UNITED NATIONS

COMMITTEE FOR COORDINATION OF INVESTIGATIONS
OF THE LOWER MEKONG BASIN

NONG KHAI / VIENTIANE BRIDGE PROJECT
LAOS AND THAILAND

SECOND PHASE REPORT

NOVEMBER 1968

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

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TOKYO JAPAN

Tokyo, 15 November 1968

LETTER OF SUBMITTAL

His Excellency Mr. Takeo Miki
Minister of Foreign Affairs
Tokyo, Japan

Excellency,

I have the honor to present herewith to Your Excellency the Second Phase Report on the Nong Khai/Vientiane Bridge Project for which the works have been entrusted to the Overseas Technical Co-operation Agency by the Government of Japan.

The Government of Japan, fully cognizant of the importance of the economic cooperation with Laos and Thailand, offered in April 1967 to undertake the feasibility study on this project in response to the request of the Committee for Coordination of Investigations of the Lower Mekong Basin.

The Agency dispatched again a team of engineer, the second phase survey team, headed by Mr. Ryozo Yoshida, Chief of the Projects Department of Nippon Koei Co., Ltd., for a period of about four months from February to June 1968.

In Japan, three members of the advisory party headed by Dr. Takeo Fukuda, Professor Emeritus of the University of Tokyo, . the president of Kozo-Keikaku Consultants Co., Ltd. were concerned in the technical advice for the feasibility study of the project in making the preparation of the Second Phase Report.

This report covers the results of the second phase investigation as well as the first phase investigation and provides necessary data for the Mekong Committee to decide the kind of bridge between a rail/highway bridge and a highway bridge at the Nong Khai bridge site which was selected from among the three proposed sites in the First Phase Report. This report also has recommended as a conclusion that the Mekong Committee selects the rail/highway bridge for the project.

The decision of the kind of the bridge to be made by the Mekong Committee is urgently required for the compilation of a draft feasibility report of the project which is to be submitted before the session of the Mekong Committee scheduled in January 1969.

Furthermore, in case that a rail/highway bridge would be finally selected, the decision of the railway route between the route C and the combined route C-D, which have been recommended to be more favorable than the other three routes A, B and D in the Second Phase Report, is necessary before proceeding to make the draft feasibility report.

Since the Government of Japan has decided to undertake before long the topographic survey on these two railway routes C and C-D combined, the preparation of a draft feasibility report had probably better be made after the results of the above survey and its subsequent feasibility study are obtained.

It is thus indispensable for the Mekong Committee to decide the kind of the bridge and, if necessary, to select between the two railway routes before the draft feasibility report is provided.

During the field investigations, the members of the survey team have duly achieved the task entrusted to them, with full cognizance of the extensive significance of this project to all the countries concerned.

On this occasion, I wish to express my sincere thanks to all concerned of the Government of Laos and Thailand who have kindly extended their supports and cooperations. My appreciation also goes to the members of the Japanese embassies, who cooperate with us during our investigation, and to the agencies of the Japanese Government and the consulting companies who assisted us in dispatching the survey team.

Respectfully submitted,

Shinichi Shibusawa
President
The Overseas Technical Cooperation Agency

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DATE 10 November 1968

LETTER OF TRANSMITTAL

Mr. Shinichi Shibusawa
President for Overseas Technical
Cooperation Agency
Tokyo, Japan

Dear Sir,

I have the great pleasure to submit herewith to you the Second Phase Report on the Nong Khai/Vientiane Bridge Project for which the works have been entrusted by you to Nippon Koei Co., Ltd.

The Nong Khai/Vientiane Bridge Project aims at constructing a bridge over the Mekong to complete the Asian Highway A-12 from Sara Buri in Thailand to Vientiane in Laos and to extend to Vientiane the existing railway in Thailand now linking Bangkok with Nong Khai, if feasible.

The feasibility study of the project has been made from engineering, economic and financial viewpoints in accordance with the provisions of the Plan of Operation that was signed on 14 April 1967 between the Mekong Committee and the Japanese Government. The works have been divided into four phases and the purpose of each phase is as described below.

First phase: To execute the preliminary investigation and study for the selection of the most favorable bridge site from among the three proposed sites, Nong Khai, Vientiane and Pa Mong, and for the selection of the kind of bridge to be constructed, i.e., a highway bridge versus a rail/highway bridge.

(The required period: 6 months)

Second phase:	To execute the feasibility investigation and study at the bridge site selected by the Mekong Committee. (The required period: 12 months)
Third phase:	To prepare a draft feasibility report on the basis of the results of the investigations and studies executed in the first and second phases. (The required period: 4 months)
Fourth phase:	To print the final feasibility report in accordance with the decisions of the Mekong Committee based on the first, second and third phase reports. (The required period: 2 months)

The first phase investigation was executed for a period from August to October 1967 and the First Phase Report was submitted to the Mekong Committee in December 1967. The Mekong Committee immediately decided to select the Nong Khai bridge site from among the three proposed sites following the recommendation stated in the First Phase Report and the advice of the Advisory Board.

The bridge site had no sooner decided than the second phase investigation was commenced. The investigation was carried out for a period from February to June 1968 and successively the Second Phase Report was prepared and thus submitted about two months ahead of the schedule of January 1969.

The main purposes of the Second Phase Report are (1) to study the engineering, economic and financial feasibilities of the two kinds of bridge, a rail/highway bridge and a highway bridge, and to select between the two by comparing the engineering, economic and financial merits and demerits of them, (2) to study the engineering, economic and financial feasibilities of linking two parts of the Asian Highway A-12 that lie separately on both Laotian and Thai territories, and (3) to study the engineering, economic and financial feasibilities regarding the extension of the existing railway running between Bangkok and Nong Khai up to Vientiane.

From the comprehensive considerations, the Second Phase Report has recommended a rail/highway bridge to be selected by the Mekong Committee for the Nong Khai/Vientiane Bridge Project.

We are now ready to proceed to the third phase work of preparing a draft feasibility report of the project. The Mekong Committee is respectfully requested to decide the following three matters so that we can start the said work.

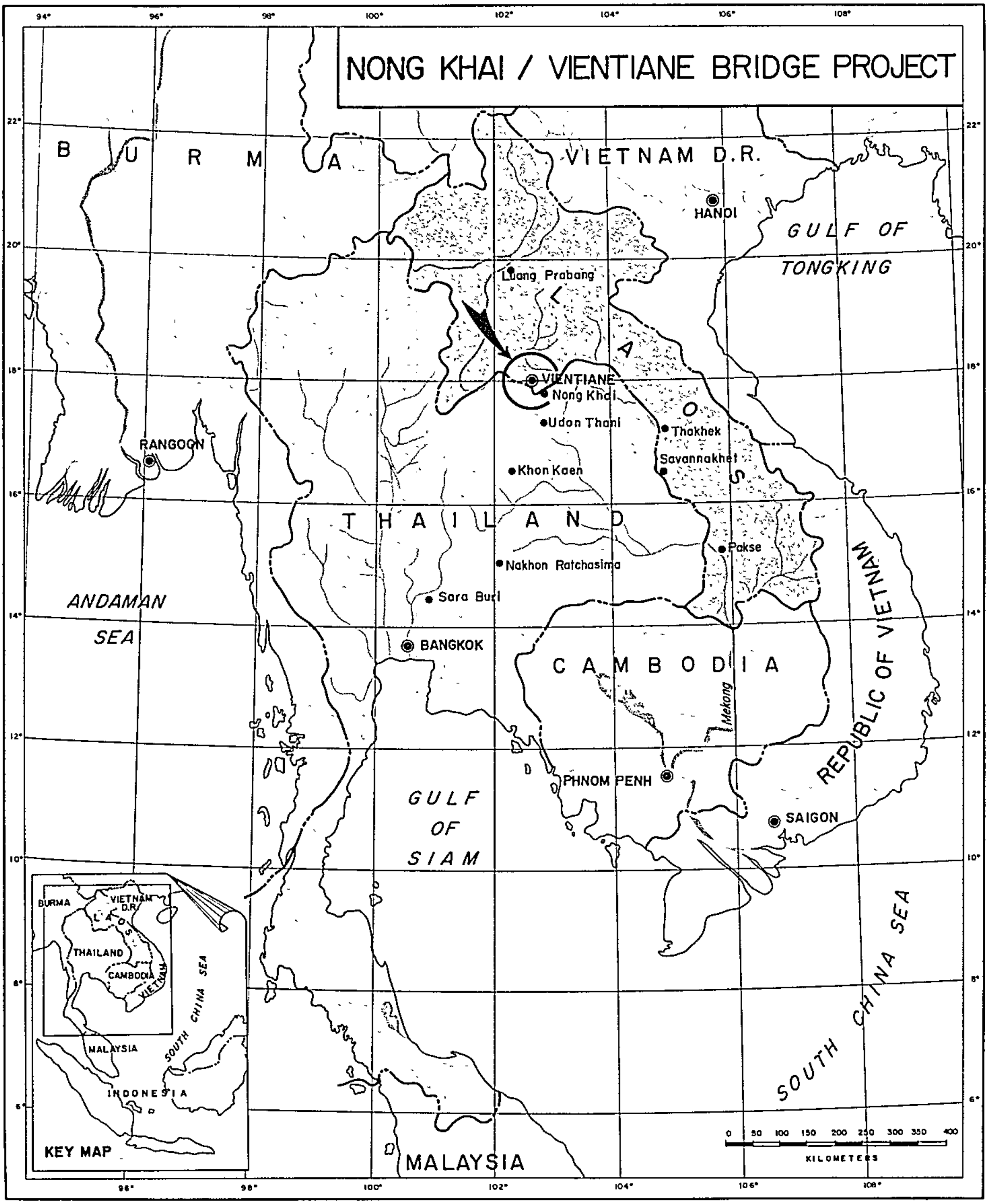
(1) To finally select between the two kinds of bridge, i.e., a rail/highway bridge or a highway bridge,

(2) To finally select between the two railway routes, C and C-D combined, in case that a rail/highway bridge is selected. These two routes have been recommended to be more profitable than the other three routes A, B, and D in the Second Phase Report. It is very difficult to recommend either of the two routes C and C-D combined, as mentioned in Chapter III, Paragraph 3.2., in this report.

The Japanese Government has decided to carry out before long the topographic survey on these two routes to make the feasibility study of the extension railway, of which the field investigations hitherto made have been confined to the extent of possibility according to the Plan of Operation.

Consequently, it is reasonable to finally select between the two after the said feasibility study is completed. The results of the above survey and study, however, are expected to be drawn in mid-April 1969 and therefore are not in time for the preparation of the draft feasibility report that is scheduled to be submitted in January 1969. If it is strongly desired that the results are reflected upon the report, the draft feasibility report should be prepared after the feasibility study of the extension railway is finished, or if it is required to prepare the draft report on schedule, either the route C or the combined route C-D has to be provisionally selected by the Mekong Committee.

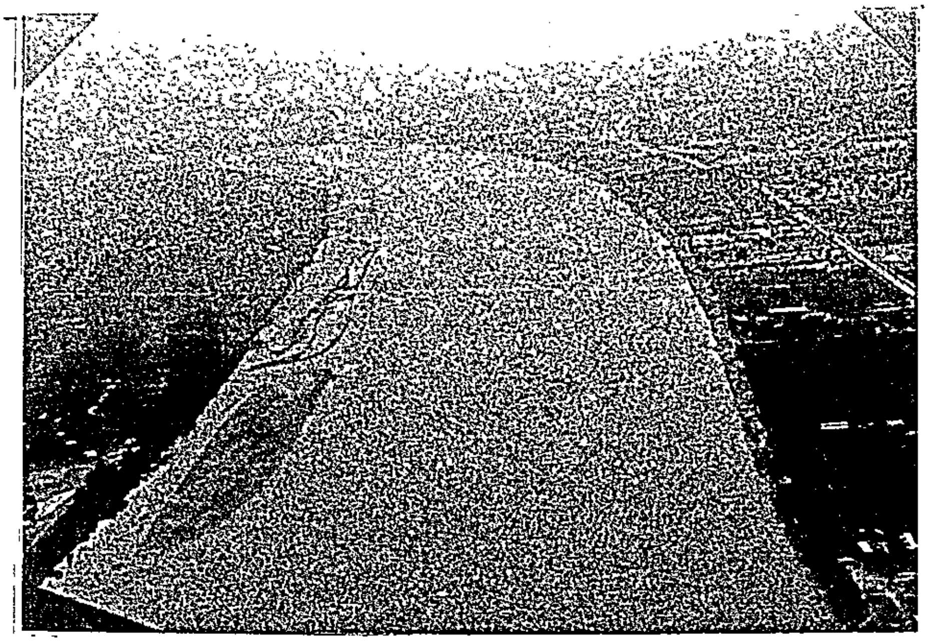
(3) It is our desire that the Mekong Committee recommends us a standard loan or two to practically make the studies of the economic and financial feasibilities of the project, although three kinds of loan have been taken up for the studies in the Second Phase Report, namely, a loan in 40 years at three-percent



NONG KHAI / VIENTIANE BRIDGE PROJECT
BURMA
VIETNAM D.R.
HANOI
GULF OF TONGKING
Luang Prabang
LAOS
VIENTIANE
Nong Khai
Udon Thani
Thakhek
Savannakhet
Khon Kaen
RANGOON
THAILAND
Pakse
Nakhon Ratchasima
Sara Buri
ANDAMAN SEA
BANGKOK
CAMBODIA
Mekong
REPUBLIC OF VIETNAM
PHNOM PENH
SAIGON
GULF OF SIAM
SOUTH CHINA SEA
MALAYSIA
KILOMETERS
0 50 100 150 200 250 300 350 400
KEY MAP
BURMA
VIETNAM D.R.
LAOS
THAILAND
CAMBODIA
VIETNAM
MALAYSIA
INDONESIA
SOUTH CHINA SEA

BRIDGE SITE

Thai side



Laotian side

VIEW FROM DOWNSTREAM

Downstream

Upstream

VIEW FROM LAOTIAN SIDE

NONGKHAI/VIENTIANE BRIDGE PROJECT

SECOND PHASE REPORT

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SEPARATE VOLUME

A report entitled "APPENDICES" has been separately provided as an integral part of the Second Phase Report.

ABBREVIATIONS

m.	meter
g.	gram
kg	kilogram
lb.	libra (pound)
kg/m^3	kilogram per cubic meter
lb/yrd	pound per yard
sec	second
hr.	hour
%	percent
$^o/oo$	per mill
^oC	centigrade
kv.	kilovolt
kva.	kilovolt ampere
P.S.	pferd-stärke (horse power)
US$	U.S. dollar
No.	number
EL.m.	elevation in meter (above mean sea level)
Fig.	figure
CBR	California Bearing Ratio
Max.	Maximum
Min.	Minimum
L.W.L.	low-water level
H.W.L.	high-water level
D.H.W.L.	design high-water level
B/C	Benefit-cost ratio

CURRENCY EXCHANGE RATE

1 U.S. dollar = 20.5 Bahts = 500 Kips

1 Baht = 24.5 Kips

SUMMARY AND RECOMMENDATION

S.1. Feasibility

Nong Khai/Vientiane Bridge Project is feasible. Whether the bridge is a rail/highway bridge or a highway bridge, the project involves no engineering difficulty and is much beneficial to Laos and Thailand undoubtedly.

A test drilling was carried out into the Mekong river-bed for four months from February to June 1968. As a result it was found that the alluvial deposits cover comparatively thinly over the Jurassic reddish siltstone with shale layers intercalated, and the siltstone is firm enough to support the bridge. It is not difficult to excavate the alluvial deposits and to found the bridge piers on the said dependable foundation rock. No grave engineering problem is assumed to occur in the course of the bridge construction, although it goes without saying that the bridge should carefully be constructed. The project structures other than the bridge are quite ordinary. The construction cost is estimated at 20,000,000 U.S. dollars in the case of a rail/highway bridge and 12,000,000 U.S. dollars in the case of a highway bridge.

After construction, the project can produce the benefit of about 9,000,000 U.S. dollars annually, provided that the construction is implemented with a generous grant or a soft loan. Even in a loan with ten-percent rate of interest, the annual benefit amounts to about 4,000,000 or more U.S. dollars equivalent.

The benefit-cost ratio is more than 7 in the case of a grant or a soft loan, and around 2 for a loan at ten-percent rate of interest. The internal rate of return is estimated at 12 percent at the worst case.

The project also brings about much indirect benefit such as the saving of transportation cost, the saving of stock in shops and factories, the increase of land price, and expedition of agricultural development, livestock industry, mining, lumber industry and so forth. In the case of a rail/highway bridge, rapid urbanization is expected in the vicinity of the Vientiane railway station that is planned to be constructed at the outskirts of Vientiane, and will cause much increase in land price. The resultant income of land-owners is estimated at about 13,000,000 U.S. dollars equivalent in the total capitalized worth of 1973 during the period from 1973 to 1990.

Viewed from the financial point, if a soft loan is financed, the project can repay the loan with the bridge tolls as low as more than one eighth of the current ferry charge for buses, personal cars, taxis and railway freight and one fourth for heavy trucks. As the annual rate of interest of loan is raised, the bridge toll of each of the traffic components also gets higher. The bridge tolls are almost equal to the current ferry charges in the case of a loan with ten-percent annual rate of interest.

As understood from the above matters, Nong Khai/Vientiane Bridge Project is feasible from the engineering, economic and financial view-points and most beneficial in case that a generous grant or a soft loan is financed.

S.2. Construction

At the present moment, two kinds of bridge are considered: a rail/highway bridge and a highway bridge. In the case of a rail/highway bridge, a single-track railway and a two-lane highway are to be separately built on a bridge. A sidewalk and a gangway for track inspection also are provided. The railway is to be extended up to Vientiane via the bridge after branching off at Nong Khai from the existing northeastern trunk line of the Royal State Railway of Thailand, and the Asian Highway A-12 that at present is divided into two parts by the Mekong is to be connected by means of the bridge. In the case of a highway bridge, only a two-lane highway with two sidewalks on either side is to be provided on a bridge and the said highway is to be linked with each other.

The following are the principal features of the project.

Table S.1. Project features

Item	Unit	Characterization	
		Rail/Highway bridge	Highway bridge
I. Project			
1. Location		600 km northeast of Bangkok, 20 km south-east of Vientiane and 3 km upstream of Nong Khai	Same as the left
2. Purpose		To build a bridge across the Mekong including the con-struction of access highway, a new rail-way to be extended to Vientiane, im-migration offices, customhouses and other structures	To build a bridge across the Mekong including the con-struction of access highway, immigration offices, customhouses and other structures
3. Construction cost	US$	20,000,000	12,000,000
II. Bridge			
1. River width	m	640	Same as the left
2. Navigation requirements			
(i) Vertical clearance	m	10	"
(ii) Horizontal clearance	m	78	"
3. Design high-water level	m	EL. 167	"
4. Type			
(i) Main part		Steel 3-span-continuous Warren truss	Steel 3-span-continuous box-girder (Battledeck floor)

- continued -

Item	Unit	Characterization	
		Rail/Highway bridge	Highway bridge
(ii) Other part			
Railway part (Ry)		Plate girder and reinforced concrete 3-span-continuous-rigid frame	
Highway part (Hy)		Composite girder and reinforced concrete 3-span-continuous-hollow slab	
5. Bridge width			
(i) Railway part	m	4.0	
(ii) Highway part	m	8.0	8.0
(iii) Sidewalk	m	1.5	1.5 each
(iv) Gangway	m	1.5	
(v) Total width	m	17.8	11.6
6. Bridge length			
(i) Main part	m	720	710
(ii) Other part			
Plate girder (Ry)	m	60	
Composite girder (Hy)	m	60	
Rigid frame (Ry)	m	341.7	
Hollow slab (Hy)	m	270	
7. Number of abutment and pier	m	11	13
8. Span			
(i) Main part	m	(70-70-70)x3+90	(50-60-50)x3+ (70-90-70)
(ii) Other part			
Plate girder (Ry)	m	30+30	
Composite girder (Hy)	m	30+30	
Rigid frame (Ry)			
Thai side	m	(10-10-10)+ (6-10-10-10)x4	
Laotian side	m	(8-15-8)+(6-10-10-10) x3+(6-8-8-6.7)	
Hollow slab (Hy)	m	(15-15-15)x6	

- continued -

Item	Unit	Characterization	
		Rail/Highway bridge	Highway bridge
9. Summit of formation	m	EL. 179.270	EL. 182.560
10. Longitudinal grade			
(i) Main part	%	1.2	4.0 (Laotian side) 2.8 (Thai side)
(ii) Other part			
Plate girder (Ry)	%	1.2	
Composite girder (Hy)	%	1.2	
Rigid frame (Ry)	%	1.2	
Hollow slab (Hy)	%	4.0	
III. <u>Highway</u>			
1. Access highway			
(i) Length			
Laotian side	Km	0.1	Same as the left
Thai side	"	4.9	5.3
(ii) Width			
Roadway (two lanes)	m	7	Same as the left
Shoulder (each on both side)	m	2.5	"
(iii) Radius of curvature	m	500, 110	500, 200
2. Administrative facilities (relative to immigration and customs)			
Laotian side	m^2	125,000	65,000
Thai side	m^2	60,000	60,000
IV. <u>Railway</u>			
1. Length			
(i) Laotian side (Route of C-D combined)	Km	19.2	
(ii) Thai side	"	0.9	
2. Track gauge	m	1.000	
3. Radius of curvature	m	600, 400	

- continued -

Item	Unit	Characterization	
		Rail/Highway bridge	Highway bridge
4. Station			
(i) Vientiane station (including administrative facilities)	m^2	107,900	
(ii) New Nong Khai station (including administrative facilities)	m^2	32,200	

The project structures are outlined in PLATE 1 to 23. These structures have been so planned as to meet the requests of both Laotian and Thai Governments as well as from engineering and economical viewpoints. As the Mekong forms the border between Laos and Thailand in this region, special administrative facilities are required to go through due formalities such as immigration and customs. Four couples of examples are shown in PLATEs 22 and 23.

As mentioned before, the project will cost about 20,000,000 U.S. dollars in the case of a rail/highway bridge and about 12,000,000 U.S. dollars in the case of a highway bridge. The annual cost is estimated at about 2,000,000 U.S. dollars in the former case and 1,000,000 U.S. dollars in the latter case, respectively. The useful life of the project is assumed to be nearly 40 years in the former case and a little more than that in the latter case.

S.3. Benefit

After the project is completed, much benefit accrues from the project. At first, traffic will rapidly increase. The users of the bridge will make a noticeable profit on the savings of travel time and vehicular operation cost, comfortable traveling, less chance of accidents, increase in carrying capacity, and so forth. Furthermore, the project will positively affect the rise in land value, drop of the price of the commodities, the rise in development value of natural resources, promotion of tourism, progress in economic activities, and so on.

Table S.2 shows the principal values of the project regarding the future traffic, benefit, cost, adequate tolls, internal rate of return, and so on. The future traffic volumes given in Table S.2 were estimated based on the results of the origin-destination survey that was executed in the first phase investigation and the economic data collected in the second phase investigation. The future traffic growth regarding vehicles largely depends on the bridge toll. If the bridge is free of charge, the future traffic remarkably increases as shown in Table S.2. In case that the bridge tolls are all the same as the current ferry charge, the future traffic growth is much less than that of the non-toll bridge as understood from the figures given in Table S.2. As for the railway freight and the railway passengers, the future growths of them are not so remarkable as that of vehicle.

The annual benefits of the bridge have been computed as the sum of the savings in the time and cost of travel and the current ferry charge in comparison with the current ferry running between Tha Naleng and Nong Khai. The values of the annual benefit given in Table S.2 are the maximum annual benefits obtainable during the amortization period in relation to the adequate tolls of the traffic components. As regards loans, three kinds of loans were considered for the economic justification and financial feasibility of the project: (1) 3-percent rate of interest and 40-year repayment period, (2) 7-percent rate of interest and 25-year repayment period and (3) 10-percent rate of interest and 20-year repayment period. The annual benefit has been estimated in case that the project is implemented with a generous grant, too.

The annual cost comprises the annual amortization cost and the working expenses such as costs of operation, maintenance and replacement of the project structures. The annual amortization cost was estimated based on the construction cost considering respective usable lifetimes of various structures.

The adequate tolls were decided so that a given loan could be entirely repaid during its amortization period and the maximum annual benefit could be obtained during that period based on the future traffic estimated under such tolls.

The financial feasibility of the project has thus been studied at the same time. The financial problem largely depends on the bridge toll. When the bridge tolls are as high as the current ferry charges, it is very easy to repay loan but the traffic growth is low. As the bridge tolls become lower, the future traffic growth becomes higher. In this project, the annual rate of interest of loan should be limited to around 10 percent or less to solve the financial problem within favorable extent.

S.4. Necessity

As mentioned above, once it is realized the project can bring about vast benefit to both Laotian and Thai peoples from the cost equivalent to some fraction of the benefit. The project not only is thus promising but also involves a pressing need for its realization as follows.

Laos is a landlocked country surrounded by Thailand, Burma, China, North Viet Nam, South Viet Nam, and Cambodia. With no direct access to the sea, Laos' trade with foreign countries has been carried out for these several years via inland routes in Thailand from the port of Bangkok to Vientiane.

Before the World War II, Laos along with Viet Nam and Cambodia formed the Indochina, a political entity under French Rule. It was then natural that all the communication systems from Laos were linked with Viet Nam and Cambodia. A long highway network was built to connect principal cities in Laos to Hanoi/1, Haiphong, Hue, and Danang.

/1 The length of each of the transportation routes is estimated to be:

(1) Hanoi to Vientiane:	800 Km long by road
(2) Saigon or Phnom Penh to Vientiane:	1,200 Km long by road
(3) Bangkok to Vientiane:	600 Km long by road or by rail

Along the Mekong in Laos, an important artery road connected Vientiane to Thakek, Savannakot, Pakse and then crossed the border into Cambodia toward Phnom Penh and Saigon.

Before 1945, most of the Laos' foreign trade was made either through Cambodia or Viet Nam and scarcely through Thailand. At present, however, with the new situation created in this region after the War, trade through Thailand has become the main route for commodities flowing in and out of Laos.

Nowadays, Bangkok serves as the main port for Laos and the goods destined for Laos are conveyed from the port of Bangkok by rail or by road to Nong Khai on the south bank of the Mekong. At Nong Khai, cargos are transshipped to the ferry to cross the Mekong and then carried to Vientiane again by trucks. Accordingly, the ferry crossing of the Mekong constitutes bottleneck for the traffic to and from Laos. The existing ferry facilities are no more able to service the increasing volume of traffic. Long rows of trucks awaiting the ferry on the Nong Khai side are witnessed these days.

It is a long cherished desire of the Laotian people as well as the Thai people to connect Laos with Thailand across the Mekong by constructing a modern structure like a bridge.

S.5. Feasibility Investigations

Pushed by such a pressing need, the Mekong Committee requested in February 1967 the assistance of the friendly countries concerned to the execution of a feasibility study of the project.

The Japanese Government offered to undertake the feasibility study at the 32nd Session of the Mekong Committee in April 1967. The Laotian and Thai representatives accepted this offer and the Plan of Operation of the investigation was signed on 14 April 1967 between the Mekong Committee and the Japanese Government.

The execution of the investigation was entrusted to the Overseas Technical Cooperation Agency by the Ministry of Foreign Affairs of the Government of Japan. The Agency requested Nippon Koei Co., Ltd. for cooperation.

According to the Plan of Operation, the feasibility study is divided into four phases. The first phase investigation was performed at site during the period from August to October 1967 and the First Phase Report was submitted to the Mekong Committee at the end of December 1967 so as to be in time for the thirty-fourth session held at Bangkok in mid-January 1968.

The Mekong Committee decided to select the Nong Khai bridge site from among the three proposed sites of Nong Khai, Vientiane and Pa Mong based on the conclusion and recommendation stated in the First Phase Report and the advice of the Advisory Board after reviewing the report at the Board meeting held successively after the thirty-fourth session. The second phase investigation was conducted as soon as the bridge site had been decided. The Japanese bridge team was despatched from mid-February 1968 to mid-June 1968.

The following six kinds of the surveys were conducted in the first and second phase investigations: topographic survey, soil survey, material survey regarding concrete aggregates and embankment materials, reconnaissance for several routes of railway and highway, collection of various kinds of engineering data and economic survey. The feasibility investigations have thus been almost completed at the present moment, but there still remain some more feasibility investigations to be made. In addition, various kinds of the detailed investigations shall be implemented before construction.

The following are such indispensable investigations.

(1) Route survey of the railway to be extended from Nong Khai to Vientiane,

(2) Field investigations concerning the bank erosion and river-bed scouring,

(3) Detailed material survey concerning concrete aggregate, river sand and gravel for pavement use, embankment materials, ballast, laterite and stone,

(4) Detailed topographic survey,

(5) Detailed design of the project structures, and

(6) Preparation of the tender documents.

S.6. Conclusion and Recommendation

Although there are thus a few feasibility investigations to be carried out in the near future, there is no room to doubt that Nong Khai/ Vientiane Bridge Project is feasible to the satisfaction of the authorities concerned and is worth undertaking the materialization of the project as soon as possible. It is advisable to seek for a favorable loan at the earliest moment for financing the project. Before that, either the rail/highway bridge or the hgihway bridge has to be selected and the feasibility report of the project shall be provided regarding the selected kind of bridge.

As for the decision of the kind of bridge, it is recommended that the rail/highway bridge be finally selected as mentioned in Chapter V. Although the highway bridge can guarantee more capitalized net benefit and higher benefit-cost ratio than the rail/highway bridge as indicated in Table S.2, the rail/highway bridge has the advantage of the highway bridge when synthetically judged from the results shown in Table S.2. taking into consideration the various indirect benefits. If the rail/ highway bridge is selected by the Mekong Committee after the submission of the Second Phase Report, successively the railway route to be constructed on Laotian soil has to be selected from among the proposed five routes, A,B,C,D and C·D combined. In the Second Phase Report, the route C and the combined route C.D are more recommended than the other three routes. In selecting between the two routes, the results of the route survey of the extension railway, which is going to be undertaken before long by the same Japanese bridge team, should be referred to. The results of this route survey are scheduled to be obtained in mid-April 1969.

Table S.2. Future traffic, benefit and cost

Item	Unit	Rail/highway bridge Toll	Rail/highway bridge Non-toll	Highway bridge Toll	Highway bridge Non-toll
I. FUTURE TRAFFIC					
1. Estimated future traffic					
(i) Vehicles					
A.D. 1973	vehicles/day	747	1,273	1,084	1,640
1990	"	4,647	8,317	6,377	10,140
2000	"	6,941	12,459	9,490	15,146
(ii) Railway freight					
A.D. 1973	tons/day	591	609		
1990	"	2,586	2,664		
2000	"	3,760	3,873		
(iii) Railway passengers					
A.D. 1973	persons/day	337	361		
1990	"	1,796	1,922		
2000	"	2,654	2,840		
II. DIRECT BENEFIT					
1. Annual benefit					
(i) Loan I, (3%, 40 years)	US$	8,784,000		8,546,000	
(ii) Loan II, (7%, 25 ")	"	5,923,000		5,902,000	
(iii) Loan III, (10%, 20 ")	"	3,929,000		4,632,000	
(iv) Grant	"		9,281,000		8,994,000
2. Capitalized benefit					
(i) Loan I	(US$)	174,846,000		170,002,000	
(ii) Loan II	"	55,404,000		55,152,000	
(iii) Loan III	"	27,612,000		32,160,000	
(iv) Grant	"		289,644,000		280,161,000
III. COST					
1. Annual cost					
(i) Loan I	US$	1,198,600		699,200	
(ii) Loan II	"	1,825,700		1,087,500	
(iii) Loan III	"	2,364,800		1,419,400	
(iv) Grant	"		1,177,600		665,700
2. Capitalized cost					
(i) Loan I	US$	27,145,000		16,598,000	
(ii) Loan II	"	24,121,000		14,652,000	
(iii) Loan III	"	23,023,000		13,945,000	
(iv) Grant	"		26,659,000		15,823,000
IV. BENEFIT-COST RATIO					
(i) Loan I		7.3		12.2	
(ii) Loan II		3.2		5.4	
(iii) Loan III		1.7		3.3	
(iv) Grant			7.9		13.5
V. CAPITALIZED NET BENEFIT					
(i) Loan I	US$	147,701,000		153,404,000	

continued

Item	Unit	Rail/highway bridge		Highway bridge	
		Toll	Non-toll	Toll	Non-toll
(ii) Loan II	US$	31,283,000		40,500,000	
(iii) Loan III	"	4,589,000		18,215,000	
(iv) Grant	"		262,985,000		264,338,000
VI. ADEQUATE TOLL					
1. Loan I					(Current ferry charge)
(i) Buses	Bahts/vehicle	5		5	(57)
(ii) Personal cars	"	5		5	(40)
(iii) Taxis	"	5		5	(40)
(iv) Heavy trucks	"	30		10	(110)
(v) Light trucks	"	5		5	(57)
(vi) Motorcycles	"	5		5	(5)
(vii) Railway freight	Bahts/ton	5			(40)
(viii) Railway passengers	Bahts/person	5			(5)
2. Loan II					
(i) Buses	Bahts/vehicle	25		5	
(ii) Personal cars	"	5		5	
(iii) Taxis	"	5		5	
(iv) Heavy trucks	"	100		50	
(v) Light trucks	"	25		5	
(vi) Motorcycles	"	5		5	
(vii) Railway freight	Bahts/ton	25			
(viii) Railway passengers	Bahts/person	5			
3. Loan III					
(i) Buses	Bahts/vehicle	55		10	
(ii) Personal cars	"	35		5	
(iii) Taxis	"	35		5	
(iv) Heavy trucks	"	110		85	
(v) Light trucks	"	40		5	
(vi) Motorcycles	"	5		5	
(vii) Railway freight	Bahts/ton	40			
(viii) Railway passengers	Bahts/person	5			
VII. INTERNAL RATE OF RETURN	%	12.4	16.1	16.0	18.7
VIII. INDIRECT BENEFIT					
1. Transportation-cost saving between Bangkok and Vientiane /6	US$	19,635	528,652	19,635	528,652
2. Stock saving /7	"	342	342	342	342
3. Income of landowners due to the increase of land price (Total present worth of those from 1973 to 1990)	"	13,140,000	13,140,000	0	0
4. Agricultural development		Expedited		Expedited	
5. Livestock industry		Self-sustaining expedited		Self-sustaining expedited	
6. Mining		Much expedited		Somewhat expedited	
7. Lumber industry		Much expedited		Somewhat expedited	
8. Urbanization		Rapid urbanization of the vicinity of the Vientiane Station expected		No urbanization expected	

CHAPTER I

INTRODUCTION

1.1. Necessities of the Project Implementation

The Kingdom of Laos is a landlocked country that is entirely separated from the sea. The neighboring countries of Laos are Thailand, Cambodia, South Viet-Nam, North Viet-Nam, China and Burma.

This geographical condition compels the imports and exports of Laos to pass through the territory of any of the neighboring friendly countries in trading with foreign countries.

Before World War II, Laos formed the Indochina, a political entity under French rule, along with Viet-Nam and Cambodia. It was natural that all the communication systems in Laos were linked with Viet-Nam and Cambodia. Several long highways were built to connect principal cities in Laos to Hanoi, Hai Phong, Hue and Da Nang. An important artery connected Vientiane to Thakhek, Savannakhet and Pakse along the Mekong in Laos and then crossed the border into Cambodia towards Phnom Penh and Saigon.

In those days, most of the commercial exchange of the Laotian district was made either through Hanoi/1 and Hai Phong or through Saigon and Phnom Penh and almost none through Bangkok in Thailand.

/1 The length of each of the transportation routes is estimated to be:

(1)	Hanoi to Vientiane	:	800 Km long by road
(2)	Saigon or Phnom Penh to Vientiane	:	1,200 Km long by road
(3)	Bangkok to Vientiane	:	600 Km long by road or by rail

With the changes in the political situation which took place after World War II in this part of the world, Laos at present is depending largely on the route through Bangkok for her foreign trade. It is natural that Laos has chosen this route because it is the shortest among the three routes. In fact, the routes through Hanoi and Saigon have completely been closed since the outbreak of hostilities in Viet-Nam.

The navigation on the Mekong can also be considered as a means of transportation. It, however, is a big problem to be solved in the future by the riparian countries. There are many rapids on the way/1 from the river mouth to Vientiane such as the Samber rapids, Khone falls and Khemarat rapids and so on. It would take much time and much money though it is one of the objectives of the Mekong Project to make possible the navigation all the way in the lower Mekong.

Under the circumstances as mentioned above, it is evident that the route through Bangkok of Thailand which presently is being fully utilized, is most advantageous and reliable. The goods destined for Laos are transported from the port of Bangkok to Nong Khai by trucks on the Asian Highway A-12 or by using the northeastern railway trunk line of the Royal State Railway. Both can ensure smooth and speedy transportation, but at Nong Khai they have to be transshipped to the ferry for crossing the Mekong. After crossing the Mekong they are carried to Vientiane by the Asian Highway A-12 about 20 kilometers away from Tha Naleng in the territory of Laos on the opposite side of Nong Khai.

It is obvious that the crossing of the Mekong by the ferry constitutes a bottleneck for the traffic from and to Laos.

/1 The route running from Vientiane to the river mouth in Viet-Nam is about 1,600 kilometers long, following the course of the main current of the Mekong.

The existing ferry facilities are no more able to service the increasing volume of traffice. Long rows of trucks awaiting the ferry on the Nong Khai side are witnessed these days. The improvement of this passage is indispensable for the promotion of the foreign trade which consequently will contribute to the socio-economic development of Laos, and will become a great incentive to the regional development in the northeastern district of Thailand.

It is a long cherished desire of the Laotian people as well as the Thai people to connect Laos with Thailand across the Mekong by constructing a modern structure like a bridge.

1.2. History of the Project

In 1956, the project of bridging across the Mekong in the Nong Khai-Vientiane region was launched out. A preliminary survey for the selection of bridge site was undertaken primarily by the United States Operations Missions (USOM) in Thailand. The Royal State Railway of Thailand also made a preliminary investigation.

This project especially has been highlighted since the Mekong Committee took it up in 1965 as one of the first priority projects in the Ten-Year Development Program of the Lower Mekong Basin.

The Government of Japan offered to undertake the feasibility study of this project at the thirty-second session of the Mekong Committee held in April 1967. This offer immediately was consented to by the Laotian and Thai representatives. The Plan of Operation was provided and signed between the Mekong Committee and the Government of Japan. The Ministry of Foreign Affairs of the Government of Japan entrusted the execution of the said study to the Overseas Technical Cooperation Agency. The Agency requested Nippon Koei Co., Ltd. for cooperation.

According to the Plan of Operation, the feasibility study is divided into four phases. The first phase investigation was performed at site during the period from August to October 1967 and the First Phase Report was submitted to the Mekong Committee at the end of December 1967 so as to be in time for the thirty-fourth session held at Bangkok in mid-January 1968.

The Mekong Committee decided to select the Nong Khai bridge site from among the three proposed sites of Nong Khai, Vientiane and Pa Mong based on the conclusion and recommendation stated in the first phase report and the advice of the Advisory Board after reviewing the report at the Board meeting held successively after the thirty-fourth session.

The second phase investigation was conducted as soon as the site had been decided. The Japanese bridge team consisting of fifteen (15) specialists and experts was despatched in mid-February 1968 with the aim of completing the site investigation in mid-June 1968. The Second Phase Report, which is a compilation of the findings of the site investigation and the results of the feasibility study, will be submitted by the end of December 1968. In addition, a draft feasibility report also will be prepared concurrently with the Second Phase Report in response to the Mekong Committee's strong desire of having both reports submitted by the end of 1968.

1.3. Purpose and Scope of the Feasibility Investigation

The main purposes of the feasibility investigation on the Nong Khai/Vientiane Bridge Project, as provided in the Plan of Operation, are as follows.

(1) To prepare the report that offers data for selection by the Mekong Committee of the bridge site,

(2) To study the engineering and economic merits and demerits of two kinds/1 of bridge,

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/1 In this report, "the kind of bridge" means the classification from the way of utilization of bridge, i.e., a highway bridge, rail/highway bridge etc., and "the type of bridge" implies the classification from the viewpoint of the structural characteristic of bridge such as a girder bridge, composite girder bridge, truss bridge, continuous bridge, and so forth.

(3) To study the engineering and economic feasibility of the extension of the Asian Highway Route A-12 and the existing railway from Nong Khai to Vientiane by constructing a bridge across the Mekong, and

(4) To prepare the feasibility report in a form acceptable to financial institutions.

Of the above four purposes, the first purpose has been fulfilled in the First Phase Report. Although the second purpose also has been studied in the first phase report, further study will be made during the period of preparing the Second Phase Report. The second phase investigation includes the third purpose. The fourth purpose, which is the preparation of the feasibility report, will be carried out in the third and fourth phase operations.

The following is the extract of Provision III "SCOPE OF WORK TO BE CARRIED OUT BY THE GOVERNMENT OF JAPAN" of the Plan of Operation.

III. SCOPE OF WORK TO BE CARRIED OUT BY THE GOVERNMENT OF JAPAN

The scope of investigation work to be carried out under this Plan of Operation will cover the following phases:

First Phase - Reconnaissance of the area from the proposed Pa Mong damsite down to Nong Khai/Tha Deua. This will involve:

(1) Study of the existing topographic maps and detailed mapping to larger scale of specific areas for the possible location of the bridge and its approaches.

(2) Study of hydrologic data for the proposed sites including the maximum discharge and the fluctuations of water levels.

(3) Reconnaissance soil survey, including a review of the existing surveys, of the possible alternative sites.

(4) Collection of economic and other data related to the project planning.

(5) Preparation of the First Phase Report (30 copies in English) giving various possible alternative sites, and justification for a road and a road/rail bridge, for selection by the Mekong Committee, with the help of the Advisory Board.

The approximate time required for carrying out this phase would be six months.

Phase II - Preparation of cost estimates and benefit appraisals of the bridge construction and the site selected by the Committee. This would involve:

(1) Larger scale topographic maps and supplementary spot levelling, including approaches.

(2) Detailed geological survey at the proposed site.

(3) Collection of detailed hydrologic and hydrographic data at the proposed site.

(4) Collection of detailed economic and other data related to the project planning.

(5) Investigation and testing of suitable construction materials available at and near the site.

(6) Preliminary design of the bridge including foundations, superstructure, and approaches.

(7) Land to be acquired.

(8) Analyses of unit costs of items applicable to the project in the area.

(9) Assessment of economic and social benefits (direct and indirect, tangible and intangible) from the project.

(10) Assessment of design flood.

(ii) Preparation of the Second Phase Report (30 copies in English) for submission to the Mekong Committee for review, with the assistance of the Advisory Board.

This phase will take approximately 12 months.

Phase III - Preparation of a draft feasibility report (30 copies in English) incorporating the suggestions of the Mekong Committee. This report will summarize the results of surveys and studies in the first and second phases. It will be prepared in a form acceptable to financial institutions, as for an application for an investment loan. This phase is likely to take about four months.

Phase IV - Printing of the final report after taking into consideration the decisions of the Mekong Committee based on the First, Second and Third Phase Reports. 100 copies of the printed report in English and 100 copies in French (but not the work of translation of the report into French) will be required.

This phase will take about two months.

The total period for carrying out the four phases would require approximately two years, not including the time during which the reports on Phases I, II and III are under consideration by the Mekong Committee.

The Second Phase Report has been prepared based on the operations stipulated in Phase II out of the four phases quoted above.

1.4. Organization

A survey team of 15 members was organized to carry out the second phase investigation and despatched in mid-February 1968 immediately after the Nong Khai site was selected as the bridge site. The period of site investigation was four months. Another group of three members forming an advisory party was not despatched in the second phase investigation. The advice and suggestions of the party, however, were given to the survey team at all times during the period in which the report had been prepared in Japan.

The advisory party and the survey team included the following members.

A. Advisory Party

	Name	Speciality	Professional position
1.	Dr. FUKUDA, Takeo	Bridge Construction	Doctor of Engineering; Professor Emeritus of the Univ. of Tokyo; President, Kozo-Keikaku Consultant Co., Ltd.
2.	Dr. SATO, Hiromasa	Highway Engineering	Doctor of Engineering; Vice-President, Mitsui Kyodo Kensetsu Consultant Co., Ltd. (Former Vice-President, Japan Highway Public Corp.)
3.	Dr. MURAKAMI, Eiichi	Bridge and Highway	Doctor of Engineering; Counselor, Japan Public Highway Corp.

B. Survey Team

1.	Mr. YOSHIDA, Ryozo	Head, Survey Team	Authorized Engineer; Deputy-Chief Engineer, Chief of Project Dept., Nippon Koei Co., Ltd.
2.	Mr. SAKAITA, Masanobu	Geology	Authorized Engineer; Director, Chief of Geological Dept., Nippon Koei Co., Ltd.
3.	Mr. NOGUCHI, Yutaka	Highway Planning	Authorized Engineer; Technical Advisor, Nippon Koei Co., Ltd.

	Name	Speciality	Professional position
4.	Mr. NAKAJIMA, Tooichi	Railway Planning	Authorized Engineer; Deputy-Chief, Overseas Dept. Japan Transportation Consultants, Inc./1
5.	Mr. TOKUNAGA, Yuzo	Highway Engineering and Survey	Authorized Engineer; Projects Dept., Nippon Koei Co., Ltd.
6.	Mr. ITO, Tohru	Bridge Engineering and Hydrology	Projects Dept., Nippon Koei Co., Ltd.
7.	Mr. SASAKI, Tsuneichi	Economics	Representative Director, Institute of Behavioral Sciences/1
8.	Mr. KOBAYASHI, Yaichi	Economics	Institute of Behavioral Sciences
9.	Mr. OGAWA, Tetsuo	Economics	Institute of Behavioral Sciences
10.	Mr. KIMURA, Hiroshi	Liaison and Accounting	Development Survey Dept., Overseas Technical Coorporation Agency
11.	Mr. OHYAMA, Hiroyoshi	Liaison and Accounting	Development Survey Dept., Overseas Technical Cooperation Agency
12.	Mr. TANIGUCHI, Isoo	Survey	Civil Engg. Dept., Nippon Koei Co., Ltd.
13.	Mr. IKEDA, Hiroshi	Survey	Projects Dept., Nippon Koei Co., Ltd.
14.	Mr. SHIRAYAMA, Kikuo	Test drilling	Geological Dept., Nippon Koei Co., Ltd.
15.	Mr. ONOUE, Takashi	Test drilling	Geological Dept., Nippon Koei Co., Ltd.

/1 Cooperative body of Nippon Koei Co., Ltd.

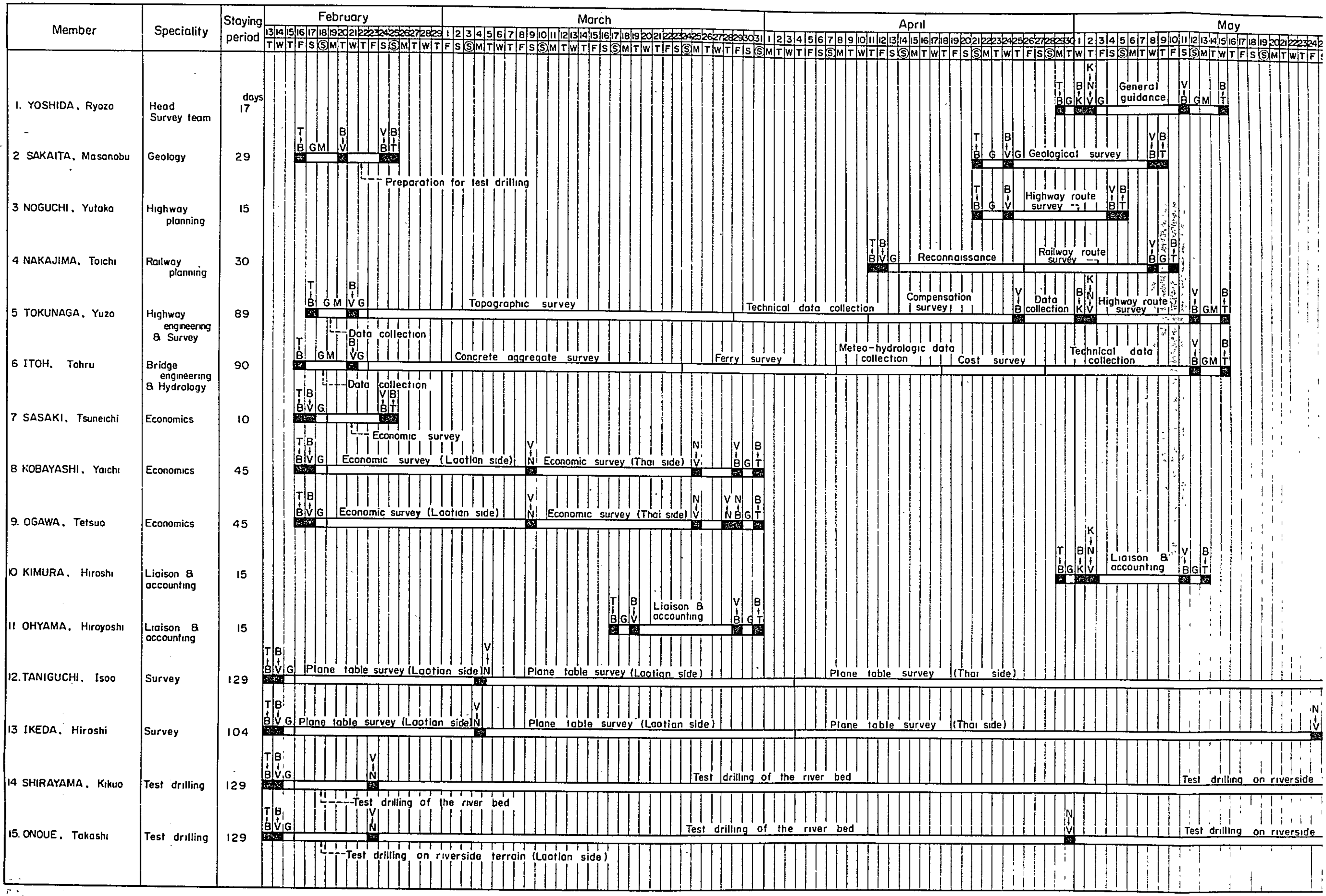
1.5. Itinerary

The first group of the survey team left Tokyo on 13 February 1968 to make the field investigation of the second phase. The second group departed from Tokyo on 16 February and stayed at Bangkok for a few days to exchange views and discuss on the project with the authorities concerned of the government agencies and the Mekong Committee and to gather necessary data for their work, and then proceeded to Vientiane.

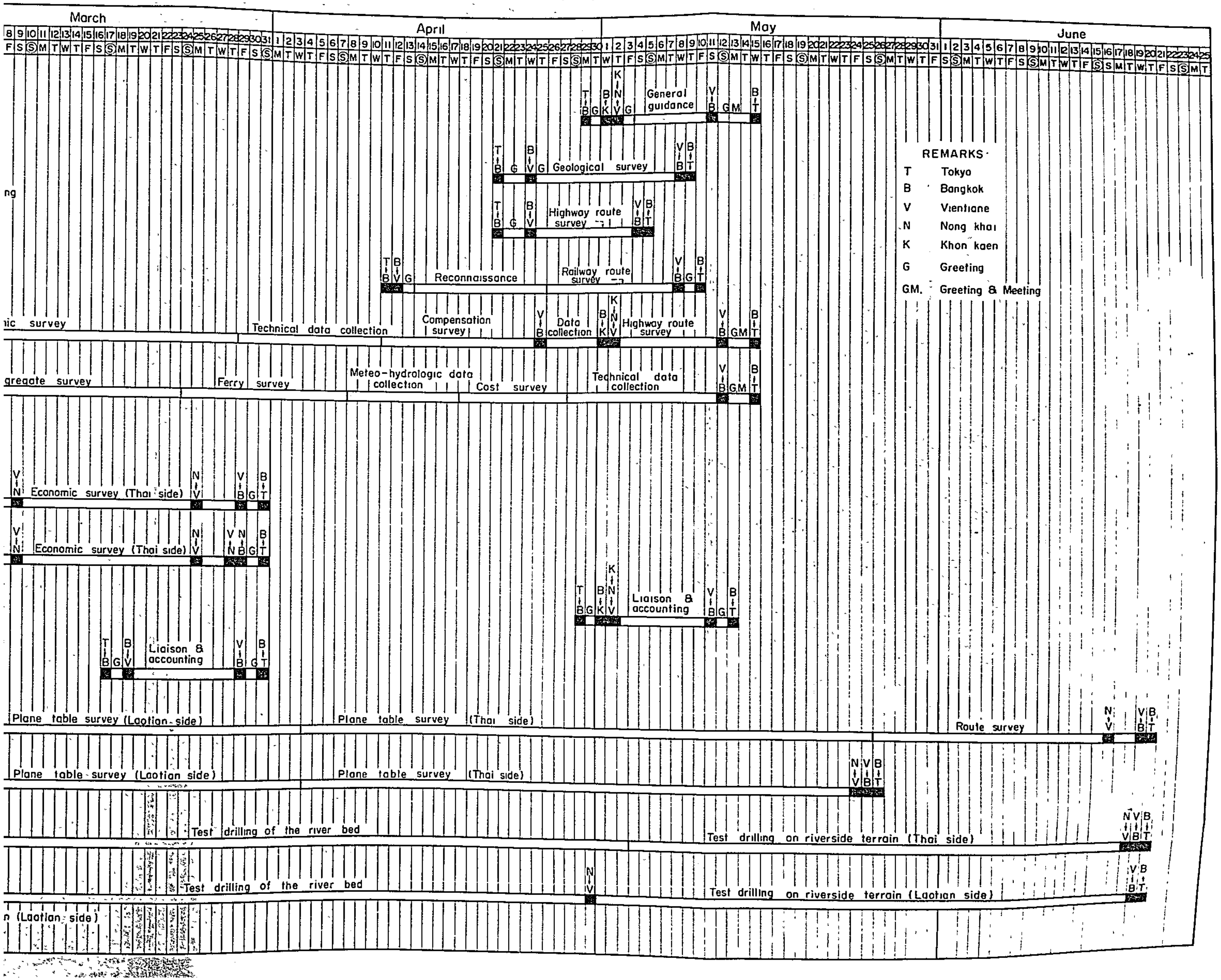
The head of the survey team visited the project site about two months after the investigation was commenced in order to give appropriate guidance and suggestions to the team based on the outcome of the topographic surveys and test drillings and the findings of the study of the necessary engineering data gathered.

The detailed itinerary of the members is shown in Fig. 1.1.

Fig. 1.1. ITINERARY FOR MEMBERS OF SURVEY TEAM FOR THE SECOND PHASE INVESTIGATION (1968)



ERARY FOR MEMBERS OF SURVEY TEAM FOR THE SECOND PHASE INVESTIGATION (1968)



CHAPTER II

SITE INVESTIGATION

2.1. Topographic Survey

It was only a map[/1] of 1 to 20,000 scale that was available before the feasibility investigation was started in August 1967. It was therefore impossible to make a complete feasibility study.

Such being the circumstances, the following topographic survey was thought necessary and was executed in two phases.

The first phase investigation had a purpose of selecting the most advantageous bridge site from among the three expected bridge sites, namely Nong Khai, Vientiane and Pa Mong, comparing their respective engineering and economic advantages. Consequently, the survey operations made during the first phase investigation were (1) the spot leveling from Vientiane to each of the three sites, (2) the echo-sounding in the Mekong river channel based upon the bench-mark established at each site, and (3) the simple triangulation to measure the width of the Mekong at each site.

As the final decision was made by the Mekong Committee to select the Nong Khai bridge site from among the three sites, the second phase investigation was made to decide which kind of bridge should be selected, a rail/highway bridge or a highway bridge, in regard to the selected site. The survey operations which were made for this purpose, were (1) the plane table survey covering the project area of the Nong Khai bridge site, including the echo-sounding of the river-bed part, (2) the route survey of the access highway and the access railway, (3) the spot leveling across the Mekong to unify the elevation of the topography of the project area extending over both countries, and (4)

/1 This map was enlarged from the aerial photograph on a scale of 1 to 40,000 which was taken about ten years ago.

the triangulation to measure the exact width of the Mekong at the bridge site.

The location or the route of the survey operations mentioned above is as shown in Fig. 2.1 and the specifications and the work quantity are outlined in Table 2.1.

Table 2.1. Survey operations

Survey operation	Unit	Work quantity	Specification
I. First phase investigation			
1. Spot leveling	km	43	Double-run leveling Diff. in elev.: 1.5 cm and less in a distance of 1 km
2. Echo-sounding	km^2	1.2	Accuracy of the machine: 1/100 Sounding depth: 25 m and more
3. Triangulation	Place	3	
II. Second phase investigation			
1. Plane table survey	km^2	8	Scale: 1/2,000, 1 m contour
2. Route survey	km	8	Transverse survey: 50 m long each on both sides of the route at intervals of 100 meters along the route
3. Spot leveling	km	1	Double-run leveling
4. Triangulation	Place	1	

The survey operations were achieved with satisfactory accuracy and the results have been compiled in the Appendices that constitute integral parts of the feasibility report.

It has become clear after completing the second phase investigation that two more survey operations are necessary, and these must be carried out in the near future by all means.

One is a route survey of the railway to be extended from Nong Khai to Vientiane, about 20 kilometers long. That which was executed in the second phase investigation covered only the routes of the access highway and the access railway adjacent to the bridge, about 8 kilometers long in total. Accordingly, the present study on the extension railway from Nong Khai to Vientiane is confined to the extent of a paper plan made using the 1/20,000 scale map, and the field reconnaissance that was performed twice up to the present. It results from the fact that the route survey covering a distance of twenty kilometers was not included in the Plan of Operation at the beginning, upon consideration that the feasibility investigation should be carried forward step by step to cut down the cost to the minimum. At present, however, it has become clear that a rail/highway bridge is as promising as a highway bridge, and therefore the execution/1 of the said route survey is indispensable to complete the feasibility study of this project.

The other is to place on the same basis the elevation of all benchmarks for construction use in the project area extending over the two countries. The topographic survey made by the Japanese bridge team throughout the first and second phase investigations was based on the original bench-mark V636/2 at the elevation of 170.105 meters above the mean sea level, with an elevation of zero meter, that was determined from a tide gage at Ko Lak in Thailand. In making the survey

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/1 The mekong Committee has strongly requested the Japanese Government to finance for this survey at the earliest moment. The bridge team is desirable of making the survey in the forthcoming dry season.

/2 This bench-mark is represented by a spike driven into the wall of the building of the Ministry of Foreign Affairs in Vientiane with the approval of the Mekong Committee.

operations on the Thai side in the second phase investigation, a level line had to be carried across the Mekong from the Laotian side, and connected with the bench-mark which had been established near the bank in the first phase investigation. On this occasion, this level line also was carried to a bench-mark in the site of Hydrographic Office at Nong Khai. According to the bridge team's reading, the elevation of this bench-mark was EL.165.861 m allowing the total error of 22 mm /1, while that learned by the Thai authorities concerned was EL.166.044 m above the same mean sea level at Ko Lak. Therefore, the difference in the readings of both parties is 0.183 meter.

At present there are many bench-marks in the project area, espeacially on the Thai side. According to the report titled "Report on Ground Control Surveys November 1959 - June 1960" /2, these bench-marks are understood to be based on the same mean sea level at Ko Lak. Whether they are based upon the same datum or not, it is a serious problem that any of the bench-marks lying in the project area has two different elevations. It is strongly recommended to unify the elevation of all bench-marks related to the project execution, beginning with the original bench-mark V-636 in Vientiane. This operation should be performed by the time of the commencement of the construction work.

/1 In the level work crossing the Mekong, it was compelled to make a long sight of about 400 meters. The effects of uncertainty due to the long sight were overcome to some extent by a double-run leveling. The error in this leveling was estimated to be 18 millimeters. In the stage of construction, more precise level work may be necessitated to reduce this kind of error.

At the time, it is customary to use what is called reciprocal leveling. This method is very useful to determine the difference of elevation between two points so situated that it is not practical to make the foresight and backsight distances nearly equal.

Furthermore, the error in the spot leveling that was made in the first phase investigation about 20 kilometers long between the original bench-mark V-636 and a bench-mark set near the bank of the Laotian side at the bridge site, was estimated to be 4 millimeters.

The total error of 22 millimeters throughout the whole route of the leveling is a sum of 18 millimeters and 4 millimeters abovementioned.

/2 Prepared by Hunting Survey Corporation Limited in December 1960.

Another problem is encountered resulting from the difference of 0.183 m in the readings of elevation.

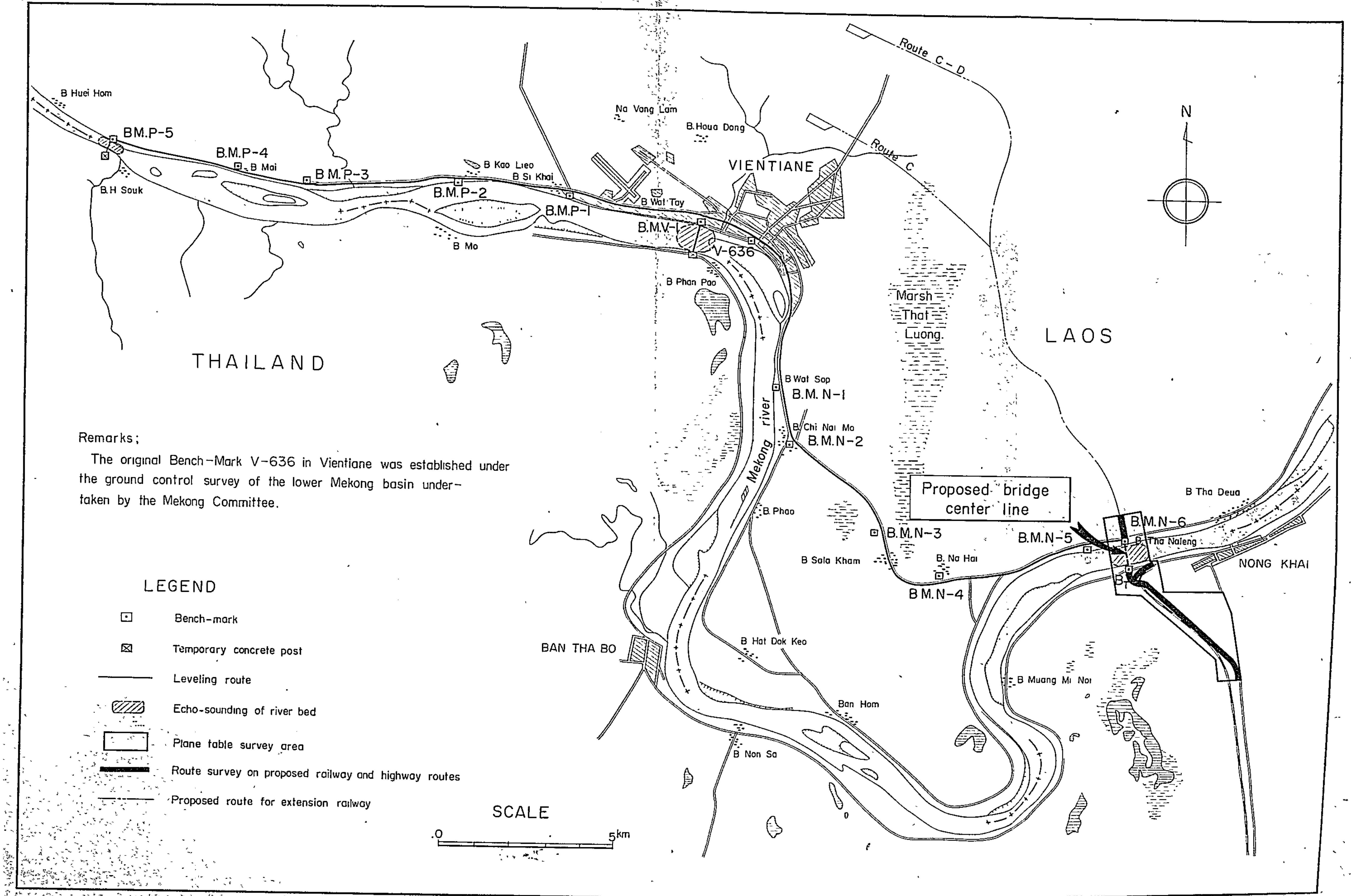
The design high-water level/1 above which the bridge keeps a vertical clearance of 10 meters for navigation, is obtained from the water level records measured by Hydrographic Office and R.I.D. /2 at Nong Khai. Should the staff gage in use in Hydrographic Office be built based on the elevation of the preceding bench-mark, the difference of 0.183 meter might affect the navigation requirement mentioned above. But, the elevation learned by the Thai authorities is higher than that obtained by the team. It is therefore judged that the five-year probable high-water level from which the design high-water level is decided, may actually happen at a level 0.183 meter lower than that estimated. It means that the actual vertical clearance may be taken more than 10 meters.

