5. Traffic

The route handles at present considerably low traffic volumes. However, improvements in the road are expected to attract higher traffic volumes in the future. Past ADT figures and traffic composition are as presented in Table 4.6.3

Table 4.6.3 Traffic Volume on Rt. 410

Average Daily Traffic (ADT):						
C-Sec	Km	1985	1987	1989	1991	1993
402	108+700	332	366	437	481	419

Traffic Composition - 1993:						
Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
187	35	16	107	42	32	419

Vehicle registrations between 1988 and 1990 in the changwat of Yala are as follows:

Table 4.6.4 Vehicle Registration for Rt. 410

	1988	1989	1990
Yala:			
Passenger Car	2,470	2,267	2,480
Van & Truck	4,794	4,340	4,840
Motorcycle	48,009	60,696	66,812

4.6.3 Existing Status of Damages

1. Spot 410/1: Debris Flow on an Embankment on Sloping Ground (RF-3-3)

At Km. 75.95, a lobe of debris spills across the road surface. Sediment from a natural stream is deposited due to a drop in stream velocity resulting from a gradient change near the road. The debris mass is about 15m wide. The existing conditions at this site are illustrated in Fig. 4.6.2.

2. Spot 410/2: Two-Dimensional Translational Landslide on a Cut Slope (SD-2-7)

At Km. 76.42, a 35m-high cut slope failed after sliding along planes of schistocity in mica schist. The slope had been protected by shotcrete after a previous failure. The debris reaches the edge of the pavement, and the schistocity surface is dipping at an angle of 40 degrees.

Drilling at this site revealed that the colluvial debris is about 7m thick, and groundwater was found 3.2m from the surface. SPT results for the colluvium were high with an average over 30. The existing conditions of the site are illustrated in Fig. 4.6.3.

3. Spot 410/3: Rotational Landslide on a Cut Slope (SD-2-6)

At Km. 82.1, a 15m-high section of cut slope failed after a rotational movement. The original slope was cut at 0.5/1 and the lowest 5m was covered with shotcrete.

The shotcrete facing has been destroyed. Similar slides can be seen at Km. 81.75, 81.9 and 82.0, all containing similar material. The debris is lying at an angle of 33 degrees.

The existing conditions are illustrated in Fig. 4.6.4.

4. Spot 410/4: Rockfalls on a Cut Slope due to Toppling (SD-2-9)

At Km. 85.7, a 15 m high cut slope has rocks toppling from it. The volume of rock debris at the base of the slope is only about 3-4 cubic metres but contains some large intact blocks. The original surface cut was not protected by vegetation.

The rock is moderately to slightly weathered schist and phyllite. It contains numerous tectonic joints. The existing conditions are illustrated in Fig. 4.6.5.

5. Spot 410/5: Gully Erosion in a Cut Slope (SD-2-3)

At Km. 96.3, a small section of cut slope is being adversely affected by gully erosion from surface runoff. The geology consists of completely weathered phyllite with a number of steeply dipping shear zones.

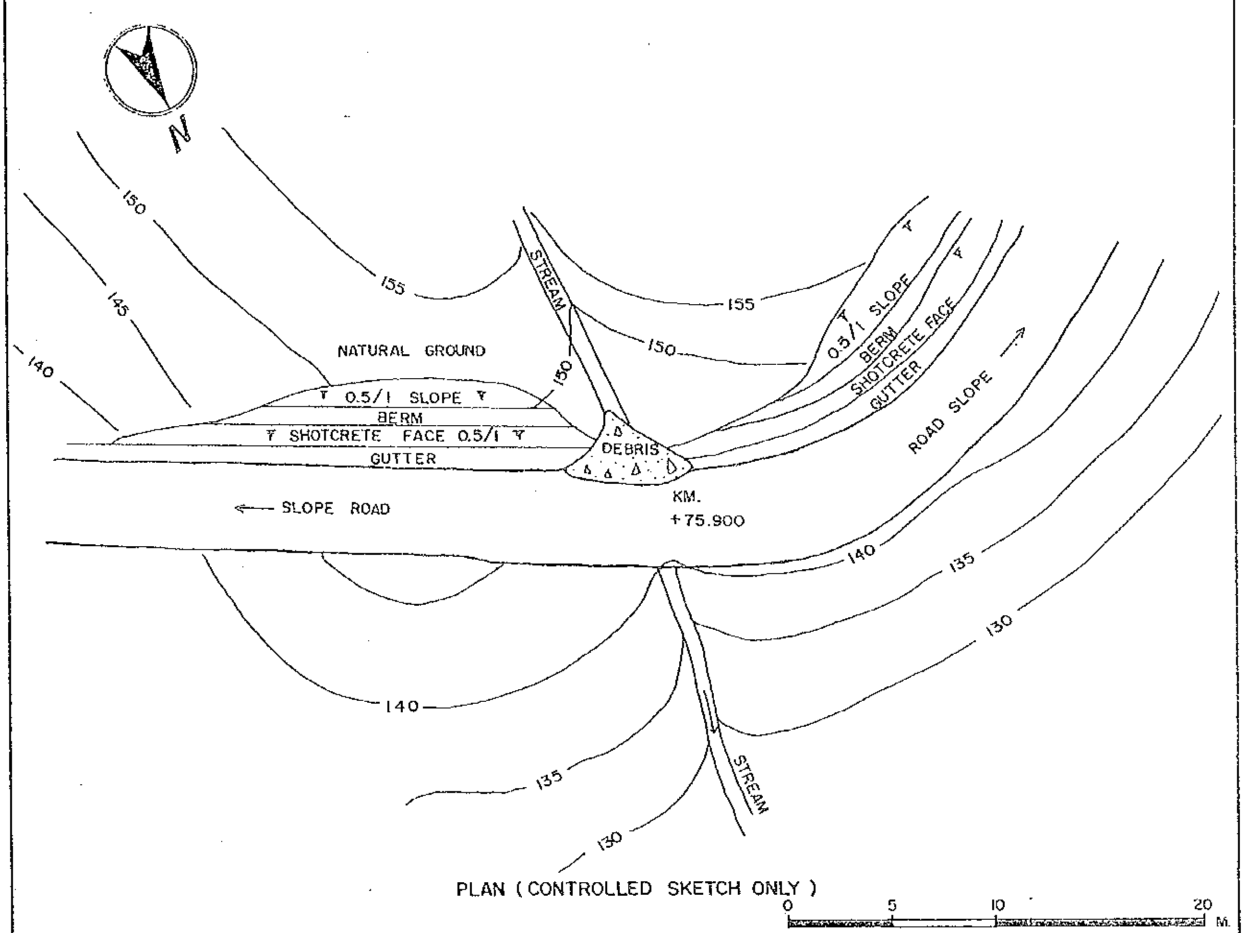
The slope is only about 10m high and was cut at 0.5/1. The erosion is occurring in the sheared areas. The existing conditions are illustrated in Fig. 4.6.6.

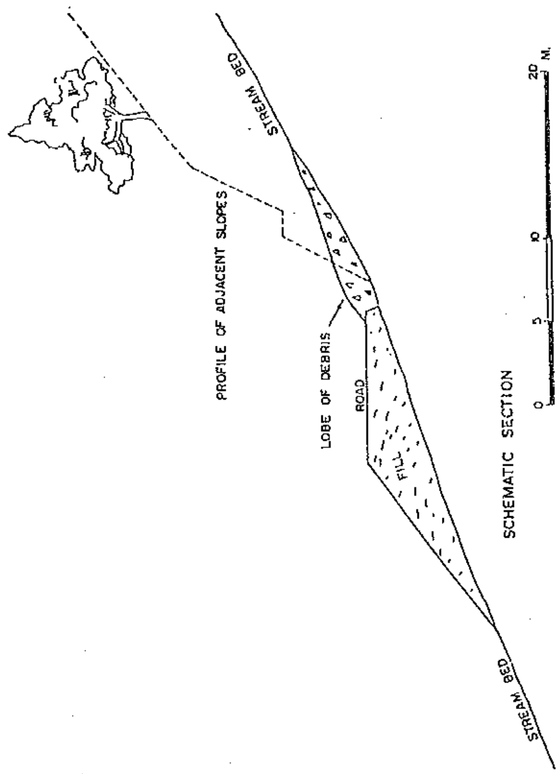
6. Spot 410/6: Three-Dimensional Translational Landslide on a Cut Slope (SD-2-8)

At Km. 97.8, three closely associated very large 3D translational landslides have occurred. The central slide is about 65 m high. The original cut slope was about 25m high with an angle of about 60-70 degrees. The rock is a fissile mica schist with extensive tectonic joints. The failed surface consists of a number of wedge intercepts rather than one very large wedge.

The natural ground slope is at an angle close to 34 degrees (1.5/1). The interception angle between the two main joint sets controlling the failure (DD225/D55, DD100/D50) is also at about 30 degrees and dips towards 162 degrees.

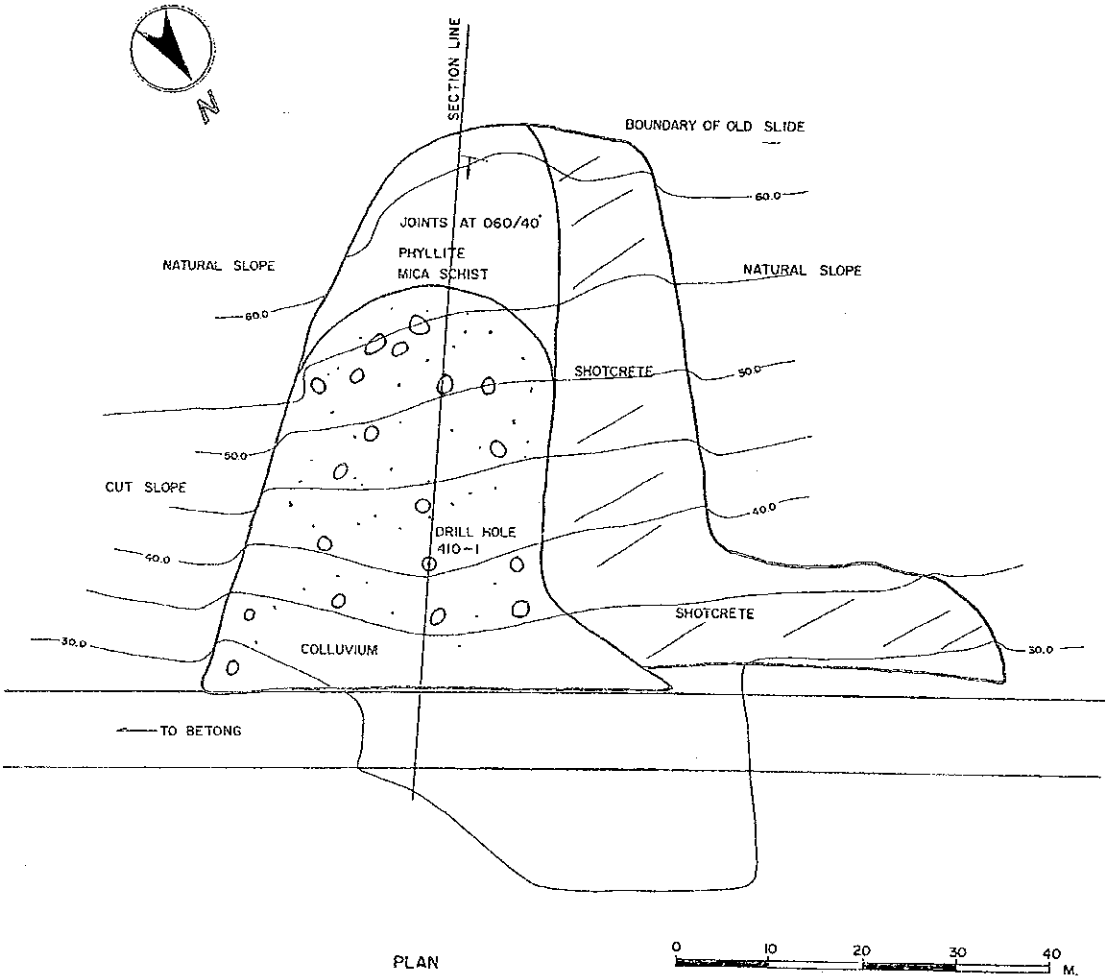
The natural slope dips towards 167 degrees. It is apparent that the original natural slope was controlled by these structures. The existing conditions are illustrated in Fig. 4.6.8.

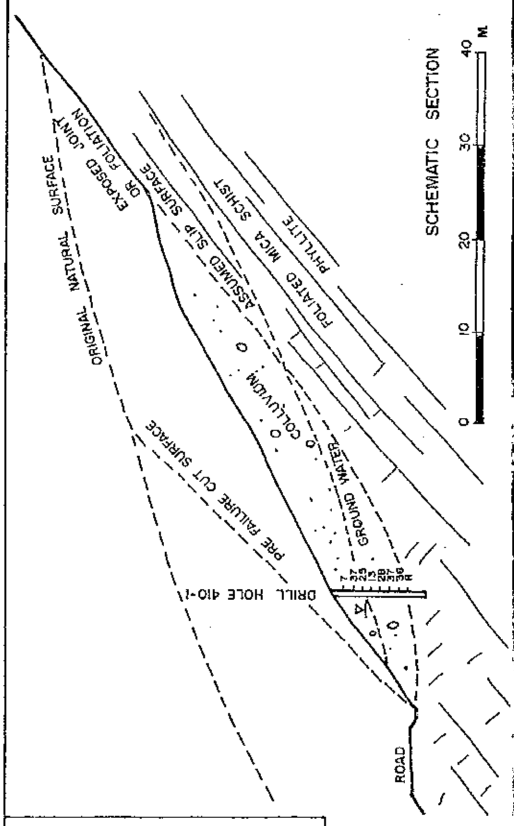


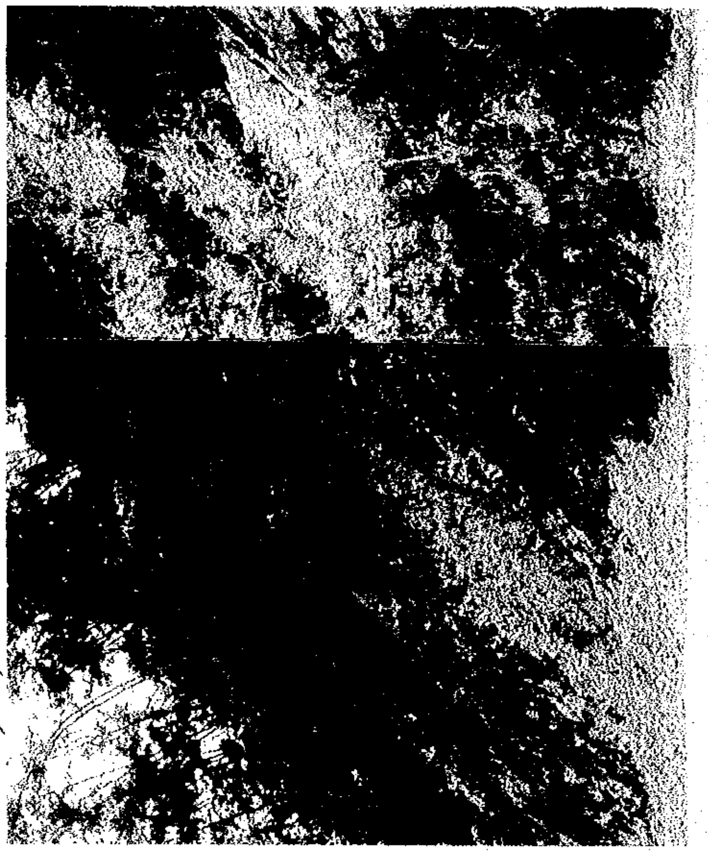


SPOT 410/1 KM. 75.950
EXISTING CONDITIONS

Fig. 4.6.2 Details of Disaster Spot

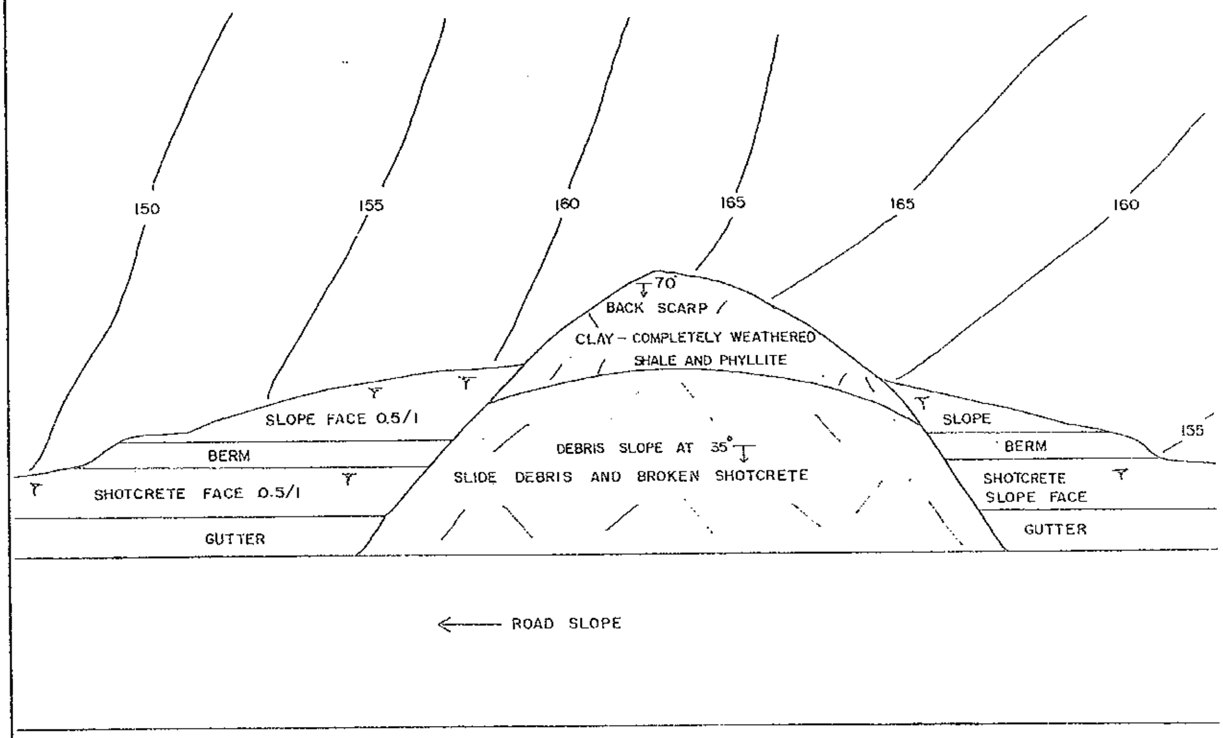




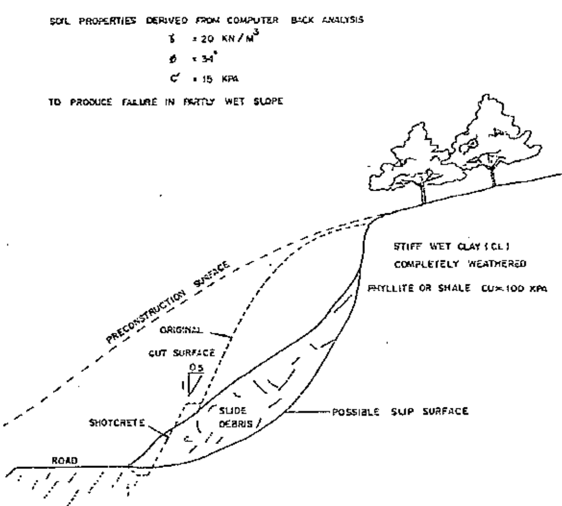


SPOT 410/2 KM. 76.42
EXISTING CONDITIONS

Fig. 4.6.3 Details of Disaster Spot



PLAN (CONTROLLED SKETCH - ONLY) 0 5 10 20 M.

