8-7 PREPARATION OF LARGE SCALE TOPOGRAPHIC MAP

The topographic features of the section traversing the Luak and the Phang Hoei Range in Segment No. 22 and 23 are steep and diversified, and require careful examination in routing and designing. Therefore, the 1/5,000 scale topographic maps were prepared in this section, based on the existing topographic maps and the aerial photos, and used for the study.

8-8 ENGINEERING STUDY

8-8-1 Design Standard

The design standard of provincial roads is subdivided into seven road classes from F0 to F6, according to the projected ADT, as shown in Table 8-4. The traffic forecast assigned to each link shows that the estimated ADT at the 7th and 15th year after opening range from 160 to 1,168 and from 193 to 1,341, respectively. Therefore, referring to the DOH's standard, F3, F4 and F5 Standards are to be applied to each corresponding segment according to the future ADT.

The design standards of these three road classes are as follows:

Summary of F3, F4 and F5 Standards

	Design Standards		
	F3	F4	F5
ADT/1	1000-2000	300-1000	below 300
Design Speed (Km/h)			
Flat and Moderately Rolling	70-90	60-80	60
Rolling and Hilly	55-70	45-60	45
Mountainous	40-55	30-45	30
Surface Type	intermediate	low	soil aggregate
Carriageway Width (m)	6.00	5.50	9.00
Shoulder Width (m)	2.00	1.75	-
Maximum Gradient (%)			
Flat and Moderately Rolling	6	8	12
Rolling and Hilly	8	10	12
Mountainous	10	10	12
Right of Way (m)	40-60	40-60	20-40

Note: /1 ADT at 15th year after opening for F3 and at 7th year for F4 and F5.

In the studies after the optimum route was decided, F3, F4 and F5 Standards were respectively applied to each road segment according to the forecasted ADT, as shown below.

Application of Design Standard

Standard	Segment No.	ADT		Length (Km)
		7th Year	15th Year	
F3	1, 2, 3, 5, 7, 12 and 18	775-1,168	896-1,341	60.1
F4	27, 29 and 30	345-829	413-987	38.0/1
F5	21, 22, 23, 24 and 25	160-265	193-317	56.6/2
	Total:			154.7

Note: /1 The length is shorter than proposed original length by 1.0 Km. The detailed description is referred in 8-8-2.

/2 6.9 Km out of 56.6 Km was planned to be paved as described below.

According to the forecasted ADT, Segment No. 5 is to be classified as F4 Standard road. However, it was included in the F3 Standard, because this short segment of only 12.7 Km long is sandwiched by the road segments of F3 Standard extending over about 50 Km in length.

From an engineering viewpoint, it is required to pave all the steep gradient portions of more than 5 percent, regardless of the traffic volumes, in order to keep road surface from erosion and from the viewpoint of safety. In such portions, road surface is easily scoured by rain water and eroded. Most of the segments for which F5 Standard is assigned traverse the steep mountainous areas and the portions where the grade is more than 5 percent count 6.9 Km in total. For these portions of 6.9 Km, low cost pavement in accordance with F4 Standard was adopted.

Furthermore, from viewpoints of accident prevention and structural preference, it is undesirable to make piecemeal pavement for steep portions only. It is recommendable to pave not only 6.9 Km of steep gradient portions but all of 56.6 Km, if financing arrangement allows.

8-8-2 Geometric Design

1) Design Speed

The relation between the design speed employed in the engineering study and the DOH's design speed is as follows:

Relation between Design Speed and DOH's Standard

Terrain Condition	Design Speed		
	F3	F4	F5
Flat or Moderately Rolling	90(70-90)	80(60-80)	60
Rolling or Hilly	70(55-70)	60(45-60)	45
Mountainous	55(40-55)	45(30-45)	30

Note: Figures in parentheses show the ranges of design speed shown in the DOH's Standard.

As seen in the above table, the upper side design speeds were applied in this study to design safer road structure.

As mentioned in 8-8-1, on the selected optimum route, the different standard, F3, F4 or F5 Standard, was applied respectively to each road segment according to the forecasted ADT. In this case, the design speed applied to each road segment is as follows:

Design Standard and Design Speed
by Segment of the Optimum Route

Design Standard	Design Speed (Km/h)	Segment No.	Length (Km)
F3	90	1, 2, 3, 5, 7 and 18	48.2
	70	12	11.9
		Total:	60.1
F4	80	19/1	(5.3)
	60	27, 29 and 30	38.0
		Total:	38.0
F5	45	21	10.2
	30	22, 23, 24 and 25	46.4
		Total:	56.6

Note: /1 Segment No. 19 is included in the Phetchabun - Chai Badan Highway Project.

2) Design Criteria and Alignment

The geometric design criteria to be applied corresponding to design speed were determined based on AASHO's recommendation on geometric designs, as follows:

Geometric Design Criteria

Description	Design Speed (Km/h)						
	90	80	70	60	55	45	30
Min. Radius of Curvature (m)	310	230	170	120	100	60	30
Min. length of Horizontal Curve (m)	150	140	120	100	90	80	50
Min. Stopping Sight Distance (m)	130	110	95	80	70	55	40
Max. Gradient (%)	3.5	4	4.5	5	5.5	6.5	8
Min. Radius of Vertical Curve (m)							
Crest	4,800	3,000	2,200	1,400	1,100	600	250
Sag	2,500	2,000	1,500	1,000	800	600	250
Min. Vertical Curve Length	80	70	60	50	45	40	25

The whole proposed alignment was re-examined corresponding to the geometric design criteria shown above, and special consideration was paid to the followings.

Some parts of the existing road between Nong Bua Rawe and Lup Pho in Segment No. 29 and 30 were found unfavorable in the horizontal alignment, as it is winding with some intersections.

Then new alignment was introduced in this section as a substitute for the existing road. The new alignment begins at the west of Nong Bua Rawe and proceeds eastward to Lup Pho by way of the bridge now under construction. The length of the new construction road is 17.0 Km and it is shorter than the existing road by 1.0 Km.

The alignment in the mountainous section crossing the Luak and the Phang Hoei Range in Segment No. 22 and 23 was refined by using the 1:5,000 scale topographic maps specially prepared for the study of this sections.

The horizontal and vertical alignments were designed following the topography, and as the result, considerable amount of earthwork was reduced. By the refinement, however, no salient change in total road length occurred in these segments.

The detailed alignment designed on the 1:5,000 scale topographic maps is shown in Drawings of Volume 2.

For the intersections with major highways, careful considerations were required. The Project road crosses two national highways, Route 11 and 21. The intersection with Route 11, now under construction, was designed as at-grade intersection in its detailed design. The other intersection with Route 21 was examined in accordance with the DOH standard, based on the traffic volume. The layout for both of these intersections are shown in Drawings of Volume 2.

Incorporating the amendments mentioned above, the optimum route was decided as shown in Figure 8-2.

3) Typical Cross Section

The typical cross sections of each standard, F3, F4 and F5 Standard, are shown in Drawing of Volume 2, dividing into embankment and cut sections. The principle of general ideas of the typical cross section is described in 8-3-2.

8-8-3 Pavement Design

1) Design Principle

As described in 8-3-1, DOH's F3, F4 or F5 Standard was applied to the respective road segment.

The kind of pavement for the road classes of F3 and F4 Standard is single bituminous surface treatment (SBST) consisting of soil aggregate subbase on a layer of selected material, crushed stone base and bituminous surface. As for class of F5 Standard, soil aggregate surfacing is solely applied on a layer of selected material, except for the portions with steep gradient where SBST is recommended as mentioned in 8-8-1.

The design of pavement was made based on "A guide to the Structural Design of Bitumen-Surfaced Roads in Tropical and Sub-Tropical Countries", by the Overseas Unit Transport and Road Research Laboratory, United Kingdom. In the said guide, the pavement design chart for flexible pavement is prepared as shown in Figure 8-3.

In it, 15 cm thick crushed stone base with surface dressing is employed with the thickness of subbase as a sole variable in the total thickness of pavement. In the chart, the determinants of subbase thickness are CBR of subgrade soil and cumulative number of standard 8,200 kg axle load during the design life. The design life of pavement was set at 7 years in this study. Since it is the normal design practice in Thailand to design pavement for an initial life of 7 years, and at the 7th year, to construct an overlay by asphalt concrete.

2) Number of Standard Axle

The axle loads of four types of commercial vehicles, in both empty and laden cases, were determined based on the results of traffic survey, as shown below:

Axle Loads

Type of Vehicles		Axle Load (ton)	
		Front	Rear
Heavy Bus	Laden	5.0	9.1
Light Truck	Empty	0.7	1.0
	Laden	0.9	2.1
Medium Truck	Empty	2.5	3.5
	Laden	2.8	6.0
Heavy Truck	Empty	2.8	2.6x2
	Laden	3.3	6.4x2

Based on the traffic forecast made in Chapter VI, the cumulative number of standard 8,200 Kg axle load during 7 years after the opening of the Project was calculated for each Standard section, separately, as shown in the following table.

Cumulative Numbers of Standard 8200 Kg Axle Load

Road Class	Type of Vehicles /1	Empty Ratio /2 (%)	Cumulative Number of Vehicles	Cumulative Number of Standard Axle Load		
				Empty	Laden	Total
F3	H/B	0	80,490	-	141,650	141,650
	L/T	50	300,220	90	660	750
	M/T	40	113,060	2,000	18,380	20,380
	H/T	40	35,140	420	13,390	13,810
	Total					176,590
F4	H/B	0	137,970	-	242,820	242,820
	L/T	50	230,590	70	510	580
	M/T	40	95,180	1,690	15,460	17,150
	H/T	40	24,280	290	9,250	9,540
	Total					270,090
F5	H/B	0	46,630	-	82,080	82,080
	L/T	50	84,960	30	190	220
	M/T	40	34,500	610	5,610	6,220
	H/T	40	10,220	110	3,890	4,000
	Total					92,520

Note: /1 H/B - Heavy Bus, L/T - Light Truck, M/T - Medium Truck, H/T - Heavy Truck

/2 Derived from the results of traffic survey.

As shown in the above table, the cumulative number of standard axle load during 7 years was calculated at 176,600, 270,100 and 92,500 for F3, F4 and F5 Standard sections, respectively. It is noted that the cumulative number of standard axle load of F4 Standard section is larger than that of F3 Standard section, despite the lower traffic volume on F4 Standard than F3 Standard section. This comes from the higher share of heavy vehicles in total traffic on F4 Standard section in Chaiyaphum part.

3) Subgrade CBR

The tests for subgrade soil were carried out to know the characteristics of soils along the selected route. Soil samplings were made in 9 places at intervals of about 15 Km. Their locations are shown in Figure 10A-1 of Appendix-10.

The results of soil tests are summarized in Table 8-6, and the details of CBR test are shown in Figure 10A-2 of Appendix-10. The CBR of subgrade soil was obtained as follows:

CBR of Subgrade Soil

Sample No.	Segment No.	CBR
S-1	2	13.0
S-2	5	11.4
S-3	7	8.7
S-4	18	1.6
E-1*	"	1.25
S-5	21	7.5
S-6	22	8.1
S-7	27	11.0
S-8	29	14.0
S-9	30	6.5

* E-1 was carried out in the survey for the Phetchabun-Chai Badan Highway Project.

As shown in the above table, CBR values vary at random along the road. Hence, pavement thickness also varies by each segment, if the CBR figures of the test result are directly applied to the design chart. But it is impractical to construct pavement with different thickness by short length. Therefore, whole length of proposed road was divided into the following three parts, considering road classes, to assign same values of design CBR to whole length of reasonable distance:

Part and Included Segments

Part	Segment No.	Road Class	Road Length (Km)
A	1 - 18	F3	60.1
B	21 - 25	F5	56.6
C	27 - 30	F4	38.0

The design CBR of subgrade to be applied to each part was calculated at 8.8, 7.4 and 6.6 for Part-A, Part-B and Part-C respectively, by the following formula:

$$CBRd = \overline{CBR} - \frac{CBR\ max. - CBR\ min.}{d}$$

where, CBRd: Design CBR

$\overline{CBR}$: Average of CBR values in each part

CBR max., CBR min.: maximum and minimum CBR values in each part.

d: Factor given by following

Number of Samples	2	3	4	5	6
d	1.41	1.91	2.24	2.48	2.67

In calculation of CBRd for Part-A, the CBR values of Sample S-4 and E-1 in Segment-18 are excluded because of their extraordinarily small value.

4) Thickness of Pavement

Applying the calculated cumulative numbers of standard axle load and subgrade design CBR to the pavement design chart in Table 8-3, sub-base thicknesses were obtained as 10, 12 and 15 cm for Part-A, Part-B and Part-C sections, respectively.

According to the typical pavement structure of DOH, however, thickness of 15 - 30 cm is necessitated for soil aggregate subbase course. As the thicknesses calculated for Part-A and Part-B are below the lower limit, thickness of 15 cm was employed following the typical pavement structure of DOH.