Consequently, this problem is not so serious because it provides a safety factor as far as the navigation requirement is concerned.

/1 The estimation of this level is made in Appendix IV, Paragraph 4.3.

/2 Abbreviation of the Royal Irrigation Department in Thailand.

Fig. 2. 1 SURVEY OPERATIONS



Remarks;

The original Bench-Mark V-636 in Vientiane was established under the ground control survey of the lower Mekong basin undertaken by the Mekong Committee.

LEGEND

- Bench-mark
- Temporary concrete post
- Leveling route
- Echo-sounding of river bed
- Plane table survey area
- Route survey on proposed railway and highway routes
- Proposed route for extension railway

2.2. Soil Survey

In making the feasibility study of this bridge project, it is indispensable to locate the bedrock under the Mekong that the bridge piers will be founded, and to know the geological condition of the original ground on which the highway or the railway will be built.

For the former purpose the survey was made by means of test drilling into the river-bed of the Mekong and the nearby land to both banks. For the latter purpose, a reconnaissance was made along the routes of highway and railway, and a test-pit digging was made at several places. Furthermore, a drilling was executed on the northern end of Marsh That Luong where the railway route C would take when the railway is extended to Vientiane.

As mentioned before, the final decision was made by the Mekong Committee to select the Nong Khai site for bridge construction in January 1968, according to the recommendation of the First Phase Report and the advice of the Advisory Board. The soil survey was therefore confined to the finally selected bridge site, Nong Khai.

As soon as the Japanese Government was informed of the final decision, the soil-survey experts were mobilized so as not to miss the prevailing dry season, because the dry season is the best season for conducting the test drilling of the river-bed. The drilling operation was thus started in mid-February 1968 and continued for four months up to June 1968. The operation was almost finished before the rainy season set in, in which the Mekong flows with high-water level and high flow velocity.

The operation was proceeded with the drilling of No.1 bore hole located at the left bank of the Mekong on the center line of bridge proposed in the First Phase Report. This drilling was aimed at obtaining the outline of the geological condition of this area before the drilling operation of the river-bed was undertaken.

The final location of the center line of the bridge was not decided until the beginning of the second phase investigation, although the Nong Khai site had been concluded in comparison with the other two bridge sites. The bridge team therefore made a field reconnaissance at the beginning to locate the bridge center line. As a result, it was made clear that there was no appropriate place except the area/1 lying between Hydrographic Office and a small tributary on the Thai side about 400 meters upstream from the office, and consequently the bridge center line proposed in the First Phase Report proved to be the best.

It is important to have certain knowledge of the comprehensive geological condition of the Mekong river-bed covering the bridge site and its environs. The drilling was therefore made not only on the bridge center line proposed in the First Phase Report, but also on the other three lines in parallel with the center line. As shown in Fig. 2.2, eight bore holes were drilled on the said bridge center line, three holes on a line about 130 meters upstream from the center line, five holes on a line about 100 meters upstream therefrom and three holes about 200 meters downstream from the center line. The bore holes totaled 19 with a total drilling length of 290 meters.

As for the drilling of the nearby land to both banks of the Mekong, a total of six bore holes were drilled, three each on both Laotian and Thai sides along the said bridge center line. Besides, two holes were drilled where the access highway on the Thai side would overpass the existing railway. This overpass/2 is taken into account only in the case of a highway bridge. One more drilling was made on the northern end of Marsh That Luong for the railway to be extended to Vientiane. A total of nine bore holes were drilled on the land and the drilling length was 244 meters in total.

/1 The reasons why there is no appropriate place except the area mentioned above are described in Chapter III.

/2 In the case of a rail/highway bridge, the access highway is planned to cross the railway with at-grade intersection for the reasons mentioned in Chapter III.

The total drilling length of the river-bed and land thus reached 534 meters and the total bore holes numbered 28. The results of drilling are described hole by hole in geological columns in Appendices.

A geological profile is given in Fig. 2.3. This profile shows the geological condition under the Mekong river-bed and its nearby land along the bridge center line proposed in the First Phase Report. The topographic survey revealed that this bridge center line was somewhat skew from the right-angled line to the river course. In the Second Phase Report, therefore, the bridge center line was corrected at right angle to the river course, as mentioned later. No remarkable change, however, can be found between the geological conditions along both bridge center lines as judged from Fig. 2.4.

The following is the outline of the geological condition at the bridge site.

In the nearby land to both banks of the Mekong, surface soil, loam, sand, gravel and weathered siltstone overlie fresh siltstone in this order from the ground downwards. The fresh siltstone surface is assumed to lie at a depth of about 15 to 20 meters with the elevation of 149 to 153 meters above mean sea level on the Laotian side, and at about 20 meters deep with EL. 144 meters on the Thai side.

In the river-bed part, the weathered siltstone overlying the fresh rock is covered with an alluvial overburden about 3 to 5 meters thick on the Laotian side and 7 to 13 meters thick on the Thai side. Mostly the overburden is a gravel layer on the Laotian side and is a fine sand layer on the Thai side.

The fresh rock consists of Jurassic reddish siltstone with thin shale layers intercalated, which extends over a vast tract of both Laos and Thailand. The bridge piers are planned to be founded on the firm bedrock at a depth of two meters from its top surface to withstand the probable scouring of the river-bed. According to the test of which the results are given in Appendices, the compressive strength of this firm rock is estimated at 170 kg/cm^2.

In the course of the drilling of the alluvial overburden layers, a standard penetration test was made at every one meter deep to estimate the bearing capacity of the alluvial overburden and the resistance of pile driving.

Two pieces of undisturbed samples also were taken from each bore hole. No samples, however, could be taken from the layers of silt, sand and gravel lying under the Mekong due to their high fluidity. In the nearby land on both banks, undisturbed samples were almost taken from alluvial deposit as stipulated, and sent to Japan for soil test. The following table shows the list of the undisturbed samples taken.

Table 2.2: Undisturbed samples

Bore hole No.	Sample No.	Sampling depth (m)
21	1	5.7 — 6.3
	2	7.4 — 7.8
	3	10.3 — 11.25
22	4	0.7 — 1.35
	5	3.0 — 3.4
24	6	6.2 — 6.93
	7	9.6 — 10.35
25	8	6.5 — 7.25
	9	7.3 — 8.2
26	10	8.0 — 8.75
	11	9.0 — 9.95
27	12	1.0 — 1.7

These twelve undisturbed samples were put to such five kinds of soil tests as properties test, grain size test, consistency test, shearing strength test and consolidation test. The results of these soil tests are compiled in Appendices and summarized in Table 2.4.

According to the technical classification of the samples made from the results of grain size and consistency tests, all the samples belong to the category of loam or clay. The samples taken from the bore holes No.21, No.22, No.24 and No.27 reveal that the layer from which the samples were taken is not quite a good foundation to support any special structure like a bridge. The samples from the bore holes No.25 and No.26 have an unfavorable nature that the compressive strength reduces due to vibration. These facts are proved by the comparison of the compressive strength obtained from the unconfined compression test with that estimated from the N-value, which is the number of blows in the standard penetration test.

The following table is prepared to show this comparison.

Table 2.3. N-value and compressive strength

Bore hole No.	Sample No.	N-value	qu'	qu
21	1	12	1 — 2	1.2
	2	11	1 — 2	0.88
	3	13	1 — 2	1.05
22	4	6	0.5 — 1	0.51
	5	6	0.5 — 2	0.47
24	6	11	1 — 2	0.86
	7	12	1 — 2	3.92
25	8	17	2 — 4	0.43
	9	17	2 — 4	0.29
26	10	11	1 — 2	0.50
	11	14	1 — 2	0.56
27	12	1 - 2	less than 0.25	0.66

Remarks: (1) qu' denotes the compressive strength estimated from the N-value in kg/cm^2 (almost equal to the cohesion because of clay).

(2) qu expresses the compressive strength obtained from the unconfined compression test.

As given above, the value qu of the samples taken from the bore holes No.21, No.22, No.24 and No.27 coincides well with the lower value of qu' estimated. These nine samples showed that the sensitivity ratios were all low. Therefore, the layer where the samples were taken is a relatively stable foundation. On the other hand, the values qu of those of the bore holes No.25 and No.26 were considerably low as compared with the corresponding qu', and the sensitivity ratios of them were high. The compressive strengths of the samples are, therefore, assumed to be lessened due to vibration or remolding.

Furthermore, the consolidation test revealed that the initial void ratio was considerably low and the preconsolidation load was fairly larger than that caused by the present overburden. Deformation of foundation due to consolidation may therefore be hard to occur.

From the above studies, the piles to be designed for the foundation of a bridge should be drived into sand or gravel layer underlying the surface loam or clay layer. The operation may be accompanied with some difficulty due to the consolidation of the overlying loam or clay layer.

Fig. 2.2. LOCATION OF THE TEST DRILLING HOLES

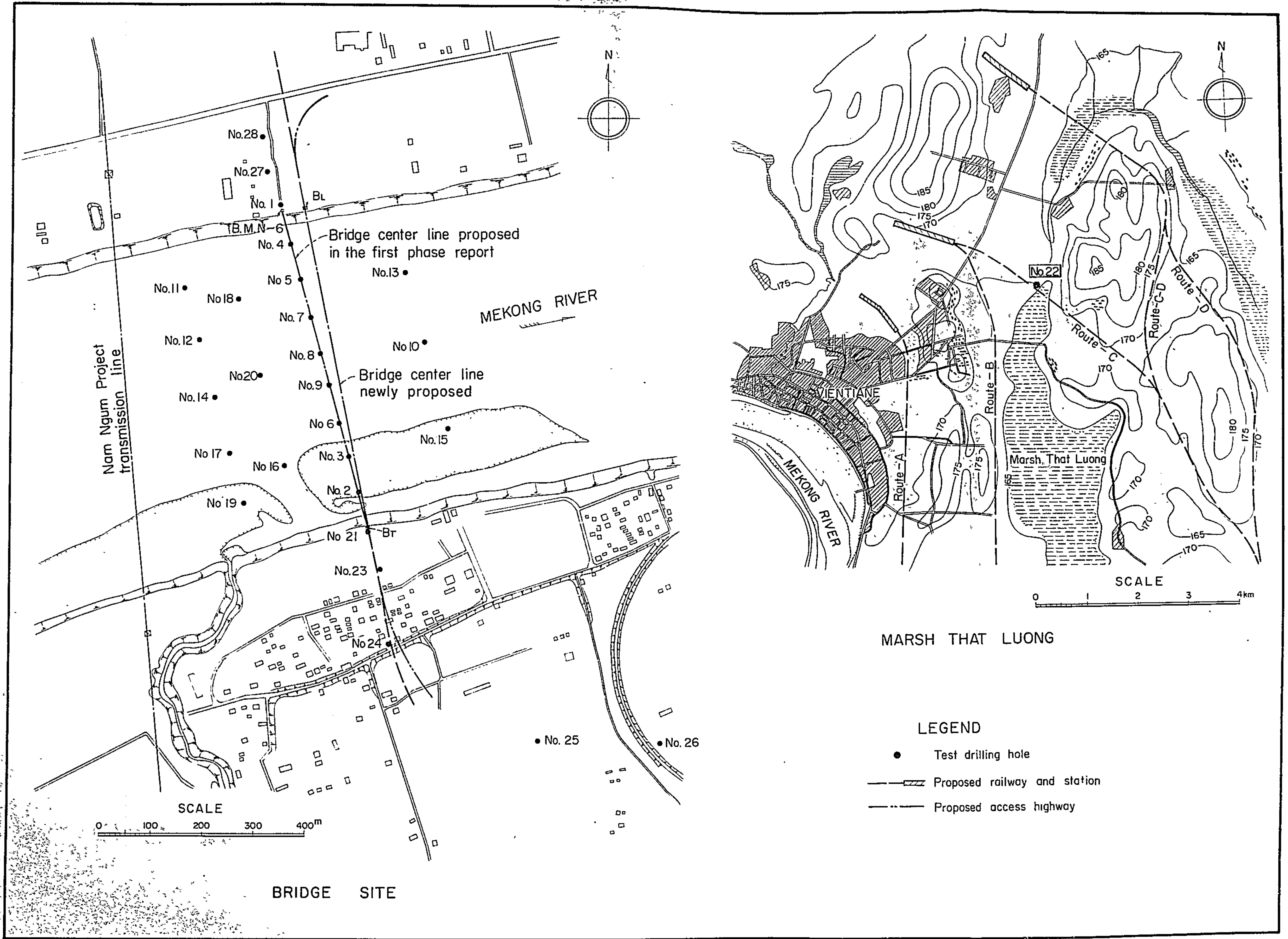


Fig. 2.3. GEOLOGICAL PROFILE

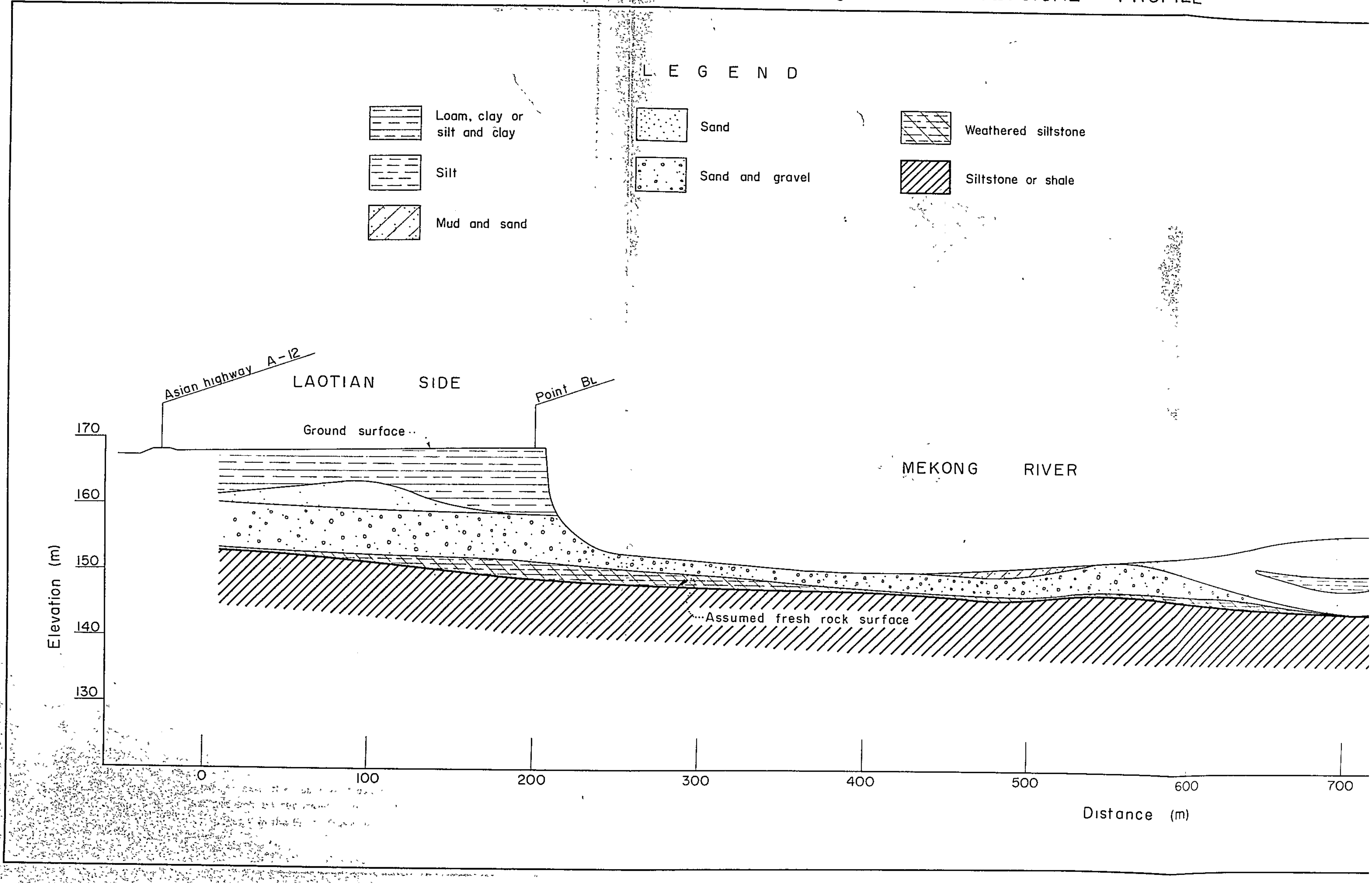


Fig. 2.3. GEOLOGICAL PROFILE

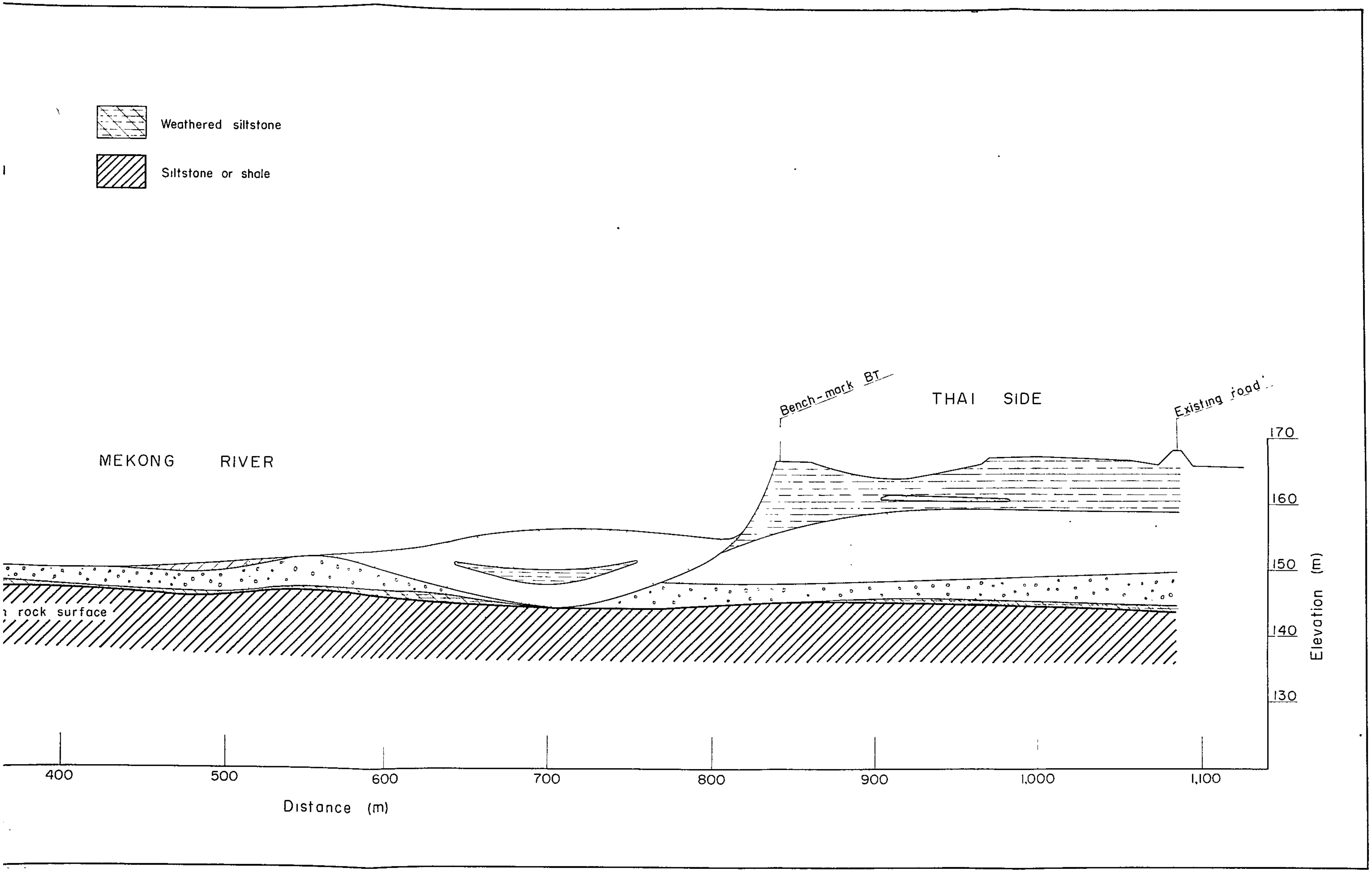
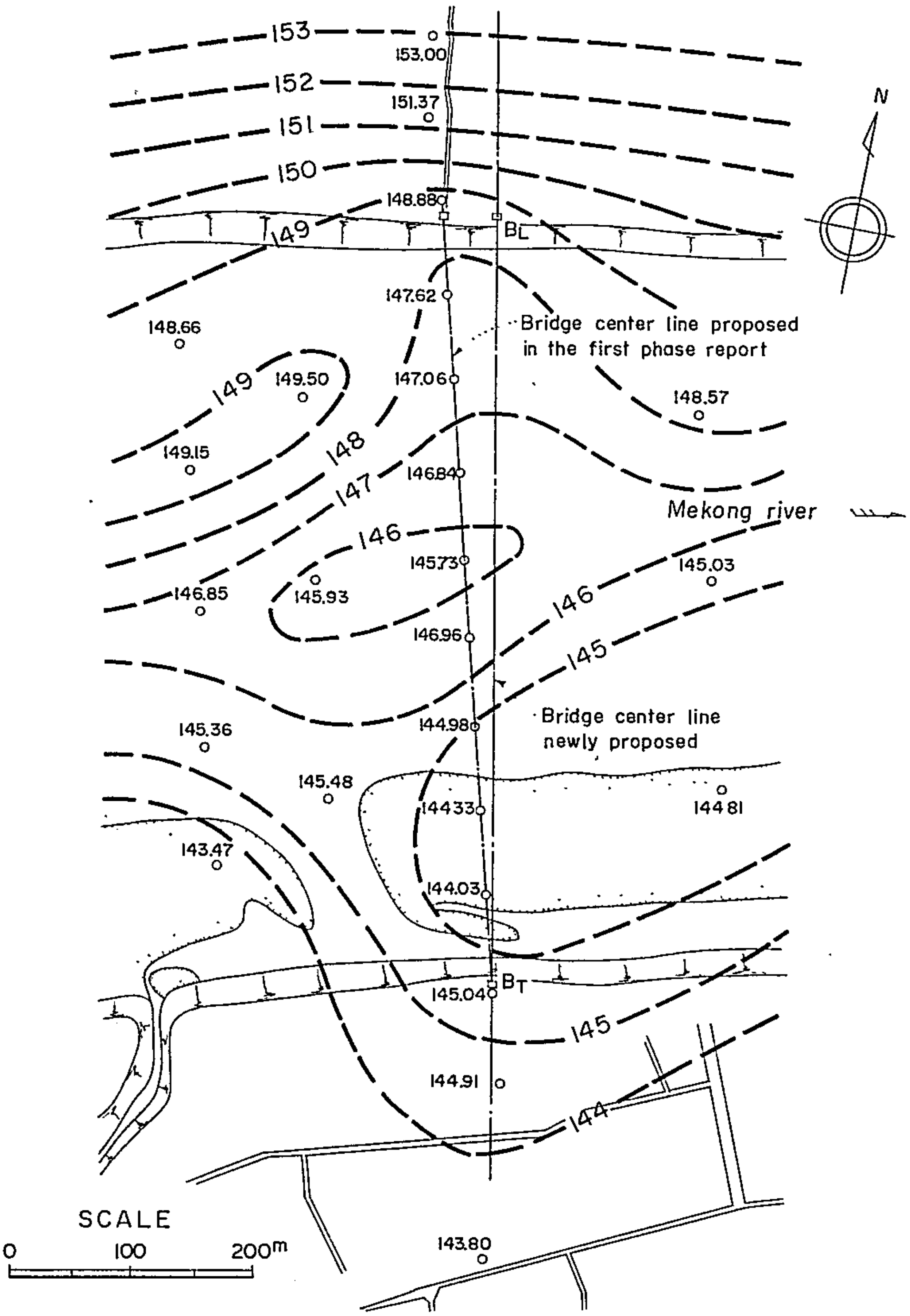


Fig. 2.4. CONTOUR MAP OF ASSUMED FRESH ROCK SURFACE AT THE BRIDGE SITE



Remarks

According to this contour map, the assumed fresh rock line along the newly proposed bridge center line can be regarded as almost the same as that along the bridge center line proposed in the First Phase Report.

Table 2.4. Summary of soil test

Location: Nong Khai

Items	Unit	1	2	3	4	5	6	7	8	9	10	11	12
		Characteristics											
Sample No.		1	2	3	4	5	6	7	8	9	10	11	12
Bore Hole No.		21	21	21	22	22	24	24	25	25	26	26	27
Sampling Depth	m	5.70-6.30	7.40-7.80	10.30-11.25	0.70-1.35	3.00-3.40	6.20-6.93	9.60-10.35	6.50-7.25	7.30-8.20	8.00-8.75	9.00-7.75	1.00-1.70
I. Observation		Reddish brown	Reddish brown	Reddish brown	Grey brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Yellow brown
II. Properties													
(1) Natural water content, w	%	20.11	21.23	24.04	26.25	36.70	22.04	28.42	25.41	25.75	25.72	25.40	16.45
(2) Specific gravity of soil, G		2.68	2.65	2.70	2.68	2.70	2.75	2.67	2.73	2.69	2.70	2.65	2.76
(3) Wet density, r_t	g/cm^3	1.875	1.940	1.893	2.044	1.789	2.009	1.792	1.899	1.891	1.948	1.992	2.067
(4) Dry density, r_d	g/cm^3	1.561	1.600	1.526	1.619	1.308	1.646	1.395	1.514	1.503	1.549	1.588	1.775
(5) Void ratio, e		0.717	0.656	0.769	0.655	1.064	0.671	0.914	0.803	0.790	0.743	0.669	0.555
(6) Degree of saturation, S	%	75.17	85.76	84.41	100	93.13	90.33	83.02	86.39	87.68	93.46	100	81.81
III. Grain Size													
(1) Constitution													
i) Gravel part	%	-	-	-	1.0	-	-	-	-	-	-	-	-
ii) Sand part	%	3.5	3.0	5.0	16.5	13.5	2.0	1.5	19.5	51.0	33.0	31.0	25.5
iii) Silt part	%	75.0	74.0	78.5	34.5	45.0	62.0	68.5	63.5	38.0	54.0	54.0	51.0
iv) Clay part	%	21.5	23.0	16.5	48.0	41.5	36.0	30.0	17.0	11.0	13.0	15.0	23.5
(2) Max. diameter	mm	0.105	0.105	0.105	4.8	2.0	0.105	0.105	0.42	0.84	0.42	0.42	2.0
(3) 60 % diameter, D_{60}	mm	0.035	0.033	0.0403	0.016	0.013	0.017	0.018	0.06	0.13	0.07	0.063	0.06
(4) 10 % diameter, D_{10}	mm	-	-	0.0018	-	0.0017	-	-	0.0018	0.004	0.0028	0.002	-
(5) Uniformity coefficient		-	-	22.4	-	7.65	-	-	33.3	32.5	25.0	31.5	-
(6) Grain size classification		Silty clay loam	Silty clay loam	Silty loam	Clay	Clay	Silty clay	Silty clay	Silty loam	Silty loam	Silty loam	Silty loam	Silty clay loam
(7) Unified classification		CL	CL	CL	CL or CH	CL or CH	CL	CL or CH	ML or CL	SC	ML or OL	CL	CL
IV. Consistency													
(1) Liquid limit, L.L.	%	33.25	39.80	35.20	49.80	52.00	37.10	53.10	28.20	24.10	26.40	26.85	36.50
(2) Plastic limit, P.L.	%	20.45	21.70	22.05	17.37	20.47	20.64	24.33	22.15	18.66	22.49	18.43	11.68
(3) Plasticity index, P.I.		12.80	18.10	13.15	32.43	31.53	16.46	28.77	6.05	5.46	3.91	8.42	24.82
(4) Flow index, F.I.		6.30	8.48	8.25	10.10	10.10	10.00	12.80	5.10	5.95	5.10	5.05	15.70
V. Shearing Strength													
(1) Unconfined compression													
i) Compression strength	kg/cm^2	1.195	0.883	1.051	0.505	0.471	0.861	3.920	0.426	0.290	0.498	0.556	0.664
ii) Sensitivity ratio		2.36	1.56	4.08	1.18	1.64	1.38	5.16	N.G./1	4.08	N.G./1	N.G./1	1.06
(2) Direct compression													
i) Cohesion, c	kg/cm^2	-	-	-	-	-	0.60	-	0.30	-	0.70	0.28	0.60
ii) Internal friction angle, ϕ		-	-	-	-	-	40°02'	-	37°36'	-	15°39'	22°47'	30°58'
(3) Triaxial compression													
i) Cohesion, c	kg/cm^2	0.50	0.80	0.45	0.925	0.20	0.82	1.15	0.21	0.10	0.35	0.24	0.50
ii) Internal friction angle, ϕ		12°25'	19°18'	10°46'	5°43'	8°32'	11°52'	13°30'	15°39'	16°42'	6°17'	8°32'	15°07'
VI. Consolidation													
(1) Initial void ratio, e_o		0.610	0.672	0.670	0.642	1.360	0.689	0.876	0.769	0.657	0.616	0.680	0.682
(2) Preconsolidation load, p_o	kg/cm^2	3.50	4.50	3.20	1.22	1.17	3.00	4.90	3.00	2.63	3.90	2.48	0.56
(3) Compression index, C_c		0.198	0.186	0.147	0.161	0.361	0.235	0.308	0.251	0.201	0.137	0.146	0.158
(4) Coef. of consolidation, C_v	cm^2/sec	$2.8x10^{-2}$	$1.66x10^{-2}$	$2.1x10^{-3}$	$8.2x10^{-3}$	$8.1x10^{-3}$	$1.22x10^{-2}$	$2.0x10^{-2}$	$2.22x10^{-2}$	$3.1x10^{-2}$	$1.29x10^{-2}$	$1.15x10^{-2}$	$1.7x10^{-2}$
(5) Coef. of volume compressibility, M_v	cm^2/g	$1.3x10^{-5}$	$7.0x10^{-6}$	$8.1x10^{-6}$	$1.95x10^{-5}$	$4.7x10^{-5}$	$1.21x10^{-5}$	$8.6x10^{-6}$	$1.36x10^{-5}$	$1.28x10^{-5}$	$6.3x10^{-6}$	$1.03x10^{-5}$	$5.4x10^{-5}$
(6) Coef. of permeability, k	cm/sec	$3.6x10^{-7}$	$1.18x10^{-7}$	$1.74x10^{-8}$	$1.6x10^{-7}$	$3.8x10^{-7}$	$1.5x10^{-7}$	$1.75x10^{-7}$	$3.04x10^{-7}$	$1.0x10^{-7}$	$8.1x10^{-8}$	$1.2x10^{-7}$	$9.2x10^{-7}$

Remarks: /1 The remoulding was impossible for testing

2.3. Material Survey

2.3.1. General

There are many kinds of construction materials in both Laos and Thailand: for instance, cement, timber, brick, laterite, stone, ballast, concrete aggregates, embankment materials and so on.

The common materials such as timber, brick, laterite, etc. are procurable anywhere in and around the project area. Cement and ballast, however, are not available in abundance in Nong Khai, Vientiane and their vicinities. Cement will probably be supplied from factories in Bangkok for this project, and ballast is available at many quarries/1 near Sara Buri about 100 kilometers north of Bangkok. According to the information furnished by the Royal State Railway of Thailand, ballast is available in many places in the regions of Boriram and Souren about 100 kilometers east of Nakhon Ratchasima, Khoa Tham Bhon located midway between Sara Buri and Boua Yay, and Loei about 130 kilometers west of Udon Thani.

These quarries were not surveyed in the second phase investigation. It is therefore necessary to select recommendable quarries/2 at the next stage.

Furthermore, the sandstone outcrops are seen on the both banks of the Mekong near Pa Mong. This sandstone is of the late mesozoic era and, because of its medium hardness, is not suitable for use as ballast which generally requires high hardness against abrasion.

Concrete aggregates and embankment materials can be collected in the vicinity of the bridge site. Since there are much to be surveyed for the project planning in these two kinds of materials, the material

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/1 The leader and two members of the bridge team made an inspection of the Asian Highway running from Bangkok to Nong Khai. They had a chance to visit these quarries for a short while on their way.

/2 In this report, ballast is supposed to be supplied from Sara Buri by rail for estimating the construction cost of this project.

survey in the second phase investigation was concentrated mainly on these two kinds.

2.3.2. Concrete aggregates

The reconnaissance was made in the Mekong within a reasonable distance from the bridge site. As a result, three promising sand and gravel deposits were found as indicated in Fig. 2.5. Site-A is located at 10.8 kilometers downstream from the bridge site on the Thai side, Site-B at 6.2 kilometers downstream on the Laotian side, and Site-C at 6.5 kilometers upstream on the Thai side.

The test samples were taken at eleven places/1 as shown in Fig. 2.5. in order to know whether the sand and gravel deposits of these three sites can be used for concrete as coarse and fine aggregates. Seven kinds/2 of concrete aggregate tests including sieve analysis, specific gravity, absorption, unit weight, decantation, organic impurity and compressive strength of concrete, were conducted for this purpose at the concrete laboratory of the Ministry of Public Works and Transportations in Vientiane in accordance with the provisions of the Japanese Industrial Standards (JIS). The test results are compiled in Appendices and summarized in Table 2.5.

According to the test results, all the samples were found satisfactory in respect of unit weight, specific gravity, absorption, decantation or percentage of materials passing No.200 sieve, and organic impurity. Decantation was less than three percent/3 and the organic impurity was of such a trace as would offer no problem.

/1 Fine sand samples were taken at two places near the bridge site other than these places.

/2 Unfortunately an abrasion test could not be made because the machine was out of order during testing.

/3 This figure is stipulated in the Japanese Industrial Standards.

The test samples also revealed that the fineness modulus of sand was relatively low in spite of the small quantity of fine materials which passed No.200 sieve. It was because more grains between 0.6 millimeter and 0.15 millimeter in size were present and those over 0.6 millimeter were much less. Some samples contained the grains between 0.6 millimeter and 0.15 millimeter as much as 80 percent. It is therefore preferable to improve the grading of sand and to raise the fineness modulus at least up to 2.6. But, the fineness moduli of sand of Samples No.5 and No.11 are acceptable.

As regards the maximum size of the coarse aggregate, it was about 60 millimeters for the samples taken from Site-A, about 20 millimeters for the samples taken from Site-B and about 45 millimeters for the samples taken from Site-C. The coarse aggregate of Site-B is too fine to be used for ordinary concrete structures, while the other two sites are acceptable.

The samples of gravels from Site-A and Site-C showed that the results of sieve analysis were within the limits stipulated in the Japanese Industrial Standards and so are acceptable. Contrariwise, the gravel from Site-B was out of the limits. All the samples of sand except Samples No.10 and No.11 also fell out of the limits.

Such being the results, only Site-C especially the area where Samples No.10 and No.11 were taken is judged to be satisfactory. If the sand and gravel deposits at Site-A and Site-B would be used for the production of concrete, the improvement of grading by means of a screening plant or others would be necessary.

As a result of the preliminary design of the concrete structures in this bridge project, it was made clear that a total of about 85,000 cubic meters of sand and gravel would be required for the works of concrete and pavement, out of which about 55,000 cubic meters are needed to be supplied somewhere on the Thai side and about 30,000 cubic meters on the Laotian side.

For the supply of 55,000 cubic meters on the Thai side, Site-C is the most recommendable source among the three sites inspected. The fine and coarse aggregates of 30,000 cubic meters on the Laotian side had better be supplied from the sand-bar/1 at Hat Khoueideng about 15 kilometers downstream from Tha Naleng rather than from Site-B.

Furthermore, the construction of the railway and the access highway calls for a large quantity of fine sand for use as an embankment material. The access railway situated on the Thai side has a need of about 12,000 cubic meters of fine sand less than 0.3 millimeter in size. The sand-bar which emerges just upstream from the bridge site in every dry season, can guarantee an inexhaustible supply of this kind of fine material.

On the other hand, the extension railway to be constructed on the Laotian side requires about 85,000 cubic meters of fine sand of the same size as mentioned above. For this supply, the sand-bar lying just in front of the city of Vientiane can be made available.

The aggregate survey so far executed thus served to see the outlook on the supply of fine and coarse aggregates for concrete production. Further detailed survey, however, will be indispensable to formulate the supply plan of aggregates for concrete inclusive of sand and gravel for pavement.

/1 At present, the Ministry of the Public Works and Transportations of Laos collects sand and gravel in large with modern facilities.

Fig. 2.5. RECOMMENDABLE SAND AND GRAVEL DEPOSITS

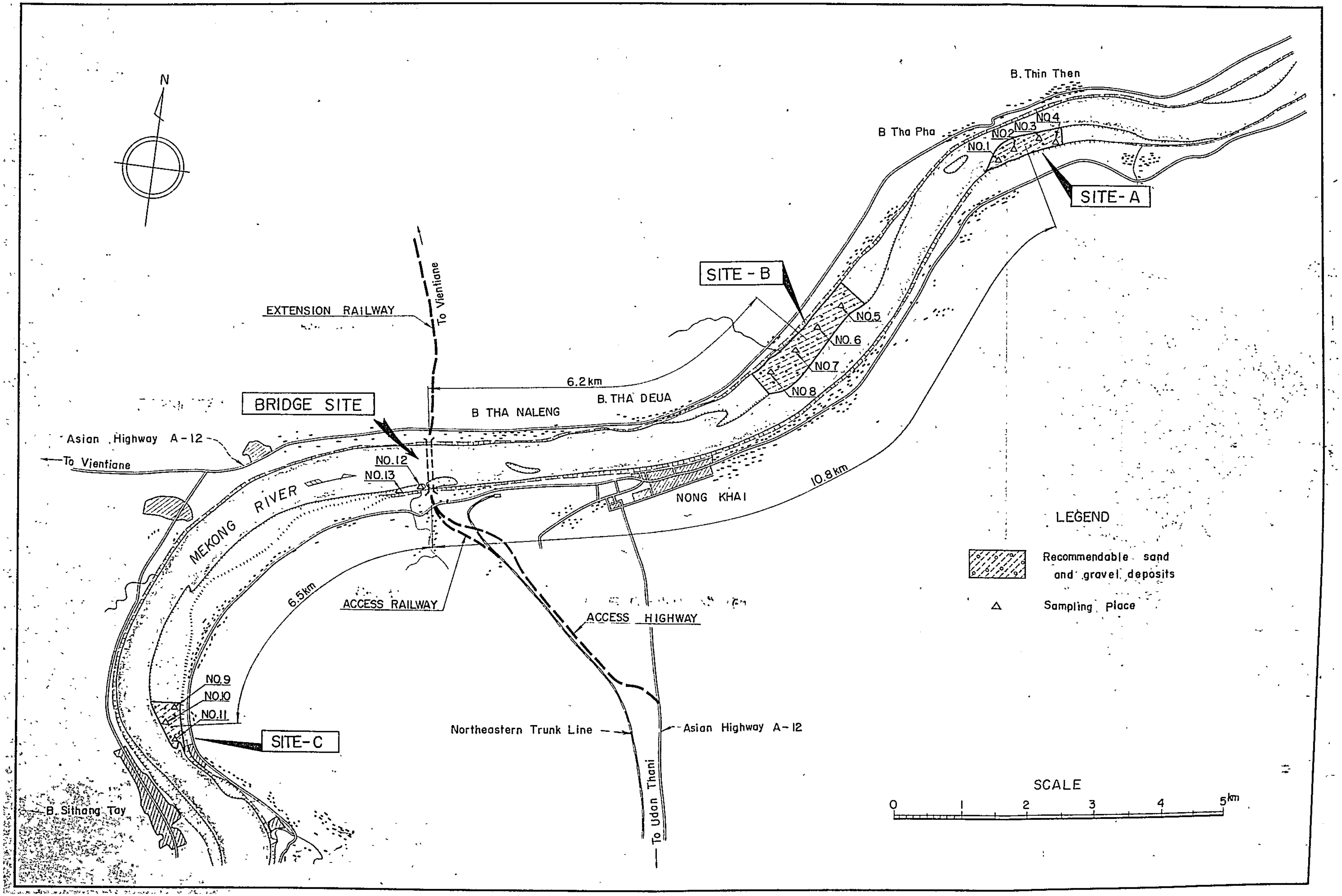

Table 2.5. Concrete aggregate tests

Items \ Site / Sample No.	A				B				C				Bridge site	
	1	2	3	4	5	6	7	8	9	10	11-1	11-2	12	13
(1) Sand														
Max. size (mm)	2.7	1.2	1.6	3.0	3.5	2.5	1.3	2.0	1.1	2.2	2.0	2.2	0.3	0.3
Fineness modulus	2.24	2.05	2.08	2.05	2.90	2.48	2.23	2.45	2.13	2.32	2.60	2.70	0.9	0.9
Unit weight (kg/m^3)		1610	1660			1560	1660			1710	1720	1710		1630
Specific gravity		2.63				2.59					2.60	2.60		2.54
Absorption (%)		1.21				1.02					0.81	1.07		2.1
Materials passing No.200 sieve (%)	0.9			1.0	1.2			0.8	0.6	0.6				
Organic impurities					Trace				Trace					
(2) Gravel														
Max. size (mm)	(60)	(60)	(45)	(53)	20	20	20	15	18	40	45	50		
Fineness modulus	7.73	7.80	7.37	7.82	6.74	6.75	6.70	6.40	6.46	7.49	7.72	7.69		
Unit weight (kg/m^3)		1730	1850			1740	1740			1820	1870	1870		
Specific gravity		2.62	2.62			2.58					2.63	2.61		
Absorption (%)		0.48	0.86			1.26					0.62	0.67		
(3) Concrete														
Slump (cm)	6.5		7.5			7.3				10.5				
σ_7 (kg/cm^2)	108		-			-				108				
σ_{28} (kg/cm^2)	-		113			170				176				

Remarks: Design mix for concrete specimen; cement: 250 kg/m^3, water: 150 kg/m^3, gravel: 1380 kg/m^3
sand: 640 kg/m^3, W/C: 60 %

2.3.3. Embankment material

It is very economical for highway construction if the embankment material of good quality is available within a short distance from the route of highway to be constructed. With this in view, the test samples were taken at six places along the three proposed routes of the access highway on the Thai side as shown in Fig. 2.6.

Then the samples were sent to Japan and the following five kinds of soil tests were made for judgement: grading test, consistency test, compaction test, shearing strength test and CBR test. In the course of testing, it was proved that all the soil samples had a nature of swelling and therefore the swelling test was executed as an additional test. The test results are compiled in detail in Appendices and summarized in Table 2.6.

According to the technical classification made from the results of grading and consistency tests, the soil samples showed that the subsoil where they were taken was unfavorable to the subgrade or embankment in highway construction by the following reason. Namely, the subsoil has a nature of largely changing its volume according to the dry and wet conditions. The compaction, triaxial compression and CBR tests made in the state of optimum water content revealed the following results: (1) the maximum density of each soil sample was comparatively high, (2) the shearing strength also was high, and so if the state is kept unchanged, there is no problem regarding the stability of embankment less than two or three meters in height in highway construction, and (3) contrary to the above two favorable matters all the samples showed extremely low CBR except Sample No.5. This results from the nature of swelling in the soil.

As mentioned above, a series of tests made it clear that the subsoil is favorable as the embankment material for highway as far as it is in the state of optimum water content, but once it is saturated with water its strength remarkably lessens. Accordingly, the swelling test was carried out in the following four cases: (1) the samples were molded in the state of optimum water content and saturated with water after curing for several days at the unloaded condition, (2) the samples were molded in the state of optimum water content and saturated with water at the loaded condition after the compressive deformation due to loading was almost completed (generally after 24 hours), (3) the samples were mixed with the sand of 0.3 millimeter in maximum size by 30 percent of the soil sample in weight in the state of optimum water content or by 60 percent of it, and saturated with water at the unloaded condition immediately after molding, and (4) the samples were mixed with cement by five percent in weight in the state of optimum water content and saturated with water after curing for several days at the unloaded condition.

As a result, the following matters were found:-

The swelling ratio at the unloaded condition was much higher than that at the loaded condition. The shearing strength almost dropped to nil. These things occurred regardless of the length of curing period. In the state that the compressive deformation was almost completed, the swelling ratio was very low and the shearing strength was almost unaffected. In the case of sand mix, the swelling ratio could not be lowered, but the shearing strength was considerably high. In the case of cement mix, the swelling ratio could remarkably be lowered and the shearing strength remained almost unchanged.

From the above considerations, following conclusions are drawn:

(1) Sample No.5 is most suitable for the embankment in highway construction among the six samples. The degree of adequacy to the embankment material is high in this order; No.5, No.3, No.4, No.1, No.2 and No.6. Therefore the subsoil where Samples No.1, No.2 and No.6 were taken should not be used for the embankment in highway construction. If the subsoil where Samples No.3, No.4 and No.5 were taken would be utilized as embankment material in highway construction without any stabilizing treatment, a soil

layer about one meter thick would be required as a surcharge load.

(2) The shoulders of highway at the embankment part should be treated for stability with soil-cement mix or other stabilizing materials such as slaked lime with pozzolana or bituminous materials.

The above conclusions were taken into account not only in the preliminary design of highway but also in that of railway. In this report, the cross section of highway was decided in accordance with the second conclusion. It, however, is desirable to reinvestigate in detail as to whether the embankment material of good quality can be located in the districts near the routes of highway and railway.

Fig. 2.6. LOCATION OF SAMPLING PLACES FOR HIGHWAY EMBANKMENT MATERIAL

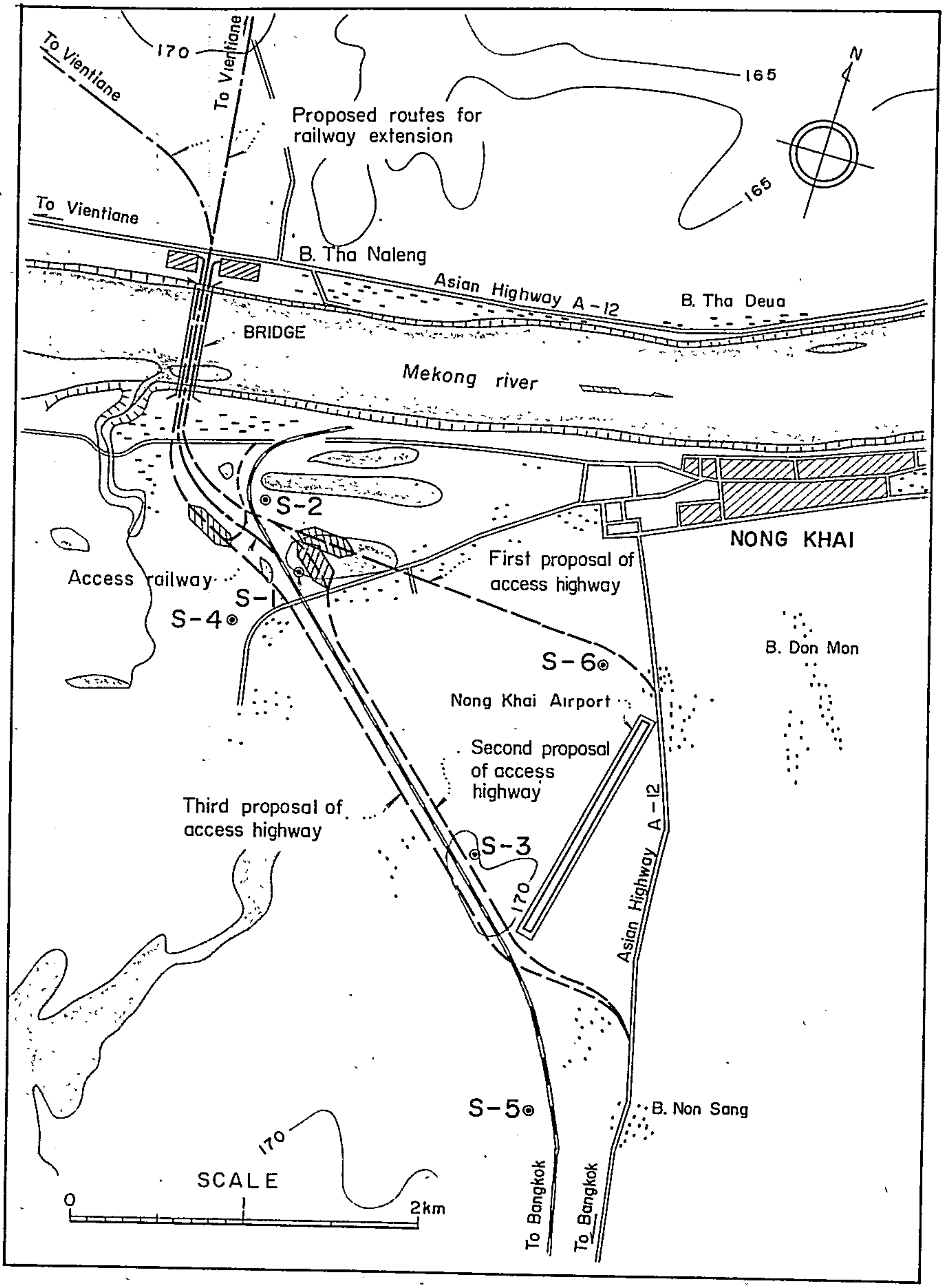

Table 2.6. Summary of soil test

Location: Nong Khai

Items	Unit	1	2	3	4	5	6
Sample No.		1	2	3	4	5	6
I. Observation		Grey brown	Grey brown	Yellow brown	Yellow brown	Yellow brown	Red brown
II. Properties							
(1) Natural water contents, w	%	32.20	30.71	9.56	12.41	14.27	14.21
(2) Specific gravity of soil, G		2.73	2.75	2.71	2.70	2.71	2.72
III. Grain size							
(1) Proportion							
i) Gravel part	%	0	0	6.0	0	8.0	0
ii) Sand part	%	0.1	1.0	24.0	5.0	12.0	8.0
iii) Silt part	%	26.9	38.0	38.0	68.0	41.0	58.0
iv) Clay part	%	73.0	61.0	32.0	27.0	39.0	34.0
(2) Maximum diameter	mm	0.105	0.105	4.8	0.42	4.8	0.25
(3) 60 % diameter, D_{60}	mm	0.032	0.0049	0.037	0.047	0.04	0.04
(4) Grain size classification		Clay	Clay	Clay	Silty clay loam	Clay	Silty clay
(5) Unified classification		CH	CH	CL	ML or CL	CH	MH or CH
(6) AASHO's classification		A-7	A-7	A-7	A-6	A-7	A-7
IV. Consistency							
(1) Liquid limit, L.L.	%	63.52	56.55	45.20	34.50	50.80	54.70
(2) Plastic limit, P.L.	%	28.32	25.07	16.81	16.04	16.61	16.00
(3) Plasticity index, P.I.		35.20	31.48	28.39	18.46	34.19	38.70
(4) Flow index, F.I.		9.73	13.60	13.12	9.76	13.60	6.80
V. Compaction							
(1) Optimum water contents		17.8	17.7	12.5	13.2	12.0	14.0
(2) Max. density, d_{max}	g/cm^3	1.638	1.750	1.970	1.918	1.896	1.881
VI. Shearing strength							
(1) Triaxial compression							
i) Cohesion, c	kg/cm^2	2.05	1.75	1.10	1.10	1.55 2.10	1.75 1.75
ii) Internal friction angle, ϕ		33°00'	16°42'	33°01'	19°18'	21°48' 33°01'	30°58' 16°46'
VII. Consolidation							
(1) Initial void ratio $_o$		0.539	0.573	0.383	0.381	0.407 0.586	0.335 0.398
(2) Preconsolidation load, P_o	kg/cm^2	0.58	0.61	0.35	0.47	0.91 0.78	0.69 0.60
(3) Compression index, C_c		0.539	0.573	0.383	0.381	0.407 0.386	0.335 0.398
(4) Coef. of consolidation, C_v	cm^2/sec	0.58	0.61	0.35	0.47	0.91 0.78	0.69 0.60
(5) Coef. of volume compressibility, M_v	cm^2/g	0.195	0.196	0.150	0.148	0.086 0.083	0.259 0.266
(6) Coef. of permeability K	cm/sec	$4.4x10^{-3}$	$1.1x10^{-2}$	$7.0x10^{-3}$	$9.8x10^{-3}$	$1.9x10^{-2}$ $1.6x10^{-2}$	$1.7x10^{-3}$ $4.7x10^{-3}$

Items	Unit	1 + 2	3 + 4	5	6
VIII. Modified C.B.R.		1.31	1.14	6.20	0.68
IX. Swelling test					
(1) Case 1					
Curing period					
0 day, Swelling ratio	%	22.84	21.34	9.24	58.28
Direct compression, C	kg/cm^2	0.112	0.062	0.17	0.028
ϕ	°	0°55'	2°07'	23°16'	0°24'
τ	kg/cm^2	0.128	0.099	0.60	0.035
1 day, Swelling ratio	%	-	12.98	4.31	-
Direct compression, C	kg/cm^2	-	0.26	0.14	-
ϕ	°	-	0°04'	28°49'	-
τ	kg/cm^2	-	0.27	0.69	-
7 days, Swelling ratio	%	-	11.10	5.52	-
Direct compression, C	kg/cm^2	-	0.24	0.25	-
ϕ	°	-	3°27'	25°39'	-
τ	kg/cm^2	-	0.30	0.73	-
14 days, Swelling ratio	%	-	19.15	11.56	-
Direct compression, C	kg/cm^2	-	0.10	0.24	-
ϕ	°	-	6°17'	20°19'	-
τ	kg/cm^2	-	0.21	0.61	-
(2) Case 2					
Surcharge load					
0.15 kg/cm^2, Swelling ratio	%	1.50	0.90	- 0.79	-
Direct compression, C	kg/cm^2	0.62	0.48	0.20	-
ϕ	°	2°52'	15°39'	31°48'	-
τ	kg/cm^2	0.67	0.76	0.82	-
0.30 kg/cm^2, Swelling ratio	%	- 0.75	- 0.05	- 1.39	-
Direct compression, C	kg/cm^2	0.48	0.70	0.57	-
ϕ	°	5°43'	2°52'	18°16'	-
τ	kg/cm^2	0.58	0.75	0.90	-
0.45 kg/cm^2, Swelling ratio	%	0.76	- 0.10	- 2.31	-
Direct compression, C	kg/cm^2	0.78	0.52	0.33	-
ϕ	°	7°59'	11°19'	25°11'	-
τ	kg/cm^2	0.92	0.72	0.80	-
(3) Case 3					
Mixing ratio					
30 %, Swelling ratio	%	-	30.55	16.13	-
Direct compression, C	kg/cm^2	-	0.28	0.12	-
ϕ	°	-	21°49'	32°38'	-
τ	kg/cm^2	-	0.68	0.76	-
60 %, Swelling ratio	%	-	27.52	12.34	-
Direct compression, C	kg/cm^2	-	0.17	0.15	-
ϕ	°	-	23°17'	31°48'	-
τ	kg/cm^2	-	0.60	0.77	-
(4) Case 4					
Curing period					
1 day, Swelling ratio	%	-	5.21	0.18	-
Direct compression, C'	kg/cm^2	-	1.12	3.20	-
ϕ	°	-	33°02'	1°44'	-
τ	kg/cm^2	-	1.77	3.23	-
7 days, Swelling ratio	%	-	3.55	1.09	-
Direct compression, C	kg/cm^2	-	1.60	0.77	-
ϕ	°	-	11°52'	51°49'	-
τ	kg/cm^2	-	1.81	2.04	-

Remarks:-

(1) The details of the cases in the swelling test are described in this paragraph of the report.

(2) In making CBR and swelling tests, the sample No.1 was mixed with the sample No.2, and the sample No.3 with the sample No.4, because of the similar characteristic each other.

(3) The CBR test was made after the samples were saturated with water for four days.

(4) The specimen that was used for the swelling test was 6 cm in diameter and 2 cm in height.

(5) The negative swelling ratio means the compression ratio.

2.4. Route Reconnaissance

After the location of the center line of the bridge selected at the first phase investigation was reviewed at the second phase investigation and confirmed to be recommendable, favorable routes of the highway and railway to be connected with the bridge were sought by reconnaissance, and are shown in Fig. 2.7.

(1) Highway

The new highway/1 is planned to connect the existing Asian Highway A-12 running from Bangkok to Nong Khai in Thailand with the same Highway leading to Vientiane from Tha Naleng in Laos after crossing the Mekong by means of the bridge.

Concerning the highway route on the Laotian side, its reconnaissance was hardly necessary because the route length is very short. As shown in PLATE 2, the existing Asian Highway runs only about 200 meters away from the riverside near the bridge site and that the administrative facilities for immigration and customs procedures are to be built on the land between the river and the Asian Highway. As the facilities need a considerably large space, this access highway linking the bridge with the facilities is only about 120 meters long. A simple reconnaissance, however, was executed. As a result, it was found out that the planning can be done as expected without any problem.

As regards the highway route on the Thai side, three favorable proposals are made.

The first proposal was made in the First Phase Report. This route branches off from the Asian Highway at a point about 1.2 kilometers south of the town of Nong Khai, and reaches the bridge site

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/1 This is comparatively short and immediately approaches the bridge after branching off from the Asian Highway. In this sense, this highway is called the "access highway".

mostly through marshy area and relatively costly land. The route length is about 3.4 kilometers.

The second is a new route proposed by the Thai Government authorities, which is to plan a highway running along the existing railway on its right side toward north. This new highway will branch off from the Asian Highway at a point about 3 kilometers south of the town of Nong Khai, and will approach the railway and turn to the bridge site with a reverse curve of a radius of 500 meters each, and then it will run straight 50 meters away from the railway and will reach the bridge site running through the administrative facilities. The total route length is about 4.4 kilometers excluding the highway about 570 meters long in the area of the administrative facilities.

The third is a proposal of planning a highway running on the left side of the existing railway toward north. This route is on the opposite side of the route proposed as the second.

The above three routes were investigated in detail, and no serious problems were encountered during the reconnaissance although all three routes pass the marshy area. Particularly noticeable is that the second and third routes run close by the Nong Khai airport/1. The comparative study on these routes is made in Chapter III.

(2) Railway

A new railway line to cross the Mekong and reach Vientiane is planned to branch off from the existing railway line running between Bangkok and Nong Khai in Thailand.

The new railway route/2 on the Thai side is very short because the branch-off point is located near the place where the line begins

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/1 The Civil Aviation Department of Thailand approved the construction of a highway running through the district lying between the existing railway line and the Nong Khai airfield.

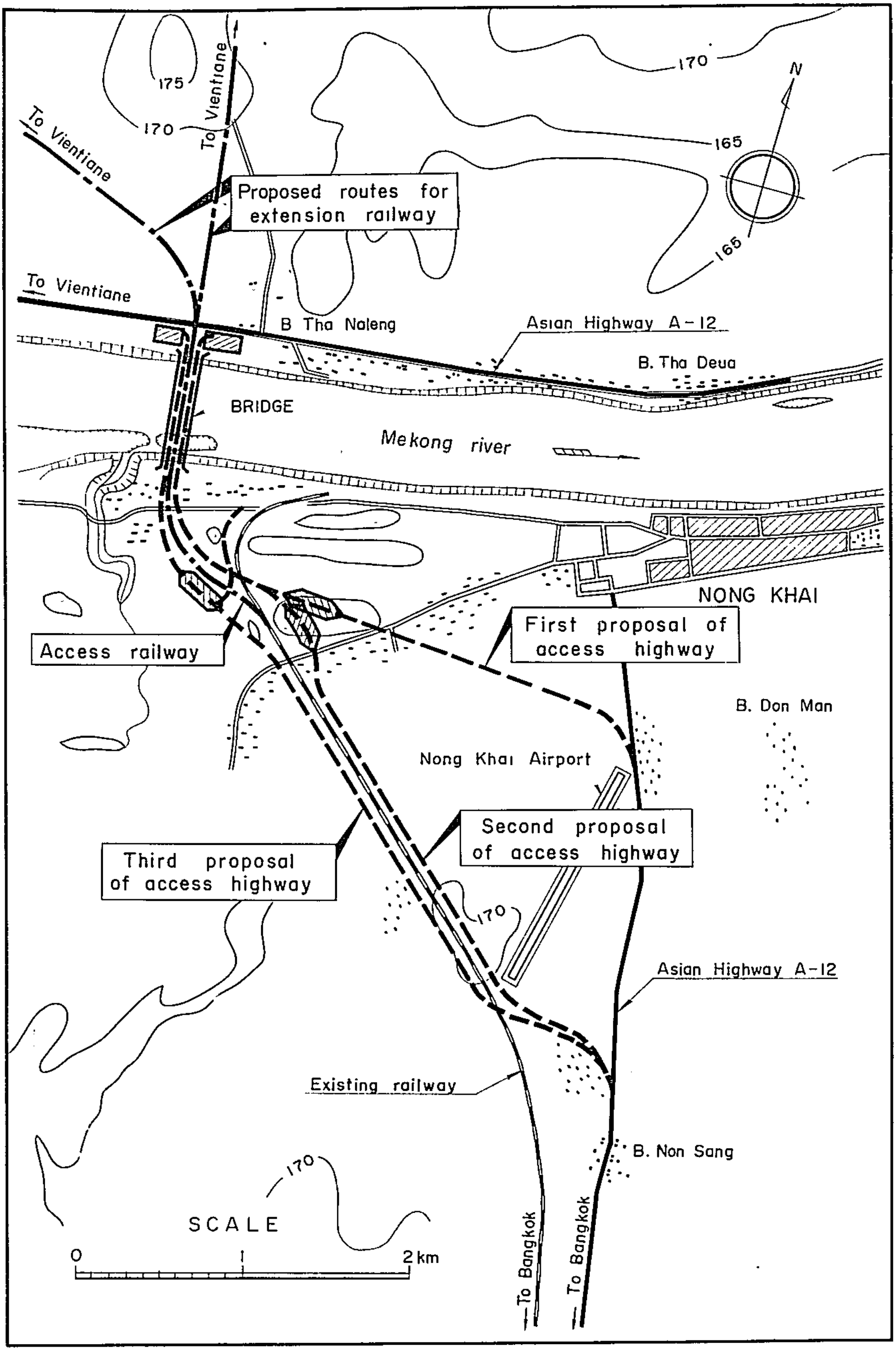
/2 As it is immediately connected with the bridge at a short distance, this railway is called the "access railway".

to take a curve toward the present Nong Khai railway station. Its length is only about 1 kilometer. As expected, the result of the field reconnaissance has revealed that no serious problems would be involved.