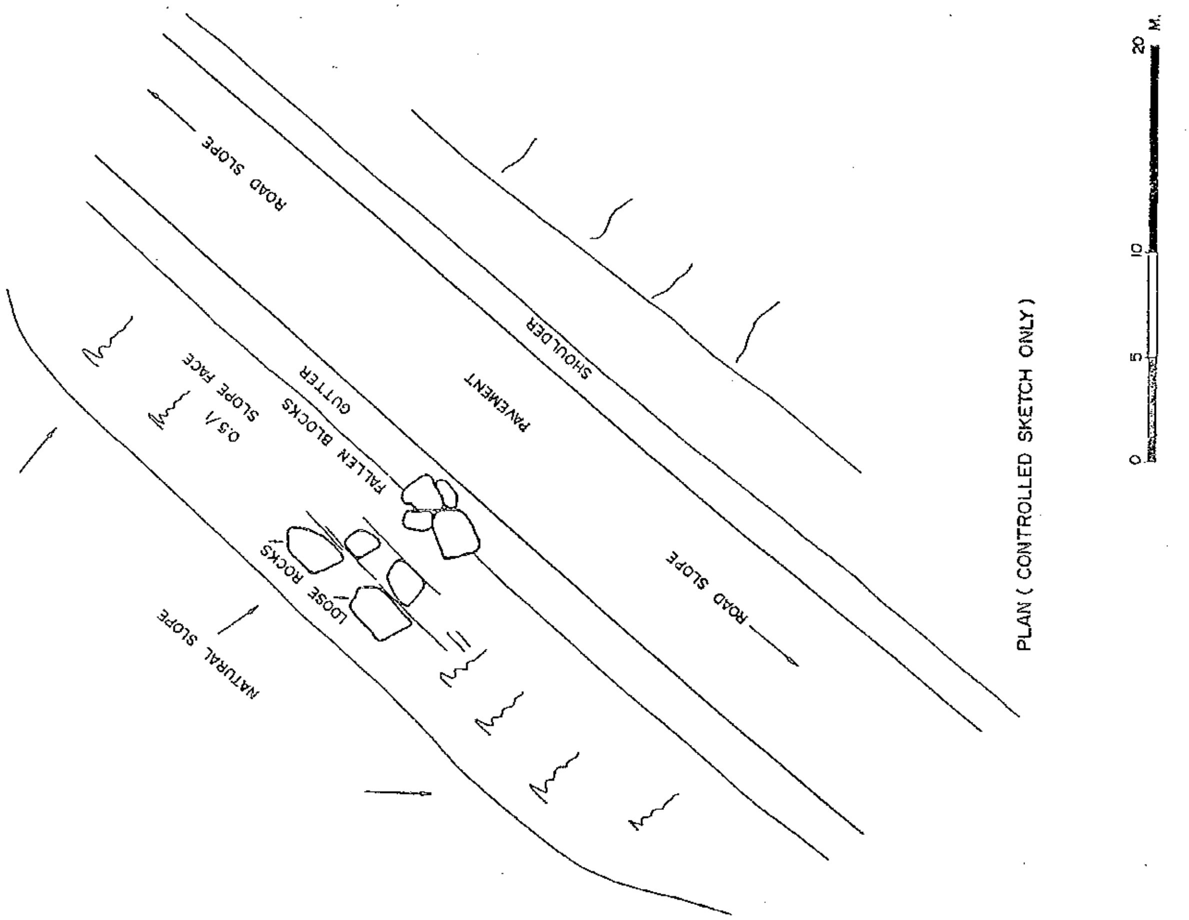


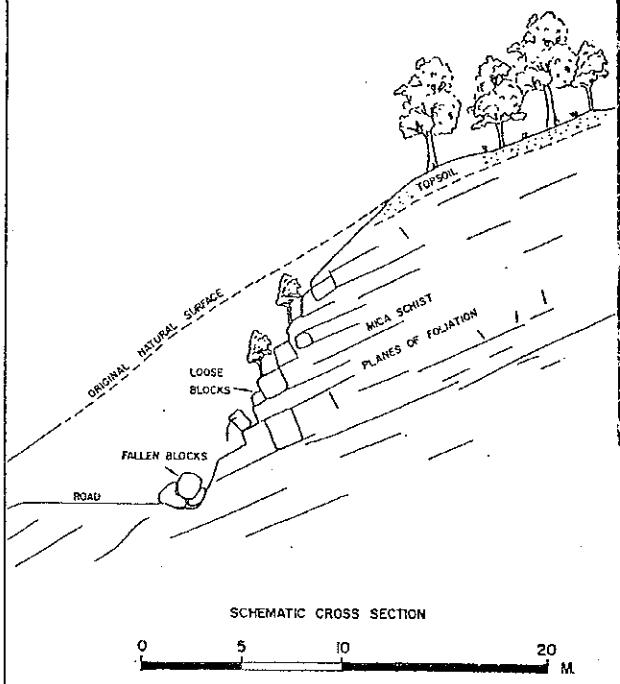
SCHEMATIC SECTION

0 5 10 20 M

SPOT 410/3 KM. 82.100
EXISTING CONDITIONS

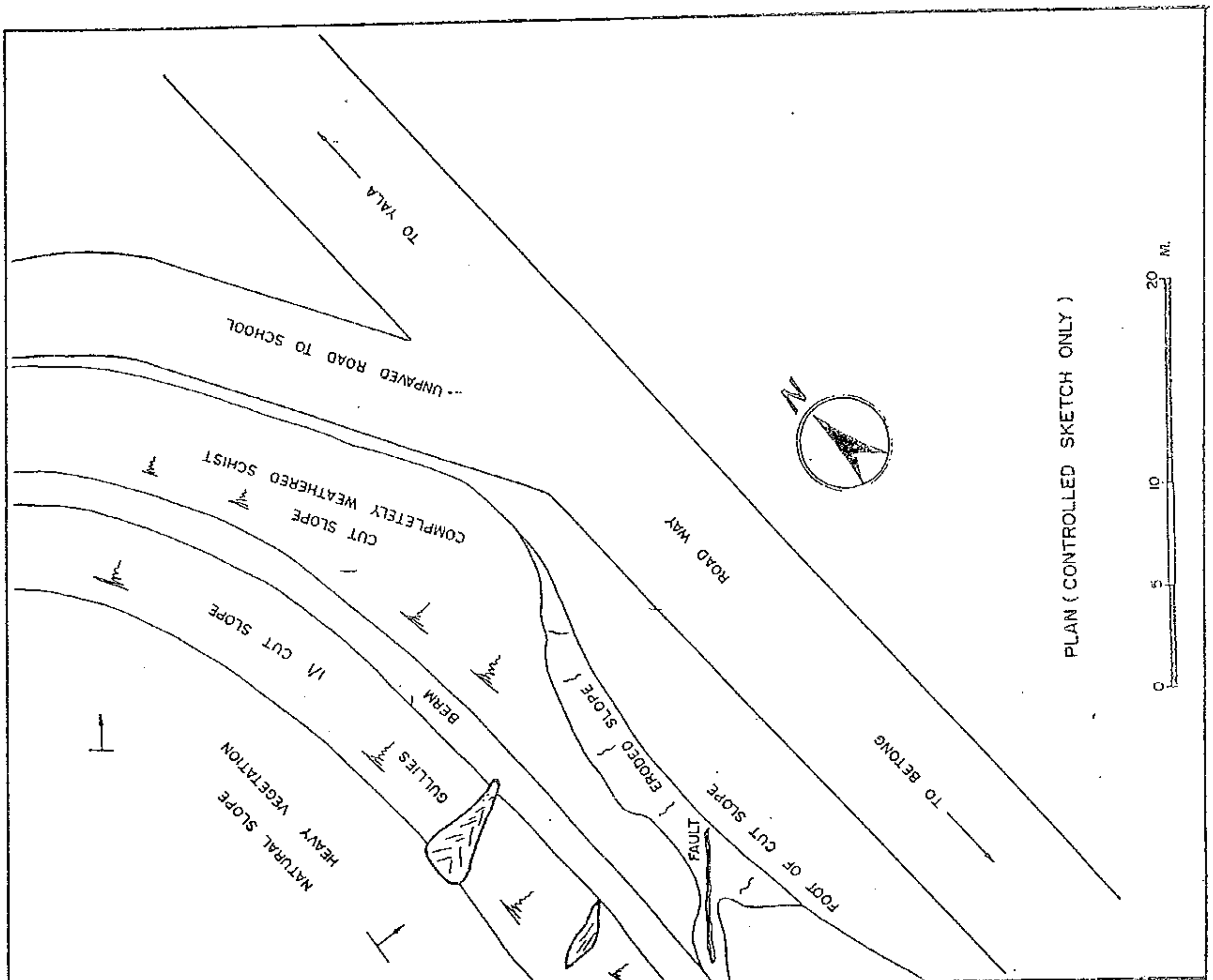
Fig. 4.6.4 Details of Disaster Spot

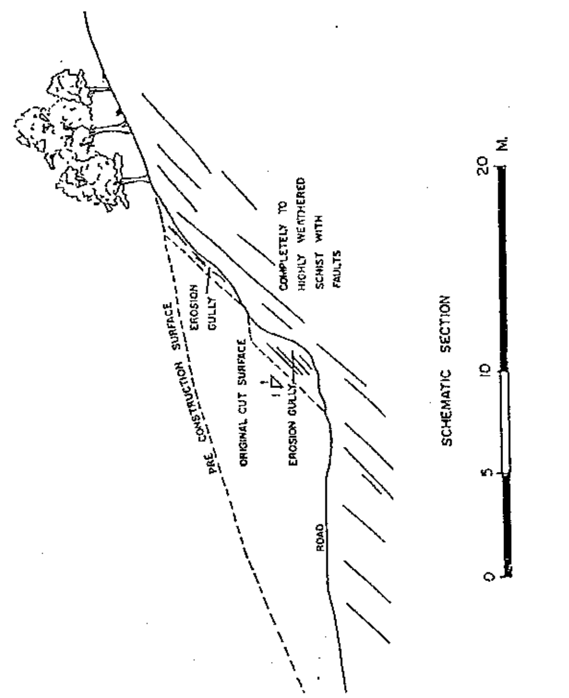




SPOT 410/4 KM. 85.700
EXISTING CONDITIONS

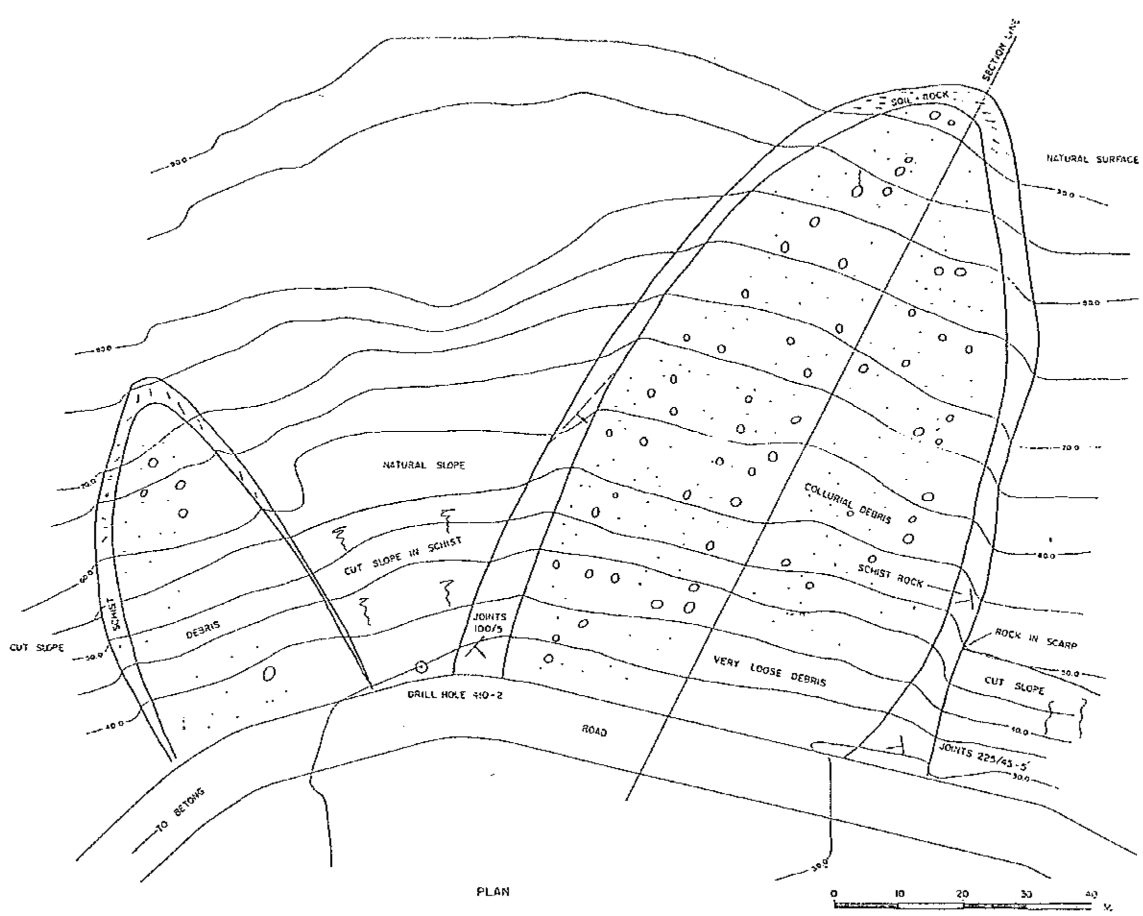
Fig. 4.6.5 Details of Disaster Spot

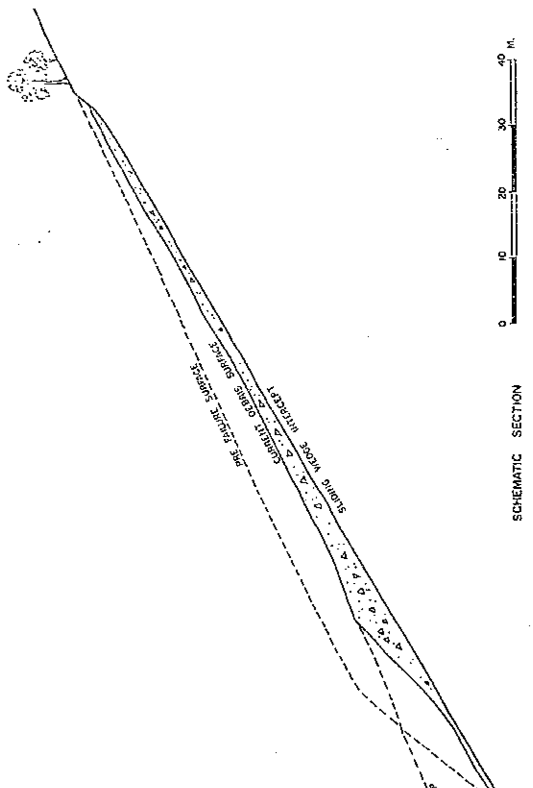


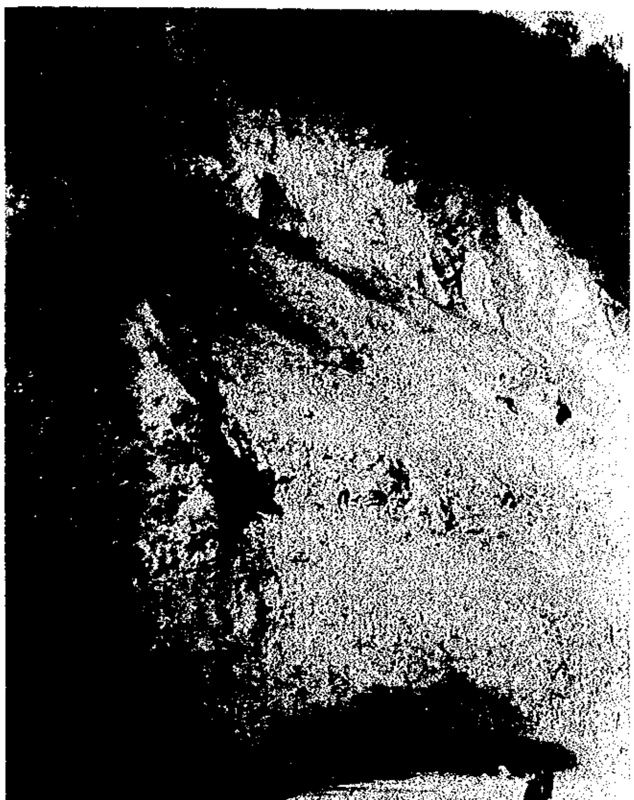


SPOT 410/5 KM. 96.300
EXISTING CONDITIONS

Fig. 4.6.6 Details of Disaster Spot







SPOT 410/6 KM. 97.8
EXISTING CONDITIONS

Fig. 4.6.7 Details of Disaster Spot

4.7 Project Road 4015

4.7.1 Natural Conditions

1. Meteorology

Changwat Nakhon Si Thammarat and Surat Thani are frequently hit by depressions, monsoons or typhoons from the Gulf of Thailand and have heavy rainfall, especially, in November and December as shown in Fig. 4.7.1.

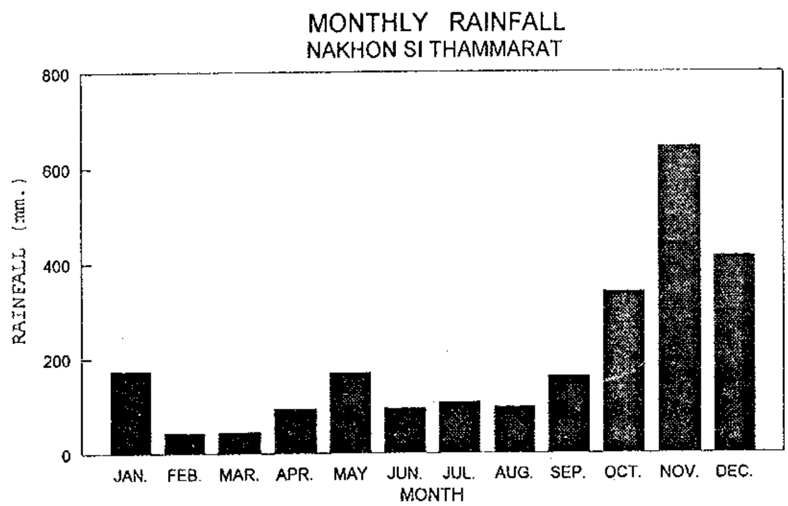


Fig. 4.7.1 Monthly Rainfall at Nakhon Si Thammarat

The maximum 24 hr rainfall intensity for a fifty-year return period reaches more than 400 mm and an average annual rainfall of 2,000mm has been recorded in the region. Both of these are the highest in Thailand.

2. Topography

The Khao Luang Mountains run in a north - south direction along the coast of the Gulf of Thailand (refer to Fig.4.7.2). The altitude of the highest mountain is close to 2,000 meters.

The Ta Pi River, which is one of the biggest rivers in southern Thailand, flows along the foot of the mountain range into the Gulf of Thailand at Surat Thani. Some of the tributaries of the river originate from this mountain range.

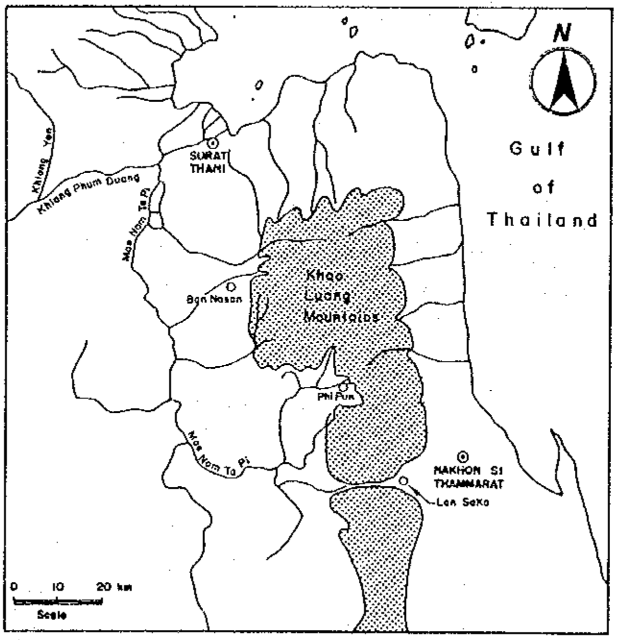


Fig. 4.7.2 Ta Pi River Basin and Khao Luang Mountain Range

The rivers are quite shallow and have a low gradient. The hydraulic capacity is relatively low and there are few dikes along the river banks for confining flood waters. Most of the rivers do not have sufficient capacity to discharge their maximum flood water to the sea without causing flooding.

3. Past Disaster Records

The inland region of the Khao Luang Mountains is one of the most disaster-prone areas in Thailand due to intense and sustained rainfall. As a consequence, many past disasters have been recorded in Amphoe Lan Saka, Phi Pun and Ban Nasan.

From November 18 to 23, 1988 up to 1,000 mm of rainfall was recorded in some regions in the South Region. The worst hit changwats were Nakhon Si Thammarat and Surat Thani. In the Amphoe of Ban Nasan, Phi Pun and Lan Saka debris flows consisting of water, sand, stones and trees caused heavy damage along rivers and in the flood plains adjacent to the Khao Luang Mountains.

The debris flows were often obstructed by bridge piers, abutments and approach embankments. The uprooted trees formed barriers that clogged the rivers at several bridges. This resulted in either overtopping of bridges, severe erosion of abutments, approach embankments and pier foundations or even the complete destruction of modern reinforced concrete bridges. Six highway bridges were either washed away or partially collapsed.

In the last two years, the collapsing of approach embankments due to river channel shifting, riverbed aggradation, scouring of abutments and other damage has been reported for Route 4015.

4.7.2 Socioeconomic Conditions

1. General

Rt. 4015 is a traversal provincial highway located in the most populated changwat of Nakhon Si Thammarat in the South Region. It was paved sixteen years ago to be an all-weather route for access to many areas in the neighboring changwat Surat Thani. At present, old pipe culverts in flood-prone areas are being replaced by concrete bridges, and improvement works include also the raising of the road level.

2. Function

Most of the traffic on this route is for the transportation of local agro-based products to the main market in Nakhon Si Thammarat. The project route starts at A. Lan Saka and there are seven villages, three schools and a hospital along the route, which passes through mountainous areas that are part of a national park.

Village development projects for small agro-based industries are being promoted in the area along the route. There are no plans for large-scale development projects in the area, but it is expected that many industrial activities will be developed with the implementation of the Southern Seaboard Development Program for the nearby Krabi - Khanom Land-bridge.

ARD and PWD roads in the area do not provide any alternatives to this route, and the shortest alternative in the case of a traffic interruption is Rt. 41 and Rt. 403 to the south.

3. Population

Nakhon Si Thammarat is the most populated changwat in the South Region and is the second largest in area. The population of the changwat and three amphoes connected by the route are presented in Table 4.7.1.

Table 4.7.1 Area and Population Influenced by Rt. 4015

	Population - 1991	Area (km²)	Density
Changwat:			
Nakhon Si Thammarat	1,436,800	9,942.5	144.51
Amphoe:			
A. Lan Saka	39,300	342.9	114.61
A. Na Bon	28,300	192.9	146.71
A. Cha Wang	104,400	764.9	136.49

4. Economy

As the most populated changwat in the South Region, Nakhon Si Thammarat's industrial share of GPP is relatively high. The changwat has future potential for more industrial activities with the implementation of the Southern Seaboard Development Program. In addition, it has the highest share of farm land in the South Region and is a main producer of cocoa and coconuts in the country. GPP at constant 1988 prices by sector is presented in Table 4.7.2.

Table 4.7.2 Economic Indicators for Rt. 4015 ('000 baht)

	1986	1991
Nakhon Si Thammarat:		
Agriculture	5,682,448	8,102,395
Crops	3,523,100	4,766,318
Livestock	506,569	738,177
Fisheries	864,129	1,455,040
Forestry	58,464	68,652
Agricultural services	136,545	140,729
Processed agri. products	593,641	933,479
Mining and quarrying	330,703	1,960,760
Manufacturing	1,124,882	1,724,329
Construction	1,087,924	2,317,443
Electricity and water supply	259,770	488,429
Transportation and communications	707,473	1,068,754
Wholesale and retail trade	3,349,728	5,007,025
Banking, insurance and real estate	339,856	864,220
Ownership of dwellings	1,026,943	1,201,858
Public administration and defense	1,193,798	1,557,508
Services	2,809,770	3,796,384
GPP	17,913,295	28,089,105

5. Traffic

Traffic volumes on the route are considerably high as it is located in a highly populated area near a changwat center. Past ADT figures and traffic composition are presented in Table 4.7.3.

Table 4.7.3 Traffic Volume on Rt. 4015

Average Daily Traffic (ADT):						
C-Sec	Km	1985	1987	1989	1991	1993
201	21+000	1172	1493	1988	2444	1901
Traffic Composition - 1993:						
Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
520	321	63	778	98	121	1901

Table 4.7.4 presents the vehicle registrations data between 1988 and 1990 in the changwat of Nakhon Si Thammarat.

Table 4.7.4 Vehicle Registration for Rt. 4015

	1988	1989	1990
Nakhon Si Thammarat:			
Passenger Car	5,300	3,894	4,240
Van & Truck	17,000	12,360	14,426
Motorcycle	80,000	81,783	94,514

4.7.3 Existing Status of Damages

1. Spot 4015/1: Scouring of Bridge Abutment (BC-1-5)

At Km. 20.15, a bridge is located that has had its abutments damaged by scouring. In the vicinity of the bridge, the road lies in a flood plain and follows a raised embankment. The superstructure and substructure of the bridge are made of reinforced concrete. The bridge has a total length of 100 metres and the height of the approach embankment above the natural ground is approximately 3 metres. The existing conditions are illustrated in Fig. 4.7.3.

The upstream side of the left abutment was damaged during heavy rainfall in December 1993. Even though the fill slope of the abutment was protected by stone riprap, it was completely destroyed and the back-fill of the abutment has eroded up to half the width of the carriageway.

2. Spot 4015/2: Washing out of Embankment at a Culvert Crossing (RC-3-2)

This disaster spot is situated in a valley floor in hilly terrain in the foothills of the Khao Luang Mountains at Km. 21.337. Before the road collapsed, a pipe culvert 1.0 metre in diameter was installed through the road embankment to discharge flood water. The existing conditions are illustrated in Fig. 4.7.4.

In November 1993, the area was hit by heavy rainfall and the embankment was heavily damaged by water overflowing from the inlet of the culvert.

It is apparent that the damage was caused by the inadequate capacity of the culvert. At present, the damage has been temporarily restored by the installation of two pipe culverts of 1.2 metres in diameter as a substitute for the old one.

3. Spot 4015/3: Scouring of Embankment at a Culvert Crossing (RC-3-1)

This disaster spot is situated in a valley floor in hilly terrain in the foothills of the Khao Luang Mountains at Km 26.850. The embankment height on the mountain side is about 2 metres and about 5 metres on the valley side. A pipe culvert 0.8 metres in diameter passes through the embankment. The existing conditions are illustrated in Fig. 4.7.5.

In November 1993, the spot was hit by heavy rainfall and the embankment was heavily scoured in the vicinity of the culvert crossing on both the inlet and outlet sides by flooding.

4. Spot 4015/4: Collapsing of Abutment Fill Slope (BC-1-6)

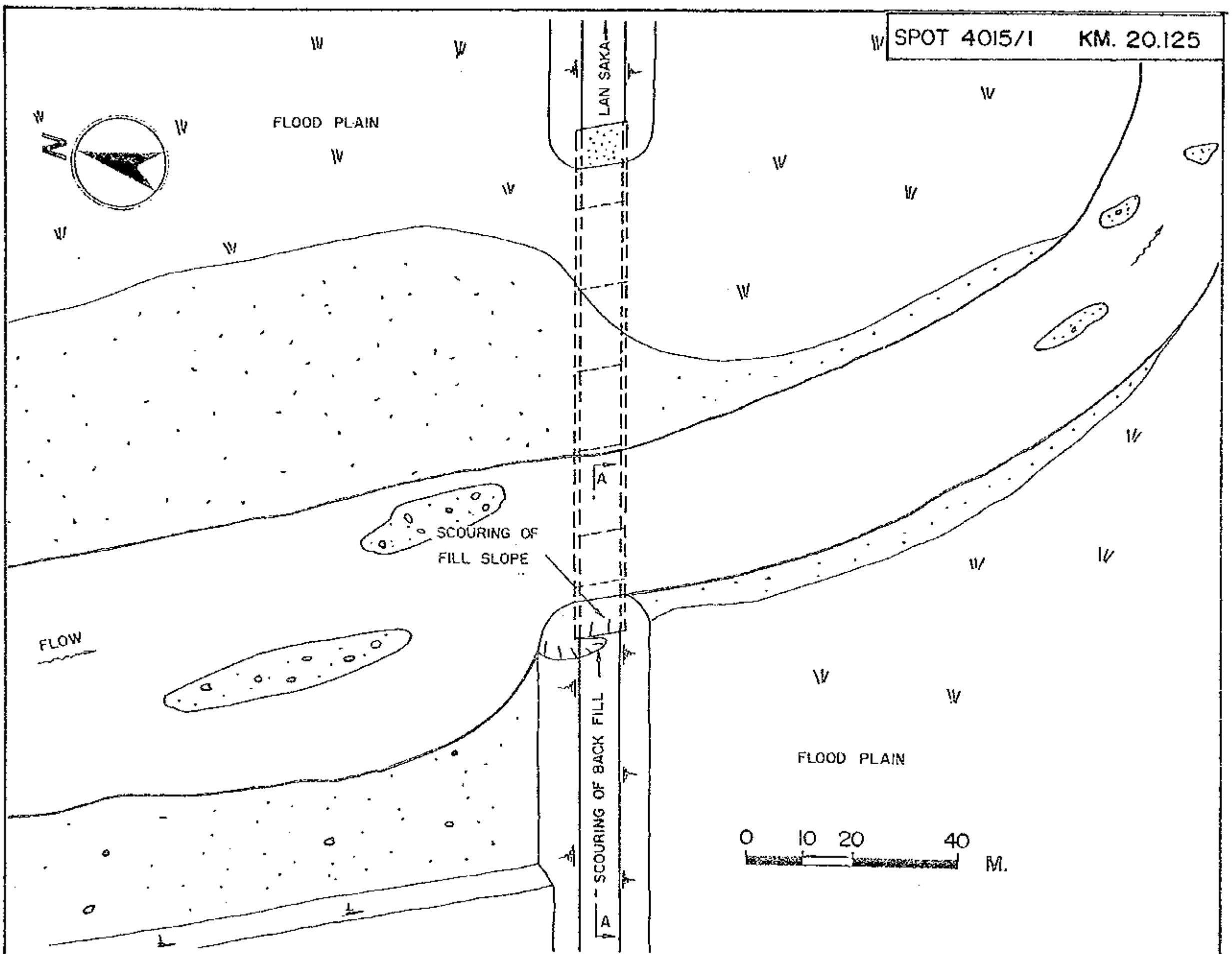
The bridge is located at Km. 26.965 in a flood plain and the roadway is constructed on a raised embankment. The bridge is 40 metres long and is built of reinforced concrete girders, piers and abutments. The fill slope of the abutment is protected with a combination of stone masonry and riprap. Refer to Fig. 4.7.6 for the existing conditions.

The fill slope riprap protection is damaged at both abutments and both slopes are not yet repaired.

5. Spot 4015/5: Erosion of Approach Road (BC-1-7)

In November 1992, the bridge at Km.29.390 and its approach embankment were damaged by flood waters. At that time, the river channel shifted and the approach embankment was completely destroyed by erosion. The damage extended from just behind the north abutment to some 20 metres along the embankment. As a result, road traffic was completely interrupted for a few days. The existing conditions are presented in Fig. 4.7.7.

Immediately after the disaster a Bailey bridge was erected for temporary use. The Bailey bridge was replaced in early 1994 with a new three-span bridge as an extension of the existing old bridge. At the same time, a new channel was dredged to ensure adequate discharge capacity.