Thus, the pavement design of SBST pavement sections was made under the following pavement thickness:

F3, F4 and F5 (Steep Gradient Portions) Standards

SBST		1.2 cm
Crushed stone base	CBR ≧ 80	15 cm
Soil aggregate subbase	CBR ≧ 20	15 cm
Selected material	CBR ≧ 6	20 cm

The pavement design of soil aggregate surfacing for F5 Standard sections was made with the following thickness, in accordance with the DOH's standard for typical pavement structures.

F5 Standard

Soil aggregate surface	CBR ≧ 20	15 cm
Selected material	CBR ≧ 6	20 cm

Typical pavement structures for F3, F4 and F5 Standard sections are shown in Drawings of Volume-2.

5) Pavement Materials

The test results suggest the following:

- Subgrade soils are classified mainly as silty and clayey soil with high plasticity, and correspond to A-4 or A-6 of AASHO classification.

- Laterites have sufficient CBR values enough to be used as subbase material. However, they do not satisfy such the conditions as specified in Standard Specifications of DOH because of their high plasticity indexes and poor gradings.

According to the information from ARD and Amphoe offices, however, there are several sources of laterite in the Area, which have been used as the soil aggregate material sources for the road construction. Therefore, it was judged to be possible to find sufficient sources of soil aggregate within a reasonable distance for the Project by detailed investigation. Some material locations are indicated in the Figure 10A-3 of Appendix-10.

The location of material sources for base and aggregate for SBST will affect largely the cost of pavement works. Some rock quarries mostly of limestone exist in the surroundings of the Project road. Those quarries are, however, far from the Project road. An alternative plan to these quarries is, therefore, to make good use of excavated rocks made of sandstone to be obtained from the Phang Hoei Range, near Na Raya in Segment No. 23. In case that the excavated rocks are available as the materials of base and SBST, long hauling can be avoided. According to the observation in reconnaissance, the fresh rocks of the Range seems to be sound and suitable as the materials of base and SBST. However, the detailed investigations will be required prior to employing such rocks in the Project.

8-8-4 Hydrological Study

To decide the suitable openings of the drainage facilities and bridges along the optimum route, more detailed hydrological studies were made by employing the rainfall pattern characteristic to the project area.

1) Catchment Area

Based on the 1/50,000 scale topographic maps, supplemented with aerial photographs, catchment area of each water course crossing the optimum route was identified as shown in Figure 11A-1 of Appendix-11.

2) Rainfall Pattern

The past records of hourly rainfall pattern were available at Lop Buri and Don Muang. They are characterized by squall, concentrating more than 75 percent of daily rainfall in an hour, as shown in the following table.

Rainfall Pattern

(mm)

Location	Hours					
	1	2	3	6	12	24
Lop Buri /1	86.8	104.4	104.4	113.6	113.6	113.6
Don Muang /2	104.3	114.0	117.0	117.2	117.5	124.0

Note: /1 recorded in 1964
/2 recorded in 1962

There are several rainfall observation stations in the Area. However, most of the available records are of monthly or annual rainfall. The maximum daily rainfall in the Area was 153.9 mm, which was recorded at the Phetchabun station on 8th September, 1951, the heaviest daily rainfall during 1951 - 1965 period (Source: climatological data, Meteorological Department).

Using this record as a control total, the above data were expanded to formulate the rainfall pattern in the Project Area. The effective hourly rainfall was then calculated by subtracting the loss, which was obtained using the following equations:

$$R_L = R \times (1 - 0.00036R^{1.5}) \qquad R \leqq 100$$

$$R_L = 64 \qquad R > 100$$

where, R_L : Cumulative loss rainfall (mm)

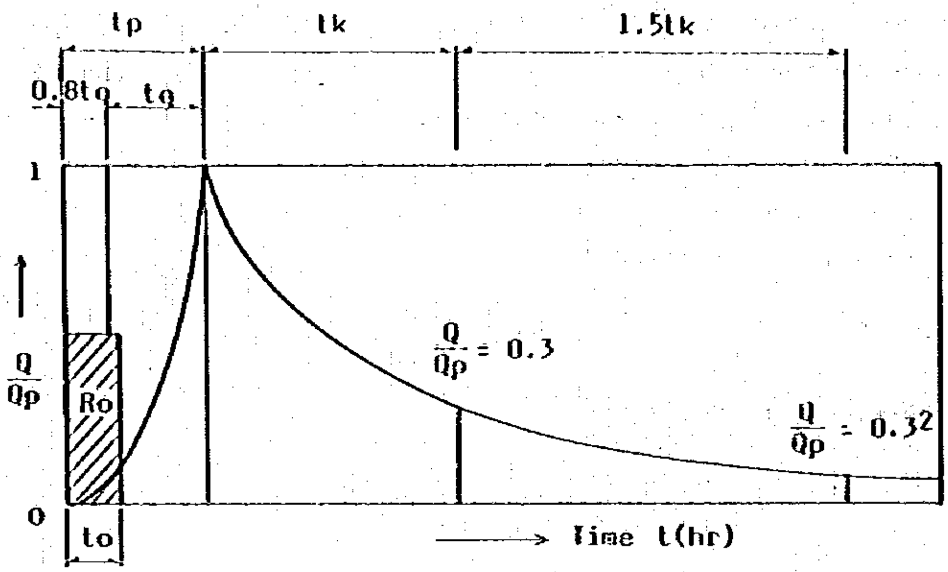
R : Cumulative rainfall (mm)

Though two patterns were formulated, the one based on the records at Dong Hoang was used in the study as this gave larger discharge. It is tabulated in Table 11A-1 of Appendix-11.

3) Discharge Analysis

For the squall type of rainfall, the Rational Method, which bases on the concept of average rainfall intensity during several hours, can not be reasonably applied in discharge calculation. Moreover, the analysis of the change of reserved volume with the lapse of time is not possible by this method. Unit Hydrograph Method which incorporates the time lag between the beginning and the peak of flood at the subject place was, therefore, used in the study.

The concept of the Unit Hydrograph Method is expressed by the following figure:



This figure shows that the flood discharge (Q) at the subject place caused by the effective rainfall (Ro) occurred in an unit duration (t_o) reaches its peak (Qp) with a time lag (t_p), then gradually decreases. The peak discharge is calculated by the following equation, of which derivation is explained in Appendix 11:

$$Q_p = \frac{0.2778\ A.Ro}{0.3t_p + t_k} \quad \text{..................... (1)}$$

$$t_p = t_g + 0.8\ t_o$$

$$t_k = 2.0\ t_g$$

where, Q_p : Peak discharge (m^3/sec)

A : Catchment area (Km^2)

Ro : Effective rainfall (mm)

t_p : Time in which the discharge increase from zero to Qp (hr)

t_k : Time in which the discharge decrease from Qp to 0.3 Q_p (hr)

tg : Time lag between 0.8 t_o and the peak of flood (hr)

t_o : Unit duration of rainfall (hr)

a) Time Lag between the Beginning and the Peak of Flood (t_p)

Time of concentration was taken as the time lag between the beginning and the peak of flood. The mean velocity of flood water was calculated by Rziha's formula shown below.

Rziha's formula

$$V = 72 \left(\frac{H}{L}\right)^{0.6} \quad .... \quad (2)$$

Where, V : Mean velocity of flood water (Km/hr)

H : Difference of elevation between subject places of river channel (Km)

L : length of river channel (Km)

Then, the time of concentration (t_p) was calculated using the mean velocity as follows:

$$t_p = \frac{L}{V}$$

b) Maximum Discharge

Unit hydrograph, which is the unit discharge curve by the unit effective rainfall of 1 millimeter in unit hour in the catchment area, was established for each catchment area, based on the respective characteristics of catching basin. The main features of unit hydrograph are shown in Table 11A-2 of Appendix-11, together with the peak discharge calculated by the equation (1).

Maximum discharge of each catchment area was calculated by superposing the hydrographs by rainfall in unit hour. An example of hydrograph for catchment area No. 10 is illustrated in Figure 11A-2 of Appendix-11.

4) Capacity Calculation

The size of box culverts and bridge openings were determined by the comparison of discharge and flow capacity. The flow capacity of box culvert and bridge was calculated by the following Manning's formula:

$$V = \frac{1}{n} \cdot R^{2/3} I^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$Q = A \cdot V$$

where, Q : Flow capacity (m^3/sec)

A : Cross sectional area of drainage structure (m^2)

V : Mean velocity (m/sec)

n : Manning's roughness coefficient; 0.02 for box culverts and 0.05 for waterway at bridge sites

R : Hydraulic radius (m)

I : Slope of the drainage facility

5) Bridge for Relief Open

The optimum route crosses the Pasak river and its tributaries in Segment-18. Due to the insufficient drainage capacity of bridge openings of the existing road, some low formation sections suffer from overflow in rainy season. For the construction of all-weather road, it is required to provide bridges necessary for relief open together with the raising up of road formation level. Hydrological study was made to decide an appropriate embankment height and length of bridge for relief open, considering the reserving capacity on the upstream side of the embankment. Discharge analysis was based on the unit hydrograph method as developed previously.

a) Maximum Discharge

As the catchment area of No. 10 is quite large, the time lag between the beginning and peak of flood is more than 90 hours. Therefore modified rainfall pattern was introduced for the discharge analysis of this catching basin. The modified rainfall pattern is shown in Figure 11A-2 of Appendix-11. The maximum discharge was decided as 1,987 m^3/sec from the discharge curve in the same Figure.

b) Bridge Length

The water level on the upstream area at the time of flood is calculated according to the reserved volume in the area. The principle applied for the determination of bridge length for relief open is that the water level should not exceed the past highest water level.

The relation between the water level and the reserved volume on the upstream area was formulated based on the topographic maps.

The following is the basic equation used for the calculation of the reserved volume.

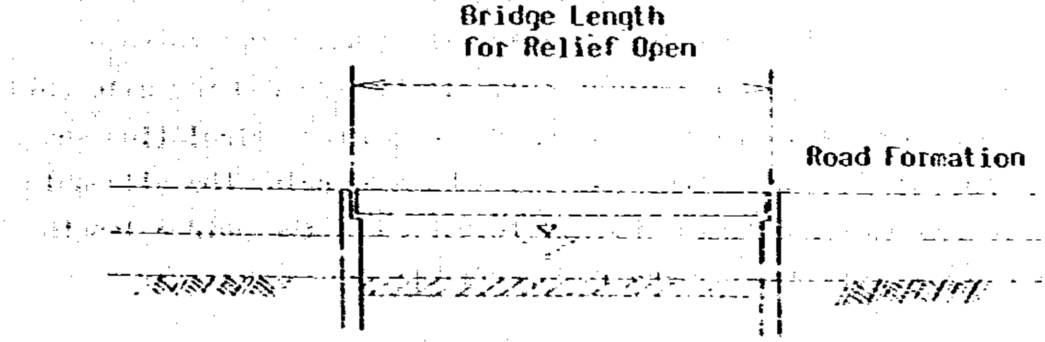
$$\frac{1}{2}(I_t+I_{t+1}) = \frac{1}{2}(O_t+O_{t+1}) + (V_{t+1}-V_t)$$

where, I_t, I_{t+1}: Inflow volume at time t and t+1 (m^3)

O_t, O_{t+1}: Outflow volume at time t and t+1 (m^3)

V_t, V_{t+1}: Reserved volume at time t and t+1 (m^3)

The general view of the river cross section at bridge site is as shown below.



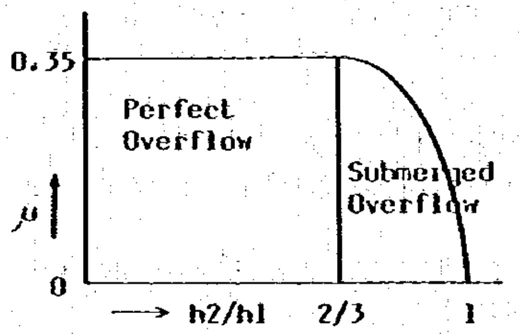
The net inflow volume (I_t, I_{t+1}) was calculated subtracting the base flow discharge which flows through the hatched area from discharge volume. The basic-flow discharge was calculated based on the results of the river cross section survey, assuming as uniform flow.

The outflow volume through the bridge opening was calculated by the following equation.

$$Q = \mu B h_1 \sqrt{2g h_1}$$

where, Q: Discharge through the bridge for relief open (m^3/sec)

μ: Discharge coefficient, $\mu = f(h_2/h_1)$



B : Length of bridge (m)

h_1: Water depth of upstream side (m)

h_2: Water depth of downstream side (m)

g : Acceleration of gravity (9.8 m/sec^2)

Using the equations and inputs mentioned above, the water level on the upstream area can be determined by the convergent calculation. The water level by flood discharge was calculated first for the length of the existing bridges. Then, it was compared with the allowable water level which was taken as the highest water level in the past. If it exceeded the allowable one, the bridge length was prolonged and another calculation was made until the calculated water level becomes below the allowable one. The examination for the determination of the bridge length for relief open is compiled in Appendix-11.