As to the extension of the railway/1 to Vientiane from the bridge site after crossing the Mekong, five promising routes are considered as shown in PLATE 1. These routes have been reconnoitered in detail in the second phase investigation, too, and their merits and demerits are given in Chapter III.

/1 The new railway in Laotian soil is named the "extension railway" in the sense that the existing railway trunk line in Thailand is extended from Nong Khai to Vientiane.

Fig. 2.7. ROUTE RECONNAISSANCE



2.5. Engineering Data Collection

Many kinds of engineering data were collected during the second phase investigation as well as the first phase investigation. They are, namely, (1) meteorological and hydrologic data, (2) design standards of highway and railway in Thailand, (3) over-all road network plans in Laos and Thailand respectively, (4) drawings of city plan in Vientiane, (5) regulations for aviation in Thailand, (6) data relative to the expenses of compensation for various kinds of land, houses and valuable trees, current prices of local materials and daily or monthly salaries of technicians and laborers in and around Vientiane and Nong Khai, (7) data concerning the present car ferry service crossing the Mekong between Tha Naleng and Nong Khai, and the sources of electricity available for construction work near the bridge site, (8) data in regard to the river-bed erosion due to structures built in the river, (9) seismic data, and (10) maps covering a part of the project area or the whole.

These data are all useful for the feasibility study, but are voluminous. What are compiled in Appendices are therefore limited to only the important ones for use as reference.

The following is a brief description of the data listed above.

(1) Meteorological and hydrologic data

The meteorological data collected involve rainfall, air temperature, relative humidity, prevailing wind direction and wind velocity, and evaporation. These data were obtained from the three meteorological stations, namely Vientiane, Nong Khai and R.I.D. (Nong Khai).

As for hydrologic data, the records of water-level, discharge, flow velocity, flood, and water temperature were collected from the six gaging stations which are at Wat Sop in Vientiane, in the site of Hydrographic Office, at Wat Hai Sok, Ban Dok Kham, Wat Sri Mong Kol and Ampho Tha Bo, of which the last four stations belong to R.I.D.

Most of the meteorological and hydrologic data are compiled in Appendices and the characteristic values of these data are summarized below.

Table 2.7. Characteristic values of the meteorological and hydrologic data

(a) Water-level

Period of analysis : 1958 to 1967
Unit : meters above sea level

Water-level	R.I.D. gaging station (Wat Hai Sok)	Hydro-graphic Office	Bridge site
Maximum ever recorded	EL. 167.6	168.4	-
95-day (rich)	159	160	161
185-day (ordinary)	156	157	157
275-day (low)	155	156	156
355-day (dry)	154	155	155
Minimum ever recorded	153	154.8	-

(b) Rainfall

Period of analysis : 1958 to 1967

Rainfall	Unit	R.I.D. meteor. station
Max. daily rainfall	mm	221.2
Max. monthly rainfall	"	727.4
Annual rainfall, max.	"	1,857.7
mean	"	1,501.5
min.	"	1,157.5
Annual rainy days/1, max.	days	117
mean	"	95
min.	"	67
Workable days/2, max.	"	256
mean	"	235
min.	"	205

Remarks:

/1 Excluding rainy days on which the daily rainfall was less than one millimeter.

/2 Not including the following day of a rainy day or of the last day of a series of rainy days. The rainy day herein stated involves the same definition as the above footnote/1.

(c) Wind velocity

Meteor. station	Max. daily-mean wind velocity (m/sec)	Remarks
Nong Khai	9.5	Period: 1966 to 1967
Vientiane	26	" : 1959 to 1968

(d) Air temperature

Meteor. station	Air temperature (°C)	Remarks
Nong Khai	35.0 (max.)	Period: 1964 to 1967
	26.6 (mean)	
	12.8 (min.)	

(e) Relative humidity

Meteor. station	Relative humidity (%)	Remarks
Nong Khai	98 (max.)	Period: 1964 to 1967
	74 (mean)	
	45 (min.)	

(f) Probable high-water level /1 at the bridge site

Recurrence year	Probable high-water level (m)
2	EL. 165.5
5	166.7
10	167.5
20	168.1
40	168.8
50	169.0
100	169.6
200	170.2

/1 These figures are estimated from the water-level records of the R.I.D. gaging station at Wat Hai Sok for the period from 1937 to 1967.

(2) Design standards of highway and railway in Thailand

Some data relative to the design standards of highway were presented by the Highway Department in Thailand, and those of railway by the Royal State Railway in Thailand. These data were utilized for making the preliminary design of highway, railway and bridge, and are extracted and put in Chapter III and Chapter IV.

(3) Over-all road network plans in Laos and Thailand respectively

These data are given in Appendices, and are useful for getting comprehensive views of the project.

(4) Drawings of city plan in Vientiane

These drawings are also given in Appendices. There is no description of the future expansion of the present city of Vientiane in these drawings.

(5) Regulations for aviation in Thailand

These data were collected from the Civil Aviation Department of Thailand in the light of the proposal that the access highway to be newly constructed on the Thai side should run through the open space lying between the existing railway and the Nong Khai airfield. These data are relative to the selection of the access highway routes mentioned in Chapter III.

(6) Data relative to the expenses of compensation for various kinds of land, houses, and valuable trees, current prices of local materials and daily or monthly salaries of technicians and laborers in and around Vientiane and Nong Khai

Reference is made to these data in estimating the construction cost and they are arranged in good order in Appendices.

(7) Data concerning the present car ferry service crossing the Mekong between Tha Naleng and Nong Khai, and the sources of electricity available for construction work near the bridge

An alternative plan to this bridge project can also be considered by gradually increasing the trans-Mekong car ferry to accommodate future growing traffic. This study is made in Chapter III based on the data of the present car ferry service.

The electric power for construction use is available at Nong Khai. A 22 kV distribution line is now under construction near the bridge site as shown in Fig. 2.8. This is an extension of the existing 22 kV distribution line running from Udon Thani. In the near future, the 22 kV distribution line is to be connected with the Nong Khai substation 5,000 kVA in capacity and 110 kV/22 kV in voltage, and by way of this substation the 110 kV transmission line runs from the Pong Neeb power station to the Nam Ngum dam site. Abundant electric power will therefore be available for this bridge project at the time of its construction through the Pong Neeb power station and later the Nam Ngum power station.

(8) Data in regard to the river-bed erosion due to structures built in the river

The team received from the Laotian authorities concerned some data about the intake tower built in the Mekong for water supply to Vientiane. In addition, an echo-sounding was made in the river around the intake tower. As a result, a depression about 5 meters deep and about 20 meters in diameter was found at the place about 20 meters downstream from the tower and about 10 meters toward the middle of the river. This depression had been found by the Laotian Government last year, the result of which is given in Fig. 2.9.

The effect of this depression seems to have extended over fifty meters toward the downstream reach. Furthermore, it is judged that the bank close to the tower is somewhat eroded by turbulent flow to the extent of about fifty meters upstream and downstream respectively.

Because both the Laotian Government and the Japanese bridge team made the survey in the dry seasons, there is unknown how the depression would develop in rainy seasons when the Mekong flows in a rapid current.

The problem is whether or not the scouring action on the river-bed caused by building piers in the Mekong will affect the shipyard now under construction close by the river in Thailand. The upstream end of the shipyard is located at about 150 meters downstream from the center line of the bridge. Consequently, judging from the results obtained by the team, the shipyard does not seem to be affected by the scouring action.

In order to obtain more certainty about this matter, it is necessary to execute an echo-sounding survey in rainy seasons and to know the aspects of the depression in the river-bed and the turbulent flow immediately downstream from the tower, or it may be better to make a model test in the hydraulic laboratory.

The measures to protect piers from scouring action or to protect banks from erosion are mentioned in Chapter III.

(9) Seismic data

A seismic report[/1] titled "SOME CONSIDERATIONS RELATIVE TO POSSIBLE INSTALLATION OF SEISMOGRAPHIC EQUIPMENT AT LOWER MEKONG PROJECTS (Note by Mekong Secretariat)" was presented to the team by the Mekong Committee.

The following is an extract from this report.

> "According to the data at present available, the site at Pa Mong lies outside the seismic belt. There are traditions of small earthquakes

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/1 Not compiled in Appendices.

> being felt in the region, but it seems probable that these were the marginal effects of large earthquakes originating at quite considerable distance. ....
> ....
> Some small earthquakes have been reported in Laotian territory from time to time, but it is generally considered that their origins are some considerable distance away".

The Mekong Committee has recommended the team that there is no necessity to consider any effect of earthquake when designing the structures for this bridge project. Accordingly, the team complies with the Mekong Committee's recommendation.

(10) <u>Maps covering a part of the project area or the whole</u>

Various scales of maps were collected from the geographical bureau in Vientiane. They are referred to the planning of the project in many aspects.

Fig. 2.8. SOURCE OF ELECTRICITY FOR CONSTRUCTION USE

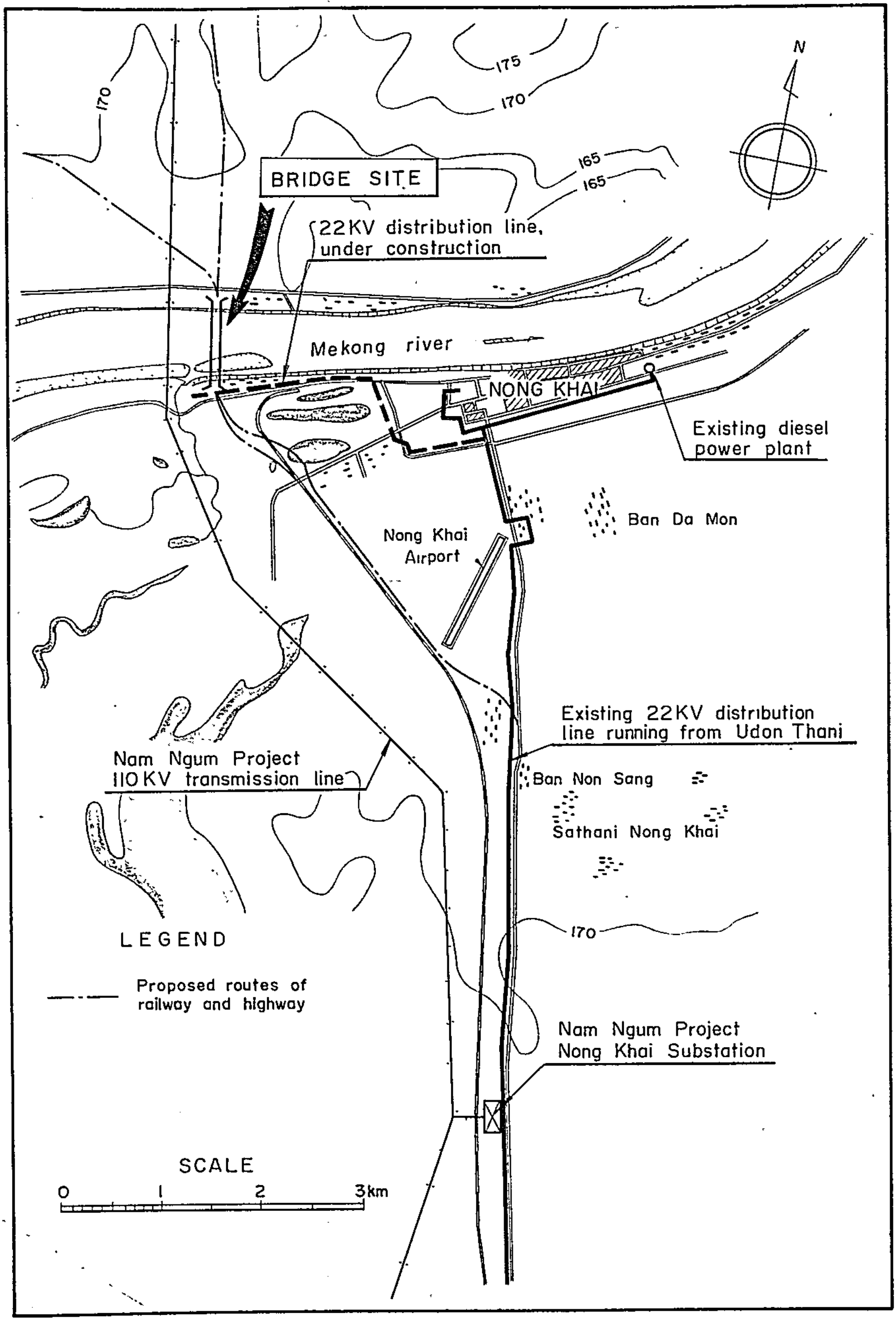
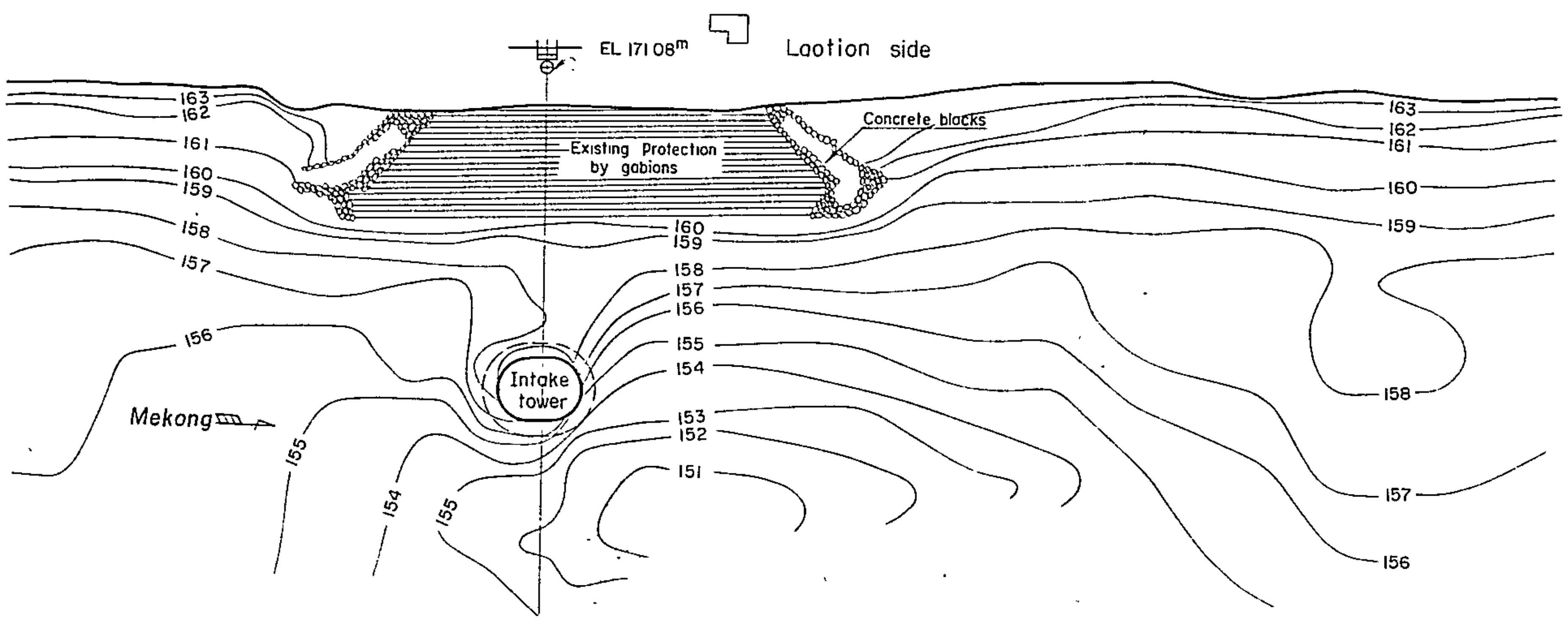
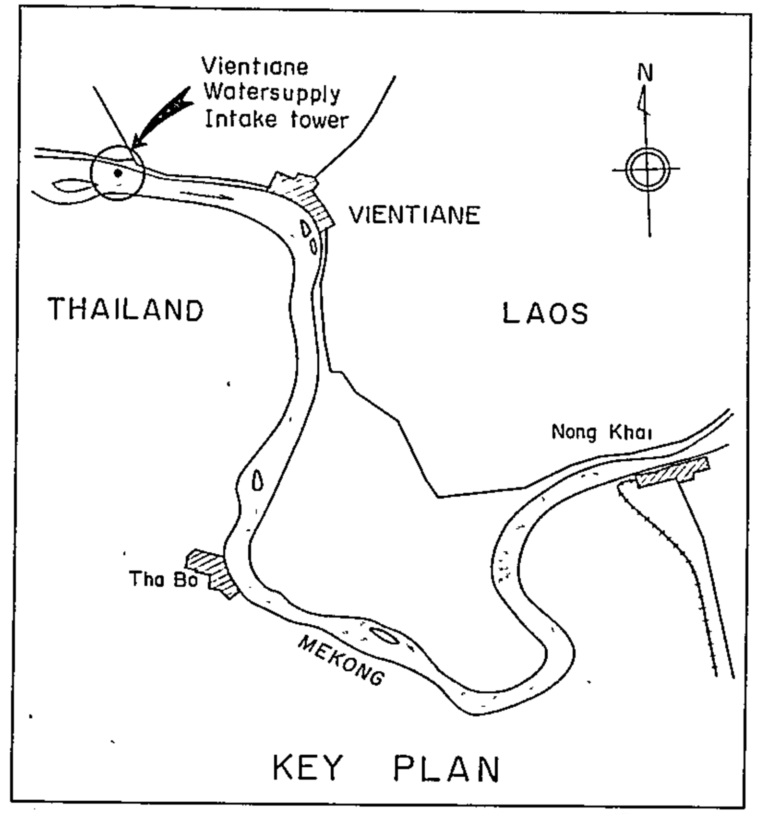


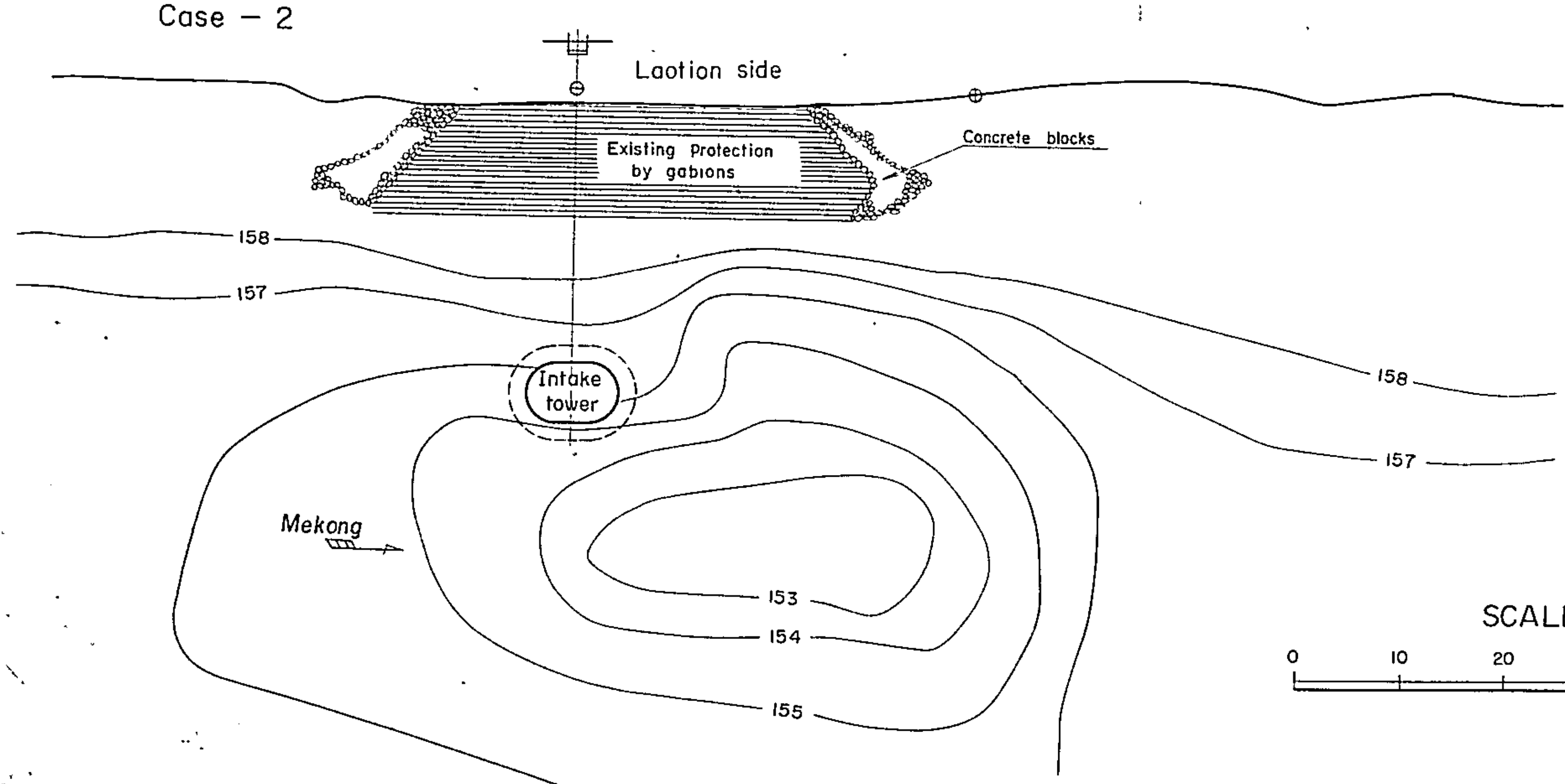
Fig. 2.9. SCOURING EFFECT BY OBSTRUCTION IN STREAM

Case – 1





Case – 2



Remarks :

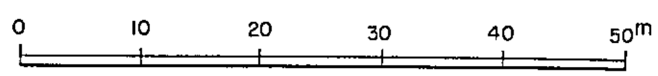
Case – 1.

This topographic map was made under the measurement conducted by the staff of T.P. in Laos on 13 March 1967.

Case – 2

This is the result of sounding measurment by Survey Team on 4 April 1968, utilizing echo-sounder.

SCALE



2.6. Economic Survey

As mentioned before, the first phase investigation was intended to select the most favorable bridge site from among the three proposed sites, and the second phase investigation aimed to choose more suitable kind of bridge between a rail/highway bridge and a highway bridge.

The purposes of these two investigations are eventually considered to be a problem of comparison between the direct benefit which the bridge project would bring about every year and the cost which would be required every year for the depreciation, operation, maintenance, and repairing of the bridge project after completion.

The cost is estimated through the engineering surveys and studies, while the direct benefit is derived from the economic surveys and studies. The economic survey was performed in two phases likewise with the other engineering surveys. In the first-phase economic survey the following four economic factors were investigated./1 The direct benefit is, in a word, a product of these factors.

(1) the imaginary initial traffic that would utilize the new bridge on the assumption that the bridge would just be constructed and opened to traffic at the time the traffic survey was made,

(2) the benefit per unit of traffic volume,

(3) the rate of natural growth, and

(4) the growth index due to the impact of bridge construction.

/1 Various data were collected in Bangkok in addition to the on-the-spot survey. The itinerary of the economic specialists who were engaged in the first-phase economic survey has been given in the First Phase Report.

The second-phase economic survey/1 was carried out to make a study of the following two items, namely, (1) the indirect benefit that would be brought about by the bridge project and (2) the relation between the bridge toll and the future traffic growth.

A brief description is made of the above six major items hereinafter.

(1) Imaginary initial traffic

Before the imaginary initial traffic is estimated, it is necessary to know the present traffic condition in and around the project area. For this purpose, the origin-destination survey/2 was carried out about the traffic of highway, waterway, railway and airway having relations with the bridge project. Various useful economic data were also collected from many government authorities concerned such as the Thai Highway Department, the Thai Customs Department, the Thai Immigration Department, the Royal State Railway of Thailand, Nong Khai railway station, Udon Thani railway station and the Civil Aviation Department of Laos.

The origin-destination surveys on the highway traffic and waterway traffic were conducted at the following ten places, as shown in Fig. 2.10.

/1 The itinerary of the economic specialists who were engaged in the second-phase economic survey is shown in Fig. 1.1. in this report.

/2 The origin-destination survey implies to make clear the origin and destination of the individual vehicles provided that the survey is made of highway traffic. A highway is utilized as a means of communication usually between the two zones calling the zone on one side Origin and the other side Destination. A vast district in which the vehicular traffic arises everywhere can therefore be divided into several major zones.

In this origin-destination survey, the freight volumes by articles were surveyed at the same time.

Table 2. 8. Survey points for the origin-destination survey and the date executed.

	Survey point	The date executed
1.	7 km. from Vientiane toward Luang Prabang	12 Sep. '67 (Tues.)
2.	11 km. from Vientiane toward Pak Sane	12 Sep. '67 (Tues.)
3.	8 km. from Vientiane toward Tha Deua	15 Sep. '67 (Fri.)
4.	Tha Naleng car ferry site	19 Sep. '67 (Tues.)
5.	Nong Khai passenger ferry site	29 Sep. '67 (Fri.)
6.	12 km. from Nong Khai toward Tha Bo	10 Oct. '67 (Tues.)
7.	17 km. from Nong Khai toward Udon Thani	11 Oct. '67 (Wed.)
8.	4 km. from Udon Thani toward Nong Bua Lamphu	3 Oct. '67 (Tues.)
9.	5 km. from Udon Thani toward Nong Han	4 Oct. '67 (Wed.)
10.	11 km. from Udon Thani toward Khon Kaen	6 Oct. '67 (Fri.)

The period of time that the survey was executed was 12 hours from 6 a.m. to 6 p.m. in the daytime on all the days mentioned above. The origin-destination survey to obtain 24-hour traffic volume was carried out only at the point of 12 kilometers from Nong Khai toward Udon Thani, because the traffic in the nighttime was light at any of these sites due to the adverse security condition. The ratio of the 12-hour traffic volume to the 24-hour traffic volume at the said point was 1 : 1.23. This ratio was applied to other survey points for converting the 12-hour traffic volume into the 24-hour traffic volume.

Furthermore, the fact-finding was made on the traffic of the main ferry routes crossing the Mekong near the project site such as those between Vientiane and Sri Chieng Mai, between Tha Bo and Hat Dok Keo, and between Nong Kahi and Tha Deua. Information on the waterway traffic linking Vientiane with Savanakhet and Luang Prabang was also gathered at the customhouses and the immigration offices located at Vientiane.

Based on the data thus obtained at the field survey, the movement of freight, passengers, and vehicles by zonal pairs was made clear as given in Tables 2.9 , 2.10, 2.11, and 2.12, and then the imaginary initial traffic was estimated on the assumption that a bridge is now open for traffic at site.

(2) Benefit per unit of traffic volume

After a bridge is constructed across the Mekong, the economical distance in zonal pairs which are obtained by coupling one with another across the Mekong from among several zones located on both sides of the Mekong, will be reduced to a large extent.

The benefit per unit of traffic volume is the direct benefit to be derived from the reduction of travel time and the saving in the cost of operation per unit of traffic volume in a zonal pair, and can be computed by

$$B = (C_o - C_1) + a(T_o - T_1)$$

in which, B : Benefit,

C_o: Cost of operation in a zonal pair on the existing route to be used until the bridge is completed,

C_1: Cost of operation in a zonal pair on the projected route to be used after the bridge is completed,

T_o: Time of travel in a zonal pair on the existing route,

T_1: Time of travel in a zonal pair on the projected route,

a : Coefficient for converting the time of travel into monetary value.

This direct benefit, which is called user benefit, changes with the type of the vehicles such as passenger car, truck, motorcycle, and so on.

The following data were collected for use in estimating the benefit per unit of traffic volume; (1) a table of geographical distances along roads in zonal pairs, (2) costs of operation of vehicles per kilometer, (3) charges and crossing times of the Mekong in the car ferry and the passenger ferrys, (4) prevailing operating speed of vehicles per kilometer, (5) charge for waiting time of vehicles for passenger use, trucks and so forth, (6) average riding or loading efficiency of each type of vehicles and (7) the national income of Thailand. The data of the first four items (1), (2), (3) and (4) were collected from the Highway Department of Thailand, the next two items (5) and (6) from the government authorities concerned of Thailand and Laos and the last item (7) from the Statistics Bureau of Thailand.

When the total direct benefit brought about by the bridge is calculated as a product of the four factors mentioned before, it is assumed that the benefit per unit of traffic volume remains unchanged irrespective of the lapse of time.

(3) Rate of natural growth

Two kinds of the natural growth can generally be considered, one is that of the benefit to be brought about from the project and the other is that of traffic. It is very difficult to forecast the natural growth of the project benefit in the future. It will therefore be kept unchanged throughout the useful life of the project.

Only the natural growth of traffic will be estimated for this bridge project as mentioned below.

In the project area, the natural increase in the number of vehicles which cross the Mekong will depend largely on the economic growth of Laos, particularly in Vientiane.

The data mentioned below were collected for the estimation of the natural traffic growth which corresponds to the economic growth.

(1) the number of passenger and the volume of freight crossing the

Mekong in time series which were given by the customhouse in Vientiane and the Immigration Department of Thailand

(2) the gross national product of Laos in the same time series as in the item (1) and the estimated gross national product of Laos in the future, which were both collected from USAID

The future gross national product of Laos which were finally adopted in the First Phase Report was estimated by referring to the rates of economic growth of other developing countries in Southeast Asia in recent years as well as the trend of the economic growth in the past years collected from USAID.

As for the estimation of the loading efficiency of each type of vehicles required in the assumption of the future traffic growth each year, reference was made to the data not only in Thailand and Laos but also in Japan.

(4) <u>Growth index due to the impact of bridge construction</u>

The completion of the bridge will bring about the reduction in the so-called economical distance of traffic and eventually will cause traffic growth. The economical distance in a zonal pair is a comparative distance between two specified zones to be determined by taking the operating time and cost of vehicles into account.

Such traffic growth can be obtained by means of the method of Gravity Model/1. According to this method, the rate of traffic growth due to the completion of bridge is given by the following equation. If P denotes the rate of traffic growth due to the completion of bridge, P becomes

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/1 Refer to Walter Isord, "Method of Regional Analysis, An Introduction to Regional Science," John Wiley, 1960.

$$P = \frac{T_{ij}(1) - T_{ij}(0)}{T_{ij}(0)} = \left\{ \frac{d_{ij}(0)}{d_{ij}(1)} \right\}^{b} - 1$$

Where

$T_{ij}(1)$: traffic volume between two zones, i and j, after the completion of bridge,

$T_{ij}(0)$: traffic volume between two zones, i and j, before the completion of bridge,

$d_{ij}(1)$: economical distance between zones, i and j, after the completion of bridge,

$d_{ij}(0)$: economical distance between zones, i and j, before the completion of bridge,

b : an exponent to be properly determined case by case.

The data to be required for the estimation of this rate P were collected from the government authorities of Thailand and Laos. They are listed up in the preceding item (2).

(5) Indirect benefit

The indirect benefit includes literally the benefits that result from the project such as (1) the increase in production profit in relation to the lowering of transportation cost of raw material to be brought about from the utilization of the better transport facilities, (2) the increase in sale due to the drop of selling price, (3) the growth of demand as a result of the fall of retail price, (4) the effect due to saving of stock to be derived from the reduction of time of transportation of raw material, (5) the increase in proceeds in export industries, (6) the rise in land values, (7) development value of natural resources, (8) promotion of tourism, (9) progress in economic activities, and so on.

In order to obtain every information and data indispensable to evaluate these indirect benefits, the door-to-door visit was made to shops, factories, markets and so on in Vientiane, Nong Khai and their environs. The factories visted were tabacco, plastic bag and footwear factories, iron works, sawmill, rice-processing mill, helm-dressing company and so on in and around the cities of Vientiane and Nong Khai, more than twenty altogether.

As for shops and markets, the shops selling rice, clothings, construction materials, vehicles, oil and so on and markets were visited.

Furthermore, the fact-finding survey was carried out on the customhouses and immigration offices located at the three ferries of Vientiane-Sri Chieng Mai, Hat Dok Keo-Tha Bo and Tha Deua-Nong Khai routes.

(6) Relation between the bridge toll and the future traffic growth

The future traffic growth will vary with the bridge toll. The adequate bridge toll ranges from free-of-charge to the amount equivalent to the current charge of the car ferry. In the First Phase Report the future traffic growth was estimated on two cases of bridge toll; one case is that the bridge toll is free and the other case is that the bridge toll is equal to the current charge of the car ferry. In the Second Phase Report, more cases will be considered in the bridge toll between free-of-charge and the current car ferry charge.

The future traffic growth can be considered to depend on production and consumption in the project area and besides to be influenced by the income standard and price level in the project area. Therefore, the field survey was conducted on these economic characteristic values of the project area. Furthermore a fact-finding survey was made at ETO and SOGOV to gather information as to what influence the bridge toll will exert on production, consumption, traffic growth and so on, because ETO has close relation with the current car ferry running between Nong Khai and Tha Naleng and SOGOV is the administrative authority of this ferry.

Fig. 2.10. SURVEY POINTS FOR ORIGIN-DESTINATION SURVEY

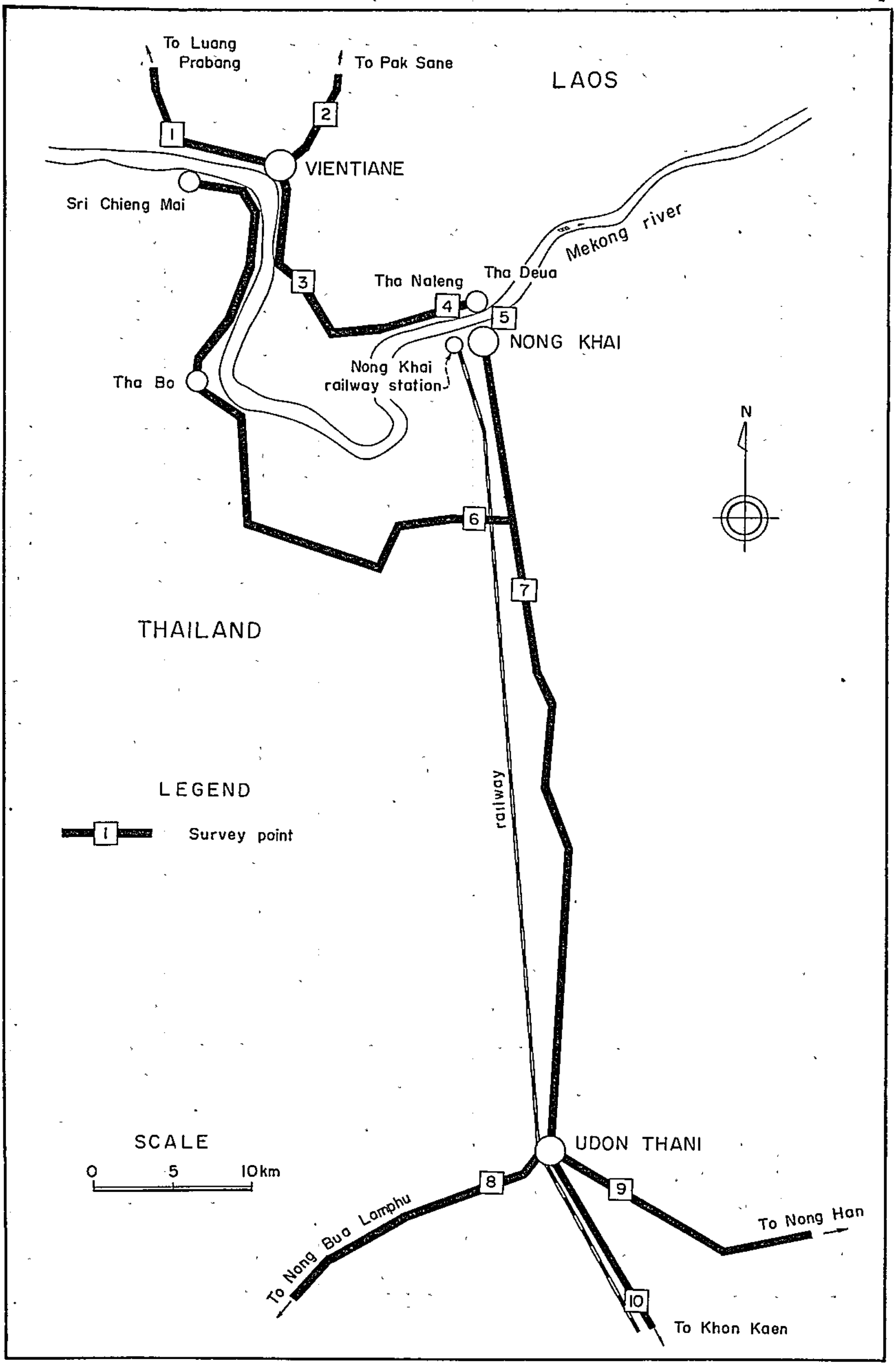


Table 2.9. Interzonal vehicles
(1967)

Unit: cars/day

No.	Zone	1 Vientiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vientiane	8 East. Dist. Vientiane	9 East. Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total
1	Vientiane		24	22	2,704	7		470	507		22				3,756
2	Nong Khai					741	238			6	88	9			1,106
3	Nong Khai Sta.				80										102
4	Tha Deua					13		2	27		51				2,877
5	Udon						242		1	1,839	2,209	840			5,892
6	Tha Bo								2	2	25				509
7	N. Dist. V'tiane								2						474
8	E. Dist. V'tiane														539
9	E. Dist. Udon										94	51			1,992
10	S. Dist. Udon											17			2,506
11	W. Dist. Udon														917
12	Upper Mekong														
13	Lower Mekong														
	Total														20,670

Table 2.10. Interzonal passengers (1967)

Unit: persons/day

No.	Zone \ Zone	1 Vien-tiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vien-tiane	8 East. Dist. Vien-tiane	9 East. Dist. Udon	10 South Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total
1	Vientiane		285	136	7,248	40	660	2,485	1,767		139				12,760
2	Nong Khai				295	3,151	798			11	452	39			5,031
3	Nong Khai Sta.				35	24			5		175				375
4	Tha Deua					10		17	3		52				7,660
5	Udon						1,289		4	35,145	12,217	5,420			57,300
6	Tha Bo								11	24	131				2,913
7	N. Dist. V'tiane								2						1,792
8	E. Dist. V'tiane														35,474
9	E. Dist. Udon										229	65			13,440
10	S. Dist. Udon											45			5,569
11	W. Dist. Udon														
12	Upper Mekong														
13	Lower Mekong														
	Total														142,314

Table 2.11. Interzonal fre'ght. – 1
(1967)

Unit: tons/day

No.	Zone	1 Vien-tiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vien-tiane	8 East. Dist. Vien-tiane	9 East Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 lower Mekong	Total
1	Vientiane		63.0	18.0	1563.0		15.5	414.0	298.0		15.8		20.0	30.0	2,437.6
2	Nong Khai				5.0	689.0	153.0			25.0	195.0	25.0			1,155.0
3	Nong Khai Sta.				236.0	21.0					243.0				518.0
4	Tha Deua					23.0		5.0	60.0		329.0				2,221.0
5	Udon						288.0			2,035.0	1,243.0	871.0			5,170.0
6	Tha Bo									6.0	59.0				521.5
7	N. Dist. V'tiane								14.0						433.0
8	E. Dist. V'tiane														372.0
9	E. Dist. Udon										655.0	215.0			2,936.0
10	S. Dist. Udon											100.0			2,839.8
11	W. Dist. Udon														1,211.0
12	Upper Mekong														20.0
13	Lower Mekong														30.0
	Total														19,865.2

Table 2.12. Interzonal freight – 2

(1967)

Unit: tons/day

No.	Zone \ Zone	1 Vientiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vientiane	8 East. Dist. Vientiane	9 East. Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total departure freights
1	Vientiane		63 (63)	0 (18)	1,537 (1,536)			276 (414)	175 (298)		0 (15)				2,051 (2,371)
2	Nong Khai					427 (689)	90 (153)			23 (25)	63 (195)	10 (25)			613 (1,150)
3	Nong Khai Sta.	18			236 (236)										254 (254)
4	Tha Deua	26				0 (23)		0 (5)	60 (60)		0 (329)				86 (2,216)
5	Udon		262		23		134 (288)			147 (2,035)	639 (1,041)	73 (871)			1,276 (4,947)
6	Tha Bo		63			154				6 (6)	2 (59)				225 (506)
7	N. Dist. V'tiane	138			5				1 (14)						144 (433)
8	E. Dist. V'tiane	123						13							136 (372)
9	E. Dist. Udon		2			1,888					200 (655)	25 (215)			2,115 (2,394)
10	S. Dist. Udon	15	132		329	404	57			455		0 (100)			1,392 (2,394)
11	W. Dist. Udon		15			798				190	100				1,103 (1,211)
12	Upper Mekong														
13	Lower Mekong														
	Total Arrival Freights	320	537	0	2,130	3,671	281	289	236	821	1,002	108			9,375 (18,790)

Remarks:- The figures in parentheses involve round-trip weights.

CHAPTER III

RAIL/HIGHWAY BRIDGE

Although the bridge site was decided as Site No.1 (Nong Khai) by the Mekong Committee in January 1968, the kind of bridge to be constructed across the Mekong is not finally decided yet by the Mekong Committee. The Second Phase Report has a purpose to offer such data as the Mekong Committee can dicide the kind of bridge for the Nong Khai/Vientiane Bridge Project.

At the present moment, two kinds of bridge are considered, i.e., a rail/highway bridge and a highway bridge. In Chapter III, a study has been made of the engineering, economic and financial feasibility of the Nong Khai/Vientiane Bridge Project provided that a rail/highway bridge is adopted, while Chapter IV presents the similar study in case that a highway bridge is adopted.

The following are the description of the study mentioned above.

3.1. <u>Engineering Feasibility on the Bridge</u>

3.1.1. General

In case a rail/highway bridge is constructed over the Mekong, the project has two purposes : one is to extend the existing railway from Nong Khai to Vientiane for the mass transportation of freight and passengers, and the other is to consummate the Asian Highway A-12 with a direct link by a modern bridge, which is now obstructed by the Mekong.

The first and second phase investigations and the subsequent studies revealed that the construction of a rail/Highway bridge is practically feasible in view of the engineering aspect, although it may be accompanied with some difficult problems to be overcome before construction such as scouring effect around piers, side erosion along both banks and so forth.

Various comparative studies have been made of the type of bridge and construction materials of bridge to select the most favorable rail/highway bridge that can meet engineering, economic and esthetic requirements. As a result, the superstructure composed of the three-span continuous truss, each span measuring 70-meters, is expected to be the most prospective one. In this case, a railway track and a two-lane highway are to be laid down between the major truss structures. A side-walk for pedestrians and a gangway for track inspection are to be provided outside the major truss structures respectively. The superstructure will be supported with the re-inforced concrete piers that will be built on the pneumatic caissons and the open caissons. The pneumatic caissons are to be built in the river channel of the Mekong and the open caissons are to be built on the riverside terrains, each caisson being founded on the firm siltstone layer.

Besides the standard span of 70 meters, a span of 90 meters will be provided for the inland navigation. According to the navigation requirements stated in the Plan of Operation, the vertical clearance of 10 meters has to be provided above the Design High-Water Level/1 and the horizonal clearance of 78 meters between both side piers. The course of navigation should be taken at the deepest place of the Mekong where is located towards the Laotian side from the middle of the river. The superstructure under which the above clearances are provided for the course of navigation comprises two cantilever arms overhanging the piers on both sides by ten meters respectively and a suspended turss 70 meters long to be sustained by the cantilever arms on both sides.

/1 The Design High-Water Level is mentioned in the next paragraph.

As for the access bridges to be linked with the main steel stuss bridge, the railway track and the roadway of the highway are separated from each other and each access bridge is built of reinforced concrete. The sidewalk and the gangway are connected with the staircases provided at the both-side banks of the Mekong.

The access bridge for reilway use is divided into two parts, a plate girder 60 meters long in total and three-span continuous rigid-frame bridges made of reinforced concrete 342 meters long in total. Each span of the latter bridge measures ten meters, and its substructure is of two-column type and is supported by the precast reinforced concrete piles.

. The access bridge for highway use is planned as a combination of a composite girder bridge 60 meters long and a three-span continuous hollow slab bridge 270 meters long made of reinforced concrete because the highway is wider than the railway and loading is much movable as compared with the railway. Each span of the hollow slab bridge measures fifteen meters. The hollow slab is supported by the two piers standing on the reinforced concrete slab, which is sustained by the reinforced concrete piles driven into the ground. These access bridges are shown in PLATES 6,7 and 8.

As a conclusion, the most recommendable type of bridge spanning the Mekong 640 meters wide at the bridge site has been envisaged as a combination of a steel truss bridge 720 meters long over the Mekong and four kinds of the access bridges over the riverside terrains on both Laotian and Thai sides.

3.1.2. Exact location of the bridge

The location of the center line of the bridge, which was proposed in the First Phase Report, was reviewed at the earliest time of the second phase investigation.

The favorable location can be expected within the range mentioned below.

(1) Three is no favorable location on the area downstream from Hydrographic Office, because the riverside terrain on the Thai side is gradually densely populated as it gets nearer to the town of Nong Khai.

(2) The Mekong ends to make a turn at a large radius at about one kilometer upstream from line on the downstream reaches therefrom does not lie in the middle of the river channel, but still lies towards the Laotian side. Therefore, it is desirable to locate the bridge as downstream as possible.

(3) The trans-Mekong transmission line crosses over the Mekong for the Nam Ngum Project at a point about 600 meters upstream from Hydrographic Office.

(4) A small tributary joins the Mekong on the Thai soil at a point about 400 meters upstream from Hydrographic Office and it often inundates in rainy seasons.

Under the above considerations, the favorable location of the center line of the bridge is confined to the area between Hydrographic Office and the confluence of the tributary with the Mekong. With this in view, the location of the center line of the bridge proposed in the First Phase Report was appropriate. According to the survey map with a scale of 1 to 2,000 made based on the plane table survey conducted during the second phase investigation, the center line was found to be somewhat skew from the river-angled line to the river course. The center line is therefore corrected at right angle to the river course, as shown in Fig. 2.2. This corrected line will be proposed in the Second Phase Report as the exact location of the center line of the bridge.

3.1.3. Preliminary design

The bridge can be divided into two major parts, superstructure and substructure. The preliminary design of the superstructure and substructure has been made to conform to the "Specification for the Supply of Steel Superstructure of Railway Bridge" of the Royal State Railway of Thailand and the "Standard Specifications for Highway Bridges" of the American Association of State Highway Officials.

The necessary clearances for highway and railway on bridges are extracted from the latter specification and illustrated in Fig. 3.1. The live loads to be applied to the design of the highway bridge and the railway bridge are also extracted from the above two specifications as shown in Fig. 3.2.

3.1.3.1. Superstructure

In making the preliminary design of the superstructure of bridge, studies were made of the following six items : (1) location of summit of bridge for navigation requirements, (2) longitudinal grade of bridge, (3) type of bridge, (4) pier spacing and (5) form of cross section.

(1) Location of summit of bridge for navigation requirements

As mentioned in Subparagraph 3.1.1., the Mekong river channel is relatively deep on the Laotian side and relatively shallow on the Thai side near the bridge site. The course of inland navigation on the Mekong should therefore be taken on the Laotian side, and the summit of the bridge also should naturally be placed just above the course of navigation.

According to the Plan of Operation, the navigation requirements are given as follows.

> The Mekong Committee's Advisory Board recommended at its Eighth Meeting in April 1967 that the bridge should have "a minimum horizontal clearance of 78 meters and a vertical clearance of 10 meters above preponderant high-water level."

The navigation on the Mekong around the project area has been limited to small-scale regional services because of the Khong Falls near the Laos-Cambodian border, 3 kilometers wide and 20 meters high, which forbids navigators to proceed from the estuary up to Vientiane. In recent years, however, pusher barges have become to be used increasingly in regional navigation. On these barges, the operator's cabin is as high as 8 or 9 meters from the water-line to command a better forward view. Besides, container-transportation has become popular.

Therefore, in the future a much greater vertical clearance will be required for navigation than what may be considered adequate based on the present river traffic. The recommendation of the 10-meter vertical clearance made by the Advisory Board can be considered appropriate accordingly.

Problem lies in the selection of the preponderant high-water level. To be implemental to this selection, high-water levels probable to occur at the bridge site were estimated based on the data observed at the gaging stations located around the project area and are listed in Table 2.7. (f) in Paragraph 2.5. The high-water levels at the bridge site listed in Table 2.7. were estimated from the 30-year (1937 - 1967) data[/1] observed at the R.I.D. gaging station located at Wat Hai Sok in Nong Khai, and the 4-year (1964 - 1967) records[/1] at Hydrographic Office at Nong Khai. The details of the probability calculation for the above are compiled in Appendix IV, Paragraph 4.2.

/1 The hydrographs of these water-level records are compiled in Appendix IV, Paragraph 4.1.

From the water-level records of the past 30 years from 1937 to 1967 of the R.I.D. gaging station, the number of days in which the water level in the past was above the estimated probable high-water levels at the bridge site and the maximum duration in days in which the water level in the past continuously remained above the estimated probable high-water level at the bridge site were computed and are given in Table A.4.2.4. in Appendix IV.

As can be seen from this table, the actual past water levels remained at a ratio of one to 50 days above the estimated 2-year probable high-water level. The ratios for the estimated 5-year and 10-year probable high-water levels are 1 to 310 and 1 to 700 at the bridge site, respectively. The last two ratios are considerably small.

Of floods in the past, the flood that the water level remained above the estimated probable high-water levels for the longest duration was the one that inundated the Vientiane plain in 1966. The water-level of this floor corresponds to the 25-year probable high-water level, and stayed continuously above the 2-, 5- and 10-year probable high-water levels for 29, 20, and 14 days, respectively. In years other than 1966, the numbers of days per year in which the actual water-levels were above the 5-year probable high-water levels are 5.

From the above consideration, the 5-year probable high-water level EL 166.7 meters was considered appropriate to be chosen as the preponderant high-water level. Consequently, the design high-water level at the bridge site which shall be based upon in making the preliminary design of the bridge was decided as EL 167 meters above mean sea level taking the allowance of 0.3 meter.

The superstructure under which the course of navigation would be taken was designed to meet the navigation requirements mentioned before. Namely the bearings on both side piers will be placed at ten meters above the design high-water level EL 167 meters and the span of the piers will be taken at 90 meters between the center lines.

Consequently, the elevation of the summit of the bridge will become EL 179.27 meters as shown in PLATE 3, provided that the summit of the bridge indicates the highest place of the formation level at the middle of the two-lane highway on the bridge. The location of the summit will be selected toward the Laotian side from the middle of the Mekong river channel, as shown in PLATE 3.

(2) <u>Longitudinal grade of bridge</u>

The longitudinal grade of the rail/highway bridge is limited to a maximum of 1.2 percent similarly to that of railway as stated in the next paragraph, and will be so provided that the highway part of the bridge could reach the ground on both banks of the Mekong from the summit of the bridge, and that the railway track could overpass the Asian Highway A-12 with a vertical clearance of 4.5 meters on the Laotian side and also could permit the traffic on the underlying roads at the riverside terrain on the Thai side.

(3) <u>Type of bridge</u>

The type of bridges is to be selected from the engineering and economic points of view. A bridge must first suit local conditions and give the greatest service for the least money. It is also required to be durable, easy to maintain and agreeable in appearance.

With these in view, a comparative study on the type of rail/highway bridge was made among five conceivable types, i.e., a continuous box girder with battledeck floors, a simple box girder, a continous through truss, a simple through truss and an arch. Out of these types, a continuous through truss bridge gives in general the least steel under the same pier spacing in the same local conditions. A simple through truss, a continuous box girder, an arch, and a simple box girder increase in the total weight of steel by about 10, 25, 30 and 35 percent as much as the continuous through truss. But, truss bridges require much more work of shop fabrication and field assambly and more cost of maintenance. Besides, through bridges, of truss or any type, are generally inconvenient when the roadway will be widened or the railway will be double-tracked in future and will narrow the drivers' sight or hinder travelers from commanding a wide view from the bridge. Under these considerations, as mentioned in Chapter IV, continuous box-girders with steel battledeck floors are recommendable for highway bridges.

However, if loaded with heavy and fast-running train loads, a continuous box-girder will undergo a large deflection accompanying vibrations due to its relatively small depth-span ratio. And, the battledeck floor is inconvenient for track laying. Thus, considering also the need that the rail level must be as low as possible in order to reduce the height of approach lines, a continuous through truss bridge is the most recommendable for a rail/highway bridge.

As an alternative for a through bridge, an arch bridge is well conceivable. But, an arch bridge, which in its nature is to be built as a single-span structure in each span, requires in general for a span of about 60 or 70 meters about 30 percent more steel than a through truss bridge continuous over three spans. Moreover, arch bridges lack rigidity. Therefore, arch construction was left out of construction.

It goes without saying that a bridge must be planned not only from the viewpoint of its superstructure but also in relation to its substructure. At sites where midstream piers are impossible or extremely difficult to construct or a very large channel opening is required, a suspension bridge is a solution. At the bridge site, however, no circumstances can be found that might hinder the construction of midstream piers, though some difficulties may arise in the work during the flood season. Hence, a suspension bridge is out of the question.

Prestressed-concrete construction was also studied for a rail/highway bridge. A prestressed-concrete bridge with a span of 70 meters or more, which are required for the bridge due to the navigation requirements, involves many problems in construction. In general, substructures of prestressed-concrete bridges require much more material and cost than in the case of steel bridges, because they must withstand greater vertical as well as horizontal forces due to the dead weight of heavy concrete girders. Besides, a prestressed-concrete bridge requires much more time of construction than a steel bridge. Therefore, the adoption of prestressed-concrete bridges was discarded.

(4) Pier spacing

Generally speaking, the truss members of the superstructure becomes larger and the total weight of steel material required increases more and more, as the span of a bridge becomes longer. As a result, the construction cost of the superstructure gets more but that of the substructure gets less because the number of piers required decreases, and vice versa. In view of these facts, the problem of pier spacing is important in making the preliminary design of the bridge.

For the study of this problem, the following two conditions are taken into account. One is that the piers of the bridge will be founded on the fresh siltstone underlying the alluvial deposits in the Mekong. The fresh siltstone will be excavated up to two meters deep from its top surface to place the pier thereon and to protect it from scouring action arising around the foundation of the pier. The other is that, however deeply excavated the firm siltstone may be, its bearing strength will be regarded as constant.

In this bridge project, the economical span length of a rail/highway bridge lies around 70 meters as shown in Fig. 3.3. A comparative study was made among 50-meter, 60-meter, 70-meter, 80-meter and 90-meter spans and some appreciable difference was found in the construction cost. Therefore, the span of 70 meters was selected as shown in PLATE 3, except a midstream 90-meter span which is provided to meet the navigation requirement that the bridge should have a horizontal clearance of not less than 78 meters prescribed in the Plan of Operation.

(5) Form of cross section

In order to find out the most economical form of cross section for a rail/highway bridge, such five cases as shown in Fig. 3.4. were considered.

Case 1 is a three-span continuous truss bridge with a railway track laid on one side thereof. The bridge consists of a 4-meter-wide railway track, to two-lane roadway of 8 meters wide in total, a 1.5-meter-wide sidewalk and a 1.5-meter-wide gangway for track inspection, totaling 15 meters in effective width. The railway track and the roadway are laid down between the two major truss structures, and a sidewalk and a gangway are placed outside them. In this case, there is a demerit that no bridge loads distribute uniformly to the both-side major truss members due to unsymmetrical allocation of the railway and the roadway and consequently the dimensions of cross section of the one major truss members differ from those of the other ones, resulting in the increase in the costs of shop design, manufacture and erection of the members. Contrariwise, there are two decisive merits that the railway and the highway are always separated without any at-grade intersection, and there is no necessity to further separate two lanes of the roadway. Owing to these two merits, Case 1 shows the less construction cost than the other four cases, as given in Table 3.1.

Table 3.1. Construction costs for the comparative study on the form of cross section

Case	Construction cost (US$		
	Main truss bridge	Access bridge	Total
1	5,400,000	800,000	6,200,000
2	5,500,000	1,100,000	6,600,000
3	7,600,000	500,000	8,100,000
4	5,500,000	1,800,000	7,300,000
5	5,700,000	1,100,000	6,800,000

Remarks : The above construction costs do not include the expense for engineering service, Government's administrative expense and interest during construction for the sake of comparison.

Case 2 is a three-span continuous truss bridge with a railway track laid in the middle thereof and two one-lane roadways separately located on both sides of the railway track. In this case the railway track is likewise 4 meters wide, and a sidewalk and a gangway one 1.5 meters wide respectively as well, but the two-lane roadway will be widened by two meters, each lane being taken at 5 meters to make possible the overtaking on the one-lane roadway. The effective width totals 17 meters. The cross section of the major truss members on both sides becomes identical due to the uniform distribution of the loads, leading to the less costs of shop design, manufacture and erection of the members than those in Case 1. Since the two lanes of the roadway, however, are separated from each other, the total bridge width will naturally become larger than in Case 1, and the two lanes of the roadway separated have to be placed together after the one one-lane roadway crosses the railway track with grade separation near the riverside terrain, resulting in longer access bridge and much more construction cost than in Case 1.

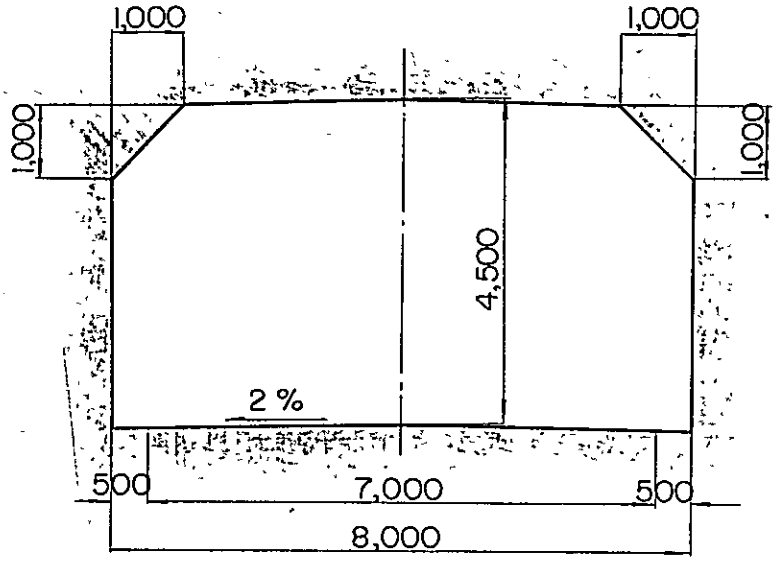
Case 3 is that two three-span continuous truss bridges for railway use and for highway use are separately built in parallel. The sum of the respective effective width of the two bridges is the same 15 meters as in Case 1. This case requires much more construction cost than Case 1 and proves eventually uneconomical. It, however, has an advantageous point that the construction work can be carried out at different period each other and the operation, maintenance and replacement costs can clearly be allocated.

Case 4 is a form of the two-storied cross section that a two-lane roadway is placed on the three-span continuous truss bridge for railway use only, and a sidewalk and a gangway 1.5 meters wide each are laid down on both sides of the railway track inside the major truss structures. This case requires much longer access bridge for highway use due to the high formation level of the roadway and results in the much increase in the construction cost. Besides, in view of the structural design to cope with the vibration caused by the railway loads, this form of cross section involves some technical difficulties.

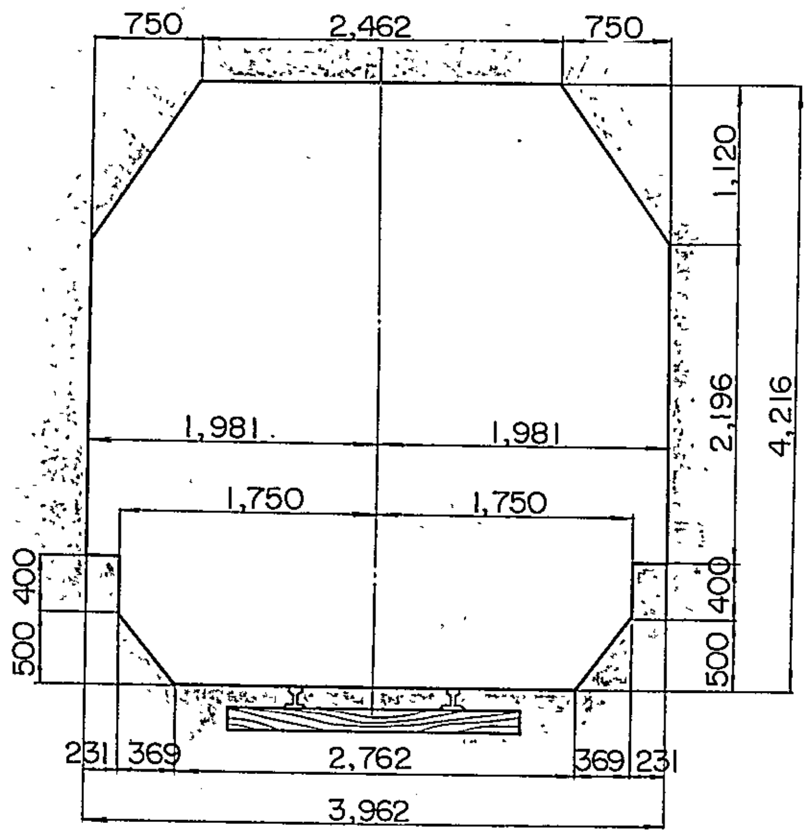
Case 5 is a form of the cross section that a three-span continuous truss bridge with a railway track only laid inside the major truss structures and with the two one-lane roadways separately built outside the major truss structures. A sidewalk and a gangway are placed further outside. In this case much wider spacing than the required construction gage has to be taken between the two major truss structures to prevent the bridge from overturning due to the eccentric loading on the bridge. Furthermore, the two one-lane roadways separated have to be united with a longer access bridge like in Case 2. It is, therefore, concluded that this case entails more construction cost than Case 1.

From the comparative study mentioned above, the most recommendable form of the cross section for the superstructure of a rail/highway bridge is Case 1.