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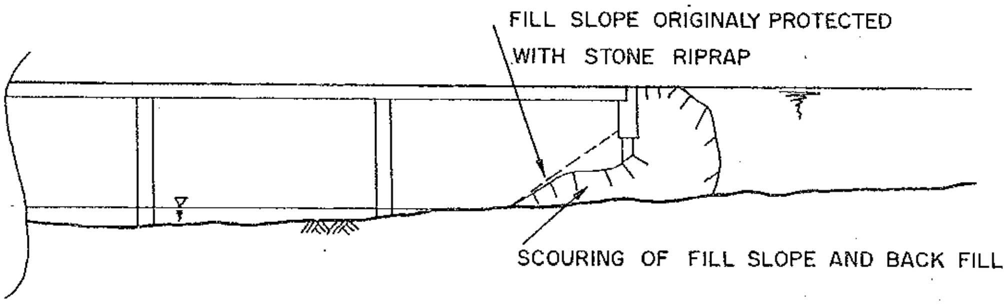
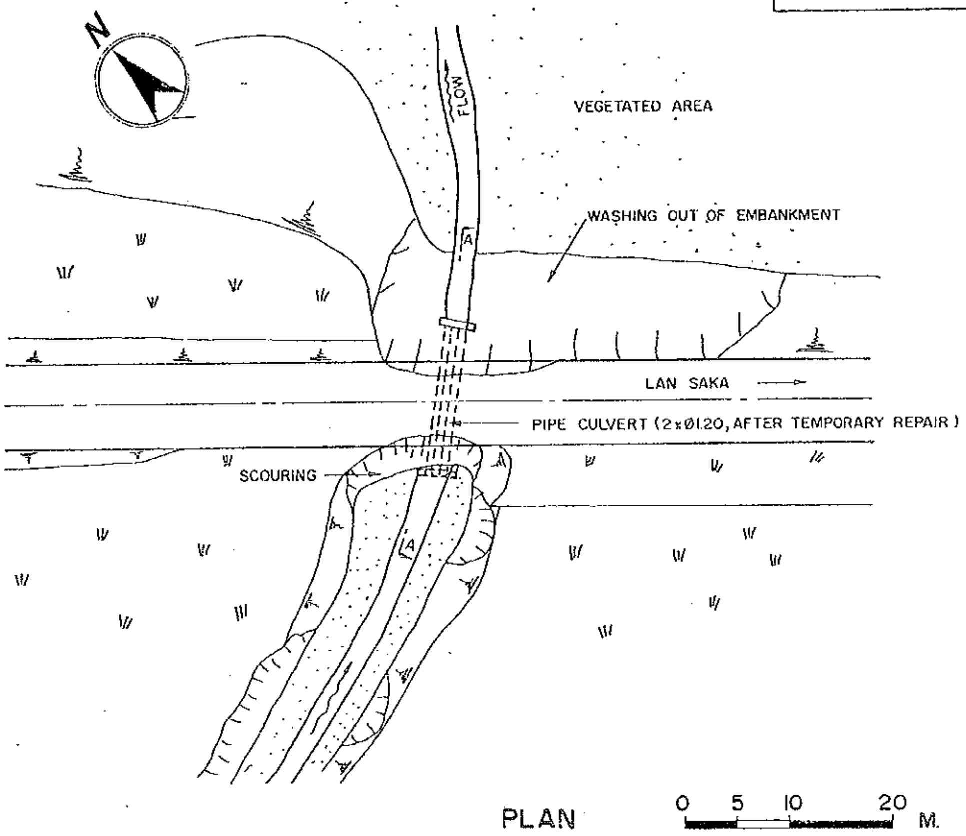


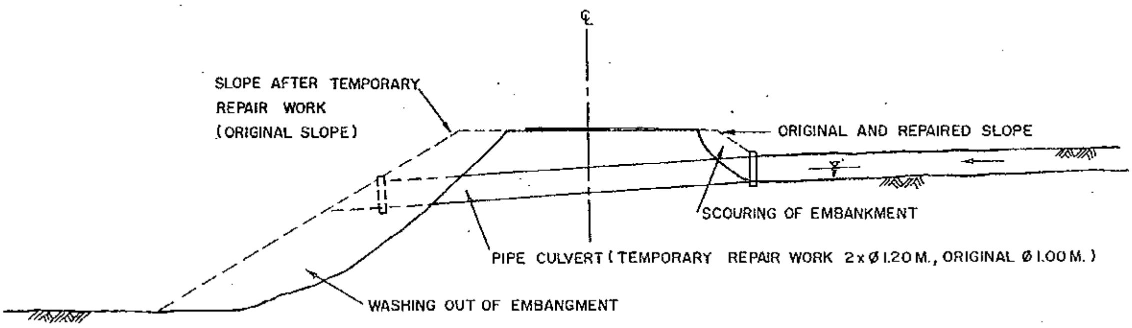
SECTION A-A

Fig. 4.7.3 Details of Disaster Spot

SPOT 4015/2 KM. 21.337

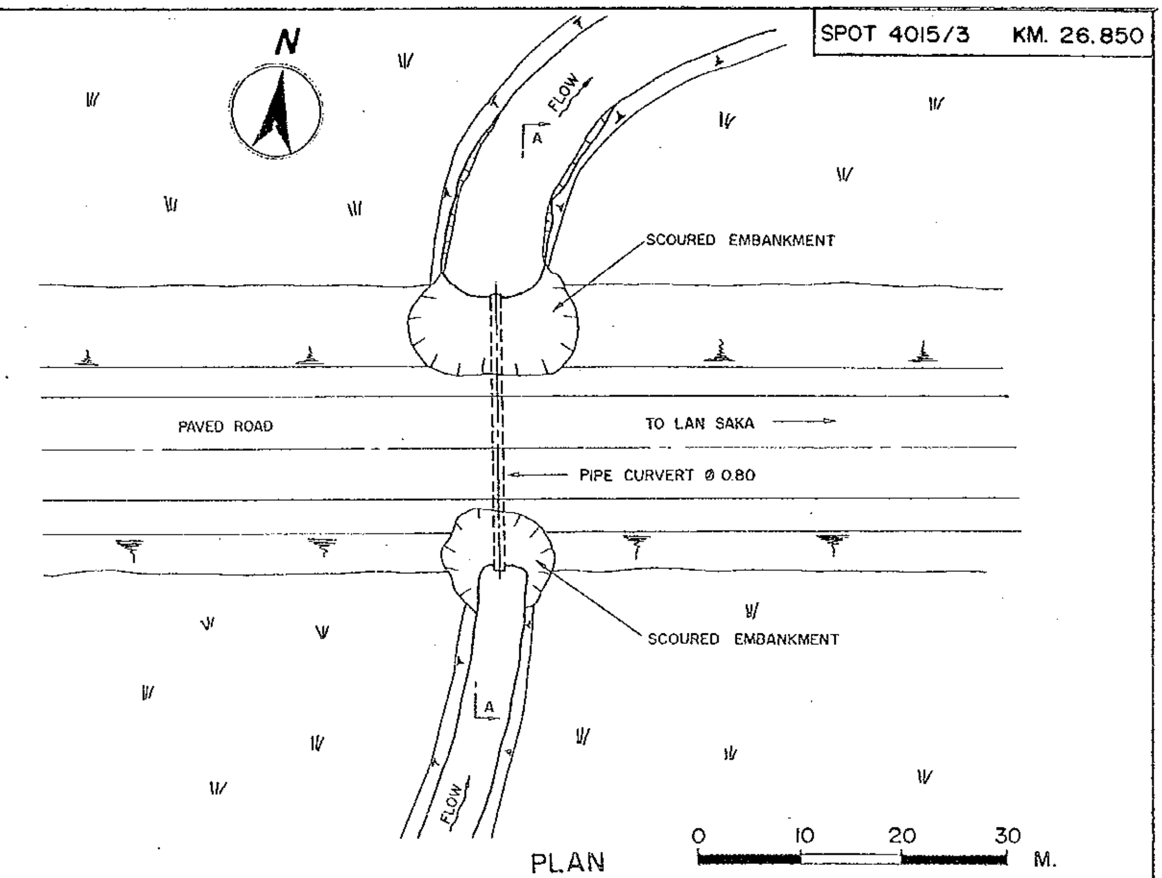


PLAN

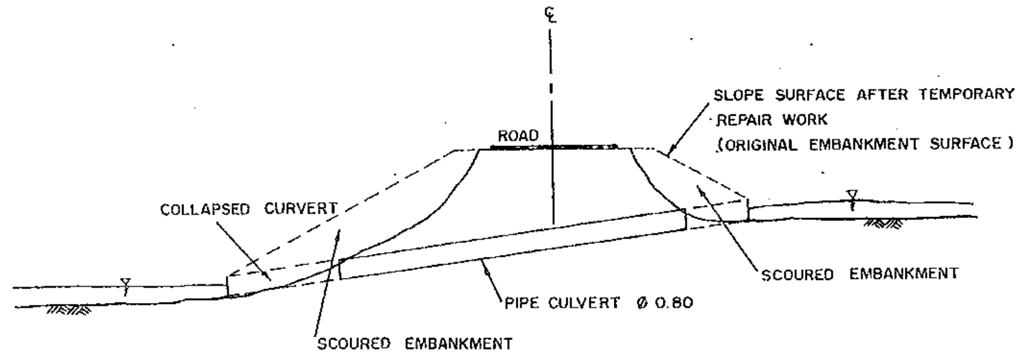


SECTION A-A

Fig. 4.7.4 Details of Disaster Spot



PLAN



SECTION A-A

Fig. 4.7.5 Details of Disaster Spot

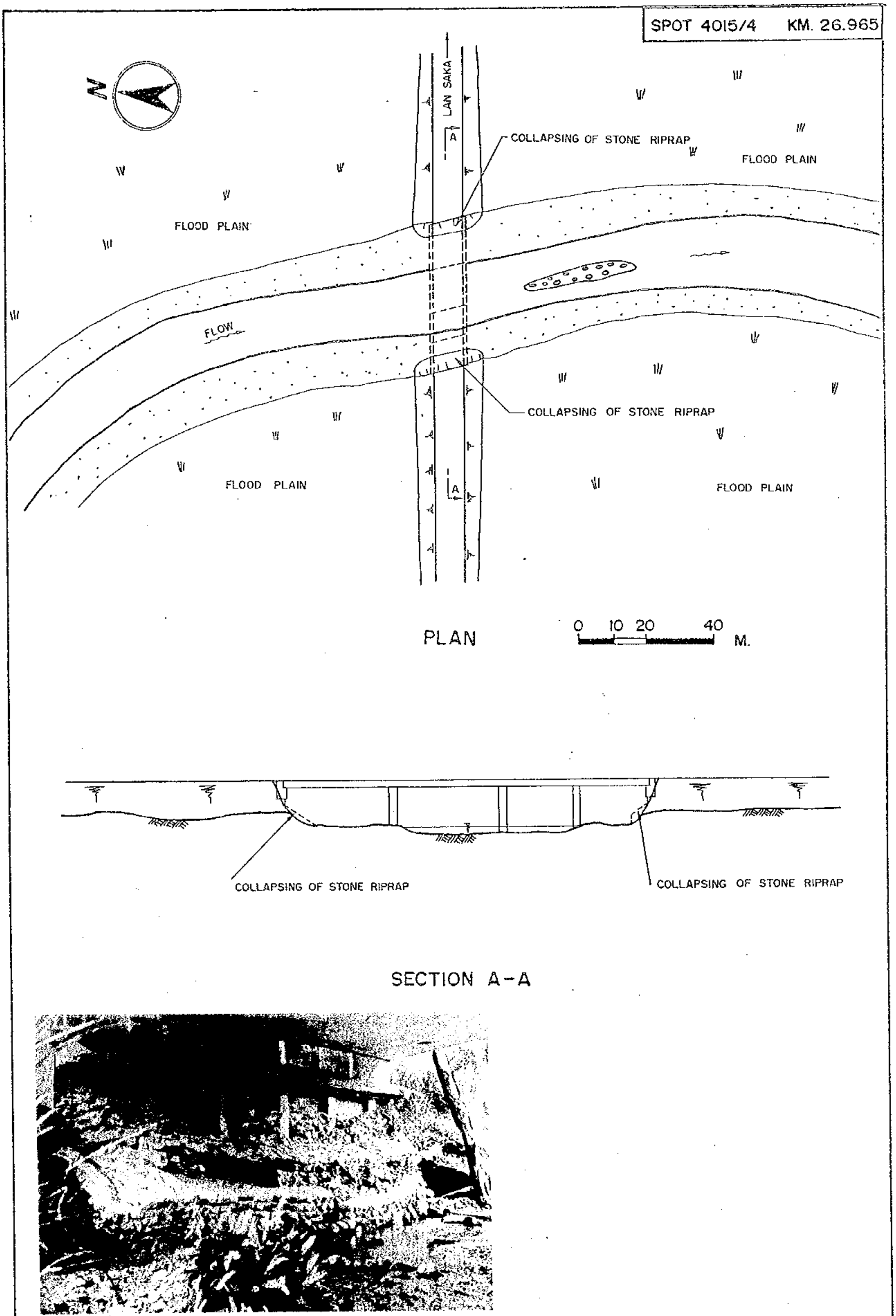


Fig. 4.7.6 Details of Disaster Spot

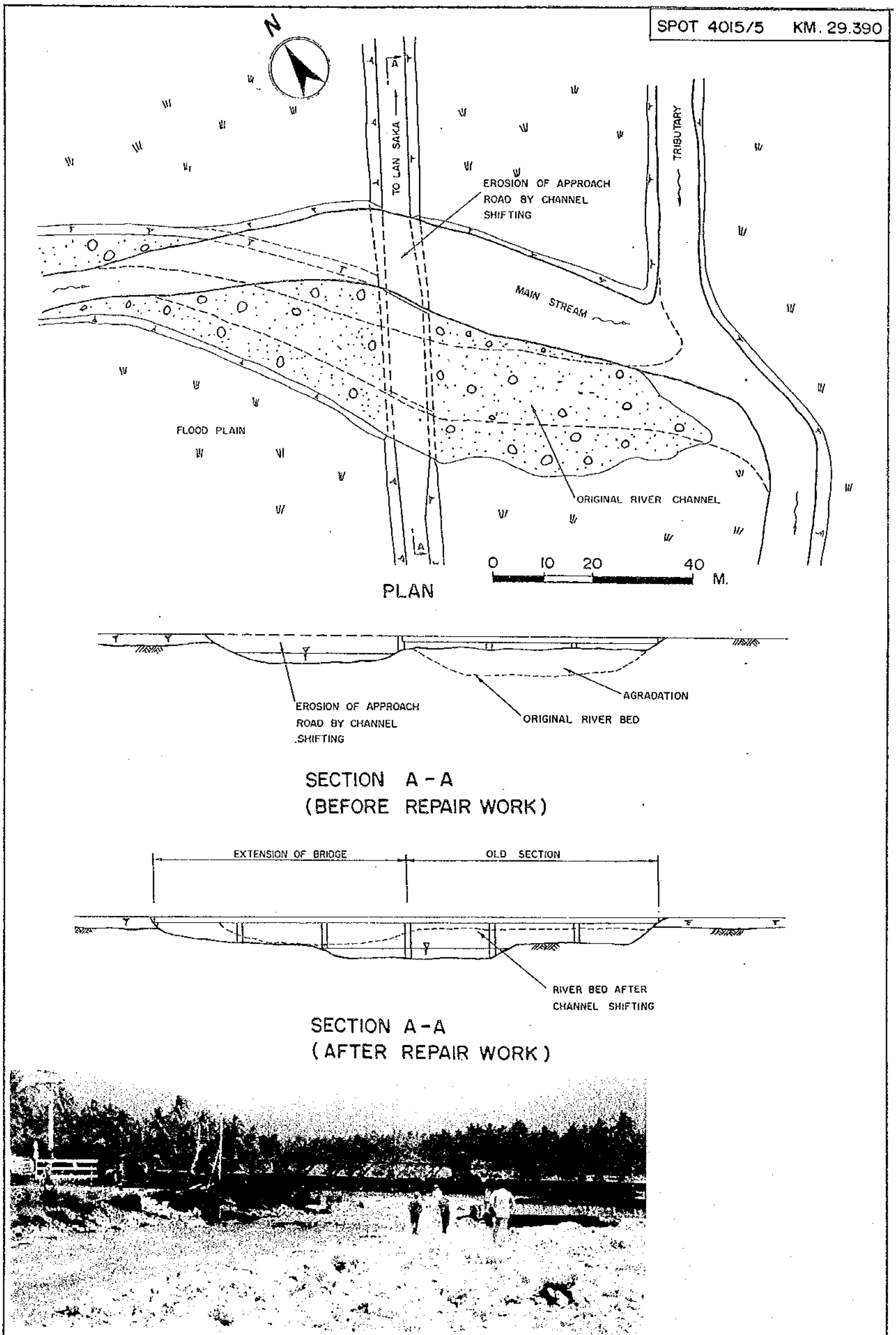


Fig. 4.7.7 Details of Disaster Spot

4.8 Project Road 4107/4058

4.8.1 Natural Conditions

1. Meteorology

The east coast of the far south of Thailand, close to the border with Malaysia, has the heaviest rainfall in the country. This is due to monsoons or typhoons coming from the Gulf of Thailand. This region has a distinct rainfall peak in October-December as shown in Fig.4.8.1.

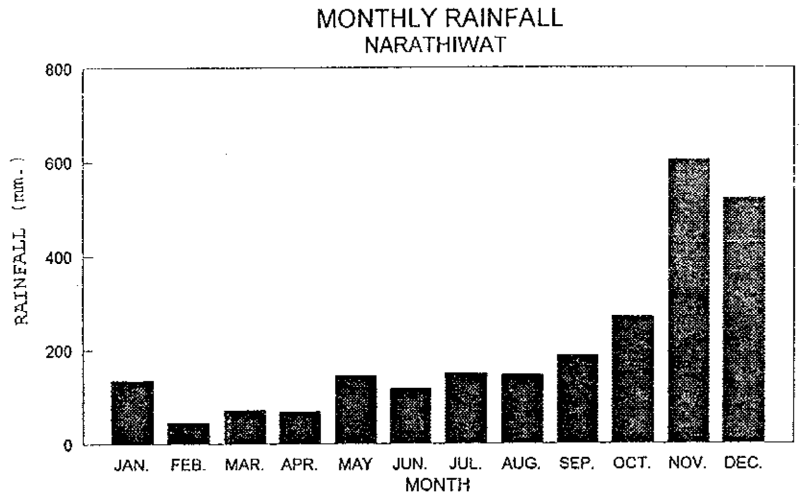


Fig.4.8.1 Monthly Rainfall in Narathiwat

The maximum 24 hr rainfall intensity with a fifty-year return period exceeds 400 mm and an average annual rainfall of more than 2,000mm has been recorded in the region.

2. Topography

Along the east coast of the peninsula, flat alluvial terrain extends as a 10-to 20-kilometer wide coastal plain. A mountain range stretches from the north to the south along the western edge of the flat terrain. Route 4107 runs along a valley through the mountain range and crosses a few tributaries of the Sai Buri River and some other mountain streams.

The tributaries are quite shallow and they have low gradients in the valley floor. There are few dikes along the river banks for confining flood water.

3. Past Disaster Records

The types of road damage on Route 4107/4058 in the past few years have been mostly caused by high-velocity water flows from the mountains and are as follows:

Route 4107: Erosion of approach roads to bridges
: Scouring of bridge abutments
: Floods flowing over bridges
: Washing out of road shoulders
Route 4058: Floods flowing over bridges
: Washing out of road shoulders

All of the damage described above is related to bridges or approach embankments to bridges.

4.8.2 Socioeconomic Conditions

1. General

The route is located entirely in the changwat of Narathiwat in flat and hilly terrain and connects the two amphoes of A. Ruso and A. Yi-Ngo. It provides the shortest travel distance to Yala and runs beside a southern railway line going to Malaysia.

2. Function

In addition to the local traffic between the two amphoes of A. Yi-Ngo and A. Ruso and to the changwat center at Narathiwat, the route handles also some of the traffic to the neighboring changwat(Yala). It supports the daily life of minority people and promotes rural development in the most southern areas of the country. With the implementation of the integrated development plans with neighboring countries in the southern triangle, the route is expected to handle more traffic in the future. Agricultural activities in the area concern mainly rubber from plantations for export either to Malaysia or via Bangkok to other countries. Seven villages and three schools are located directly along the route.

3. Population

The population of Narathiwat and the two amphoes connected by the route are presented in Table 4.8.1.

Table 4.8.1 Area and Population Influenced by Rt. 4107/4058

	Population - 1991	Area (km²)	Density
Changwat:			
Narathiwat	577,900	4,475.4	129.13
Amphoe:			
A. Yi Ngo	33,700	200.5	168.08
A. Ruso	49,400	468.3	105.49

4. Economy

With about 50% of the total land area being farm land, Narathiwat's agricultural sector accounts for a high 37% of the total GPP at constant 1988 prices, as shown in the Table 4.8.2, with rubber and coconuts as the main agricultural products.

Table 4.8.2 Economic Indicators for Rt. 4107/4058 ('000 baht)

	1986	1991
Narathiwat:		
Agriculture	3,393,394	4,125,799
Crops	2,734,750	3,461,580
Livestock	117,283	174,578
Fisheries	9,832	18,161
Forestry	175,481	20,880
Agricultural services	20,409	25,194
Processed agri. products	335,639	425,406
Mining and quarrying	13,545	20,870
Manufacturing	241,479	443,676
Construction	443,571	635,018
Electricity and water supply	87,524	130,485
Transportation and communications	397,378	577,179
Wholesale and retail trade	1,252,130	1,958,783
Banking, insurance and real estate	146,012	227,516
Ownership of dwellings	405,453	468,805
Public administration and defense	358,996	460,450
Services	1,231,338	1,974,584
GPP	7,970,820	11,023,165

5. Traffic

ADT figures and the traffic composition for the two routes are as presented in the following table.

Vehicle registrations between 1988 and 1990 in the changwat of Narathiwat are presented in Table 4.8.4.

Table 4.8.3 Traffic Volume on Rt. 4107/4058

Average Daily Traffic (ADT):

Rt. No.	C-Sec	Km	1985	1987	1989	1991	1993
4107	200	4+500	604	646	951	1571	1219
4058	100	4+011			977	1854	1706

Traffic Composition - 1993:

Rt. No.	Car & Taxi	Light Bus	Heavy Bus	Light Truck	Medium Truck	Heavy Truck	Total
4107	292	8	28	590	124	177	1219
4058	411	135	33	935	112	80	1706

Table 4.8.4 Vehicle Registration for Rt. 4107/4058

	1988	1989	1990
Narathiwat:			
Passenger Car	1,404	1,963	1,723
Van & Truck	4,410	6,222	5,097
Motorcycle	63,579	87,995	77,603

4.8.3 Existing Status of Damages

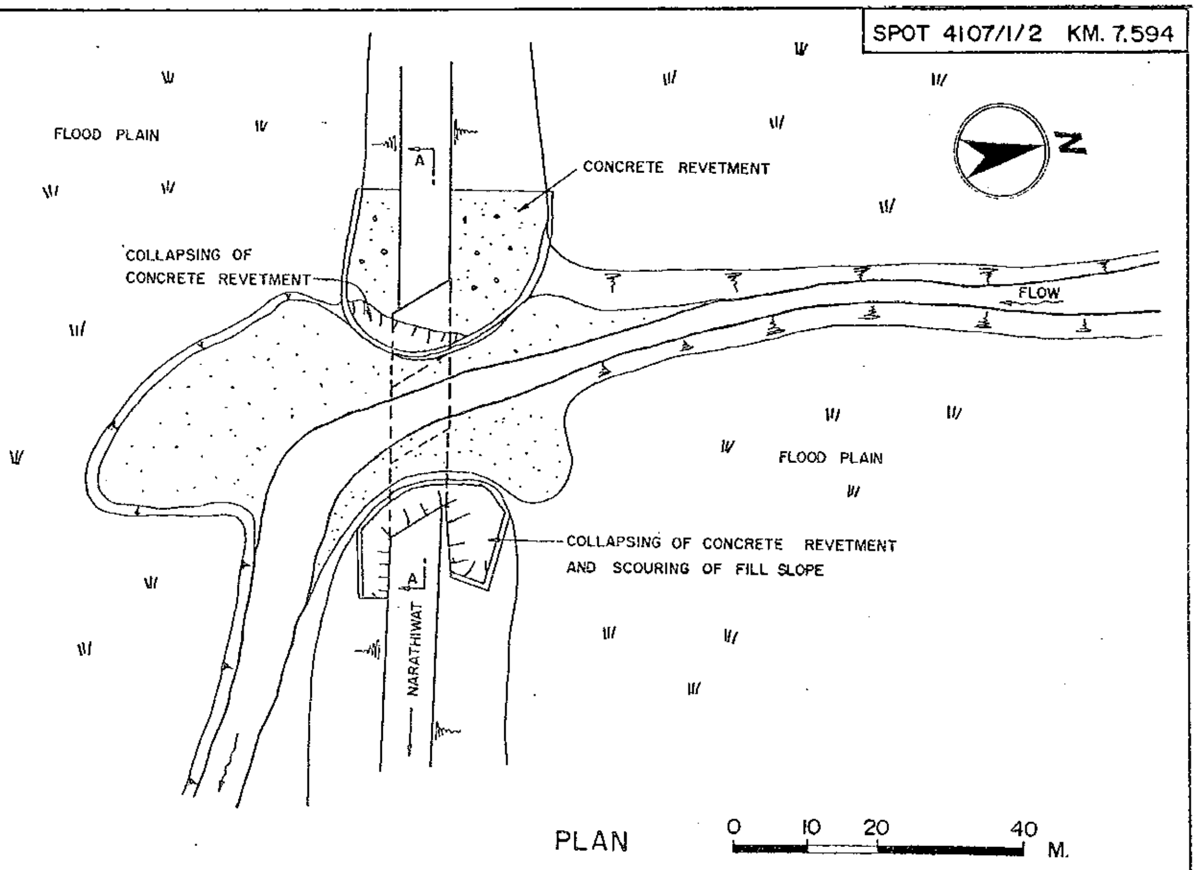
1. Spot 4107/1/2: Scouring of Abutment Fill Slope (BC-1-5)
   Collapsing of Abutment Protection (BC-1-6)

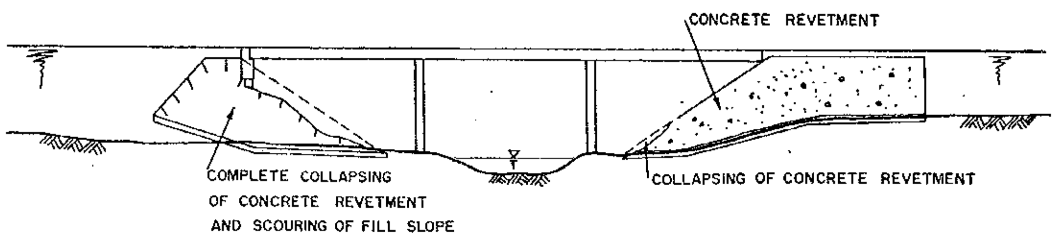
At Km. 7.594, there is a 30m long bridge. The bridge superstructure and substructure are constructed of reinforced concrete. In the vicinity of the bridge, the project road runs in a flood plain. The bridge and the river have a skewed crossing with an intersecting angle of 60 degrees. The existing river channel turns sharply to the left soon after crossing the bridge. These conditions are illustrated in Fig 4.8.2.