6) Drainage Structure

Discharge calculation was made to each water course by the procedure mentioned above. Then the drainage facility with suitable opening to each place was selected.

a) Box Culvert

A size of 2.1 m x 2.1 m double cell concrete box culvert with headwalls and aprons was applied. The standard drawings of box-culvert are shown in Drawings of Volume 2.

b) Bridge

I-shaped pre-stressed concrete girder and reinforced concrete slab were employed for long span and short span bridge respectively. The detailed description on both super-structure and sub structure of bridge is mentioned in 8-3-6. The standard drawings are shown in Volume-2.

c) Pipe Culvert

As described in 8-3-5, required locations of pipe culverts were identified by inventory survey and field reconnaissance, with the following intervals as a standard.

Interval of Pipe Culverts

Topography	Average Interval (m)
Terrace area	500
Paddy area	300

The minimum diameter of pipe culverts was set at 80 cm for easy maintenance. The standard drawings are shown in Volume-2.

8-8-5 Bridge Design

Out of the total 74 bridges included in the route alternatives, the number of bridges to be constructed in the optimum route is totally 26, as shown below:

Replacement of timber bridge	9 bridges
New bridges	16
New bridge for relief open	1
Total	26 bridges

The structural studies on Bridge are described in 8-3-6.

The list of those bridges in the optimum route is shown in Table 8-7, together with proposed length and type, determined by the procedure mentioned in 8-3-6.

The length of bridges was calculated based on the hydrological analysis of discharge and flow capacity as described in 8-8-4. The results of calculations for bridges in the optimum route are shown in Table 11A-2 of Appendix 11. In determining the bridge length, the bridge formation was set as to keep clearance of 1.5 m above the high water level.

8-9 IMPLEMENTATION METHOD AND SCHEDULE

8-9-1 Design Method

Among the proposed road of about 155 Km in total length, the section of about 105 Km does not involve any complex problems on its design, but the remaining section of about 50 Km, Segment No. 18, No. 22 and No. 23, has many difficult and complicated matters which require the high level of engineering practice for the design.

Segment No. 18 is the section between Rahun and Nong Daeng, crossing the Pasak River and its basin. As mentioned previously in this Chapter, this segment requires the construction of new bridges of more than 230 m in total length and of the raising up of embankment extending for about 6 Km as countermeasures to protect the proposed road from the flood of the Pasak River and its tributaries. In this report, the plans of these works have been determined by a hydrological analysis based on the fairly simplified assumptions.

The suitability of the plans,however, gives the great influence not only on the construction cost but also on the social life of the local inhabitants living in the area suffered from the flood water. In the stage of the detailed design, therefore, it is necessary to plan them based on the more detailed surveys and studies including the following:

- Determination of the flood discharge based on the analyzed rainfall data. The rainfall data must be collected from as many rainfall guaging stations in the basin of the Pasak River as possible.

- Determination of the length and the location of the bridge for relief open in comparison of the flood discharge and run-off capacity.

- Investigation of the influence area to be covered with flood water.

- Comparative study of bridge types, especially on the suitability of the application of the standard design.

Segment No. 22 and No. 23 are sections between Wang Wat and Tha Pong passing through two mountain ranges, the Luak and the Phang Hoei, which have steep and complicated topographic features. In this study, the routing of this section was carried out based on the topographic map of 1/5,000, prepared specially for this work, but more precise survey will be required in the detailed design stage. Moreover, the considerable amount of rock excavation, about 500,000 m^3 is expected. As the volume of rock excavation influences greatly the construction cost, the design should be carried out so as to minimize the excavation volume.

In consideration of these points, it is proposed to carry out the following works for the detailed design, especially for the above-mentioned sections:

- Preparation of a topographic map of 1/1,000 based on the aerial photographic survey.

- Planning of the horizontal alignment in application of appropriate transition curves.

- Carrying out of a seismic prospecting survey in order to check the volume and quality of rocks to be excavated.

- Study of the slope protection and the drainage in order to prevent erosion.

- Examination of the utilization of the excavated hard rock as materials of the base course.

In view of the complexity of the detailed design works as mentioned above, it is desirable to employ a highly qualified and experienced consulting engineers for the detailed design.

8-9-2 Construction Method

As mentioned above, the design of the proposed road involves many problems which need a high engineering level to solve them. On the other hand, the construction works seem to require neither sophisticated technique nor special type of equipment. It was judged, therefore, that construction execution by local contractors is reasonable.

Although no special method for the construction is required, some consideration to be taken on the operation are described below.

1) Earthwork

The side borrow method by bulldozer will be applied generally for the construction of embankment. For the new construction sections, side borrow will be made from both sides of road to minimize the earth moving. On the other hand, for the widening sections of the existing road without raising up, side borrow is desirable to be made from one side to keep the existing traffic during construction.

However, for raising up of the existing submerged sections, side borrow method is not applicable, because the soils on roadside are not suitable as embankment material. Materials should be transported from suitable borrow pits by the shovel and dump truck method. For these sections, as the existing traffic has also to be kept, the construction will be carried out half by half of road width. During the embankment of first half, the traffic will use the other half, and upon completion of the embankment of first half, the traffic will be led to the completed half and the embankment will proceed to the remaining half.

Most of soils along the proposed road are classified mainly as silty or clayey soils range from A-2 to A-7 in AASHO's classification and are mostly same kind of soils along the Phetchabun-Chai Badan Highway studied in 1978. According to the results of test carried out in the above project, the cone indexes range from 2 to 7, in case the soils are compacted at the natural moisture content, and it decreases to less than 2 when compacted at about 5 percent above the natural moisture content. The required cone index is more than 3 for 15 ton class bulldozer and more than 5 for 21 ton class bulldozer. In rainy season when the water content of soil is anticipated to increase considerably, the construction will become difficult even by 15 ton class bulldozer. Therefore, earthwork was judged to be carried out in dry season only.

The soaked CBR values at 95% of maximum dry density by AASHO's T-99 compaction test method were measured in this study, while ones by AASHO's T-180 have been measured in the study of the Phetchabun-Chai Badan Highway study. Comparing both the results, the CBR values by AASHO's T-99 are generally higher than ones by AASHO's T-180. As the soils for both of the projects are mostly the same, this fact shows that it is desirable to apply the compaction by AASHO's T-99 method as the standard of compaction in this proposed road.

In Segment No. 22 and 23, considerable amount of rock excavation, about 500,000 m^3, is expected. As the rock excavation affects greatly the construction cost and schedule, it is necessary to study the effective construction method including application of appropriate construction equipment prior to the start of the construction.

2) Pavement Works

The pavement works should also be carried out in dry season. Heavy rain will increase the water content of subbase and base course materials and accordingly causes difficulty in compaction. Moreover the rain will decrease the adhesion of bituminous materials and make the workmanship of SBST poor.

Great quantities of base course material, about 100,000m^3, will be required for the Project. In case that the excavated hard rock is judged unsuitable as the material of the base course, these must be purchased. In order to supply a considerable amount of them in a short time period, it is preferable to produce crushed stones and stock them in suitable manner prior to the construction.

3) Bridge Construction

The bridge construction is also recommendable to be carried out in dry season, when no temporary bridge will be required because the traffic can go on the dried up riverbed as a detour, and moreover no coffering or drainage work will be required for the construction of sub-structure.

8-9-3 Construction Schedule

The whole length of the proposed road would be divided into five lots for construction:

Lot I	35.4 Km	Segment No. 1, 2, 3, 5 and 7
Lot II	24.7 Km	Segment No. 12 and 18
Lot III	26.3 Km	Segment No. 21 and 22
Lot IV	30.3 Km	Segment No. 23, 24 and 25
Lot V	38.0 Km	Segment No. 27, 29 and 30

The construction quantities of each lot are shown in Figure 8-4.

These lots were decided in consideration of the reasonable size of construction quantities and scale of construction. Accessibility to the construction from both ends of lot by utilizing the existing roads was also taken into consideration.

Judging from the construction quantities of each lot, and capacity of main local contractors, it is estimated that the construction of each lot can be completed in two years and a half. However, as Lot III and IV involve considerable amount of rock excavation and Lot II and V involve bridges of fairly long in total length, special attention on these matters is necessary in qualifying bidders.

The tentative construction schedules for the lots together with the implementation schedule were prepared and are shown in Figure 8-4.

8-10 WORK QUANTITIES AND CONSTRUCTION COST

In the calculation of the work quantities on the optimum route, following three major work items which appear in F3 and F4 Standard were added to the work items introduced in the comparison of route alternatives as mentioned in 8-4.

o) Crushed stone base

p) Soil aggregate shoulder

q) Prime coat and SBST

The work quantities of the optimum route by segment are shown in Table 8-8.

The unit price to those work items were developed by the same manner as mentioned in 8-5 and shown in Table 8-9.

The percentage of tax component and the percentage of foreign currency portion included in the unit price in Table 8-9 were determined referring to the previous studies/1 on the similar type of construction in Thailand, under the assumption that the construction would be performed by local contractors.

The construction costs of major work items were calculated by applying these unit prices to the estimated work quantities. The costs of minor items were added to the construction costs of major work items.

The total construction costs of the optimum route were calculated by adding the following cost items to them.

Physical contingency	: 15% of direct construction costs
Engineering and Administration	: 8% of direct construction costs

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/1 "Report on Investment Alternatives in Highways in the Corridors between Muak Lek and Ban Chai Badan, Ban Chai Badan and Dan Khun Thot", Vallentine, Laurie and Davies, August 1975

The construction costs of the optimum route by segment are shown in Table 8-10. The total construction costs of the whole length of the optimum route are given below, and the details are shown in Table 8-11.

Total Construction Costs

(million Baht)

Description	Financial Cost	Economic Costs
Direct Construction Cost	378.9	341.0
Physical Contingency	56.8	51.1
Engineering & Administration	30.3	27.3
Land Acquisition	11.9	11.9
Total	477.9	431.3

It was assumed that the construction work would start in mid 1981 for a period of two and a half years after the detailed design in 1980. Yearly disbursement was calculated assuming that; half of engineering & administration costs would be expensed for detailed design in 1980, land acquisition costs in 1981, and 20 percent of the remaining costs in 1981 and 40 percent in each year of 1982 and 1983.

Total investment costs were calculated by adding price contingency to the total construction costs dividing into foreign and local portions as summarised below:

SUMMARY OF INVESTMENT COSTS

(Financial Cost)

	In Baht (million)			US$ Equivalent/1 (million)		
	Local	Foreign	Total	Local	Foreign	Total
Direct Construction Costs	203.3	175.6	378.9	10.17	8.78	18.95
Physical Contingency	30.5	26.3	56.8	1.53	1.31	2.84
Engineering & Administration	10.3	20.0	30.3	0.52	1.00	1.52
Land Acquisition	11.9	-	11.9	0.60	-	0.60
Sub Total	256.0	221.9	477.9	12.82	11.09	23.91
Price Contingency/2	89.0	45.5	134.5	4.45	2.28	6.73
Total	345.0	267.4	612.4	17.27	13.37	30.64

Remarks: /1 At exchange rate of US$1.00 = Baht 20

/2 At assumed annual escalation rates of: 10% (1979-1982) for local component, and 6.5% (1979) and 6% (1980-1982) for foreign component.

Table 8-1 ROAD SEGMENTS

SEGMENT NO.	SEGMENT FROM	SEGMENT TO	SEGMENT LENGTH (KM) EXISTING ROAD	SEGMENT LENGTH (KM) NEW ROAD	REMARKS
1	Nong Bua	National Highway Route No. 11	2.4		Mine road
2	National Highway Route No.11	Ang Hin		4.7	
3	Ang Hin	Nong Phai		4.6	
4	National Highway Route No.11	Nong Ngu Luam	32.0	-	Mine road
5	Nong Phai	Nong Ngu Luam		12.7	
6	Ang Hin	Wang Phikun		26.9	
7	Nong Ngu Luam	Sap Sombun		11.0	
8	Nong Ngu Luam	Hin Dat Yai	13.3		Rural road
9	Wang Phikun	Sap Mai Daeng	12.3		ARD road
10	Hin Dat Yai	Sap Mai Daeng	6.0		ARD road
11	Hin Dat Yai	Khao Khat	4.7		Rural road
12	Sap Sombun	Rahun		11.9	
13	Khao Khat	Rahun		7.3	
14	Khao Khat	Sap Samo Thot (North)	6.7		Rural road
15	Sap Mai Daeng	Sap Samo Thot (South)	7.3		ARD road
16	Sap Samo Thot (South)	Rat Charoen		5.8	
17	Sap Samo Thot (North)	Rat Charoen		7.0	
18	Rahun	Nong Daeng	12.8		ARD road
19 1/	Nong Daeng	Sap Bon	(5.3)		ARD road
20	Rat Charoen	Wang Wat		20.2	
21	Sap Bon	Wang Wat		10.2	
22	Wang Wat	Na Raya		16.1	
23	Na Raya	Tha Pong (West)		21.3	
24	Tha Pong (West)	Tha Pong (East)		4.3	
25	Tha Pong (East)	Wang Katha		4.7	
26	Tha Pong (East)	Huai Nam Dam		23.0	
27	Wang Katha	Non Bua Rawe	21.0		ARD road
28	Huai Nam Dam	Lup Pho	33.0		RID road
29	Nong Bua Rawe	Non Puai		11.3	
30	Non Puai	Lup Pho	5.7		Rural road
	Total		157.2	203.0	

Note: 1/ Segment No. 19 constitutes Phetchabun - Chai Badan Highway Project and excluded from engineering studies in this Project.