Fig. 3.1. CLEARANCE DIAGRAMS ON BRIDGE

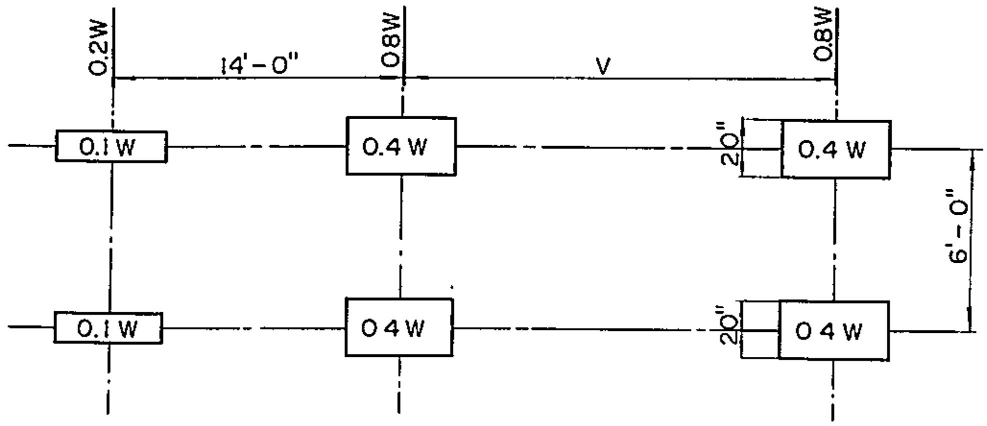


CLEARANCE OF TWO-LANE HIGHWAY ON BRIDGE



CLEARANCE OF RAILWAY ON BRIDGE

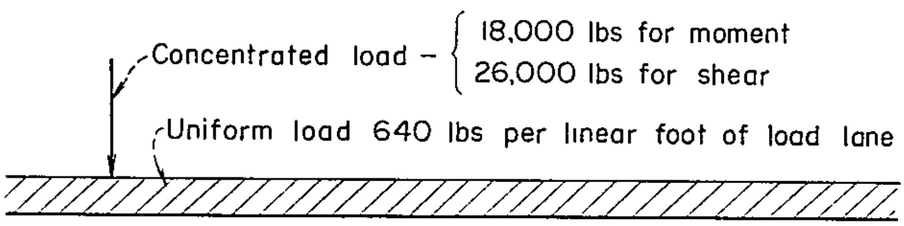
Fig. 3. 2. LIVE LOARDS FOR HIGHWAY AND RAILWAY BRIDGES



W = Combined weight on the first two axles which is the same as for the corresponding H-truck, W = 40,000 lbs.

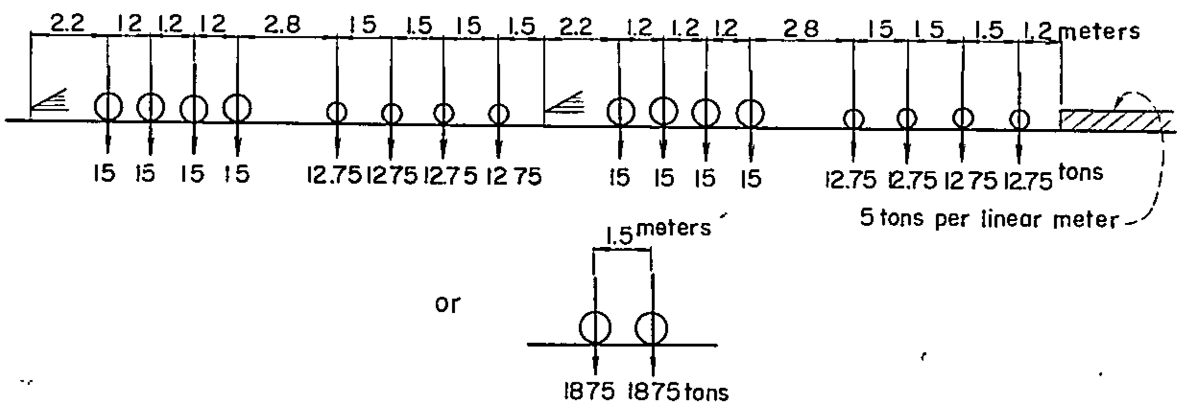
V = Variable spacing – 14 feet to 30 feet inclusive. Spacing to be used is that which produces maximum stresses.

Standard HS20-44 truck



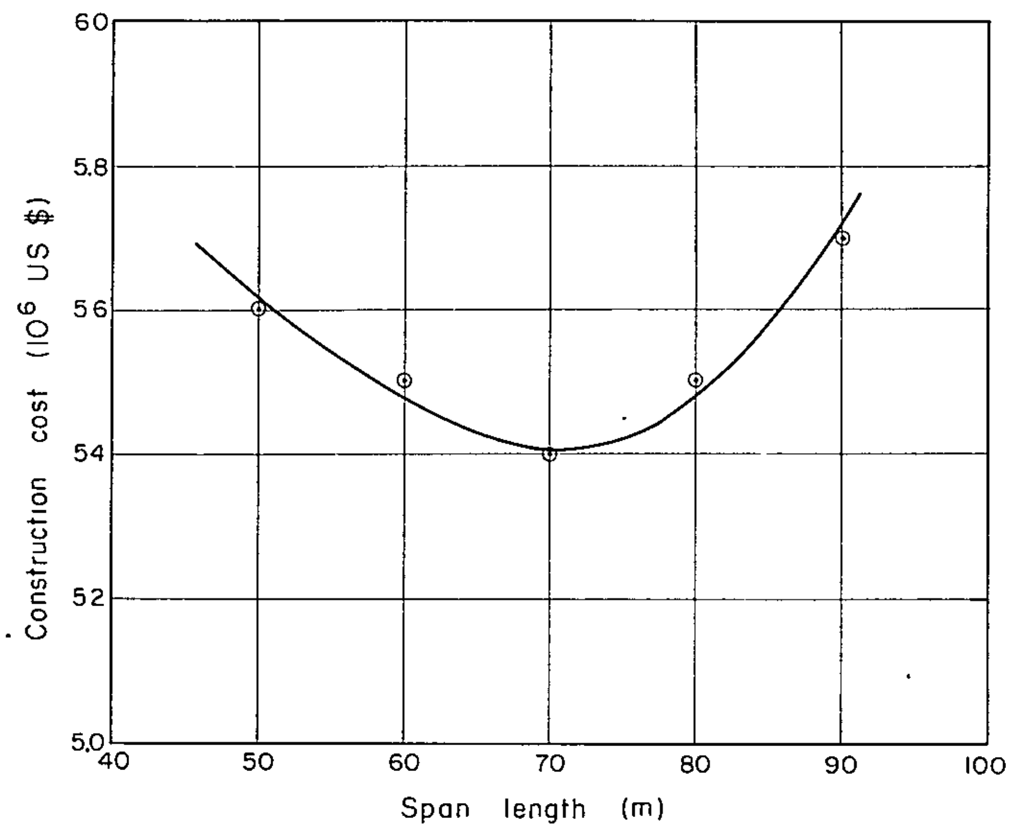
HS 20-44 lane loading

HS 20-44 LOADING FOR HIGHWAY BRIDGE



STANDARD 15-TON LOADING FOR RAILWAY BRIDGE

Fig 3.3 THE MOST ECONOMICAL PIER SPACING

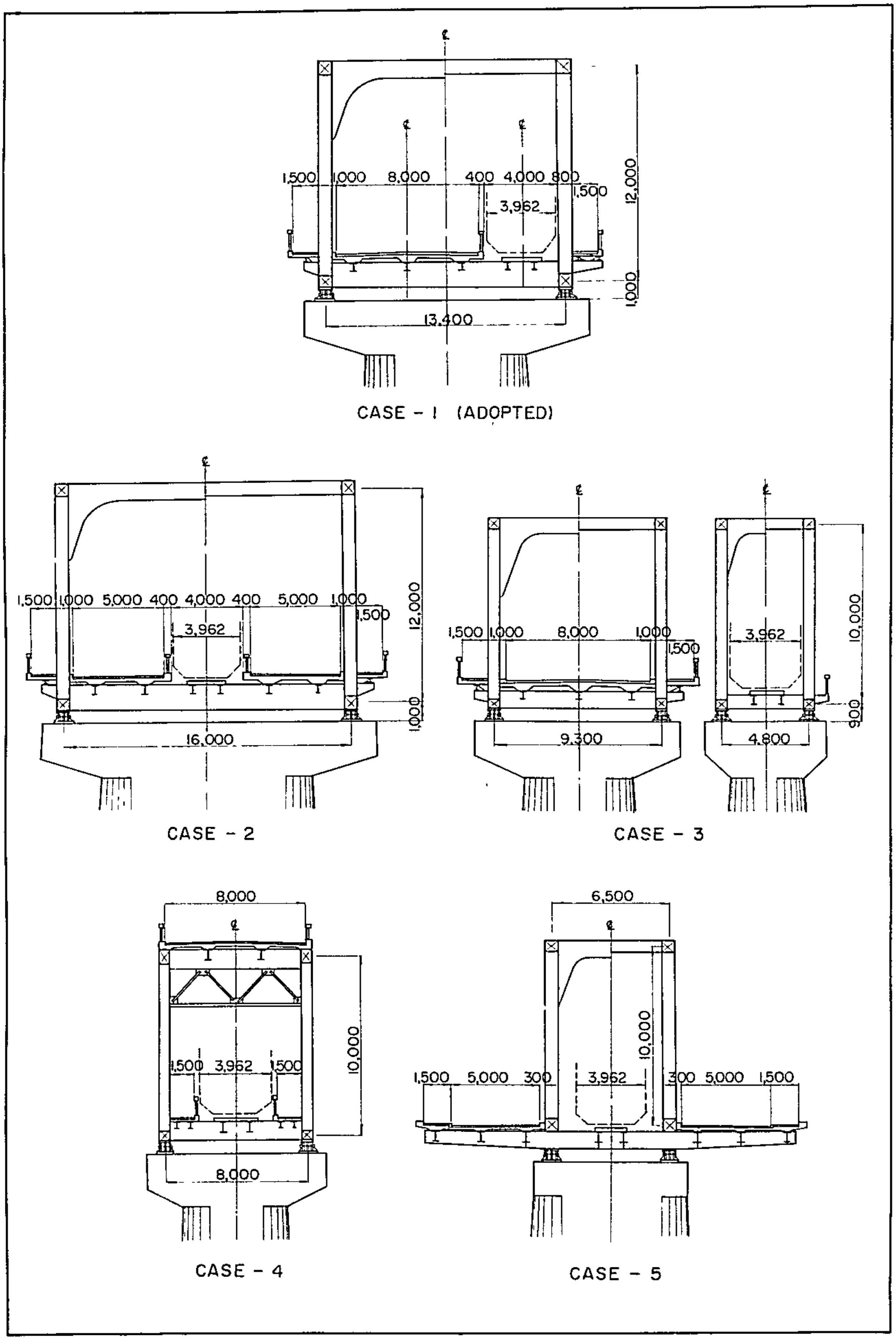


Case No.	Span length (m)	Numbers of pier (Nos)	Steel material (tons)	Construction cost (US. $)		
				Sub	Super	Total
1	50	15	2,900	3,500,000	2,100,000	5,600,000
2	60	13	3,300	3,100,000	2,400,000	5,500,000
3	70	11	3,600	2,800,000	2,600,000	5,400,000
4	80	10	4,100	2,700,000	2,800,000	5,500,000
5	90	9	4,600	2,500,000	3,200,000	5,700,000

Remarks

The above construction costs do not include such indirect costs as the expense for engineering service, Government's administrative expense and the interest during construction.

Fig. 3.4. VARIOUS CROSS SECTIONS FOR A RAIL/HIGHWAY BRIDGE



3.1.3.2. Substructure

For the substructure of the main steel truss bridge 720 meters long, reinforced concrete piers are envisaged and as their foundation pneumatic caissons are designed to be founded on the firm siltstone layer underlying the alluvial deposits of the Mekong.

For the substructure of the access bridges on both Laotian and Thai soils such as rigid-frame bridges, hollow slab bridges and so forth, two-column type reinforced concrete piers that are supported by precast reinforced concrete piles driven into the sand or gravel layer are envisaged. Although there is nothing to be specially mentioned about the substructure of the access bridges, various comparative studies are made of the substructure of the main steel truss bridge and there are much to be reported as follows.

Three different kinds of piers are considered for the comparative study, namely, a steel structure, a prestressed concrete structure and a reinforced concrete structure. The former two cases are not recommendable because these kinds of piers and the underlying caisson have such a weak point that they cannot be rigidly connected at the joint. Reinforced concrete piers not only do not have such a crucial weak point but also gives the least construction cost. Therefore, reinforced concrete piers have been finally adopted.

As to the shape of the pier, the oval section was taken up to make least the cross sectional area and the running water pressure. The head of the pier was so enlarged as to sufficiently support the superstructure.

Since the study of the foundation of pier is so important as to control the engineering feasibility of the bridge construction, the bridge team has done their best to make the study of the foundation of pier.

The following four kinds were studied foı the foundation of the pier, namely, pile, footing, open caisson and pneumatic caisson. After making a comparative study of these four structures, a combination of open and pneumatic caissons is recommended from the viewpoints of economy, soundness of construction and reliability in the progress of work.

The pile foundation was at first deemed to be economical because the construction machines and equipment to be required for pile foundation are usually not so many as those for footing or caissons, and constructiion is easy and can be finished in a short time. However, it was found necessary to drive the piles into the fresh siltstone layer underlying the alluvial deposits in the Mekong to make the foundation withstand scouring action. It is judged to be technically impossible or to be accompanied with much difficulties to drive steel piles or precast concrete piles into the firm siltstone layer. The pile foundation has been discarded accordingly.

When the foundation of pier is shaped with footing and built on the land, its construction is generally simple and its construction cost is low. However, it is not profitable to built footing in the river. In this bridge project very wide footing is required to wishstand the stress that is conveyed from the superstructure and as a result wide space is required for coffering. Such would largely reduce the flow area of the Mekong and accelerate the flow velocity with the effect of backwater, and would eventually make it difficult to maintain various construction machines and equipment at site. Furthermore, since the coffer would be made of steel sheet piles and the inside open space would be drived and excavated, the problem that the river water considerably leaks in from the lower part of the coffer would be encountered. Such leakage cannot entirely be cut off, and would affect the construction period most adversely. This open-cut excavation is found not reliable technically as well as from the viewpoint of completing the construction work within the limited construction period.

The open caisson can be constructed on the land without any difficulty. But, once it is provided in the river, it will require much time to settle on the firm foundation rock and especially in this bridge project it suggests tight schedule because the nine caissons shall be built in the Mekong river channel within the two dry seasons/1. Furthermore, in the open caisson it is impossible to ascertain whether or not the bottom edge of the caisson reaches the fresh siltstone that is excavated out at the depth of two meters from its top surface for the purpose of withstanding the scouring action around the caisson. If this unfavorable condition could be admitted, an open caisson would cast about 230,000 U.S.dollars while a pneumatic caisson 240,000 U.S. dollars/2, taking into consideration the local conditions of the project. However, when the importance of the bridge is stressed as an international Mekong bridge, the open caisson should not be recommended in spite of giving lower construction cost.

After making the above studies, the foundation of eleven piers for the main steel truss bridge 720 meters long has been recommended as follows in this report, as shown in PLATE 5. Open caissons will be provided for the two piers located on both banks of the Mekong where the construction is not affected by the river water, and pneumatic caissons will be built for the nine piers located in the Mekong to warrant sound construction. The methods and procedures of construction of caissons are mentioned in detail in Paragraph 3.4.

/1 Exactly speaking, the construction is confined to the period when the water level of the Mekong stays below L.W.L. EL154.000 above sea level. Usually the period ranges from November to May in the following year.

/2 The pneumatic caisson requires higher cost than the open caisson because the former caisson shall be equipped with the pneumatic dispatch facilities.

3.1.4. Bank erosion

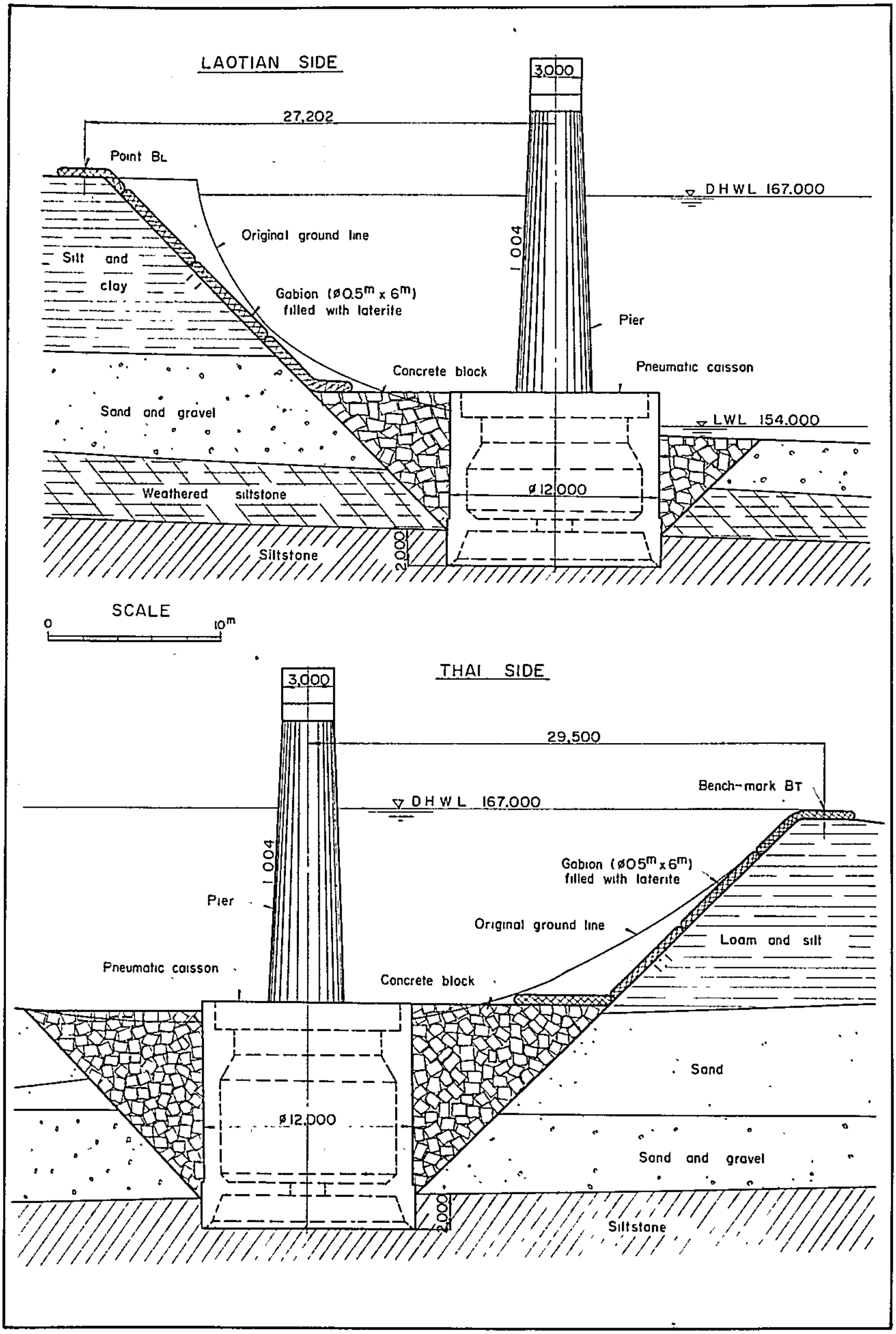
The bend of the Mekong located upstream from and nearest to the bridge site ends at about one kilometer upstream from the bridge site. The stream line on the downstream reaches therefrom, however, does not lie in the middle of the river channel, but lies toward the Laotian side. Consequently, the river bank on the Laotian side is being eroded little by little each year and sedimentation occurs on the Thai side.

The bank erosion is estimated to develop about 20 centimeters a year at present. If a bridge pier is built near the river bank, the bank erosion will increase perceptibly. According to the proposal in this report, the rail/highway bridge will be situated at approximately 6 meters above the bank and the outermost pier on the Mekong has been planned to be built about 30 meters away from the bank, as shown in Fig. 3.5. In this case the bank erosion will undoubtedly be more violent due to the turbulent flow caused by the pier. It is necessary to protect the bank from erosion by means of gabions and/or dumped riprap of lumps of laterite or concrete blocks.

The bridge team surveyed in the second phase investigation the condition of the bank new being eroded by the turbulent flow around the water supply tower located on the Mekong about six kilometers upstream from Vientiane. It has become clear that the bank has been somewhat eroded to an extent of about 50 meters both upstream and downstream, as mentioned in Chapter 2, Paragraph 2.5. This result can be applied to this project, but it would be advisable to establish appropriate measures against erosion that would suit to the local conditions around the bridge site. The most appropriate measures should be planned after the bank is left as it is for one rainy season after the outermost pier would have been constructed, and the degree of bank erosion is actually confirmed. The protection work should be carried out in succession each year for the maintenance of the bank protection in association with the investigation of the state of bank erosion. Fortunately the piers on the riverside terrains are to be built about 40 meters away from the bank, and no detrimental damage to the piers could be expected in a few years even if the bank is left unprotected.

Under the above considerations, the cost for bank protection is included in the item of contingency and reserve in the construction cost estimated in this report. If the bank protection works would be executed by means of gabions as shown in Fig.3.5. over the reach of 50 meters upstream and downstream respectively on both Laotian and Thai sides, the cost is estimated at about 40,000 U.S. dollars.

Fig. 3.5 BANK PROTECTION



3.1.5. River-bed erosion

The results of the test drilling of the river-bed are as given in Chapter 2, Paragraph 2.2. On the Laotian side from the middle of the river channel, the hard siltstone underlies the weathered siltstone layer that is covered with alluvial deposits about 3 to 5 meters thick and 7 to 13 meters thick on the Thai side.

The scouring action of the river-bed due to bridge piers generally is most conspicuous in rainy seasons when the Mekong flows in big discharge and high velocity/1. In dry seasons the scouring effect little occurs and it is even assumed that those portions scoured in rainy seasons are embedded with silt to some extent during dry seasons. It is said that the scouring repeats this phenomenon every year.

As mentioned before, the bridge team surveyed in the second phase investigation the scouring effect of the river-bed around the water supply tower on the Mekong. As given in Chapter 2, Paragraph 2.5., the results of the investigation revealed that a hollow about 20 meters in diameter and 5 meters deep had been developed slightly toward the middle about 20 meters downstream of the tower. This fact suggests that the scouring of the river-bed was due to the tower.

Judging from this phenomenon, it could well be expected that the sand and gravel deposits around the piers will most probably be washed away by scouring after the piers would be constructed at the bridge site. To protect the piers from scouring action, the foundation of the bridge pier will be built in such a way that the foundation will stand firm and stably on the hard siltstone excavated to a depth of two meters from its top surface. As mentioned previously, pneumatic caissons have been considered for the foundations of piers. Generally, the bearing strength of the foundation rock is assumed to be unchange-

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/1 The flow velocity of the Mekong at the bridge site is assumed to be 0.5 to 1.0 meter per second in dry seasons and 2.5 to 3.0 meters per second in rainy seasons.

able irrespective of its location. The drilling cores of siltstone layer have shown that the siltstone underlying the Mekong river-bed is very hard and that if the siltstone would be excavated up to two meters for the foundations of piers, the piers could satisfactorily be protected from fearful scouring action. It is therefore estimated that there is no necessity for the piers to be placed at depths more than two meters.

The state of scouring of the river-bed around the piers should be investigated every year and for the maintenance of the piers lumps of laterite or stones or concrete blocks should be dumped on all such occasions to protect the piers according to the development of scouring effect.

With this in view, the problem of river-bed scouring involves much to be solved at the stage of operation and maintenance of the project. Therefore, the cost required for protection against scouring has been included in the item of contingency and reserve in the construction cost estimated in this report. The initial cost required for protection is estimated at about 100,000 U.S. dollars for laying down concrete blocks around nine piers on the Mekong.

3.2. Engineering Feasibility on the Railway

3.2.1. General

When a rail/highway bridge is built over the Mekong for this bridge project, the Northeastern trunk line of the Royal State Railway of Thailand will be extended by about 20 kilometers from Nong Khai to Vientiane via the bridge. The construction of this railway scarcely gives rise to any serious engineering problem, because the topographic features of the project area are generally gentle and the ground presents comparatively firm foundation.

The only conceivable problem is that the earth having the nature of swelling when saturated with water prevails over the project area, and as a result favorable earth for use as embankment material is not easily obtainable in the project area. This problem, however, can be solved by mixing and using as embankment material the unfavorable earth with very find sand inexhaustibly available at the sand-bars that are found here and there in the Mekong.

Another problem is that the railway should be protected from abnormal floods that sometimes occur and inundate the Vientiane plain. For this purpose the formation level of the railway is so decided as not to be submerged by the probable flood of 40-year recurrence which is equivalent to the useful life of the railway. Furthermore, slope protection and flood bridges are provided where the railway faces the violent stream of disastrous floods.

Regarding the selection of the railway route, no comparative study is necessary for the selection on the Thai side because the bridge site is located at a short distance from the existing railway. On the Laotian side five routes are considered, each of which has its particular merits. The final selection of the route will be made so that the railway could serve for the development of the city of Vientiane in the future.

3.2.2. Selection of route

For the sake of convenience, the railway to be constructed to connect the Mekong bridge with the existing railway on the Thai soil is called "Access railway" and the railway to be extended from the bridge site to Vientiane on the Laotian soil is called "Extension railway".

As for the access railway, the route has been decided to branch off from the existing railway line with the curve of 600-meter radius near the place where the line begins to take a turn toward the present Nong Khai station. In this connection, it is proposed to construct a new Nong Khai railway station at the branch point. This site is very convenient to make communication with the town of Nong Khai, and that may become in the future a prosperous administrative center along with the administrative facilities to be provided to carry out due formalities for immigration and customs for vehicles. The route of the access railway and the location of the new Nong Khai station are shown in PLATE 2.

Concerning the extension railway which leads to Vientiane from the bridge site, five promising routes are proposed. As is seen in PLATE 1, the two routes A and B pass the lowlands similarly to the route of the existing Asian Highway A-12 and cross the That Luong Marsh. The other three routes C, D, and C.D combined run of the highlands east of the That Luong Marsh and cross the marsh at its northmost part or pass far away therefrom.

The former routes A and B aim at the public convenience to be brought about by the railway and the further urbanization of the districts lying along the proposed railway route and the said highway A-12 where population is now growing. On the other hand, the latter three routes stress the transportation of imports and exports in Laos' trading with foreign countries and no public convenience nor urbanization can be expected in these routes because the highlands on the routes are covered with dense jungle. These routes thus have their own merits. In the First Phase Report, the route B was recommended in the light of the regional development along the route.

Taking a view of construction cost, the routes A and B pass near the densely populated area and therefore the railway has to be planned to cross many existing roads with grade separation resulting in the increase in the construction cost, as given in Table 3. The other three routes pass relatively hilly area slightly populated and are selected along the contour line of the ground. The work quantities of excavation and embankment are not so much accordingly. These routes therefore give less construction costs than the route A and B. Among the five routes, the route C is the shortest and offers the least construction cost, and the combined route C·D is the second least in construction cost, as given in the following table.

Table 3.2. Comparison of the construction costs on the respective routes of the extension railway

Route	Route length (Km)	Construction cost/1 (US$)
A	19.8	7,600,000
B	18.8	5,300,000 /2
C	16.7	3,900,000
D	19.0	4,300,000
C·D combined	19.2	4,100,000

Remarks:

/1 These construction costs include no indirect costs such as expense for engineering service, Governments administrative expense, interest during construction and so forth.

/2 In the First Phase Report, the construction cost of the route B was 3,200,000 U.S. dollars. The difference accrues from the fact that in the Second Phase Report the formation level of the railway has been placed just above the water-level of the 40-year probable flood so that the railway could never be submerged during the useful life, whereas it was planned to stay above the water-level of the 5-year probable flood in the First Phase Report.

Concerning the location of the Vientiane railway station, it is located at the site about two kilometers distant from the flourishing area of Vientiane toward the northeast in the case of the route A, about four kilometers in the routes B and C, and about seven kilometers in the route D and C·D combined.

The location in the route A is too close to the present city of Vientiane and so there is a fear that the station is surrounded soon with the residential, commercial and industrial quarters. In this connection, the other two locations are much better. That of the routes B and C is greatly convenient for service to the present city of Vientiane due to comparatively short distance, while that of the routes D and C·D combined is much advantageous in directing the future expansion of Vientiane toward inland or north, though it is somewhat inconvenient to the people living in the present urban area.

The Laotian Government has expressed the intention that the extension railway should be constructed along the combined route C·D to locate the Vientiane railway station at the outskirts comparatively away from the present urban area in anticipation of the expansion of Vientiane toward the station. In response to the strong desire of the Laotian Government, the construction cost of the combined route C D is referred to for the study of the economic evaluation of the project which is made in the later paragraph. It, however, is pointed out that the location of the station in the route C also possesses such merits as cannot simply be disregarded. It is very difficult at the present moment to choose the two, the combined route C·D or the route C. The final selection should be made by the Mekong Committee after some findings are drawn from the results of the topographic survey of these two routes that is going to be carried out before long.

3.2.3. Preliminary design

The preliminary design of the access and extension railways was conducted in accordance with the Design Standards of the Royal State Railway of Thailand, from which the main articles are extracted in Table 3.3.

Table 3.3. Main articles extracted from the Design Standards

Article	Description
1. Design speed:	Max. 90 km/hr
2. Gage:	One meter gage
3. Rail:	80 lbs/yrd. (British Standard)
4. Fastening:	Elastic spike
5. Sleeper:	Timber, 15 x 20 x 190 cm hardwood Sleeper's spacing 65 cm
6. Ballast:	Crushed stone, not bigger than ∅ 6 cm with the hardness not less than limestone.
7. Curve:	Minimum curve, 400 m in radius. Transition curve not less than 700 times of superelevation.
8. Gradient:	In mountain zone not more than 12 $^{o}/oo$, in curve 400 m in radius. In station not more than 1.1 $^{o}/oo$.
9. Right of way:	Both sides, 40 m of width from the center of track.

The clearance diagram of railway for track and building is described in Fig. 3.6.

The preliminary design is mentioned below about the following major items: track and earthwork, stations, bridges on its route other than the Mekong bridge, culverts and so forth.

(1) Track and earthwork

Rails of 50, 60 and 70 lbs/yd are used in the present lines of the Royal State Railway of Thailand but they are to be replaced by rails of 80 lbs/yd in the future. The Northeast Line from Bangkok to Nong Khai is of single track of 1-meter narrow gage. Consequently, the railway to be constructed in this bridge project was decided to be a single-track line of 1-meter narrow gage with 80-lbs rails. The spacing of wooden sleepers will be taken at 65 centimeters and the crushed stone for ballast will be laid down by 30 centimeters thick. The standard cross sections of track are given in PLATE 11.

As for the standard section of eathwork, the composite section will be taken up where the embankment is comparatively high and is often exposed to the menace of disastrous floods, i.e., the Mekong fine sand will be placed at the inner part of the embankment for the sake of drainage and soundness and the admixture of earth and sand at the rate of 50 percent each will be spread at its outer part. The embankment should be so compacted as to obtain the CBR-value of more than ten percent and to ensure the trafficability of the embankment. This composite section is assumed to reduce exceedingly the adverse effect of the earth that tends to swell when it is saturated with water.

Where the embankment is comparatively low, the earth of as good quantity as possible should be sought for and utilized as embankment material. In this section, the adverse effect of the earth is expected to be reduced to some extent by the ballast of crushed stone because of low material.

The cutting section is so planned as to be given in PLATE 11, and consists of two layers of the ballast and sub-ballast to be laid on the fresh ground coming out by excavation.

The sub-ballast 20 or 40 centimeters thick made of lumps of laterite will be laid down under the ballast throughout the route for the purpose of preventing the underlying earth from jamming up directly into the ballast.

The cutting slopes on both sides of the route will be protected with sod facing and the banking slopes with lamps of laterite dumped into latticed timber frame or concrete blocks pitched on.

As mentioned before, the formation level of the railway has been so decided that the railway could not be submerged by the abnormal probable flood of 40-year recurrence equivalent to the useful life of the railway, as shown in PLATES 11, 12, 13 and 14. The maximum vertical grade and the minimum radius of horizontal curve permissible for railways are 1.2 percent and 400 meters, respectively. These limits are what are to be observed in future construction of improvement of the Thai Royal State Railway.

In most cases of the routes selected, the railway passes the That Luong Marsh. The track construction across the marsh may be done without any serious difficulty because the marsh spreads on a relatively firm ground.

The access highway to be constructed on the Thai soil inevitable crosses the existing railway line somewhere between the new Nong Khai Station and the existing one. In the case of a rail/highway bridge, the highway is planned to cross the railway with at-grade intersection. The Geometric Design Stadnards of the Highway Department of Thailand provide that a highway shall be separated from a railway when traffic exceeds 4,000 cars per day with more than six trains per day. In the case of a rail/highway bridge, the estimated future traffic in this bridge project much exceeds 4,000 cars per day but the train frequency of the railway line between the new Nong Khai Station and the existing one will markedly decrease after the project is completed. It is estimated to be at most four times a day, which is less than six times a day stipulated, because the line may be limited to the small-scale transportation of freight from Na Tha or the new Nong Khai Station to the present Nong Khai terminal.

Consequently, in the case of rail/highway bridge the at-grade intersection can be permitted. However, in the case of a highway bridge the grade separation has to be taken into account because the train frequency is naturally more than six times a day in the future.

(2) Stations

The present railway station at Nong Khai is the terminal of the northeastern trunk line of the Thai railway that runs about 600 kilometers from Bangkok. There is, however, no facility enough to shunt cars, and the shunting is now being made at Na Tha Station located about 6 kilometers south of Nong Khai. Na Tha station had been the terminal of the railway line until the extension line from Na Tha to Nong Khai was completed. As shown in Fig. 3.7. , Na Tha Station is provided with various facilities of car operation, repair shops and others which are now in use.

Considering the above fact and other features of the site, the line to reach the bridge has been planned, instead of extending from the present Nong Khai terminal, to branch from the existing line at a point a little distance of the terminal, where the line curves eastward to reach the terminal, and it is proposed that a new Nong Khai Station be established there, as shown in PLATE 17. All the passenger services in the present Nong Khai Station will be shifted on to this new station. Due formalities for immigration and customs will be dealt with at the immigration office to be provided in the station building and as for the transit passengers these services will be carried out inside the coaches. To carry out the customs procedures, four ridings are provided at the new Nong Khai Station: two in each of the two directions, from Laos to Thailand and the reverse.

The base for the operation and maintenance of trains will be placed at Na Tha Station so that the existing useful facilities could be made available.

The transportation of freight to be brought to the present Nong Khai Station can be treated through small-scale train operation from Na Tha Station or the new Nong Khai Station.

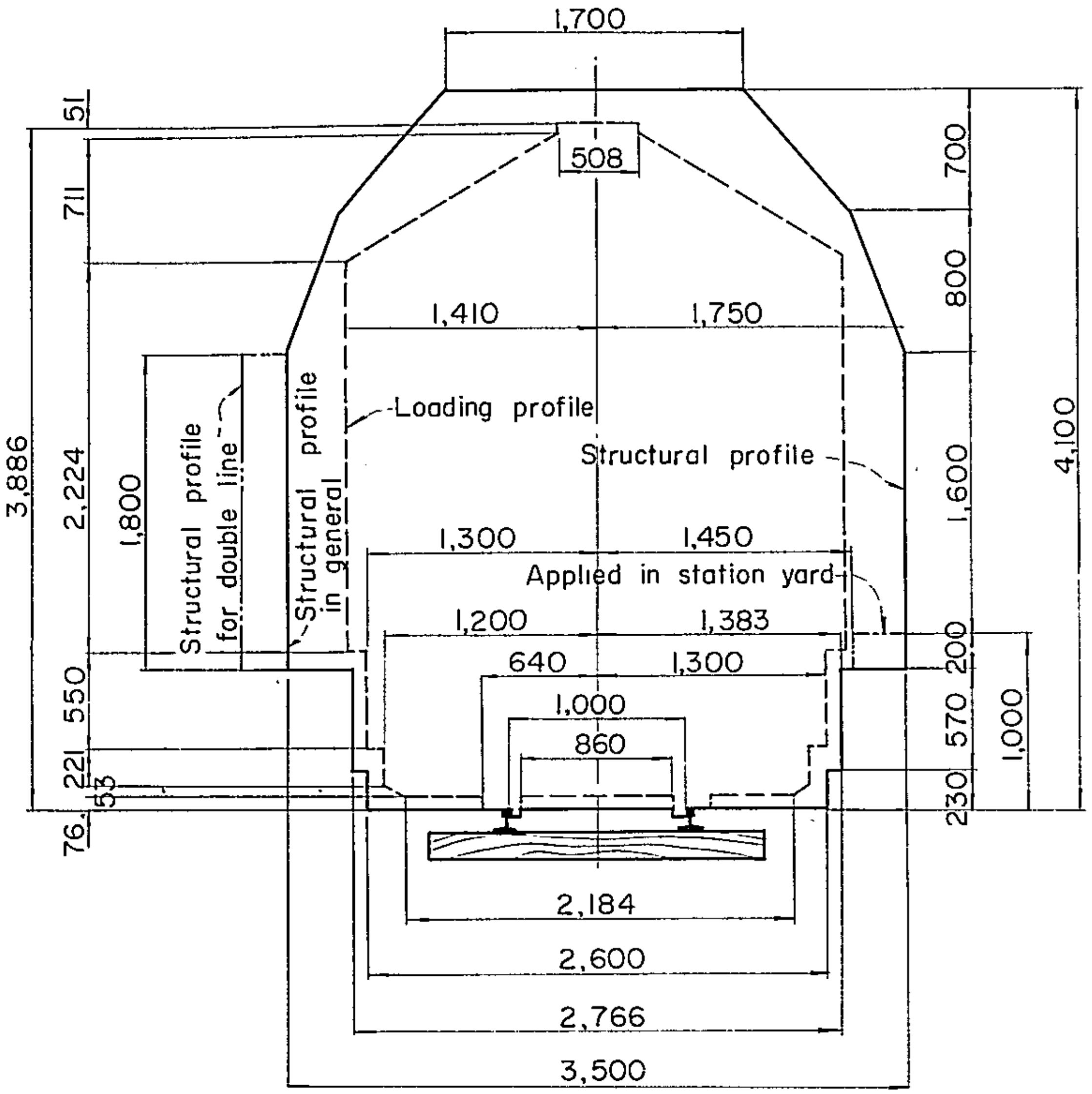
The Vientiane Station to be newly constructed on the Laotian soil as the terminal of the extension railway has been planned, as shown in PLATE 17, to furnish the immigration office and the customhouse in the station building other than due facilities to the operation of railway. Four platforms will be provided for passenger, freight and oil loading purposes.

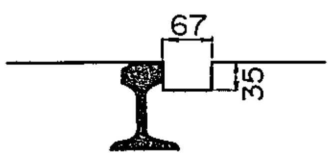
(3) Bridges and culverts

On the route from Nong Khai to Vientiane, many bridges and culverts shall be built, as described in PLATES 15 and 16, to overpass rivulets and roads or for drainage purpose. In the case of the combined route C·P, two flood bridges, three overpasses and six culverts will be built.

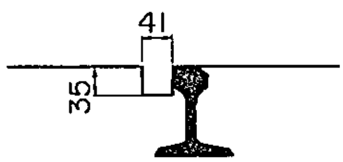
In regard to flood bridges, the three-span-continuous bridge will be built where it is relatively high from the ground to the formation level of the railway, while the simple slab bridge will be considered where it is not so high. The overpass will be built as the reinforced concrete T-beam bridge of simple span. The culverts more than two meters high and two meters wide will be built as the box culvert, and those less than two meters wide as the slab culvert.

Fig. 3.6. CLEARANCE DIAGRAM OF RAILWAY FOR TRACK AND BUILDING



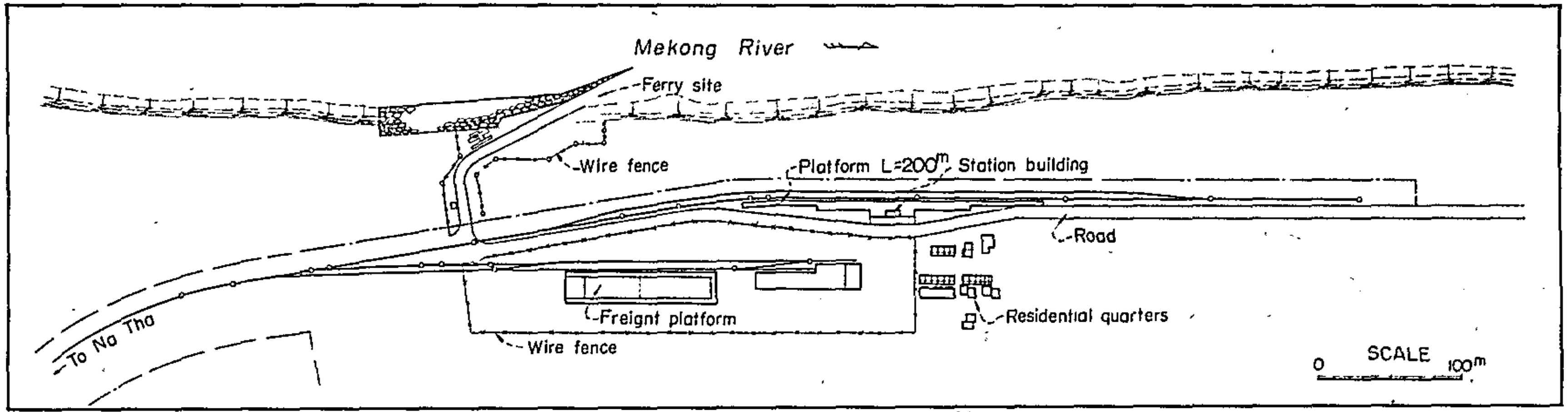


Clearance in general

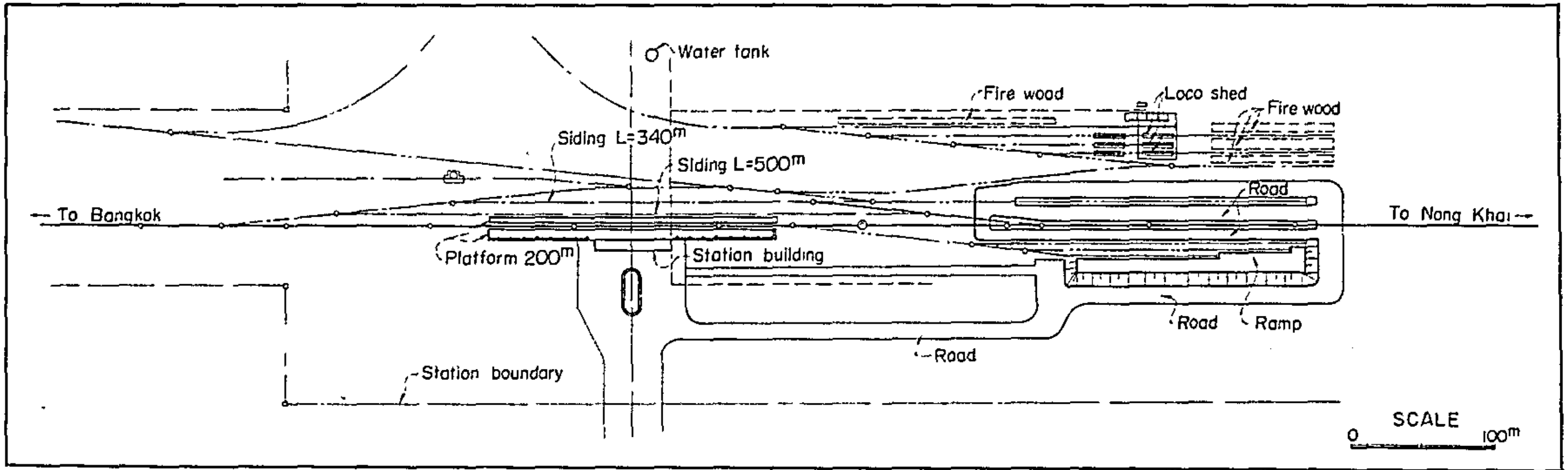


Clearance for grade crossing and dead end siding

Fig. 3.7. EXSTING NONG KHAI AND NA THA RAILWAY STATIONS



NONG KHAI STATION



NA THA STATION

3.3. Engineering Feasibility on the Access Highway

3.3.1. General

At present, the Asian Highway A-12 runs from Sara Buri to Nong Khai in Thailand and from Tha Naleng to Vientiane in Laos. In order to link these two parts of the same Highway extending over the two countries, a bridge and its access highways are planned to be constructed close by the town of Nong Khai.

In this paragraph, a study is made of the engineering feasibility on the access highway.

At first, a route study was made. As mentioned in the next subparagraph, three promising routes were considered on the access highway on the Thai side. As a result of the comparative study, the second proposal is most recommendable, in which the access highway starts at a point on the existing Asian Highway about 500 meters north of the Na Tha railway station in Thailand, and reaches the Mekong bridge with a length of 5 kilometers. Other than the access highway, the administrative facilities including immigration office, customhous, warehouse, etc. are to be established at suitable places on both Laos and Thailand for the immigration and custom procedures, and access control is to be made for the bridge and access highway between the Thai and Laotian administrative facilities.

In the second place, the preliminary design of the access highway and administrative facilities was made. There are no technical problems on the preliminary design, but a soil-engineering problem that the surrounding subsoil where the access highway is to be constructed tends to swell when it is saturated with water and in the saturated condition, and this makes it unsuitable for use as embankment material for highway. As mentioned before, the soil tests were conducted on the samples taken from different places along the three promising routes of the access highway, and the results made it clear that the soil samples had a nature of remarkable swelling when saturated.

Accordingly, the embankment of the access highway was designed to obtain stability against swelling by using improved soil. For this purpose, a soil-cement mix was considered. This problem has not been satisfactorily solved at the present stage. Further study, should be made as to the soil-cement mix or soil-sand mix as an alternative, or on the investigation of other sources for the embankment material of good quality, etc.

The route study and the preliminary design have revealed as a conclusion that there is no doubt about the engineering feasibility of the access highway including the administrative facilities.

3.3.2. Selection of route

Generally the highway routes depend on the topography and the stage of land use in the project area. The topographic survey and the field route reconnaissance were made to clarify these two points. As a result, three promising routes were considered for an access highway on the Thai side. As regards that on the Laotian side, the route studies were not particularly necessary because the Asian Highway A-12 to be connected with the bridge runs only about 200 meters away from the river bank.

The three promising highway routes on the Thai side are briefly described in Chapter II, Paragraph 2.4. and also in Fig. 2.7. The merits and demerits of each of these three routes are as given in the following table.

Table 3.4. Merits and demerits of the three highway routes

Description	Merits and demerits
1. Route length	The route of the first proposal is the shortest as follows: First proposal 3.4 Km./1 Second proposal 5.0 Km. Third proposal 4.9 Km.

- continued -

Description	Merits and demerits
2. Foundation	The subsoil where the route of the first proposal runs does not make a good foundation for the highway, because there are many swampy areas on the route. As they almost pass through the paddy fields and shrubby lands, the second and third proposals are better than the first proposal.
3. Compensation	The compensation for land use for the first proposal is assumed to be rather higher than those for the other two proposals.
4. Convenience	The first and second proposals give easier access to the town of Nong Khai than the third proposal. The third proposal is inconvenient because an overpass has to be built across the existing railway when the necessity to gain access to the town from this route would occur in the future. Furthermore, there is a fear that the route of the first proposal may run through the middle of city after twenty or thirty years due to the expansion of the town of Nong Khai. The prefectural authorities of Nong Khai expressed their opinion that a highway like the Asian Highway should still be outside of the town even after a few decades.

- continued -

Description	Merits and demerits
	Under these considerations, the second proposal is the best.
5. Relation with other facilities	The routes of the second and third proposals run near the Nong Khai airfield. The Thai Civil Aviation Department officially approved to construct a highway running through the district lying between the existing railway and the Nong Khai airfield. Besides, if the national regulations provided by the Department are applied to this airfield, the take-off climb surface of the runway has some allowance in height above the necessary vertical clearance for highway as shown in Fig. 3.8. At the present moment, there is no obstruction which hinders the construction of highway and railway along the respective routes.

Remarks: /1 Including the length of highway in the area of the administrative facilities.

As the route of the second proposal is longer than those of the other two proposals, the construction cost of the highway in the second proposal is assumed to be the highest among the three proposals. In this respect, the second proposal is the least advantageous, but when comprehensively judged from the above comparative studies the most recommendable proposal is the second one.

In the case of a rail/highway bridge, the access highway in the second proposal will be planned to take a curve toward the direction further from Vientiane after approaching and crossing the bridge over the Mekong from the Thai side to avoid grade crossing with the railway.

3.3.3. Preliminary design

The preliminary design was made of the access highway and the administrative facilities in accordance with the provisions of the "GEOMETRIC DESIGN STANDARDS FOR TWO-LANE PRIMARY HIGHWAYS (RURAL)" of the Highway Department of Thailand. The American Association of State Highway Officials' Standards and the Japan Highway Standards also were used as supplementary guide.

Table 3.7 shows the extraction of the main articles of the design standards of the Highway Department of Thailand mentioned above, and Fig. 3.9. gives the clearance diagram adopted for the design of the access highway.

3.3.3.1. Access highway

The Asian Highway A-12 in both Laos and Thailand is a two-lane primary highway. The access highway has been therefore designed as a two-lane primary highway as well.

The shape of the cross section that was adopted for the access highway is the same as that of the existing Asian Highway as described in PLATE 18 and outlined below.

Roadway:	7m. wide with two lanes
Shoulder:	2.5m. wide each
Cross-grade:	2 % at roadway
	3 % at shoulder
Side slope:	1 to 1 for cutting
	2 to 1 for banking

The longitudinal grade depends on the topography along the route of the access highway. As the topography is generally flat or gentle here, the access highway is almost level. The longitudinal grade is confined to four percent at maximum as stipulated at the terminal part of the access highway joining with the Mekong bridge. On the route, the longitudinal grade as gentle as one percent is seen only at two places.

A curve or a radius of 500 meters is adopted for the design of the access highway on the Thai side and a curve of a radius of 110 meters for that on the Laotian side due to the circumstance that the existing Asian Highway to be connected with the bridge runs only about 200 meters away from the riverside. At present it is possible to increase the running speed up to 120 kilometers per hour on the existing Asian Highway A-12, but the speed limit enforced at present is 80 kilometers per hour. If the design speed for the access highway would be fixed at 80 kilometers per hour, the minimum radius of the curve would be 420 meters/1 on condition that no roadway superelevation is provided. This is the reason why the curve of a radius of 500 meters has been adopted for the design of the access highway on the Thai side. For the access highway on the Laotian side, the design speed is decided as 50 kilometers/2 per hour taking six percent for the rate of roadway superelevation.

No widening of pavement is needed on the highway curve with a radius of 500 meters on the Thai side, while the pavement on the curve of the access highway with a radius of 110 meters on the Laotian side should be widened by about 0.5 meter to make operating conditions on the curve comparable to those on tangents.

/1 In this calculation, a value of 0.12 was taken for the side friction factor.

/2 In this case, the side friction factor was regarded as 0.14.

The formation level of the access highway is placed at elevations higher than the elevation of 167.5 meters above mean sea level so that the access highway could not be submerged at the time of occurrence of a 10-year probable flood of the Mekong. The reason why this magnitude of flood has been adopted in deciding the formation level of the access highway is that the existing Asian Highway on the Laotian side partly gets submerged and fails to maintain its required or expected action when a 10-year probable flood or more would happen on the Mekong near the project site.

The cross section of the access highway is decided as shown in PLATE 18, taking account of the unfavorable nature of the soil in the district along the route on the Thai side. Namely, as mentioned in detail in Chapter II, the subsoil in the district where the access highway is expected to be constructed on the Thai side is not suitable for use as an embankment material for highway construction because it tends to swell when saturated with water. Besides, the soil test revealed that the said soil had a considerably high shearing strength in the state of the optimum water content, while once the soil is saturated with water its shearing strength rapidly falls to almost nil.

The cross section of the access highway has been determined on the basis of the above findings. For the cutting section on the route, the roadway consists of three kinds of courses for pavement on the roadbed, i.e. 5-centimeter-thick cold mix wearing course, 15-centimeter-thick base course and 30-centimeter-thick subbase course. The shoulder consists of 20-centimeter-thick soil-cement layers for stabilization. For the banking section, the roadway is almost the same as that of the cutting section. The pavement is composed of the three courses mentioned above. Different from the composition of the roadway for the cutting section is that the subgrade is provided under the pavement. The subgrade is to be banked up with the surrounding subsoil of good quality on the roadbed in the state of the optimum water content to obtain the possible highest shearing strength. The shoulder, 2.5 meters wide, is treated with soil-cement mix in like manner. The soil-cement mix treatment aims at protecting the inner subgrade from infiltration of rainfall and flood water and keeping the subgrade in the state of the optimum water content permanently.

The values of the modified CBR/1 for each course of pavement and subgrade are as given below.

Table 3.5. The values of the modified CBR for pavement and subgrade

Item	Modified CBR (%)
1. Base course, 15 cm. thick	80 to 90
2. Subbase course, 30 cm. thick	20 to 30
3. Subgrade	5 to 10

The crushed stone is usually used to provide the three courses of pavement. It, however, is hard to procure near the project site about 45,000 cubic meters of crushed stone required for the construction of the access highway. It may be more advantageous to make use of the river sand and gravel as they are. When making detailed field investigation before commencing construction work, it is indispensable to investigate as to whether or not the river sand and gravel of the Mekong can be used for the wearing, base and subbase courses in conformity with the above CBR-values with adequate mixing ratio of sand and gravel. If they are found to be not suitable, some other measures will have to be taken to secure the crushed river gravel,

/1 The modified CBR test is stipulated in the Japanese Industrial Standards.

or to reinforce the river sand and gravel by adding poor cement milk or to seek other sources.

Mentioned below is the at-grade intersection adopted for the access highway crossing the existing railway on the Thai soil in case that the bridge is a rail/highway bridge. The access railway to be extended to Vientiane across the Mekong is planned to branch off from the existing Northeastern trunk line of the Thai Royal State Railway at a point about 120 meters on the side of Na Tha from the place where the existing line begins to take a curve eastward to reach the Nong Khai railway station. The new Nong Khai railway station is to be built at this branch-off point. Consequently, the line lying between the existing railway station and the proposed new railway station will become a branch line in the future, and the train traffic will decrease largely. It is estimated that the number of trains will amount to only four of freight trains each day. The access highway is planned to cross the railway at some place on this line between the two stations. According to the provision stated in Item 3 in Table 3.7., it is not necessary to design the access highway with grade separation at the said place.

In the case of a highway bridge, the access highway is designed with grade separation because the train frequency is expected to exceed the limit stipulated in the future.

In the last place, the capacity of the access highway is figured out. Generally, three kinds of highway capacity are considered : basic capacity, possible capacity and practical capacity.

The basic capacity means a possible capacity for ideal roadway and traffic conditions, which is estimated at 2,500 cars per hour for the two-lane primary highway with the roadway 7 meters wide.

The possible capacity is defined as the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under the prevailing roadway and traffic conditions, regardless of their effect in delaying drivers and restricting their freedom to maneuver. The difference between basic capacity and possible capacity is accounted for by the effects of the prevailing roadway and traffic conditions. The possible capacity is the product of the basic capacity by the capacity reduction factors due to composition of traffic and restrictive lateral clearances. Composition of traffic is normally expressed as the percentage of tracks during the period of the future design hourly volume (DHV). For the access highway of this bridge project, the percentage of trucks approximates to 25 percent and the capacity reduction factor due to composition of traffic is estimated at 0.80. The capacity reduction factor due to restrictive lateral clearances is 1.00/1 because the wider shoulders are provided on both sides of the roadway for the access highway. Consequently, the possible capacity is 2,000 cars per hour.

Practical capacity represents the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under the prevailing roadway and traffic conditions, without unreasonable delay or restriction to the drivers' freedom to maneuver. The practical capacity is estimated to range from 900 to 1,200 cars per hour for the two-lane primary highway.

The design capacity is defined as the practical capacity or lesser value determined for use in designing the highway to accommodate the design volume. Where traffic flow is uninterrupted, practical capacity and design capacity have essentially the same meaning and are equal numerically. Consequently, the design capacity for the access highway has been made equal to the practical capacity.

/1 For the highway on the bridge, this factor is estimated at 0.85 because clearance from pavement edge to obstruction becomes 0.5 meter on either side of the pavement.

When the aforesaid possible capacity of 2,000 cars per hour is computed on a daily unit, the value is estimated at about 17,000 cars per day, taking the rate of conversion of 0.12. On the other hand, the annual-average daily traffic (ADT) is roughly estimated at about 14,000 cars exclusive of motorcycle after the useful life of 40 years/1 in the case of a rail/highway bridge, from the results of the origin-destination survey executed at site. In the case of a highway bridge, it approximates to 18,000 cars per day exclusive of motorcycle. These two figures suggest that the access highway and the bridge are nearly serviceable to traffic during the period of their useful life of 40 years.

3.3.3.2. Administrative facilities

The Nong Khai/Vientiane Bridge is an international bridge to be built across the Mekong forming the border between Laos and Thailand. All the traffic on the bridge are therefore requested to go through due formalities for immigration and customs. For this purpose, the administrative facilities will be provided at appropriate places on either side of the Mekong as shown in PLATE 2 .

The facilities include immigration offices, customhouses, warehouses, booths to check for immigration and customs or to collect tolls if necessary, and so forth. The layout of these facilities is planned in PLATEs 22 and 23. The administrative facilities to be constructed on the Thai side require an area 110 meters by 570 meters and those on the Laotian side require an area 180 meters by 550 meters. The highways in the area of the facilities are to be paved with asphalt in the same way as the access highway. Two warehouses, 20 meters by 100 meters each, are provided on the Thai side, and two warehouses measuring 20 meters by 140 meters and 20 meters by 60

/1 It indicates the year of 2012 if the bridge is opened to traffic in 1973.

meters respectively on the Laotian side. Two warehouses on each side will have double accommodation capacity of the existing warehouses in the car ferry at The Naleng.

The traffic volumes of the bridge are estimated as follows, and are also given in the later paragraph.

Table 3.6. Traffic volume

Calendar Year	Traffic Volume (Vehicle/day)	
	Rail/highway bridge	Highway bridge
1973	1,000	1,400
2000	10,000	13,000
2012	14,000	18,000

Remarks:-

(1) No motorcycle is included in the above traffic volumes.

(2) Those in 2000 and 2012 are estimated very roughly.

(3) At present, the bridge is scheduled to be open for traffic in 1973.

(4) The bridge is assumed to be durable for use until 2012.

To handle such traffic volumes, at least five booths will be required in 1973, thirty-five to forty-five in 2000 and finally fifty to sixty are necessary in 2012 whether it is a rail/highway bridge or a highway bridge, assuming an average handling time is five minutes per vehicle for due formalities for immigration, health and customs and 288 vehicles are to be handled per booth per day. However, to avoid any delay which may occur in the facilities, ten booths are to be provided in 1973 in the respective administrative facilities on both the Laotian side and the Thai side: five each for incoming and outgoing flows respectively. The administrative facilities also are so designed as to secure ample space for the booths to be increased stage by stage in the future.

Another problem that must be settled is that the traffic in Laos keeps to the right whereas in Thailand it keeps to the left. It is not difficult to make some special arrangement to effect the change-over of the left and right. It has only to provide an interchange on either Laotian on Thai side.

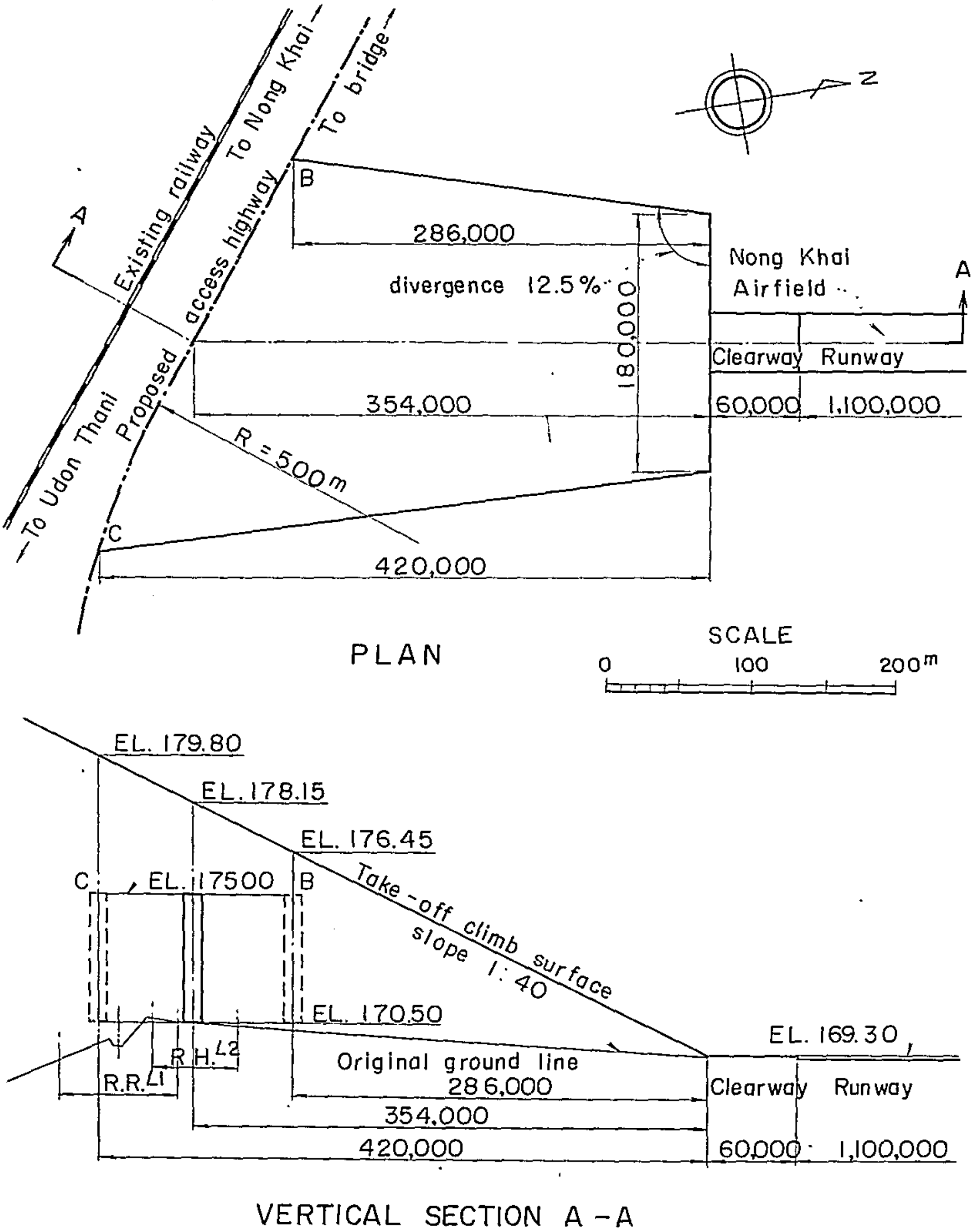
It, however, is forecasted that the traffic over the bridge can not always flow smoothly in an international bridge like the Mekong bridge because it takes much time to clear the necessary formalities for entry and exit. In other words, the interchange does not seems to fully display its function in an international bridge like this.