Even though the fill slopes had surface protection in the form of concrete revetments, both were damaged by flood waters resulting from heavy rainfall in December 1993. In particular, the concrete revetment on the left abutment completely collapsed and the fill slope was scoured. On the right abutment, the collapse of the concrete revetment was partial.

2. Spot 4058/1: Overflow (BC-1-8)

At Km. 8.624, there is a 21 metre long bridge. It is constructed of reinforced concrete girders. The approach embankments are 0.5 to 1.0 metres high. The clearance from the riverbed to the bottom of the girders is about 1.5 metres. In the vicinity of the spot the road is constructed in a flood plain on a low embankment as shown in Fig. 4.8.3. In the last few years, the bridge and the approach embankment were repeatedly inundated by floods.





SECTION A-A

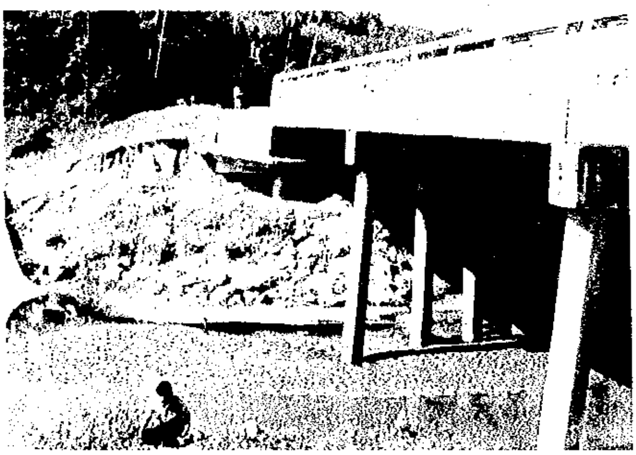
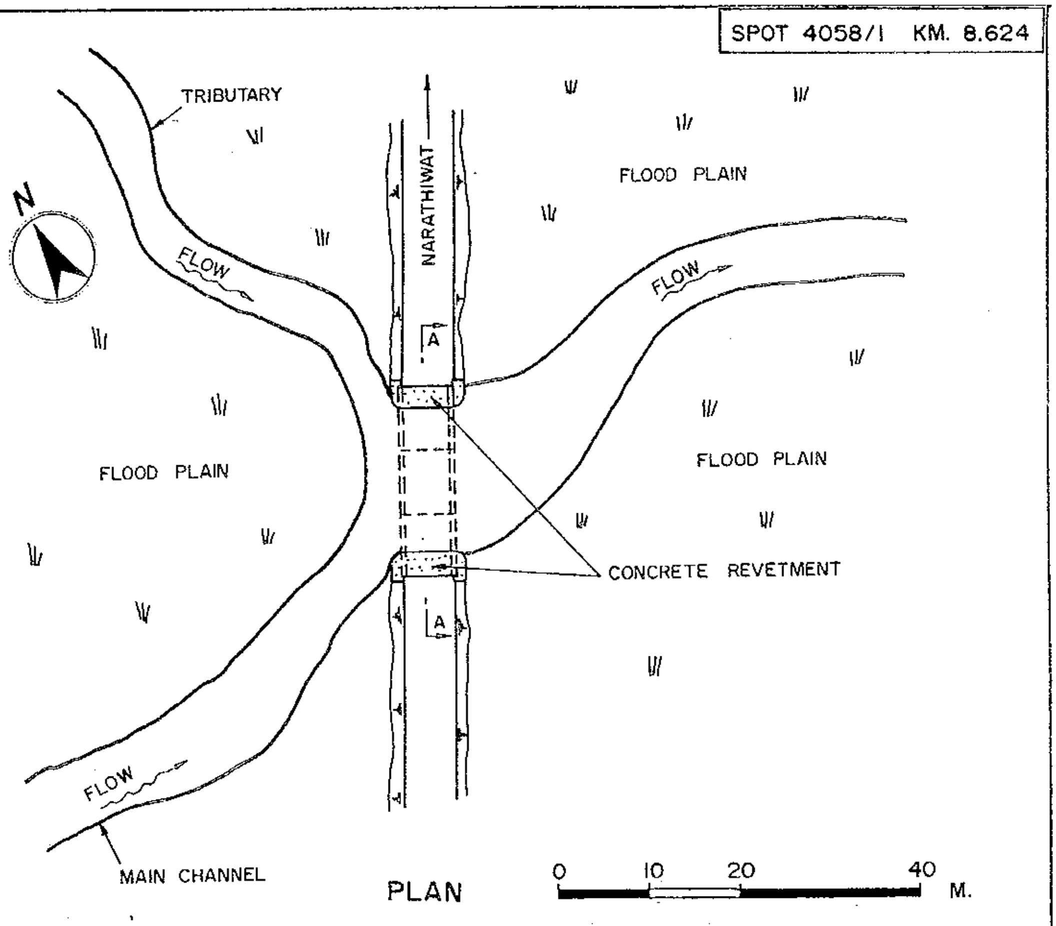


Fig. 4.8.2 Details of Disaster Spot



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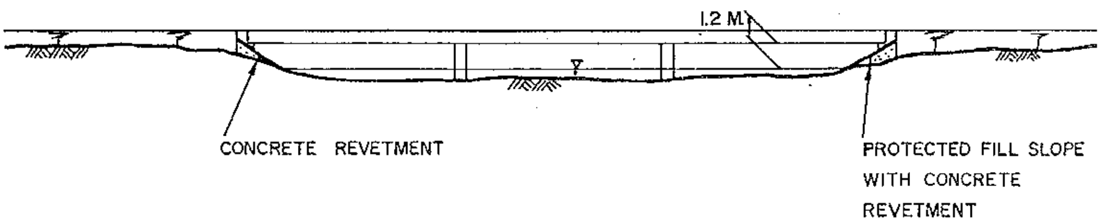


SECTION A-A

Fig. 4.8.3 Details of Disaster Spot

PART 2

FEASIBILITY STUDY

Chapter 5

Technical Surveys

Chapter 5 Technical Surveys

Three technical surveys on traffic, geotechnical conditions and topographical characteristics were carried out on the project routes for the Study. The following sections describe the methodologies applied in each of these technical surveys while their main results are presented in the appendices.

5.1 Traffic Survey and Analysis

In order to investigate the main characteristics of the present traffic pattern in the area that are influenced by the project routes and to forecast the future traffic demand on these routes, the traffic composition and volume data were collected through a traffic count survey. The survey gives traffic count data by vehicle category that are applied to different fluctuation factors to estimate the present average daily traffic volumes on the project routes. These traffic volumes are subject to a prediction procedure using the highly-associated indicators in the established socioeconomic framework so that the future traffic demand, required for the economic analysis and evaluation process, can be forecasted for each of the project routes.

5.1.1 Traffic Count Survey

Basically, the average daily traffic volume data of the DOH are used in the Study. However, this survey is conducted to supplement and update these data.

1. Purpose

The purpose of this survey is to determine the present average daily traffic volume and the distribution of vehicle categories in the traffic flow on the project routes.

2. Procedure

The traffic count survey was conducted in the Study on five out of the eight project routes, and the criteria in selecting the number of survey stations was set mainly to collect data on routes that have large ADT variations in the DOH records of past years. The survey stations were located on the same sites used by the DOH for each of the designated routes and the survey was carried out on weekdays to avoid the abnormal characteristics of weekend traffic. Table 5.1.1 presents the locational details of the survey stations and Figure 5.1.1 is a map of these stations.

Table 5.1.1 Traffic Survey Stations

Station No.	Route No.	Control Section	Km Post	Changwat
N-1	109	200	72+819	Chiang Mai
N-2	1149	100	3+150	Chiang Rai
N-3	1256	101	3+500	Nan
S-1	4015	201	21+000	Nakhon Si Thammarat
S-2	4107	200	4+500	Narathiwat

The survey period at each station was twelve hours (06:00-18:00) and manual counters were used to calculate the number of vehicles per category per direction at 15-minute intervals for the following vehicle categories:

- Tricycle (with engine)
- Motorcycle
- Passenger car and taxi
- Light bus
- Medium bus
- Heavy bus
- Pick-up
- 4-wheel truck (light truck)
- 6-wheel truck (medium truck)
- 10-wheel truck (heavy truck)
- Other vehicles (with engine)

3. Traffic Survey Results

To estimate average daily traffic volumes at the surveyed stations, hourly and daily traffic variations, as well as monthly and/or seasonal traffic fluctuations, were applied to the collected data. Hourly factors are applied to expand the 12-hour traffic count data to 24-hour traffic volumes and other fluctuation factors are applied so the bias in the collected data can be adjusted. Basically, data from the Traffic Engineering Division of DOH were used to obtain daily night traffic volumes.

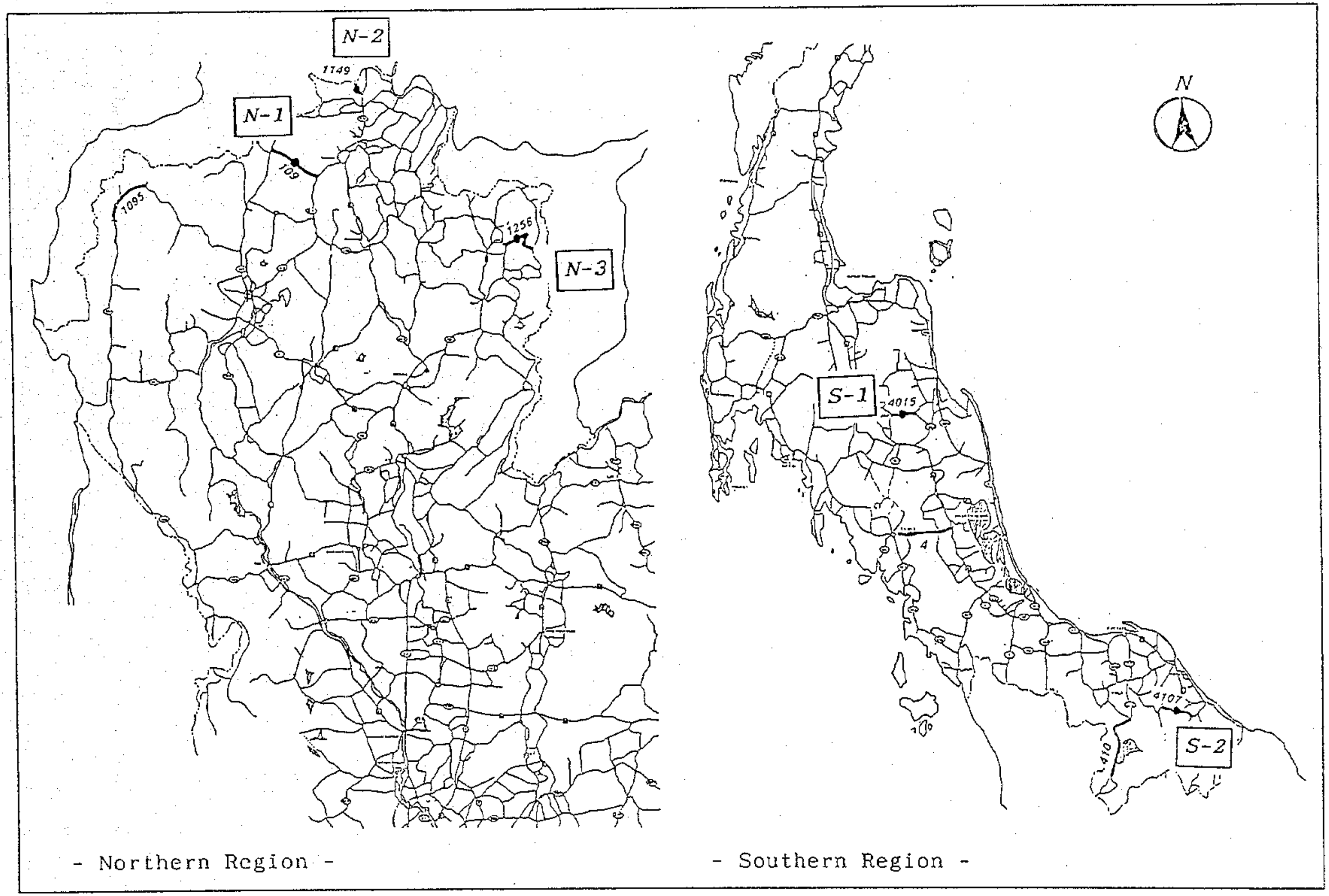


Fig. 5.1.1 Location of Traffic Survey Stations

The estimated values for both the expansion and fluctuation multiplying factors for all the vehicle categories, as well as the counted data and the estimated average daily traffic volumes, are presented in Appendix 5.1 for each survey station. Appendix 5.2 shows the hourly traffic volume variations during the survey period, while the traffic composition at each survey station is shown graphically in Appendix 5.3.

5.1.2 Traffic Demand Forecast

To provide basic data for forecasting the future traffic demand on the eight project routes, a socioeconomic framework was established using population and economic indicators for areas influenced by the project routes. Population was established on the amphoe level, while the economic indicators were on the changwat level since there is no data for amphoes. Highly associated parameters in the framework are applied to estimate the traffic growth rates and forecast the future traffic volumes on the project routes.

1. Socioeconomic Framework

The three main objectives of the Seventh National Economic and Social Development Plan (1992-1996) are as follows: 1) to maintain economic growth rates at appropriate levels to ensure sustainability and stability, 2) to redistribute income and decentralize development to the regions and rural areas more widely, and 3) to accelerate the development of human resources and upgrade the quality of life, the environment and natural resources management.

To achieve these objectives, national development quantitative targets were set at 8.2% per year for the overall economic growth rate, with growth in the agricultural and industrial sectors set at 3.4% and 9.5%, respectively. Human resource targets aim to reduce the population growth rate to less than 1.2% per year, which will bring the population of Thailand to 61 million by the end of the plan.

As the growth rates in the population and economic indicators are the main parameters to be applied in forecasting the growth in traffic volumes, the following sections estimate future population and economic growth for the project areas.

1) Population

Future population in the Study is based on past trends and the regional results of the "Population Projections for Thailand 1980 - 2015", which was estimated by the Human Resources Planning Division of the National Economic and Social Development Board (NESDB).

The long-term national population projection estimated by NESDB gives an annual growth rate of 1.4% for the period of the Seventh Plan and 1.2% for the Eighth Plan. As the target of the National Development Plan is to reduce the population growth rate to less than 1.2%, modifications were done based on the actual growth trend till 1991 and target growth.

Assuming that regional population growth will decrease at the same rate as the national population, the future regional population was estimated, based on the 1991 population and the concluded growth rates using national population as a control total. Next, future changwat population, for the changwats of the North and South regions, was estimated on the basis of past trends up till 1991 and by applying regional population as a control total. Figure 5.1.2 shows the growth in national, regional and changwat population till the year 2021. The future national and regional population is presented in Table 5.1.2.

Changwat population projections till the year 2012 is presented in Appendix 3.4, for the changwats in the North and South regions in which there are project routes.

The same procedure was applied to estimate future amphoe population in changwats on project routes, using future changwat population as a control total and past trends as a basis for the estimation. Past amphoe population is presented in Appendix 3.5, while Appendix 5.6 projects future amphoe population.

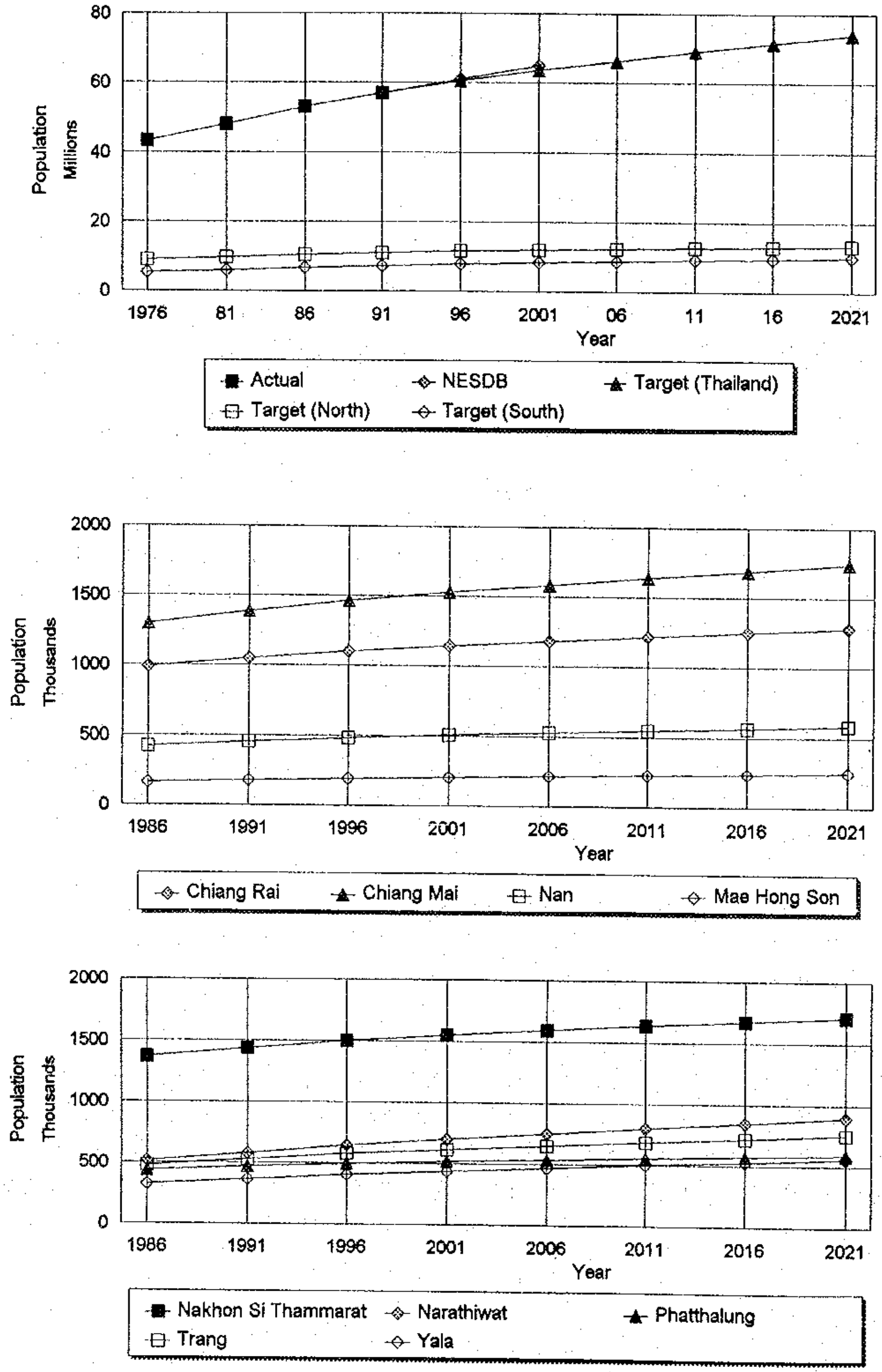


Fig. 5.1.2 National, Regional and Changwat Population Growth

Table 5.1.2 Regional Population Projection

	1976	1981	1986	1991	1996	2001	2006	2011	2016	2021
Population ('000):										
North	9,048	9,714	10,490	11,022	11,512	11,914	12,246	12,586	12,893	13,206
South	5,330	5,935	6,608	7,208	7,781	8,265	8,674	9,103	9,497	9,907
Northeast	14,793	16,394	18,552	20,045	21,458	22,642	23,637	24,676	25,623	26,606
East	2,622	2,945	3,418	3,740	4,048	4,309	4,531	4,763	4,977	5,200
West	2,604	2,866	3,146	3,337	3,515	3,661	3,783	3,909	4,022	4,139
Central	2,417	2,557	2,724	2,854	2,973	3,071	3,152	3,234	3,308	3,384
BMR	6,400	7,465	8,031	8,702	9,339	9,873	10,324	10,795	11,224	11,671
Thailand	43,213	47,875	52,969	56,907	60,613	63,705	66,294	68,989	71,438	73,973

	1976-1981	-1986	-1991	-1996	-2001	-2006	-2011	-2016	-2021
Annual Growth (%):									
North	1.43	1.55	0.99	0.87	0.69	0.55	0.55	0.48	0.48
South	2.17	2.17	1.75	1.54	1.21	0.97	0.97	0.85	0.85
Northeast	2.08	2.50	1.56	1.37	1.08	0.86	0.86	0.76	0.76
East	2.35	3.02	1.82	1.60	1.26	1.01	1.01	0.88	0.88
West	1.94	1.88	1.19	1.04	0.82	0.66	0.66	0.57	0.57
Central	1.13	1.27	0.94	0.82	0.65	0.52	0.52	0.45	0.45
BMR	3.13	1.47	1.62	1.42	1.12	0.90	0.90	0.78	0.78
Thailand	2.07	2.04	1.44	1.27	1.00	0.80	0.80	0.70	0.70

2) Economic Indicators

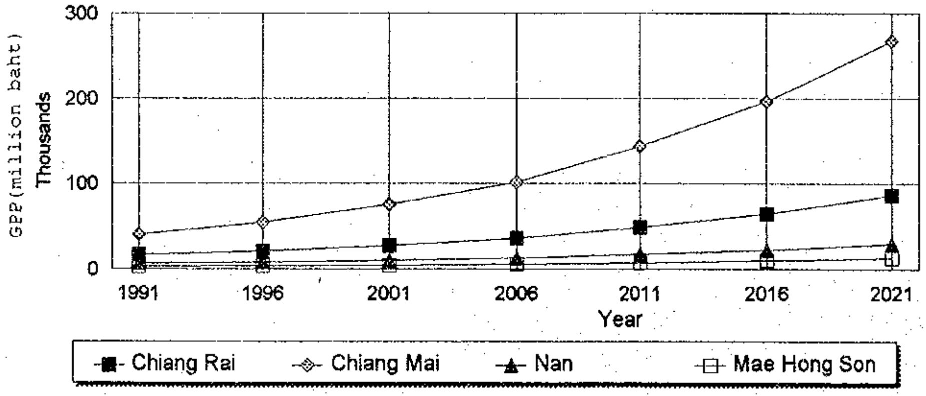
To maintain economic growth at an appropriate level, the target for the annual average growth of gross domestic products (GDP) was set at 8.2% for the period of the Seventh Plan between 1991 - 1996, compared with 10.9% actual growth in the Sixth Plan. NESDB estimations for future periods till 2011 show gradual decreases in the growth rate as presented in Table 5.1.3, in which the future growth rates between 2011 and 2021 were estimated by means of extrapolations.

The currently published NESDB data for gross regional product (GRP) and gross provincial product (GPP) for the period 1981 - 1991 at 1988 constant prices were used for the projections. Data for 1991 was the base of the projection procedure to estimate the future GPP for all the changwats in the North and South regions, taking GRP as a control total. Figure 5.1.3 shows the growth in GPP for the changwats in which the projects routes are located, while Appendix 5.7 presents the GPP projection results for the changwats in the two regions.

Table 5.1.3 Projection of GRP at 1988 Constant Prices (mil.baht)

	1986	1991	1996	2001	2006	2011	2016	2021
Gross Regional Products (GRP):								
Northeast	171,745	241,260	319,214	423,663	557,234	989,085	1,310,157	
North	151,831	210,856	277,671	370,271	487,008	655,507	872,628	1,161,369
South	124,723	185,869	254,161	346,989	462,899	628,947	845,206	1,135,535
East	111,466	198,668	362,005	607,839	911,128	1,285,204	1,784,844	2,478,094
West	68,339	91,410	136,539	198,067	274,353	374,521	505,674	682,581
Central	53,078	81,627	120,807	178,520	250,770	348,806	477,643	653,902
BMR	575,996	1,098,559	1,656,101	2,447,274	3,469,948	4,871,798	6,734,158	9,306,076
Thailand	1,257,177	2,108,249	3,126,498	4,572,623	6,413,341	8,911,290	12,209,239	16,727,716

	1986-1991	-1996	-2001	-2006	-2011	-2016	-2021
Annual Growth (%):							
Northeast	7.0	5.9	5.9	5.7	6.1	5.8	5.8
North	6.8	5.8	6.0	5.7	6.2	5.9	5.9
South	8.3	6.6	6.5	6.0	6.4	6.1	6.1
East	12.3	12.9	11.0	8.5	7.2	6.8	6.8
West	6.0	8.5	7.8	6.8	6.5	6.2	6.2
Central	9.0	8.3	8.2	7.1	6.9	6.5	6.5
BMR	13.8	8.7	8.2	7.3	7.1	6.7	6.7
Thailand	10.9	8.2	7.9	7.0	6.8	6.5	6.5



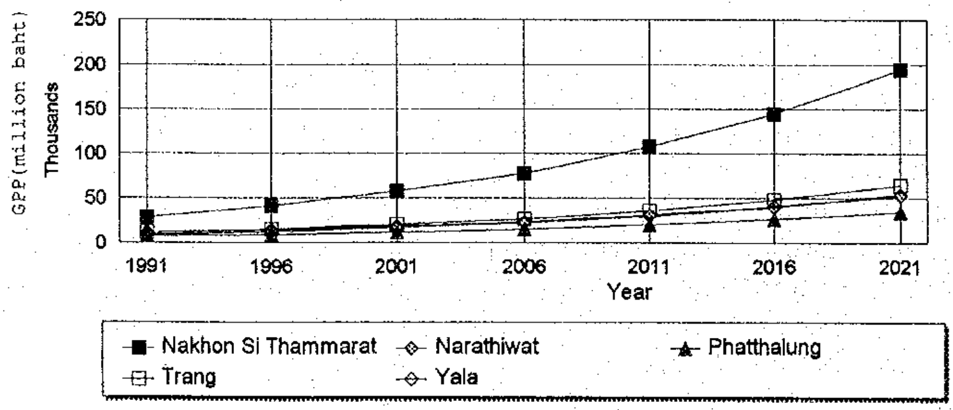


Fig.5.1.3 Economic Growth of GPP

2. Traffic Volume Forecast

Future traffic volumes on the project routes are a main output of the economic evaluation process for the project. To forecast these volumes, a future socioeconomic framework was established, as described in the previous section, in which predictions of the future population and economic indicators were carried out. In this traffic forecasting procedure, the methodology applied utilizes the expected growth in population and economic indicators to estimate the traffic growth rates for each of the project routes. The applied methodology can be simplified as in the flow chart presented in Fig. 5.1.4.