Table 8-2 MAJOR ITEMS OF INVENTORY SURVEY

ITEM	METHOD OF SURVEY	PURPOSE
Distance	Distance meter of Land Rover	To determine road link length and location of structure sites
Alignment	Observation and survey using hand level	To determine sections to be improved
Cross section	Tape measurement	To judge the necessity of widening
Road surface	Observation	To judge the necessity of raising up the formation and of additional drainage structures
Flood condition	Observation and hearing	To determine the location and the height of raising up the formation and to judge the necessity of bridges for relief open
Topography	Observation	To determine the locations of additional drainage structures
Drainage structures	Tape measurement and observation	To determine the length of extension and to evaluate capacity and structural soundness
Bridge	Tape measurement	To evaluate the capacity of opening, clearance and structural soundness

Table 8-3 SUMMARY OF ROAD INVENTORY

ROAD SEGMENT NO.	SEGMENT LENGTH (km)	POOR ALIGNMENT SECTIONS (km)	NARROW WIDTH SECTION		CULVERT		BRIDGE				OVERFLOW SECTION		SURFACE TYPE	
			WIDTH (m)	LENGTH (km)	PIPE (each)	BOX (each)	TIMBER (each)	TIMBER (m)	CONCRETE (each)	CONCRETE (m)	HEIGHT OF OVERFLOW (m)	LENGTH (km)	SOIL AGGREGATE (km)	EARTH (km)
1	2.4	-	-	-	1	-	-	-	-	-	-	-	3.0	-
4	32.0	0.2	5.0-8.8	32.0	42	-	7	92.6	-	-	1.0-2.0	0.4	26.5	5.5
8	13.3	2.0	4.7-7.8	13.3	15	-	2	18.4	-	-	0.2-0.6	0.7	13.3	-
9	12.3	-	7.0-8.8	9.8	15	-	2	26.3	-	-	0.4-1.0	1.4	12.3	-
10	6.0	-	7.0-8.5	6.0	14	-	1	9.0	-	-	0.2	0.1	6.0	-
11	4.7	0.5	4.5-5.7	4.7	6	-	-	-	-	-	0.6	0.2	4.7	-
14	6.7	-	5.2-5.7	6.7	6	1	2	14.0	-	-	-	-	6.7	-
15	7.3	-	7.3-8.6	7.3	8	-	1	18.0	-	-	-	-	7.3	-
18 1/	12.8	4.0	6.0-7.0	10.0	12	-	4	53.8	1	75.0	0.5	5.6	12.8	-
19 1/	5.3	-	7.5-8.5	3.3	1	-	1	15.0	-	-	-	-	5.3	-
27,29	33.0	2.6	3.0-8.5	33.0	59	-	4	91.5	2	205.0	0.8-3.0	5.7	31.0	2.0
28	33.0	1.7	4.5-8.5	31.0	39	3	-	-	4	80.0	0.5-1.5	2.1	23.0	10.0
30	6.0	0.4	4.8-6.0	6.0	6	-	4	51.0	-	-	-	-	6.0	-

Note: 1/ Inventory Survey for Segment 18, 19 was carried out in Phetchabun - Chai Badan Highway Project.

Table 8-4 MINIMUM DESIGN STANDARDS FOR PROVINCIAL ROADS

1. Access control: When designated under the Highway Law.
2. Highway crossing: Grade separation only after proven viable by economic feasibility calculations.
3. Railroad crossing: Grade separation only after proven viable by economic feasibility calculations.
4. Bridge width (1): 8 m. for F_1 & F_2, 7 m. for F_3 to F_6
5. Vertical clearance = 4.50 m
6. Design bridge loading = HS 20
7. Pavement design shall be based on the accumulated number of equivalent axle load predicted during the first 7-year after construction.
8. Follow AASHO recommendation for any design details not separately specified.

<table>
<tr><th>Class</th><th>(5)</th><th>F_D</th><th>F₁</th><th>F₂</th><th>F₃</th><th>F₄</th><th>F₅</th><th>F₆</th></tr>
<tr><td>Average Daily Traffic</td><td>(5)</td><td>Above 8,000</td><td>4,000-8,000</td><td>2,000-4,000</td><td>1,000-2,000</td><td>300-1,000</td><td colspan="2">Below 300</td></tr>
<tr><td>Design Speed k.p.h.</td><td>(2)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Flat and moderately rolling</td><td></td><td colspan="4">70 - 90</td><td>60-80</td><td colspan="2">60</td></tr>
<tr><td>Rolling and hilly</td><td></td><td colspan="4">55 - 70</td><td>45-60</td><td colspan="2">45</td></tr>
<tr><td>Mountainous</td><td></td><td colspan="4">40 - 55</td><td>30-45</td><td colspan="2">30</td></tr>
<tr><td>Maximum Gradient %</td><td>(3)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Flat and moderately rolling</td><td></td><td colspan="4">6</td><td>8</td><td colspan="2">12</td></tr>
<tr><td>Rolling and hilly</td><td></td><td colspan="4">8</td><td>10</td><td colspan="2">12</td></tr>
<tr><td>Mountainous</td><td></td><td colspan="4">10</td><td>10</td><td colspan="2">12</td></tr>
<tr><td>Suggested Surface Type</td><td></td><td colspan="2">High</td><td colspan="2">Intermediate</td><td>Low</td><td colspan="2">Soil Aggregate</td></tr>
<tr><td>Width of Carriageway m.</td><td></td><td>Divided 2 @7.00</td><td>7.00</td><td>6.50</td><td>6.00</td><td>5.50</td><td>9.00</td><td>6.00</td></tr>
<tr><td>Width of Shoulder m.</td><td></td><td>2.50</td><td>2.50</td><td>2.25</td><td>2.00</td><td>1.75</td><td>Travelled way</td><td>Travelled way</td></tr>
<tr><td>Right of Way m.</td><td>(4)</td><td colspan="5">40 - 60</td><td colspan="2">20 - 40</td></tr>
</table>

Explanatory Notes

(1) Any F_D, F_1 or F_2 road that planned to be raised to National Highway system in the future, bridges less than 15 m. long shall be to the full roadbed width.

(2) Design speed may be relaxed in exceptional circumstances on account of right of way difficulties or mountainous terrain.

(3) Refer to the AASHO Policy on Geometric Design of Rural Highways to relate desirable grade lengths, climbing lanes, etc.

(4) May be reduced in urban or semi-urban conditions at the discretion of the Department provided that a suitable cross section including service roads, where necessary, is obtainable.

(5) Class F_D roads are required on the basis of a 7-year ADT projection or be justified by economic feasibility calculations. Class F_1 to F_3 roads are required on the basis of a 15-year ADT projection. Class F_4 roads have a projected ADT more than 300 in 7 years and less than 1,000 in 15 years. Class F_5 roads have a projected ADT less than 300 in 7 years and more than 300 in 15 years. Class F_6 roads have a projected ADT less than 300 in 15 years.

Remark.

In special cases, the Department may reduce the carriageway width to 3.5, 4, 4.5 or 5 m. on various roadbed widths, i.e. 4 m. on 8 m. roadbed width. Such the case the class of the road will be defined as class F_4 (4/8). If the geometric standard of the road section in the said case below than F_4 then the road class will be defined as F (4) (4/8).

For laterite road the travelled way width may be reduced from 9 m. to 7 m. and the standard will be defined as class F_5 (0/7).

Table 8-5 MINIMUM DESIGN STANDARDS FOR SECONDARY HIGHWAY (RURAL)

1. Access control: When designated under the Highway Law.
2. Highway crossing: Grade separation only after proven viable by economic feasibility calculations.
3. Railroad crossing: Grade separation only after proven viable by economic feasibility calculations.

Design Feature	Flat and Moderately Rolling	Rolling and Hilly	Mountainous
Design Speed k.p.h (2)	70 - 90	55 - 70	40 - 55
Maximum Gradient % (3)	6	8	10
Right of Way m (4)	<---------- 40	-	60 ---------->

4. Bridge width (1): 8 m between curbs (9 m preferable for S1, 7m preferable for S5)

   Sidewalks: 1.5 m for bridges in urban and suburban areas.
   1.0 m for bridges in rural areas.
   0.4 m for bridges with no pedestrian.

5. Vertical clearance = 4.50 m
6. Design bridge loading = HS 20
7. Pavement design shall be based on the accumulated number of equivalent exle load predicted during the first 7-year after construction.
8. Follow AASHO recommendation for any design details not separately specified.

Class (5)	S_D	S_1	S_2	S_3	S_4	S_5
Average Daily Traffic (5)	Above 8,000	4,000 - 8,000	2,000 - 4,000	1,000 - 2,000	300 - 1,000	Below 300
Suggested Surface Type	<------- High	------->	<------- Intermediate	------->	Intermediate to low	Soil Aggregate
Width of Carriageway m.	Divided 2 @7.00	7.00	6.50	6.00	5.50	9.00
Width of Shoulder m.	2.50	2.50	2.25	2.00	1.75	Travelled way

Explanatory Notes

(1) Bridges on sharp horizontal curve or less than 15 m long shall be to the full roadbed width.

(2) Design speed may be relaxed in exceptional circumstances on account of right of way difficulties or mountainous terrain.

(3) Refer to the AASHO Policy on Geometric Design of Rural Highway to relate desirable grades to grade lengths, climbing lanes, etc.

(4) May be reduced in urban or semi-urban conditions at the discretion of the Department provided that a suitable cross section including service roads, where necessary, is obtainable.

(5) Class S_D roads are required on the basis of a 7-year ADT projection or be justified by economic feasibility calculations. Class S_1, S_2 and S_3 roads are required on the basis of a 15-year ADT projection. Class S_1 roads may exceed an ADT projection of 8,000 beyond the 7th year and should be planned to for upgrading to S_D when ADT reaches 8,000 or it is shown to be economically viable. Class S_4 roads have a projected ADT more than 300 in 7 years and less than 1,000 in 15 years. Class S_5 roads have a projected ADT less than 300 in 7 years.

Remark

In special cases, the Department may reduce the carriageway width to 3.5, 4, 4.5 or 5 m. on various roadbed widths, i.e., 5 m. on 8 m. roadbed width. Such the case the class of the road will be defined as class S4 (5/8). If the geometric standard of the road section in the said case below than S4 then the road class will be defined as S (4) (5/8).

