. At Km. 47.5 the shales of the Devonian Tanaosi Formation are found and extend to Km. 50. Recent alluvium covers most of the rest of the road to Trang.

3. Topography

The recent alluvium to Km. 23 is flat lying with meandering streams. Rolling low hills characterize the tertiary sediments to Km. 28.4. The limestone terrain is karstic with very steep cliffs of limestone with flat intermediate plains of clayey residual soil. The emergence of granite is marked by a change to rounded mountains with side slopes of about 20 to 30 degrees. After the granite is passed at Km.45.5, the terrain consists of rolling low hills until a recent alluvial plain is found at about Km. 50.

4. Past Disaster Records

DOH records for this section of Route 4 over the last 10 years consist of three incidences of minor surface damage and one incident of inundation without damage at Km. 27.5.

4.5.2 Socioeconomic Conditions

1. General

The project route is a section of national highway Rt.4, which connects the two changwat centers of Phatthalung and Trang in the South Region. The route is one of four main trunk roads in the country and it handles heavy traffic volumes. There are plans to widen the entire route to a 4-lane highway.

The route section in Trang is characterized as both flat and mountainous with many horizontal and vertical curves, while the Phatthalung section is flat and rolling. As the South Region is, in general, subject to heavy rains every year, this trunk road faces annual traffic interruptions due to the resulting flooding or landslides.

2. Function

In addition to connecting two changwat centers, this section of Rt. 4 is the only access road to one amphoe and fourteen villages located along its alignment between the two changwat centers. As a result, numerous socioeconomic activities are located at the roadsides in the non-mountainous areas with schools, hospitals, commercial areas and farmlands. The project route is a traversal west-east road, which has its importance in connecting changwats on the Andaman Sea of the South Region to other changwants on the Gulf of Thailand.

Routes which can be considered as alternatives for connecting the two changwats in the case of a traffic interruption are Rt. 4151 to the north, in which pavement works are still under progress, and Rt. 406 to the south. ARD or PWD roads in the area do not provide alternatives.

3. Population

The population of the two changwats of Phatthalung and Trang as well as their municipality areas and K.A. Na Yong, which are located along the project route, are presented in the following table:

Table 4.5.1 Area and Population Influenced by Rt. 4

	Population - 1991	Area (km^2)	Density
Changwat:			
Phatthalung	465,600	3,642.9	127.81
Trang	526,700	4,917.4	107.11
Amphoe:			
Muang Phatthalung	135,400	653.1	207.32
Muang Trang	61,200	533.9	114.63
K.A. Na Yong	38,800	165.0	235.15

4. Economy

Trang has a considerably high share of about 44% for the agricultural sector, which is only 32% for Phatthalung, as shown in Table 4.5.2 of the sectoral GPP at constant 1988 prices for the two changwats accommodating the project route.

Industrial-related sub-sectors account about 10% for both changwats. As in most changwats in the southern region, rubber is a main agricultural product in Trang, while Phat-thalung has a high rice production. Trang is also one of the main producers of the oil palm in the country.

Table 4.5.2 Economic Indicators for Rt. 4 ('000baht)

	1986	1991
Phatthalung:		
Agriculture	2,099,458	2,255,170
Crops	1,589,803	1,645,801
Livestock	196,949	259,107
Fisheries	51,320	73,863
Forestry	8,260	2,387
Agricultural services	69,494	62,386
Processed agri. products	183,632	211,626
Mining and quarrying	37,230	38,024
Manufacturing	302,602	373,150
Construction	269,220	382,049
Electricity and water supply	44,674	79,464
Transportation and communications	264,418	440,749
Wholesale and retail trade	1,081,337	1,638,404
Banking, insurance and real estate	89,426	176,503
Ownership of dwellings	379,344	430,878
Public administration and defense	357,396	450,677
Services	622,279	762,337
GPP	5,547,384	7,027,405
Trang:		
Agriculture	3,885,137	4,948,224
Crops	2,273,294	2,763,037
Livestock	160,009	226,647
Fisheries	646,161	1,010,013
Forestry	224,384	22,270
Agricultural services	23,368	20,482
Processed agri. products	557,921	905,775
Mining and quarrying	33,306	9,819
Manufacturing	331,513	472,553
Construction	385,317	540,397
Electricity and water supply	99,876	190,324
Transportation and communications	915,271	540,548
Wholesale and retail trade	1,421,949	1,946,512
Banking, insurance and real estate	166,648	352,816
Ownership of dwellings	349,652	437,096
Public administration and defense	336,597	435,144
Services	973,516	1,355,549
GPP	8,896,782	11,228,982