As the project routes represent a limited number of national and provincial highways with present traffic volumes of about 1,000-2,000 ADT for five routes, more than 5,000 ADT for one route and less than 500 ADT for two routes, a macroeconomic approach was used for forecasting future traffic demand. Since the past traffic volume data of the project routes are widely scattered and do not represent a reasonable traffic growth trend, these data, combined with data collected during the traffic survey, were first analyzed via regression analysis to determine the past traffic growth trend and to establish a model for estimating future traffic growth by vehicle type.

Traffic volume by vehicle type was used as the dependent variable and socioeconomic indices were applied as independent variables to be used in developing the traffic growth model via multiple-regression analysis. Based on statistical criteria regarding the stability of the multiple correlation coefficient R^2, it was found that the amphoe population of areas influenced by project roads and the gross provincial product (GPP) for changwats in which the project roads are located give the optimum values for the correlation coefficient for each vehicle category. In this procedure, since changwat-level GPP is used in estimating future traffic growth, generated trips and traffic volumes for small-scale projects for rural and village development near the project routes are not separately estimated.

The developed traffic growth model is based on the first principal component score method, which was applied to estimate traffic volume growth using a component score for traffic volume by vehicle category for each five-year plan period. In this technique, a calibration procedure was applied and the resulting growth factors, starting from the base-year 1991, were multiplied by the estimated base-year traffic volume by vehicle category for each project route to conclude the future traffic demand.

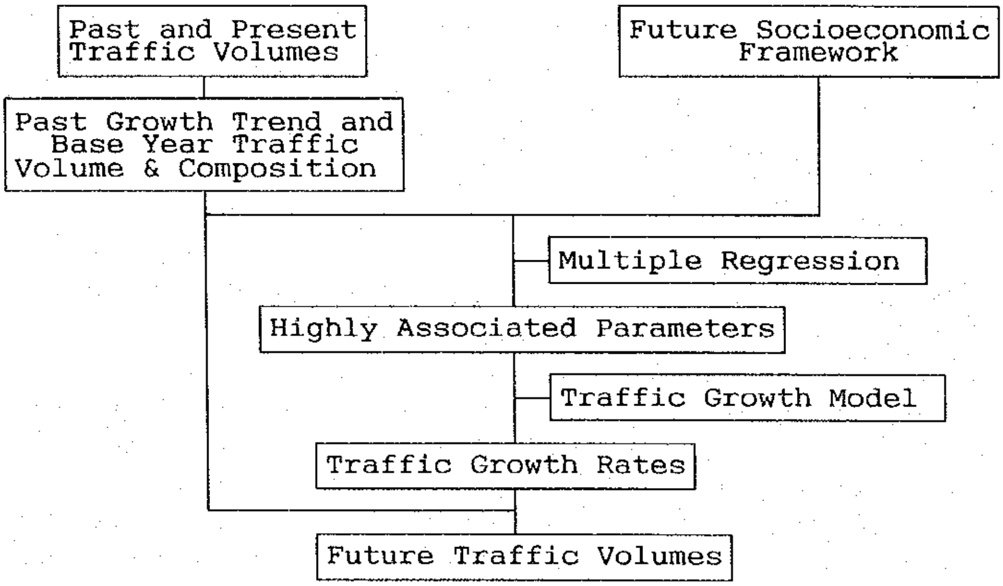


Fig. 5.1.4 Forecasting of Future Traffic Demand

Traffic growth results are shown in Fig. 5.1.5 and the applied model has the following form:

$$Z_{cvn}=P_{an}(a_1+a_2P_{an}+a_3P_{an}^2+a_4P_{an}^3)+bGPP_{cn}+c$$

where,

Z_{cvn} : first principal component score of traffic volume in year n for vehicle type v for changwat c

P_{an} : population of amphoe a, which is influenced by a project route, in year n

GPPc : gross provincial product of a project route's changwat c in year n

a_1, a_2, a_3, a_4, b & c : parameters with values shown in the table below

	a_1	a_2	a_3	a_4	b	c	Multiple Correlation Coefficient R^2
Motorcycle	62.7313	0.0524	-0.004	1E-05	0.0343	-3159	0.9338
Passenger Car	-3.753	0.1238	-0.001	4E-06	0.0402	-130.7	0.9087
Light Bus	124.05	-1.747	0.0096	-2E-05	-0.002	-2848	0.9264
Medium & Heavy Bus	-11.08	0.1584	-9E-04	2E-06	0.0019	258.15	0.9232
Light Truck	-219.4	3.4452	-0.02	4E-05	0.0018	4722	0.8853
Medium & Heavy Truck	-112.8	1.6919	-0.01	2E-05	0.0099	2495.7	0.9402
ADT	-223	3.672	-0.023	5E-05	0.0521	4496.9	0.9696

3. Future Traffic Demand

Results of the traffic forecast procedure for future traffic demand at the midsection of project routes are as presented in Table 5.1.4.

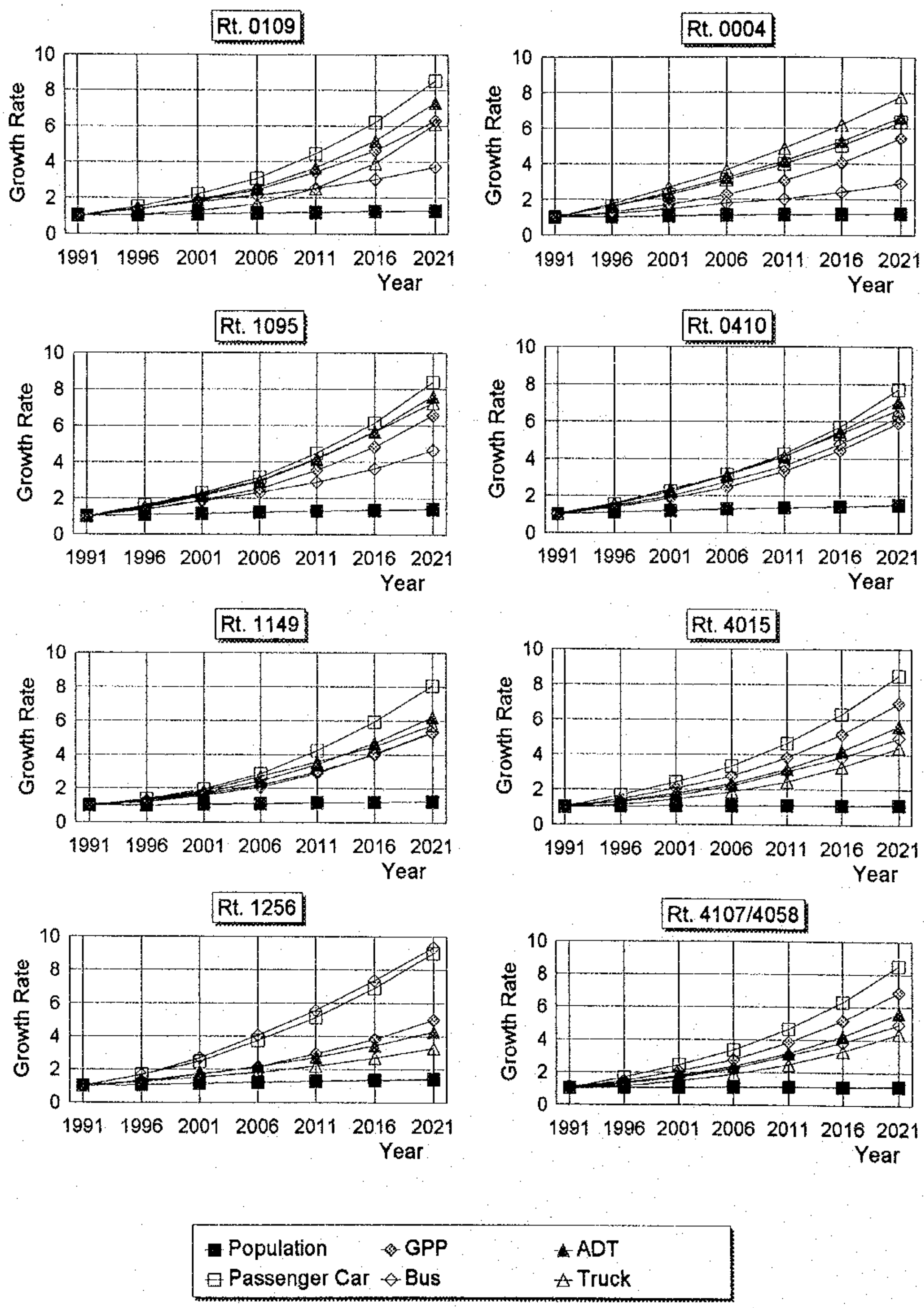


Fig. 5.1.5 Future Socioeconomic and Traffic Growth

Table 5.1.4 Future Traffic Demand (1/2)

	1996	2001	2006	2011	2016	2021
Rt. 109:						
Motorcycle	1,554	2,058	2,862	4,334	6,433	9,050
Passenger Car	1,434	2,123	2,975	4,290	5,951	8,214
Light Bus	153	193	227	244	268	299
Medium & Heavy Bus	50	66	88	126	176	247
Light Truck & Pick-up	174	188	206	295	502	882
Medium & Heavy Truck	345	431	605	940	1,416	2,115
ADT	2,156	3,001	4,101	5,895	8,313	11,757
Rt. 1095 :						
Motorcycle	1,369	1,896	2,487	3,363	4,417	5,816
Passenger Car	1,108	1,581	2,166	3,091	4,238	5,786
Light Bus	162	206	255	299	357	443
Medium & Heavy Bus	47	69	97	139	192	262
Light Truck & Pick-up	108	156	204	263	325	400
Medium & Heavy Truck	182	262	370	556	792	1,034
ADT	1,607	2,274	3,092	4,348	5,903	7,925
Rt. 1149:						
Motorcycle	755	1,138	1,711	2,617	3,780	5,164
Passenger Car	512	730	1,060	1,567	2,209	2,993
Light Bus	715	926	1,219	1,685	2,326	3,096
Medium & Heavy Bus	60	102	126	183	297	357
Light Truck & Pick-up	288	388	575	731	899	1,122
Medium & Heavy Truck	52	65	103	157	218	319
ADT	1,627	2,211	3,083	4,323	5,949	7,887
Rt. 1256:						
Motorcycle	1,322	1,588	2,153	2,548	2,953	3,411
Passenger Car	82	120	183	251	337	442
Light Bus	35	56	85	118	156	196
Medium & Heavy Bus	6	11	16	21	28	38
Light Truck & Pick-up	343	410	468	564	707	866
Medium & Heavy Truck	103	142	182	222	265	317
ADT	569	739	915	1,176	1,493	1,859

Table 5.1.4 Future Traffic Demand (2/2)

	1996	2001	2006	2011	2016	2021
Rt. 4:						
Motorcycle	4,680	6,739	8,580	11,762	13,260	16,661
Passenger Car	1,680	2,399	3,171	4,121	5,182	6,517
Light Bus	840	956	1,126	1,196	1,360	1,586
Medium & Heavy Bus	190	292	405	545	700	898
Light Truck & Pick-up	3,504	5,617	7,566	9,850	12,125	15,055
Medium & Heavy Truck	1,487	2,088	2,939	4,149	5,646	7,293
ADT	7,701	11,292	15,207	19,861	25,013	31,349
Rt. 410:						
Motorcycle	492	713	929	1,187	1,516	1,913
Passenger Car	338	492	699	942	1,268	1,714
Light Bus	53	71	94	124	158	198
Medium & Heavy Bus	36	49	75	96	134	182
Light Truck & Pick-up	215	315	418	534	668	804
Medium & Heavy Truck	126	189	257	354	480	621
ADT	768	1,116	1,543	2,050	2,708	3,519
Rt. 4015:						
Motorcycle	892	1,264	1,702	2,374	3,200	4,304
Passenger Car	946	1,356	1,873	2,608	3,525	4,758
Light Bus	466	572	768	1,051	1,315	1,688
Medium & Heavy Bus	92	118	149	203	271	358
Light Truck & Pick-up	927	1,221	1,517	1,975	2,648	3,482
Medium & Heavy Truck	285	347	486	663	894	1,211
ADT	2,716	3,614	4,793	6,500	8,653	11,497
Rt. 4107:						
Motorcycle	1,086	1,319	1,553	1,837	2,154	2,547
Passenger Car	426	616	908	1,338	1,971	2,799
Light Bus	10	16	22	30	42	58
Medium & Heavy Bus	47	69	97	134	183	242
Light Truck & Pick-up	888	1,150	1,413	1,696	1,998	2,376
Medium & Heavy Truck	512	729	983	1,274	1,646	2,051
ADT	1,883	2,580	3,423	4,472	5,840	7,526
Rt. 4058:						
Motorcycle	2,012	2,446	2,879	3,406	3,994	4,721
Passenger Car	434	628	925	1,363	2,009	2,852
Light Bus	117	187	257	350	490	677
Medium & Heavy Bus	41	60	84	116	159	210
Light Truck & Pick-up	1,018	1,318	1,619	1,944	2,290	2,723
Medium & Heavy Truck	236	336	454	588	760	947
ADT	1,845	2,529	3,339	4,361	5,707	7,408

5.2 Geological Survey

The geological survey was composed of two phases. The first was comprised of field inspections and the taking of notes on all locations of road damage. Rock types, general topography, weathering states, slope inclinations and orientations and damage types were recorded.

After careful evaluation, landslide spots were selected for more detailed studies and were drilled and the surfaces mapped. The drilling locations were selected on the basis of providing a means of determining the "at depth" location of the failure surfaces and to measure the piezometric surface if a water table was present. The SPT results gave an indication of the strength of the colluvial debris on failed cut slopes or the density and shear strength on fill slopes. The core logs provided rock mass properties based on RQD as well as the relative orientation and surface of joints and other discontinuities.

The laboratory procedures were limited to simple index testing for classification. The results of drilling and testing are presented in APPENDICES C.

For each study spot the existing geological conditions have been derived by either direct mapping and drilling or by interpretation of photographs, notes and preconstruction contour maps. The results have been presented in a series of plan and section drawings.

Table 5.2.1 Quantity of Soil and Weathered Rock Drillings

Route No.	km.	Nos.	Total depth(m)	Soil	Weathered Rock	SPT's	Undisturbed (Nos.)Samples
1149	km. 5.2	1	10.45	10.45	0	5	0
109	km. 24.6	1	12.8	8.52	4.28	9	0
1095	km. 161.3	1	16.5	10.50	6.5	5	0
1256	km. 25.6	1	15.45	13.95	1.5	15	0
1256	km. 40.1	1	21.58	21.58	0	21	0
1256	km. 45.7	1	15	0	15	0	0
4	km. 44.7	1	15.45	15.45	0	15	0
410	km. 76.4	1	10.05	10.05	0	10	0
410	km. 97.8	1	5	0	5	0	0
Total		9	122.28	90.50	32.28	80	0

Table 5.2.2 Quantities of Laboratory Soil Tests

Route No.	km.	NWC	PSA	AL
1149	5.2	5	5	5
109	24.6	5	5	4
1095	161.3	3	3	2
1256	25.6	3	3	3
1256	40.1	4	4	4
1256	45.7	0	0	0
4	44.7	5	5	5
410	76.4	2	2	2
410	97.8	0	0	0
Total		27	26	25

NWC: Natural Water Content
PSA: Particle Size Analysis
AL : Atterberg Limits

5.3 Topographic Surveys

5.3.1 Plane Table Surveys

Plane table surveys were carried out, as shown in table 5.3.1. Their purpose was to obtain geographical information for the geometry of slopes at eight disaster spots, for a road at one disaster spot and for bridges at four disaster spots. The results of the plane table surveys were presented in drawings at a scale of 1:200

Table 5.3.1 Locations of Plan Table Surveys

Damage Type	Project Road	Control No.	Chainage	Remarks
Slope	109	0100	24+650	
	1095	0500	161+350	
	1149	0100	5+200	
	1256	0101	25+650	
	1256	0101	40+150	
	4	3900	44+700	
	410	0401	76+420	
	410	0401	97+800	
Road	4015	0201	21+337	
Bridges	1256	0101	5+963	-
	4	3900	16+970	NA THOM Bridge
	4015	0201	26+390	K.RANGKIAT Bridge
	4107	0200	7+594	-

5.3.2 Cross-Section Surveys

Cross-section surveys were carried out, as shown in Table 5.3.2, to obtain river profile information to aid in the study of remedial measures to prevent bridges from collapsing at four bridge sites. The results of the cross-section surveys were drawn at a scale of 1:100

Table 5.3.2 Locations of Cross Section Surveys

Project Road	Control No.	Chainage	No. of Cross Sections for Survey
1256	0101	5+963.5	3
4	3900	16+970	6
4015	0201	29+390	4
4107	0200	7+593.5	3

Chapter 6

Preliminary Design

Chapter 6 Preliminary Design

6.1 Selection of Road Restoration Measures

6.1.1 Definition of Repair Work

Repair work was divided up into the following three categories taking into consideration time and quality.

1. Urgent Repair Work

Urgent repair work focuses on reopening as soon as possible a road section closed to traffic due to some unforeseen occurrence. Consequently, emphasis is placed on how quickly the damaged spot is passable for traffic and not on the quality of the repair work itself.

However, since this work for the selected disaster spots has already been implemented, it is not handled in the preliminary design.

2. Temporary Repair Work

If permanent repair work is not feasible at present, temporary repair work with a lifetime of more than 5 years is carried out as makeshift repair work.

Temporary repair work shall be applied in the following cases:(1) when a detour route, which does not result in a large increase in traveling time, is available; (2) for road sections with a small amount of traffic volume that does not justify the higher repair costs of permanent repair work; and (3) when further damage is not anticipated in the near future.

3. Permanent Repair Work

Permanent repair work shall be applied in two cases: (1) when the lifetime of a temporary repair job is about to expire; and (2) when the project road is an important part of the road network that will produce adverse socioeconomic consequences if not permanently repaired.

In these cases, the feasibility of permanent repair work will be checked via a feasibility study. Also, the lifetime of permanent repair work shall be more than 20 years.

6.1.2 Road Restoration Measures

Road restoration measures that can be effectively applied for road disasters in Thailand were derived from the examples of various countries. They are summarized by objective in Table 6.1.1 - 6.1.2 and illustrated in Appendix 4.1.

In the table below, A stands for generally used measures in Thailand, B stands for rarely used measures, C stands for measures under study and experimentally used, and D stands for unused measures.

Table 6.1.1 Restoration Measures for Slope Damage (1)

Type of Restoration Measures		Application in Thailand
	Protection of slope surface	
A-1.1	Block sodding	B
A-1.2	Stripe sodding	B
A-2.1	Erosion control with local material	D
A-2.2	Seed packet work	C
A-3.1	Wicker work	C
A-3.2	Pick-hole seedling work	C
A-4.1	Seed spraying with a pump (seed spraying)	C
A-4.2	Seed-mix spraying with a gun (hydroseeding)	B
A-5	Stone or block pitching	B
A-6	Shotcrete	A
A-7	Concrete block pitching	C
A-8	Cribwork	C
	Slope drainage	
B-1.1	Berm ditches	A
B-1.2	Crest ditches	D
B-1.3	Toe ditches	A
B-2.1	Gutters	A
B-2.2	Ditch made of soil cement	D
B-3	Vertical ditches	B
B-4	Surface drainage	A

Table 6.1.1 Restoration Measures for Slope Damage (2)

Type of Restoration Measures		Application in Thailand
	Slope drainage	
B-5.1	Underground drainage with pits/pipes	B
B-5.2	Underground drainage with blankets	B
B-6	Drainage with pit-run gravel	B
B-7.1	Horizontal drain holes	D
B-7.2	Horizontal weep holes	A
	Slope support	
C-1.1	Cylinder gabions	D
C-1.2	Mat gabions	A
C-2.1	Gravity-type retaining walls	B
C-2.2	Gravity-type retaining walls with anchors	D
C-2.3	T-shaped retaining walls	B
C-2.4	Crib retaining walls	B
C-2.5	Crib retaining walls with anchors	D
C-3.1	Prevention piles	B
C-3.2	Prevention piles with anchors	D
C-4	Reinforced embankments	B
	Earth work	
D-1	Recutting	A
D-2.1	Earth removal	A
D-2.2	Removal of unstable material	A
D-3	Counterweight fill	B
D-4	Filling & compacting	B
	Prevention of rocks falling onto roads	
E-1	Nets to catch rocks	D
E-2	Fences to catch rocks	B
E-3.1	Concrete barriers for debris catch basins	D
E-3.2	Gabion barriers for debris catch basins	D
E-4	Rock bolts	D

Table 6.1.1 Restoration Measures for Slope Damage (3)

Type of Restoration Measures		Application in Thailand
Others		
F-1.1	: Viaduct work	B
F-1.2	: Trestle work	B
F-2	: Shifting of road alignment	B
Urgent		
G-1.1	: Removal of debris	A
G-1.2	: Removal of unstable material	A
G-2.1	: Earth filling/refilling	A
G-2.2	: Filling work using selected material	A
G-3	: Ditch work	A
G-4.1	: Sandbag work	A
G-4.2	: Gabion work	D
G-5	: Sheet covering	D
G-6	: Wooden fencing	B
G-7.1	: Wooden pilings	B
G-7.2	: H-piles	D
G-8.1	: Construction of Bailey bridges	A
G-8.2	: Trestle work	A
G-9	: Gravel surfacing	A

Table 6.1.2 Restoration Measures for Road & Bridge Damage (1)

Type of Restoration Measures		Application in Thailand
Protection from submerging		
H-1	: Raising roadway elevation	A
Securing of adequate waterway opening		
I-1	: Extending the length of bridges	A
I-2	: Removal of obstacles	A
I-3	: Longer bridge spans	B

Table 6.1.2 Restoration Measures for Road & Bridge Damage (2)

Type of Restoration Measures		Application in Thailand
I-4	: Auxiliary bridges	D
I-5	: Auxiliary culverts	B
I-6	: Channel dredging	B
I-7	: Raising roadway elevation	A
	Protection of abutments and road embankments	
J-1.1	: Concrete revetments	A
J-1.2	: Articulated concrete revetments	A
J-1.3	: Stone riprap revetments (with mortar)	A
J-1.4	: Cribwork with stone riprap	B
J-1.5	: Gabions	A
J-2.1	: Sheet-pile toe walls	D
J-2.2	: Deep embedment of bases	B
J-2.3	: Riverbed protection	B
J-3	: Vertical abutment walls	D
J-4	: Extension of protection to upstream side	B
J-5	: Guide dikes	D
	Protection of riverbanks	
K-1.1	: Concrete revetments	A
K-1.2	: Articulated concrete revetments	A
K-1.3	: Stone riprap revetments	A
K-1.4	: Cribwork with stone riprap	B
K-1.5	: Gabions	A
K-1.6	: Dumped Rock	A
	Channel stabilization	
L-1.1	: Stabilization of stream banks with dumped rock	A
L-1.2	: Stabilization of stream banks with gabions	A
L-2	: Guide dikes	D
L-3	: Realignment of trailwater channels	B
L-4	: Dredging of stream channels	B

Table 6.1.2 Restoration Measures for Road & Bridge Damage (3)

Type of Restoration Measures		Application in Thailand
Securing of adequate discharge capacity for culverts		
M-1	Enlargement of cross-sectional area	A
M-2	Replacing existing culverts with bridges	A
Adequate water flow		
N-1	Channel realignment	B
N-2	Steeper culvert gradients	B
Inlet and outlet control, etc.		
O-1	Side-tapered inlets	A
O-2	Foot protection at culvert entrances	A
O-3	Training walls at culvert entrances	B
O-4	Anti-seep collars	A
O-5	Side-tapered outlets	A
O-6	Open or closed chutes for trailwater	D
Urgent work		
P-1.1	Construction of Bailey bridge	A
P-1.2	Trestle work	A
P-2	Refilling of scoured embankments	A
P-3	Abutment/embankment fill protection using gabions/sandbags	B
P-4	Inlet/outlet protection using gabions/sandbags for culverts	B
P-5	Partial repavement of road surface	A

6.1.3 Selection Procedures for Restoration Measures

There are a large number of technical solutions to most of the problems considered in the Study. In Table 6.1.1 and 6.1.2, various alternatives are presented, but usually there are one or two techniques that seem to be most appropriate for a particular spot.

In order to select the most appropriate countermeasures for a spot, a socioeconomic evaluation is also needed in addition to technical and economical considerations.