It is considered economical to carry out a change-over with at-grade intersection on the site of the administrative facilities in either Laos or Thailand. In this report, the layout of the individual building in the administrative facilities has been drawn up to carry out a change-over with at-grade intersection and to avoid the congestion of traffic as much as possible. In order to find out the method of the change-over, the following two cases are conceivable:- one is that the traffic on the bridge keeps to the right and the other is to keep to the left on the bridge. In the former case, the change-over will be carried out in the territory of Thailand and in the latter case on the territory of Laos. The layout plans of the administrative facilities for the two cases are described in PLATEs 22 and 23. According to the comparative studies made on these two layout plans, the construction cost hardly differs from each other and the places where the heavy traffic congestion would happen due to at-grade intersection are numerically almost the same. Consequently, it is very difficult to discuss the comparative merits of the two cases.

Nevertheless, if it is compelled to choose between the two, the former case that the traffic on the bridge keeps to the right seems to be preferable in so far as the administrative facilities shown in PLATEs 22 and 23 are concerned. The reason is that the former case gives less traffic-congestion points than the latter case, as shown in Fig. 3.10.

In view of the above fact, it is recommended in this report to take up the former case for the final solution to the change-over problem.

Fig. 3.8. RELATION BETWEEN THE TAKE-OFF CLIMB SURFACE OF THE RUNWAY AND THE NECESSARY VERTICAL CLEARANCE FOR THE ACCESS HIGHWAY



Remarks

∠1. The right of way for railway is 40 meters on both sides of its center line.

∠2. The right of way for highway is 30 meters on both sides of its center line. In this case, it overlaps with the right of way for railway by the width of 20 meters on one side.

Table 3.7. Geometric design standards for two-lane primary highways (rural)

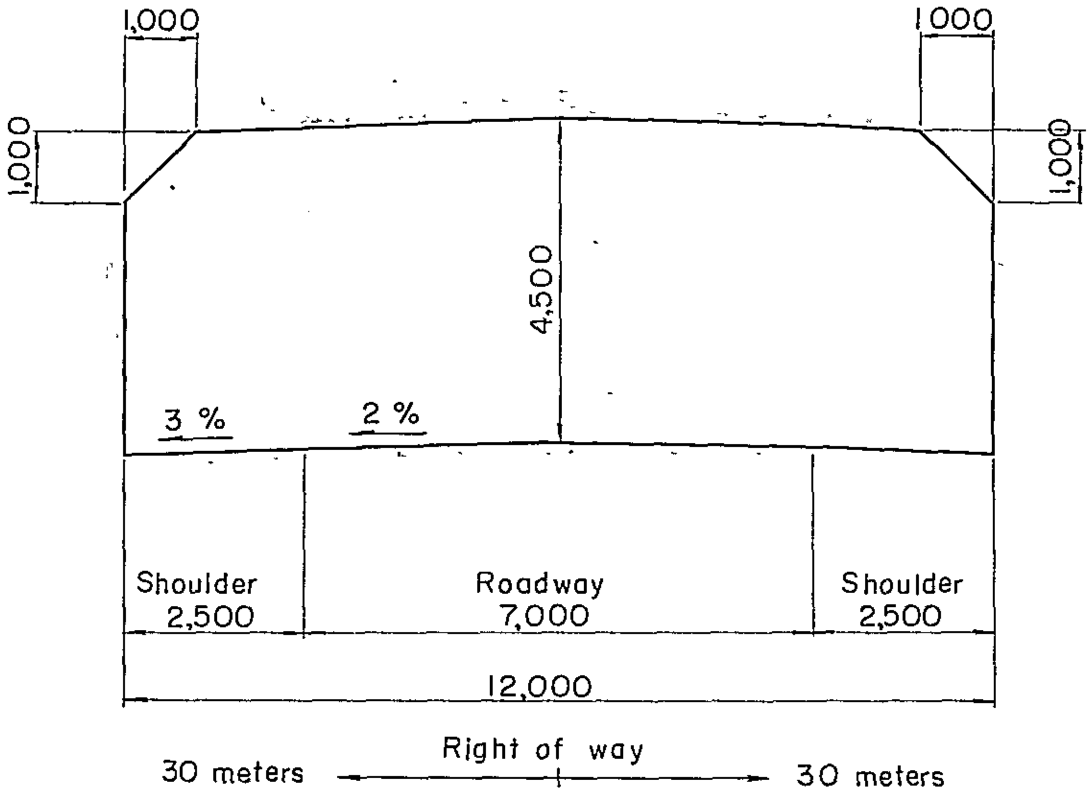
1. Control of access: when daily traffic over 3,000.
2. Highway crossing at grade acceptable.
3. Railroad crossing: Separate when traffic exceed 4,000/day with 6 or more trains per day.

   Automatic signal is required when the highway traffic x trains per day exceeds 3,500.
4. Design speed: 80 - 100 km/hr.
5. Maximum gradient: 4 %.
6. Right of way: 60 - 80 m.
7. Clearance: See Fig. 3.9.
8. Others

Item	Class I	Class II	Class III
Annual equivalent average daily traffic	8,000-4,000	4,000-1,500	below 1,500
Width of pavement (m)	7.00-6.50	7.00-6.00	6.00
Width of shoulder (m)	2.75-2.50	2.50-2.25	2.00

Source: Highway Department of Thailand.

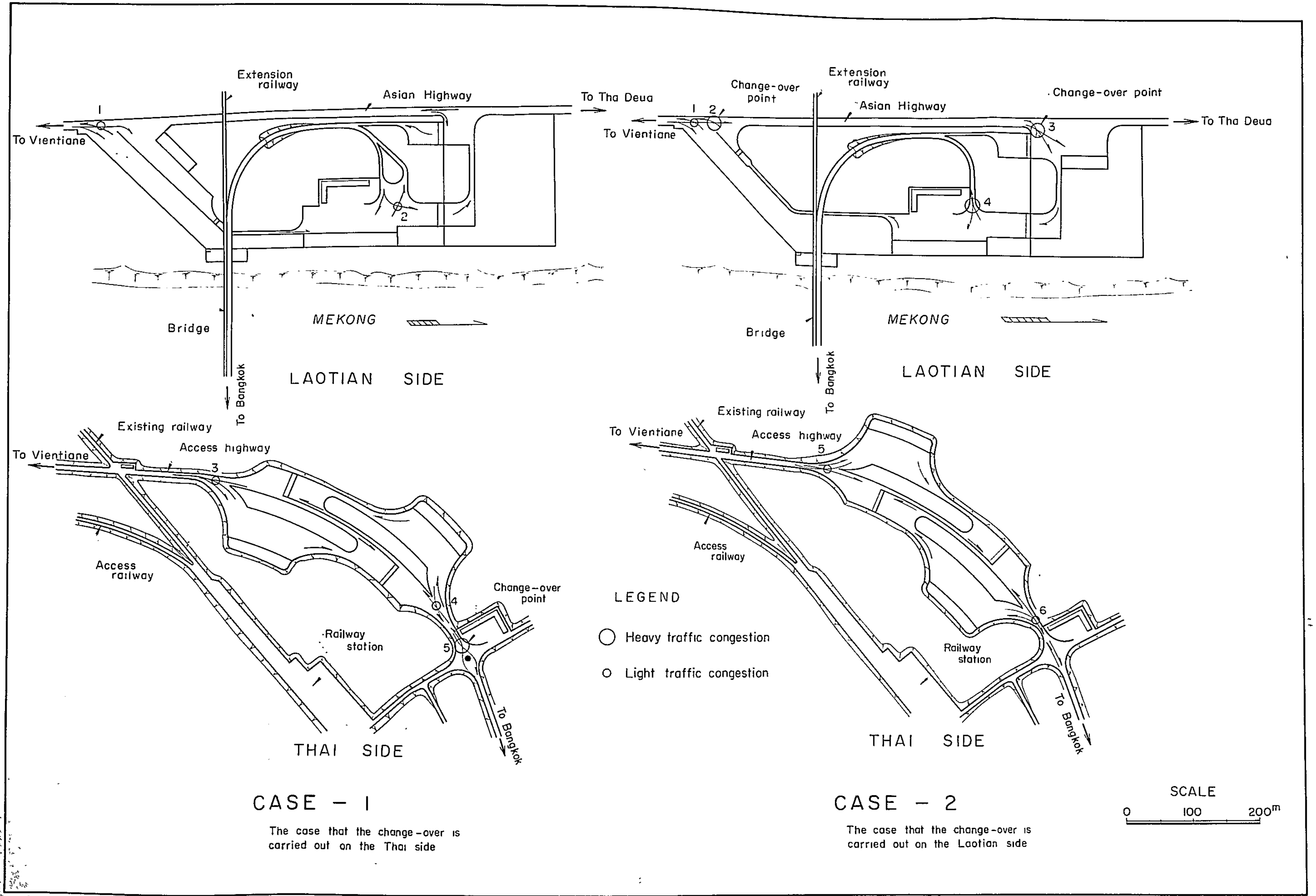
Fig. 3.9. CLEARANCE DIAGRAM OF THE ACCESS HIGHWAY



Remarks :

This is a modified clearance diagram adopted for the design of the access highway. Modifications were made on the clearance diagram of the Japan Highway Standards, taking account of the figures designated by the Highway Department of Thailand.

Fig. 3. 10. CHANGE-OVER BETWEEN THE LEFT AND RIGHT



3.4. Construction Plan

Generally, Southeastern Asian projects are much affected with the monsoon peculiar to this region. This bridge project is also not exceptional. The construction works are often disturbed with heavy rains in rainy seasons and are subjected to the sweltering heat of the sun in dry seasons.

The construction plan of the bridge project should therefore be formalized to conform to such local climate conditions. The construction time schedule given in Fig. 3. 11. has been prepared under such consideration. The works will be executed concentrically to make remarkable progress in dry seasons, exactly speaking, in the period from November to April in the next year. The actual construction of the project will require two years and the preparation period from the detailed design of the project to the decision of a successful bidder or bidders will take about one and half a year.

The substructure of the main truss bridge 720 meters long comprising a total of eleven piers and caissons will be constructed in two dry seasons, out of which six ones will be completed from the Thai side in the first dry season and the rest five in the second dry season from the Laotian side. In sinking pneumatic caissons into the Mekong, such methods that caissons are made on the land beforehand and are carried to site by boat should not be taken because the water level is too low for boats to pull caissons on the Mekong in dry seasons. The most recommendable method is that artificial islets should be provided at each building site of caissons by making coffers with steel sheet piles and filling up inside with the Mekong fine sand, and then caissons should be essembed on the islets and be sunk into the river-bed. A temporary bridge should be constructed across the Mekong to carry construction materials, machinery and equipment to the islets. It, however, is impossible to connect Laos with Thailand with this bridge because the regional navigation on the Mekong should not be obstructed during the construction period.

Namely, some open space has to be provided on the Mekong for navigation.

For the erection of the superstructure of the main truss bridge, it is advisable to take such a method as to furnish a portable crane running on the upper chords of the first span on the Thai side that will be erected by means of a stiff-crane, and to push forward like cantilever the trusses assembled.

There is nothing to be specially mentioned for the construction of the railway, but no ballast material of high quality can be found in and around the project area. It may be supplied from Sara Buri. In this case it should be transported to Laos during rainy seasons by the car ferry.

As for the construction of the highway, it is desirable to finish the embankment work about one month before a rainy season begins, so that the embankment material might not swell due to infiltration of rainwater. As mentioned before, the embankment material obtainable near the highway route on the Thai side has an unfovorable nature that it remarkably swells when saturated with water. But it is very good for use as embankment material in the state of the optimum water content.

The temporary construction facilities should be furnished on both banks of the Mekong near the bridge site for the sake of convenience. As such facilities, temporary camp buildings, power supply system, water supply system and so on are considered. Fig. 3.12. shows an example for the location of these facilities.

At present there is no power supply facilities available for construction on the Laotian side near the bridge site. On the Thai side, abundant electricity can be fed at present by the Pong Neeb power station and in the near future can be supplied from Nam Ngum power station, too.

The aggregate plants should be so capable as to collect the Mekong sand and gravel during a dry season as much as the sand and gravel could cater for the concrete to be required in the following rainy season as well as that to be required in the dry season.

Two different means of transportation are available for the construction machinery, equipment and materials which are to be imported from foreign countries for the bridge project, i.e., the Asian Highway and the north-eastern trunk line of the Royal State Railway running about 600 kilometers from Bangkok to Nong Khai. At the present moment, there is no bridge on these two routes to be strengthened for the transportation, but the existing Nong Khai Station should be strengthened in many aspects. Especially it should be equipped with large gantry cranes and sufficient unloading yard.

The foreign construction machinery and materials to be required for the construction of railway, access bridges and part of the main truss bridge on the Laotian soil should be carried by the car ferry from Nong Khai to Tha Naleng and thence to the construction site, especially in rainy seasons because the capacity of the car ferry remarkably drops in dry seasons.

3.5. Construction Cost

During the first and second phase investigations, a survey was made, mainly in Vientian-Nong Khai area, on the costs of various items such as materials, labor and freight, by which the construction cost will be broken down.

Based on the results of the survey and the work quantities estimated from the preliminary design, the construction cost has been estimated for the case that the Mekong bridge is constructed as a rail/highway bridge, as given in Table 3.8. The construction costs are broken down by principal items of cost and are given in U.S. dollars including costs that shall be required in local currency. Duties and taxes are not included in the estimation, and such exchange rate that one U.S. dollar equals to 20.5 Bahts or 500 Kips has been taken into account. The unit prices taken for the estimation have been carefully prepared, taking into consideration a rise in prices in the future.

The total construction cost has been estimated at 20,000,000 U.S. dollars equivalent for the case of a rail/highway bridge in this report as shown in Table 3.8., whereas it was 15,100,000 U.S. dollars equivalent in the First Phase Report. The difference between the two mainly results from the following reasons : (1) the idea of common use of a lane of two-lane roadway and a single-track railway proposed in the First Phase Report is abandoned and the total effective width of the bridge has been widened for the purpose of separate use of them in the Second Phase Report, (2) pneumatic caissons have been adopted for the foundation of piers this time whereas in the First Phase Report the foundation of a simple footing type was considered, (3) such measures as to cope with an unfavorable nature of swelling that the embankment material prevailing in the project area possesses have been taken in the construction of the highway and railway, as given in PLATEs 11 and 18, and (4) such administrative facilities as to give smooth stream of traffic have been considered on both Laotian and Thai sides, as illustrated in PLATEs 22 and 23.

Out of the above four reasons, the three reasons (1), (3) and (4) are common to the three bridge sites, Nong Khai, Vientiane and Pa Mong. The reason (2) may not be common between Nong Khai and Pa Mong, and between Vientiane and Pa Mong. Even if it is not common each other, it little affects within the limits of ten percent the annual cost that is estimated from the total construction cost and as a result it is stressed that Nong Khai site still takes precedence of the other two sites.

Table 3.8. Construction cost

(In the case of a rail/highway bridge)

Item	Construction Cost (US$)	Remarks
I. GOVERNMENTS' PREPARATORY WORKS	1,000,000	
1. Construction facilities	400,000	
2. Land and rights	600,000	
II. MAIN CONSTRUCTION WORKS	13,500,000	
1. Bridge	(6,200,000)	
(i) Steel truss bridge	(5,400,000)	720 m. long
Superstructure	2,600,000	
Substructure	2,800,000	
(ii) Access bridges/1	800,000	/1 Including plate girder, composite girder, rigid frame and hollow slab bridges
2. Highway	(2,200,000)	
(i) Access highway	1,000,000	
(ii) Administrative facilities	1,200,000	
3. Railway	(4,900,000)	
(i) Access railway	800,000	
(ii) Extension railway	4,100,000	
4. Permanent residential buildings	200,000	
III. ENGINEERING SERVICE	1,300,000	
IV. GOVERNMENTS' ADMINISTRATIVE EXPENSE	800,000	6% of (I) and (II)
V. CONTINGENCY AND RESERVE	2,300,000	16% of (I) and (II)
VI. INTEREST DURING CONSTRUCTION	1,100,000	6% of (I) to (V)
Total	20,000,000	

Fig. 3. 11. CONSTRUCTION TIME SCHEDULE FOR NONG KHAI / VIENTIANE BRIDGE PROJECT
(in the case of a rail / highway bridge)

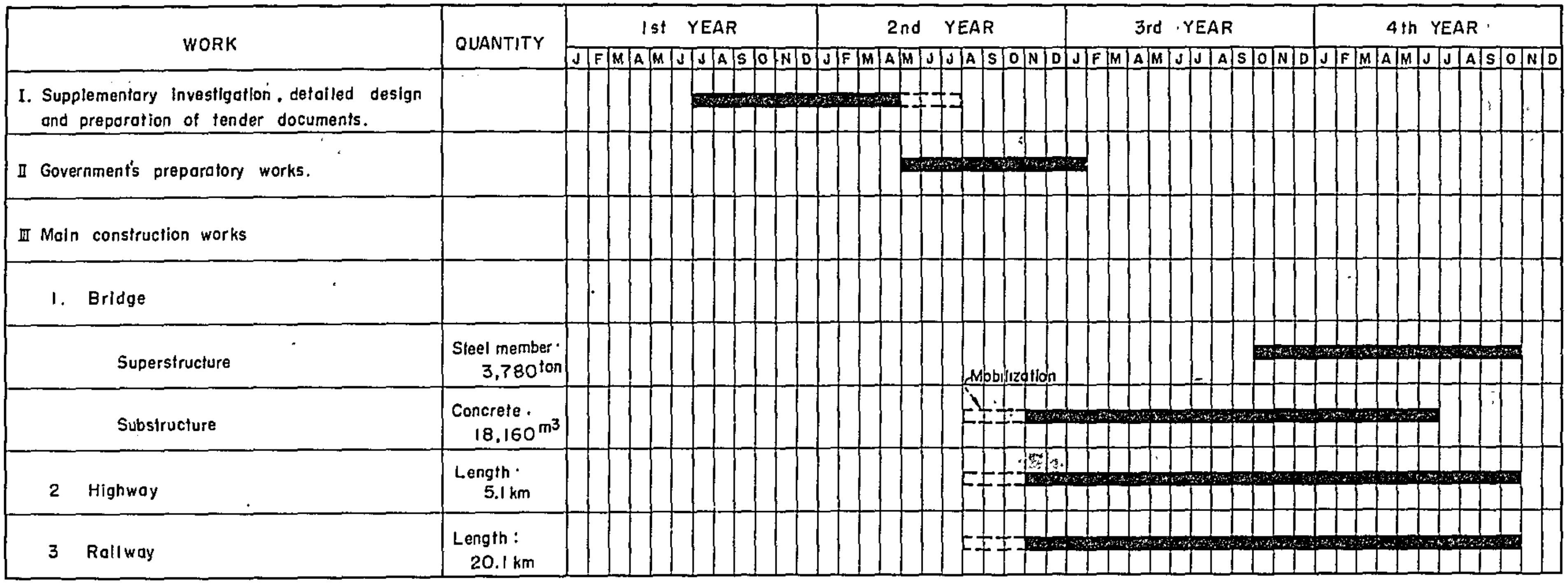
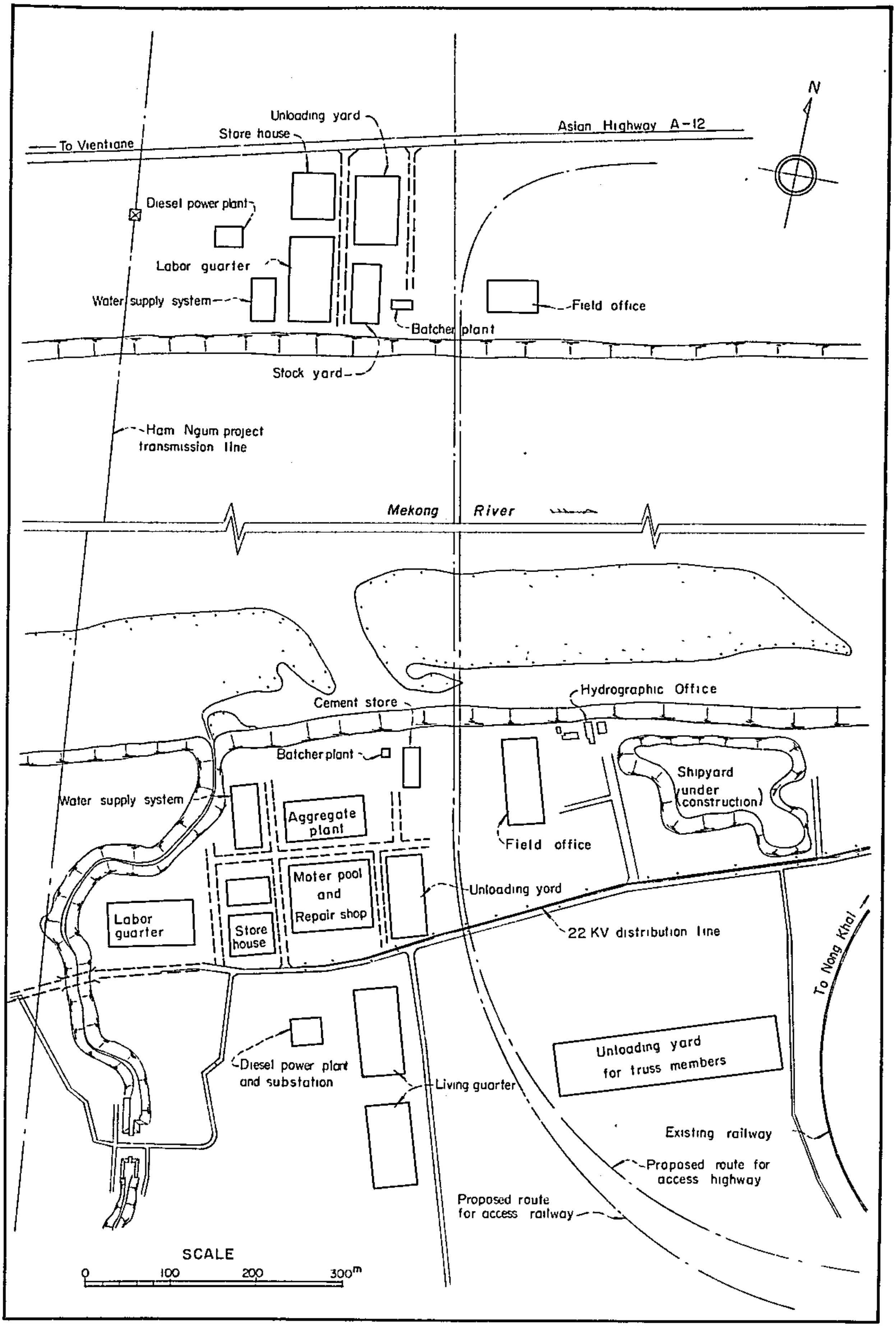


Fig. 3:12. CONSTRUCTION FACILITIES



3.6. Economic justification

3.6.1. General

This paragraph contains the economic justification of the project in case it is a rail/highway bridge. The benefit-cost ratio and capitalized net benefit have been finally calculated to make the economic evaluation after the estimation of the future traffic volume, valuation of the benefits, and calculation of the annual cost have been conducted.

First of all, the basic future traffic volume, which would form the basis of calculation of the benefits, was estimated under Subparagraph 3.6.2. assuming that the toll rate equal to th. current ferry charge would be charged. The actual traffic volume is liable to change according to the toll rates determined. After studying how to estimate from the basic future traffic volume the actual future traffic volume which would be affected by the actual toll rates applied, a formula has been made for obtaining the actual future traffic volume.

Explanations are given under Subparagraph 3.6.3 on direct benefits. Direct benefits include the savings in the cost and time of travel, economy in car operation, increase in carrying capacity, less chance of accidents, comfortable traveling, etc., but only the time benefit and the operation benefit have been taken into consideration in the calculation of direct benefits. Again, the unit benefit was obtained for the calculation of the amount of benefits. The unit benefit is the difference between the traveling time and operating costs when the existing ferry is used, and those when the bridge is used. This unit benefit has been obtained for each traffic component such as buses, personal cars, taxis, heavy trucks, light trucks, railway freight and railway passengers.

In Subparagraph 3.6.4, the annual benefit was calculated. The future traffic will change its volume according to the toll rate, and the benefits too will change consequently. Therefore, the toll rates which should be adopted were determined under this subparagraph. The annual benefit is obtained by multiplying the traffic volume for the adopted toll rates by unit benefit. In order to calculate the capitalized net benefit, the annual benefit was capitalized to the total present worth as of 1973.

The annual cost was calculated under Subparagraph 3.6.5. The annual cost comprises the annual fixed cost and the annual working expense, and was estimated as shown in Table 3.21. Again, the capitalized cost as of 1973 was calculated for the purpose of calculating the capitalized net benefit.

The benefit-cost ratio and capitalized net benefit were calculated in Subparagraph 3.6.6. This can be used as reference when comparing the advantage and disadvantage of a highway bridge and a rail/highway bridge.

In Subparagraph 3.6.7, the internal rate of return was calculated. The value will be checked if the rate is sufficiently high as compared with normal international standards.

Though not included in the calculation of the annual benefit, the indirect benefits, which the project might bring about, are explained under Subparagraph 3.6.8.

In Subparagraph 3.6.9., the annual costs of a rail/highway bridge and the existing ferry, that must improve and increase its facilities with the increase of traffic volume in the future, were compared.

3.6.2. Future traffic

The traffic in the future on the new bridge can be obtained by multiplying the imaginary initial traffic by the rate of future traffic growth.

The imaginary initial traffic is obtained on the assumption that the bridge is opened to traffic in 1967, and based on the present traffic of the project area analyzed according to the result of the origin-destination survey of the traffic on highway, waterway, railway and airway having relation with the bridge project.

The growth of the traffic in the future is composed of the natural growth of the present traffic and the rapid increase in the number motoring public who will be incited the construction of a new bridge.

The natural traffic growth in general can be estimated in relation to the growth of the gross national product which is turn is generally influenced by the national production activity, because the movement of people and freight is closely related to the production activity in the area concerned. The relationship of the traffic volume of the ferry passengers, ferry freight and the freight arriving as Nong Khai railway terminal to the gross national product can be expressed in linear equations, and these linear equations are analyzed on the basis of the data gathered from various sources during the first and second phase investigations. The equations are as shown below.

$$\begin{aligned} A_F &= -253,313 + 2,324\ P_L \\ A_P &= -240,743 + 1,713\ P_L \\ A_R &= -253,750 + 2,555\ P_L \end{aligned} \qquad (1)$$

where A_F : amount of ferry freight in tons

A_P : number of ferry passengers in person

A_R : amount of freight arriving at Nong Khai railway terminal in tons

P_L : gross national product of the country concerned (in this case, Laos) in U.S.\$ 1 million

The increase in the traffic due to a large number of the motoring public could be anticipated as a result of the reduction of the so-called economical distance of traffic to be made available by the improvement, which is this case, is the construction of the Mekong bridge. The economical distance in a zonal pair is a comparative distance between two specified zones to be determined by taking the twenty time and the operating cost of traffic into account. Such traffic increase, as mentioned in Paragraph 2.6., can be obtained by means of the method of Gravity Model/1, and the rate of increase can be explained by the following equation.

$$P = \frac{T_{ij(1)} - T_{ij(0)}}{T_{ij(0)}} = \left\{ \frac{d_{ij(0)}}{d_{ij(1)}} \right\}^{b} - 1 \qquad (2)$$

From the result of the origin-destination survey, the exponent "b" was estimated at 1.6229.

Under the basic conditions mentioned above, the imaginary initial traffic volume, the growth rates and the traffic volumes for 1973 (1 year after the completion of the bridge), 1990 (18 years after the completion of the bridge) are as given under Table 3.9. in the case that the toll of the rail/highway bridge is equal to the current charge of the existing car ferry.

The traffic for the period from 1973 to 1990 will increase at a certain growth rate for traffic component such as types of vehicle, railway freight and railway passengers, and the traffic after 1990 will increase constantly in terms of the number of vehicles each year/2. The traffic of the highway and the railway for each year from 1973 to 2000 is given as Table 3.10. As for the estimation of the traffic after 2000, no traffic growth was considered.

According to Table 3.9., the traffic of the highway per day in 1990 is 4,700 cars, which corresponds to 6.23 times of the traffic volume in 1973, while the traffic of railway freight and passengers per day in 1990 are 2,600 tons, which corresponds to 4.38 times of

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/1 Refer to Walter Isord, "Method of Regional Analysis, An Introduction to Regional Sience," John Wiley, 1960.

/2 As the value of the annual growth, the value of the average annual growth for the period from 1967 to 1990 has been used.

the traffic in 1973, and 1,800 persons which corresponds to 5.33 times the traffic in 1973, respectively. The average annual rates of traffic growth are 11.4 percent for the highway traffic, 9.1 percent for the railway freight and 10.4 percent for the railway passengers.

The traffic of highway per day in 2000 will reach 9,000 cars, which will be 9.29 times of the traffic of 1973. The railway freight and passengers in 2000 will be 3,800 tons and 2,700 persons respectively, and the rate of increase compared with that of 1973 is 6.38 times for the freight, and 7.88 times for the passengers/1.

The growth rate of the highway traffic for the period from 1973 to 1990 is expected to be the greatest for the personal cars and the taxis, and the share of the personal cars and taxis in the total traffic will rise from 45 percent in 1973 to 60 percent in 1990. On the contrary, the expected growth rate of the heavy trucks for the period from 1973 to 1990 is 8.4 percent, and its share of 30 percent in 1973 of the total traffic is expected to drop to 19 percent in 1990.

Furthermore, it is necessary to study the relationship between the traffic and the bridge toll, because the traffic largely varies due to the variation in the toll charge of bridge.

Generally, the relationship between the traffic Q and the traffic expense C is shown in the following equation.

$$Q = F(C)$$

The relation between the traffic and the bridge toll, also can be expresed as follows in like manner.

$$\frac{Q_{ij}}{Q_{if}} = F\left(\frac{C_{ij}}{C_{if}}\right)$$

where Q_{if} : the traffic of i traffic component is the case of a toll bridge that the toll is set equally to the current ferry charge.

Q_{ij} : the traffic of i traffic component for the toll j of the bridge.

/1 These growth rates are not overestimated values when compared with the rate of the traffic growth of 5.54 times between Udon Thani and Nong Khai for the period of 1962 to 1966 according to the data given by the Highway Department of Thailand.

C_{if} : the bridge toll of i traffic component equally set to the current ferry charge.

C_{ij} : the toll j of the bridge of i traffic component.

And when $\frac{C_{ij}}{C_{if}} = 1$, $\frac{Q_{ij}}{Q_{if}} = 1$, when $\frac{C_{ij}}{C_{if}} = 0$, $\frac{Q_{ij}}{Q_{if}} = \alpha_i$ (extreme value)

and when $\frac{C_{ij}}{C_{if}} = \infty$, $\frac{Q_{ij}}{Q_{if}} = 0$

From the above conditions it follows:

$$\frac{Q_{ij}}{Q_{if}} = \alpha_i^{1-\frac{C_{ij}}{C_{if}}} \quad /1$$

$$Q_{ij} = Q_{if} \cdot \alpha_i^{1-\frac{C_{ij}}{C_{if}}} \qquad (3)$$

/1 This formula is led as follows.

$$Y_i = \frac{Q_{ij}}{Q_{if}} \quad , \quad X_i = \frac{C_{ij}}{C_{if}}$$

$$Y_i = F(X_i)$$

when $X_i = 1$, $Y_i = 1$, when $X_i = 0$, $Y_i = \alpha_i$ and when $X_i = \infty$, $Y_i = 0$

From the above it follows that $Y_i = F(X_i)$ is the exponential function, which can be expressed as follows.

$$Y_i = A^{bX_i} \cdot F(X_i) \qquad (1)$$

from $X_i = 1$ and $Y_i = 1$, $b \cdot \log A + \log F_i(X_i) = 0$ (2)

from $X_i = 0$ and $Y_i = \alpha_i$, $\log F_i(X_i) = \log \alpha_i$ (3)

from (3) $F_i(X_i) = \alpha_i$ (4)

$\cdot$ $b \cdot \log A + \log \alpha_i = 0$

$$A^b = \frac{1}{\alpha_i} \qquad (5)$$

from (4) and (5)

$$Y = \left(\frac{1}{\alpha_i}\right)^{X_i} \cdot \alpha_i = \alpha_i^{1-X_i} = \alpha_i^{1-\left(\frac{C_{ij}}{C_{if}}\right)}$$

The coefficient of variation α_i can be expressed in the form of the following equation according to the data of highways in Japan.

$$\alpha_i = \frac{Q_{in}}{Q_{if}} = \left(\frac{C_{ir} + C_{in}}{C_{ir}} \right)^{K_i} \qquad (4)$$

where C_{ir} : operating cost

C_{in} : current ferry charge

K_i : coefficient

From the equation (3), the traffic Q_{if} is figured out and shown in Table 3.10.

The corfficient of traffic variation α_i is estimated from following three items as given in Table 3.13.: (1) the current ferry charge, (2) the operating cost obtained by the survey of the project area and (3) the coefficient K_i calculated on the basis of the values obtained for several toll roads released for free in Japan shown in Table 3.11. Therefore, the traffic Q_{ij} for the bridge toll C_{ij} is obtained by putting the above two values, Q_{if} and α_i, into the equation (3). The relation between C_{ij}/C_{if} and Q_{ij}/Q_{if} is shown in Fig. 3.13., and the traffic for each bridge toll is given in Fig. 3.14.

The respective traffic of 1973, 1990 and 2000 in the case of a non-toll bridge is shown in Table 3.14.

Table 3.9. Estimated future traffic

(in the case of a toll bridge that the tolls are set equally to the current ferry charges)

Part	Items		Imaginary initial traffic /1 1967	Future traffic /1 1973	1990	2000	Growth index 1973	1990	2000	Annual growth rate 1973 to 1990 (%)	Daily /1 growth volume 1990 to 2000
Highway part	Car ferry vehicles at present	Buses	2	6	32	47	1.00	5.33	7.83	10.4	1.5
		Personal cars	29	68	548	830	1.00	8.06	12.21	13.1	28.2
		Taxis	1	3	26	40	1.00	8.67	3.33	13.6	1.4
		Heavy trucks	187	217	855	1,230	1.00	3.94	5.67	8.4	37.5
		Light trucks	3	7	31	45	1.00	4.43	6.43	9.2	1.4
		Motorcycles	-	-	-	-	-	-	-	-	-
		Sub-total	122	301	1,492	2,191	1.00	4.95	7.28	9.9	69.9
	Vehicles diverted from passenger ferries	Buses	12	28	151	223	1.00	5.39	7.96	10.4	7.2
		Personal cars	56	132	1,058	1,603	1.00	8.02	12.14	13.0	54.5
		Taxis	57	135	1,149	1,745	1.00	8.51	12.93	13.5	59.6
		Heavy trucks	2	4	16	23	1.00	4.00	5.75	8.5	0.7
		Light trucks	-	-	-	-	-	-	-	-	-
		Motorcycles	62	146	781	1,155	1.00	5.35	7.91	10.4	37.4
		Sub-total	189	445	3,155	4,750	1.00	7.09	10.67	12.2	159.5
	Total traffic	Buses	14	34	183	271	1.00	5.38	7.97	10.4	8.8
		Personal cars	79	201	1,606	2,432	1.00	7.99	12.10	13.0	82.6
		Taxis	58	138	1,175	1,785	1.00	8.51	12.93	13.4	61.0
		Heavy trucks	95	221	871	1,253	1.00	3.94	5.67	8.4	38.2
		Light trucks	3	7	31	45	1.00	4.43	6.43	9.2	1.4
		Motorcycles	62	146	781	1,155	1.00	5.35	7.91	10.4	37.4
		Sub-total	311	747	4,647	6,941	1.00	6.23	9.29	11.4	229.4
Railway part	Freight diverted from ferry		254	591	2,586	3,760	1.00	4.38	6.36	9.1	117.4
	Car passengers diverted to railway passengers		6	18	95	140	1.00	5.28	7.78	10.3	4.5
	Ferry passengers diverted to railway passengers		135	319	1,701	2,514	1.00	5.33	7.88	10.4	81.3
	Total railway passengers		141	337	1,796	2,654	1.00	5.33	7.88	10.4	85.8

Remarks: /1 Vehicles per day for buses, taxis, personal cars, heavy trucks, light trucks and motorcycles, tons per day for railway freight and persons per day for railway passengers.

Table 3.10. Estimated future traffic for each year

(In the case of a toll bridge that the tolls are set equally to the current ferry charge)

Calendar year	Ordinal year	Highway part (vehicles/day)							Railway part/1	
		Buses	Personal cars	Taxis	Heavy trucks	Light trucks	Motor-cycles	Total	Railway freight	Railway passengers
1973	1	34	201	138	221	7	146	747	591	337
1974	2	38	227	157	240	8	161	831	645	372
1975	3	41	257	178	260	8	178	922	703	410
1976	4	46	290	201	282	9	196	1,024	767	453
1977	5	51	328	228	305	10	217	1,139	836	500
1978	6	56	370	259	331	11	239	1,266	912	551
1979	7	62	419	294	359	12	264	1,410	995	608
1980	8	68	473	333	389	13	291	1,567	1,085	671
1981	9	75	534	378	421	14	321	1,743	1,184	741
1982	10	8[illegible]	604	429	457	15	355	1,943	1,291	817
1983	11	9[illegible]	683	486	495	17	392	2,165	1,408	902
1984	12	10[illegible]	771	552	537	18	432	2,411	1,536	995
1985	13	11[illegible]	872	626	582	20	477	2,689	1,675	1,098
1986	14	123	985	710	631	22	526	2,997	1,827	1,212
1987	15	136	1,113	805	684	24	581	3,343	1,993	1,337
1988	16	150	1,258	913	741	26	641	3,729	2,174	1,475
1989	17	166	1,421	1,036	803	28	708	4,162	2,371	1,628
1990	18	183	1,606	1,175	871	31	781	4,647	2,586	1,796
1991	19	192	1,689	1,236	909	32	818	4,876	2,703	1,882
1992	20	201	1,771	1,297	947	34	856	5,106	2,821	1,968
1993	21	209	1,854	1,358	986	35	893	5,335	2,938	2,053
1994	22	218	1,937	1,419	1,024	37	930	5,565	3,055	2,139
1995	23	227	2,019	1,480	1,062	38	968	5,794	3,173	2,225
1996	24	236	2,102	1,541	1,100	39	1,005	6,023	3,290	2,311
1997	25	244	2,185	1,602	1,139	41	1,042	6,253	3,407	2,397
1998	26	253	2,267	1,663	1,177	42	1,080	6,482	3,525	2,483
1999	27	262	2,350	1,724	1,215	44	1,117	6,712	3,642	2,568
2000	28	271	2,432	1,785	1,253	45	1,155	6,941	3,760	2,654

/1 Tons per day for railway freight and persons per day for railway passengers.

Table 3.11. Coefficient K

Traffic component	Traffic before release for free-of-charge (Q_{io})	Traffic after release for free-of-charge (Q_{im})	Toll (C_{im})	Operating cost (C_{ir})	$\alpha i = \frac{Q_{im}}{Q_{if}}$	$\frac{C_{ir} + C_{im}}{C_{ir}}$	$K_i = \frac{\log \alpha_i}{\log(\frac{C_{ir} + C_{im}}{C_{ir}})}$
Buses	464	483	249	4,980	1.049	1.050	0.98
Personal cars	3,470	4,328	99	228	1.315	1.434	0.76
Taxis	1,735	2,164	99	108	1.547	1.917	0.67
Heavy trucks	4,361	4,527	190	3,230	1.046	1.059	0.79
Light rucks	3,758	9,180	172	74	2.522	3.324	0.77
Motorcycles	3,275	4,168	45	43	1.559	2.047	0.62
Railway passengers	-	-	-	-	-	-	0.98
Railway freight	-	-	-	-	-	-	0.79

Remarks: (1) The values of the toll roads in Japan released for free charge. The data regarding traffic before release for free-of-charge, that after release for free-of-charge, toll, and operation listed above are what are obtained from the highways of Japan.

(2) The values of coefficient K for the railway freight and railway passengers are assumed to be equal to those of heavy trucks and buses, respectively.

Table 3.12. Operating costs and current ferry charges

Traffic component	Typical origin and destination	Distance from origin to distination (km)	Operating cost per km (Baht)	Operating cost (C_{ir}) (Baht)	Mekong crossing facilities	Current ferry charge (C_{im}) (Baht)	Total cost ($C_{ir} + C_{im}$) (Baht)
Buses	Udon Thani-Vientiane	77	0.88	68	Car ferry	57	125
Personal cars	Udon Thani-Vientiane	77	0.67	52	"	40	92
Taxis	Nong Khai-Vientiane	23	0.67	15	"	40	55
Heavy trucks	Bangkok-Vientiane	647	1.92	1,242	"	110	1,352
Light trucks	Nong Khai-Vientiane	23	0.88	20	"	57	77
Motorcycles	Nong Khai-Vientiane	23	0.77	2	Passenger ferry	5	7
Railway passengers	Bangkok-Vientiane	647	-	120	"	5	125
Railway freight	Bangkok-Vientiane	647	-	460	Car ferry	40	500

Remarks: (1) The current ferry charge of buses 57 Bahts referred to in the above is taken equally to that of light truck because the riding efficiency of buses is too high at present and so will be certainly reduced in the future.

(2) The present one-way ferry charge of per-vehicle heavy truck is estimated as follows.

(One-way charge) = $\frac{1}{2}$(13 tons x 17 Bahts/ton) = 110 Bahts, provided that weight of body = 7 tons, weight of freight = 6 tons but empty in the return way and ferry charge in the round-trip for freight inclusive of body of truck = 17 Bahts/ton.

(3) The present one-way ferry charge of per-vehicle light truck is estimated as follows.

(One-way charge) = 40 Bahts + ($\frac{1}{2}$ x 2 tons x 17 Bahts/ton) = 57 Bahts, provided that ferry charge of body per vehicle (one-way) = 40 Bahts, weight of freight = 2 tons but empty in the return way and ferry charge in the round-trip for freight = 17 Bahts/ton.

(4) The operating cost per ton for railway freight is estimated as follows.

(Operating cost) = (330 Bahts + 170 Bahts) - (13 tons x 17 Bahts/ton / 6 tons) = 460 Bahts/ton because the present transit rate per ton between Bangkok and Tha Naleng = 330 Bahts, miscellaneous handling costs such as laborer cost, tip, etc. = 170 Bahts, weight of freight = 6 tons and ferry charge per ton = 17 Bahts/ton.

Table 3.13. <u>Coefficient of variation α</u>

Traffic component	Operating cost (C_{ir}) (Baht)	Current ferry charge (C_{im}) (Baht)	$\frac{C_{ir} + C_{im}}{C_{ir}}$	K_i	$\alpha_i = \left(\frac{C_{ir} + C_{im}}{C_{ir}}\right)^{K_i}$
Buses	68	57	1.838	0.98	1.82
Personal cars	52	40	1.769	0.76	1.54
Taxis	15	40	3.667	0.67	2.38
Heavy truck	1,242	110	1.089	0.79	1.07
Light truck	20	57	3.850	0.77	2.81
Motorcycle	2	5	3.500	0.62	2.17
Railway passengers	120	5	1.042	0.98	1.03
Railway freight	460	40	1.087	0.79	1.07

Remarks: The values of operating cost C_{ir}, current ferry charge C_{im} and ratio $(C_{ir} + C_{im})/C_{ir}$ are referred to Table 3.12.

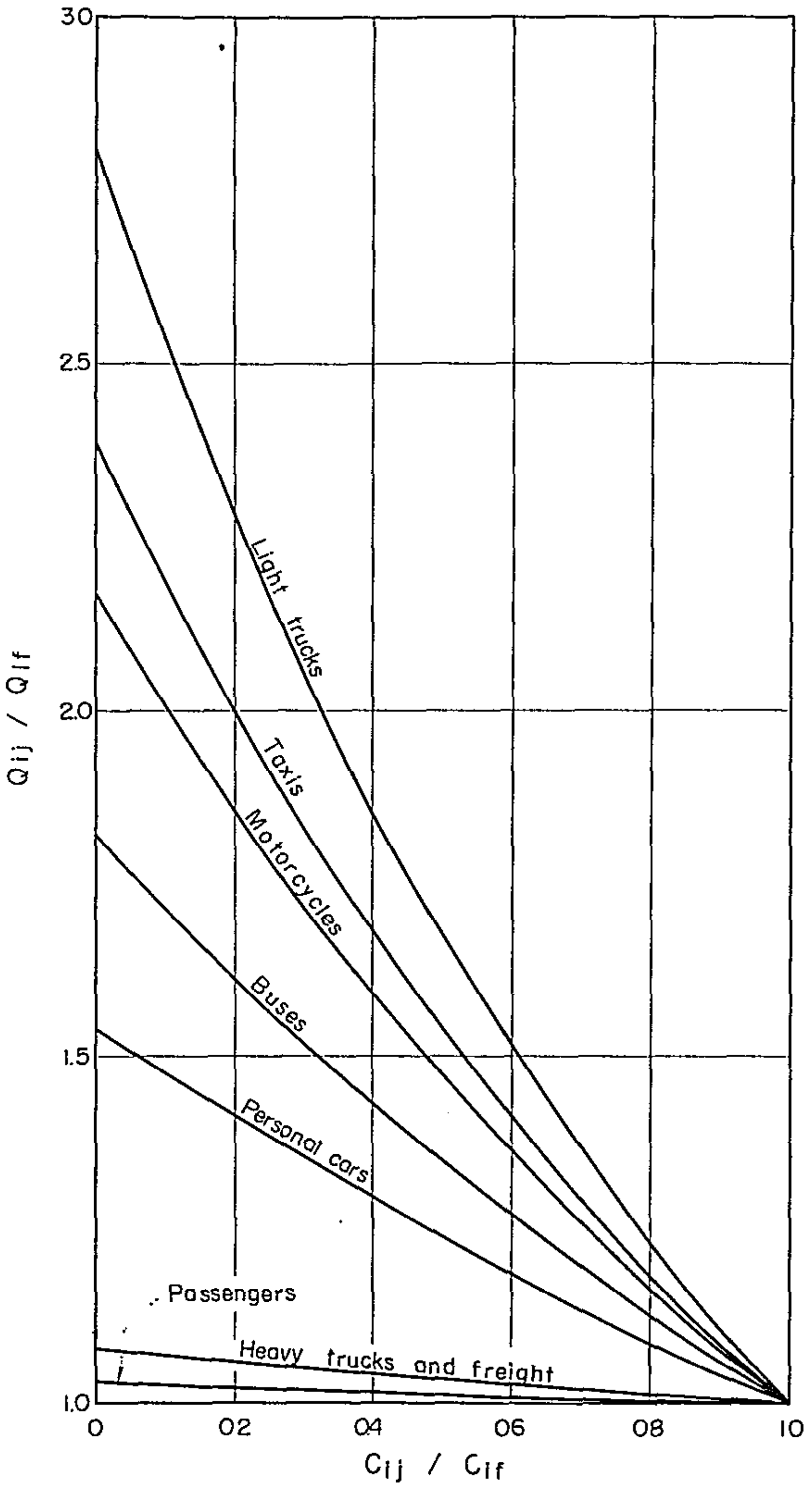
Table 3.14. Estimated future traffic

(in the case of a non-toll bridge)

	Items		Imaginary initial traffic/1	Future traffic/1			Growth index			Annual growth rate	Daily/1 growth volume
			1967	1973	1990	2000	1973	1990	2000	1973 to 1990 (%)	1990 to 2000
Highway part	Car ferry vehicles at present	Buses	3	11	58	87	1.00	5.27	7.91	10.3	2.9
		Personal cars	36	107	844	1,276	1.00	7.89	11.93	12.9	43.2
		Taxis	2	7	62	95	1.00	8.86	13.57	13.7	3.3
		Heavy trucks	200	232	915	1,316	1.00	3.94	5.67	8.4	40.1
		Light trucks	8	20	87	126	1.00	4.35	6.30	9.0	3.9
		Motorcycles	-	-	-	-	-	-	-	-	-
		Sub-total	249	377	1,966	2,900	1.00	5.21	7.69	10.2	93.4
	Vehicles diverted from passenger ferries	Buses	22	51	275	406	1.00	5.39	7.96	10.4	13.1
		Personal cars	86	203	1,629	2,469	1.00	8.02	12.16	13.0	84.0
		Taxis	136	321	2,735	4,152	1.00	8.52	12.94	13.5	141.8
		Heavy trucks	2	4	17	25	1.00	4.25	6.25	8.9	0.8
		Light trucks	-	-	-	-	-	-	-	-	-
		Motorcycles	135	317	1,695	2,506	1.00	5.35	7.91	10.4	81.1
		Sub-total	381	896	6,351	9,559	1.00	7.09	10.67	12.2	320.8
	Total traffic	Buses	25	62	333	493	1.00	5.37	7.95	10.4	16.0
		Personal cars	122	310	2,473	3,745	1.00	7.98	12.08	13.0	127.2
		Taxis	138	328	2,797	4,248	1.00	8.53	12.95	13.4	145.1
		Heavy trucks	202	236	932	1,341	1.00	3.95	5.68	8.4	40.9
		Light trucks	8	20	87	126	1.00	4.35	6.30	9.0	3.9
		Motorcycles	135	317	1,695	2,506	1.00	5.35	7.91	10.4	81.1
		Sub-total	630	1,273	8,317	12,459	1.00	6.53	9.79	11.4	414.2
Railway part	Freight diverted from ferry		262	609	2,664	3,873	1.00	4.37	6.36	9.1	120.9
	Car passenger diverted to railway passengers		7	20	102	150	1.00	5.10	7.50	10.0	4.8
	Ferry passengers diverted to railway passengers		144	341	1,820	2,690	1.00	5.34	7.89	10.4	87.0
	Total railway passengers		151	361	1,922	2,840	1.00	5.32	7.87	10.4	91.8

Remarks: /1 Vehicles per day for buses, taxis, personal cars, heavy trucks, light trucks and motorcycles, tons per day for railway freight and persons per day for railway passengers.

Fig. 3.13. RELATION BETWEEN Q_{ij}/Q_{if} AND C_{ij}/C_{if}



Values of α_i

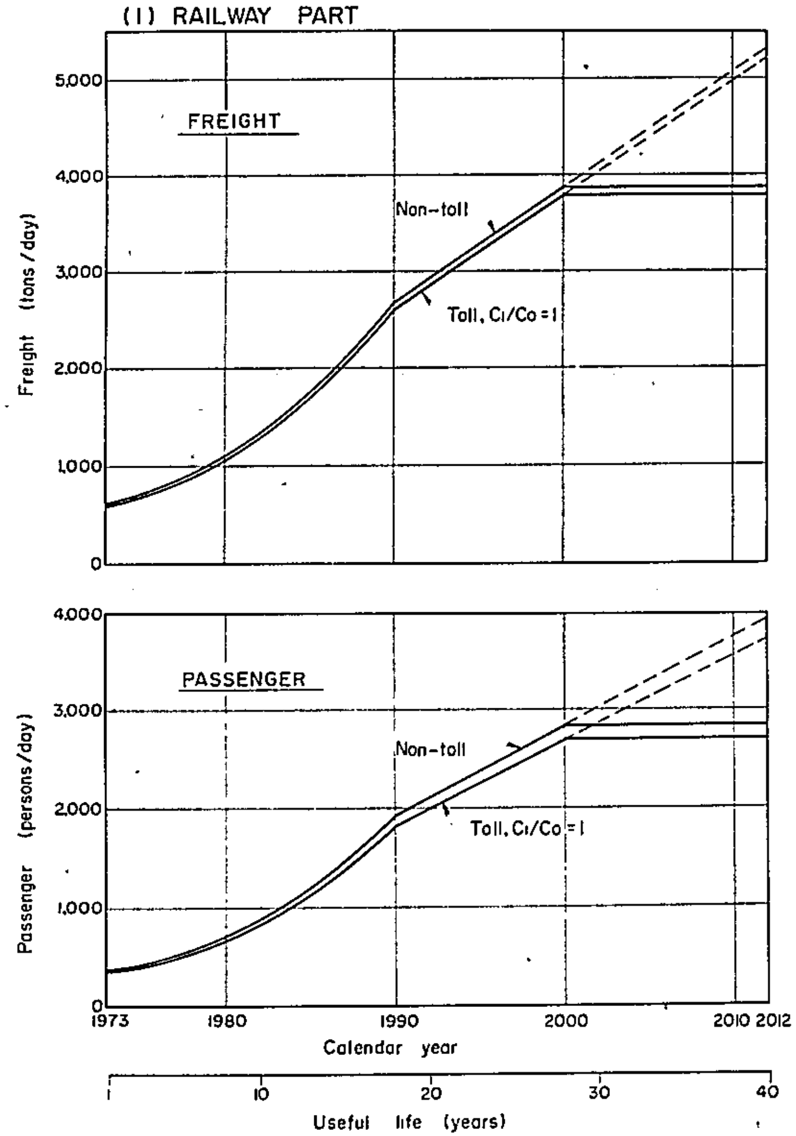
Kind of vehicles	α_i
1 Buses	1.820
2 Personal cars	1.540
3. Taxis	2.380
4. Heavy trucks	1.070
5 Light trucks	2.810
6 Motorcycles	2 170
7. Passengers	1.030
8 Freight	1 070

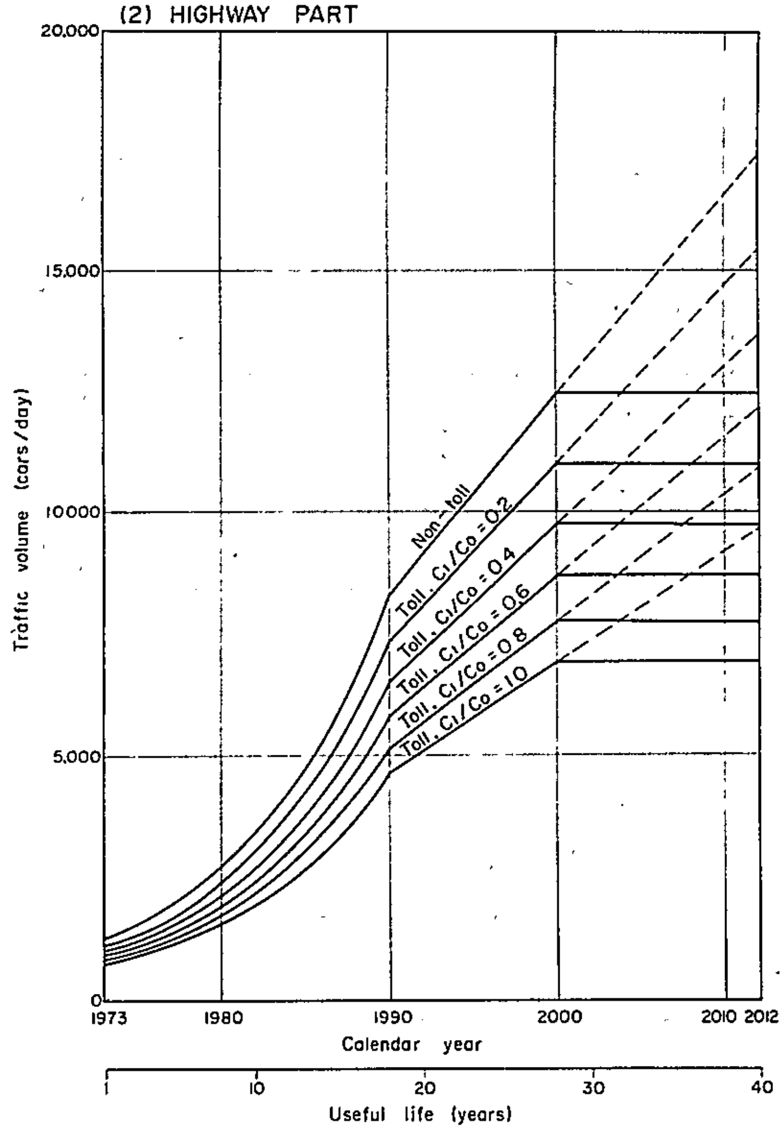
Remarks

$\alpha_i \cdot Q_{in} / Q_{if}$

$Q_{ij} / Q_{if} = \alpha_i^{(1-\frac{C_{ij}}{C_{if}})}$

Fig. 3. 14. FUTURE TRAFFIC VOLUME (in the case of a rail / highway bridge)





Remarks: C_i = Toll charge of rail/highway bridge
C_o = Current ferry charge

3.6.3. Direct benefit

The direct benefit comprises savings in the cost and time of travel, economy in car operation, increase in carrying capacity, less chance of accidents, comfortable traveling, and so forth.

The benefits from less travel time and the saving in the cost of car operation are called the time benefit and the operation benefit, respectively. While these two benefits can be estimated reasonably to some extent, the other benefits cannot be evaluated even in a rough estimate.

In this project, only the time and operation benefits are considered in estimating the direct benefit.

Total benefit is obtained by multiplying the traffic volume by the benefit per unit of traffic volume.

As mentioned in Paragraph 2.6., the benefit per unit of traffic volume comprises the operation benefit and the time benefit in a zonal pair, and can be computed as follows:

$$B = (C_0 - C_1) - a(T_0 - T_1)$$

The average benefit $\overline{B}$ per unit of traffic volume can be obtained from the following formula as an average of the benefit per unit of traffic volume of each zonal pair.

$$\overline{B} = \frac{\sum f_{ij} \cdot B_{ij}}{\sum f_{ij}}$$

where f_{ij} : traffic volume between two zones, i and j

B_{ij} : the benefit per unit of traffic volume between two zones, i and j

The average benefit per unit of traffic volume is obtained as given in Table 3.16 on the basis of the basic data shown in Table 3.15

The benefits per day for 1973, 1990 and 2000 respectively in case the bridge toll is set equally to the current charge of the existing car ferry are obtained by multiplying the benefit per unit of traffic volume given in Table 3.16. by the traffic per day shown in Table 3.9. and these values shown in Table 3.17.

The basic annual benefit is obtained by multiplying the average benefit ($\bar{B}$) per unit of traffic volume by the traffic volumes (Q_{if}) given in Table 3.10. and further multiplied by 365 days. The results are as given in Table 3.18.

The above benefits thus obtained are estimate to be actually much more values by the following two reasons.

i) The Mekong gets shallow in the dry seasons, and the ferry port on the Laotian side of the ferry running between Nong Khai and Tha Naleng is moved to Tha Deua which is 2 kilometers downstream from Tha Naleng. This inevitably makes the ferry route longer with extra amount of travel time and reduced number of trips. As a dry season lasts for 4 months from January to April, the benefits receivable from the bridge for this period will be correspondingly large.

ii) Damage to transported commodities during transshipment and theft can be prevented.

Table 3.15. Basic data for the estimation of operation and time benefits

(1) Distance of zonal pair

(Unit: km)

Zonal pair	Vientiane Tha Bo, Sri Chieng Mai	Vientiane -Nong Khai station	Vientiane -Nong Khai	Vientiane -Udon	Tha Deua -Nong Khai station	Tha Deua -Nong Khai	Tha Deua -Udon
Existing route	80.6	20.5	22.7	76.6	3.4	5.6	59.5
New route	80.8	20.7	22.9	76.8	5.4	7.6	61.5

(2) Travel times and expenses

Vehicles	Operating cost (Bahts/km)	Speed per hour (km)	Charge for ferry (Bahts)	Waiting time (hours)
Small-sized buses	0.98	72	40	0.5
Large-sized buses	2.49	72	195	0.5
Taxis and personal cars	0.67	80	40	0.5
Heavy trucks	1.92	72	110	0.5
Light trucks	0.88	72	57	0.5

(3) Travel times and expenses for passengers and freight

Items	Travel expenses per km	Charge for handling (Bahts/ton)		Time for handling (hours)		Speed per hour	Charge for ferry (Bahts/ton or Bahts/person)	Waiting time
	Bahts	Nong khai sta.	Ferry site	Nong khai sta.	Ferry site	(km)		(hours)
Passengers by passenger ferry	0.14	-	-	-	-	72	5.0	0.5
Passengers by car ferry	0.22	-	-	-	-	80	13.0	0.5
Freight by car ferry	0.45	12.0	-	3.0	-	72	17.0	0.5
Freight by passenger ferry	0.45	12.0	17.0	3.0	3.0	72	5.0	0.5

(4) Unit time benefit

Vehicles	Calculations	Benefit per hour (Bahts)
Buses	(45.4 Kips/24.5 Kips/Baht) x (14 persons/car/4 persons/car)	6.50
Personal cars	45.4 Kips/24.5 Kips/Baht	1.85
Taxis	45.4 Kips/24.5 Kips/Baht	1.85
Heavy trucks		8.30
Light trucks	8.3 Bahts x (0.25 ton/car/2.69 ton/car)	0.77
Freight	8.3 Bahts/2.69 tons	3.10
Passengers	(45.4 Kips/24.5 Kips/Baht)/4 persons = 0.46 Baht (2,784 Bahts/365 days)/8 hours = 0.95 Baht (0.46 Baht + 0.95 Baht)/2	0.71

Remarks:

(1) The charge for wating time of taxi per hour in Laos 45.4 Kips was taken as the benefits of personal car and taxi per hour, and the benefit of bus per hour was obtained by multiplying the waiting-time charge of taxi per hour in Laos 45.4 Kips by the ratio of the riding efficiency of bus 14 persons per car to that of taxi 4 persons per car, and then converted into a Baht basis.

(2) The charge of heavy truck per hour in Thailand 8.3 Bahts was taken as the benefit of heavy truck per hour, and the benefit of light truck per hour was obtained by multiplying the charge of heavy truck per hour 8.3 Bahts by the ratio of the riding efficiency of light truck 0.25 ton per car to that of heavy truck 2.69 tons per car.

(3) The benefit of freight per ton per hour was obtained by dividing the benefit of heavy truck per hour 8.3 Bahts by the riding efficiency the benefit per 2.69 tons per car.

(4) The mean value of the waiting-time charge of taxi per person per hour 0.46 Paht and the national income per person per hour in Thailand 0.95 Baht was taken as the benefit of passenger per person per hour. The national income per person in Thailand is 2,784 Bahts per annum.