5. Traffic

As one of the main trunk roads in the country, Rt. 4 handles heavy traffic volumes. ADT figures for past years show an average annual growth rate of about 13.1%. Table 4.5.3 shows the past ADT figures and the traffic composition on the route for 1993.

Table 4.5.3 Traffic Volume on Rt. 4

Average Daily Traffic (ADT):

C-Sec	Km	1985	1987	1989	1991	1993
3900	15+000	2275	2950	3754	4070	5632

Traffic Composition - 1993:

Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
1219	889	123	2323	605	473	5632

Vehicle registrations between 1988 and 1990 in the two changwats are as presented in Table 4.5.4.

Table 4.5.4 Vehicle Registration for Rt. 4

	1988	1989	1990
Phatthalung:			
Passenger Car	631	763	770
Van & Truck	2,440	3,103	2,948
Motorcycle	27,048	31,429	31,058
Trang:			
Passenger Car	2,979	2,238	3,395
Van & Truck	6,806	5,025	8,075
Motorcycle	47,500	54,245	53,021

4.5.3 Existing Status of Damages

1. Spot 4/1: Rotational Landslide on a Cut Slope (SD-2-6)

At Km. 44.7 an 85m long section of shotcrete has been fragmented by the movement in the underlying material. The slope angle of the debris is only 20 degrees but the original cut slope is thought to have been 45 degrees between berms. The geology of the site consists of colluvium comprised of completely to highly weathered meta sandstone and shale. The site is surrounded by deeply weathered granite. It is suspected that the colluvium comes from a segment of metasediments above the slope forming a roof pendant in a batholith of granite.

Groundwater was seen seeping from the surface of the debris slope about 4-5m above the base and was encountered at a depth of 3.2 m during drilling. The existing conditions are illustrated in Fig. 4.5.2.