Repair work, as described in Section 6.1.1, is classified into the three categories of urgent, temporary, and permanent repair work. In addition to these measures, no repair work and rerouting are also possible choices to solve a particular problem. For example, when damage is minor and no further damage is anticipated in the near future, no repair work is a viable candidate as a countermeasure. On the other hand, when damage is too large to repair, rerouting would be a more appropriate choice.

In order to conveniently select road restoration measures, selection procedures for slope damage and the collapsing of bridges and roads are shown in Appendix 4.2 as flow charts.

One or more road restoration measures are proposed for each step in a flow chart, with the most appropriate measures being selected by considering the four issues below.

1) Availability of local materials: Priority shall be placed on materials that are locally produced.
2) Experience in Thailand: Construction methods that are familiar in Thailand are most appropriate.
3) Cost reductions: Cost-effective measures shall be given high priority.
4) Transferring of new technology: Measures that are technically highly effective will be proposed, even if they have not been applied before in Thailand.

6.2 Preliminary Design for Restoration Measures

6.2.1 Design Conditions

1. Road Class

DOH, in accordance with defined functions, classifies its highways into national and provincial highways. In addition, national highways are subdivided into primary and secondary highways as follows.

National Highways

* Primary Highways (single-digit and double-digit numbers)
* Secondary Highways (three-digit numbers)

Provincial Highways (four-digit numbers)

Highways are further subdivided into five classes as shown below.

- Class D highways are defined as highways with a 7-year ADT of more than 8,000 vehicles or shall be justified by economic feasibility calculations. Especially, Class D highways have a divided carriageway with two lanes for each direction.

- Class 1, 2 and 3 highways are defined using minimum specified 15-year ADT values. These roads consist of a two-lane carriageway.

- Class 4 highways are defined as highways with a 7-year ADT of more than 300 vehicles, and a 15-year ADT of less than 1,000 vehicles.

- Class 5 highways are defined as highways with a 7-year ADT of less than 300 vehicles and a 15-year ADT of more than 300 vehicles.

The road class of each project road is shown in Table 6.2.1.

Table 6.2.1 The Road Class of Project Roads

Route No.	Control No.	Road Class
109	0100	5
	0200	3
1095	0500	4
1149	0100	4
1256	0101	4
4	3800	3
	3900	3
410	0301	4
	0302	4
	0401	1
	0402	4
4015	0201	4
4107	0200	5
4058	0100	2

Highway design standards are mainly based on AASHTO practices (The American Association of State Highway and Transportation Officials). Table 6.2.2 shows the minimum design standards for highways.

2. Cross Section

Fig. 6.2.1 shows a typical cross section for a highway at a cut and fill section. Slope gradients for three types of cut sections and one type of fill section are standardized. Appendix 4.3 shows the standard cross section for each project road.

The width of a bridge is based on the following criteria:

(1) The outside edge of a bridge roadway shall have a 1.50 meter wide sidewalk. A 0.50 meter thick barrier shall be on both edges.

Table 6.2.2 Minimum Design Standard for HighwayS

Class	D	1	2	3	4	5	Urban area	Frontage road
Average daily traffic (adt)	Above 8,000	4,000 - 8,000	2,000 - 4,000	1,000 - 2,000	300 - 1,000	Below 300	–	–
Design speed, (kph), • Flat and moderately rolling • Rolling or hilly • Mountaineous	9 - 110 8 - 110 7 - 80				70 - 90 55 - 70 40 - 55	60 - 80 50 - 60 30 - 50	60 60 60	70 - 90 70 - 80 60 - 70
Maximum gradient, (%) • Flat and moderately rolling • Rolling or hilly • Mountaineous	4 6 8				4 8 12	4 8 12	Varies Varies Varies	4 6 8
Suggested surface type	High			High to intermediate		Soil aggregate	High	High to intermediate
Width of carriageway, (M).	7.00 Min. for each direction	7.00	6.50	6.00	6.00	8.00	3.00 - 3.50 Perlane	3.00 - 3.50 Perlane
Width of shoulder, (M).	Left side 2.50 - 3.00 Right side 1.50	2.50 - 3.00	2.25	2.00	1.50		2.50 or sidewalk	2.00 Min. or sidewalk
Bridge roadway width, (M). • Rural area	11.00 Min. for each direction	12.00	11.00	10.00	9.00	8.00	Full roadway width 0.50 M. Barrier width each side	
• Urban or suburban area	9.50 Min.	9.00	9.00	8.00	8.00	8.00	1.50 M. Sidewalk width each side	
Special bridge (total length more than 80.00 M) (M) • with sidewalk	9.50	9.00	9.00	8.00	8.00	8.00	1.50 M. Sidewalk width each side	
• without sidewalk	10.00	10.00	10.00	9.00	9.00	9.00	0.50 M. Barrier width each side	
Right of way (M)	60 - 80		40 - 60		30 - 40		Varies	
Maximum rate of superelevation (%)	10						6	10

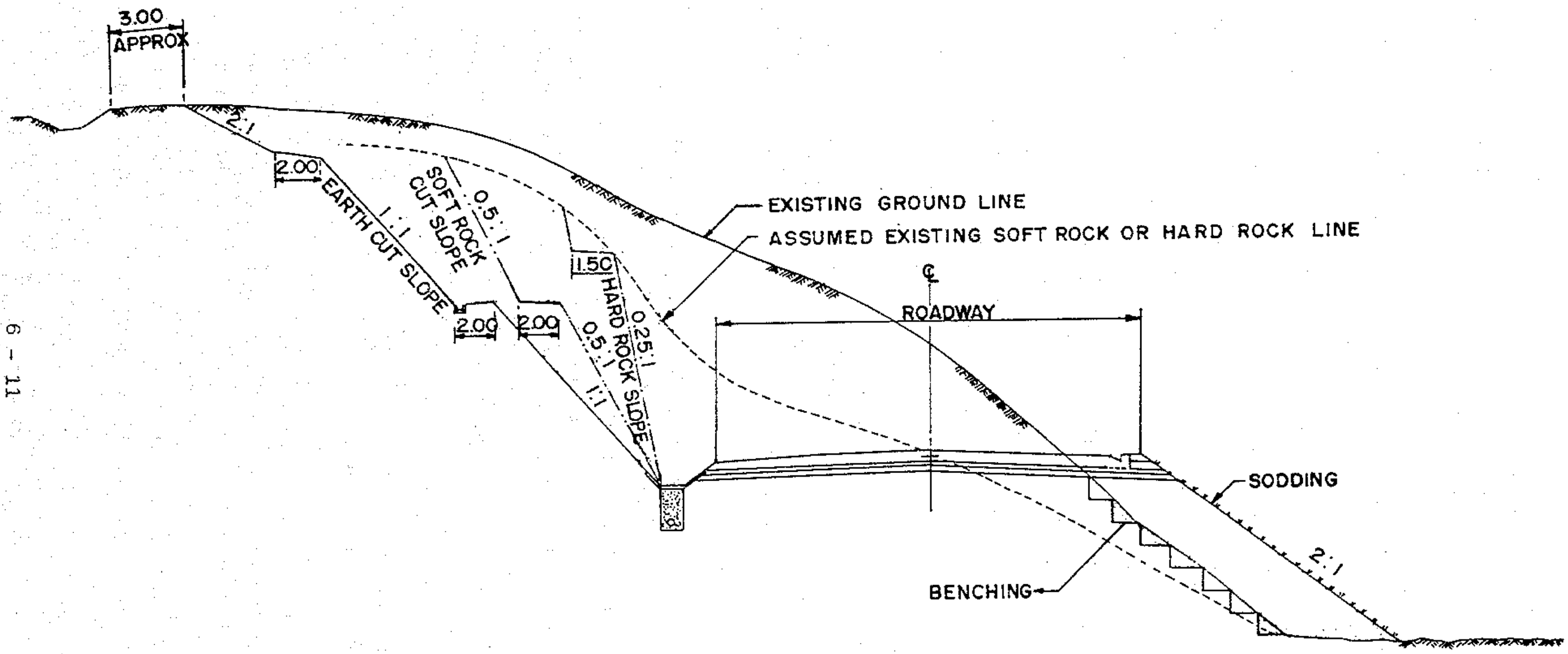


Fig.6.2.1 Typical Highway Cross Section

(2) Roadway width, sidewalk width, barrier width and railing of bridges in urban areas may be specially designed to conform to existing conditions.

(3) For bridges located on a horizontal curve, the bridge roadway width shall be widened in conformance with the following:

1) Generally, bridge roadway width shall be as wide as the width of the approach road (pavement plus shoul ders).

2) If condition 1) cannot be fulfilled, the width of a bridge roadway shall be at least as wide as the approach road pavement width.

3) Bridge roadway width conforming to condition 1) or 2) shall be rounded to the nearest full meter.

3. Bridge Design

For new bridge construction and bridge improvement and repair works, preliminary design was carried out mainly based on DOH standards. The fundamental conditions for designing a bridge are as follows:

- the calculation of earth pressure using Coulomb's equation;
- an allowance ratio of less than 5% for river flow blockage at the time of flooding based on Japanese bridge standards.
- 60cm clearance between the bottom of a girder and flood waters based on Japanese bridge standards for bridges shorter than 50m; and
- concrete strength of 400kg/sqcm for precast concrete and 210kg/sqcm for cast-in-place concrete.

A Bailey bridge is used in urgent work, and shall satisfy the allowable stresses below.

- Allowable bending tensile stress : 2100kg/sqcm
- Allowable bending compressive stress: 2100kg/sqcm
- Allowable shearing stress : 1200kg/sqcm

In a Bailey bridge, the unit girder can generally be assembled in three ways in order to match the load conditions(see Fig.6.2.2.)

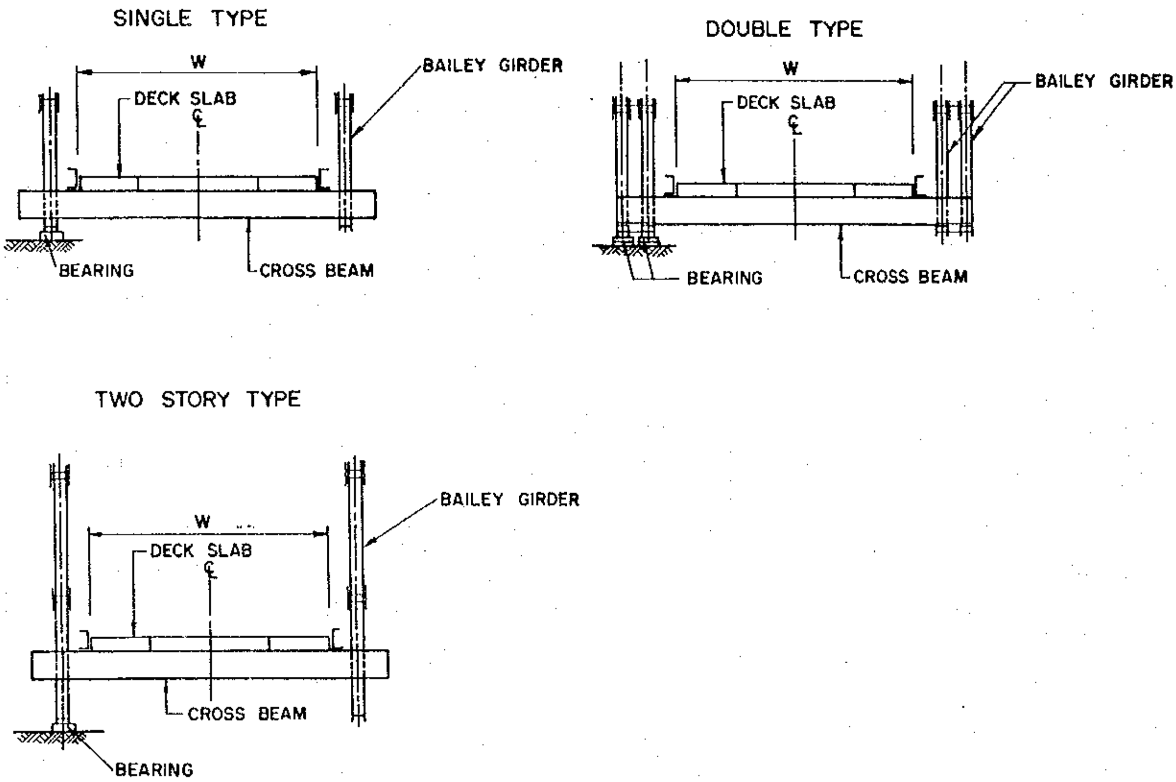


Fig.6.2.2 Types of Bailey Bridges

4. Design Load

DOH limits maximum axle load as shown below and gross vehicle weight as shown in Fig. 6.2.3 to prevent overloaded vehicles.

Type of Axle	Maximum Axle Load
Single Axle	
- Single Tire	6,800 kg.
- Dual Tire	9,100 kg.
Tandem Axle (Axle spaced not less than 1.0 m. and not more than 2.0 m.)	
- Single Tire	6,100 kg.
- Dual Tire	8,200 kg.

Vehicle Type	Gross Weight	Vehicle Type	Gross Weight	Trailer Type
1,700 nn. (Kg) 6,800 nn. (Kg)	8,500 nn.(Kg)	3,700 nn. (Kg) 6,800 nn. (Kg)	10,500 nn.(Kg)	6,800 nn. (Kg)
2,900 nn. (Kg) 9,100 nn. (Kg)	12,000 nn.(Kg)	4,900 nn. (Kg) 9,100 nn. (Kg)	14,000 nn.(Kg)	9,100 nn. (Kg)
3,100 nn. (Kg) 6,100 6,100 nn. (Kg)	15,300 nn.(Kg)	6,600 nn. 6,100 6,100 nn. (Kg) (Kg)	18,800 nn.(Kg)	6,100 6,100 nn. (Kg)
4,600 nn. (Kg) 8,200 8,200 nn. (Kg)	21,000 nn.(Kg)	8,800 nn. 8,200 8,200 nn (Kg) (Kg)	25,200 nn.(Kg)	8,200 8,200 nn. (Kg)

Legend: ◎ Single Tire ● Dual Tire

Fig.6.2.3 Limits on Axles and Vehicular Gross Weight

5. Culvert

The main conditions for designing a culvert are follows:

- The discharge capacity of a culvert shall be larger than discharge volume by 20 percent.
- The longitudinal gradient of a culvert shall be more moderate than 10 percent.

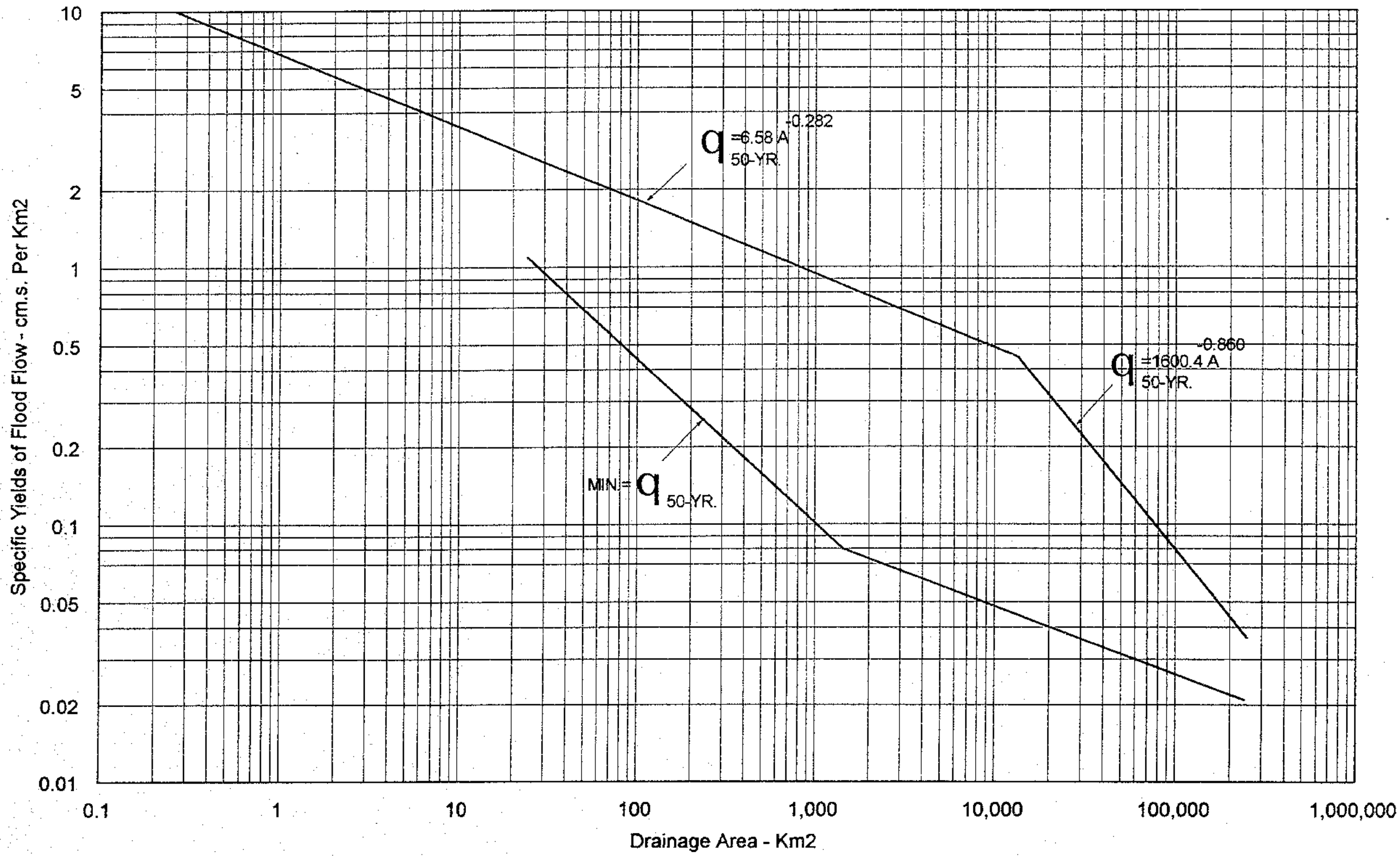
6. Rainfall Intensity

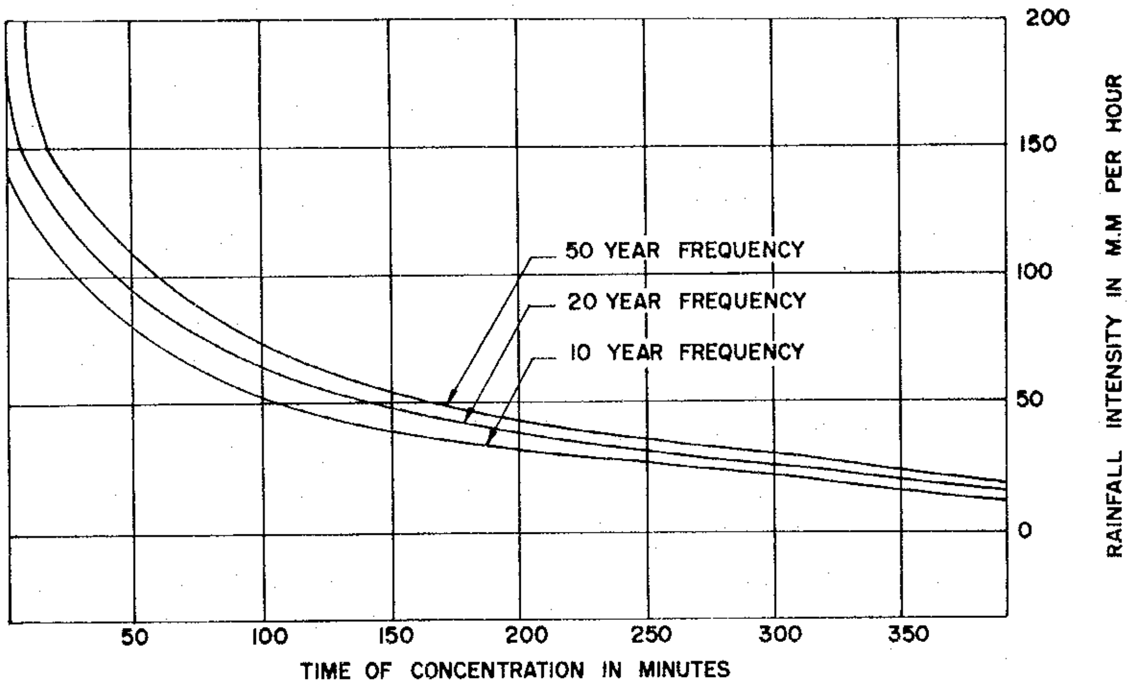
The waterway openings at bridges and culverts, and the cross sections of ditches for surface drainage, are calculated based on rainfall intensity at site and specific yields of flood flows (refer to Fig.6.2.4).

- In the case the catchment area is larger than 25 sqkm, the return period shall be 20 years.
- In calculating slope surface discharge, the return period shall be 3 years.

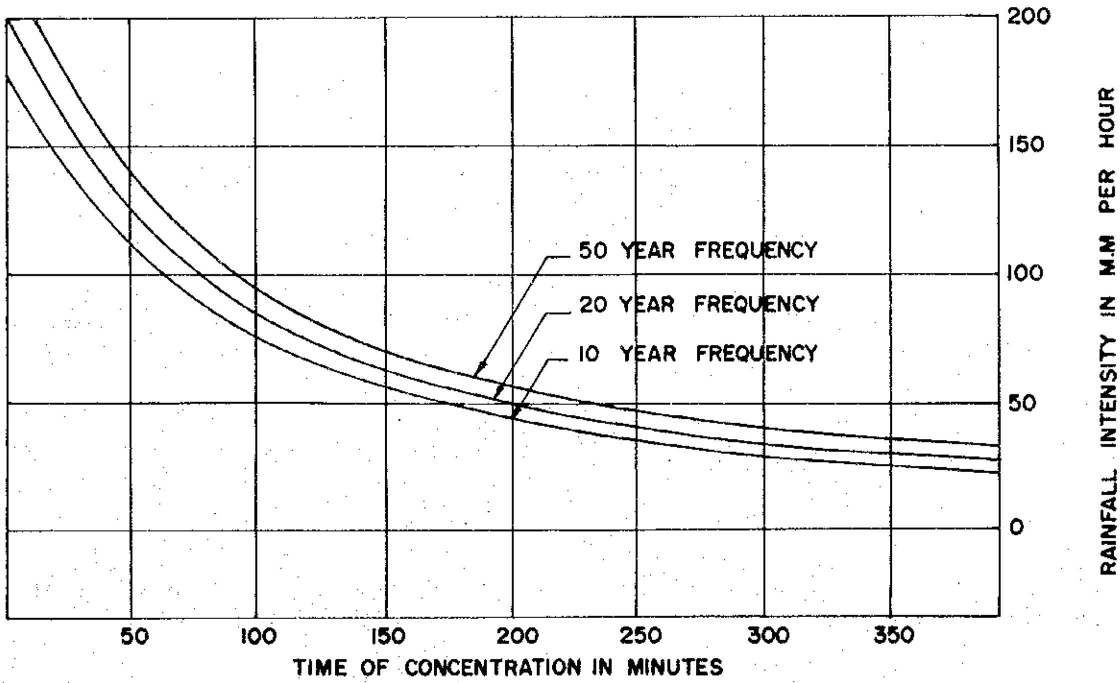
In the Study, the intensity duration curves for Chiang Mai were used for the five project roads in the North Region. In the South Region, the curves for Songkla were used. Two rainfall intensity curves are shown in Fig.6.2.5.

Fig.6.2.4 Specific Yields of Flood Flow





CHIANGMAI STATION



SONGKLA STATION

Fig.6.2.5 Intensity Duration Curves

6.2.2 Designing

Fundamental and general methods to design the main restoration measures are discussed in this section. Drawings of most of the restoration measures are shown in "DRAWINGS" of Volume 2.

1. Bridges Collapsing

1) Securing of Waterway Openings

(1) Discharge capacity

At a bridge crossing, the area of a river's waterway opening should be checked to see whether the discharge volume is larger than the discharge capacity.

The discharge volume is calculated according to the Rational Formula, as follows:

$$Q = \frac{1}{3.6} \cdot C \cdot I \cdot A$$

Where,

- Q = Discharge volume (cubic meters/sec)
- C = Run-off coefficient
- I = Rainfall intensity within time of concentration (mm/h)
- A = Catchment area (sq. meters)

The following values are used for the run-off coefficient in the above formula:

Mountainous catchment	= 0.6
Flat catchment	= 0.5
Paddy field	= 0.7

The discharge capacity of a river is obtained by applying the Manning Formula:

$$Qc = \frac{1}{n} \cdot R^{2/3} \cdot i^{1/2} \cdot A$$

Where,

Q_c = Discharge capacity (cubic meters/sec)
n = Roughness coefficient (sec/m1/3)
R = A/P: Hydraulic radius (m)
 A : Cross-sectional area of water flow
 P : Length of wetted perimeter
i = Hydraulic gradient

The values of Manning's roughness ratio are as follows:

Cast-in-place concrete ---------------------------- 0.015
Precast concrete ---------------------------------- 0.013
Rivers in mountainous terrain (with huge boulders & boulders) -- 0.040
Rivers in mountainous terrain (with boulders & gravel) -- 0.050
Rivers in flat terrain (grass,bush)--------------- 0.035
Rivers in flat terrain (grass, pebble) ----------- 0.045

The result of discharge volume for discharge capacity is shown in Appendix 4.4.

(2) Ratio of river flow blockage by piers

At a bridge section, the ratio of river flow blockage by piers shall be calculated according to the following formula:

$$N = \frac{B}{W} \cdot 100 \leq Na$$

Where,

N = Ratio of river flow blockage by piers
Na = Allowable ratio of river flow blockage (5%)
B = Total sectional width of piers
W = Width of water flow at flood levels

The ratio of river flow blockade on project roads are presented in Appendix 4.5. A conceptual illustration is shown in Fig.6.2.6.