Table 8-6 RESULT OF SOIL TESTS

SEGMENT NO.	SAMPLE NO.		NATURAL MOISTURE CONTENT(%)	SPECIFIC GRAVITY	CONSISTENCY(%) (AASHTO T-90) L.L.	P.I.	SIEVE ANALYSIS(%) (PASSING ASTM SIEVE) 1"	3/4"	3/8"	4#	10#	40#	200#	COMPACTION O.M.C(%)	MAX. DRY DENSITY(g/Cm³)	C B R (AASHTO T-193) 95% OF MAX. DRY DENSITY C.B.R(%)	SWELL(%)	H.R.B. CLASSIFI-CATION	DESCRIPTION OF SAMPLE
2	S-1	A	9.57	2.81	N.P.					100	99.8	67.7	37.3	7.6*	2.010	13.0	-	A-4	Gray-brown Silty sand
		B	8.68	2.81	N.P.					100	99.4	54.9	23.6	-	-	-	-	A-2-4	"
5	S-2	A	15.84	2.97	34.7	14.8		100	99.0	89.3	68.9	46.0	34.6	13.2*	1.958	11.4	0.20	A-2-6	Reddish brown Silty clay
		B	17.49	2.92	37.1	14.7	100	97.8	94.2	80.4	60.2	42.1	32.3	-	-	-	-	A-2-6	"
7	S-3	A	14.34	2.76	35.1	12.2	100	98.9	91.4	76.7	62.7	54.8	51.0	16.0*	1.786	8.7	0.48	A-6	Gray Clayey silt
		B	16.47	2.57	42.6	19.8		100	89.7	68.5	52.9	48.5	46.0	-	-	-	-	A-7-5	"
18	S-4	A	36.78	2.66	68.7	34.8				100	99.7	98.4	96.7	30.5*	1.408	1.6	5.96	A-7-6	Dark gray Clay
		B	35.23	2.65	70.2	23.7				100	99.1	98.9	97.4	-	-	-	-	A-7-6	"
21	S-6	A	15.63	2.74	30.8	6.6		100	98.9	88.5	71.8	62.5	54.7	15.6*	1.877	7.5	0.62	A-4	Brown Silty clay
		B	12.77	2.66	30.3	10.3		100	99.8	90.4	78.8	71.8	62.1	-	-	-	-	A-6	"
22	S-6	A	18.78	2.67	26.5	6.1				100	99.8	98.6	73.5	14.8*	1.838	8.1	0.68	A-4	Brown Clayey silt
		B	21.38	2.65	29.2	2.1					100	98.9	81.6	-	-	-	-	A-4	"
27	S-7	A	8.35	2.74	29.3	9.2		100	97.9	95.8	88.8	84.5	75.4	12.8*	1.897	11.0	0.31	A-4	Reddish brown Silty clay
		B	11.77	2.71	29.4	12.1			100	98.3	95.3	93.0	84.0	-	-	-	-	A-6	"
29	S-8	A	8.29	2.62	N.P.				100	99.9	99.7	99.1	43.1	11.7*	1.873	14.0	-	A-4	Dark brown Silty sand
		B	10.45	2.65	N.P.						100	99.6	43.4	-	-	-	-	A-4	"
30	S-9	A	10.34	2.41	23.0	3.4			100	99.4	98.5	97.2	80.2	12.6*	1.880	6.5	0.07	A-4	Dark brown Silty soil
		B	8.74	2.64	25.4	4.8				100	98.9	97.6	91.3	-	-	-	-	A-4	"
18	E-1 /1		19.2		47.3	27.7		100	99.6	98.9	97.9	96.8	94.7	18.2**	1.707	1.25			
	E-2 /1		18.67		36.3	19.6		100	91.4	81.1	65.8	50.8	37.6						
	L-1	A	17.96	2.95	42.5	18.0		100	98.6	84.0	32.6	12.2	8.8	-	-	-	-	A-2-7	Reddish brown Laterite
		B		2.96	67.8	34.7		100	98.4	79.8	36.8	23.5	20.9	14.2**	2.236	48.0	-	A-2-7	"
	L-2	A	10.87	2.94	39.6	15.7	100	89.9	68.3	43.0	24.1	17.8	15.0	-	-	-	-	A-2-7	Yellow brown Laterite
		B		2.93	42.9	17.1	100	91.1	69.7	44.4	25.8	19.8	17.3	9.6**	2.208	50.4	0.30	A-2-6	"
	L-3	A	12.54	2.78	42.4	13.8	100	97.7	87.7	65.8	34.9	24.2	17.1	-	-	-	-	A-2-7	Reddish Laterite
		B		2.77	54.0	17.4	100	96.9	83.8	61.2	33.5	23.5	19.0	13.0**	1.980	55.0	0.38	A-2-7	"

Note: /1 Those two samples are incorporated from Phetchabun - Chai Badan Highway Project

* AASHTO T-99 METHOD
** AASHTO T-180 METHOD

Table 8-7 LIST OF PROPOSED BRIDGES

ROAD SEGMENT NO.	STATION	BRIDGE LENGTH (M)	REMARKS
3	10+700	20.0	Bridge on New Construction Road
5	12+400	15.0	- do -
	13+050	25.0	- do -
	15+350	25.0	- do -
12	42+950	25.0	- do -
18	50+300	21.0	New Construction Bridge
	50+600	24.0	- do -
	50+900	16.0	Replacement of Timer Bridge (W=4.4, L=15.5)
	51+700	176.0	Bridge for Relief Open
21	66+950	15.0	Bridge on New Construction Road
	71+200	15.0	- do -
	72+900	30.0	- do -
22	86+800	15.0	- do -
23	92+900	20.0	- do -
	95+050	40.0	- do -
	112+400	40.0	- do -
25	121+100	10.0	- do -
	121+900	20.0	- do -
27	126+500	25.0	Replacement of Timber Bridge (W=4.0, L=25.3)
	131+250	30.0	- do - (W=4.0, L=22.5)
	141+250	25.0	- do - (W=4.0, L=20.3)
29	143+700	30.0	- do - (W=4.0, L=20.4)
30	158+900	30.0	- do - (W=3.6, L=15.5)
	159+100	25.0	- do - (W=3.6, L=6.0)
	159+250	30.0	- do - (W=3.6, L=11.7)
	159+800	30.0	- do - (W=3.4, L=17.8)

Table 8-8 CONSTRUCTION QUANTITIES BY SEGMENT IN OPTIMUM ROUTE

DESCRIPTION	UNIT OF Q'ty	ROAD SEGMENT NUMBER AND ROAD CLASS															
		1 (F3)	2 (F3)	3 (F3)	5 (F3)	7 (F3)	12 (F3)	18 (F3)	21 (F5)	22 (F5)	23 (F5)	24 (F5)	25 (F5)	27 (F4)	29 (F4)	30 (F4)	Total
SEGMENT LENGTH	km	2.4	4.7	4.6	12.7	11.0	11.9	12.8	10.2	16.1	21.3	4.3	4.7	21.0	11.3	5.7	154.7
WORK ITEMS																	
Clearing and Grubbing	ha	3	19	18	51	44	48	15	41	64	85	17	19	71	45	20	560
Earth Excavation	m^3	0	0	0	0	0	29,140	161,840	13,490	256,290	160,850	18,550	4,890	24,520	0	0	669,570
Soft Rock Excavation	m^3	0	0	0	0	0	8,330	0	3,860	153,770	120,640	13,920	3,680	0	0	0	304,200
Hard Rock Excavation	m^3	0	0	0	0	0	4,160	0	1,930	102,510	120,640	13,920	3,680	0	0	0	246,840
Embankment, Side Borrow	m^3	4,890	51,390	60,010	93,460	53,790	79,980	33,850	68,800	309,600	193,680	16,540	25,640	91,260	74,080	35,430	1,192,400
Embankment, Borrow Pit	m^3	0	0	0	0	0	0	156,730	0	0	0	0	0	0	0	0	156,730
Embankment with Selected Material	m^3	2,280	10,720	10,490	28,960	25,080	27,130	28,820	20,810	32,910	43,630	8,800	9,590	10,400	23,230	0	282,850
Soil Aggregate Subbase 1/	m^3	1,610	7,570	7,410	20,450	17,710	19,160	20,350	19,180	29,600	38,150	7,750	8,840	30,390	16,310	8,320	252,800
Crushed Stone Base 2/	m^3	2,520	4,940	4,830	13,340	11,550	12,500	13,270	0	1,570*	4,410*	780*	0	20,400	10,950	5,590	106,650
Soil Aggregate Shoulder 2/	m^3	960	1,880	1,840	5,080	4,400	4,760	5,060	0	540*	1,530*	270*	0	7,080	3,800	1,940	39,140
Prime Coat and SBST 2/	m^2	14,400	28,200	27,600	76,200	66,000	71,400	75,840	0	8,800*	24,750*	4,400*	0	114,480	61,440	31,350	604,860
Pipe Culvert	m	28	112	107	286	232	304	277	215	528	752	68	70	239	433	178	3,829
Box Culvert	m	0	17	17	17	0	17	26	0	105	20	34	0	0	0	0	253
Long Span Bridge	m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short Span Bridge	m	0	0	20	65	0	25	237	60	15	100	0	30	80	30	115	777
LAND ACQUISITION																	
Highly Developed Land	ha	4	11	11	30	26	24	0	8	13	17	3	4	20	36	22	229
Less Developed Land	ha	0	8	7	21	18	24	0	33	51	68	14	15	0	9	0	268

Note: 1/ To be understood as laterite surfacing in case that F5 Standard is applied.

2/ To be excluded in case that F5 Standard is applied.

* Surface treatment is executed for steep gradient portions.

Table 8-9 UNIT RATES FOR CONSTRUCTION

DESCRIPTION	UNIT OF QUANTITY	FINANCIAL UNIT RATE (Baht)	TAX COMPONENT (%)	FOREIGN CURRENCY PORTION(%)
Clearing and Grubbing	ha	15,000	9.1	42
Earth Excavation	m^3	35	9.9	46
Soft Rock Excavation	m^3	95	13.7	51
Hard Rock Excavation	m^3	135	13.7	51
Embankment, Side Borrow	m^3	55	9.6	41
Embankment, Borrow Pit	m^3	60	9.6	41
Embankment, Selected Material	m^3	80	9.6	41
Soil Aggregate Subbase /1	m^3	140	10.8	47
Crushed Stone Base	m^3	380	6.7	51
Soil Aggregate Shoulder	m^3	140	10.8	47
Prime Coat and SBST	m^2	40	5.5	55
Asphalt Concrete	ton	750	5.5	55
Pipe Culvert	m	2,100	8.2	34
Box Culvert	m	19,000	10.8	38
Long Span Bridge	m	65,000	11.3	46
Short Span Bridge	m	40,000	11.3	46
Land Acquisition				
- Highly Developed Land	ha	40,000	-	-
- Less Developed Land	ha	10,000	-	-

Note: /1 To be understood as laterite surfacing in case that F5 Standard is applied.

Table 8-10 CONSTRUCTION COSTS BY SEGMENT IN OPTIMUM ROUTE

(1,000 Baht)

SEGMENT NO.	SEGMENT LENGTH (km)	ROAD CLASS	DIRECT CONSTRUCTION COST	LAND ACQUISI-TION	COST/Km 1/
1	2.4	F3	2,693	160	1,450
2	4.7	F3	9,741	520	2,660
3	4.6	F3	10,991	510	3,050
5	12.7	F3	25,781	1,410	2,610
7	11.0	F3	17,859	1,220	2,110
12	11.9	F3	24,835	1,200	2,670
18	12.8	F3	45,816	0	4,410
21	10.2	F5	13,971	650	1,750
22	16.1	F5	75,275	1,030	5,820
23	21.3	F5	70,846	1,360	4,160
24	4.3	F5	9,116	260	2,670
25	4.7	F5	6,823	310	1,860
27	21.0	F4	31,958	800	1,910
29	11.3	F4	19,965	1,530	2,310
30	5.7	F4	13,242	880	3,020
	154.7		378,912	11,840	

Note: 1/ Costs of 15 and 8 percent of direct construction cost for physical contingency and engineering & administration, respectively are included.

Table 8-11 TOTAL CONSTRUCTION COST OF OPTIMUM ROUTE

DESCRIPTION	UNIT OF Q'ty	FINANCIAL UNIT RATE (Baht)	TAX (%)	Q'ty	FINANCIAL COST (1,000 Bahts)	ECONOMIC COST (1,000 Bahts)
DIRECT CONSTRUCTION COST						
Clearing and Grubbing	ha	15,000	9.1	560	8,400	7,636
Earth Excavation	m^3	35	9.9	669,570	23,434	21,114
Soft Rock Excavation	m^3	95	13.7	304,200	28,899	24,940
Hard Rock Excavation	m^3	135	13.7	246,840	33,324	28,759
Embankment, Side Borrow	m^3	55	9.6	1,192,400	65,581	59,285
Embankment, Borrow Pit	m^3	60	9.6	156,730	9,404	8,501
Embankment with Selected Material	m^3	80	9.6	282,850	22,627	20,455
Soil Aggregate Subbase 1/	m^3	140	10.8	252,800	35,391	31,569
Crushed Stone Base	m^3	380	6.7	106,650	40,527	37,812
Soil Aggregate Shoulder	m^3	140	10.8	39,140	5,479	4,887
Prime Coat and SBST	m^2	40	5.5	604,860	24,195	22,864
Pipe Culvert	m	2,100	8.2	3,829	8,042	7,383
Box Culvert	m	19,000	10.8	253	4,807	4,288
Long Span Bridge	m	65,000	11.3	0	0	0
Short Span Bridge	m	40,000	11.3	777	31,080	27,568
Sub total					341,190	307,061
Minor Items 2/					37,722	33,949
Total					378,912	341,010
PHYSICAL CONTINGENCY 3/					56,836	51,152
ENGINEERING AND ADMINISTRATION 4/					30,312	27,281
Sub Total					466,060	419,443
LAND ACQUISITION						
Highly Developed Land	ha	40,000	-	229	9,160	9,160
Less Developed Land	ha	10,000	-	268	2,680	2,680
Sub Total					11,840	11,840
GRAND TOTAL					477,900	431,283

Note: 1/ To be understood as laterite surfacing in case that F5 Standard is applied.
2/ 10% of direct construction cost of major work items with extra cost in mountainous area.
3/ 15% of direct construction cost.
4/ 8% of direct construction cost.