(5) The exchange rate
1 Baht = 24.5 Kips

Table 3.16. Benefit per unit of traffic volume

Zonal pair	Route	Small-sized buses: Operat-ing cost (Bahts)	Small-sized buses: Travel time (hrs.)	Large-sized buses: Operat-ing cost (Bahts)	Large-sized buses: Travel time (hrs.)	Personal cars: Operat-ing cost (Bahts)	Personal cars: Travel time (hrs.)	Taxis: Operat-ing cost (Bahts)	Taxis: Travel time (hrs.)	Heavy trucks: Operat-ing cost (Bahts)	Heavy trucks: Travel time (hrs.)	Light trucks: Operat-ing cost (Bahts)	Light trucks: Travel time (hrs.)	Motorcycles: Operat-ing cost (Bahts)	Motorcycles: Travel time (hrs.)	Railway freight: Operat-ing cost (Bahts)	Railway freight: Travel time (hrs.)	Railway passengers: Operat-ing cost (Bahts)	Railway passengers: Travel time (hrs.)
Vientiane - Tha Bo, Sri Chieng Mai	Existing route	119.0	1.62					94.0	1.51										
	New route	79.0	1.12					54.0	1.01										
	Difference	40.0	0.50					40.0	0.50										
	Nos. of car	1						1											
Vientiane - Nong Khai Station	Existing route			246.0	0.78	53.4	0.75	53.4	0.75	148.4	0.78								
	New route																		
	Difference																		
	Nos. of car			3		19		13		94									
Vientiane - Nong Khai	Existing route			251.5	0.82	55.2	0.78	55.2	0.78	153.6	0.82								
	New route			56.5	0.32	15.2	0.28	15.2	0.28	43.6	0.32								
	Difference			195.0	0.50	40.0	0.50	40.0	0.50	110.0	0.50								
	Nos. of car			5		28		27		24									
Vientiane - Udon	Existing route			385.7	1.56	91.3	1.46			257.1	1.56	124.4	1.56						
	New route			190.7	1.06	51.3	0.96			147.1	1.06	67.4	1.06						
	Difference			195.0	0.50	40.0	0.50			110.0	0.50	57.0	0.50						
	Nos. of car			1		19				71		2							
Tha Deua - Nong Khai Station	Existing route			207.6	0.56	43.3	0.55	43.3	0.55		1								
	New route			13.4	0.08	3.6	0.07	3.6	0.07										
	Difference			194.2	0.48	39.7	0.48	39.7	0.48										
	Nos. of car			1		5		3											
Tha Deua - Nong Khai	Existing route			213.1	0.58	44.8	0.58	44.8	0.58										
	New route			18.9	0.11	5.1	0.10	5.1	0.10										
	Difference			194.2	0.47	39.7	0.48	39.7	0.48										
	Nos. of car			6		27		27											
Tha Deua - Udon	Existing route											109.4	1.33						
	New route											54.1	0.85						
	Difference											55.3	0.48			39	3.5	8	0.78
	Nos. of car											1				254		141	
Total operating cost		40.0		2,529.4		3,150.4		2,311.0		10,450		169.3				9,906.0		1,128.0	
Operation benefit per unit of traffic volume		40.0		194.57		39.88		39.84		110.00		56.43		5		39.00		8.0	
Total difference of travel time		0.50		6.39		38.86		28.40		47.50		1.48				889.0		109.98	
Mean difference of travel time		0.50		0.49		0.49		0.49		0.50		0.49		0.5		3.50		0.78	
Hourly benefit		6.5		6.5		1.85		1.85		8.3		0.77		1.85		3.1		0.71	
Time benefit per unit of traffic volume		3.25		3.19		0.91		0.91		4.15		0.38		0.93		10.85		0.55	
Total benefit per unit of traffic volume		43.25		197.76		40.79		40.75		114.15		56.81		5.93		49.85		8.55	
- do. - , adopted			121			41		41		114		57		6		50		9	

Remarks:

(1) The value of the operating cost in each zonal pair is obtained from Tables 3.15.

(2) The number of car shown in this table denotes the present traffic made clear by the origin-destination survey.

(3) The mean value of the unit benefits of the small-sized buses and the large-sized buses was taken as the benefit per bus.

(4) The operation benefit of motorcycle is represented by the current ferry charge per motorcycle, and the mean difference of travel time 0.5 hour is figured out as the mean value of those of buses, personal cars, taxis and trucks.

(5) In the column of railway freight, the difference of the operating cost between Tha Deua and Udon 39 Bahts is the present handling cost of the Nong Khai station, and the difference of the travel time 3.5 hours is the sum of the handling time at the Nong Khai station 3 hours and the difference of travel time between the existing and new routes 0.5 hour.

(6) In the column of railway passengers, the difference of the operating cost between Tha Deua and Udon 8.0 Bahts is the sum of the current ferry charges 5 Bahts and the charge of vehicle between the Nong Khai station and the ferry site 3 Bahts, and the difference of travel time 0.78 hours is to sum of the change time at the Nong Khai station 0.28 hour and the waiting time at the ferry site 0.5 hours.

Table 3.17. Benefit per day

(In the case of a toll bridge that the tolls are set equally to the current ferry charges)

	Benefit per unit of traffic volume/1	1973		1990		2000	
		Traffic/1	Benefit (Bahts/day)	Traffic/1	Benefit (Bahts/day)	Traffic/1	Benefit (Bahts/day)
Buses	121	34	4,114	183	22,143	271	32,791
Personal cars	41	201	8,241	1,606	65,846	2,432	99,712
Taxis	41	138	5,658	1,175	48,175	1,785	73,185
Heavy trucks	114	221	25,194	871	99,294	1,253	142,842
Light trucks	57	7	399	31	1,767	45	2,565
Motorcycles	6	146	876	781	4,686	1,155	6,930
Sub-total	-	747	44,482	4,647	241,911	6,941	358,025
Railway freight	50	591	29,550	2,586	129,300	3,760	188,000
Railway passengers	9	337	3,033	1,796	16,164	2,654	23,886
Sub-total	-	-	32,583	-	145,464	-	211,886
Total	-	-	77,065	-	387,375	-	569,911

/1: Bahts/vehicles for the traffic component of a highway part such as buses, personal cars, taxis, heavy trucks, light trucks and motorcycles, Bahts/ton for railway freight and Bahts/person for railway passengers.

/2: Vehicles/day for the traffic component of a highway part and ton/day for railway freight and persons/day for railway passengers.

Table 3.18 Annual benefit

(In the case of a toll bridge that the tolls are set equally to the current ferry charges)

(Unit: Bahts)

Calen-dar year	Ordi-nal year	Buses	Personal cars	Taxis	Heavy trucks	Light trucks	Motor-cycles	Sub-total	Railway freight	Railway passengers	Sub-total	Total
1973	1	1,501,610	3,007,965	2,065,170	9,195,810	145,635	319,740	16,235,930	10,785,750	1,107,045	11,892,795	28,128,725
1974	2	1,657,889	3,399,100	2,342,454	9,968,431	158,958	352,889	17,879,721	11,764,098	1,221,549	12,985,647	30,865,368
1975	3	1,830,433	3,841,095	2,656,968	10,805,967	173,499	389,475	19,697,437	12,831,190	1,347,897	14,179,087	33,876,524
1976	4	2,020,935	4,340,565	3,013,710	11,713,871	189,370	429,853	21,708,304	13,995,075	1,487,313	15,482,388	37,190,692
1977	5	2,231,262	4,904,981	3,418,351	12,698,057	206,694	474,418	23,933,763	15,264,533	1,641,149	16,905,682	40,839,445
1978	6	2,463,480	5,542,791	3,877,322	13,764,932	225,602	523,603	26,397,730	16,649,141	1,810,897	18,460,038	41,857,768
1979	7	2,719,865	6,263,537	4,397,918	14,921,445	246,240	577,888	29,126,893	18,159,343	1,998,202	20,157,545	49,284,438
1980	8	3,002,933	7,078,004	4,988,413	16,175,127	268,766	637,800	32,151,043	19,806,531	2,204,880	22,011,411	54,162,454
1981	9	3,315,462	7,998,378	5,658,191	17,534,142	293,353	703,924	35,503,450	21,603,132	2,432,936	24,036,068	59,539,518
1982	10	3,660,517	9,038,432	6,417,898	19,007,340	320,188	776,903	39,221,278	23,562,698	2,684,580	26,247,278	65,468,556
1983	11	4,041,483	10,213,727	7,279,609	20,604,314	349,479	857,448	43,346,060	25,700,011	2,962,252	28,662,263	72,008,323
1984	12	4,462,098	11,541,849	8,257,018	22,335,464	381,449	946,343	47,924,221	28,031,195	3,268,644	31,299,839	79,224,060
1985	13	4,926,489	13,042,671	9,365,662	24,212,063	416,344	1,044,455	53,007,684	30,573,834	3,606,728	34,180,562	87,188,246
1986	14	5,439,211	14,738,649	10,623,159	26,246,331	454,430	1,152,739	58,654,519	33,347,110	3,979,780	37,326,890	95,981,409
1987	15	6,005,293	16,655,161	12,049,497	28,451,517	496,001	1,272,248	64,979,717	36,371,943	4,391,417	40,763,360	105,743,074
1988	16	6,630,291	18,820,882	13,667,345	30,841,979	541,375	1,404,148	71,906,020	39,671,151	4,845,631	44,516,782	116,422,802
1989	17	7,320,335	21,268,219	15,502,415	33,433,285	590,900	1,549,723	79,664,877	43,269,621	5,346,826	48,616,447	128,281,324
1990	18	8,082,195	24,033,790	17,583,875	36,242,310	644,955	1,710,390	88,797,515	47,194,500	5,899,860	53,094,360	141,891,875
1991	19	8,469,288	25,270,603	18,496,740	37,833,281	674,327	1,792,193	92,536,432	49,336,191	6,181,790	55,517,981	148,054,413
1992	20	8,856,381	26,507,416	19,409,605	39,424,251	703,699	1,873,996	96,775,348	51,477,882	6,463,721	57,941,603	154,716,951
1993	21	9,243,475	27,744,230	20,322,470	41,015,222	733,070	1,955,799	101,014,266	53,619,574	6,745,651	60,365,225	161,379,491
1994	22	9,630,568	28,981,043	21,235,335	42,606,192	762,442	2,037,602	105,253,182	55,761,265	7,027,581	62,788,846	168,042,028
1995	23	10,017,661	30,217,856	22,148,200	44,197,163	791,814	2,119,405	109,492,099	57,902,956	7,309,511	65,212,467	174,704,566
1996	24	10,404,754	31,454,669	23,061,065	45,788,134	821,186	2,201,208	113,731,016	60,044,647	7,591,442	67,636,089	181,367,105
1997	25	10,791,848	32,691,483	23,973,930	47,379,104	850,557	2,283,011	117,969,933	62,186,338	7,813,372	69,999,710	187,969,643
1998	26	11,178,941	33,928,296	24,886,795	48,970,075	879,929	2,364,814	122,208,850	64,328,029	8,155,302	72,483,331	194,692,181
1999	27	11,566,034	35,165,109	25,799,660	50,561,045	709,301	2,446,616	126,447,765	66,469,721	8,437,233	74,906,954	201,354,719
2000	28	11,953,127	36,401,922	26,712,525	52,152,016	938,673	2,528,419	130,686,682	68,611,412	8,719,163	77,330,575	208,017,257

Remarks: (Annual benefit) = (Benefit per unit of traffic volume) x (Traffic per day shown in Table 3.10.) x 365 days

3.6.4. Annual benefit

As mentioned in Subparagraph 3.6.3., the annual benefit can be obtained by adding up the product of the traffic volume and the unit benefit of each traffic component such as buses, trucks, personal cars, railway freight and railway passengers, etc. Generally, the future growth of traffic veries according to the toll rate of bridge. Therefore, the traffic volume to be used for the calculation of the annual benefit should be such that results from the most appropriate toll/1 system which produces the maximum residual benefit/2 expressed in total present worth, on condition that the toll revenue can amortize the total investment of the project in the case of a toll bridge.

Therefore, the adequate tolls for all the traffic components can be obtained by selecting from among all conceivable combinations of toll rates for traffic components a combination which satisfies the following equations (1) and (2).

$$\sum_{k=1}^{n} \frac{1}{(1+r)^{k-1}} \cdot \sum_{i=1}^{\ell} Q_{(ij)k}(B_i - C_{(ij)}) = \text{maximum} \quad \ldots\ldots (1)$$

$$\sum_{k=1}^{n} \frac{1}{(1+r)^{k-1}} \cdot \sum_{i=1}^{\ell} Q_{(ij)k} \cdot C_{(ij)} = C \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where B_i : The unit benefit of a traffic component "i"

$C_{(ij)}$: A toll rate "j" of a traffic component "i" In this case, toll rates considered are the valves from zero to the current ferry charge of the traffic component "i"

$Q_{(ij)k}$: The traffic volume of a traffic component "i" in a year "k" when the toll rate is $C_{(ij)}$

/1 Hereinafter called "adequate toll"

/2 The residual benefit means the remainder after subtracting the collected amount of toll from the total benefit.

r : Annual discount rate

n : Amortization period in years

i : Numbers of traffic component

C : Total investment in total present worth

As is clear from the above two equations, the adequate tolls vary accordingly with the annual discount rate "r" and the amortization period "n" for the capital invested. In this report, the adequate tolls for verious traffic components have been computed for three kinds of loans, namely, loans of 3% annual interest rate with amortization period of 40 years (Loan I), 7% with 25 years (Loan II), and 10% with 20 years (Loan III), respectively. The valves are as given in Table 3.19.

In Table 3.19. are also given the total present worths of toll revenue necessary for amortizing the loan, the amount of revenue from the adequate tolls adopted, and the amount of residual benefits that the users of bridge are receivable in case the adequate tolls have been collected, for each Loans I, II and III respectively. The required amount of toll revenue necessary for the amortization of loan is the sum of the total construction cost and the total present worth of annual working expenses.

Table 3.19. shows that the adequate tolls for buses, personal cars, taxis, light truck and railway freight are approximately one-tenth of the current ferry charges in the case of Loan I. The adequate toll for heavy trucks is as high as one-fourth of the current ferry charge. This results from the fact that the traffic of heavy trucks hardly decreases even if the toll rate is remarkable raised. The adequate tolls for bicycles and railway passengers have come to the same 5 Bahts as the current ferry charges, because 5 Bahts was considered as the minimum charge in the calculation of adequate tolls.

Table 3.19 Adequate tolls

Unit: Baht

Traffic Component	Current ferry charges	Loan I/1	Loan II/2	Loan III/3
Buses	57	5	25	55
Personal cars	40	5	5	35
Taxis	40	5	5	35
Heavy trucks	110	30	100	110
Light trucks	57	5	25	40
Motorcycles	5	5	5	5
Passengers	5	5	5	5
Freight	40	5	25	40

Unit: 10^3 Bahts

Items	Loan I	Loan II	Loan III
Required income/4 in present worth	560,862	489,013	469,341
Total present worth of toll revenue	573,946	492,607	470,323
Total present worth of residual value	3,010,399	643,166	95,721

Remarks: In the case of finding adequate tolls, the tolls of bridge for various kind of vehicles were given tentatively by 5 Bahts interval-tolls from zero to current ferry charges for respective vehicles.

/1 .... In the case of a loan with the annual interest rate of 3% and the amortization period of 40 years

/2 .... In the case of a loan with the annual interest rate of 7% and the amortization period of 25 years

/3 .... In the case of a loan with the annual interest rate of 10% and the amortization period of 20 years

/4 .... The amount of toll revenue required to amortize the total investment added the total present worth of annual working expenses to the total construction cost.

In the case of Loan III, the adequate tolls for most of traffic components are almost the same or very close to the current ferry charges. The adequate tolls in Loan II lie between there in Loans I and III.

By using the adequate tolls thus obtained together with the traffic volume "Q" and the coefficients "α" of future traffic variation obtained in Subparagraph 3.6.2. and the unit benefits "B" obtained in Subparagraph 3.6.3., the mean annual benefit and capitalized benefit to the total present worth can be obtained from the following equations.

$$B_m = \frac{1}{m} \sum_{k=1}^{m} \cdot \sum_{i=1}^{l} (Q_{(ij)k} \times 365) \times \alpha_i^{\,1-\frac{C_{ij}}{C_{if}}} \times B_i \quad \text{..........} \ (3)$$

$$B_c = \sum_{k=1}^{n} \frac{1}{(1+r)^{k-1}} \cdot \sum_{i=1}^{l} (Q_{(ij)k} \times 365) \times \alpha_i^{\,1-\frac{C_{ij}}{C_{if}}} \times B_i \quad .. \ (4)$$

where B_m : Mean annual benefit

B_c : Capitalized benefit to be total present worth

$Q_{(ij)k}$ /1 : Average daily traffic of a traffic component "i" in a year "k", when the toll rate of bridge is as same as the current ferry charge.

α_i /2 : Coefficient of future traffic variation of a traffic component "i"

C_{ij} /3 : Toll of bridge for a traffic component "i"

C_{ij} /4 : Current ferry charge for a traffic component "i"

B_i /5 : Unit benefit of a traffic component "i"

/1 Refer to Table 3.10.
/2 Refer to Table 3.13.
/3, /4 Refer to Table 3.19
/5 Refer to Table 3.16

ℓ : Total number of traffic component

m : Analysis period. In the case of a non-toll bridge, a period of 28 years was taken because the future traffic beyond 28th year after the completion of bridge cannot be estimated. In the case of a toll bridge, the amortization period was taken because the future traffic will vary after the capital investment is fully amortized.

n : Discount period. Mean useful lifetime of 40 years was taken in the case of a non-toll bridge and the amortization period in the case of a toll bridge.

The mean annual benefit and the capitalized benefit to the total present worth thus obtained are as given in Table 3.20.

Table 3.20. Mean annual benefit and capitalized benefit

Unit : Baht

Kind of capital	Mean annual benefit(Bm)	Capitalized benefit(Bc)
Toll Bridge		
Loan I/1	180,063,000	3,584,345,000
Loan II/2	121,413,000	1,133,773,000
Loan III/3	80,534,000	566,044,000
Non-toll bridge		
Grant/4	190,250,000	5,937,702,000

/1 A loan of 3% annual interest rate with amortization period of 40 years.
/2 A loan of 7% annual interest rate with amortization period of 25 years.
/3 A loan of 10% annual interest rate with amortization period of 20 years.
/4 Although it was considered that the whole investment was provided with the grant, the annual rate of interest of 3% and the discount period of 40 years as long as mean useful lifetime of the project was considered for the analysis of benefit and cost.

3.6.5. Annual cost

The annual cost comprises the annual fixed cost and the annual movable cost of the project.

The annual fixed cost means the annual cost by which the total construction cost of the project would be amortized during its useful lifetime, and is given by the following equation.

$$C_f = \sum_{t=t_1}^{t_n} C_t \frac{i(1+i)^t}{(1+i)^{t-1}} \quad \text{.........} \quad (1)$$

where C_f : Equivalent annual fixed cost.

C_t : Construction costs of project structures of different useful lifetimes.

i : Annual discount rate.

t : Useful lifetimes of project structures in years.

In the estimation of the annual fixed cost, the annual discount rate was taken at 3 percent, 7 percent and 10 percent in the same manner as in the case of calculating benefits. The annual fixed cost was calculated from the construction costs and useful lifetimes of various kinds of project structure as shown in Table 3.22.

The annual movable cost means the annual working expense for operation, maintenance and replacement costs of the bridge, highway and railway facilities such as the maintenance costs of wearing course, shoulder, ditch, lighting facilities, etc., and the periodical cost of repainting the bridge. Furthermore, office expenses for toll collection are needed in the case of a toll bridge. The annual working expense was estimated in Table 3.23.

The annual costs thus estimated are also shown in Table 3.22.

Furthermore, the annual costs will be capitalized to the total present worth as of 1973 for the calculation of the capitalized net benefit, as shown in Table 3.21. The total present worth of the annual cost can be expressed in the form of the following equation.

$$C_c = \frac{1}{(1+i)^m} \left[\sum_{t=1}^{l} C_t + E \cdot \frac{(1+i)^n - 1}{i(1+i)^n} \right] \quad \ldots\ldots \quad (2)$$

where C_c: Total present worth of the annual cost

C_t: Construction costs of project structures of different useful lifetimes

i : Annual discount rate

E : Annual working expense

m : The duration of time in years between the present and the target year of bridge completion. In this report, the value of "m" was taken to be zero.

n : Discount period. In this report, mean useful lifetime of 40 years of the project structures was considered in the case of a non-toll bridge, and the amortization period in the case of a toll bridge.

l : Number of project structures of different useful lifetimes.

The result of calculation of costs is summarized in the following Table 3.21.

Table 3.21. Annual cost and capitalized cost

Unit : Baht

Kind of capital	Annual cost, C_a	Capitalized cost, C_c
Total bridge		
Loan I/1	24,571,000	556,468,000
Loan II/2	37,427,000	494,476,000
Loan III/3	48,478,000	471,965,000
Non-toll bridge		
Grant/4	24,141,000	546,518,000

/1, /2, /3, /4, Refer to Table 3.20 in Subparagraph 3.6.4.

Table 3.22. Annual Cost

Unit: US$

Item	Useful life-time (1)	Mean useful life-time (2)	Total construction cost (3)	Capital recovery factor (4) Toll Loan I	Toll Loan II	Toll Loan III	Non-toll Grant	Annual fixed cost (5) Toll Loan I	Toll Loan II	Toll Loan III	Non-toll Grant	Annual working expenses (6) Toll	Non-toll	Annual cost = (7) Toll Loan I	Toll Loan II	Toll Loan III	Non-toll Grant
I. BRIDGE		41	9,000,000	0.04326	0.07501	0.10226	0.04326	389,400	675,100	920,300	389,400	12,600	12,600	402,000	687,700	932,900	402,000
1) Truss bridge composite and plate girder bridges	40		8,020,000														
2) Rigid-frame & hollow slub bridges	50		860,000														
3) Asphalt pavement	10		40,000														
4) Railway track	20		80,000														
II. HIGHWAY		40	3,600,000	0.04326	0.07501	0.10226	0.04326	155,700	270,000	368,100	155,700	127,000	106,000	282,700	397,000	495,100	261,700
Access Highway		(42)	(1,720,000)									(2,140)	(2,140)				
1) Earth work, culverts	50		1,260,000														
2) Asphalt pavement	10		310,000														
3) Permanent residential buildings	45		150,000														
Administrative Facilities		(39)	(1,880,000)									(124,860)	(103,860)				
1) Earth work	50		470,000														
2) Asphalt pavement	10		540,000														
3) Booths and offices	50		870,000														
III. RAILWAY		35	7,400,000	0.04654	0.07723	0.10369	0.04654	344,400	571,500	767,300	344,400	169,500	169,500	513,900	741,000	936,800	513,900
1) Earth work	50		1,630,000														
2) Track	20		1,630,000														
3) Flood bridges, culverts	50		300,000														
4) Residential buildings, communication facilities and others	15		890,000														
5) Stations	30		2,950,000														
Total			20,000,000					889,500	1,516,600	2,055,700	889,500	309,100	288,100	1,198,600	1,825,700	2,364,800	1,177,600

Remarks:

1. The mean useful lifetime of this project is figured out to be 39 years
2. $(2) = (\Sigma(1) \times (3)) / \Sigma(3)$, $(5) = (3) \times (4)$ and $(7) = (5) + (6)$

Table 3.23. Annual working expenses

Unit: US$

Items	Unit cost	Quantities	Annual working expenses: Toll bridge	Annual working expenses: Non-toll bridge
I. Bridge			12,600	12,600
(1) Painting of steel members	0.2/m^2	51,000 m^2	10,200	10,200
(2) Lighting	0.017/m^2	8,400 m^2	140	140
(3) Asphalt pavement	0.19/m^2	8,400 m^2	1,600	1,600
(4) Sundries (5% of about (1)+(2)+(3))		L.S.	660	660
II. Highway			127,000	106,000
Access highway			(2,140)	(2,140)
(1) Asphalt pavement	445/km	4.3 km	1,900	1,900
(2) Shoulder	55/km	4.3 km	240	240
Administrative facilities			(124,860)	(103,860)
(1) Asphalt pavement	0.12/m^2	140,000 m^2	16,800	16,800
(2) Lighting	0.015/m^2	140,000 m^2	2,100	2,100
(3) Personal expenses	1,000/person /1	100 persons	100,000	80,000
(4) Sundries (5% of about (1)+(2)+(3))		L.S.	5,960	4,960
III. Railway			169,500	169,500
(1) Maintenance of way and structure	2,075/km	20.1 km	41,700	41,700
(2) Maintenance of equipments	2,155/km	20.1 km	43,400	43,400
(3) Traffic and transportation	3,040/km	20.1 km	61,100	61,100
(4) Miscellaneous operation	250/km	20.1 km	5,000	5,000
(5) Personal expenses	1,000/person	20 persons	20,000	20,000
(6) General expenses	810/km	20.1 km	16,300	16,300
Total annual working expenses			309,100	288,100

/1 In the case of a non-toll bridges, the unit cost for the personal expenses is 800 US$ per person.

3.6.6 Benefit-cost ratio and capitalized net benefit.

The benefit-cost ratio of the project is the ratio of the mean annual benefit to the annual cost, and capitalized net benefit is the difference between the capitalized benefit and capitalized cost. These are computed from the values given in Table 3.20 and 3.21, and are given in Table 3.24.

Table 3.24 Benefit-cost ratio and capitalized net benefit

Kind of capital	Benefit-cost ratio (B_m/C_a)	Capitalized net benefit in Baht. (B_c - C_c)
Toll bridge		
Loan I/1	7.3	3,027,876,000
Loan II/2	3.2	641,297,000
Loan III/3	1.7	94,078,000
Non-toll bridge		
Grant/4	7.9	5,391,185,000

As indicated in Table 3.24., the benefit-cost ratio is greater than one and the benefit is greater than the cost in any case of capital investments. In the case of a toll bridge, the benefit-cost ratio is 1.7 even in the case of Loan III, and it is as high as 7.3 in the case of Loan I. It shows higher value of 7.9 in the case of Grant for a non-toll bridge.

The capitalized net benefit shows the highest value of about 5.4 billion Bahts in the case of a non-toll bridge. In the case of a toll bridge, the capitalized net benefit is the greatest under the Loan I amounting to about 3 billion Bahts, and the amount is approximately 0.1 billion under the Loan III.

/1, /2, /3, /4 Refer to Table 3.20 in Subparagraph 3.6.4.

The following is made clear when these values of benefit-cost ratio and capitalized net benefit are compared with these of the highway bridge. (Refer to Table 4.18)

In the case of Loan I, the benefit-cost ratio is 7.3 in the case of a rail/highway bridge and 12.2 for a highway bridge. The capitalized net benefit does not differ much being approximately 3.0 billion Bahts for the rail/highway bridge and 3.1 billion Bahts for the highway bridge.

In the case of a non-toll bridge, the benefit-cost ratio and the capitalized net benefit of the highway bridge are 13.5 and 5.4 billion Bahts respectively while the ratio and the net benefit of the rail/highway bridge are 7.9 and 5.4 billion Bahts respectively.

3.6.7. Internal rate of return

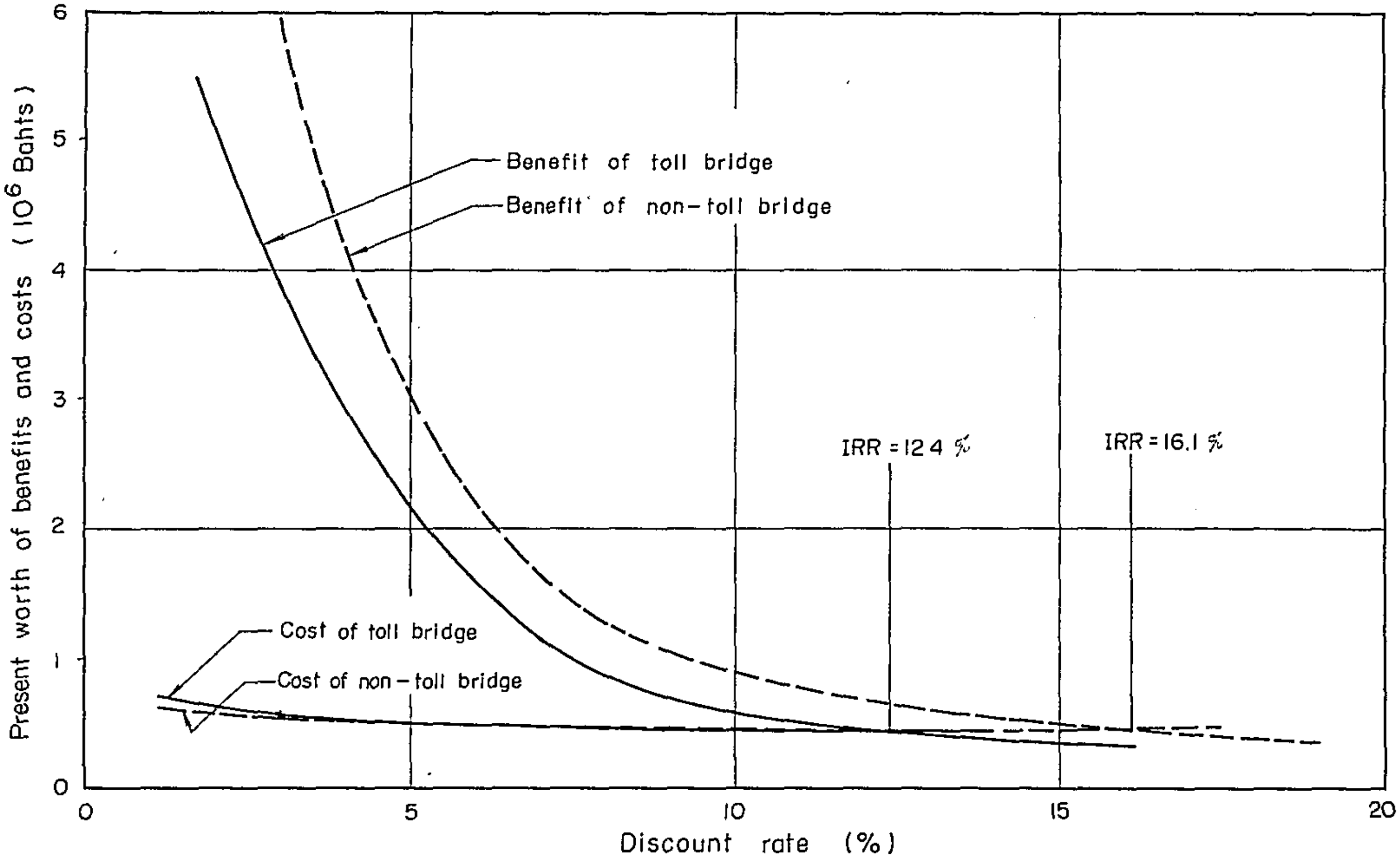
Although benefit-cost ratio and capitalized net benefit were compared in Subparagraph 3.6.6., it also is desirable to compute the internal rate of return and to compare this with the minimum rate which is widely recognized as 12 percent at the present time and is acceptable for this type of project. The internal rate of return is such that gives the total present worth of benefit equal to the total present worth of cost.

The total present worths of benefit and cost were computed from Eq. (4) in Subparagraph 3.6.4 and Eq. (2)in Subparagraph 3.6.5, respectively. As for the discount period for each kind of capital investment, the amortization period was taken into account in the case of a toll bridge and a period of 40 years equivalent to the average useful lifetime of the project in the case of a non-toll bridge.

The benefits and costs thus computed were plotted in Fig. 3.15. The point at which the curve of benefits intersects the curve of costs gives the value of the internal rate of return.

As seen in the figure, the internal rate of return is 12.4 percent in the case of a toll bridge and 16.1 percent in the case of a non-toll bridge. These values exceed the minimum rate of 12 percent and therefore suggests that the project is feasible and worth being developed.

Fig. 3.15. INTERNAL RATE OF RETURN



3.6.8. Indirect benefit

In addition to the direct benefits mentioned previously, the project can produce many kinds of the indirect benefit. The following are the major indirect benefits taken up for the economic evaluation of the project.

(1) Effect on the field of consumption and production, especially on the prices by the saving on the transportation cost due to the construction of the bridge

(2) Effect on the saving of stock in shops and factories derived from less travel time

(3) Effect on the socio-economic development of which the need will gradually arise in the course of time under the better condition accruing from the construction of the bridge

A brief description is given below of the above three.

(1) Effect on the field of consumption and production, especially on the prices by the saving the transportation cost due to the construction of the bridge

The saving on transportation cost consists of the saving in the cost required in crossing the Mekong and a reduction in the transportation cost of ETO (Express Transportation Organization) from Bangkok to Nong Khai. The bridge team was informed that the reduction in ETO charges could be expected because of the intensified competition among the transportation agents.

The following three kinds of the cost required in crossing the Mekong now are considered: (1) the cost by self-transportation, 750 Kips/ton, (2) the cost of freight by general transportation agents, 1,250 Kips/ton, and (3) the cost of freight by ETO, 1,750 Kips/ton.

All these costs will be saved in the case that the bridge is of non-toll. The amount of saving in transportation cost is shown in Table 3.25.

On the other hand, it is expected that the ETO charges imposed on the transportation from Bangkok to Nong Khai will be reduced by about 750 Kips per ton as much as the cost required in crossing the Mekong.

Given in Table 3.25. are the amounts of savings of the cost required in crossing Mekong and those of savings on freight handled by ETO.

In order to know how much the savings of the transportation cost mentioned above affect the cost prices of the imports and exports in Laos, the ratio between the two in each of the major articles is figured out in Table 3.26. According to this table, the following matters can be drawn.

i) For the articles to be transported between Vientiane and Nong Khai or its vicinity, the savings show high percentage. This is because the transporting distance is short, and the cost required in crossing the river occupies a major portion of the transportation expenses. Such articles include water melon, cement and timber for export.

ii) The percentage of the savings is comparatively high for such items that the cost price per ton is low, even if the transporting distance is long. Such items are petroleum, round bar, household electrical appliances, beer, etc.

The influence of savings in the transportation cost thus estimated to be exerted on the field of consumption and production in Vientiane and its vicinity is studied hereinafter.

Effect on the field of consumption

In the following consumer goods imported into Vientiane district from Thailand, the savings in the cost required in crossing the Mekong can be expected as the result of the construction of the bridge; namely, foodstuff such as rice, water melon and hogs to be transported to Vientiane from the opposite bank of the Mekong and imported foodstuff such as beer and juice, household electrical appliances such as refrigerators and fans, bicycles and motorcycles unloaded in Bangkok and transshipped to Vientiane through Thailand.

In case when a non-toll bridge should have been constructed in 1967, the amount of savings made when importing the abovementioned consumer goods would have amounted to 34 million Kips, and it would have reached 42 million Kips if the ETO's rate should have been reduced by 750 Kips per ton mentioned before. The dealers who handle such consumer goods are supposed to receive most of the benefits thus derived, but the consumers can receive some of them in the form of a reduction in price. Such benefits will stimulate a new demand.

The manufacturers in the vicinity of Vientiane in Laos can reduce the cost price of materials because of the savings in the freight charges of imported materials, and the consumers can enjoy the benefits proportionately if the prices of manufactured goods should be reduced in the same way as mentioned before. In this connection, the savings estimated in 1967 were between 1,990,000 and 3,530,000 Kips.

Should the bridge be a toll bridge, the amount of savings will be smaller by the amount of bridge toll than that in the case of a non-toll bridge.

The abovementioned amount of savings is based on the amount of imported articles crossing the river in 1967, and so this amount will naturally increase largely with the increase in the volume of import along with the increase of the national income. Assuming the annual growth rate of the import of consumer goods is 5 percent, the amount of savings on the transport charges of the imported consumer goods in 1990 will be about three times the amount of savings in 1967.

This means that the improvement of transportation of the consumer goods will much contribute to the improvement of the living standards of the people of Laos.

Effect on the field of production

The savings in the cost required for crossing the bridge are expected in the following production goods to be imported from Thailand to Vientiane. They are mainly construction materials such as round bar, steel sheets and plywood, transportation machines such as passenger cars and trucks, and raw materials for tobacco, sandals, and for polyethelene but petroleum and cement to be imported from foreign countries other than Thailand are excluded.

In case when a non-toll bridge should have been constructed in 1967, the amount of savings on the transportation cost for the import of production goods would have amounted to 197 million Kips, and to 198 million Kips if ETO's rate should have been reduced by about 750 Kips per ton.

Related industries, since the savings in the transportation cost can reduce the cost price, can obtain more profit. Petroleum industry among all other industries will get the most benefit. It would be possible to save 130 million Kips which corresponds to approximately 25 percent of the transportation cost of 550 million Kips on the articles of 104,000 tons imported by private enterprises in 1967. Moreover, the Government of Laos imported in 1967 a larger amount of petroleum than the amount imported by the private enterprises. Including the amount imported by the Government, the benefits from the savings in the transportation cost will be enjoyed by the petroleum industry, private enterprises and the Government. Such savings will definitely contribute much to the economic and industrial growth of Laos.

Besides the above, a reduction in the transportation cost of passenger cars and trucks allows the shop-owners and manufacturers in Laos to purchase vehicles for business use at lower prices, which consequently will accelerate their business activities. Lower cost of transportation of construction materials will be useful in promoting the construction works in Laos. Again, the producers who use the imported materials can increase their production since they can reduce the cost price as the result of lowered cost of transportation of the materials. It is believed that the import of production goods will even exceed the import of consumer goods in the future with the progress of economic and industrial developments of Laos. Therefore, the savings on the transportation cost will hereafter exert more influence over the production field.

In case of cement, for example, and assuming that the bridge was completed in 1967, a reduction of 2,010 Kips per ton of transportation cost for transportation from Nong Khai to Vientiane could be expected. This would mean that the construction companies and others who must buy cement would make a profit of 40 million Kips. This amount is equivalent to 10.7 percent of the cost price of cement. Assuming that the import of cement which was recorded 20,000 tons in 1967 would increase at the rate of 10 percent each year, the total amount of import of cement will come to 200,000 tons a year by 1990. The savings which the bridge will contribute will reach 250 million Kips, and this shows that the construction works in Laos in the future will be remarkably profitable.

(2) Effect on the saving stock in shops and factories derived from less travel time

Reduced transportation time made possible by the use of the Mekong bridge will allow the shops and factories to reduce the volume of consumer goods and production goods in stock.

The stock of goods is divided into three categories, namely the basis stock, stock in transit and reserve stock, of which the stock in transit and reserve stock can be reduced due to transportation time less time is required, and interest on investment capital in stock can be thereby saved.

The basic stock is very difficult to be numerically evaluated while the latter two kinds of stock can be easily evaluated and be computed by

$$S = 2 \cdot R \cdot (t - t') \cdot i/365$$

in which
- S : saving in stock in transit and reserve stock per annum
- R : annual total amount required for purchase
- t : transportation time by using the existing route
- t': transportation time by using a new route
- i : annual rate of interest

Provided R, total amount of import of Laos in 1966, = 10 billion Kips, $t - t' = 30$ minutes = 1/16 day and $i = 0.05$, the saving in stock is estimated at 171,232 kips from the above equation. Assuming the annual growth rate of import is 10 percent, the amount of saving in stock in 1990 will be about 9 times that of 1966.

The articles for which such savings can be expected are agricultural products, petroleum, transportation machines, electrical appliances and construction materials.

(3) Effect on the socio-economy development of which the need will gradually arise in the course of time under the better condition accruing from the construction of the bridge

Agriculture

Rice is the main agricultural product of Laos, and a certain amount of corn, tobacco, cotton and coffee were produced.

Vientiane district is depending entirely on Sri Chieng Mai - Ta Bo district on the other side of the Mekong for vegetables, and such situation will remain the same for some time even after the bridge is constructed.

However, the development and improvement of the road network in the vicinity of Vientiane, which is brought about by the construction of Mekong bridge, will promote the development of agriculture on commercial base in this area.

It is said that the production of corn in northeastern Thailand increased from 186,000 tons in 1958 up to 1,200,000 tons in 1966 corresponding to 6.5 times after the Asian Highway A-12 was constructed. As judged from this fact, if an improved road will run direct to Bangkok from Vientiane, this may open a way to Laos for the export of agricultural products to foreign countries.

Livestock industry

At present, most of the cattle (hogs and buffaloes) consumed in Vientiane district are imported from the opposite bank of the Mekong. The bridge, when it should be constructed, will place the economy of Laos in a closer relations with the economy of the northeastern district of Thailand, and this will promote the development of the livestock industry in the vicinity of Vientiane district forward self-support of livestock for Laos.

For instance, the amount of import of pork in the Vientiane district, which in 1967 was 888 tons, will reach 2,600 tons in 1990, assuming that the consumption of pork in Vientiane district will increase at the rate of 5 percent each year, and some part of it has to be produced domestically.

Lumber industry

The saving on the transportation cost will promote the development of the export of lumber supported by the fact that Thailand tends to run short of the sources of lumber and also by the favorable economic growth being enjoyed by Thailand. Through the improvement and development of road network, the cutting area can be expanded, and the value of the resources of lumber will rise. Again, a new industry like the manufacturing of secondary lumber products such as plywood will also be developed following the development of lumber industry.

The abovementioned effects are roughly estimated as follows; the saving on the transportation cost is 750 Kips per ton which corresponds to 3.8 percent of the purchasing price in Thailand or the lumber imported from Laos, totaling 24.3 million Kips per annum. Assuming that this trade will increase at the rate of 10 percent each year until 1990, the annual export of lumber in Laos in 1990 will amount to approximately 300,000 tons, and when calculated on the basis of 1967 price of 14,750 kips per ton, the amount of export totals 4,425 million Kips, of which 225 million Kips are the saving on the transportation cost.

Mining

Mining, with the exception of tin, is undeveloped in Laos, and no investigation or prospecting have been carried out so far. However, it is estimated that mineral resources for gold, copper, lead, iron, limestone, gypsum, manganese, tungsten, etc. do exist in Laos. Among these, the development of copper ore deposits, and iron ore deposits in Xieng Khouang district estimated to have several hundred million tons of iron deposits is being considered most promising. The development of these deposits of great potential has been delayed because of undeveloped domestic overland transportation network and because Laos does not possess any favorable port for the development of foreign trade.

When a bridge, particularly a rail/highway bridge, should be constructed, Laos will have her first railway which will be extended from Thailand, and a through railway running between Vientiane and Bangkok will be opened for traffic. The railway can be easily extended to the mines when they should be developed in the future, and such will make simple the transportation of mineral ore to the port of Bangkok, which is the main door for the foreign trade of Laos. In this way, the bridge will definitely contribute to the development of mineral resources of Laos.

Urbanization

After the construction of the bridge, it could be anticipated that the land prices will rise and the utility value of land will be increased in the districts lying along the highway and the railway running between Vientiane and Tha Naleng. Particularly, when a rail/highway bridge should be constructed, it is anticipated that the districts around the extension railway to Vientiane and the Vientiane railway station will be rapidly developed since the districts are almost undeveloped at the present time.

The demand for land in the districts along the highway and the railway for the construction of factories, shops and residences will invite a rise in land prices. With a rise in land prices, the income of a landowner in the form of rent will increase. Accordingly, this income from land rent is one of the indirect benefits which are derived from the construction of the bridge.

The abovementioned income from land rent has been estimated from following conditions.

1. The influence area is estimated at 3,140,000 m^2 within the radius of 1 km of the new railway station.
2. The price of land in 1973, which is the first year after the completion of bridge, is assumed as 1,000 Kips per square meter, because the prices of the land are 1,000 Kips per square meter for the land around Tha Deua and 800 Kips per square meter for forest, respectively, according to the second phase investigation in 1968.
3. The annual growth rates of land price are assumed to be 10 percent from 1973 to 1990 and 5 percent after 1990.
4. The rent of land is assumed to be 5 percent of the land price uniformly.
5. Interest rate is 4 percent per annum.

Calculated on the basis of the conditions mentioned above, the price of land in 1990 will rise to 5,000 Kips, which is equal to the present land price of Vientiane, and the income from the rent of land for a period of 40 years is estimated at 6,570 million Kips, which corresponds to 42 times of the total income for 1973.

Table 3.25 Saving on transportation cost

Item		Transport section	Classification of transportation agent	Quantity	Saving on transportation cost/1: Unit cost (Kip/ton or Kip/no.)	Saving on transportation cost/1: Total (Kip)	Saving on transportation cost including ETO/2: Unit cost (Kip/ton or Kip/no.)	Saving on transportation cost including ETO/2: Total (Kip)
I. Import								
1) Consumer goods								
Cereal	Rice	Nong Khai-Vientiane	Private	30,000 tons	750/3	22,500,000	750/3	22,500,000
Vegetable & fruit	Watermelon	Loei-Vientiane	Private	1,620 tons	1,100/3	1,782,000	1,100/3	1,782,000
Meat	Pork	Tha Bo-Hat Dok Keo	Private	888 tons	500	444,000	500	444,000
Drinks	Beer	Bangkok-Vientiane	ETO/4	2,250 tons	1,750	3,937,500	3,500	7,875,000
	Juice	Bangkok-Vientiane	ETO	300 tons	1,750	525,000	3,500	1,050,000
Electrical instruments	Refrigerator	Bangkok-Vientiane	ETO	5,400 tons	750	4,050,000	1,500	8,100,000
	Fan	Bangkok-Vientiane	ETO	600 nos.	150	90,000	300	180,000
Vehicles	Bicycle	Bangkok-Vientiane	Transport. agent	3,600 nos.	70	252,000	70	252,000
	Motorcycle	Bangkok-Vientiane	Transport. agent	1,000 nos.	70	70,000	70	70,000
Sub-total						33,650,500		42,253,000
2) Production goods								
Fuel	Petroleum	Bangkok-Tha Naleng	ETO	100,000 tons/5	1,250	125,000,000	1,250	125,000,000
Vehicles	Personal car	Bangkok-Tha Naleng	Private	400 nos.	900	360,000	900	360,000
	Truck	Bangkok-Tha Naleng	Private	40 nos.	900/3	36,000	900/3	36,000
Construction materials	Cement	Nong Khai-Vientiane	Transport. agent	20,000 tons	2,010/3	40,200,000	2,010/3	40,200,000
	Steel bar	Bangkok-Vientiane	Transport. agent	2,400 tons	1,250	3,000,000	1,250	3,000,000
	Steel plate	Bangkok-Vientiane	Transport. agent	2,400 tons	1,250	3,000,000	1,250	3,000,000
	Veneer	Bangkok-Vientiane	Transport. agent	130 tons	2,500/3	325,000	2,500/3	325,000
Raw materials	Raw materials for tabacco	Bangkok-Vientiane	ETO	1,000 tons	18,000/3	18,000,000	18,400/3	18,400,000
	Raw materials for sandals	Bangkok-Vientiane	Private	360 tons	1,250/3	450,000	1,250/3	450,000
	Raw materials for polyethylene	Bangkok-Vientiane	ETO	180 tons	37,150/3	6,687,000	38,900/3	7,002,000
Sub-total						197,058,000		197,773,000
Total						230,708,500		240,026,000
II. Export								
Construction materials	Timber	Vientiane-Nong Khai	Private	32,400 tons	750	24,300,000	750	24,300,000
Grand total						255,008,500		264,326,000

/1 Saving on current ferry charge in the case of a non-toll bridge

/2 Saving on current ferry charge and transportation cost in case ETO's transportation charges by ETO between Bangkok and Nong Khai are reduced.

/3 Including allowance for buglary and breakage at the time of transhipment

/4 Express Transportation Organization

/5 Only private import

Table 3.26 Ratio of saving on transportation cost to cost price

Items		Cost price /1 (Kip/ton or Kip/no.)	Saving on transportation cost /2		Saving on transportation cost including ETO /3	
			Unit cost (Kip/ton or Kip/no.)	Ratio to cost price (%)	Unit cost (Kip/ton or Kip/no.)	Ratio to cost price (%)
I. Import						
1) Consumer goods						
Cereal	Rice	94,500	750	0.8	750	0.8
Vegetable & fruit	Watermelon	17,200	1,100	6.4	1,100	6.4
Meat	Pig	274,000	500	1.8	500	1.8
Drinks	Beer	214,000	1,750	0.8	3,500	1.6
	Juice	152,100	1,750	1.2	3,500	2.3
Electrical instruments	Refrigerator	50,400	750	1.5	1,500	3.0
	Fan	15,350	150	1.0	300	2.0
Vehicles	Bicycle	15,650	70	0.6	70	0.6
	Motorcycle	67,250	70	0.5	70	0.5
2) Production goods						
Fuel	Petroleum	41,500	1,250	3.0	1,250	3.0
Vehicles	Personal car	735,000	900	0.1	900	0.1
	Truck	2,760,000	900	0.0	900	0.0
Construction materials	Cement	18,750	2,010	10.7	2,010	10.7
	Steel bar	75,250	1,250	1.7	1,250	1.7
	Steel plate	130,000	1,250	1.0	1,250	1.0
	Veneer	225,000	2,500	1.1	2,500	1.1
Raw materials	Tobacco	900,000	18,000	2.0	18,400	2.0
	Sandals	175,000	1,250	0.7	1,250	0.7
	Polyethylene	155,000	37,150	24.0	38,900	25.1
II. Export						
Construction materials	Timber	20,000	750	3.8	750	3.8

/1 Including customs duty charge

/2 Saving on current ferry charge in the case of a non-toll bridge

/3 Saving on current ferry charge and transportation cost in case ETO's transportation charges between Bangkok and Nong Khai are reduced.

3.6.9. Comparison between a bridge and the ferry facilities

In coping with the traffic which is increasing year after year, the advantage a bridge over the ferry facilities is studied herein by comparing the annual costs of both.

Since the annual cost of a rail/highway bridge has been given under Subparagraph 3.6.5., only the annual cost of the ferry facilities is given in details in this paragraph.

Annual cost of ferry facilities

The annual cost of the ferry facilities comprises the annual fixed cost and the annual working expenses.

The annual fixed cost means the amortization of the construction cost of the ferry facilities during the useful life, as given below.

$$C_F = \frac{i\ (1+i)^n}{(1+i)^n-1} \quad \Sigma \left(C \cdot \frac{i\ (1+i)^t}{(1+i)^t-1} \cdot \frac{(1+i)^{n-x} - 1}{i\ (1+i)^{n-x}} \cdot \frac{1}{(1+i)^x} \right)$$

where C_F : equivalent annual fixed cost

C : construction cost

i : annual rate of interest, 3, 7 & 10 percent

x : time from the completion of construction of the bridge (the zero point) to the commencement of different stages of additional construction of the ferry facilities

n : period of analysis, 40 years

t : useful life of ferry facilities, 25 years

The estimate of the construction cost has been based on the construction cost of the existing facilities and the unit cost given in Paragraph 3.5. The ferry facilities can be divided roughly into four parts, the ferry boat, dredger, access ramp and buildings. Since about 200 tons of the capacity of ferry boar is assumed as maximum limit in assumed as maximum limit in such a river as the Mekong in the viewpoint of site erection of boat and the scale of the wharf. 100 tons of boat capacity equal to the existing facility is tentatively adopted for this study. The basic data for the estimation of construction costs are as given in Table 3.29.

According to the data supplied by SOGOV, the effective permissible traffic per ferry at present is 144 vehicles per day while the maximum capacity per ferry for the annual average time for one journey there and back, 40 minutes/1, is 216 vehicles per day. The capacity per ferry of 216 vehicles per day are adopted to avoid overestimate in the economic comparison with the bridge.

The two kinds of future traffic in the cases of a toll bridge, that the toll is set equally to the current ferry charge, and a non-toll bridge are taken for this comparative study. The future traffic of each traffic components such as bus, personal car, taxi, light truck and motorcycle is converted into that of heavy truck for the sake of convenience.

The schedule of the additional construction and the general layout of the ferry facilities are shown in Fig. 3.16. and 3.17., respectively.

Based on the construction plan of additional ferry facilities, the construction cost and the annual cost for a period of 40 years have been computed, as shown in Table 3.30.

These costs have been converted into the present worth at the time of completion of the bridge, and the annual equivalent cost is also given in Table 3.32.

The annual working expenses mean the annual cost of operation,

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/1 The mean travel time in rainy season is estimated at 20 minutes, and that in dry season, 60 minutes.

maintenance and replacement of the ferry facilities including ferry boats, dredgers, buildings, access highway, access ramp and personnel expenses. The equivalent annual working expenses are given as follows.

$$E = \frac{i\ (1+i)^n}{(1+i)^n-1} \cdot \sum_{x=1}^{n} \frac{C_x}{(1+i)^x}$$

The estimate of these costs is made in Table 3.32. based on the data given in Table 3.31.

The annual cost of the ferry facilities has thus been obtained, and the results are summarized below.

Table 3.27. Annual cost of ferry facilities

(1,000 US$)

Item	Case (1)/1			Case (2)/2
Assumed annual interest rate	3 %	7 %	10 %	3 %
Fixed cost	1,280	1,610	1,830	1,780
Working expenses	1,950	1,540	1,320	2,760
Total/3	3,230	3,150	3,150	4,540

Comparison of the annual costs of a bridge and the ferry facilities

The following table shows the comparison of the annual costs of a bridge and the ferry facilities.

/1 The additional construction to cope with the future traffic in the case of a toll bridge that the toll is set equally to the current ferry charge.

/2 The additional construction to cope with the future traffic in the case of a non-toll bridge.

/3 Annual cost per vehicle in the case of a heavy track is around 2.5 US$.

Table 3.28 Comparison of the annual costs of a bridge and the ferry facilities

Assumed annual interest rate	Toll Bridge 3 %	Toll Bridge 7 %	Toll Bridge 10 %	Non-toll Bridge 3 %
Bridge	1,199	1,826	2,365	1,178
Ferry	3,230	3,150	3,150	4,540
Ratio/1	0.27	0.58	0.75	0.26

The above table clearly shows that the annual cost of a bridge in any of the four cases of different interest rates is far less than the annual cost of the ferry facilities. It is evident that a modern bridge should take the place of the additional ferry facilities to solve the problem of the increasing traffic volume for the future.

/1 The ratio of the annual cost of the bridge to that of the ferry facilities.

Table 3.29. Basic data for the estimation of construction cost

Item	Useful life (Year)	Unit construction cost (US$)	Remarks
Access highway (per meter)	40	200	
Access ramp (")	40	150	
Vessel			
100-ton ferry boat	10	90,000	
Pusher	10	35,000	
Dredger	10	40,000	500 P.S., 300 m^3/hr
Building			
Custom house (Laotian side)	50	80,000	25 m x 15 m
" (Thailand side)	50	20,000	10 m x 10 m
Warehouse	35	196,000	20 m x 140 m
Repair shop	24	84,000	15 m x 70 m
House for staff	45	1,600	10 m x 10 m

Table 3.30. Construction cost of the ferry facilities

(a) Case (1)

Year	No. of access ramp	No. of increase of ferry boat	Construction cost (US$)
1972	0 - 3	8	7,230,000
1974	4	2	1,620,000
1977	5	"	1,300,000
1979	6	"	1,460,000
1980	7	"	1,390,000
1982	8	"	1,530,000
1983	9	"	1,300,000
1984	10	"	1,320,000
1985	11	"	1,720,000
1986	12	"	1,430,000
1987	13 - 14	4	3,210,000
1988	15	2	1,300,000
1989	16	"	1,420,000
1990	17	"	1,350,000
1991	18	"	1,300,000
1992	19	"	1,510,000
1994	20	"	1,310,000
1995	21	"	1,750,000
1996	22	"	1,300,000
1997	23	"	1,710,000
1999	24	"	1,300,000

(b) Case (2)

Year	No. of access ramp	No. of increase of ferry boat	Construction cost (US$)
1972	0 - 4	10	8,850,000
1973	5	2	1,300,000
1975	6	"	1,460,000
1976	7	"	1,390,000
1978	8	"	1,530,000
1979	9	"	1,300,000
1980	10	"	1,320,000
1981	11	"	1,720,000
1982	12	"	1,430,000
1983	13 - 14	4	3,210,000
1984	15	2	1,300,000
1985	16 - 17	4	2,770,000
1986	18 - 19	"	2,810,000
1987	20 - 21	"	3,060,000
1988	22 - 23	"	3,010,000
1989	24 - 25	"	2,600,000
1990	26	2	1,300,000
1991	27	"	1,300,000
1992	28	"	1,700,000
1993	29 - 30	4	2,810,000
1994	31	2	1,300,000
1995	32	"	1,300,000
1996	33	"	1,300,000
1997	34	"	1,300,000
1998	35	"	1,300,000
1999	36 - 37	4	1,300,000

Table 3.31. Basic data for the estimation of the annual working expenses

Item		Specification	Unit annual working expenses (US$)
1. Access highway & ramp (per meter)			5
2. Ferry boat & building			
Ferry boat	Repairing	125,000 US$ x 0.174/1	21,600
	Fuel	0.9 US$/hr x 1,420 hr	
Customhouse		4.6 US$/m² x 375 m²	1,730
Warehouse		1.0 " x 2,800 "	2,800
Repair shop		1.0 " x 1,050 "	1,050
Garage		0.25 " x 100 "	25
Personnel expenses		60 persons x 3 US$/day/person x 260 days	47,000
3. Dredger	Repairing	400,000 US$ x 0.138/1	56,000
	Fuel	1.5 US$/hr x 540 hr	

/1 Annual rate of repairing cost.

Table 3.32 Annual cost of ferry facilities

Case	Case (1)			Case (2)/1
Annual rate of interest	3%	7%	10%	3%
Present worth of construction cost (10^3US$)	29,540	21,520	17,880	41,040
Present worth of working expenses (10^3US$)	45,030	20,560	12,960	63,830
Capital recovery factor	0.0433	0.0750	0.1023	0.0433
Equivalent annual fixed cost (10^3US$)	1,280	1,610	1,830	1,780
Equivalent annual working expenses (10^3US$)	1,950	1,540	1,320	2,760
Total annual cost (10^3US$)	3,230	3,150	3,150	4,540

/1 Although it was considered that the whole investment was provided with the grant, only the annual rate of interest of 3 percent was considered for the anlysis of cost.

Fig. 3.16. ADDITIONAL CONSTRUCTION OF FERRY FACILITIES

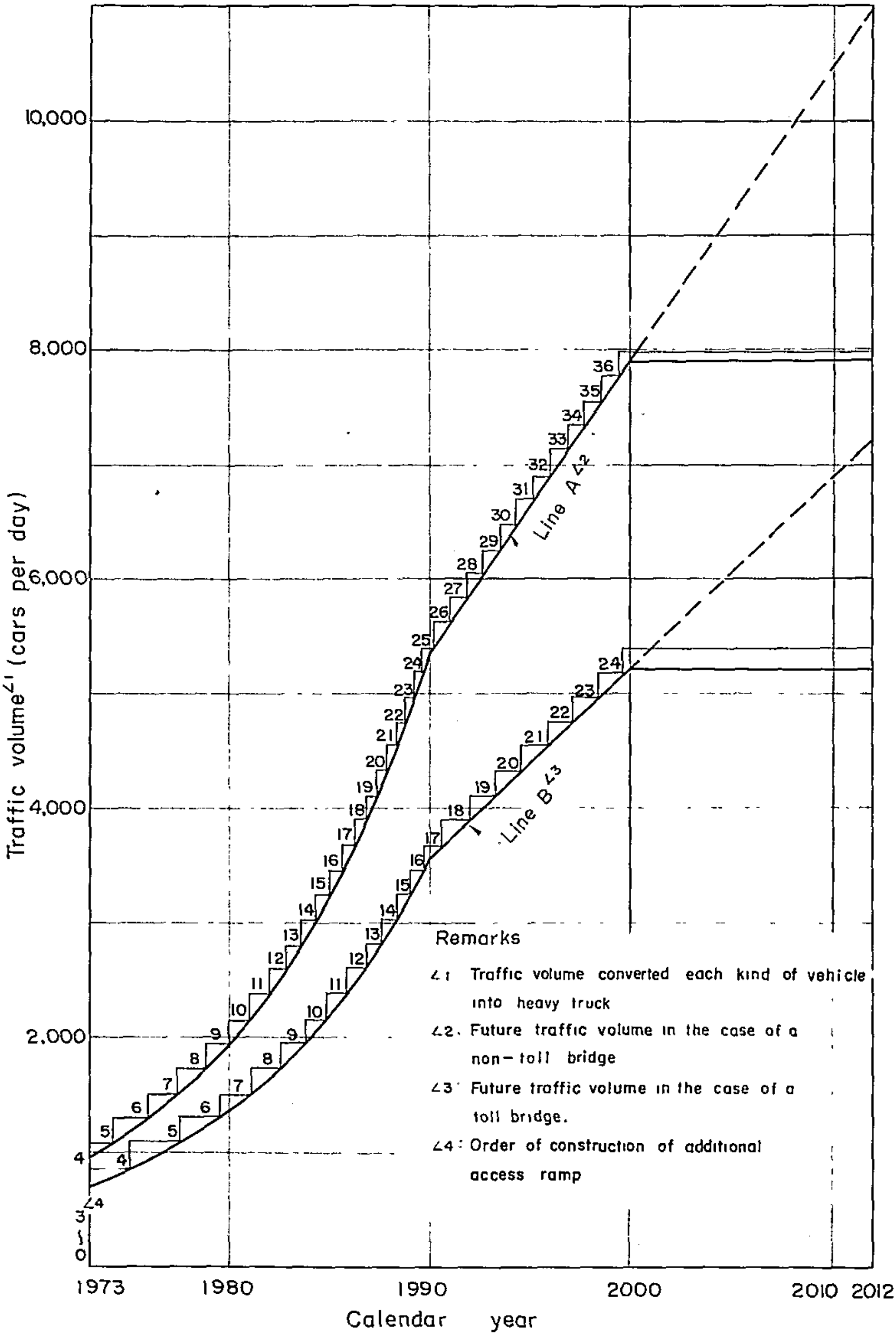
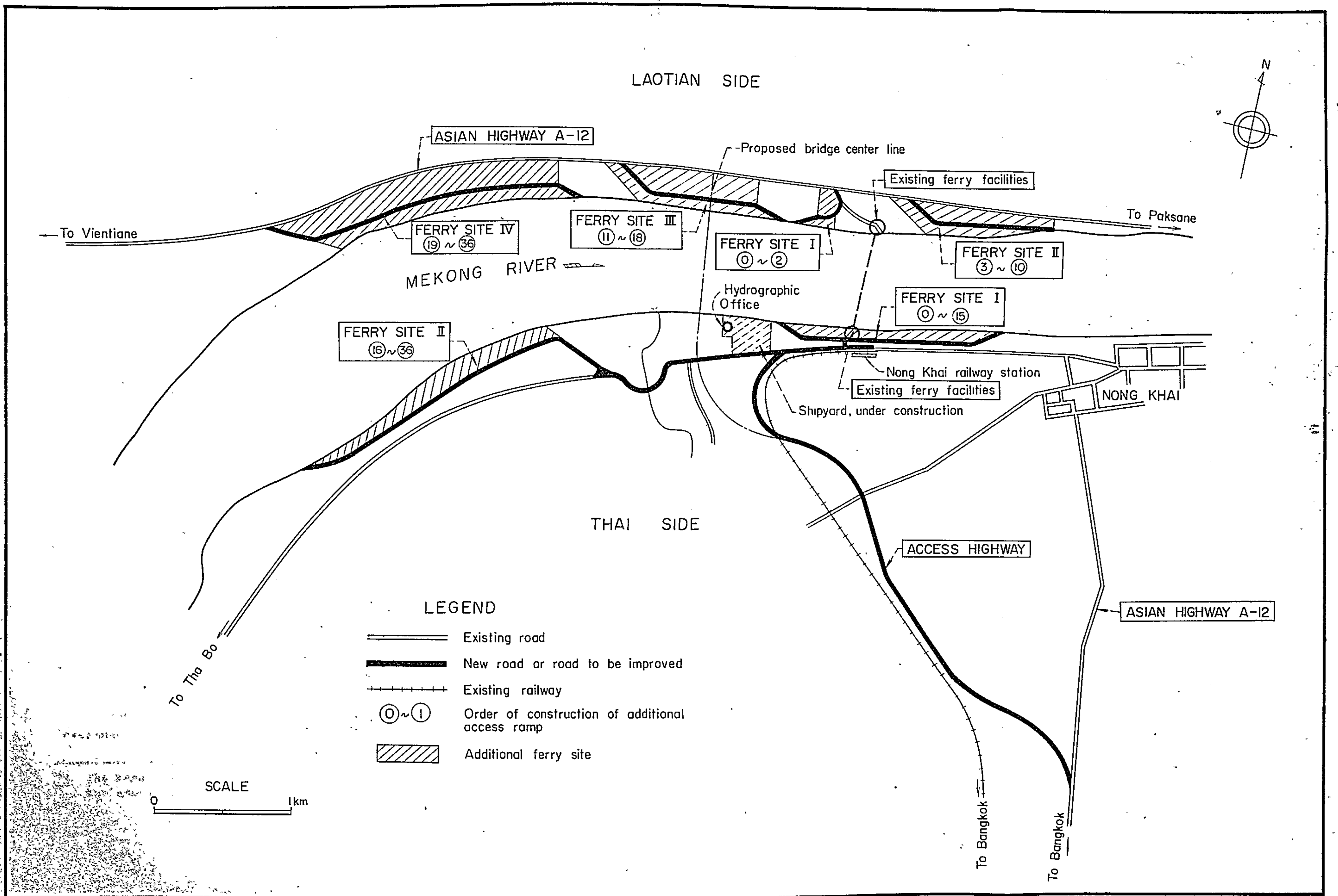


Fig. 3.17. GENERAL LAYOUT OF ADDITIONAL FERRY FACILITIES



3.7. Financial Feasibility

3.7.1. Financial statement

Concerning a toll bridge, the financial feasibility study was made under the following three kinds of loans.