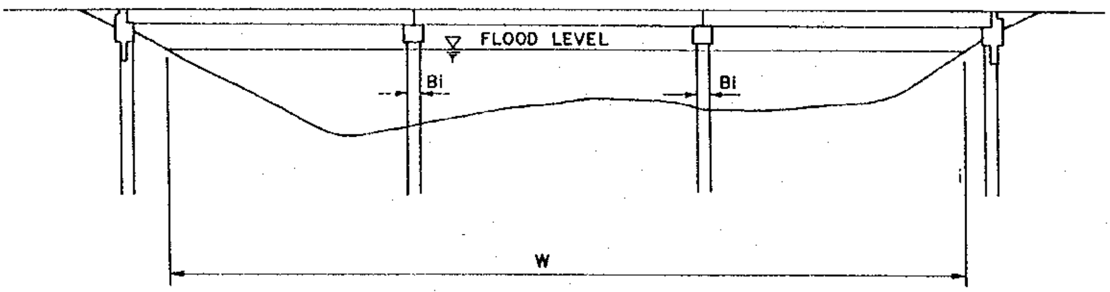


Fig.6.2.6 Conceptual Illustration on Blocked Water Flow

2) Raising of Bridge Elevation

At the time of flooding, the distance from the bottom of a girder to the flood water level should be more than 60 cm (depth of the cross beam of the pier) to prevent floating debris from colliding with the superstructure.

In raising bridge elevation, the following two construction methods can be applied:

(1) Changing span length (refer to Fig.6.2.7)

Here, the main item to be checked is the support capacity of the pier piles. They should be examined to see if they can withstand the increase in girder weight and live load.

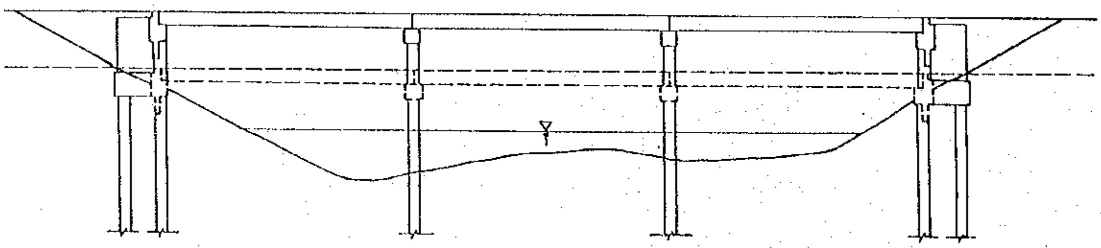


Fig.6.2.7 Illustration of Bridge Elevation Raising Method (1)

(2) No change in span length (refer to Fig.6.2.8)

In this case, major structural changes are made in the abutment structure. Both sides of an abutment are modified in order to withstand increases in earth pressure, which might require another row of piles.

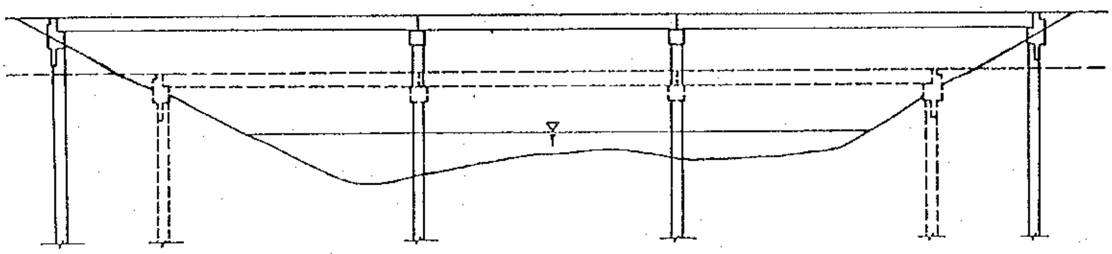


Fig.6.2.8 Illustration of Bridge Elevation Raising Method(2)

3) Protection of Abutment Fill Slopes and River Banks

Abutment fill slope protection measures should be prepared for the following two cases.

(1) When a stream is confined to a river channel even during a flood

In this case, the abutment fill slopes should be considered as a part of the river bank. The range of river bank protection basically depends on the configuration of the river flow. The outside bank of bends, where erosion is most active as a result of impinging flow, should be protected. The ranges of protection are illustrated in Fig.6.2.9.

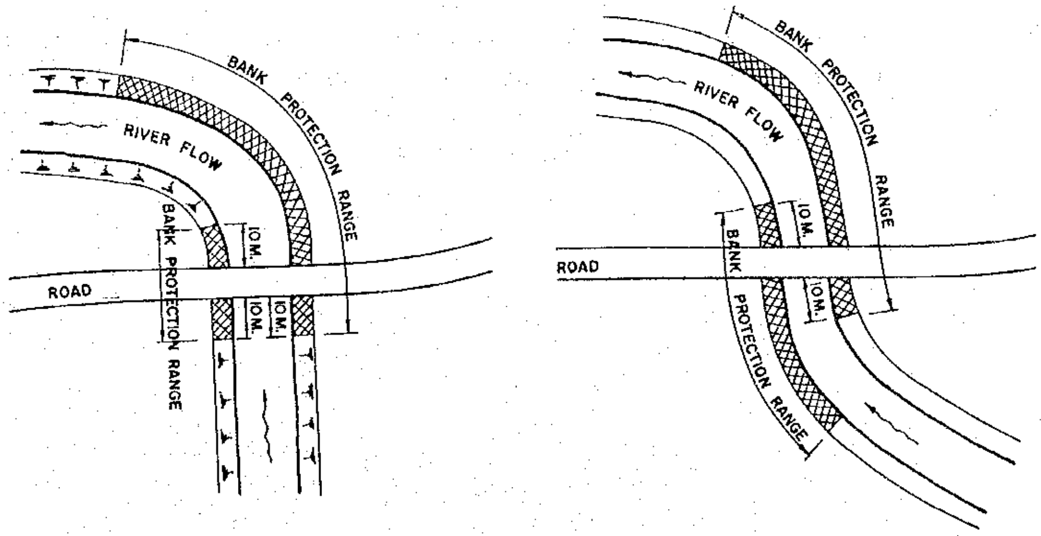


Fig.6.2.9 Range of River Bank Protection

(2) When a river is in a flood plain and the river channel is subject to shifting druring floods.

When a large upstream water flow passes a waterway opening, the high velocity of the water flow generates eddies (see Fig.6.2.10). As a result, an abutment fill slope is liable to be damaged by scouring from the high-velocity flood flows.

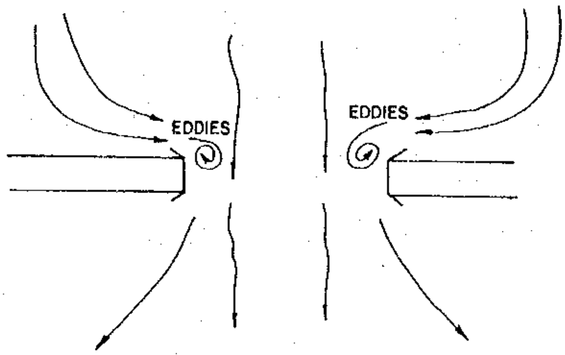
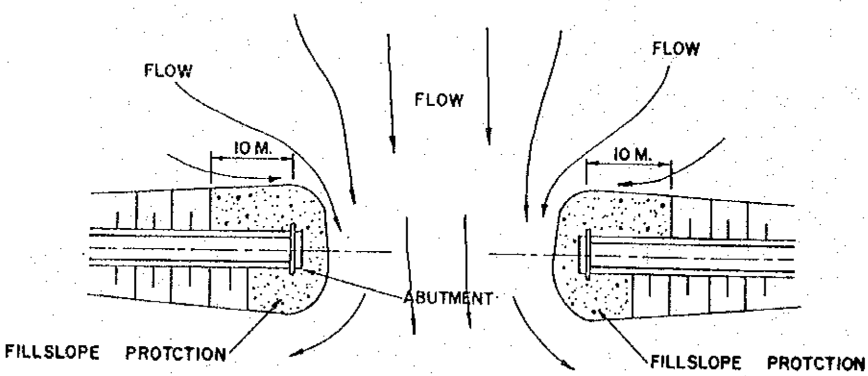
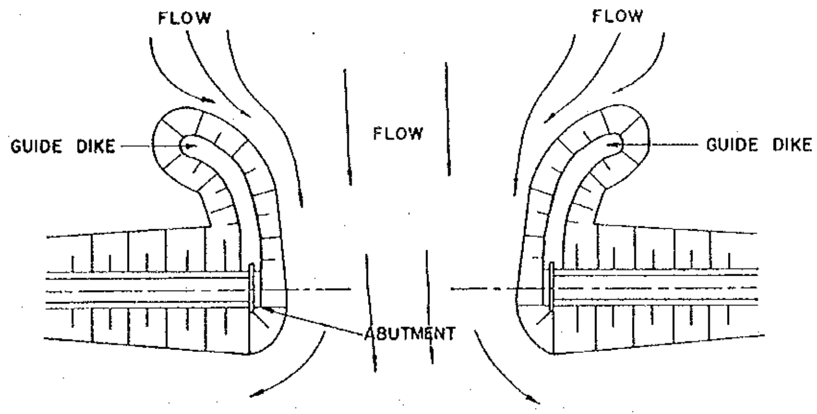


Fig.6.2.10 Upstream Eddy Current Caused by Contracted Flood Plain Flows at a Bridge Site

Since upstream flows have a high velocity along the embankment of a bridge approach, the upstream embankment slope should be protected with revetments at the portion adjacent to the abutments or equipped with guide dikes to prevent the occurrence of eddies (see Fig.6.2.11).



Abutment Fill Slope Protection



Guide Dikes

Fig.6.2.11 Abutment Fill Slope Protection and Guide Dikes

2. Slope Failure

1) Surface Drainage

Surface drainage such as crest, berm, vertical, and toe ditches are designed as decribed below.

Run-off rain is calculated according to the Rational Formula using a two-year design rainfall probability period.

$$Q = \frac{1}{3.6 \cdot 10^6} \cdot C \cdot I \cdot A$$

Where,

Q = Run-off (cubic meters/sec)
C = Run-off coefficient
I = Rainfall intensity within time of concentration (mm/h)
A = Catchment area (sq. meters)

The following values are used for the run-off coefficient in the above formula:

Paved road surfaces ------------------ 0.80
Road shoulders, man-made slopes ------ 0.70
Hilly areas with steep gradients ----- 0.50

As for average run-off speed, it is obtained by the Manning Formula:

$$V = \frac{1}{n} \cdot R^{2/3} \cdot i^{1/2}$$

Where,

V = Average run-off speed (m/sec)
R = A/P: Hydraulic radius (m)
  A : Cross-sectional area of water flow
  P : Length of wetted perimeter
i = Hydraulic gradient
n = Roughness coefficient ($sec/m^{1/3}$)

A roughess coefficient of 0.02 is applied to ditches made of rough stone or wet stone masonry in the above formula.

Although crest and berm ditches are expected to be cleaned during maintenance work, their actual cross sections are 20 percent greater than the calculated cross sections in order to provide a margin of safety.

2) Earth Work

(1) Recutting

Unstable slopes with steep gradients should be recut to achieve a stable gradient. This work was applied for the following two cases in the Study:

- deeply eroded slopes.
- slopes adjacent to a slope damaged by a landslide.

Cut slopes are usually provided with surface drainage (refer to previous item) and berms. The goals of a berm are (1) to moderate the average gradient of a slope and (2) to reduce the velocity of surface water running down the slope, thus preventing erosion and scouring. In general, berms 1.5m to 2.0m in width are constructed at 5.0m to 10.0m intervals. When a slope consists of different layers, it is desirable to provide berms at the borders of the different layers.

In the Study, recutting was designed by the following standards.

Table 6.2.3 Recutting Standards

Item	Kind of Rock		
	Soil	Soft Rock	Hard Rock
Gradient	1.0 : 1	0.5 : 1	0.25 : 1
Berm Interval	Every 5m	Every 5-7m	Every 7m
Berm Width	2.0m	2.0m	1.5m

(2) Refilling and compaction

Some slopes can be damaged by a single huge gully, in despite of the rest of the surface being sound. Refilling was applied to repair such erosion in the Study.

A slope should be restored to its original condition by refilling with compaction. Refilling material should be either soil or soil cement. Generally, refilled slopes collapse due to insufficient compaction. In this case, the following points should be kept in mind:

- the thickness of one layer should be less than 50 cm,
- compaction should be done for each layer by a compactor, and
- a completed slope should be compacted by slope tamping.

After refilling, a slope surface should be protected from further erosion by surface drainage and vegetation.

3) Hydroseeding

Hydroseeding is a method that sprays a mud-like mixture composed of seeds, fertilizer, and soil onto a slope, using a pump gun or air compressor. Specifications for hydroseeding applied in the Study are as follows:

- the quantity of soil to be used should be 0.01 m^3/m^2

- since hydroseeding is not common in Thailand, theype of grass that is suitable in the country is not well known. It will be necessary in the future to determine the type of grass most appropriate for local conditions by making trial sprays.

- asphalt emulsions should be used for film curing andsprayed at a ratio of 1 liter/m^2

4) Shotcrete

In shotcrete, mortar or concrete is sprayed onto slopes of highly weathered or easily weathered rock using spray guns, in order to prevent further weathering, erosion, and scouring of a slope surface due to surface water flows. In general, the method is not applied to earthen slopes or slopes having spring water, since adhesion with slope surface is poor and separation may occur.

The thickness of shotcrete is determined based on the slope gradient, degree of weathering, cracking conditions, etc., but the standard thickness is 5 to 10cm for mortar and 10 to 15cm for concrete. The specifications for shotcrete applied in the Study are as follows:

- The concrete mixture is 1:3:2 (cement, sand and gravel), and the ratio of water to cement is 45 percent.

- Shotcrete that is 15cm thick is applied with a reinforced steel net to slopes with drastically weathered rock, to slopes with loose rock of a fairly large size, and to slopes that are expected to have large volumes of surface water. For other slopes shotcrete 10cm thick with a wire net is applied.

- Weep holes are provided every 2 square meters, which is the maximum standard interval.

An illustration of shotcrete is shown in Fig.6.2.12.

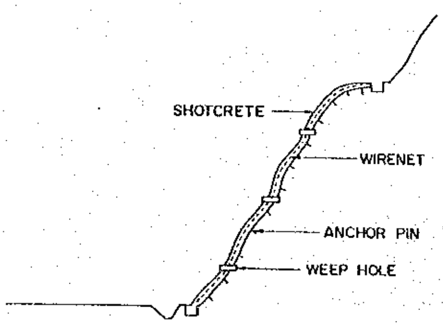


Fig.6.2.12 Shotcrete

5) Cribwork

In general, cribs consists of cast-in-place concrete cribs, sprayed concrete cribs, and pre-cast concrete cribs. In the Study, sprayed concrete cribs are applied due to following advantages:

- no forms are needed to pour the concrete of cribs,
- since the configuration of a crib is adaptable to a slope's surface, undulations on the slope surface are allowable, and
- on-site work is simpler than that of the other two methods.

An illustration of a crib is shown in Fig.6.2.13.

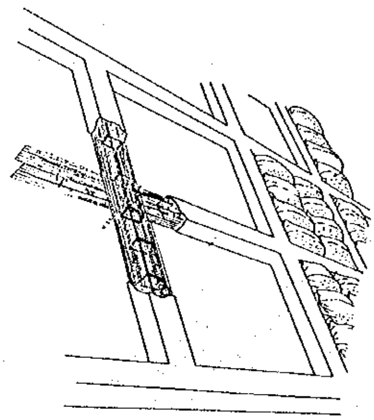


Fig.6.2.13 Sprayed Concrete Crib

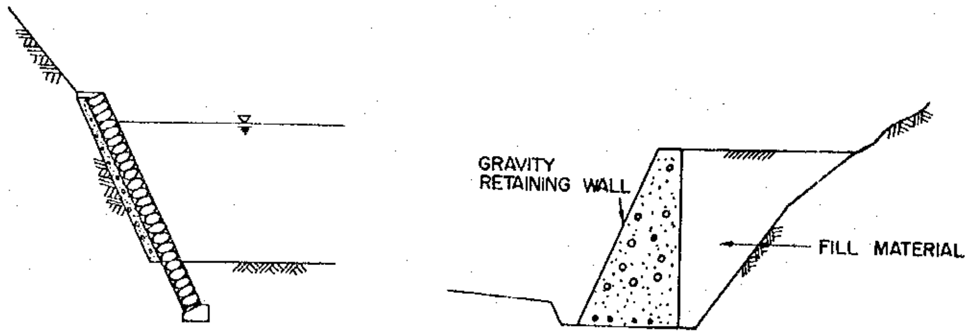
6) Retaining Wall

The types of retaining wall adopted in the Study are stone masonry, gravity-type, and gabion retaining walls. They are illustrated in Fig.6.2.14 with their applicable heights. Design standards for the stabilization of retaining walls are shown in Table 6.2.4.

Table 6.2.4 Design Conditions

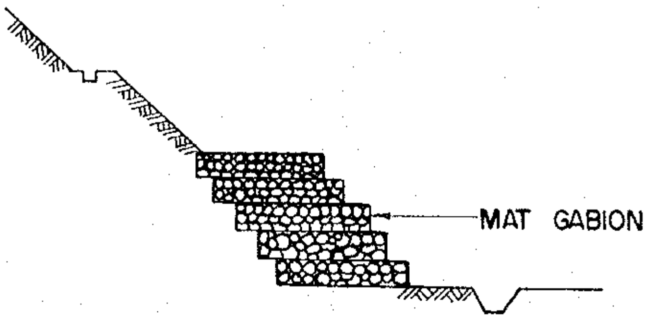
Safety Factor for Sliding	> 1.5
Stability for Overturning	e < B/3
Safety Factor for Bearing Capacity	> 3.0

Note: e = eccentric distance
B = width of retaining wall



Stone Masonry Gravity-type

Fig.6.2.14 Retaining Wall(1)



Gabion

Fig.6.2.14 Retaining Wall(2)

7) Rockfall Prevention

In the Study, barriers for debris catch basins and anchor wire nets are applied as road restoration measures.

(1) Barrier for debris catch basin

This type of measure can be applied at road sections where there is room between the foot of the slope and the road shoulder. This space is for a barrier to serve as a debris catch basin.

In general, the barrier is a gravity-type retaining wall. It is designed based on the concept that the kinetic energy of falling rocks changes into transformation energy of the barrier and the bearing layer. Accordingly, the dimensions of the barrier depend on the weight and the bouncing height of the falling rock.

In order to enhance the capacity of the barrier, a catch fence at the top of the retaining wall can be jointly attached.

An illustration of a rockfall barrier with a catch fence is shown in Fig.6.2.15.

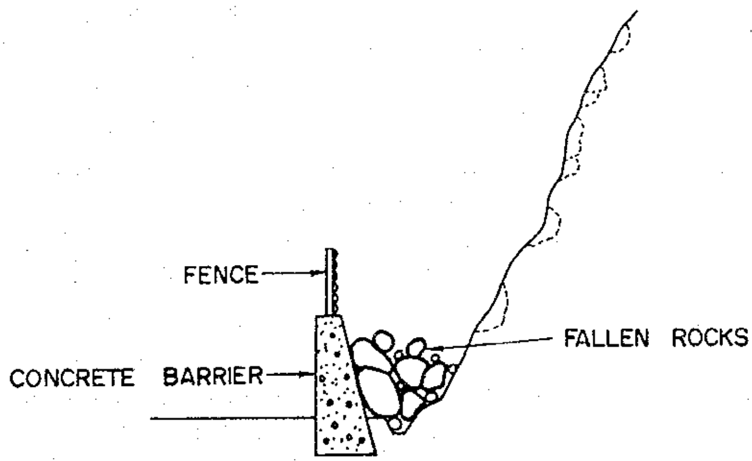


Fig.6.2.15 Rockfall Barrier

(2) Anchor wire net

This net aims to prevent rocks from falling full force by covering a slope with a net. There are two kinds of net: the first is made of chemical fiber and the other is a metal net. The chemical fiber net is used for small falling rocks weighing less than 60kg. The durability of this net is uncertain when exposed to sunlight. For this reason, the metal net was adopted for the Study.

An illustration of an anchor wire net is shown in Fig.6.2.16.

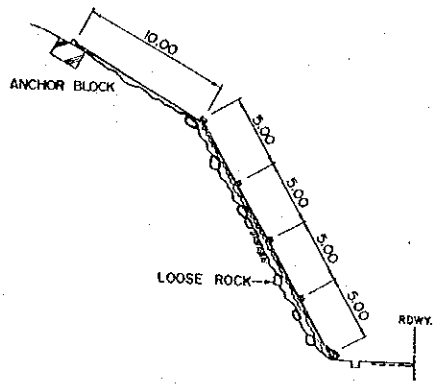


Fig.6.2.16 Anchor Wire Net

8) Slope Stabilization after a Landslide

Three measures were taken to stabilize slopes at the site of a landslide in the Study: (1) removal of unstable material, (2) use of counterweights, and (3) dewatering of groundwater.

As for the types of landslides, there are generally three types: (1) the rotational landslide, (2) the two-dimensional landslide, and (3) the three-dimensional landslide.

(1) Slope stabilization

In all the cases mentioned above, sliding should be examined to calculate the safety factor as follows:

- Assume a sliding plane based on the results of boring and the configuration of slide debris.

- Assuming a present safety factor of 1.0, apply the linear equation below containing cohesion (c) and the angle of internal friction (ϕ).

$$Fs = \frac{\tan \phi \cdot \Sigma(N - U) + c \cdot \Sigma L}{\Sigma T}$$

Where,

Fs = Safety factor (assumed to be 1.0)
T = Shearing stress of slice on sliding surface (t/m^2)
N = Vertical stress of slice on sliding surface (t/m^2)

U = Pore water pressure on sliding surface (t/m^2)
c = Cohesion (t/m^2)
ϕ = Angle of internal friction (°)
L = Sliced length of arc along sliding surface (m)

The stability calculation model is illustrated in Fig.6.2.17 and its results are presented in Appendix 4.6.

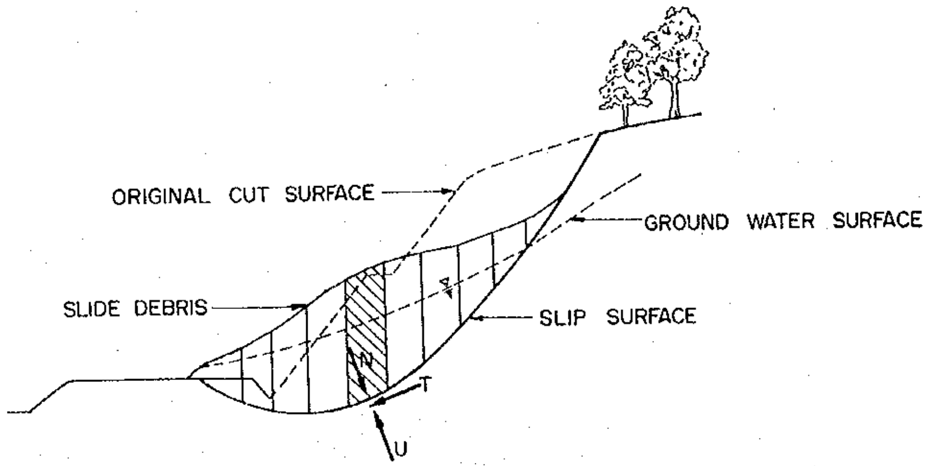


Fig.6.2.17 Stability Calculation Model

In case the counterweight method is taken up as a restoration measure, the safety factor for sliding should be calculated by the following equation.

$$(Wc - Uc) \cdot \tan\phi \geq \frac{\tan\phi \cdot \Sigma(Ws - Us) + c \cdot \Sigma L}{\Sigma T}$$

Where,

Wc = Weight of counterweight (t)
Ws = Weight of slide debris (t)
Uc = Buoyancy of counterweight (t)
Us = Buoyancy of slide debris (t)
c = Cohesion (t)
ϕ = Angle of internal friction (°)
L = Length of sliding arc surface (m)

The calculation model for the counterweight method is illustrated in Fig.6.2.18.

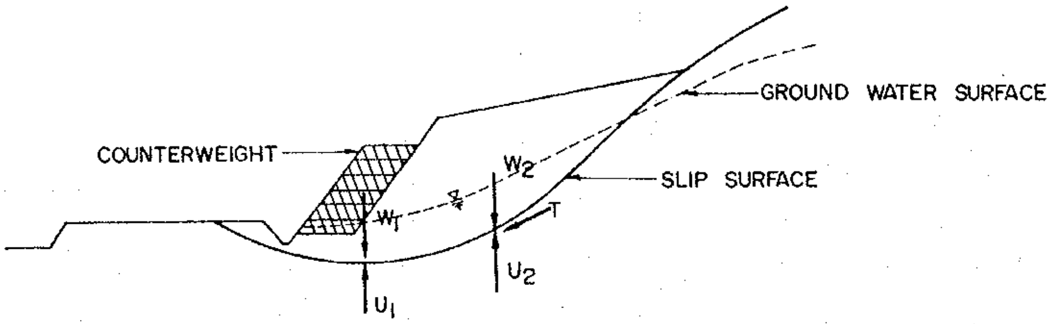


Fig.6.2.18 Stabilization Calculation Model for the Counterweight Method

(2) Dewatering of groundwater

Dewatering of groundwater is one of the most effective measures against landslides. In the Study, horizontal drain holes with the following specifications were selected as a countermeasure:

- a drain hole 66mm in diameter is made by boring,
- a hard polyvinyl chloride pipe is inserted into the bored hole to sustain the hole and to collect and drain the water,
- boring is done at an upward angle of 5 degrees, and installed about 10 meters into the water holding layer outside of the sliding plane,
- drain holes are made at intervals of 5 meters along the sliding plane.

An illustration of horizontal drain holes is shown in Fig.6.2.19.