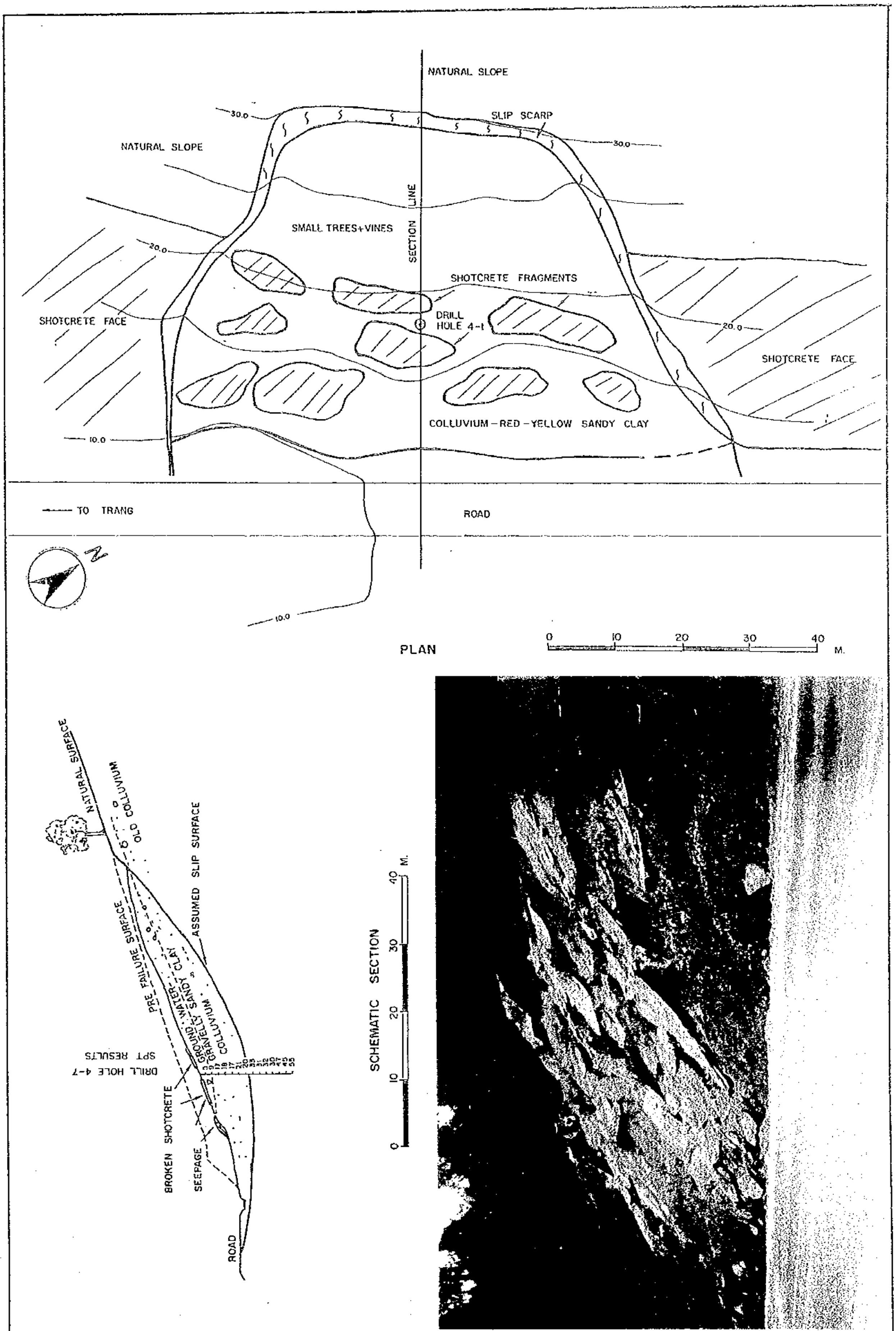
2. Spots 4/2/3: Scouring of Abutment (BC-1-5)
   Scouring of River Bank (BC-1-9)

The bridge at Km. 16.97 is 24 metres long and both the substructure and superstructure are constructed of reinforced concrete. The piers and abutments use bent-pile structures. In front of one of the abutments there are the remains of an old abutment structure. The existing conditions are illustrated in Fig. 4.5.3.

The southwestern abutment previously was protected by a riprap covered slope, but this was completely destroyed by scouring from the high velocity stream flows during heavy rains in December 1993. These flows also scoured the fill in the abutment to half the road's width. The damage caused by the erosion of the abutment back-fill was repaired temporarily soon after the water level fell. The collapsed fill slope of the abutment was repaired a few months afterwards.

In the vicinity of the bridge, there is a weir installed about 170 metres upstream from the bridge to prevent the degrading of the riverbed due to the rapid stream flow.

The river banks are protected by stone riprap only in the vicinity of the weir, with after portions remaining unprotected. Due to the heavy rains mentioned above, some portions of the outside curves of the river banks were scoured.