(1) a loan with 3 percent annual rate of interest and 40-year amortization period (Loan I)

(2) a loan with 7 percent annual rate of interest and 25-year amortization period (Loan II)

(3) a loan with 10 percent annual rate of interest and 20-year amortization period (Loan III)

A loan will be amortized by the revenue from the adequate tolls for various traffic components which are given in Subparagraph 3.6.4. The revenue of the project will increase annually according to the future growing traffic. It, however, was conservatively considered to be constant in 28 years after the completion of bridge because the future traffic volume after the 28th year cannot be estimated precisely, and therefore has been regarded as constant.

The amortization was considered as follows instead of the equal annual repayment method. The method herein adopted is that the loan is repaid with surplus revenue exceeding the annual expenditure/1.

Tables 3.33, 3.34, and 3.35 persent the result for the above three cases of Loans I, II and III, respectively.

In the case of Loan I, as shown in Table 3.33, the amount of investment is 410 million Bahts. The total expenditure of annual

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/1 The annual expenditure consists of the annual amortization cost and annual working expense.

interest and annual working expense is about 18.6 million Bahts in the 1st year (1973), while the revenue from the toll in the 1st year is approximately 5.9 million Bahts only. This creates a deficit of approximately 12.8 million Bahts. The outstanding amount of amortization at the end of the fiscal year, therefore, will amount to approximately 422.8 million Bahts.

The amount of deficit will gradually decrease after the 2nd year, but this will continue until the 15th year.

In other words, the amortization of capital and interest will begin substantially in the 16th year. The outstanding amount of capital and interest will amount to approximately 538.5 million Bahts by the end of the 16th year (1987) because of the deficits created during a period of fifteen years after opening the bridge. This amount is approximately 130 million Bahts or 30 percent more than the amount of initial investment of 410 million Bahts. This means a working capital equivalent to about 30% of the construction cost will be required besides the construction cost.

In the case of Loan II (Refer to Table 3.34.), the decifit in the 1st year is 18.3 million Bahts, and the project will keep on creating the decifit for 12 years thereafter. The maximum amount of the outstanding capital and interest will reach 564 million Bahts, of which the working capital amounts to 154 million Bahts.

In the case of Loan III (Refer to Table 3.35.), the decifit in the 1st year is approximately 22 million Bahts, and the project will keep on creating the decifit for 10 years thereafter. The maximum amount is equivalent to 41 percent of the construction cost of 410 million Bahts.

According to the result for the above three cases, the project will continue to be in deficit finance for quite a long period after opening the bridge, and financing of the working capital of about 30 to 40 percent of the construction cost will be required besides the construction cost. This is because the adequate toll system, which gives rather low rate of toll, were adopted for the purpose of obtaining the maximum residual benefit/1.

If higher toll rates were adopted, it is possible to reduce the period of deficit finance with less amount of working capital.

An example is shown as follows in the case that the toll rates are the same as the current ferry charges. The annual interest rates of the loans were taken at 3%, 7% and 10% likewise. The results of the calculation are as given in Table 3.36.

In the case of a loan of 3% annual interest rate, the revenue from the toll will increase to 24.6 million Bahts in the last year, and it will be possible to amortize capital and interest from the 1st year and amortization will be completed in 14 years. Moreover, working capital is not at all required.

In the case of a loan of 7% annual interest rate, the project will be indeficit finance for the first five years, but is possible to fully amortize the capital and interest in seventeen years. The working capital required will be as low as 28.3 million Bahts. This amount corresponds to 7% of the construction cost.

In the case of a loan of 10% annual interest rate, it is not much different from when the adequate toll rates have been applied. The project will be in deficit finance for the first ten years, and it will require 21 years to amortize the capital and interest.

The followings are the conclusions of the financial studies under above :

/1 Refer to Eq. (1) in Subparagraph 3.6.4.

(1) When the adequate tolls are collected, the period of deficit finance is long, and a large amount of working capital will be required as a consequence. This problem can be solved by collecting the toll charges higher than the adequate tolls at the time the bridge is first opened, and then lowering the toll rates in a few stage along with the increase in the traffic volume.

(2) As in the cases of Loan II and Loan III, the adequate tolls are considerably high because the amortization periods of these loans are short, and the pretty large amount of working capital will be required even if the toll rates should be higher than the adequate tolls from the beginning. On the contrary, Loan II and Loan III can be amortized in about half the time of the useful life of the bridge which is 40 years. If the toll is continued to be collected likewise for the remaining period of about 20 years, it would be possible to create enough funds to cover the construction cost of another bridge of the same scale, or increase the benefits of the users of the bridge by making them free of charge.

Table 3.33 Financial statement in the case of collecting the adequate tolls of bridge-Loan I

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	410,000,000	12,300,000	6,336,550	18,636,550	5,867,549	-12,769,001
2	1974	422,769,001	12,683,070	6,336.550	19,019.620	6,451.100	-12,568,520
3	1975	435,337,521	13,060,126	6,336,550	19,396,676	7,074,218	-12,322,457
4	1976	447,659,979	13,429,799	6,336,550	19,766,349	7,770,765	-11,995,585
5	1977	459,655,563	13,789,667	6,336,550	20,126,217	8,531,116	-11,595,101
6	1978	471,250,664	14,137,520	6,336,550	20,474,070	9,376,145	-11,097,924
7	1979	482,348,589	14,470,458	6,336,550	20,807,008	10,312,895	-10,494,113
8	1980	492,842,702	14,785,281	6,336,550	21.121,831	11,330,907	-9,790,924
9	1981	502,633,625	15,079,009	6,336,550	21,415,559	12,454,334	-8,961,225
10	1982	511,594,850	15,347,845	6,336,550	21,684,395	13,709,966	-7,974,430
11	1983	519,569,280	15,587,078	6,336,550	21,923,628	15,086,841	-6,836,787
12	1984	526,406,067	15,792,182	6,336,550	22,128,732	16,607,584	-5,521,148
13	1985	531,927,215	15,957,816	6,336,550	22,294,366	18,290,690	-4,003,677
14	1986	535,930,892	16,077,927	6,336,550	22,414,477	20,145,822	-2,268,655
15	1987	538,199,547	16,145,986	6,336,550	22,482,536	22,197,111	-285,426
16	1988	538,484,973	16,154,549	6,336,550	22,491,099	24,458,493	1,967,394
17	1989	536,517,579	16,095,527	6,336,550	22,432,077	26,964,832	4,532,755
18	1990	531,984,824	15,959,545	6,336,550	22,296,095	29,746,203	7,450,108
19	1991	524,534,716	15,736,041	6,336,550	22,072,591	31,146,811	9,074,220
20	1992	515,460,496	15,463,815	6,336,550	21,800,365	32,553,288	10,752,923
21	1993	504,707,573	15,141,227	6,336,550	21,477,777	33,960,520	12,482,743
22	1994	492,224,830	14,766,745	6,336,550	21,103,295	35,365,882	14,262,587
23	1995	477,962,243	14,338,867	6,336,550	20,675,417	36,767,605	16,092,188
24	1996	461,870,055	13,856,102	6,336,550	20,192,652	38,168,213	17,975,562
25	1997	443,894,493	13,316,835	6,336,550	19,653,385	39,582,052	19,928,667
26	1998	423,965,826	12,718,975	6,336,550	19,055,525	40,983,775	21,928,250
27	1999	402,037,576	12,061,127	6,336,550	18,397,677	42,387,285	23,989,607
28	2000	378,047,968	11,341,439	6,336,550	17,677,989	43,789,008	26,111,019
29	2001	351,936,950	10,558,108	6,336,550	16,894,658	43,789,008	26,894,349
30	2002	325,042,600	9,751,278	6.336,550	16,087,828	43,789,008	27,701,180
31	2003	297,341,420	8,920,243	6,336,550	15,256,793	43,789,008	28,532,215
32	2004	268,809,205	8,064,276	6,336,550	14,400,826	43,789,008	29,388,182
33	2005	239,421,024	7,182,631	6,336,550	13,519,181	43,789,008	30,269,827
34	2006	209,151,196	6,274,536	6,336,550	12,611,086	43,789,008	31,177,922
35	2007	177,973,275	5,339,198	6,336,550	11,675,748	43,789,008	32,113,260
36	2008	145,860,015	4,375,800	6,336,550	10,712,350	43,789,008	33,076,657
37	2009	112,783,358	3,383,501	6,336,550	9,720,051	43,789,008	34,068,957
38	2010	78,714,400	2,361,432	6,336,550	8,697,982	43,789,008	35,091,026
39	2011	43,623,375	1,308,701	6,336,550	7,645,251	43,789,008	36,143,757
40	2012	7,479,618	224,389	6,336,550	6,560,939	43,789,008	37,228,069

Table 3.34 Financial statement in the case of collecting the adequate toll of bridge-Loan II

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	410,000,000	28,700,000	6,336,550	35,036,550	16,715,842	-18,320,708
2	1974	428,320,708	29,982,450	6,336,550	36,319,000	18,273,628	-18,045,372
3	1975	446,366,080	31,245,626	6,336,550	37,582,176	19,906,622	-17,675,554
4	1976	464,041,633	32,482,914	6,336,550	38,819,464	21,744,734	-17,074,731
5	1977	481,116,364	33,678,146	6,336,550	40,014,696	23,712,428	-16,302,267
6	1978	497,418,632	34,819,304	6,336,550	41,155,854	25,898,568	-15,257,287
7	1979	512,675,918	35,887,314	6,336,550	42,223,864	28,294,183	-13,929,681
8	1980	526,605,599	36,862,392	6,336,550	43,198.942	30,878,655	-12,320,287
9	1981	538,925,886	37,724,812	6,336,550	44,061,362	33,701,934	-10,359,428
10	1982	549,285,314	38,449,972	6,336,550	44,786,522	36,835,865	-7,950,657
11	1983	557,235,971	39,006,518	6,336,550	45,343,068	40,244,448	-5,098,620
12	1984	562,334,590	39,363,421	6,336,550	45,699,971	43,976,649	-1,723,323
13	1985	564,057,913	39,484,054	6,336,550	45,820,604	48,069,175	2,248,571
14	1986	561,809,342	39,326,654	6,336,550	45,663,204	52,541,419	6,878,215
15	1987	554,931,127	38,845,179	6,336,550	45,181,729	57,445,583	12,263,854
16	1988	542,667,273	37,986,709	6,336,550	44,323,259	62,793,604	18,470,345
17	1989	524,196,929	36,693,785	6,336,550	43,030,335	68,664,778	25,634,443
18	1990	498,562,486	34,899,374	6,336,550	41,235,924	75,133,308	33,897,384
19	1991	464,665,101	32,526,557	6,336,550	38,863,107	78,554,071	39,690,964
20	1992	424,974,137	29,748,190	6,336,550	36,084,740	82,000,522	45,915,783
21	1993	397,058,354	26,534,085	6,336,550	32,870,635	85,444,188	52,573,553
22	1994	326,484,801	22,853,936	6,336,550	29,190,486	88,881,819	59,691,333
23	1995	266,793,468	18,675,543	6,336,550	25,012,093	92,311,402	67,299,309
24	1996	199,494,159	13,964,591	6,336,550	20,301,141	95,732,165	75,431,023
25	1997	124,063,135	8,684,419	6,336,550	15,020,969	99,194,588	84,173,619
26	1998	39,889,517	2,792,266	6,336,550	9,128,816	102,624,171	93,495,354

Remarks : The amortization period for Loan II originally considered was 25 years. The discrepancy 26 years in this Table is resulted from the adequate tolls calculated using 5 Bahts as a unit.

Table 3.35 <u>Financial statement in the case of collecting the adequate toll of bridge - Loan III</u>

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	410,000,000	41,000,000	6,336,550	47,336,550	25,089,012	-22,247,538
2	1974	432,247,538	43,224,754	6,336,550	49,561,304	27,572,740	-21,988,563
3	1975	454,236,102	45,423,610	6,336,550	51,760,160	30,213,668	-21,546,492
4	1976	475,782,594	47,578,259	6,336,550	53,914,809	33,178,675	-20,736,134
5	1977	496,518,728	49,651,873	6,336,550	55,988,423	36,406,489	-19,581,934
6	1978	516,100,661	51,610,066	6,336,550	57,946,616	39,994,094	-17,952,522
7	1979	534,053,183	53,405,318	6,336,550	59,741,868	43,970,998	-15,770,870
8	1980	549,824,053	54,982,405	6,336,550	61,318,955	48,285,443	-13,033,513
9	1981	562,857,566	56,285,757	6,336,550	62,622,307	53,051,660	-9,570,646
10	1982	572,428,212	57,242,821	6,336,550	63,579,371	58,366,951	-5,212,420
11	1983	577,640,632	57,764,063	6,336,550	64,100,613	64,202,356	101,743
12	1984	577,538,890	57,753,889	6,336,550	64,090,439	70,637,200	6,546,761
13	1985	570,992,129	57,099,213	6,336,550	63,435,763	77,763,449	14,327,686
14	1986	556,664,443	55,666,444	6,336,550	62,002,994	85,605,746	23,602,752
15	1987	533,061,691	53,306,169	6,336,550	59,642,719	94,283,730	34,641,011
16	1988	498,420,680	49,842,068	6,336,550	56,178,618	103,851,334	47,672,716
17	1989	450,747,965	45,074,796	6,336,550	51,411,346	114,439,293	63,027,946
18	1990	387,720,018	38,772,002	6,336,550	45,108,552	126,189,424	81,080.872
19	1991	306,639,146	30,663,915	6,336,550	37,000,465	132,122,310	95,121,846
20	1992	211,517,300	21,151,730	6,336,550	27,488,280	138,079,148	110,590,868
21	1993	100,926,433	10,092,643	6,336,550	16,429,193	144,030,749	127,601,556

Remarks : The amortization period for Loan III originally considered was 20 years. The discrepancy 21 years in this Table is resulted from the adequate tolls calculated using 5 Bahts as a unit.

Table 3.36 Financial statements in the case of collecting the same amounts of bridge tolls as current ferry charges

(interest rate 3 percent)

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	410,000,000	12,300,000	6,336,550	18,636,550	24,548,414	5,911,864
2	1974	404,088,136	12,122,644	6,336,550	18,459,194	26,987,992	8,528,798
3	1975	395,559,337	11,866,780	6,336,550	18,203,330	29,583,540	11,380,210
4	1976	384,179,127	11,525,374	6,336,550	17,861,924	32,498,067	14,636,143
5	1977	369,542,684	11,086,290	6,336,550	17,422,840	35,673,779	18,250,939
6	1978	351,292,045	10,538,761	6,336,550	16,875,311	39,203,294	22,327,983
7	1979	328,964,062	9,868,922	6,336,550	16,205,472	43,118,844	26,913,372
8	1980	302,050,690	9,061,521	6,336,550	15,398,071	47,367,822	31,969,751
9	1981	270,080,958	8,102,428	6,336,550	14,438,978	52,063,963	37,624,985
10	1982	232,455,953	6,973,679	6,336,550	13,310,229	57,303,591	43,993,362
11	1983	188,462,591	5,653,878	6,336,550	11,990,428	63,059,661	51,069,233
12	1984	137,393,357	4,121,801	6,336,550	10,458,351	69,407,750	58,949,400
13	1985	78,443,958	2,353,319	6,336,550	8,689,869	76,443,441	67,753,572
14	1986	10,690,386	320,712	6,336,550	6,657,262	84,188,591	77,531,330

(interest rate 7 percent)

Unit : Baht

1	1973	410,000,000	28,700,000	6,336,550	35,036,550	25,032,127	-10,004,423
2	1974	420,004,423	29,400,310	6,336,550	35,736,860	27,519,775	-8,217,084
3	1975	428,221,507	29,975,505	6,336,550	36,312,055	30,166,467	-6,145,588
4	1976	434,367,096	30,405,697	6,336,550	36,742,247	33,138,423	-3,603,824
5	1977	437,970,919	30,657,974	6,336,550	36,994,514	36,376,710	-617,804
6	1978	438,288,723	30,701,211	6,336,550	37,037,761	39,975,773	2,938,012
7	1979	435,650,711	30,495,550	6,336,550	36,832,100	43,968,477	7,136,377
8	1980	428,514,334	29,996,003	6,336,550	36,332,553	48,301,178	11,968,625
9	1981	416,545,709	29,158,200	6,336,550	35,494,750	53,089,854	17,595,104
10	1982	398,950,605	27,926,542	6,336,550	34,263,092	58,432,726	24,169,634
11	1983	374,780,972	26,234,568	6,336,550	32,571,218	64,302,216	31,730,998
12	1984	343,049,973	24,013,498	6,336,550	30,350,048	70,775,391	40,425,343
13	1985	302,824,631	21,183,724	6,336,550	27,520,274	77,949,716	50,429,442
14	1986	252,195,189	17,653,663	6,336,550	23,990,213	85,847,480	61,857,267
15	1987	190,337,923	13,323,655	6,336,550	19,660,205	94,591,082	74,930,878
16	1988	115,407,045	8,078,493	6,336,550	14,415,043	104,236,434	89,821,390
17	1989	25,585,655	1,790,996	6,336,550	8,127,546	114,914,622	106,787,076

(interest rate 10 percent)

Unit : Baht

1	1973	410,000,000	41,000,000	6,336,550	47,336,550	25,394,911	-21,941,638
2	1974	431,941,638	43,194,164	6,336,550	49,530,714	27,918,613	-21,612,101
3	1975	453,553,740	45,155,374	6,330,550	51,691,924	30,603,662	-21,088,262
4	1976	474,642,001	47,464,200	6,336,550	53,800,750	33,618,690	-20,182,060
5	1977	494,824,061	49,458,406	6,336,550	55,818,956	36,903,909	-18,915,047
6	1978	513,739,109	51,373,911	6,336,550	57,710,461	40,555,132	-17,155,329
7	1979	530,894,438	53,089,444	6,336,550	59,425,994	44,605,701	-14,820,293
8	1980	545,714,730	54,471,473	6,336,550	60,908,023	49,001,195	-11,906,828
9	1981	557,621,558	55,762,156	6,336,550	62,098,706	53,859,272	-8,239,434
10	1982	565,860,992	56,586,099	6,336,550	62,922,649	59,279,577	-3,643,072
11	1983	569,504,064	56,950,406	6,336,550	63,286,956	65,234,132	1,947,176
12	1984	567,556,888	56,755,689	6,336,550	63,092,239	71,801,121	8,708,882
13	1985	558,848,006	55,884,801	6,336,550	62,221,351	79,079,422	16,858,071
14	1986	451,989,935	54,198,993	6,336,550	60,535,543	87,091,646	26,556,103
15	1987	515,433,832	51,543,383	6,336,550	57,879,933	95,961,967	38,087,034
16	1988	477,351,798	47,755,180	6,336,550	54,071,730	105,757,106	51,675,377
17	1989	425,676,421	42,567,642	6,336,550	48,904,192	116,580,051	67,675,859
18	1990	358,000,562	35,800,056	6,336,550	42,136,606	128,608,352	86,471,746
19	1991	271,528,816	27,157,882	6,336,550	33,489,432	134,665,618	101,176,187
20	1992	170,352,629	17,035,263	6,336,550	23,371,813	140,746,646	117,374,833

3.7.2. Various favorable loans

Although the financial condition for three kinds of loans was studies in Subparagraph 3.7.1, various favorable loans will be looked for in this subparagraph from a broader point of view. The favorable loans mean those which can be fully amortized by the toll revenue based on certain toll rates under various combinations of annual interest rate and amortization period.

In making this study, the toll rates of various traffic components have been taken at a certain percentage of the current ferry charges of respective traffic components. From zero to the current ferry charges, ten different toll rates have been taken into consideration.

The formula for the calculation is as given below.

$$U_n = C(1 + i)^{n+1} + E \cdot \sum_{j=o}^{n-1} (1 + i)^j - R \cdot \sum_{k=o}^{n-1} (1 + r)^k (1 + i)^{n-1-k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where,

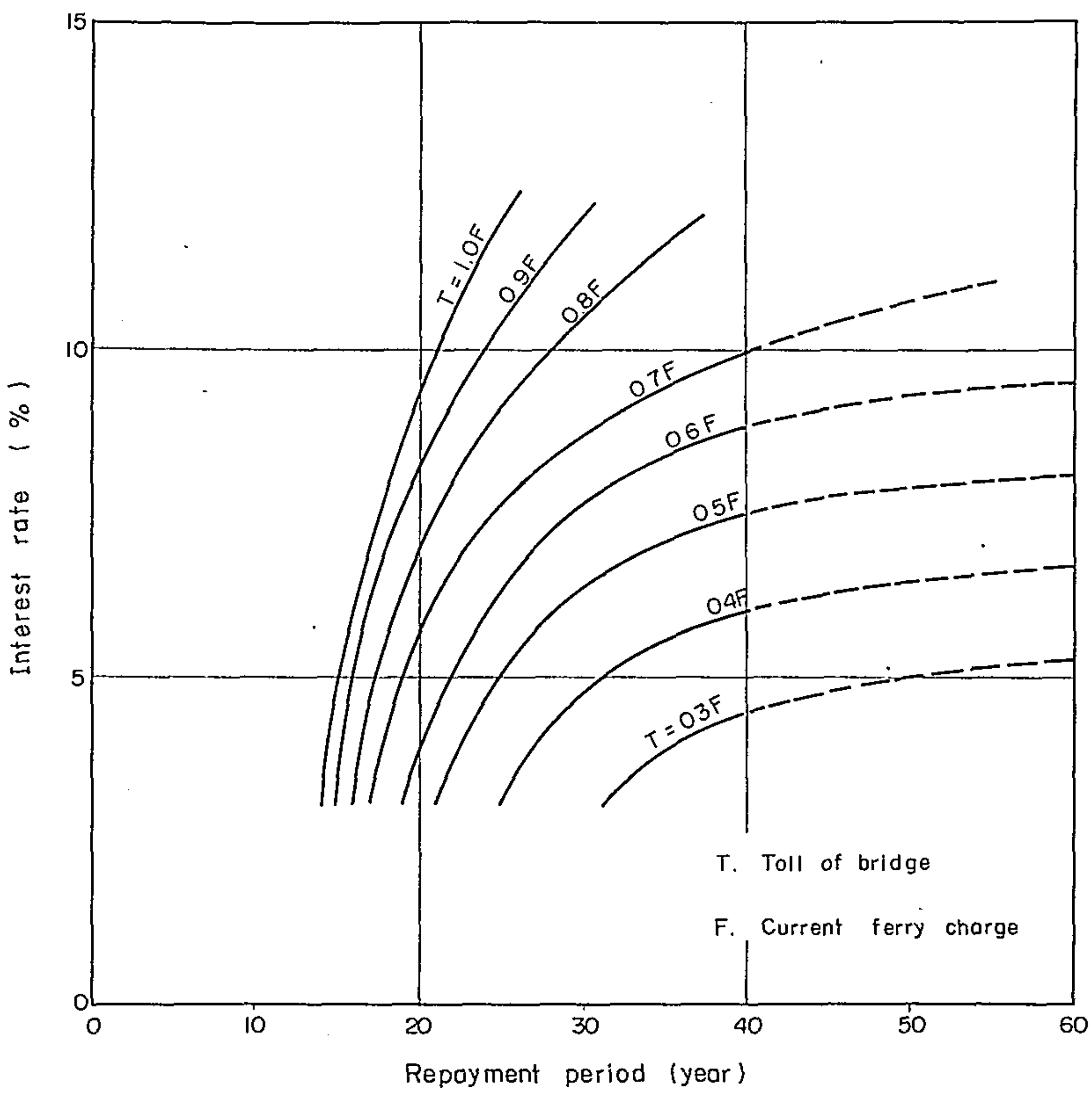
- U_n : Outstanding amount in the year "n".
- C : Amount of capital investment.
- i : Annual rate of interest.
- E : Annual working expense.
- R : Total amount of toll revenue in the initial year.
- r : Growth rate of toll revenue. In this case, the growth rate of toll revenue is equal to that of traffic. /1

The combinations of interest rate "i" and amortization period "n" which satisfies $U_n = 0$ of the above formula were calculated for 10 different toll rates. The results are as shown in Fig. 3.18.

/1 Refer to Table 3.9.

This figure makes clear the following facts. For example, a loan of 5% annual interest rate and amortization period of 25 years can be amortized when the toll rate of each traffic component is fixed at above 50% of the current ferry charge. Again, if the toll rates are equal to the current ferry charges, a loan of 12% annual interest rate can be amortized in 25 years. Also, it is only necessary to secure a loan of 6% annual interest rate when it is desired to amortize the capital and interest in 30 years with the toll revenue from 40% toll of the current ferry charges.

Fig. 3. 18 : RELATION BETWEEN INTEREST RATE AND REPAYMENT PERIOD



CHAPTER IV

HIGHWAY BRIDGE

The idea that envisages to erect a highway bridge over the Mekong is an alternative plan of the rail/highway bridge mentioned in Chapter III. In the case of a highway bridge, the railway running from Bangkok to Nong Khai is not extended up to Vientiane in Laos. The bridge only aims to link two parts of the Asian Highway A-12 which is now separated by the Mekong.

Studies were made of the engineering, economic and financial feasibilities of the project on the assumption that a highway bridge having such a purpose is adopted as Nong Khai/Vientiane Bridge Project. The following are the outline of the studies.

4.1. Engineering Feasibility on the Bridge

The construction of a highway bridge crossing the Mekong has no technical difference from that of a rail/highway bridge. As mentioned in detail in Chapter III, there is no menace to the engineering feasibility of the rail/highway bridge to be built over the Mekong. Also in the case of a highway bridge, no menace can be considered.

The two cases are similar in many respects. The exact location of the center line of the bridge recommended in the case of a rail/highway bridge should be adopted in the case of a highway bridge, too. The specifications to be used for the design, navigation requirements, the location of the summit of bridge, the shape of piers, adoption of pneumatic caissons for the foundation of piers, and the problems of bank erosion and river-bed scouring are all the same to both cases.

Some design conditions, however, are different. Out of them, outstandingly different points are listed up below.

(1) Highway loading is quite different from railway loading as shown in Fig. 3.2. The live loads for highways are much smaller than those for railways.

(2) The longitudinal grade of highway bridges can be taken at four percent as stipulated in the Geometric Design Standards of the Highway Department of Thailand and extracted in Table 3.7., while that of the highway part in the rail/highway bridge has to be taken at 1.2 percent in connection with the railway part.

In consequence, there is no necessity to build access bridges on the riverside terrains as given in PLATE 9.

(3) As it is admitted to take lighter loads for highway design, different type of bridge will be taken up for the highway bridge. Pier spacing also is naturally different, and the form of cross section is, needless to say, different because no space is required for railway track in the case of a highway bridge.

The preliminary design was carefully made on the three points of the type of bridge, pier spacing and the form of cross section. A detailed description of them is made below.

(1) <u>Type of bridge</u>

A continuous box-girder bridge with steel battledeck floors should be taken up for a highway bridge crossing the Mekong according to such reasons as mentioned in Chapter III, Subparagraph 3.1.3.1., Item (3).

The bridge of this type has many advantages over the continuous through truss bridge, though the former requires more construction cost than the latter.

The steel battledeck floor has been selected with the purpose of making the superstructure as light as possible and lowering the burden of the substructure as much as possible. Girders will be made taller on the piers where the largest negative moment occurs and be gradually made short between the two piers, lower flanges being raised with some geometric curves so that the bridge could offer an elegant appearance.

(2) Pier spacing

Generally, the most economical three-span continuous box-girder bridge lies in such pier spacing that the ratio of side span to middle span is 1 : 1.25. A 90-meter span shall be provided in some part of the bridge to warrant the horizontal clearance of 78 meters for navigation. When it is a middle span, the most economical side spans on both sides will become 70 meters accordingly.

The most economical pier spacing in other part of the bridge has been found with the following studies. Conceivable for this purpose are the following three cases.

Table 4.1. Pier spacing

Case No.	Pier spacing (m)	Bridge length (m)	Number of pier (No.)	Number of abutment(No.)	Construction cost (US$)		
					Super-structure	Sub-structure	Total
1	(70+90+70) +4·(40+50+40)	750	14	2	2,300,000	2,900,000	5,200,000
2	(70+90+70) +3·(50+60+50)	710	11	2	2,500,000	2,400,000	4,900,000
3	3·(70+90+70)	690	8	2	3,700,000	2,000,000	5,700,000

As is seen in Table 4.1., the case 2 is the most economical. In this report the case 2 has been adopted.

(3) Form of cross section

The girder of box type is adopted for the bridge because of being very convenient for manufacture, transportation and erection. The roadway is eight meters wide with two lanes in accordance with the provision of the Geometric Design Standards. 1.5-meter sidewalks are provided on both sides of the roadway.

4.2 Engineering Feasibility on the Access Highway

The engineering feasibility on the access highway including the administrative facilities in the case of a rail/highway bridge has been fully stated in Chapter III, paragraph 3.3. The description touches upon the selection of route, preliminary design and various incidental problems. In the case of a highway bridge, these studies are made similarly to those in the case of a rail/highway bridge. There is no essential difference between the two cases in making the studies. Therefore, for the route of the access highway, the second proposal is recommended in the case of a highway bridge, too. The preliminary design is also made in the same manner as stated in Chapter III.

However, these two cases differ from each other on the following four points, which are not essential but incidental.

(1) The access highway to be constructed on the Thai side has to overpass the existing railway in accordance with the Design Standards of the Highway Department of Thailand the extract of which is given in Table 3.7. under Chapter III, while in the case of a rail/highway bridge the access highway is planned to cross the existing railway at grade.

The overpass is so designed as shown on PLATE 21. Since the proposed site is not so sound as the foundation of an overpass as other sites along the highway route, foundation piles should be driven into the gravel layer lying at thedepth of ten to fifteen meters from the ground.

(2) In the case that the Mekong bridge is only a highway bridge,

the construction of another highway is called for to connect the bridge with the present Nong Khai railway station. Unless the existing railway is extended to Vientiane, the traffic between Vientiane and the railway station will become increasingly heavier in the future. This highway is also designed in like manner.

(3) The administrative facilities on the Thai side are located at a place within a short distance of two hundred meters from the riverside so that the above highway could take the shortest way. This location involves no technical difficulty because a highway bridge makes it possible to take the allowable maximum longitudinal grade of four percent for the bridge and as a result the bridge ends at a place close to the Mekong on the riverside terrain. On the contrary, in the case of a rail/highway bridge the longitudinal grade is confined to 1.2 percent at maximum and it is somewhat difficult to locate the administrative facilities near the Mekong. Besides, there is no decisive necessity to do so in the case of a rail/highway bridge.

In the case of a highway bridge, the layout of the individual building in the administrative facilities also is more or less different from that in the case of a rail/highway bridge.

(4) Once the construction begins for this bridge project, the local road at present running in front of Hydrographic Office at Nong Khai will be utilized for construction and the present situation will change remarkably. It is necessary to provide a detour for the inhabitants who live in the neighborhood of this road.

The route for this detour in the case of a highway bridge is a little different from that in the case of a rail/highway bridge.

As has been made clear by the various studies made hitherto, the construction of the access highway and the administrative facilities is technically feasible, and there is nothing hesitant about the realization of such construction whether it is a highway bridge or a rail/highway bridge.

4.3. Construction Plan

The construction plan of the highway bridge is almost similar to that of the rail/highway bridge. It, however, is advisable to erect the superstructure by means of cable crane, not by portable crane running on the upper chords. Namely, side spans will be erected by cable crane and middle spans will be pushed forward like cantilever on the one-side span.

4.4. Construction Cost

Various conditions to be required for the estimation of the construction cost of the project in the case of a highway bridge are all the same as those mentioned in Chapter III, Paragraph 3.5. The construction cost estimation in the Second Phase Report as given in Table 4.2., amounts to 12,000,000 U.S. dollars, while that in the First Phase Report was 8,900,000 U.S. dollars. The main reasons why the difference has arisen are (1) that pneumatic caissons were adopted for the foundation of piers instead of footings, (2) that the route of the access highway on the Thai soil was changed and became longer than that proposed in the First Phase Report, and (3) that the administrative facilities were strengthened as shown in PLATEs 22 and 23. It is added that these alterations gives no influence on the precedence of Nong Khai bridge site over the other two alternative sites, Vientiane and Fa Mong.

Table 4.2. Construction cost

(In the case of a highway bridge)

Item	Construction cost (US$)	Remarks
I. GOVERNMENTS' PREPARATORY WORKS	800,000	
1. Construction facilities	400,000	
2. Land and rights	400,000	
II. MAIN CONSTRUCTION WORKS	7,300,000	
1. Steel box-girder bridge	(4,700,000)	710 meters long
(i) Superstructure	2,300,000	
(ii) Substructure	2,400,000	
2. Highway	(2,400,000)	
(i) Access highway	1,200,000	
(ii) Administrative facilities	1,200,000	
3. Permanent residential buildings	200,000	
III. ENGINEERING SERVICE	1,100,000	
IV. GOVERNMENTS' ADMINISTRATIVE EXPENSE	500,000	6% of (I) and (II)
V. CONTINGENCY AND RESERVE	1,600,000	20% of (I) and (II)
VI. INTEREST DURING CONSTRUCTION	700,000	6% of (I) and (II)
Total	12,000,000	

4.5. Economic Justification

4.5.1. General

Given in this paragraph is the economic justification of a highway bridge carried out in the same manner as in the case of a rail/highway bridge in Paragraph 3.6.

First, the basic future traffic volume was estimated, and the coefficient of future traffic variation /1 was obtained. By using this coefficient, it is possible to calculate the future traffic volume for all toll rates.

Next, the unit benefit was obtained for each traffic component, and the toll rates to be collected actually were decided, and then the annual benefit was obtained by multiplying the unit benefit by the future traffic volume based on the above toll rates. Again, the annual benefit was capitalized to the total present worth as of 1973 to obtain the capitalized net benefit.

The annual cost and capitalized cost were obtained from the construction cost and the annual working expense. From these and the annual benefit and capitalized benefit, the benefit-cost ratio and the capitalized net benefit were obtained.

Also, the internal rate of return for a highway bridge was obtained as had been in the case of a rail/highway bridge.

The comparison of annual costs of the highway bridge and the ferry was made in the same manner as it was made for the rail/highway bridge.

/1 Refer to Table 4.5.

4.5.2. Future traffic

The future traffic on the highway bridge is estimated on the assumption that the toll of the bridge is set equally to the current charge of the existing car ferry based on the explanations on the rail/highway bridge given in Paragraph 3.6.2., and then, based on this future traffic, the future traffic for various tolls is estimated from the relation between the traffic and the bridge toll.

The imaginary initial traffic volume the growth rates and the traffic volumes for 1973 (1 year after the completion of the bridge), 1990 (18 years after the completion of the bridge) and 2000 (28 years after the completion of the bridge) are as given under Table 4.3. in the case that the toll of the highway bridge is set equally to the current charge of the existing car ferry.

The traffic volume for the period from 1973 to 2000 is estimated as shown in Table 4.4. in the same manner as in the case of a rail/highway bridge.

According to Table 4.3., the traffic in 1973 is 1,100 cars per day which is 350 vahicles more than that of the rail/highway bridge. The traffic in 1990 will reach 6,300 vehicles which is 1,300 vehicles more than that of the highway portion of the rail/highway bridge, and the ratio of the traffic of 1973 to that of 1990 is 5.9 which is smaller than that of the highway part of the rail/highway bridge. In 2000, the number of vehicles will increase to 9,500 which is 2,600 more than that of the highway part of the rail/highway bridge. As in the case of the rail/highway bridge, the traffic growth of the personal car and the taxi exceeds that of the heavy truck.

The relationship between toll ranging from free to the current ferry charge and the traffic has already been mentioned under Subparagraph 3.6.2.

The traffic of the highway bridge is considered to include the traffic of highway part and the traffic diverted from the railway. The coefficient of variation α_i of the highway bridge can be obtained from the weighted average of the traffic of both parts. The estimation of α_i is given under Table 4.5., and the relation between C_{ij}/C_{if} and Q_{ij}/Q_{if} is given under Fig. 4.1.

The traffic for 1973, 1990 and 2000 in the case of a non-toll bridge is shown in Table 4.6., and the variation in the traffic volume due to changes in toll charges is given in Fig. 4.2.

Table 4.4. **Estimated future traffic**

(In the case of a toll bridge that the tolls are set equally to the current ferry charges)

Items		Imaginary initial traffic (vehicles/day)	Future traffic (vehicles/day)			Growth index			Annual growth rate	Daily growth volume
		1967	1973	1990	2000	1973	1990	2000	1973 to 1990 (%)	1990 to 2000 (vehicles)
Car ferry vehicles at present	Buses	2	6	32	47	1.00	5.33	7.83	10.4	1.5
	Personal cars	29	86	691	1,047	1.00	8.03	12.17	13.1	35.6
	taxis	1	3	26	40	1.00	8.67	13.33	13.6	1.4
	Heavy trucks	187	436	1,719	2,474	1.00	3.94	5.67	8.4	75.5
	Light trucks	3	7	31	45	1.00	4.43	6.43	9.2	1.4
	Mortorcycles	-	-	-	-	-	-	-	-	-
	Sub-total	222	538	2,499	3,651	1.00	4.64	6.79	9.5	115.2
Vehicles diverted from passenger ferries	Buses	15	35	189	280	1.00	5.40	8.00	10.5	9.1
	Personal cars	69	163	1,304	1,975	1.00	8.00	12.12	13.0	67.1
	Taxis	70	165	1,411	2,144	1.00	8.55	12.99	13.5	73.3
	Heavy trucks	2	4	16	23	1.00	4.00	5.75	8.5	0.7
	Light trucks	-	-	-	-	-	-	-	-	-
	Motorcycles	76	179	958	1,416	1.00	5.35	7.91	10.4	45.8
	Sub-total	232	546	3,908	5,867	1.00	7.20	10.75	12.2	195.9
Total traffic	Buses	17	41	221	327	1.00	5.39	7.98	10.4	10.6
	Personal cars	98	249	1,995	3,022	1.00	8.01	12.14	13.0	102.7
	Taxis	71	168	1,437	2,183	1.00	8.55	12.99	13.4	74.6
	Heavy trucks	189	440	1,735	2,497	1.00	3.94	5.68	8.4	76.2
	Light trucks	3	7	31	45	1.00	4.43	6.43	9.2	1.4
	Motorcycles	76	179	958	1,416	1.00	5.35	7.91	10.4	45.8
	Total	454	1,084	6,377	9,490	1.00	5.88	8.75	11.0	311.2

Table 4.4. Estimated future traffic for each year

(In the case of a toll bridge that the tolls are set equally to the current ferry charges)

Unit : Vehicles/day

Calender year	Ordinal year	Traffic volume: Buses	Personal cars	Taxis	Heavy trucks	Light trucks	Motor-cycles	Total
1973	1	41	249	168	440	7	179	1,084
1974	2	45	281	191	477	8	198	1,200
1975	3	50	318	216	517	8	218	1,327
1976	4	55	359	245	561	9	241	1,470
1977	5	61	406	278	608	10	266	1,629
1978	6	67	459	316	659	11	293	1,805
1979	7	74	519	358	714	12	324	2,001
1980	8	82	587	407	774	13	357	2,220
1981	9	91	663	461	839	14	394	2,462
1982	10	100	749	523	910	15	435	2,732
1983	11	110	847	594	986	17	480	3,034
1984	12	122	957	674	1,069	18	530	3,370
1985	13	135	1,082	764	1,159	20	585	3,745
1986	14	149	1,223	867	1,256	22	646	4,163
1987	15	164	1,382	984	1,362	24	713	4,629
1988	16	181	1,562	1,116	1,476	26	786	5,147
1989	17	200	1,765	1,267	1,600	28	868	5,728
1990	18	221	1,995	1,437	1,735	31	958	6,377
1991	19	232	2,098	1,512	1,811	32	1,004	6,689
1992	20	242	2,200	1,586	1,887	34	1,050	6,999
1993	21	253	2,303	1,661	1,964	35	1,095	7,311
1994	22	263	2,406	1,736	2,040	37	1,141	7,623
1995	23	274	2,509	1,810	2,116	38	1,187	7,934
1996	24	285	2,611	1,885	2,192	39	1,233	8,245
1997	25	295	2,714	1,960	2,268	41	1,279	8,557
1998	26	306	2,817	2,034	2,344	42	1,325	8,868
1999	27	316	2,919	2,109	2,421	44	1,370	9,179
2000	28	327	3,022	2,183	2,497	45	1,416	9,490

Table 4.5 Coefficient of variation α

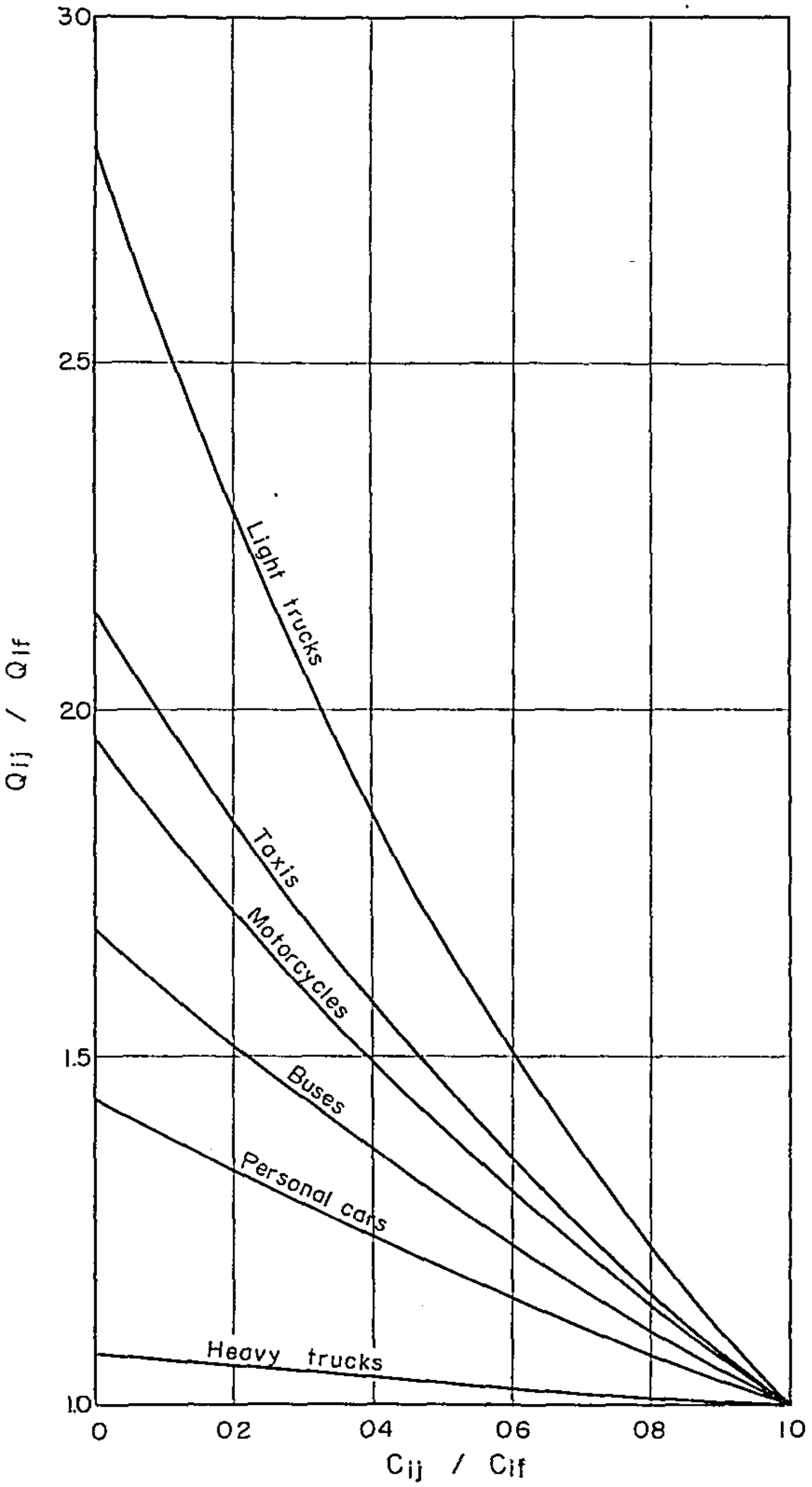
Traffic component	α of rail/highway bridge		Utilization ratio of traffic		α of highway bridge
	Highway	Railway	Highway	Railway	(5) = (1)x(3) +(2)x(4)
	(1)	(2)	(3)	(4)	
Buses	1.82	1.03	0.829	0.171	1.68
Personal cars	1.54	1.03	0.806	0.194	1.44
Taxis	2.38	1.03	0.820	0.180	2.14
Heavy trucks	1.07	1.07	0.502	0.498	1.07
Light trucks	2.81	1.07	1.000	-	2.81
Motorcycles	2.17	1.03	0.816	0.184	1.96

Table 4.6. Estimated future traffic volume

(in the case of a non-toll bridge)

Items		Imaginary initial traffic (vehicles/day)	Future traffic (vehicles/day)			Growth index			Annual growth rate	Daily growth volume
		1967	1973	1990	2000	1973	1990	2000	1973 to 1990 (%)	1990 to 2000 (vehicles)
Car ferry vehicles at present	Buses	3	10	54	79	1.00	5.40	7.90	10.5	2.5
	Personal cars	42	124	995	1,508	1.00	8.03	12.16	13.1	51.3
	Taxis	2	7	55	84	1.00	7.85	12.00	12.9	2.9
	Heavy trucks	200	467	1,839	2,647	1.00	3.94	5.67	8.4	80.8
	Light trucks	8	20	87	126	1.00	4.35	6.30	9.0	3.9
	Motorcycles	-	-	-	-	-	-	-	-	-
	Sub-total	255	628	3,030	4,444	1.00	4.82	7.08	9.7	141.4
Vehicles diverted from passenger ferries	Buses	26	59	317	470	1.00	5.37	7.97	10.4	15.3
	Personal cars	99	235	1,878	2,844	1.00	7.99	12.10	13.0	96.6
	Taxis	150	353	3,020	4,588	1.00	8.56	13.00	13.5	156.8
	Heavy trucks	2	4	17	25	1.00	4.25	6.25	8.9	0.8
	Light trucks	-	-	-	-	-	-	-	-	-
	Motorcycles	149	351	1,878	2,775	1.00	5.35	7.91	10.4	89.7
	Sub-total	426	1,002	7,110	10,702	1.00	7.10	10.68	12.2	859.2
Total traffic	Buses	29	69	371	549	1.00	5.38	7.96	10.4	17.8
	Personal cars	141	359	2,873	4,352	1.00	8.00	12.12	13.0	147.9
	Taxis	152	360	3,075	4,672	1.00	8.54	12.98	13.4	159.7
	Heavy trucks	202	471	1,856	2,672	1.00	3.94	5.67	8.4	81.6
	Light trucks	8	20	87	126	1.00	4.35	6.30	9.0	3.9
	Motorcycles	149	351	1,878	2,775	1.00	5.35	7.91	10.4	89.7
	Total	681	1,640	10,140	15,146	1.00	6.18	9.24	11.3	500.6

Fig. 4.1. RELATION BETWEEN Q_{ij} / Q_{if} AND C_{ij} / C_{if}



Values of α_i

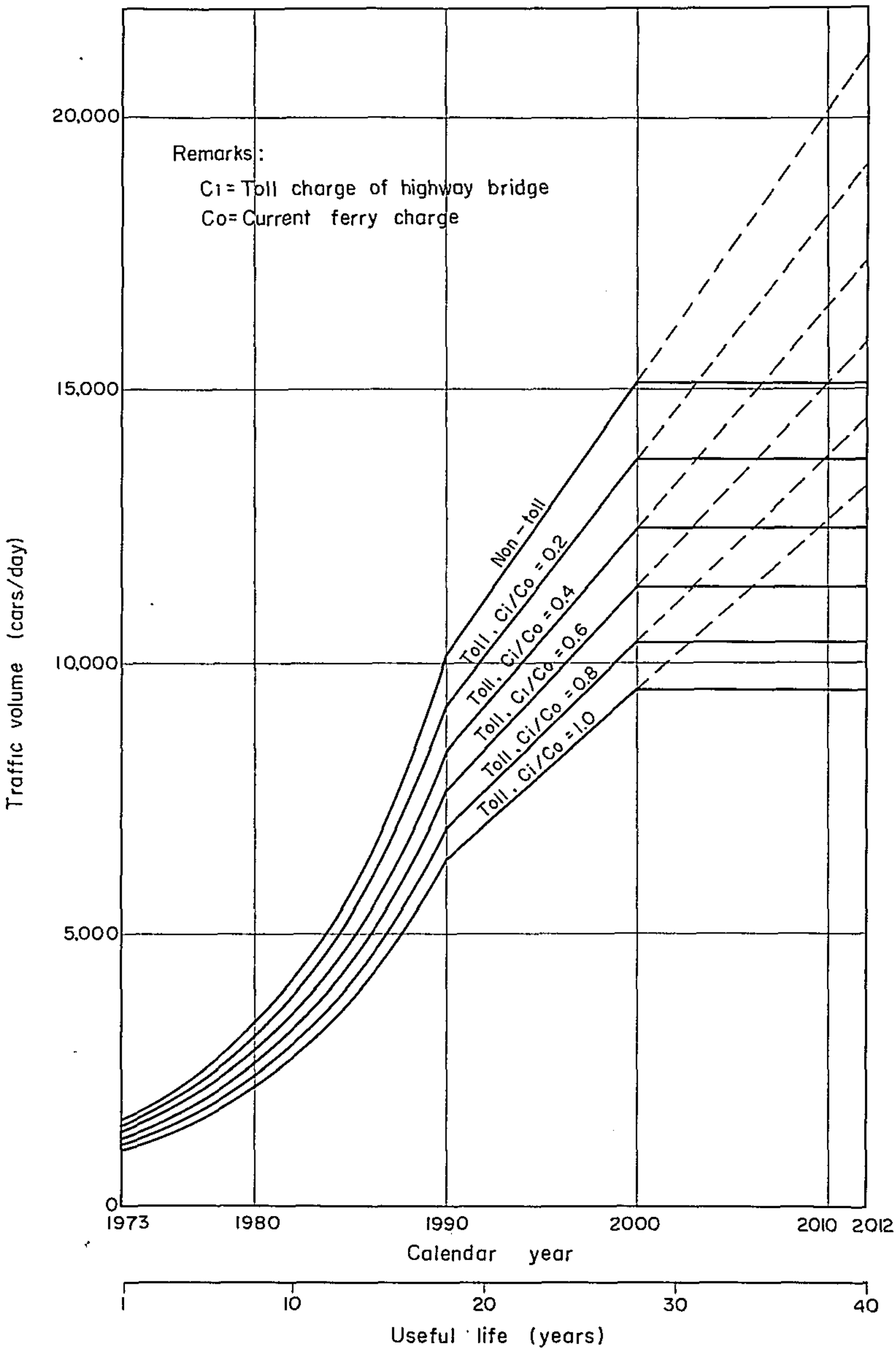
Kind of vehicles	α_i
1 Buses	1.680
2 Personal cars	1.440
3 Taxis	2 140
4 Heavy trucks	1.070
5 Light trucks	2 810
6 Motorcycles	1.960

Remarks

α_i : Q_{in} / Q_{if}

$$Q_{ij} / Q_{if} = \alpha_i^{\left(1-\frac{C_{ij}}{C_{if}}\right)}$$

Fig. 4.2. FUTURE TRAFFIC VOLUME
(in the case of a highway bridge)



4.5.3. Direct benefit

In the economic justification of the project in the case of a highway bridge, the direct benefit is figured out in the same manner as in the case of a rail/highway bridge.

The traffic per day for 1973, 1990 and 2000 is shown in Table 4.6. The benefit per unit of traffic volume and the benefit per day for 1973, 1990 and 2000 are given in Tables 4.7. and 4.8., respectively.

According to Table 4.8., the benefits from the highway bridge are smaller than that of the rail/highway bridge by 4.4 percent in 1973, 3.8 percent in 1990 and 3.7 percent in 2000, respectively, and this results from the fact that the traffic of the highway bridge is smaller than that of the rail/highway bridge. The benefits itemized by the traffic component show the largest value for the heavy truck as seen in the case of a rail/highway bridge.

The amount of benefits for each year from 1973 to 2000, which is obtained by multiplying the benefit per day by 365 days, is as shown in Table 4.9.

Table 4.7. Benefit per unit of traffic volume

Zonal	Route	Small-sized buses: Operating cost (Bahts)	Small-sized buses: Travel time (hrs.)	Large-sized buses: Operating cost (Bahts)	Large-sized buses: Travel time (hrs.)	Personnel cars: Operating cost (Bahts)	Personnel cars: Travel time (hrs.)	Taxis: Operating cost (Bahts)	Taxis: Travel time (hrs.)	Heavy trucks: Operating cost (Bahts)	Heavy trucks: Travel time (hrs.)	Light trucks: Operating cost (Bahts)	Light trucks: Travel time (hrs.)	Motorcycles: Operating cost (Bahts)	Motorcycles: Travel time (hrs.)
Vientiane - Tha Bo, Sri Chieng Mai	Existing route	119.0	1.62					94.0	1.51						
	New route	79.0	1.12					54.0	1.01						
	Difference	40.0	0.50					40.0	0.50						
	Nos. of car	1						1							
Vientiane - Nong Khai Station	Existing route			246.0	0.78	53.4	0.75	53.4	0.75	148.4	0.78				
	New route			51.5	0.29	13.7	0.26	13.7	0.26	39.4	0.28				
	Difference			194.5	0.49	39.7	0.49	39.7	0.49	109.0	0.50				
	Nos. of car			3		19		13		94					
Vientiane - Nong Khai	Existing route			251.5	0.82	55.2	0.78	55.2	0.78	153.6	0.82				
	New route			56.5	0.32	15.2	0.28	15.2	0.28	43.6	0.32				
	Difference			195.0	0.50	40.0	0.50	40.0	0.50	110.0	0.50				
	Nos. of car			5		28		27		24					
Vientiane - Udon	Existing route			385.7	1.56	91.3	1.46			257.1	1.56	124.4	1.56		
	New route			190.7	1.06	51.3	0.96			147.1	1.06	67.4	1.06		
	Difference			195.0	0.50	40.0	0.50			110.0	0.50	57.0	0.50		
	Nos. of car			1		19				71		2			
Tha Deua - Nong Khai Station	Existing route			207.6	0.56	43.3	0.55	43.3	0.55						
	New route			13.4	0.08	3.6	0.07	3.6	0.07						
	Difference			194.2	0.48	39.7	0.48	39.7	0.48						
	Nos. of car			1		5		3							
The Deua - Nong Khai	Existing route			213.1	0.58	44.8	0.58	44.8	0.58						
	New route			18.9	0.11	5.1	0.10	5.1	0.10						
	Difference			194.2	0.47	39.7	0.48	39.7	0.48						
	Nos. of car			6		27		27							
The Deua - Udon	Existing route											109.4.	1.33		
	New route											54.1	0.85		
	Difference											55.3	0.48		
	Nos. of car											1			
Total operating cost		40.0		3,112.9		3,904.7		2,817.1		20,696.0		169.3			
Operation benefit per unit of traffic volume		40.0		194.57		39.84		39.68		109.50		56.43		5	
Total difference of travel time		0.5		7.83		48.17		35.37		94.5		1.48			
Mean difference of travel time		0.5		0.49		0.49		0.49		0.50		0.49		0.5	
Hourly benefit		6.5		6.5		1.85		1.85		8.3		0.77		1.85	
Time benefit per unit of traffic volume		3.25		3.19		0.91		0.91		4.15		0.38		0.93	
Total benefit per unit of traffic volume		43.25		197.76		40.75		40.59		113.65		56.81		5.93	
- do. - , adopted			121			41		41		114		57		6	

Remarks: (1) The value of the operating cost in each zonal pair is obtained by the basic data given in Table 3.15.

(2) The number of car shown in this table denotes the present traffic made clear by the origin-destination survey.

(3) The mean value of the unit benefits of the small-sized buses and the large-sized buses was taken as the benefit per bus.

(4) The operation benefit of motorcycle is represented by the current ferry charge per motorcycle, and the mean difference of travel time 0.5 hour is figured out as the mean value of these of buses, personal cars, taxis and trucks.

Table 4.8. Benefit per day

(In the case of a toll bridge that the tolls are set equally to the current ferry charge)

	Benefit per unit of traffic volume /1	1973		1990		2000	
		Traffic (vehicles/day)	Benefit (Bahts/day)	Traffic (vehicles/day)	Benefit (Bahts/day)	Traffic (vehicles/day)	Benefit (Bahts/day)
Buses	121	41	4,961	221	26,741	327	30,567
Personal cars	41	249	10,209	1,995	81,795	3,022	123,902
Taxis	41	168	6,888	1,437	58,917	2,183	89,503
Heavy trucks	114	440	50,160	1,735	197,790	2,497	284,658
Light trucks	57	7	399	31	1,767	45	2,565
Motorcycles	6	179	1,074	958	5,748	1,416	8,496
Total		1,084	73,691	6,377	372,758	9,490	548,691

/1 Obtained by Table 4.7.

Table 4.9. **Annual benefit**

(In the case of a toll bridge that the tolls are set equally to the current ferry charge)

(Unit: Bahts)

Calender year	Ordinal year	Buses	Personal cars	Taxis	Heavy trucks	Small trucks	Motor-cycles	Total
1973	1	1,810,765	3,726,285	2,514,120	18,308,400	145,635	392,010	26,897,215
1974	2	1,999,392	4,211,506	2,857,451	19,847,244	158,958	432,664	29,502,215
1975	3	2,207,668	4,759,911	3,236,312	21,515,429	173,499	477,534	32,370,353
1976	4	2,437,639	5,379,727	3,671,830	23,323,828	189,370	527,058	35,529,452
1977	5	2,691,567	6,080,252	4,165,957	25,284,225	206,694	581,717	39,010,412
1978	6	2,971,947	6,871,998	4,726,580	27,409,395	225,602	642,045	42,847,567
1979	7	3,281,533	7,766,840	5,362,647	29,713,189	246,240	708,629	47,079,078
1980	8	3,623,369	8,778,206	6,084,311	32,210,619	268,766	782,119	51,747,390
1981	9	4,000,814	9,921,267	6,903,092	34,917,962	293,353	863,230	56,899,718
1982	10	4,417,578	11,213,173	7,832,057	37,852,860	320,188	952,753	62,588,609
1983	11	4,877,755	12,673,306	8,886,036	41,034,440	349,479	1,051,560	68,872,576
1984	12	5,385,869	14,323,571	10,081,851	44,483,436	381,449	1,160,613	75,816,789
1985	13	5,946,913	16,188,727	11,438,589	48,222,324	416,344	1,280,977	83,493,874
1986	14	6,566,400	18,296,755	12,977,907	52,275,470	454,430	1,413,823	91,984,785
1987	15	7,250,420	20,679,282	14,724,375	56,669,288	496,001	1,560,445	101,379,811
1988	16	8,005,693	23,372,052	16,705,869	61,432,413	541,375	1,722,274	111,779,676
1989	17	8,839,643	26,415,464	18,954,018	66,595,883	590,900	1,900,885	123,296,793
1990	18	9,760,465	29,855,175	21,504,705	72,193,350	644,955	2,098,020	136,056,670
1991	19	10,228,094	31,392,169	22,621,798	75,363,053	674,327	2,198,374	142,477,815
1992	20	10,695,724	32,929,162	23,738,891	78,532,756	703,699	2,298,727	148,898,959
1993	21	11,163,353	34,466,156	24,855,985	81,702,459	733,070	2,399,081	155,320,104
1994	22	11,630,983	36,003,149	25,973,078	84,872,162	762,442	2,499,434	161,741,248
1995	23	12,098,612	37,540,143	27,090,171	88,041,865	791,814	2,599,788	168,162,393
1996	24	12,566,241	39,077,136	28,207,264	91,211,568	821,186	2,700,141	174,583,536
1997	25	13,033,871	40,614,130	29,324,358	94,381,271	850,557	2,800,495	181,004,682
1998	26	13,501,500	42,151,123	30,441,451	97,550,974	879,929	2,900,848	187,425,825
1999	27	13,969,130	43,688,117	31,558,544	100,720,676	909,301	3,001,202	193,846,970
2000	28	14,436.759	45,225,110	32,675,637	103,890,379	938,673	3,101,555	200,268,113

Remarks: (Annual benefit) = (Benefit per unit of traffic volume) x (Traffic volume per day shown in Table 4.4) x365 days

4.5.4. Annual benefit

For the toll highway bridge, the adequate toll was first obtained. The principle and the method of calculation are exactly the same as those applied to the rail/highway bridge mentioned under Subparagraph 3.6.4, and the adequate tolls were obtained for each of the three loans considered in the case of a rail/highway bridge. The values are as shown in Table 4.10.

The adequate tolls calculated for the highway bridge generally show lower figures than those for the rail/highway bridge. In the case of Loan I, the toll for heavy trucks alone is 10 Bahts while the adequate tolls for other traffic components are 5 Bahts. In the case of a rail/highway bridge, the adequate toll for heavy trucks is 30 Bahts, which is three times as much as in the case of a highway bridge.

In the case of Loan III, the adequate tolls remains the same tolls under Loan I for all traffic components except the heavy trucks and buses, for which the adequate tolls will be raised to 85 Bahts and 10 Bahts, respectively. In the case of a rail/highway bridge, the toll rates were almost the same as the current ferry charges, but the toll rates in this case is much lower.

The toll rates "C_{ij}" in the case of a highway bridge, coefficient of future traffic variation "α_i", basic future traffic $Q_{(ij)k}$ and unit benefit "B_i" given in the subparagraphs of Paragraph 4.6 were applied to Equations (3) and (4) in Subparagraph 3.6.4 to figure out the mean annual benefit and capitalized benefit. The results are as shown in Table 4.11. The analysis period of the benefits has been the same as that in the case of a rail/highway bridge.

Table 4.10. Adequate tolls

Unit : Baht

Traffic Component	Current ferry charges	Loan I/1	Loan II/2	Loan III/3
Buses	57	5	5	10
Personal cars	40	5	5	5
Taxis	40	5	5	5
Heavy trucks	110	10	50	85
Light trucks	57	5	5	5
Motorcycles	5	5	5	5

Note:

Unit : 10^3 Bahts

Items	Loan I	Loan II	Loan III
Required income/4 in present worth	343,077	296,843	284,185
Total present worth of toll revenue	375,541	307,341	285,236
Total present worth of residual benefit	3,109,506	823,280	374,047

Reamrks: In the case of finding adequate tolls, the tolls of bridge for various kind of vehicles were given tentatively by 5 Bahts interval-tolls from zero to current ferry charge for respective vehicles.