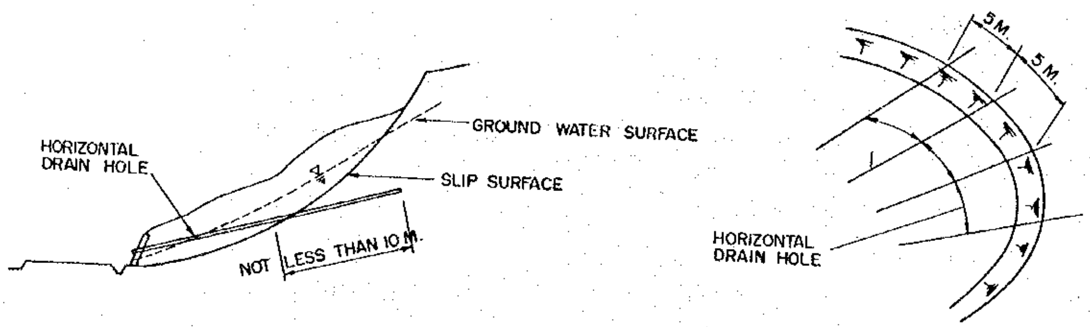


Fig. 6.2.19 Horizontal Drain Holes

6.2.3 Applied Restoration Measures for Selected Disaster Sites

1. Route 109

Site 109/1 SD-2-10 (Rockfall on a cut slope)

Countermeasures are planned to be implemented stepwise. Temporary measures are executed first and permanent measures follow when the traffic volume is large enough to make permanent repair work feasible.

1) Temporary Measures

An immediate danger is the existence of exposed boulders on the surface, which should be removed as quickly as possible. Since rockfalls are induced by slope erosion, the solution to this problem is closely linked to stopping erosion that undermines core stone boulders. To prevent surface water runoff, a crest ditch would be helpful. Hydroseeding is also effective against slope erosion.

2) Permanent Measures

In addition to the above temporary measures, the refilling of large erosion gullies and berm ditch work are proposed as permanent measures.

The presence of large erosion gullies makes it difficult to install surface drainage unless they are filled or removed by recutting. In this case, since the gullies are not too extensive, it should be possible to refill the cavities prior to installing berm drains.

Site 109/2 SD-2-3 (Erosion on a cut slope)

1) Temporary Measures

Basically, there are no short-term solutions to this problem. However, the traffic volume of the route is not large enough to justify permanent restoration measures. Consequently, temporary measures consisting of hydroseeding and crest ditch work are proposed as makeshift repair work.

2) Permanent Measures

Slope restoration measures can be divided into slope forming and slope protection. In order to reform the slope, slope recutting, which is deeper than the gully damage, is proposed. For slope protection, cribworks with vegetation is most appropriate.

Site 109/3 SD-2-6 (Landslide on a cut slope)

Dewatering appears to be the only solution to this site's problem. However, there are no effective measures for dewatering except for the horizontal-drain-hole method, which is too costly as a temporary measure. For this reason, only permanent measures are proposed.

In addition to horizontal drain holes, surface drainage with a crest ditch, berm ditch, or toe ditch are helpful for dewatering. The removal of slide debris and scarp would also contribute to the stabilization of the whole slope.

2. Route 1095

Site 1095/1 SD-2-7 (Landslide on a cut slope)

From field observations and drilling work, it is apparent that the reason for the original slope failure occurred as a translation along bedding uplifting by artesian water pressure in contact between shale and sandstone.

Dewatering is likely to be the best solution, but rock drilling work to install horizontal drain holes is costly. For these reasons, the simplest thing to do would be to remove all of the slide debris and to recut the scarp and install a crest ditch as a permanent measure.

Site 1095/2 SD-2-9 (Rockfalls on a cut slope)

The scale of the rockfalls at this site is not large, but the frequent falling of rocks onto the pavement presents a hazard to motorists and requires constant maintenance.

If space was available between the foot of the slope and the edge of the pavement, construction of a barrier/catch ditch would be the simplest solution. However, since such space is nonexistent, the following permanent measures are proposed: 1) removal of unstable rocks, 2) drainage control, and 3) rockfall prevention net.

Site 1095/3 SD-2-6 (Landslide on a cut slope)

The cause of the landslide here is due to groundwater pressure. Reports that slide debris is still moving in the dry season suggests that water control should be the main consideration at this site.

However, there is no simple way here to lower the underground water pressure effectively without costly measures. Therefore, the following permanent measures are proposed.

Slide debris should be left in place, but horizontal drain holes should be installed to reduce the piezometric head. The outlet of the drain holes should be fixed and protected by a mat gabion retaining wall. Surface drainage is also required along the slope crest and on the debris's surface. The naked surface should be planted using hydroseeding spraying.

Site 1095/4 SD-2-8 (Landslide on a cut slope)

This site requires that immediate work be carried out to remove hazardous large boulders from the slope surface. This can best be effected by hydraulic sluicing during a temporary road closure.

The failure is bounded by two main discontinuous surfaces. If the slide debris on the slope is cleared, no further movement is possible at this site. The underlying rock is resistant to erosion and no special precautions are needed, except near the top of the slide where residual soil is present. A crest drain and vegetation work with sodding should solve this problem.

3. Route 1149

Site 1149/1 SD-2-6 (Landslide on a cut slope)

This spot was recut in the past after a previous failure and it is still unstable. The solution lies in controlling groundwater with subhorizontal drains.

The surface is rather well vegetated and does not require anti-erosion measures, except for the construction of a ditch and block sodding on naked surfaces.

Site 1149/2 SD-2-3 (Erosion on a cut slope)

On this slope, the single large erosion gully should be repaired. Since most of the slope surface already has vegetation established, other precaution works are not needed.

1) Temporary Measures

In order to prevent the damage from progressing, a crest interceptor drain should be installed as an immediate measure.

2) Permanent Measures

The single large gully should be refilled with compaction work. The refilled surface should be protected from erosion using partial sodding and drainage work.

4. Route 1256

Site 1256/1 RF-1-2 (Road flooding)

This site's road is situated on flat terrain that is subject to occasional inundation in the wet season. Except for establishing adequate river control in the area, the only solution to this problem is to raise the road embankment, which is also costly.

In this context, no immediate work should be carried out until traffic volume on this road is large enough to justify the measures mentioned above.

Site 1256/2/3 BC-1-5/9 (Scouring of abutment & river bank)

Damage has been incurred by the river bank and by the abutment protection. Damage to the abutment was caused by inadequate embedding of the fill slope revetments.

1) Temporary Measures

The base of the fill slope revetments should be temporarily protected with mat gabions. Existing slope revetments should remain as they are.

A portion of the scoured river bank should be protected by dumping rocks there.

2) Permanent Measures

Existing revetments for the abutment fill slope should be replaced with new concrete revetments equipped with adequate base structures.

The damaged river bank adjacent to the abutment should be protected by stone riprap filled with mortar.

Site 1256/4 SD-2-3 (Erosion on a cut slope)

There is a single large erosion gully at this slope, which is due to the weakness of the soil caused by a fault line. However, most of the slope is undamaged. The solution for this problem lies in protecting the weak soil near the fault line from further erosion by channelling surface runoff.

1) Temporary Measures

In order to protect the damaged portion from further erosion, a crest ditch is proposed.

2) Permanent Measures

The same measures proposed for Site 1149/2 are appropriate.

Site 1256/5 SD-3-6 (Landslide on a fill slope)

A landslide of the fill slope was induced by the scouring of the fill toe by a nearby stream.

1) Temporary Measures

Construction of a retaining wall at the fill toe using a mat gabion.

2) Permanent Measures

It is recommended that the road alignment be set back by recutting the backslope. To minimize the shift, the fill slope side can be supported by a gravity-type retaining wall.

Site 1256/6 SD-2-6 (Landslide on a cut slope)

Two separate landslides have occurred at this site. Each follows failure planes that combine rotational movement in the weathered sandstone and sliding on the bedding inclination.

Adjacent slopes and sections between the two slides are suspect as they have the same geometric configurations as the failed sections.

1) Temporary Measures

To avoid highly probable damages, the slope between the two slides and steep scarps should be recut with crest drains and vegetation work carried out on the soil sections.

2) Permanent Measures

To prevent the slide debris from sliding further, horizontal-drain-hole work should be implemented. Block sodding for exposed surfaces and surface drainage will also enhance the effect of dewatering work.

Site 1256/7 SD-2-7 (Landslide on a cut slope)

Slide debris on the rock bedding appears thin enough to remove. Removal of slide debris is proposed as a permanent measure at this site. Reforming and vegetation of scarp are also recommended together with drainage work.

Site 1256/8 SD-3-7 (Landslide on a fill slope)

Due to the angle of the natural surface's slope, uncompacted fill with a low-shear strength can not be safely used on this site.

After comparing the costs of several alternatives, shifting the road alignment has been determined to be the most appropriate. The road elevation should be lowered so that the carriageway width can be constructed by only cutting the natural surface.

Site 1256/9 SD-2-1 (Erosion on a cut slope)

The slaking shale surface can only be stabilized by reducing the magnitude of the changes in the moisture content. Here, the favored practical solution is shotcrete over all surfaces that have exposed shale. Crest drain work will also contribute to reducing the moisture content.

Site 1256/10 SD-2-10 (Rockfalls on a cut slope)

The underlying cause of rockfalls at this site is the differential in erosion of shale and sandstone.

1) Temporary Measures

Temporary measures to stabilize this area consist of removing loose blocks, covering affected layers with shotcrete, and installing crest drains.

2) Permanent Measures

When rockfalls occur again, the permanent measures mentioned below should be taken.

The existing slope should be recut and a rockfall prevention net installed and drainage work carried out. It is also proposed that a concrete barrier to catch debris be placed along the road shoulder.

Site 1256/11/12 SD-2-6 (Landslide on a cut & fill slope)

Damage at this site consists of two types: a landslide of the cut slope and a landslide of the fill slope, with the latter caused by the erosion of its slope toe. At present, only one of the two road lanes is passable.

1) Temporary Measures

In order to keep the road's two lanes open to traffic, a wooden trestle is proposed.

2) Permanent Measures

As a final solution, the realignment of the road is recommended, because the cost for realignment is not high due to the low backslope height.

5. Route 4

Site 4/1 SD-2-6 (Landslide on a cut slope)

Route 4 is one of the main routes in the South Region and has a large traffic volume. In addition, the detour route is much longer than Route 4. Consequently, the implementation of quick permanent measures are proposed at this site.

The slope at this site has a gentle angle, but the low material strength and groundwater conditions make it difficult to stabilize.

Analysis revealed that stability can be obtained by significantly reducing groundwater pressure using horizontal drains. A toe weight made from a gravity-type retaining wall can be an additional method of stabilization. A certain amount of natural vegetation already exists, but some additional vegetation using sodding is needed for areas with only bare soil.

Site 4/2/3 BC-1-5/9 (Scouring of abutment & river bank)

Permanent measures should be applied for this spot based on the same reasoning as Site 4/1.

There are two problems to be solved at this site. The first is the scouring of the abutment fill slope, which also induces the abutment backfill to erode, and the second is the scouring of the river banks.

Analysis of the discharge water revealed that the waterway opening at the bridge section is sufficient. Therefore, remedial measures should focus on methods to protect the abutment and river bank.

Concrete revetments are proposed for abutment protection and stone riprap filled with mortar to protect the river banks. The upstream river bank between the bridge and weir should be protected in order to guarantee the safety of inhabitants residing along the river. On the downstream side, revetments should be placed on the outside bank of a bend where erosion is most active as a result of impinging flow.

6. Route 410

Site 410/1 RF-3-3 (Overflow)

A box culvert with sufficient capacity should be constructed in place of the existing small pipe after removing debris. The gradient of the culvert should also be steeper than the existing one.

Site 410/2 SD-2-7 (Landslide on a cut slope)

This site's high cut slope experienced a landslide along the planes of its mica shist. The landslide was due to the steepness of the cut slope and the high groundwater pressure.

1) Temporary Measures

To stabilize the slide debris, a counterweight made of mat gabion is proposed with drainage work and block sodding on the naked surface.

2) Permanent Measures

To ensure slope stabilization, horizontal drains are proposed as an additional measure.

Site 410/3 SD-2-6 (Landslide on a cut slope)

Permanent measures are recommended for this site and consist of recutting the slope using a retaining wall of gabions, surface drainage work, and vegetation work.

Site 410/4 SD-2-9 (Rockfall on a cut slope)

The site is well covered by natural vegetation. If the existing unstable rock is removed, it will take a few years until new unstable rock appeares on the slope. Therefore, removal of existing loose rocks is an appropriate temporary measure.

As for a permanent measure, construction of a concrete barrier as a debris catch basin is proposed to ensure the safety of traffic.

Site 410/5 SD-2-3 (Erosion on a cut slope)

The slope surface at this site appears stable despite erosion. Therefore, taking a wait-and-see attitude seems to be the best choice.

If erosion worsens, the slope should be protected with hydroseeding work and drainage work, such as a crest or toe ditch.

Site 410/6 SD-2-8 (Landslide on a cut slope)

This is a very large and complex slope failure. There is the immediate risk of further movement in the slide debris. The scarp sides are also at risk as is the adjacent high cut slope.

The slide debris on the failed slope should be removed by hydraulic sluicing. To stabilize the unaffected adjacent slope, it should be recut and hydroseeded. In addition, installing a debris barrier wall at the base of the slope would prevent any further debris falls from affecting the road.

7. Route 4015

Site 4015/1 BC-1-5 (Scouring of abutment fill slope)

This site is located in a broad flood plain and has a bridge crossing a river. Since the waterway opening at the bridge crossing is sufficient for the amount of discharge , the solution to this problem is closely linked to stream channel stabilization.

In order to train the stream, construction of guide dikes, whose slopes are protected by dumping rocks there, are proposed. Abutment fills should be placed with concrete revetments with a mat gabion at the toe of the slope. Piers in the stream should be protected from scouring using mat gabions.

Site 4015/2 RC-3-2 (Washing out of road shoulder & embankment)

At this site, due to the lack of discharge capacity, the embankment on the upstream side was damaged by scouring and the downstream side washed out during a heavy rainfall in November 1993.

The solution here is to replace the existing pipe culverts (2m x 2m) with a box culvert (2.1m x 2.1m). In addition, inlet and outlet control measures should be taken.

Site 4015/3 RC-3-1 (Scouring of road embankment)

At this site's culvert crossing, the road embankment was damaged on the upstream side and downstream side. The former damage was caused by contact scouring and the latter damage by tunnel erosion.

The existing culvert consists of five pipes one meter in diameter, and the total discharge capacity is sufficient for the amount of rainfall discharge. However, the inlet functions are not adequate for making full use of the discharge capacity.

Given this situation, the solution to the above problem should focus on improving the function of the inlet and the culvert itself. Therefore, it is proposed that the existing culvert be replaced by a box culvert and that improvements be made in the inlets and outlets.

Site 4015/4 BC-1-6 (Collapsing of abutment protection)

The bridge at this site is located on a wide flood plain with indistinct boundaries, and both abutment fill slopes sustain damage from contact scouring when it floods.

After analyzing the discharge volume, it was discovered that the waterway opening at the bridge section exceeded the discharge volume. The measures for contact scouring should be abutment protection and road embankment protection in the portion adjacent to the abutment on the upstream side.

Site 4015/5 BC-1-7 (Erosion of approach road embankment)

There is a bridge spanning a river that has low embankment approaches. The embankment behind the abutment on the Lan Saka side was completely washed away after the river channel shifted when it flooded. After the damage, the bridge length was doubled in early 1994.

According to flood discharge analysis, discharge capacity would be sufficient if the top of the waterway opening is more than 2 meters from the bottom of girders.

In order to eliminate the main causes of embankment collapsing, the river flow should be trained by constructing river banks and dredging the stream channel.

8. Route 4107/4058

Site 4107/1/2 BC-1-5/6 (Scouring of abutment fill slope & collapsing of abutment protection)

This site has a bridge and embankment approaches located on a wide flood plain. Both abutment protections are damaged, and the fill slope revetments on the east side are completely destroyed and the fill slope itself scoured. The abutment and fill slope on the west are also partially damaged.

The major cause of damage to the east abutment is contact scouring. The partial damage to the fill slope on the west was induced by turbulent trailwater, which is due to the sharp bend in the river channel just downstream of the bridge.

To restore the abutment protection, the revetment base should be constructed with sufficient earth cover. The revetments on the upstream side should be extended by more than 20 meters each.

River bank protection is also proposed to prevent turbulent trailwater flows on the downstream side.

Site 4058/1 BC-1-8 (Overflow)

The bridge at this site is located in a flood plain with low embankment approaches, and it has repeatedly suffered from flood water overflows in the last few years.

The only solution to this problem is to raise the elevation of the roadway and the bridge. Fortunately, the road elevation sags in the vicinity of the bridge.

All restoration work for the 38 disaster spots are tabulated in Table 6.2.5(1)-(5) and illustrated in VOLUME 2: DRAWINGS.

Table 6.2.5 Countermeasure for Restoration Work (1)

Spot No.	Damage Type	Temporary Measures	Permanent Measures
109/1	SD-2-10 - Rockfall on cut slope	D-2.2 Removal of Boulder B-1.2 Crest ditch A-4.1 Hydroseeding	D-2.2 Removal of boulder D-4 Refilling with compaction B-1.1 Berm ditch B-1.2 Crest ditch A-4.1 Hydroseeding
109/2	SD-2-3 - Erosion on cut slope	A-4.1 Hydroseeding B-1.2 Crest ditch	D-1 Recutting B-1.2 Crest ditch A-8 Cribwork with vegetation
109/3	SD-2-6 - Landslide on cut slope		D-2.1 Earth removal (Slide Debris) B-1.2 Crest ditch B-1.3 Toe ditch B-4 Surface drainage B-7.1 Horizontal drain hole A-1.1 Block sodding (Naked surface) D-2.2 Removal of unstable scarp C-1.2 Mat gabion
1095/1	SD-2-7 - Landslide on cut slope		D-2.2 Removal of slide debris and unstable scarp A-4.1 Hydroseeding B-1.2 Crest ditch B-1.3 Toe ditch B-3 Vertical ditch
1095/2	SD-2-9 - Rockfall on cut slope		D-2.2 Removal of unstable rocks E-1 Rockfall prevention net B-1.2 Crest ditch
1095/3	SD-2-6 - Landslide on cut slope		D-2.2 Removal of unstable scarp C-1.2 Mat gabion B-7.1 Horizontal drain hole A-4.1 Hydroseeding B-1.2 Crest ditch B-1.3 Toe ditch B-4 Surface drainage
1095/4	SD-2-8 - Landslide on cut slope		D-2.2 Removal of unstable scarp and slide debris B-1.2 Crest ditch A-1.1 Block sodding (partial)

Table 6.2.5 Countermeasure for Restoration Work (2)

Spot No.	Damage Type	Temporary Measures	Permanent Measures
1149/1	SD-2-6 - Landslide on cut slope		D-2.2 Removal of unstable scarp B-1.2 Crest ditch B-4 Surface drainage B-7.1 Horizontal drain hole A-1 Block sodding (Naked surface) C-1.2 Mat gabion
1149/2	SD-2-3 - Erosion on cut slope	B-1.2 Crest ditch	D-4 Refilling with compaction B-1.2 Crest ditch A-1 Block sodding (Naked surface)
1256/1	RF-1-2 - Overflow on road		H-1 Raising of roadway elevation M-1 Enlarge cross-sectional area of the culvert
1256/2/3	BC-1-5/9 - Scouring of abutment and river bank	J-2.3 River bed revetment K-1.6 Dumped rock	J-1.1 Concrete revetment J-2.3 River bed revetment K-1.3 Stone riprap with mortar
1256/4	SD-2-3 - Erosion on cut slope	B-1.2 Crest ditch	D-4 Refilling with compaction B-1.2 Crest ditch A-4.1 Hydroseeding
1256/5	SD-3-6 - Landslide on fill slope	C-1.2 Mat gabion	F-2 Shift of alignment C-2.1 Gravity type retaining wall A-4.1 Hydroseeding B-1.2 Crest ditch B-1.3 Toe ditch
1256/6	SD-2-6 - Land slide on cut slope	D-2.2 Removal of unstable scarp and slide debris D-1 Recutting A-1.1 Block sodding(Naked surface) B-1.2 Crest ditch	D-2.2 Removal of slide debris and unstable scarp A-1.1 Block sodding(Naked surface) B-4 Surface drainage B-1.2 Crest ditch B-7.1 Horizontal drain hole D-1 Recutting C-1.2 Mat gabion
1256/7	SD-2-7 - Land slide on cut slope		D-2.2 Removal of unstable scarp and slide debris B-1.2 Crest ditch A-4.1 Hydroseeding

Table 6.2.5 Countermeasure for Restoration Work (3)

Spot No.	Damage Type	Temporary Measures	Permanent Measures
1256/8	SD-3-7 - Lanslide on fill slope		F-2 Shift of alignment
1256/9	SD-2-1 - Erosion on cut slope		B-1.2 Crest ditch A-6 Shotcrete work D-2.2 Removal of unstable material
1256/10	SD-2-10 - Rockfall on cut slope	D-2.2 Removal of unstable rocks A-6 Shotcrete work B-1.2 Crest ditch	D-1 Recutting E-3.1 Concrete barrier for rock catch basin B-1.2 Crest ditch E-1 Rockfall prevention net B-1.3 Toe ditch
1256/11 /12	SD-2-8, 3-7 - Landslide on cut slope and fill slope	D-2.2 Removal of slide debris F-1.2 Trestle work	F-2 Shift of alighnment
4/1	SD-2-6 - Landslide on cut slope		D-2.2 Removal of unstable scarp and shotcrete fragment and debris C-2.1 Gravity type retaining wall B-1.2 Crest ditch B-1.3 Toe ditch A-1.1 Block sodding (whole surface) B-7.1 Horizontal drain hole C-1.2 Mat gabion
4/2/3	BC-1-5/9 - Scouring of abutment and river bank		J-1.1 Concrete revetment K-1.3 Stone riprap with mortar J-2.3 Riverbed protection J-2.1 Sheet-pile toe wall
410/1	RF-3-3 - Debris flow on embankment		M-1 Enlarge cross-sectional area of the culvert D-2.2 Removal of debris
410/2	SD-2-7 - Landslide on cut slope	C-1.2 Mat gabion B-1.2 Crest ditch A-1.1 Block sodding D-2.2 Removal of debris	C-1.2 Mat gabion B-1.2 Crest ditch A-1.1 Block sodding B-7.1 Horizontal drain hole C-1.2 Mat gabion
410/3	SD-2-6 - Landslide on cut slope		D-2.2 Removal of unstable scarp C-1.2 Mat gabion B-1.2 Crest ditch A-1.1 Block sodding (Naked surface)
410/4	SD-2-9 - Rockfall on cut slope	D-2.2 Removal of unstable rocks	D-2.2 Removal of unstable rocks E-3.1 Concrete barrier for rock catch basin

Table 6.2.5 Countermeasure for Restoration Work (4)

Spot No.	Damage Type	Temporary Measures	Permanent Measures
410/5	SD-2-3 - Erosion on cut slope		B-1.2 Crest ditch B-1.3 Toe ditch
410/6	SD-2-8 - Landslide on cut slope		D-2.2 Removal of slide debris D-1 Recutting B-1.2 Crest ditch B-1.3 Toe ditch A-4.1 Hydroseeding E-3.1 Concrete barrier for rock catch basin
4015/1	BC-1-5 - Abutment scouring		J-1.1 Concrete revetment J-2.2 River bed revetment J-5 Guide dike
4015/2	RC-3-2 - Washing out of shoulder and embankment		M-1 Enlargement cross-sectional area of the culvert O-1 Side-tapered inlet O-2 Foot protection at culvert entrance O-3 Training walls at culvert entrance O-4 Anti-seep collars O-5 Side-tapered outlet O-6 An open chute for trailwater
4015/3	RC-3-1 - Scouring of embankment		M-1 Enlargement cross-sectional area of the culvert O-1 Side-tapered inlet O-2 Foot protection at culvert entrance O-3 Training walls at culvert entrance O-4 Anti-seep collars O-5 Side-tapered outlet
4015/4	BC-1-6 - Collapsing of abutment protection		J-1.1 Concrete revetment J-2.2 River bed revetment J-4 Extension of protection on upstream side
4015/5	BC-1-7 - Erosion of approach road		I-6 Channel dredging J-1.1 Concrete revetment L-1.1 Stabilize the stream bank with dumped rock
4107/1	BC-1-5/6 - Abutment scouring		J-1.1 Concrete revetment V-2.2 River bed revetment

Table 6.2.5 Countermeasure for Restoration Work (5)

Spot No.	Damage Type	Temporary Measures	Permanent Measures
	- Collapsing of abutment protection - Riverbank protection		J-4 Extension of protection on upstream side K-1.1 Concrete revetment on downstream side
4058/1	BC-1-8 - Overflow on bridge and road		H-1 Raising of roadway elevation

6.3 Allocation of Material and Equipment

In cases of urgent repair work, it is necessary to have the required materials and equipment on hand in order to cope with emergency situations effectively. For this reason, it is suggested that materials and equipment for urgent repair work be strategically allocated within DOH as shown in Table 6.3.1 and Table 6.3.2.

Table 6.3.1 List of Main Stored Materials

MATERIAL NAME	TYPE / SIZE	MATERIAL NAME	TYPE / SIZE
Pipe for Culverts	Dia 0.40 - 1.00 m	Sacks for Sand Bags	
Cold Asphalt		Portland Cement	
Vinyl Sheeting		Sand	
Wire	# 8 - 10	Crushed Stone	
Rope		Gravel	

Table 6.3.2 List of Main Standby Equipment

EQUIPMENT NAME	TYPE / SIZE	EQUIPMENT NAME	TYPE / SIZE
Motorized Grador		Truck Crane	
Tandom Roller		Back Hoe	10 - Wheel
Tyre Roller		Bulldozer	0.1 - 0.6 cum
Concrete Breaker		Pump / Hose	
Concrete Mixer		Tamper / Rammer	
Light Truck	4 - Wheel	Jack Hammer	
Medium Truck	6 - Wheel	Bailey Bridge	

In the case of temporary and permanent restoration works, they are basically executed on a contractual basis and the materials and equipment are procured by contractors. Here, because these types of works do not require urgent attention, it is not necessary for DOH to keep materials and equipment on hand for their implementation.

As for the projects roads in the Study, they have received only temporary are permanent restoration work. Therefore, it has been decided that the issue of material and equipment allocation does not need to be addressed.