SPOT 4/1 KM. 44.70
EXISTING CONDITIONS

Fig. 4.5.2 Details of Disaster Spot

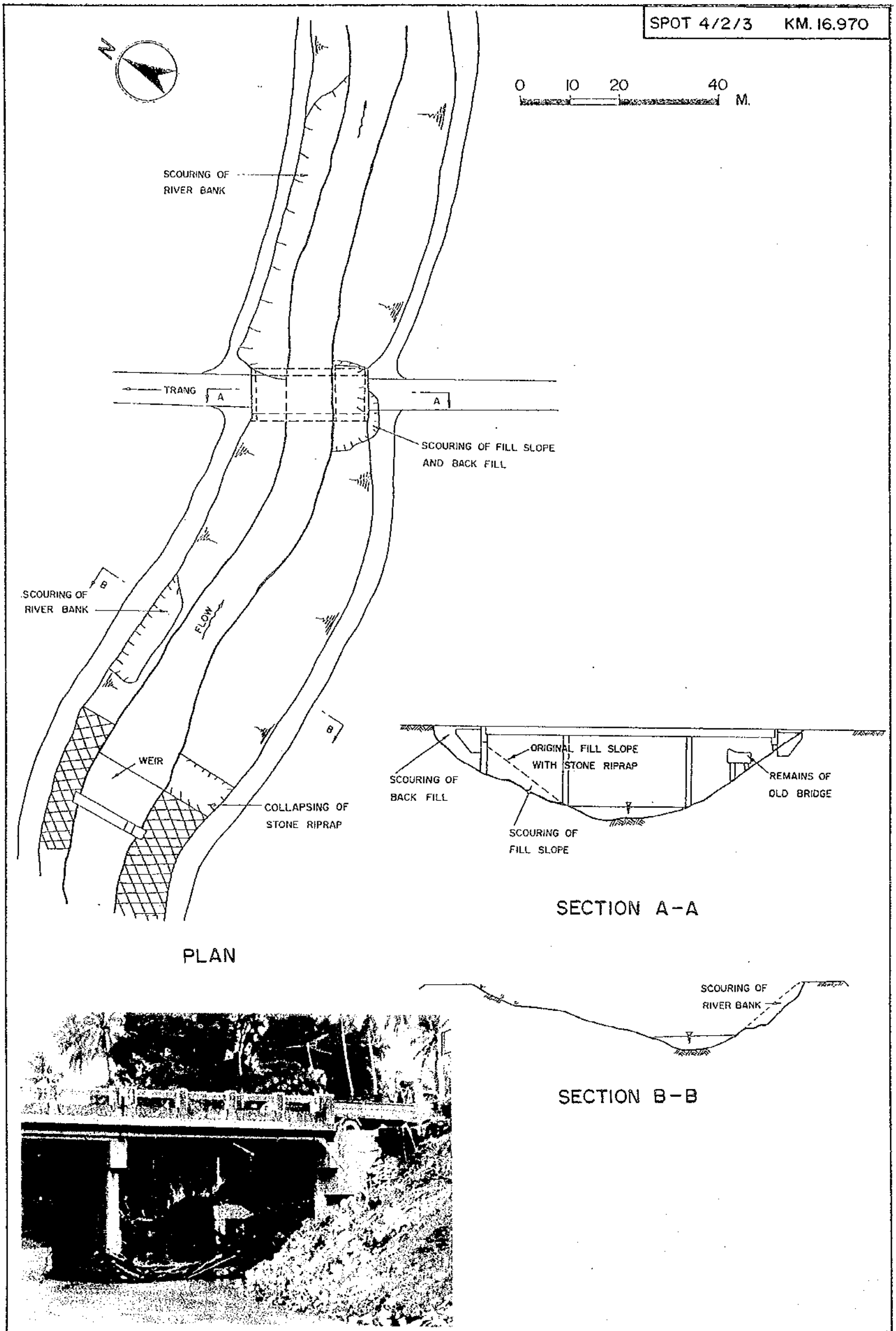


Fig. 4.5.3 Details of Disaster Spot

4.6 Project Road 410

4.6.1 Natural Conditions

1. Meteorology

The closest meteorological station to this route is at Pattani on the east coast. This station receives an annual average rainfall of 1751 mm. The annual distribution of rainfall is illustrated in Fig.4.6.1. The 24hr rainfall intensity is 305 mm with a 50-year return period. The station is about 100 km. from the location of the disaster spots and it is expected that the rainfall volume and intensity to be less as there is a general reduction from east to west. The area is subject to typhoons in the latter part of the year.