FIGURE 8-1 SEGMENT FOR ENGINEERING STUDY

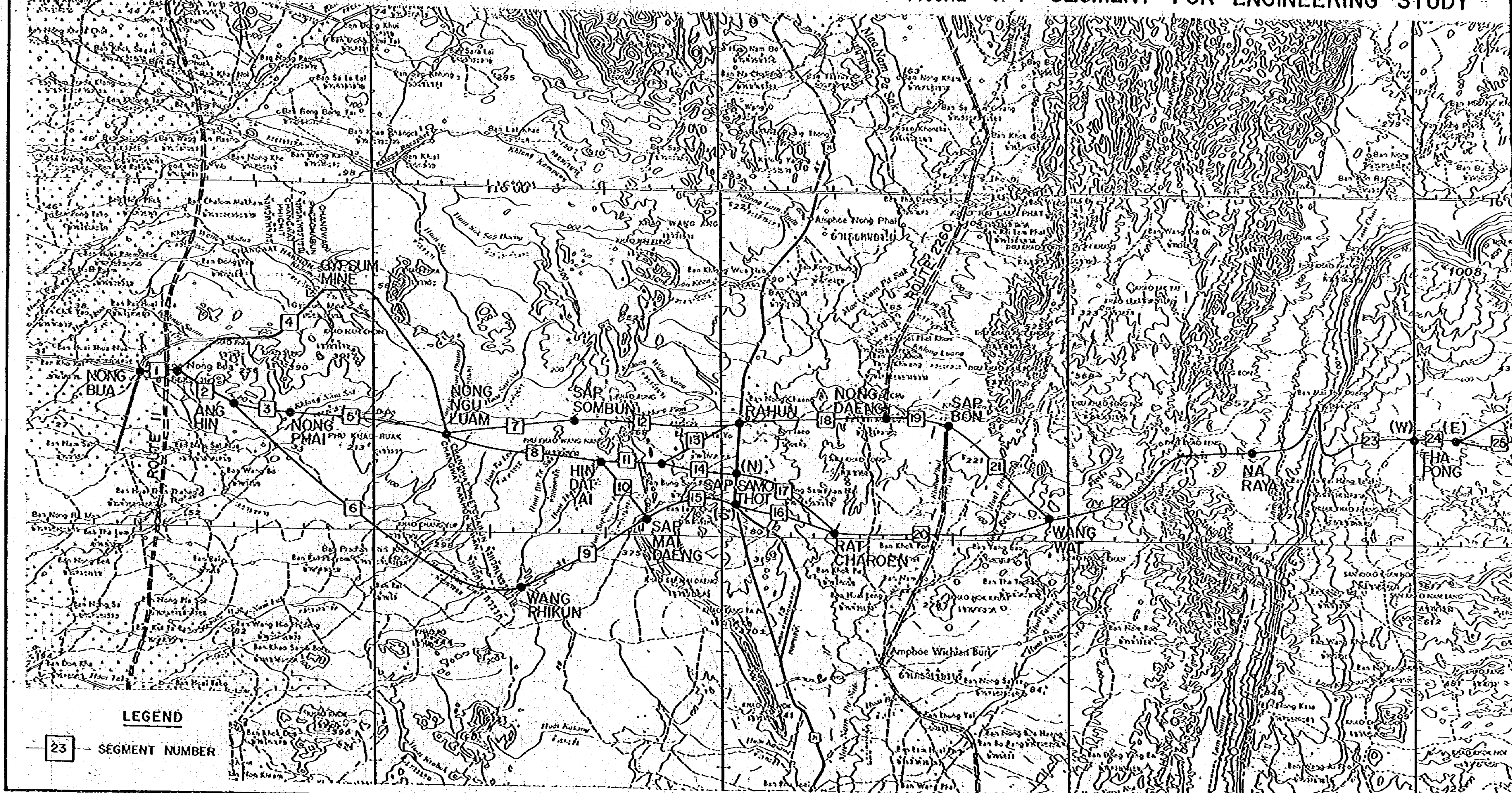
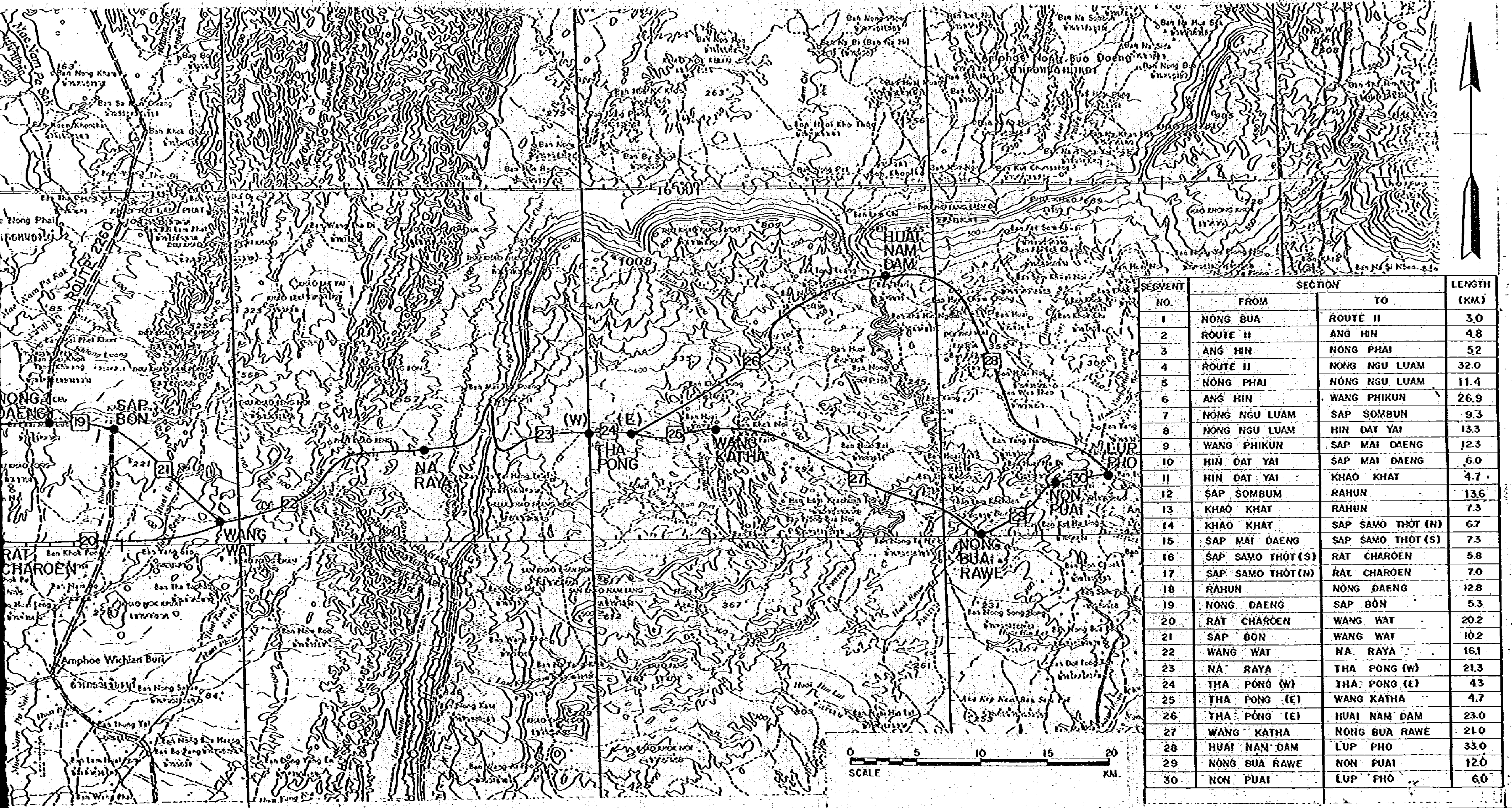


FIGURE 8-1 SEGMENT FOR ENGINEERING STUDY



SEGMENT NO.	SECTION FROM	SECTION TO	LENGTH (KM.)
1	NONG BUA	ROUTE II	3.0
2	ROUTE II	ANG HIN	4.8
3	ANG HIN	NONG PHAI	5.2
4	ROUTE II	NONG NGU LUAM	32.0
5	NONG PHAI	NONG NGU LUAM	11.4
6	ANG HIN	WANG PHIKUN	26.9
7	NONG NGU LUAM	SAP SOMBUN	9.3
8	NONG NGU LUAM	HIN DAT YAI	13.3
9	WANG PHIKUN	SAP MAI DAENG	12.3
10	HIN DAT YAI	SAP MAI DAENG	6.0
11	HIN DAT YAI	KHAO KHAT	4.7
12	SAP SOMBUM	RAHUN	13.6
13	KHAO KHAT	RAHUN	7.3
14	KHAO KHAT	SAP SAMO THOT (N)	6.7
15	SAP MAI DAENG	SAP SAMO THOT (S)	7.3
16	SAP SAMO THOT (S)	RAT CHAROEN	5.8
17	SAP SAMO THOT (N)	RAT CHAROEN	7.0
18	RAHUN	NONG DAENG	12.8
19	NONG DAENG	SAP BON	5.3
20	RAT CHAROEN	WANG WAT	20.2
21	SAP BON	WANG WAT	10.2
22	WANG WAT	NA RAYA	16.1
23	NA RAYA	THA PONG (W)	21.3
24	THA PONG (W)	THA PONG (E)	4.3
25	THA PONG (E)	WANG KATHA	4.7
26	THA PONG (E)	HUAI NAM DAM	23.0
27	WANG KATHA	NONG BUA RAWE	21.0
28	HUAI NAM DAM	LUP PHO	33.0
29	NONG BUA RAWE	NON PUAI	12.0
30	NON PUAI	LUP PHO	6.0

LEGEND

- SELECTED ROUTE (SBST ROAD)
- SELECTED ROUTE (SOIL AGGREGATE SURFACED ROAD)
- A PART OF THE PROPOSED PHETCHABUN - CHAI BADAN HIGHWAY
- EXISTING ROAD
- EXISTING SMALL TRACK
- [23] SEGMENT NUMBER

SEGMENT NO	SECTION FROM	SECTION TO	LENGTH (KM)
1	NONG BUA	ROUTE 11	2.4
2	ROUTE 11	ANG HIN	4.7
3	ANG HIN	NONG PHAI	4.6
5	NONG PHAI	NONG NGU LUAM	12.7
7	NONG NGU LUAM	SAP SOMBUN	11.0
12	SAP SOMBUM	RAHUN	11.9
18	RAHUN	NONG DAENG	12.8
19	NONG DAENG	SAP BON	5.3
21	SAP BON	WANG WAT	10.2
22	WANG WAT	NA RAYA	16.1
23	NA RAYA	THA PONG (W)	21.3
24	THA PONG (W)	THA PONG (E)	4.3
25	THA PONG (E)	WANG KATHA	4.7
27	WANG KATHA	NONG BUA RAWE	21.0
29	NONG BUA RAWE	NON PUAI	11.3
30	NON PUAI	LUP PHO	5.7

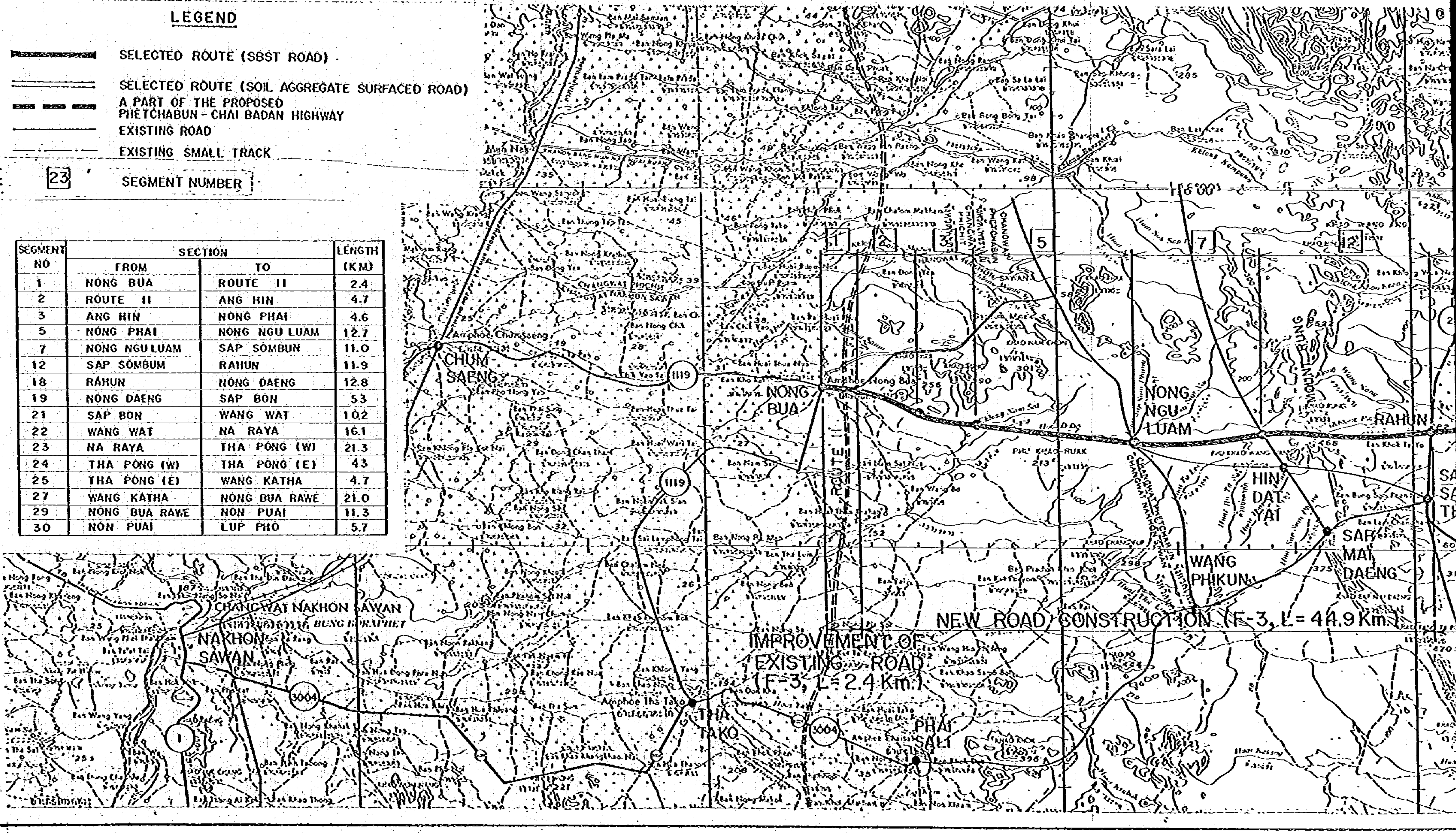
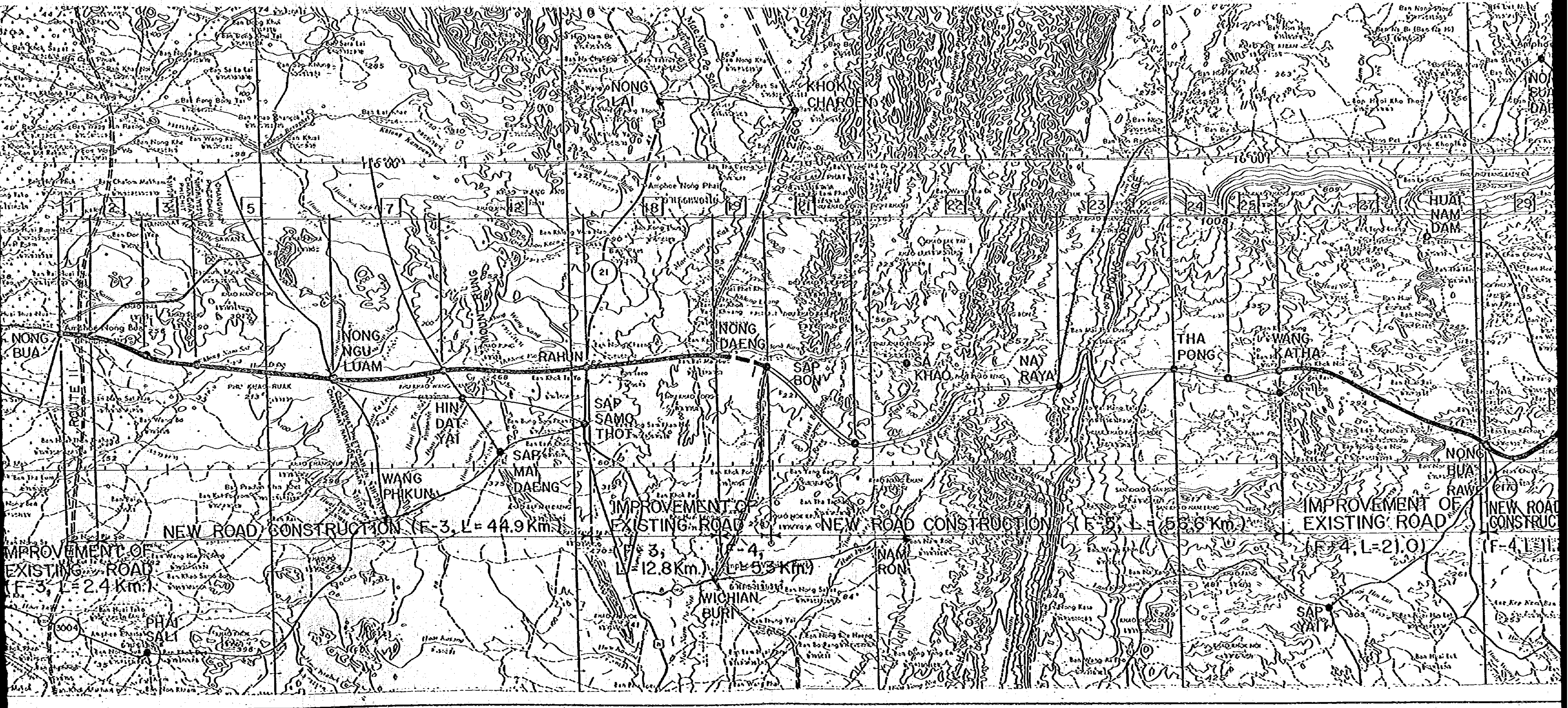


FIGURE 8-2 SELECTED OPTIMUM ROUTE



SELECTED OPTIMUM ROUTE

FIGURE 8-2

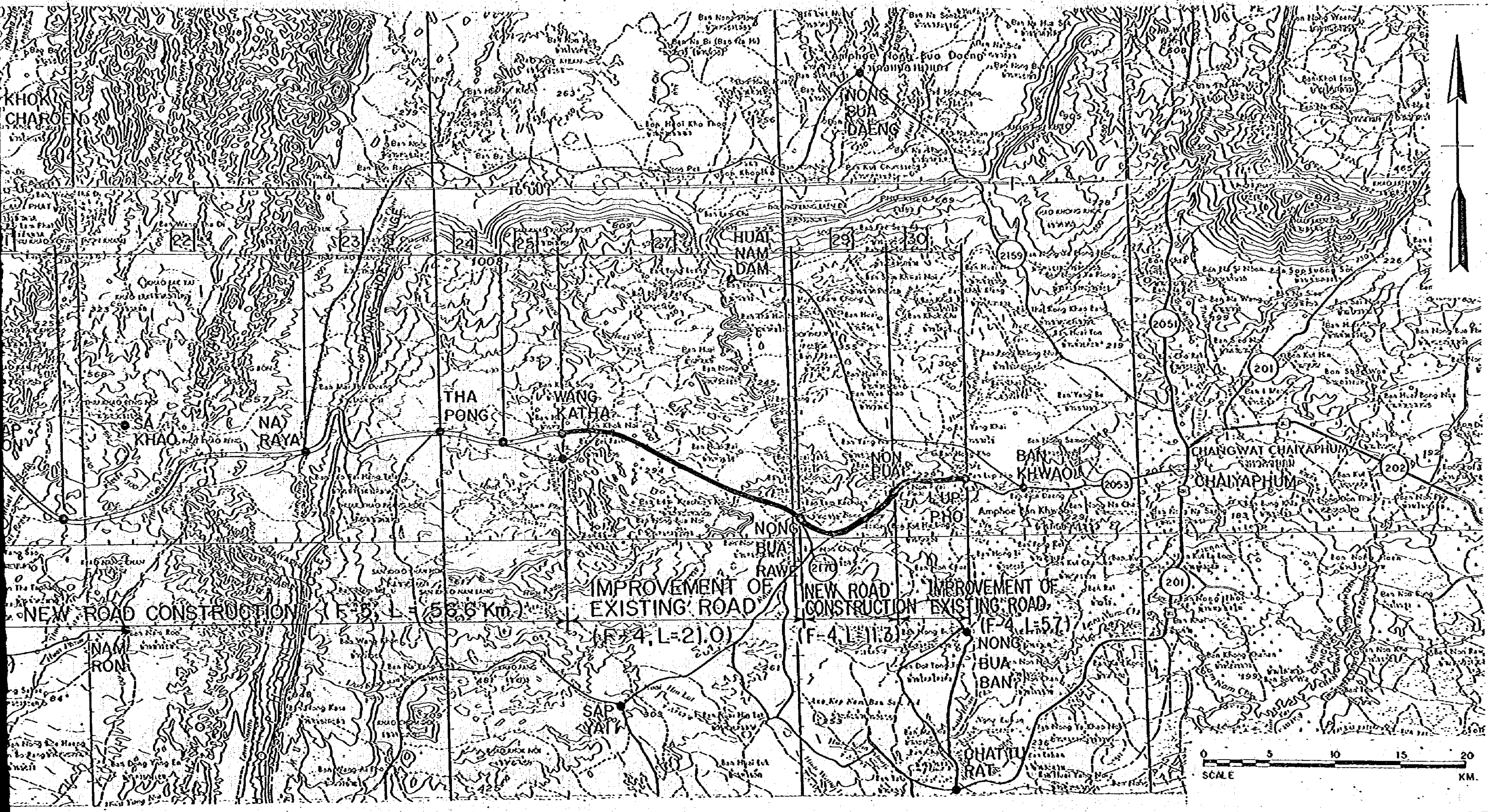


Figure 8-3 PAVEMENT DESIGN CHART

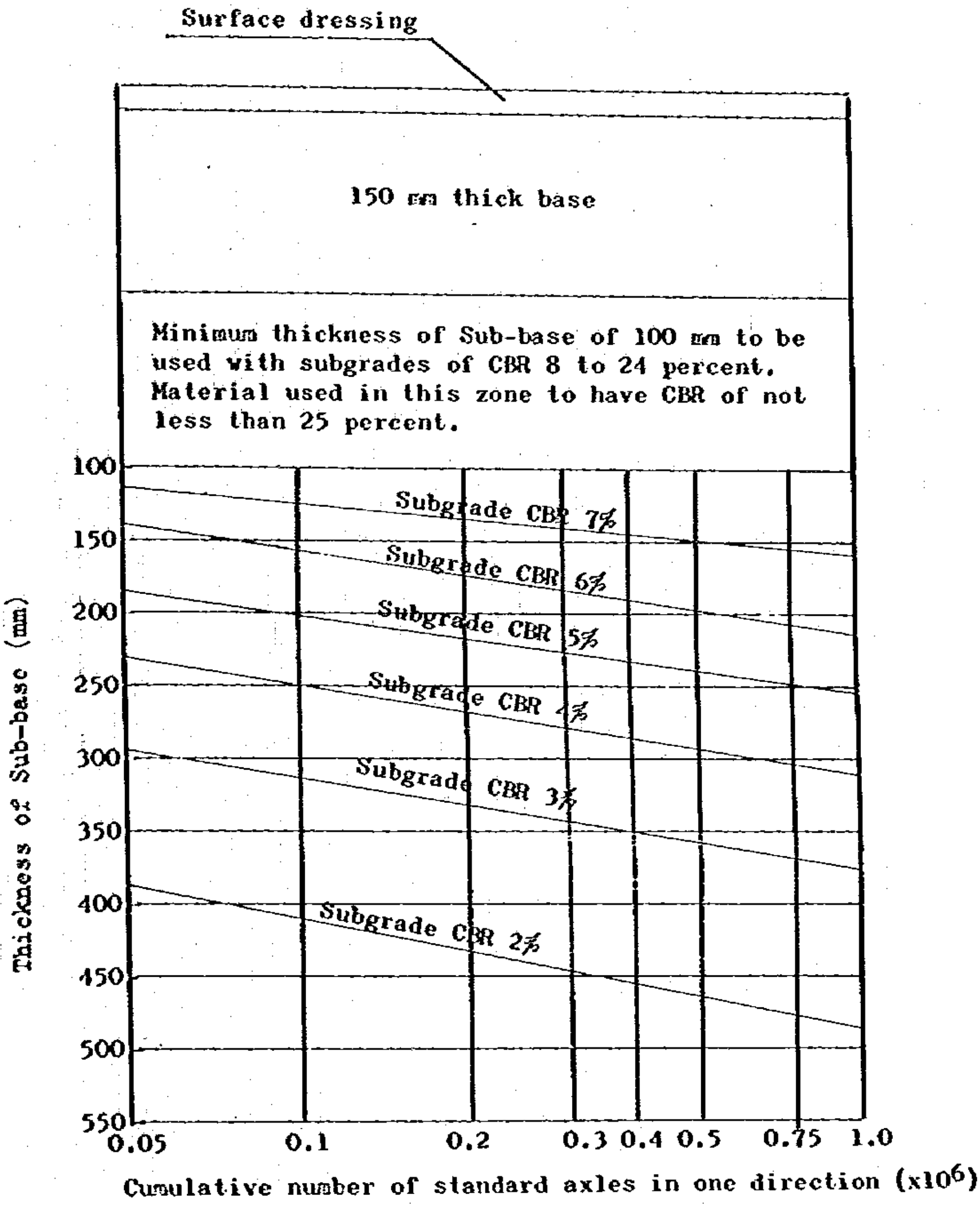


Figure 8-4 IMPLEMENTATION AND WORK SCHEDULE

IMPLEMENTATION SCHEDULE

Item	1979	1980	1981	1982	1983	1984
Feasibility Study						
Detailed Design						
Tendering - Contract Award						
Land Acquisition						
Construction						
Opening						

WORK SCHEDULE (LOT - I) L = 35.4 KM (STA. 0+000 - STA.35+400)