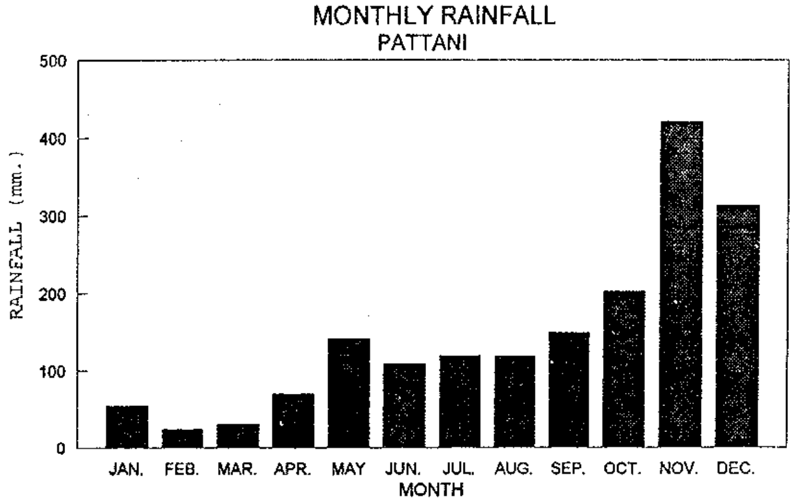


Fig. 4.6.1 Monthly Rainfall at Pattani

2. Geology

From Km. 39 to about Km. 70 the road passes over sandstone and slaty or tuffaceous shale of the Mayo Formation of the Carboniferous Kaeng Krachan Group. Outcrops of limestone of the younger Permian Tarn To Formation of the Ratburi Group are also crossed or form adjacent steep karstic terrain.

At about Km. 70 the geology changes to the metasediments of the Ban To Formation of the Silurian - Devonian Tanaosi xGroup. These rocks consist of mix schists and Phyllites with a prominent foliation.

At Km. 114 until the end of the study section Triassic granites are encountered. The granite is generally deeply weathered and coarse grained. A number of shallow rotational type slides were seen in this rock type.

3. Topography

The topography of the route is largely controlled by the geology. The first section from Bannang Sata to about Km. 70 passes over undulating hills with some very steep adjacent mountains of limestone. The route becomes mountainous with very steep natural slopes in the metasediments and is adjacent to the reservoir of the Banglang Dam. At Km. 114, the hills become more rounded and the side slopes are more gentle as granitic terrain is encountered.

4. Past Disaster Records

The DOH files for the last 10 years recorded a total of 17 incidents of damage on this road. They mainly concern failures on cut and fill slopes. A total expenditure of 5,668,000 baht was noted over this period.

4.6.2 Socioeconomic Conditions

1. General

Rt. 410 connects Pattani to Yala on the southern border of the country with Malaysia. The project route is located in the southern part of Yala, which is characterized by its mountainous terrain. Some sections of the route are currently under an improvement project that includes a new alignment and widening. Most of the population in the area is composed of religious minority groups.

2. Function

Due to the sharp curves and steep terrain of the route at present, it does not fulfill the function of an international route to Malaysia. Most of the traffic coming from Malaysia (about 100 vehicles on average per day) has its destination at A. Betong near the border. It does serve, however, socioeconomic activities in the area for more than twenty villages, ten schools, two hospitals and commercial areas that are completely dependent on this route. The route supports to a large extent the daily life of the minority groups living in the South Region. Rubber is widely produced in the area, which also has an excellent reputation for fruit produce. As the route is located near the border of the country, it is important for national security reasons. For local transportation activities, there are no alternatives to this route in the case of interruptions to traffic.

3. Population

The population of Yala and the two amphoes connected directly by the project route are presented in the following table.

Table 4.6.1 Area and Population Influenced by Rt. 410

	Population - 1991	Area (km^2)	Density
Changwat:			
Yala	362,600	5,220.1	69.46
Amphoe:			
M. & A. Betong	35,400	1,328.0	26.66
A. Than To	13,200	648.0	20.37

4. Economy

Agriculture in Yala accounts for a high 38% of total GPP, at constant 1988 prices, as shown in Table 4.6.2, with rubber as the main agricultural product.

Table 4.6.2 Economic Indicators for Rt. 410 ('000 baht)

	1986	1991
Yala:		
Agriculture	2,059,569	3,409,265
Crops	1,716,112	2,542,364
Livestock	49,085	213,532
Fisheries	5,825	26,013
Forestry	54,073	258,038
Agricultural services	10,472	14,003
Processed agri. products	224,002	355,315
Mining and quarrying	32,398	29,338
Manufacturing	251,459	356,935
Construction	363,212	777,553
Electricity and water supply	136,143	161,553
Transportation and communications	331,930	422,767
Wholesale and retail trade	855,356	1,383,550
Banking, insurance and real estate	140,145	240,126
Ownership of dwellings	250,336	304,661
Public administration and defense	348,661	490,263
Services	837,500	1,381,201
GPP	5,606,709	8,957,212