Work Item	Unit	Quantity	1981	1982	1983	1984
Mobilization and Preparatory Works	-					
Clearing and Grubbing	ha	135				
Soil Excavation	m^3	0				
Rock Excavation	m^3	0				
Embankment	m^3	263,540				
Selected Fill	m^3	77,530				
Subbase and Shoulder	m^3	68,910				
Base	m^3	37,180				
Prime and SBST	m^2	212,400				
Pipe Culvert	m	765				
Box Culvert	m	51				
Short Span Bridge	m	85				

WORK SCHEDULE (LOT - II) L = 24.7 KM (STA. 35+400 - STA.60+100)

Work Item	Unit	Quantity	1981	1982	1983	1984
Mobilization and Preparatory Works	-					
Clearing and Grubbing	ha	63				
Soil Excavation	m^3	190,980				
Rock Excavation	m^3	12,490				
Embankment	m^3	270,560				
Selected Fill	m^3	55,950				
Subbase and Shoulder	m^3	49,330				
Base	m^3	25,770				
Prime and SBST	m^2	147,240				
Pipe Culvert	m	581				
Box Culvert	m	43				
Short Span Bridge	m	262				

WORK SCHEDULE (LOT - III) L = 26.3 KM (STA. 65+400 - STA. 91+700)

Work Item	Unit	Quantity	1981	1982	1983	1984
Mobilization and Preparatory Works	-					
Clearing and Grubbing	ha	105				
Soil Excavation	m^3	269,780				
Rock Excavation	m^3	262,070				
Embankment	m^3	378,400				
Selected Fill	m^3	53,720				
Subbase and Shoulder	m^3	49,320				
Base	m^3	1,570				
Prime and SBST	m^2	8,800				
Pipe Culvert	m	743				
Box Culvert	m	105				
Short Span Bridge	m	75				

WORK SCHEDULE (LOT - IV) L = 30.3 KM (STA. 91+700 - STA. 122+000)

Work Item	Unit	Quantity	1981	1982	1983	1984
Mobilization and Preparatory Works	-					
Clearing and Grubbing	ha	121				
Soil Excavation	m^3	184,290				
Rock Excavation	m^3	276,480				
Embankment	m^3	235,860				
Selected Fill	m^3	62,020				
Subbase and Shoulder	m^3	56,540				
Base	m^3	5,190				
Prime and SBST	m^2	29,150				
Pipe Culvert	m	890				
Box Culvert	m	54				
Short Span Bridge	m	130				

WORK SCHEDULE (LOT - V) L = 38.0 KM (STA. 122+000 - STA. 160+000)

Work Item	Unit	Quantity	1981	1982	1983	1984
Mobilization and Preparatory Works	-					
Clearing and Grubbing	ha	136				
Soil Excavation	m^3	24,520				
Rock Excavation	m^3	0				
Embankment	m^3	200,770				
Selected Fill	m^3	33,630				
Subbase and Shoulder	m^3	67,840				
Base	m^3	36,940				
Prime and SBST	m^2	207,270				
Pipe Culbert	m	850				
Box Culbort	m	0				
Short Span Bridge	m	225				

Chapter IX

EVALUATION

9-1 GENERAL

The proposed Project is an integral part of the Government's program to improve the rural and provincial highway networks in order to stimulate and accelerate the socio-economic development in the rural areas. The proposed road, which connects three Changwats in an east-west direction, meets consequently the Government's policy to decentralize the industrial activities away from Bangkok and to enhance the economic exchanges between rural centers. The immediate objectives of the Project include (i) to reduce the transportation costs, (ii) to improve access especially in rainy season and (iii) to accelerate the agricultural development along the route. The first objective will be evaluated in estimation of savings of road users' costs for forecasted traffic. The other two objectives will be assessed in estimation of net added value of agricultural development.

In addition to the above quantifiable benefits, one of the most important effects of the Project will be that the proposed road improves greatly trunk road network in the area connecting major centers in three Changwats in an east-west direction.

9-2 ECONOMIC EVALUATION

9-2-1 Economic Costs

The economic costs of the Project include construction costs and road maintenance costs, estimated by deducting tax elements from the financial costs. They were estimated at 1979 constant price.

The economic construction costs, composed of direct construction cost, engineering and administration costs, physical contingency and land acquisition costs, were estimated in 8-10 and are summarized below:

Construction Costs

(million Baht)

Year	
1980	13.7
1981	93.0
1982	162.3
1983	162.3

The economic road maintenance costs were estimated by the conventional type of equations. Since little information was available of the correlation between road maintenance costs and level of traffic volume by surface type, the following equations were derived based on the previous study/1 after some modifications:

For soil aggregate surface road (F5 Standard)
19,000 + 27 x ADT (Baht/km)

For SBST road (F3 and F4 Standard)
22,000 + 22 x ADT (Baht/km)

For asphalt concrete road (after overlay)
22,500 + 16 x ADT (Baht/km)

/1 "Feasibility Study for Provincial Road Improvements", April,1978.

Annual routine maintenance costs were estimated as shown below. In addition, an overlay cost in 1990, 7th year after opening, was estimated at 50.7 million Baht for F3 and F4 sections.

Annual Routine Maintenance Costs

Year	(million Baht)
1984	5.0
1990	1.4 (only for F5 section)
1998	5.3

To attain the projected agricultural benefits, the initial land preparation costs and the annual production costs are required. However, these costs were not incorporated in the project costs but deducted in the calculation of net agricultural benefits.

9-2-2 Economic Benefits

For the calculation of economic internal rate of return, the following two quantifiable benefits are considered; (i) the savings of road user's costs and (ii) the increment of net added value of agricultural production attributable to the Project.

The savings of road users' costs, which consist of vehicle operating costs and occupants' time cost, were calculated as discussed in Chapter VII and repeated below.

Road Users' Costs Savings

Year	(million Baht)
1984	113.6
1990	130.7
1998	161.6

The agricultural benefits attributable to the proposed road is the increment of net added value of production, that is the difference in net added value between with and without the Project, as discussed in Chapter V. They are summarized below:

Agricultural Benefits

(million Baht)

	1984		1990		1998	
	W	W̄	W	W̄	W	W̄
Net Value of Production	135.5	111.2	181.2	122.5	193.0	137.7
Land Preparation Cost	26.6	3.5	3.4	3.5	3.4	3.5
Net Value Added	108.9	107.7	177.8	119.0	189.6	134.2
Increment	1.2		58.8		55.4	

Note: W : with project W̄ : without project

9-2-3 Economic Justification

Discounting the economic costs and benefits mentioned above over a 20 years evaluation period, the economic internal rate of return (EIRR) of the Project was calculated at 21.7 percent which indicates the Project is justifiable economically. Streams of costs and benefits are tabulated in Table 9-1.

Sensitivity of the EIRR was tested for a case assuming 20 percent increase of costs and reduction of benefits by the same rate. The result shows that the EIRR decreases to 14.5 percent which indicates the Project is still viable economically even in such pessimistic case as the above.

As stated in 8-8-1, it is desirable to pave all sections where F5 standard is assigned, not only steep gradient sections. The additional construction costs were estimated at 40.2 million Baht for the additional pavement of 49.7 km in case that all sections were paved. This increases total construction cost by 6.6 percent and decreases the EIRR from 21.7 percent to 20.7 percent, but the Project is still justifiable economically.

Analysis to check the optimum timing of the Project showed that a postponement of one year would reduce discounted costs of 40.9 million Baht but also reduce discounted benefits of 73 million Baht. This means that the postponement of the Project is not justified and the Project is recommended to be implemented as early as possible.

9-3 EFFECTS TO THE FARMERS

Farmers also benefit from the improvement of road. Farmers' income will increase as a consequence of raising up of farmgate prices owing to the savings of transportation costs and handling costs. Furthermore, improvement of farming practice to be stimulated owing to the Project will bring about the increase of crop production. Annual crop income, after deduction of production cost from gross production revenue, of typical farms, with 25 rai on the Nakhon Sawan/Phetchabun side and 20 rai on the Chaiyaphum side, will be changed as follows:

Annual Farm Income of Typical Farms

(Baht)

Type of Farm	1978		1998			
			Without Project		With Project	
	N/P	C	N/P	C	N/P	C
Paddy Farm	7,217	4,367	7,505	4,633	8,274	5,350
Maize Farm	3,442	2,728	3,608	2,953	4,987	4,104
Cassava/Kenaf Farm	-	7,210	-	7,210	-	11,222

Note: N/P : Nakhon Sawan/Phetchabun Side
C : Chaiyaphum Side

Details are given in Appendix - 13.

9-4 SOCIAL IMPACTS

The Project will have a remarkable social impact to the Area. The project road provides direct connection between three Changwats in an east-west direction. While road network surrounding the Area is relatively denser in a north-south direction, roads in an east-west direction are scarce. There exist only Route 12 and Route 205 which apart more than 150 km each other. In this situation, the proposed road will give a great impact to induce the economic exchanges and communications among three Changwats. The proposed all-weather road will provide better access to the established social institutions such as schools, health centers and administrative centers, and consequently will contribute to the raising up of socio-cultural standard of the rural communities.

9-5 SECTIONAL ANALYSIS

One of the most remarkable characteristics of the Project is that a new road section involving a mountainous section causes an expensive construction cost in spite of small traffic volume. Especially, Road Segment No.21, No.22, No.23 and No.24, Sap Bon to Wang Katha, costs 282.0 million Baht, about 46 percent of total project costs, while its length shares only 36 percent of the total and the forecasted traffic volume does not exceed 300 in ADT in 7th year after opening. However, a sectional economic evaluation showed that the above-mentioned section would be justifiable economically having EIRR of 12.7 percent. Furthermore, the construction of this section is of vital importance in view of the completeness of the inter-Changwat road network, as this section lacks any road at present. Viewing the above, it is recommendable to implement the whole section of the Project.

9-6 CONCLUSION

The evaluation indicates that the Project of the optimum route is technically sound, economically viable and socially desirable. It is worthy of taking further actions toward earliest implementation of the Project. In the subsequent stage, careful work of detailed design is required.

TABLE 9-1

Table 9-1 COSTS AND BENEFITS STATEMENT

(million Baht)

Year	COSTS			BENEFITS				DISCOUNTED AT 12%	
	Const. Cost	RMC	Total	Agricultural Benefit	VOC Saving	Time Cost Saving	Total	Costs	Benefits
1980	13.7		13.7					13.7	
1981	93.0		93.0					83.0	
1982	162.3		162.3					129.4	
1983	162.3		162.3					115.5	
1984		5.0	5.0	1.2	64.5	49.1	114.8	3.2	65.1
1985		5.1	5.1	10.2	66.2	50.2	126.6	2.9	64.1
1986		5.2	5.2	19.3	68.0	51.3	138.6	2.6	62.7
1987		5.3	5.3	28.4	69.7	52.4	150.5	2.4	60.8
1988		5.4	5.4	37.5	71.4	53.6	162.5	2.2	58.6
1989		5.5	5.5	59.2	73.2	54.7	187.1	2.0	60.2
1990		52.1	52.1	58.8	74.9	55.8	189.5	16.8	54.5
1991		5.0	5.0	58.4	77.0	57.5	192.9	1.4	49.5
1992		5.0	5.0	58.0	79.2	59.2	196.4	1.3	45.0
1993		5.1	5.1	57.5	81.3	61.0	199.8	1.2	40.9
1994		5.1	5.1	57.1	83.5	62.7	203.3	1.0	37.1
1995		5.1	5.1	56.7	85.6	64.4	206.7	0.9	33.7
1996		5.2	5.2	56.2	87.7	66.2	210.1	0.8	30.6
1997		5.2	5.2	55.8	89.9	67.9	213.6	0.8	27.8
1998		5.3	5.3	55.4	92.0	69.6	217.0	0.7	25.2
Total	431.3	124.6	555.9	669.7	1,164.1	875.6	2,709.4	381.8	715.8

Discounted Economic Costs:	381.8	
Construction costs	341.6	(89%)
RMC	40.2	(11%)
Discounted Economic Benefits:	715.8	
Agricultural development benefits	157.1	(22%)
VOC saving	318.9	(45%)
Time cost saving	239.8	(33%)
Net Present Value:	334.0	
Benefit Cost Ratio:	1.87	(1.25 if excluded time saving)
IRR:	21.7%	(15.1 if excluded time saving)

Chapter X

RECOMMENDATION

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RECOMMENDATION

1) As the Project is justifiable technically, economically and socially, it is strongly recommended to take necessary actions so as to implement the Project as scheduled.

2) Although the Project is originally classified as a provincial highway, it is recommendable to designate the Project as a secondary national highway in view of a significant importance of the Project to the improvement of inter-regional highway network in the area concerned.

3) It is recommendable to implement the Project as a whole judging from the results of the analysis on the optimum timing of the Project and also of the sectional evaluation. Considering that the massive amount of fund is required for the full development of the Project, it will be one of the possible measures to arrange with an external source for financing the Project.

4) As the detailed design work of the Project would involve engineering problems of high complexity, especially for the difficult section of the mountain crossing and the Pasak crossing, it is desirable to employ a qualified and experienced consulting engineers for the detailed design work.

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