/1 .... In the case of a loan with the annual interest rate of 3% and the amortization period of 40 years.

/2 .... In the case of a loan with the annual interest rate of 7% and the amortization period of 25 years.

/3 .... In the case of a loan with the annual interest rates of 10% and the amortization period of 20 years.

/4 .... The amount of toll revenue, required to amortize the total investment added the total present worth of annual working expenses to the total construction cost.

Table 4.11. Mean annual benefit and capitalized benefit

Unit: Baht

Kind of capital	Mean and benefit (B_m)	Capitalized benefit (B_c)
Toll bridge		
Loan I /1	175,185,000	3,485,047,000
Loan II /2	120,994,000	1,130,621,000
Loan III /3	94,957,000	659,283,000
Non-toll bridge		
Grant /4	184,386,000	5,743,300,000

/1, /2, /3, /4
Refer to Table 3.20 in Subparagraph 3.6.4.

4.5.5. Annual cost

The annual cost of the highway bridge was calculated with the same method mentioned in Subparagraph 3.6.5. The annual cost was calculated from the construction cost of project structures and the annual working expense, and is shown in Table 4.16.

Furthermore, for the calculation of the capitalized net benefit, the capitalized cost was calculated by using Eq. (2) given in Subparagraph 3.6.5. The result of calculation is as given in Table 4.15 together with the annual cost calculated in the manner described above.

Table 4.12. Annual cost and capitalized cost

Unit: Bahts

Kind of capital	Annual cost C_a	Capitalized cost C_c
Toll bridge		
Loan I /1	11,334,000	340,249,000
Loan II /2	22,294,000	300,360,000
Loan III /3	29,098,000	285,875,000
Non-toll bridge		
Grant /4	13,647,000	324,376,000

/1, /2, /3, /4
Refer to Table 3.20 in Subparagraph 3.6.4.

Table 4.13. Annual Cost

Unit: US$

Item	Useful life-time (1)	Mean useful life-time (2)	Total construction cost (3)	Capital recovery factor (4) Toll Loan I	Toll Loan II	Toll Loan III	Non-toll Grant	Annual fixed cost (5) Toll Loan I	Toll Loan II	Toll Loan III	Non-toll Grant	Annual working expenses (6) Toll	Non-toll	Annual cost (7) Toll Loan I	Toll Loan II	Toll Loan III	Non-toll Grant
I. BRIDGE		45	7,620,000	0.04079	0.07350	0.10139	0.04079	310,800	560,100	772,600	310,800	8,500	8,500	319,300	568,600	781,100	319,300
1) Box girder bridge	15		7,580,000														
2) Asphalt pavement	10		40,000														
II HIGHWAY		40	4,380,000	0.04326	0.07501	0.10226	0.04326	189,500	328,500	447,900	189,500	190,400	156,900	379,900	518,900	638,300	346,400
Access Highway		(42)	(2,410,000)									(2,550)	(2,550)				
1) Earth work	50		1,080,000														
2) Asphalt pavement	10		430,000														
3) Overpass bridge, box culverts	50		550,000														
4) Permanent residential buildings	45		350,000														
Administrative facilities		(38)	(1,970,000)									(187,850)	(154,350)				
1) Earth work	50		500,000														
2) Asphalt pavement	10		570,000														
3) Booths and offices	50		900,000														
Total			12,000,000					500,300	888,600	1,220,500	500,300	198,900	165,400	699,200	1,087,500	1,419,400	665,700

Remarks: 1. The mean useful lifetime of this project is figured out to be 43 years.

2. (2) = (Σ(1) x (3)) / Σ(3), (5) = (3) x (4) and (7) = (5) + (6)

Table 4.14 Annual working expenses

Unit : US$

Items	Unit cost	Quantities	Annual working expenses: Toll bridge	Annual working expenses: Non-toll bridge
I. Bridge			8,500	8,500
(1) Painting of steel members	0.2 m^2	34,700 m^2	6,940	6,940
(2) Lighting	0.017/m^2	5,680 m^2	100	100
(3) Asphalt pavement	0.19/m^2	5,680 m^2	1,060	1,060
(4) Sundries (5% of above (1) + (2) + (3))		L.S.	400	400
II. Highway			190,400	156,900
Access highway			(2,550)	(2,550)
(1) Asphalt pavement	445/km	5.1 km	2,270	2,270
(2) Shoulder	55/km	5.1 km	280	280
Administrative facilities			(187,850)	(154,350)
(1) Asphalt pavement	0.12/m^2	140,000 m^2	16,800	16,800
(2) Lighting	0.015/m^2	140,000 m^2	2,100	2,100
(3) Personal expenses	1,000/person /1	160 persons	160,000	128,000
(4) Sundries (5% of above (1) + (2) + (3))		L.S.	8,950	7,450
Total annual working expenses			198,900	165,400

/1 In the case of a non-toll bridges, the unit cost for the personal expenses is 800 US$ per person.

4.5.6. Benefit-cost ratio and capitalized net benefit

The benefit-cost ratio and capitalized net benefit were computed from the values of benefits and costs in Tables 4.14 and 4.15, and are summarized in the following Table 4.18.

Table 4.15. Benefit-cost ratio and capitalized net benefit

Kind of capital	Benefit-cost ratio (B_m/C_a)	Capitalized net benefit in Baht (B_c-C_c)
Toll bridge		
Loan I /1	12.2	3,144,798,000
Loan II /2	5.4	830,262,000
Loan III /3	3.3	373,407,000
Non-toll bridge		
Grant /4	13.5	5,418,924,000

/1, /2, /3, /4

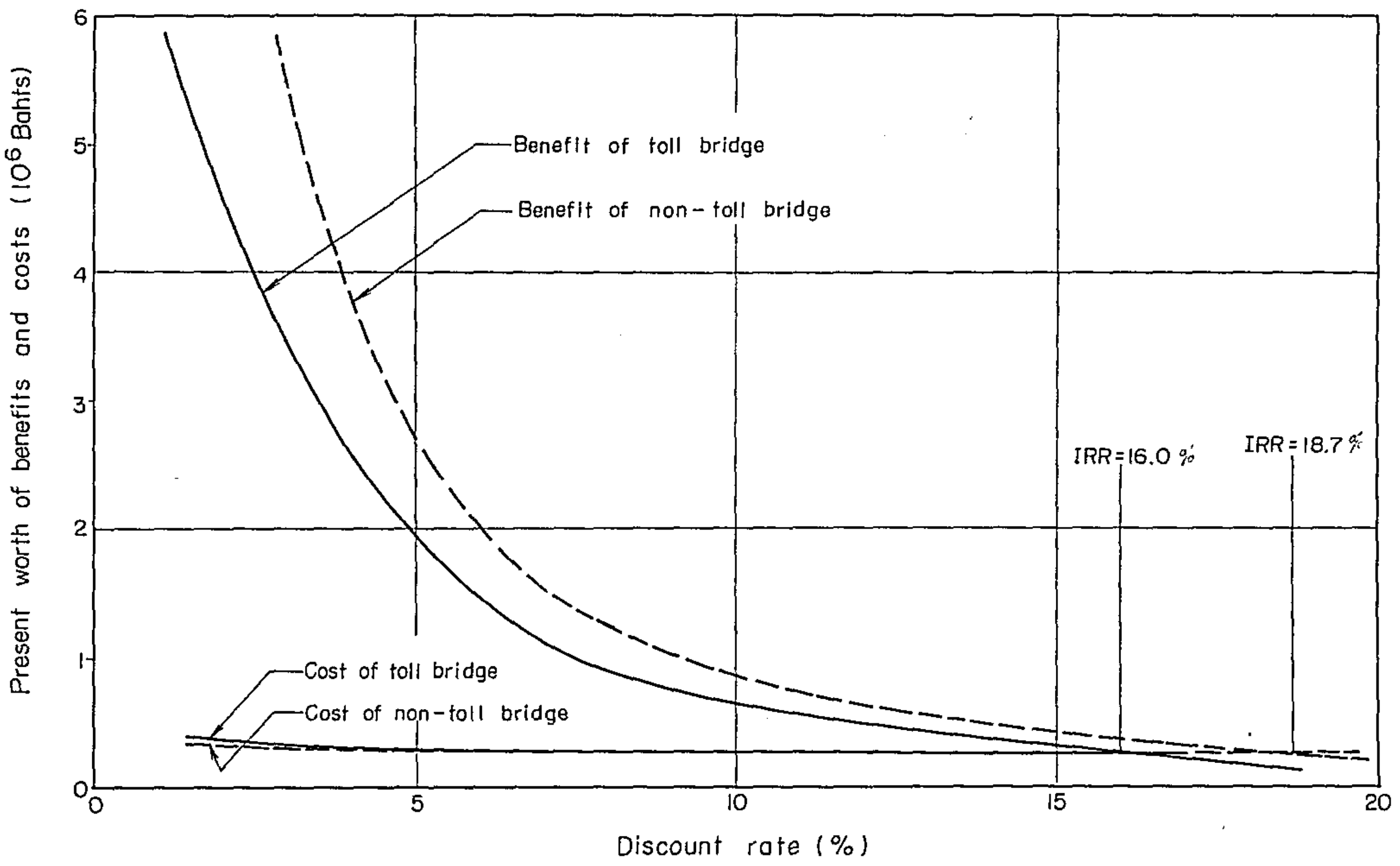
Refer to Table 3.20 in Subparagraph 3.6.4.

4.5.7. Internal rate of return

The internal rate of return for the highway bridge was obtained by applying the same method and conditions used in the case of a rail/highway bridge. As shown in Fig. 4.2., the internal rate of return is 16.0 percent in the case of a toll bridge, and it is 18.7 percent in the case of a non-toll bridge which is slightly higher.

The highway bridge is slightly more advantageous when compared with the rail/highway bridge which shows the internal rate of return of 12.4 percent and 16.1 percent, respectively. Apart from this, this project is quite feasible because the internal rate of return in any of the four cases is higher than 12 percent which is considered as reasonable for a project of this type.

Fig. 4.3. INTERNAL RATE OF RETURN



4.5.8. Indirect benefit

The influence of the construction of a rail/highway bridge which will be exerted over the economy of Laos has been studied under Subparagraph 3.6.8. The influence of a highway bridge, though is similar to that of a rail/highway bridge, seems to be less significant on the following points.

1. At present almost all the imported goods handled by ETO are transported by railway to Nong Khai. If this situation is left unchanged after the completion of the bridge in the future, the saving on the transportation cost and time will be much less for the highway bridge than for a rail/highway bridge since the former is required to have the railway freight transshipped at Nong Khai Railway Station to trucks, whereas a rail/highway bridge makes possible the transportation by railway to Vientiane. In the case of a highway bridge, the passengers are required to make a change at Nong Khai Railway Station, making the condition less favorable than that of a rail/highway bridge.

2. Subparagraph 3.6.8. has made a detailed description of the importance of the railway for the promotion of development of mining in Laos in the future, and a highway bridge certainly will disadvantageous in this respect, because a railway has to be constructed with some delay of time and eventually causes the delay of the mining development.

3. In the case of a highway bridge, there can be no urbanization which definitely can be expected from the extension of a railway to Vientiane. According to the calculation made under Subparagraph 3.6.8. the amount of benefits from the abovementioned urbanization for a period of forty years will come to 6,570 million Kips, and this amount of benefits cannot be obtained in case the bridge is a highway bridge.

4. Concerning the saving on stock of shops and factories handling the imported commodities, extra time will be required for transshipment at Nong Khai Railway Station in the case of a highway bridge as mentioned above, and this means a decrease in the saving on stock for the amount of time thus lost. Consequently, the indirect benefit equivalent to the interest on this extra amount invested in the commodities in stock will be reduced when compared with the benefit obtainable from a rail/highway bridge.

4.5.9. Comparison between a bridge and the ferry facilities

To solve the problem of the traffic volume which is increasing year after year, the advantage of a bridge over the ferry facilities is studied herein similarly to Subparagraph 3.6.9.

The annual cost of a highway bridge and the ferry facilities has been mentioned under Subparagraphs 4.5.5. and 3.6.8., respectively. In this paragraph, only the results are given.

Table 4.16. Comparison of the annual costs of a bridge and the ferry facilities

(1,000 US$)

Assumed annual interest rate	Toll Bridge 3%	Toll Bridge 7%	Toll Bridge 10%	Non-toll 3%
Bridge	699	1,088	1,419	666
Ferry	3,230	3,150	3,150	4,540
Ratio /1	0.28	0.35	0.45	0.15

The above table shows that the annual cost of the ferry facilities is higher than that of a bridge. It proves that a highway bridge has the advantage of the additional ferry facilities.

/1 The ratio of the annual cost of the bridge to that of the ferry facilities.

4.6. Financial Feasibility

4.6.1. Financial statement

A study has also been made for a highway bridge similarly to that made on the financial feasibility of the three kinds of loans considered for a rail/highway bridge. The principle and the conditions are the same as those applied in the case of a rail/highway bridge. The result is as given in Tables 4.17, 4.18, and 4.19.

Table 4.17. shows the financial statement in the case of Loan I (3 percent annual interest rate and 40-year amortization period). The figures of the toll revenue have been obtained by applying the adequate tolls given in Table 4.10 and the traffic volume obtained for such adequate tolls. As in the case of a rail/highway bridge, deficit finance will continue for a long period of the first fourteen years, and the amortization of capital and interest will commence in the 15th year. As regards the necessary working capital, the highway requires 78 million Bahts, which is more favorable when compared with 174 million Bahts required for the rail/highway bridge. This is due to the magnitude of the construction costs (410 million Bahts for a rail/highway bridge and 246 million Bahts for a highway bridge).

The condition of amortization of Loan II (7 percent annual rate of interest and 25-year amortization period) by means of collecting the adequate tolls is as given in Table 4.18. The amortization of the capital and interest will commence from the 13th year, and the working capital required besides the construction cost will amount to 87 million Bahts.

The condition of amortization of Loan III (10 percent annual rate of interest and 20-year amortization period) is as shown in Table 4.19. The amortization of capital and interest is possible from the 11th year, and the working capital required will be 86 million Bahts, which is about 35 percent of the total construction cost.

The above three cases show the condition of amortization by the toll revenue accruing from collecting the adequate tolls. Though the amount is smaller than that in the case of a rail/highway bridge, a working capital of 70 to 90 million Bahts still will be required in each case.

As seen in the case of a rail/highway bridge, it is possible to reduce the amount of the working capital by changing the toll rates like those equal to the current ferry charges. For this purpose a calculation has been made as given in Table 4.22, taking the interest rates at 3 percent, 7 percent and 10 percent.

In the cases of the interest rates of 3 percent and 7 percent, the annual toll revenue will exceed the total annual expenditure from the 1st year, and the amortization of capital and interest can be commenced from the 1st year and can be finished in 9 years and 11 years respectively. The working capital isn't necessary in both cases.

In the case of 10 percent annual rate of interest, deficit finance will continue for the first two years, but the working capital required is small because it is possible to commence the amortization of the capital and interest from the 3rd year. Amortization will be completed in 12 years.

Table 4.17 Financial statement in the case of collecting the adequate toll of bridge-Loan I

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	246,000,000	7,380,000	4,077,450	11,457,450	3,460,414	-7,997,036
2	1974	253,997,036	7,619,911	4,077,450	11,697,361	3,822,486	-7,874,875
3	1975	261,871,911	7,856,157	4,077,450	11,933,607	4,216,401	-7,717,206
4	1976	269,589,117	8,087,674	4,077,450	12,165,124	4,660,998	-7,504,125
5	1977	277,093,242	8,312,797	4,077,450	12,390,247	5,153,803	-7,236,444
6	1978	284,329,686	8,529,891	4,077,450	12,607,341	5,699,385	-6,907,956
7	1979	291,237,642	8,737,129	4,077,450	12,814,579	6,303,366	-6,511,213
8	1980	297,748,855	8,932,466	4,077,450	13,009,916	6,979,345	-6,030,570
9	1981	303,779,425	9,113,383	4,077,450	13,190,833	7,723,817	-5,467,016
10	1982	309,246,441	9,277,393	4,077,450	13,354,843	8,553,658	-4,801,185
11	1983	314,047,626	9,421,429	4,077,450	13,498,879	9,481,358	-4,017,520
12	1984	318,065,147	9,541,954	4,077,450	13,619,404	10,510,115	-3,109,290
13	1985	321,174,437	9,635,233	4,077,450	13,712,683	11,657,712	-2,054,971
14	1986	323,229,407	9,696,882	4,077,450	13,774,332	12,934,611	-839,721
15	1987	324,069,128	9,722,074	4,077,450	13,799,524	14,357,393	557,869
16	1988	323,511,259	9,705,338	4,077,450	13,782,788	15,936,341	2,153,553
17	1989	321,357,706	9,640,731	4,077,450	13,718,181	17,704,407	3,986,226
18	1990	317,371,480	9,521,144	4,077,450	13,598,594	19,678,627	6,080,033
19	1991	311,291,447	9,338,743	4,077,450	13,416,193	20,633,560	7,217,366
20	1992	304,074,081	9,122,222	4,077,450	13,199,672	21,584,120	8,384,448
21	1993	295,689,633	8,870,689	4,077,450	12,948,139	22,541,140	9,593,001
22	1994	286,096,632	8,582,899	4,077,450	12,660,349	23,497,853	10,837,504
23	1995	275,259,128	8,257,774	4,077,450	12,335,224	24,449,182	12,113,958
24	1996	263,145,170	7,894,355	4,077,450	11,971,805	25,401,566	13,429,761
25	1997	249,715,409	7,491,462	4,077,450	11,568,912	26,358,279	14,789,367
26	1998	234,926,042	7,047,781	4,077,450	11,125,231	27,309,607	16,184,376
27	1999	218,741,666	6,562,250	4,077,450	10,639,700	28,265,860	17,626,160
28	2000	201,115,507	6,033,465	4,077,450	10,110,915	29,217,188	19,106,273
29	2001	182,009,234	5,460,277	4,077,450	9,537,727	29,217,188	19,679,461
30	2002	162,329,774	4,899,893	4,077,450	8,947,343	29,217,188	20,269,845
31	2003	142,059,929	4,261,798	4,077,450	8,339,248	29,217,188	20,877,940
32	2004	121,181,989	3,635,460	4,077,450	7,712,910	29,217,188	21,504,278
33	2005	99,677,711	2,990,331	4,077,450	7,067,781	29,217,188	22,149,406
34	2006	77,528,305	2,325,849	4,077,450	6,403,299	29,217,188	22,813,889
35	2007	54,714,416	1,641,432	4,077,450	5,718,882	29,217,188	23,498,305
36	2008	31,216,111	936,483	4,077,450	5,013,933	29,217,188	24,203,254
37	2009	7,012,857	210,386	4,077,450	4,287,836	29,217,188	24,929,352

Remarks : The amortization period for Loan I originally considered was 40 years. The discrepancy 37 years in this table is resulted from the adequate tolls calculated using 5 Bahts as a unit.

Table 4.18 Financial statement in the case of collecting the adequate toll of bridge - Loan II

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	246,000,000	17,220,000	4,077,450	21,297,450	10,384,438	-10,913,012
2	1974	256,913,012	17,983,911	4,077,450	22,061,361	11,330,158	-10,731,203
3	1975	267,644,215	18,735,095	4,077,450	22,812,545	12,355,093	-10,457,452
4	1976	278,101,667	19,467,117	4,077,450	23,544,567	13,494,034	-10,050,532
5	1977	288,152,199	20,170,654	4,077,450	24,248,104	14,728,877	-9,519,227
6	1978	297,671,426	20,837,000	4,077,450	24,914,450	16,079,864	-8,834,586
7	1979	306,506,012	21,455,421	4,077,450	25,532,871	17,552,726	-7,980,145
8	1980	314,486,157	22,014,031	4,077,450	26,091,481	19,176,912	-6,914,569
9	1981	321,400,726	22,498,051	4,077,450	26,575,501	20,948,847	-5,626,654
10	1982	327,027,379	22,891,917	4,077,450	26,969,367	22,901,323	-4,068,044
11	1983	331,095,423	23,176,680	4,077,450	27,254,130	25,031,493	-2,222,636
12	1984	333,318,060	23,332,264	4,077,450	27,409,714	27,373,781	-35,933
13	1985	333,353,993	23,334,779	4,077,450	27,412,229	29,946,322	2,534,093
14	1986	430,819,900	23,157,393	4,077,450	27,234,843	32,759,782	5,524,939
15	1987	325,294,961	22,770,647	4,077,450	26,848,097	35,862,233	9,014,135
16	1988	316,280,825	22,139,658	4,077,450	26,217,108	39,248,578	13,031,470
17	1989	303,249,355	21,227,455	4,077,450	25,304,905	42,963,583	17,678,678
18	1990	285,570,677	19,989,947	4,077,450	24,067,397	47,100,200	23,032,802
19	1991	262,537,875	18,377,651	4,077,450	22,455,101	49,258,139	26,803,038
20	1992	235,734,837	16,501,439	4,077,450	20,578,889	51,411,620	30,832,731
21	1993	204,902,106	14,343,147	4,077,450	18,420,597	53,587,269	35,166,672
22	1994	169,735,434	11,881,480	4,077,450	15,958,930	55,747,024	39,788,094
23	1995	129,947,340	9,096,314	4,077,450	13,173,764	57,901,288	44,727,524
24	1996	85,219,816	5,965,387	4,077,450	10,042,837	60,056,628	50,013,791
25	1997	35,206,025	2,464,422	4,077,450	6,541,872	62,216,384	55,674,512

Table 4.19 Financial statement in the case of collecting the adequate toll of bridge-Loan III

Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	246,000,000	24,600,000	4,077,450	28,677,450	16,457,019	-12,220,431
2	1974	258,220,431	25,822,043	4,077,450	29,899,493	17,915,986	-11,983,507
3	1975	270,203,937	27,020,394	4,077,450	31,097,844	19,497,713	-11,600,131
4	1976	281,804,068	28,180,407	4,077,450	32,257,857	21,247,892	-11,009,965
5	1977	292,814,033	29,281,403	4,077.450	33,358,853	23,137,758	-10,221,095
6	1978	303,035,128	30,303,513	4,077,450	34,380,963	25,198,244	-9,182,719
7	1979	312,217,848	31,221,785	4,077,450	35,299,235	27,437,967	-7,861,268
8	1980	320,079,116	32,007,912	4,077,450	36,085,362	29,899,999	-6,185,362
9	1981	326,264,478	32,626,448	4,077,450	36,703,898	32,580,716	-4,123,182
10	1982	330,387,660	33,038,766	4,077,450	37,116,216	35,523,778	-1,592,438
11	1983	331,980,098	33,198,010	4,077,450	37,275,460	38,715,903	1,440,444
12	1984	330,539,655	33,053,965	4,077,450	37,131,415	42,221,212	5,089,797
13	1985	325,449,858	32,544,986	4,077,450	36,622,436	46,055,301	9,432,865
14	1986	316,016,993	31,601,699	4,077,450	35,679,149	50,228,989	14,549,840
15	1987	301,467,153	30,146,715	4,077,450	34,224,165	54,817,442	20,593,277
16	1988	280,873,877	28,087,388	4,077,450	32,164,838	59,805,094	27,640,257
17	1989	253,233,620	25,323,362	4,077,450	29,400,812	65,284,045	35,883,233
18	1990	217,350,387	21,735,039	4,077,450	25,812,489	71,300,922	45,488,434
19	1991	171,861,953	17,186,195	4,077,450	21,263,645	74,524,022	53,260,376
20	1992	118,601,577	11,860,158	4,077,450	15,937,608	77,739,795	61,802,188
21	1993	56,799,390	5,679,939	4,077,450	9,757,389	80,994,059	71,236,670

Remarks : The amortization period for Loan III originally considered was 20 years. The discrepancy 21 years in this table is resulted from the adequate tolls calculated using 5 Bahts as a unit.

Table 4.20 Financial statements in the case of collecting the same amounts of bridge tolls as current ferry charges

(interest rate 3 percent) Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	246,000,000	7,380,000	4,077,450	11,457,450	25,455,708	13,998,258
2	1974	232,001,742	6,960,052	4,077,450	11,037,502	27,919,366	16,881,864
3	1975	215,119,878	6,453,596	4,077,450	10,531,046	30,610,867	20,079,821
4	1976	195,040,057	5,851,202	4,077,450	9,928,652	33,610,603	23,681,952
5	1977	171,358,105	5,140,743	4,077,450	9,218,193	36,905,608	27,687,415
6	1978	143,670,690	4,310,121	4,077,450	8,387,571	40,530,335	32,142,765
7	1979	111,527,926	3,345,838	4,077,450	7,423,288	44,509,607	37,086,320
8	1980	74,441,606	2,233,248	4,077,450	6,310,698	48,939,747	42,629,049
9	1981	31,812,557	954,377	4,077,450	5,031,827	53,794,822	48,762,996

(interest rate 7 percent) Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	246,000,000	17.220,000	4,077,450	21,297,450	25,957,298	4,659,848
2	1974	241,340,152	16,893,811	4,077,450	20,971,261	28,469,502	7,498,241
3	1975	233,841,911	16,368.934	4,077,450	20,446,384	31,214,037	10,767,653
4	1976	223,074,257	15,615,198	4,077,450	19,692,648	34,272,881	14,580,233
5	1977	208,494,024	14,594,582	4,077,450	18,672,032	37,632,812	18,960,780
6	1978	189,533,244	13,267,327	4,077,450	17,344,777	41,328,963	23,984,186
7	1979	165,549,058	11,588,434	4,077,450	15,665,884	45,386,644	29,720,760
8	1980	135,828,298	9,507,981	4,077,450	13,585,431	49,904,077	36,318,647
9	1981	99,509,651	6,965,676	4,077,450	11,043,126	54,854,819	43,811,693
10	1982	55,097,958	3,898,857	4,077,450	7,976,307	60,334,445	52,358,138
11	1983	3,339,820	233,787	4,077,450	4,311,237	66,389,801	62,078,563

(interest rate 10 percent) Unit : Baht

	Year	Outstanding amount	Interest	Annual working expenses	Total expenditure	Toll revenue	Balance
1	1973	246,000,000	24,600,000	4,077,450	28,677,450	26,333,491	-2,343,959
2	1974	248,343,959	24,834,396	4,077,450	28,911,846	28,882,103	-29,743
3	1975	248,373,702	24,837,370	4,077,450	28,914,820	31,666,414	2,751,594
4	1976	245,622,108	24,562,211	4,077,450	28,639,661	34,769,590	6,129,929
5	1977	239,492,179	23,949,218	4,077,450	28,026,668	38,178,215	10,151,547
6	1978	229,340,631	22,934,063	4,077,450	27,011,513	41,927,933	14,916,420
7	1979	214,424,211	21,442,421	4,077,450	25,519,871	46,044,421	20,524,550
8	1980	193,899,661	19,389,966	4,077,450	23,467,416	50,627,325	27,159,909
9	1981	166,739,752	16,673,975	4,077,450	20,751,425	55,649,816	34,898,391
10	1982	131,841,361	13,184,136	4,077,450	17,261,586	61,208,857	43,947,271
11	1983	87,894,089	8,789,409	4,077,450	12,866,859	67,351,972	54,485,113
12	1984	33,408,976	3,340,898	4,077,450	7,418,348	74,143,545	66,725,197

4.6.2. Various favorable loans

Similarly to the case of a rail/highway bridge, a study was made on various favorable loans in the case of a highway bridge. Ten different toll rates for each traffic component ranging from 0 to the current ferry charge have been considered. The toll for each traffic component was assumed to be charged uniformly at some grade; for instance, when the toll rate of buses is 30 percent of the current charge of existing ferry for buses, it was assumed that the toll rates for heavy trucks, personal cars, motorcycles are also 30 percent of the respective charges of existing ferry. Equation (1) given in Subparagraph 3.7.2 was used for the calculation, and the result is given in Fig. 4.4.

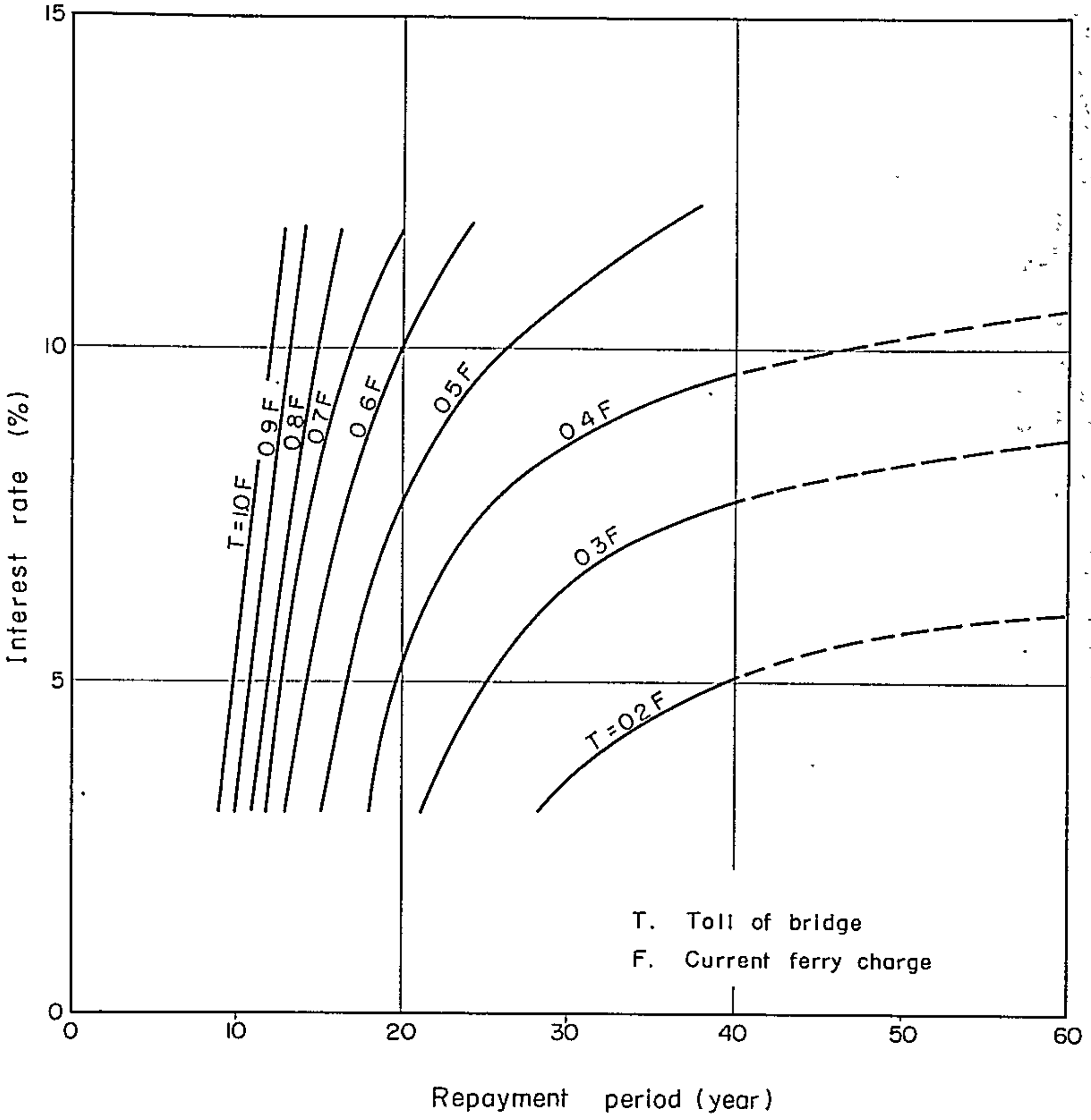
Fig. 4.4 makes clear the following.

(1) In case when the toll rate is equal to the current ferry charges, it is possible to fully amortize a loan of 12 percent annual interest rate in 13 years.

(2) If the toll rate which is half of the current ferry charge is collected for each traffic component, it is possible to fully amortize the loans of 5 percent annual interest rate and 17-year amortization period, 10 percent interest rate and 26 years, and 12 percent interest rate and 37 years.

(3) If it is desired to amortize a loan by the revenue from toll equal to about 20 percent of the current ferry charges, any softer loan than a loan of 5 percent annual interest rate and 40-year amortization period can be amortized.

Fig. 4.4. RELATION BETWEEN THE INTEREST RATE AND REPAYMENT PERIOD



CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1. Feasibility of the Project

The Second Phase Report has three purposes as mentioned in Chapter 1, Paragraph 1.3.: (1) to study the engineering and economic feasibility of the two kinds of bridge, a rail/highway bridge and a highway bridge and to select between the two by comparing the engineering, economic and financial merits and demerits of them, (2) to study the engineering and economic feasibility of linking two parts of the Asian Highway A-12 that lie separately on both Laotian and Thai teritories, and (3) to study the engineering and economic feasibility regarding the extension of the existing railway running between Bangkok and Nong Khai up to Vientiane.

These studies have been made in detail in Chapters III and IV. As understood from these studies, the engineering feasibility can be studied individually about the structures of the project such as a rail/highway bridge, a highway bridge, an access highway to link two parts of the Asian Highway and a new railway to be built up to Vientiane. But, the economic and financial evaluations should not be made about the respective structures, but about the whole project. With this in view, the economic and financial feasibilities of the access highway and the new railway should be studied in close relation to the rail/highway bridge or the highway bridge. Namely, the feasibility study of the project can be divided into two cases having the three purposes mentioned above : one is that a rail/highway bridge is constructed over the Mekong and the other is that a highway bridge is built. Chapter III describes the former case and Chapter IV, the latter case.

As regards the engineering feasibility of the project in both cases, there is no such a technical problem as to threaten the project execution. A few technically difficult problems may be encountered on the occaision of the construction of the project. For example, the problems of the settlement of pneumatic caissons on the firm siltstone and the construction of the highway and the railway stabilized with soil-cement mix or soil-sand mix will arise at that time. It, however, is not impossible to solve such problems, and they never make hesitate the authorities concerned to perform the project. It goes without saying that the construction of the four major structures, that is, a rail/highway bridge, a highway bridge, an access highway for linking two parts of the existing Asian Highway A-12, and a new railway to be extended up to Vientiane, is quite feasible from the engineering viewpoint.

On the other hand, the economic and financial feasibilities of the project in both cases have been studied in comparison with the present car ferry running between Tha Naleng and Nong Khai. The detailed studies have been made in Chapters III and IV and summarized in the next Paragraph 5.2. As is well understood therefrom, the two cases of the project are satisfactorily feasible from the economic and financial viewpoints, too.

In the last place, it is proved that from enterprisers' position that the modern bridge is far superior to the ferry to cope with the growing traffic that crosses the Mekong at the project site.

The bridge is scheduled to open to traffic in 1973 after the construction period of two years, and is planned to cater for the growing traffic during the useful life of the bridge estimated at about 40 years. The growing traffic in the future is quite different according to the kind of the transportation facilities provided at site. A bridge generally brings much more growing traffic than a ferry. However, the study will be made as to the case that the ferries would meet the growing traffic estimated in the case of bridge. First of all, it will be made as to how many and when the ferries should be additionally provided during the same period as the useful life of the bridge. Then the equivalent annual cost to be required for the additional ferry construction and operation, maintenance and replacement of the ferries already constructed is estimated and compared with that of the bridge. One which gives lower equivalent annual cost suggests to have the advantage of the other.

The following table shows that the bridge surpasses the ferries for the purpose of meeting the future traffic from the viewpoint of enterprisers. It goes without saying that the bridge surpasses the ferries from the viewpoint of users, too. As understood from Table 5.1., the working expenses which are required for the operation, maintenance and replacement of the ferry facilities are extremely costly and as a result the annual cost of the bridge is much less than that of the ferries in most cases.

Because the modern bridge thus has much more advantage of the ferries, the growing traffic in the project area should be overcome with the bridge.

Table 5.1. Comparison between the bridge and the ferries

Item	Bridge (US$)		Ferry (US$)
	Rail/highway Bridge	Highway Bridge	
I. Construction Cost (Present worth)			
Loan I (3 %, 40 years)	20,000,000	12,000,000	29,540,000
Loan II (7 %, 25 years)	"	"	21,520,000
Loan III (10 %, 20 years)	"	"	17,880,000
Grant (3 %, 40 years)	"	"	41,040,000
II. Equivalent Annual Cost			
1. Equivalent annual fixed cost			
Loan I	889,500	500,300	1,280,000
Loan II	1,516,600	888,600	1,610,000
Loan III	2,055,700	1,220,500	1,830,000
Grant	889,500	500,300	1,780,000
2. Annual working expense			
Loan I	309,100	198,900	1,950,000
Loan II	"	"	1,540,000
Loan III	"	"	1,320,000
Grant	288,100	165,400	2,760,000
3. Equivalent annual cost			
Loan I	1,198,600	699,200	3,230,000
Loan II	1,825,700	1,087,500	3,150,000
Loan III	2,364,800	1,419,400	3,150,000
Grant	1,177,600	665,700	4,540,000
III. Ratio			
Loan I	0.37	0.22	1
Loan II	0.58	0.35	1
Loan III	0.75	0.45	1
Grant	0.25	0.15	1

Remarks

(1) Facilities

Bridge: A rail/highway bridge or a highway bridge including an access highway, and a new railway only in the case of a rail/highway bridge.

Ferry: 24 ferry facilities including 48 ferry boats of 100-ton capacity and 3 dredgers in the comparison with the toll bridge and, 37 ferry facilities including 74 ferry boats and 5 dredgers in the comparison with the non-toll bridge.

(2) Loan I indicates a loan of the annual rate of interest of three percent with 40-year repayment period.

(3) Grant means that the construction cost is financed with the subsidy from the Governments concerned or the contribution from foreign countries. Also in the case of grant, the annual rate of interest of three percent will be considered likewise with the case of Loan I.

5.2. Comparison between the Rail/highway Bridge and the Highway Bridge

In order to attain the latter half of the first purpose mentioned in the preceding Paragraph 5.1., the engineering, economic and financial merits and demerits are compared below, and then some suggestions and recommendations are mentioned so that the Mekong Committee could finally select between the two cases of the project.

(1) Engineering feasibility

Many technical problems such as bank protection, river-bed erosion, settlement of pneumatic caissons on the firm siltstone, pier spacing, type of bridge, forms of cross sections of bridge, highway and railway, and so on will arise in designing and constructing the project. These problems are all common to both cases although some of them may be difficult of solution and some may be easy. Generally the construction works of the highway bridge are easier than those of the rail/highway bridge because the highway loads are lighter than the railway loads and the project structures are smaller in the case of a highway bridge accordingly. However, the erection of the box girders for the highway bridge is much more difficult than that of the truss members for the rail/highway bridge.

As a conclusion, no definite difference can be found between the engineering feasibilities of the rail/highway bridge and the highway bridge.

(2) Economic and financial feasibilities

Table 5.2 has been prepared in order to make a comparison between the economic and financial feasibilities of the rail/highway bridge and the highway bridge.

According to this table, the estimated future traffic has almost no difference between the two cases because the difference of the vehicular traffic is diverted to the railway freight and the railway passengers.

As for the direct benefit, the rail/highway bridge has the advantage of the highway bridge provided that a generous grant or a soft loan less than around seven percent of the annual rate of interest would be financed for the project. Contrariwise, as the annual rate of interest of loan is raised, the highway bridge becomes superior to the rail/highway bridge. This results from that, as the annual rate of interest is raised, the rail/highway bridge shows more increasing toll than the highway bridge and as a result the future traffic growth would more be alleviated because the annual cost to be repaid to lenders would more increase in consequence in the former case.

The rail/highway bridge gives more construction cost than the highway bridge. This is a natural consequence because an extra railway is included in the case of a rail/highway bridge. But the rail/highway bridge is certainly disadvantageous in the light of the fact that the project having more initial investment is more difficult and takes more time to finance.

The benefit-cost ratios and the capitalized net benefits are all less in the case of a rail/highway bridge. The adequate tolls of the traffic component in this case, such as bus, personal car, taxi, heavy truck, light truck, motorcycle, railway freight and railway passenger, are also the same as or more expensive than those in the case of a highway bridge. In view of these points, the highway bridge is superior to the rail/highway bridge.

As regards the indirect benefit, the urbenization of the vicinity of the Vientiane Station cannot be disregarded. It roughly amounts to 13,140,000 U.S. dollars in the total present worth. This reveals that the rail/highway bridge is much more advantageous than the highway bridge. Furthermore the rail/-highway bridge more remarkably expedites the developments of the lumber industry and mining industry in Laos than the high-way bridge.

Stress should be placed on the result that the rail/high-way bridge presents the slightly larger sum of the capitalized net benefit of the direct benefit and the indirect benefit to be derived from the urbanization above-mentioned than the highway bridge.

From the comprehensive considerations upon the direct and indirect benefits and besides upon the intangible benefits such as the expedition of the agricultural development, live-stock industry, mining industry, lumber industry and so forth, it is recommended that the rail/highway bridge should finally be selected for Nong Khai/Vientiane Bridge Project by the Mekong Committee.

5.3. Various Subjects of Study

After submitting the First Phase Report early in January 1968 to the Mekong Committee, the bridge team have received many useful comments from the Mekong Committee, the Advisory Board, and the government authorities concerned of both Laos and Thailand. The team has studied the comments as guide for preparing the Second Phase Report.

The results of the team's study are mentioned below.

(1) Bridge width

Following the request made by the Thai National Mekong Committee and the Advisory Board concerning the width of the rail/highway bridge, it has been decided to abandon the idea of common use of a single-track railway and a lane of the two-lane roadway in highway suggested in the First Phase Report. The bridge has been widened so that a two-lane highway and a single-track railway could be constructed severally as shown in PLATE 3.

The width of the roadway on the bridge has been decided at 8 meters in compliance with the geometric design standards of the Highway Department of Thailand, and the width of a single-track railway has been taken at 4 meters from the construction gage stipulated by the Royal State Railway of Thailand. Consequently, the width between the center lines of the truss members comes to 13.4 meters, and a sidewalk and a gangway to inspect the railway track each measuring 1.5 meters wide will be provided outside of the two major truss structures, totaling the bridge width of 17.8 meters in the rail/highway bridge. In the case of a highway bridge, the total bridge width comes to 11.6 meters including the two-lane roadway of 8 meters and the two sidewalks of 1.5 meters wide each.

(2) The influence of the bridge on the Nong Khai Shipyard now under construction in connection with scouring, silting, etc.

The Mekong bridge proposed in this report is located at about 150 meters upstream from the upstream end of the shipyard. It is very difficult to estimate how the bridge would exert its influence on the docking operation of the shipyard in the future.

A sand-bar emerges in front of the shipyard in the dry season every year. The aspect of this sand-bar was surveyed in the second phase investigation as shown in PLATE 2. The influence of the bridge on the shipyard depends on how the sand-bar will be affected by the scouring action which may be caused by the bridge piers and also by the resultant silting over the downstream area, after the bridge is constructed.

The bridge team tried to estimate the influence on the sand-bar to some extent in the second phase investigation by inspecting the aspect of the river-bed by means of echo-sounding around the intake tower already built on the Mekong for water-supply to Vientiane. The results have been given in detail in Chapter II, Paragraph 2.5. As far as these results are concerned, the shipyard does not seem to be affected by the scouring action. It, however, is recommended to carry out a model test to obtain reliable data on scouring and silting.

On the other hand, the bridge piers and caissons will reduce the flow area of the Mekong by about 10 percent in rainy seasons and about 15 percent in dry seasons. There seams to be no remarkable change in the present stream of the Mekong due to such reduction.

(3) Bank erosion

This problem is very important for the construction of the bridge. The detailed study has been made in Chapter III, Subparagraph 3.1.4.

(4) River-bed erosion

This also is one of the most important problems. The detailed description has been made in Chapter III, Subparagraph 3.1.5.

(5) Comparative study of a rail/highway bridge and separate bridges of railway and highway

As mentioned in detail in Chapter III, Subparagraph 3.1.3.1., a rail/highway bridge requires 3,600 tons of steel and its construction cost is estimated at 6,200,000 U.S. dollars/1.

In the case of constructing a highway bridge and a railway bridge separately, 2,200 tons of steel for a highway bridge and 1,800 tons of steel for a railway bridge, totaling 4,000 tons, will be required and their construction costs amount to approximately 8,100,000 U.S. dollars in case when both are the truss bridge, as given in Table 3.1.

The two separate bridges thus require more construction cost by 30 percent than the rail/highway bridge, and so are not favorable.

(6) Change-over

Traffic in Laos keeps to the right, whereas it keeps to the left in Thailand. It is therefore necessary to make the change-over to the left or to the right somewhere either in Laos or Thailand.

/1 This amount does not include the expense for engineering service, Governments' administrative expense, contingency and reserve, and interest during construction. The amount of 8,100,000 U.S. dollars seen at the later line is also the same.

As seen in Table 5.2. in the preceding paragraph, the traffic volume of the bridge will show a remarkable increase in the future. The administrative facilities are so designed as to be able to handle such a large traffic volume. As far as these facilities are concerned, it is proferable that the change-over is made on the Thai soil. In other words, the traffic keeps to the right on the bridge as mentioned in detail in Chapter III, Paragraph 3.3.

A grade-separated change-over is not necessary for this bridge project because the traffic cannot be expected to flow smoothly on the bridge due to the due formalities that the freight and the passengers are required to go through for immigration, health and customs both in Laos and in Thailand. Namely, even though some special arrangement like an interchange would be provided for the grade-separated change-over on the riverside terrain, it would not fully desplay its function. It is more economical to adopt the at-grade change-over.

(7) Traffic growth

Based on the results of the origin-destination survey made in the first phase investigation and the supplementary survey made in the second phase investigation, the future traffic is estimated to increase at a constant rate each year for a period of 17 years beginning in 1973 when the bridge will be open for traffic, and afterwards to increase at a constant volume until 2000. It is impossible to estimate the traffic growth after 2000 judging from the accuracy of the surveys conducted.

The future traffic estimated is as given in Table 5.2. The rate of the traffic increase for the period from 1973 to 1990 will be an average of about 11 percent for bus, taxi, and trucks, 9 percent for railway freight and 10 percent for railway passengers. The traffic growth for the period from

1990 to 2000 is shown in Table 5.2., and the annual increase rate will be about 5 percent for some years closer to 1990 and will gradually drop to about 3 percent for years nearing to 2000. The average is about 4 percent. The estimated traffic volume in 2000 is about nine times as much as that in 1973 for vehicles, six times for railway freight and eight times for railway passengers.

These traffic volumes are not overestimate. According to the information supplied by the Highway Department of Thailand, the traffic on main inter-urban highway routes in Thailand has been growing at an average rate of about 20 percent per year over the last five years. The data which the bridge team has collected at site in the first phase investigation show that the traffic of vehicles running between Udon Thani and Nong Khai has increased up to ten times for the recent four years.

(8) Discount rate

Three kinds of the discount rate, 3 percent, 10 percent were considered for the economic justification and the study of the financial feasibility of the bridge project. The repayment periods for these discount rates were fixed at 40 years, 25 years and 20 years, respectively.

The economic evaluation was made by means of the internal rate of return method, too.

(9) Transshipment cost

The saving of the transshipment cost in Tha Naleng car ferry has been taken into account for the estimation of the benefit of the project in the Second Phase Report as well as in the First Phase Report.

It was suggested by the Advisory Board that the possible present cost of intermediate trade might disappear in case a rail/highway bridge with a railway station in Vientiane would be constructed, and that in case direct shipment could be made from Bangkok to Vientiane either by mail or by road, the decrease in the cost of imported commodities in Vientiane should be much more important than the transportation and transshipment costs saved by the bridge.

The bridge team is fully aware of the above two matters. Since the saving could be considered as a direct benefit, it was not taken up in the analysis of the direct benefit in the Second Phase Report, but was taken up as an indirect benefit.

5.4. Further Investigations

Most of the feasibility investigations have been completed in the first and second phase investigations, but there still remain some more fasibility investigations to be made. Furthermore, various kinds of the detailed investigations will be necessary for the actual construction works of the project, and the detailed design of the project structures and the preparation of the tender documents have to be undertaken before the construction works will be commenced.

The following are the main field investigations to be carried out before construction.

(1) Route survey of the railway to be extended from Nong Khai to Vientiane

In case that the Mekong bridge would be decided as a rail/highway bridge, the northeastern trunk line of the Royal State Railway of Thailand will be extended over 20 kilometers to run between Tha Naleng and Vientiane in the territory of Laos, after crossing the Mekong.

As explained in detail in Chapter III, Paragraph 3.2., five routes are conceivable. The merits and demerits of each of these routes have been studied in Paragraph 3.2.. As a result, the route C gives the least construction cost and the combined route C.D is particularly desired by the Laotian Government. These two routes are finally considered to be more promising than the other three.

Although the reconnaissance of the five routes was already made in the first and second investigations, no detailed survey has been executed yet. The Plan of Operation describes only to make the reconnaissance of the routes and to study the possibility of the extension railway. This was because it was considered that there was almost no possibility of constructing a rail/highway bridge along with the extension railway up to Vientiane at the time when the Plan of Operation was signed. The final conclusion of the Second Phase Report, however, is to construct a rail/highway bridge for the Nong Khai Bridge Project from the results of the feasibility studies. This conclusion has accorded with the strong demand of both Laos and Thailand.

Such being the circumstances, it is imdispensable to make the feasibility study of the railway with the same accuracy as the bridge and for this purpose the route survey of the railway should be conducted.

The Japanese Government is going to carry out this survey in a very near future in compliance with the strong requent made by the Mekong Committee and the Laotian Government.

(2) Field investigations concerning the bank erosion and river-bed scouring

The problems of the bank erosion and river-bed erosion attributable to the bridge piers have been solved to a certain degree in the second phase investigation. The bridge team made an investigation on the bank erosion and river-bed scouring around the water supply tower located at about six kilometers upstream of Vientiane as a good example. The results of the investigation have been given in detail in Chapter II. This sort of the investigation was also made in the past by the Laotian Government, and the data obtained are also given in Chapter II. As both investigations were made in dry seasons, the actual conditions of river-bed scouring and bank erosion which are most violent in rainy seasons have not been grasped fully. It is impossible to formulate the most appropriate measures against these two unfavorable actions under such circumstances. Therefore, the field investigations should be performed in a rainy season to grasp the actual conditions of the river-bed scouring and the bank erosion around the water supply tower in the Mekong.

Furthermore, the erosion of the bank on the Laotian side that at present causes due to the bend of the river course upstream from and nearest to the bridge site, and siltation on the Thai side near the bridge site should be analyzed for future reference. It is also necessary to ascertain the flow condition of the Mekong near the bridge site during flood seasons.

It is adviable to conduct a model test to obtain the comprehensive solution of the above hydraulic problems.

(3) Detailed material survey

Considerably detailed investigations were made in the second phase investigation as to the concrete aggregates, embankment materials and so on, but more detailed investigations will be required on the materials mentioned below for making a detailed design of the project structures.

(1) Concrete aggregates

To decide the design mix for concretes with different design compressive strengths and to make plans for the supply of cement and aggregates, it is required to grasp the physical properties of the aggregates of the finally selected aggregate pits.

(ii) River sand and gravel for pavement use

Crushed stone is generally used for the wearing course, base course, and subbase course in highways, but it is not easy to obtain crushed stone near the project area. For this reason, it was planned in the Second Phase Report to use the sand and gravel of the Mekong assuming that they could meet the required values of CBR. It is therefore necessary to do CBR test actually at site at an earliest moment.

(iii) Embankment materials

The investigation was made on the embankment material for highway in the second phase investigation, and it was found that the subsoil in the project area has a nature to swell when saturated with water. This kind of soil is unsuitable for use as embankment material for highway and railway. Detailed explanations are given in Chapters II and III concerning this matter and the data of soil test are compiled in Appendices. Soil-cement mix was considered as a measure against swelling in this report, but it is indispensable to further probe into this problem in the future. It is also recommendable to seek embankment material of better quality from other sources.

(iv) Ballast

Ballast of high hardness is not available near the project area. It shall be transported from the area around Sara Buri or Loi. Although the ballast was assumed to be supplied from Sara Buri in the Second Phase Report, the detailed investigation should be made on the sources of supply.

(v) Laterite and stone

A detailed investigation should be made regarding these materials, too.

(4, Detailed topographic survey

The plane table survey and the route survey mode in the second phase investigation are not enough to make the detailed design of the project structures. A detailed topographic survey shall be made over the whole project area before construction.

First of all, it is required to unify the elevation of a number of bench-marks lying here and there in the project area extending over both countries. For, a difference of 18 centimeters was found between the elevation of the bench-mark in the site of Hydrographic Office that was learned by the Thai authority concerned and the reading of the elevation of the said bench-mark that was measured in the second phase investigation based on the original bench-mark V-636, EL170.105 meters above mean sea level, in Vientiane. The reading on the Thai side was higher, and the accuracy of the survey made by the bridge team was within two centimeters.

The different indication of the elevation of one bench-mark in the project area has to be avoided by all means because such may give rise to a serious mistake in the construction of the project structures.

Table 5.2. Comparison between the rail/highway bridge and the highway bridge

Item	Unit	Rail/highway bridge		Highway bridge	
		Toll	Non-toll	Toll	Non-toll
I. FUTURE TRAFFIC					
1. Estimated future traffic/1					
(i) Vehicles					
A.D. 1973	Vehicles/day	747	1,273	1,084	1,640
1990	"	4,647	8,317	6,377	10,140
2000	"	6,941	12,459	9,490	15,146
(ii) Railway freight					
A.D. 1973	tons/day	591	609		
1990	"	2,586	2,664		
2000	"	3,760	3,873		
(iii) Railway passengers					
A.D. 1973	Persons/day	337	361		
1990	"	1,796	1,922		
2000	"	2,654	2,840		
2. Annual traffic growth rate (1973 to 1990)					
(i) Vehicles	%	11.4	11.4	11.0	11.0
(ii) Railway freight	"	9.1	9.1		
(iii) Railway passengers	"	10.4	10.4		
3. Annual traffic growth volume (1990 to 2000)					
(i) Vehicles	Vehicles/year	83,731	151,183	113,588	182,719
(ii) Railway freight	tons/year	42,851	44,129		
(iii) Railway passengers	Persons/year	31,317	33,507		
II. DIRECT BENEFIT					
1. Annual benefit/2					
(i) Loan I/3, (3 %, 40 years)	US$	8,784,000		8,546,000	
(ii) Loan II, (7 %, 25 ")	"	5,923,000		5,902,000	
(iii) Loan III, (10 %, 20 ")	"	3,929,000		4,632,000	
(iv) Grant/4	"		9,281,000		8,994,000
2. Capitalized benefit					
(i) Loan I	(US$)	174,846,000		170,002,000	
(ii) Loan II	"	55,404,000		55,152,000	
(iii) Loan III	"	27,612,000		32,160,000	
(iv) Grant	"		289,644,000		280,161,000
III. CONSTRUCTION COST	(US$)	20,000,000	20,000,000	12,000,000	12,000,000
IV. ANNUAL COST					
1. Annual fixed cost					
(i) Loan I	US$	889,500		500,300	
(ii) Loan II	"	1,516,600		888,600	

Continued

Item	Unit	Rail/highway bridge		Highway bridge	
		Toll	Non-toll	Toll	Non-toll
(iii) Loan III	US$	2,055,700		1,220,500	
(iv) Grant	"		889,500		500,300
2. Annual working expense	"	309,100	288,100	198,900	165,400
3. Annual cost					
(i) Loan I	US$	1,198,600		699,200	
(ii) Loan II	"	1,825,700		1,087,500	
(iii) Loan III	"	2,364,800		1,419,400	
(iv) Grant	"		1,177,600		665,700
4. Capitalized cost					
(i) Loan I	US$	27,145,000		16,598,000	
(ii) Loan III	"	24,121,000		14,652,000	
(iii) Loan III	"	23,023,000		13,945,000	
(iv) Grant	"		26,659,000		15,823,000
5. Useful life	years	39	39	43	43
V. BENEFIT-COST RATIO					
(1) Loan I		7.3		12.2	
(2) Loan II		3.2		5.4	
(3) Loan III		1.7		3.3	
(4) Grant			7.9		13.5
VI. CAPITALIZED NET BENEFIT					
(1) Loan I	US$	147,701,000		153,404,000	
(2) Loan II	"	31,283,000		40,500,000	
(3) Loan III	"	4,589,000		18,215,000	
(4) Grant	"		262,985,000		264,338,000
VII. ADEQUATE TOLL[5]					
(1) Loan I					(Current ferry charge)
(i) Buses	Bahts/vehicle	5		5	(57)
(ii) Personal cars	"	5		5	(40)
(iii) Taxis	"	5		5	(40)
(iv) Heavy trucks	"	30		10	(110)
(v) Light trucks	"	5		5	(57)
(vi) Motorcycles	"	5		5	(5)
(vii) Railway freight	Bahts/ton	5			(40)
(viii) Railway passengers	Bahts/person	5			(5)
(2) Loan II					
(i) Buses	Bahts/vehicle	25		5	
(ii) Personal cars	"	5		5	
(iii) Taxis	"	5		5	
(iv) Heavy trucks	"	100		50	
(v) Light trucks	"	25		5	
(vi) Motorcycles	"	5		5	
(vii) Railway freight	Bahts/ton	25			

Continued

Item	Unit	Rail/highway bridge		Highway bridge	
		Toll	Non-toll	Toll	Non-toll
(viii) Railway passengers	Bahts/person	5			
(3) Loan III					
(i) Buses	Bahts/vehicle	55		10	
(ii) Personal cars	"	35		5	
(iii) Taxis	"	35		5	
(iv) Heavy trucks	"	110		85	
(v) Light trucks	"	40		5	
(vi) Motorcycles	"	5		5	
(vii) Railway freight	Bahts/ton	40			
(viii) Railway passengers	Bahts/person	5			
VIII. INTERNAL RATE OF RETURN	%	12.4	16.1	16.0	18.7
IX. INDIRECT BENEFIT					
1. Transportation-cost saving between Bangkok and Vientiane /6	US$	19,635	528,652	19,635	528,652
2. Stock saving /7	"	342	342	342	342
3. Income of landowners due to the increase of land price (Total present worth of those from 1973 to 1990)	"	13,140,000	13,140,000	0	0
4. Agricultural development		Expedited		Expedited	
5. Livestock industry		Self-sustaining expedited		Self-sustaining expedited	
6. Mining		Much expedited		Somewhat expedited	
7. Lumber industry		Much expedited		Somewhat expedited	
8. Urbanization		Rapid Urbanization of the vicinity of the Vientiane Station expected		No urbanization expected	

Remarks:-

/1 These values have been estimated under the condition that the bridge tolls are all the same as the current ferry charges.

/2 These benefits are the sum of the time benefit and cost benefit, and are the largest that is obtainable within the amortization period of loan.

/3 Three kinds of loans have been take as favorable loans. The first loan has the repayment period of 40 years at 3 percent rate of interest, the second loan has that of 25 years at 7 percent rate of interest and the third loan has that of 20 years at 10 percent rate of interest.

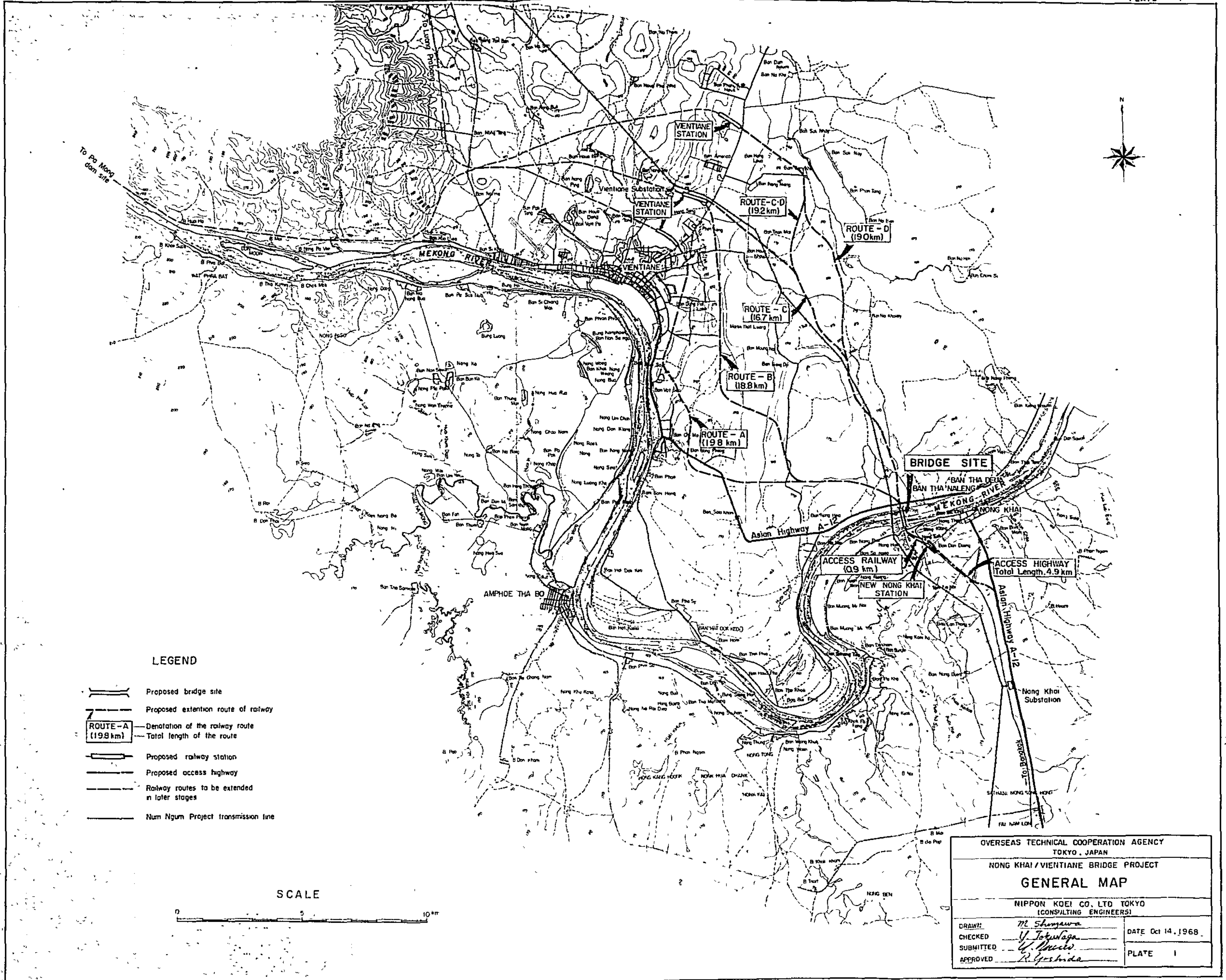
/4 In case that the construction cost is financed with some generous grant, the bridge is of non-toll and therefore no repayment is necessary. But, the grant will be treated in the same manner as the Loan I to confirm the advantage of the project.

/5 The adequate toll of each traffic component has been so decided as to give the maximum benefit during the amortization period of the loan.

/6 These values have been estimated on the basis of the data of the import of Laos in 1968.

/7 These values have been estimated based on the data of the import of Laos in 1966.

PLATE



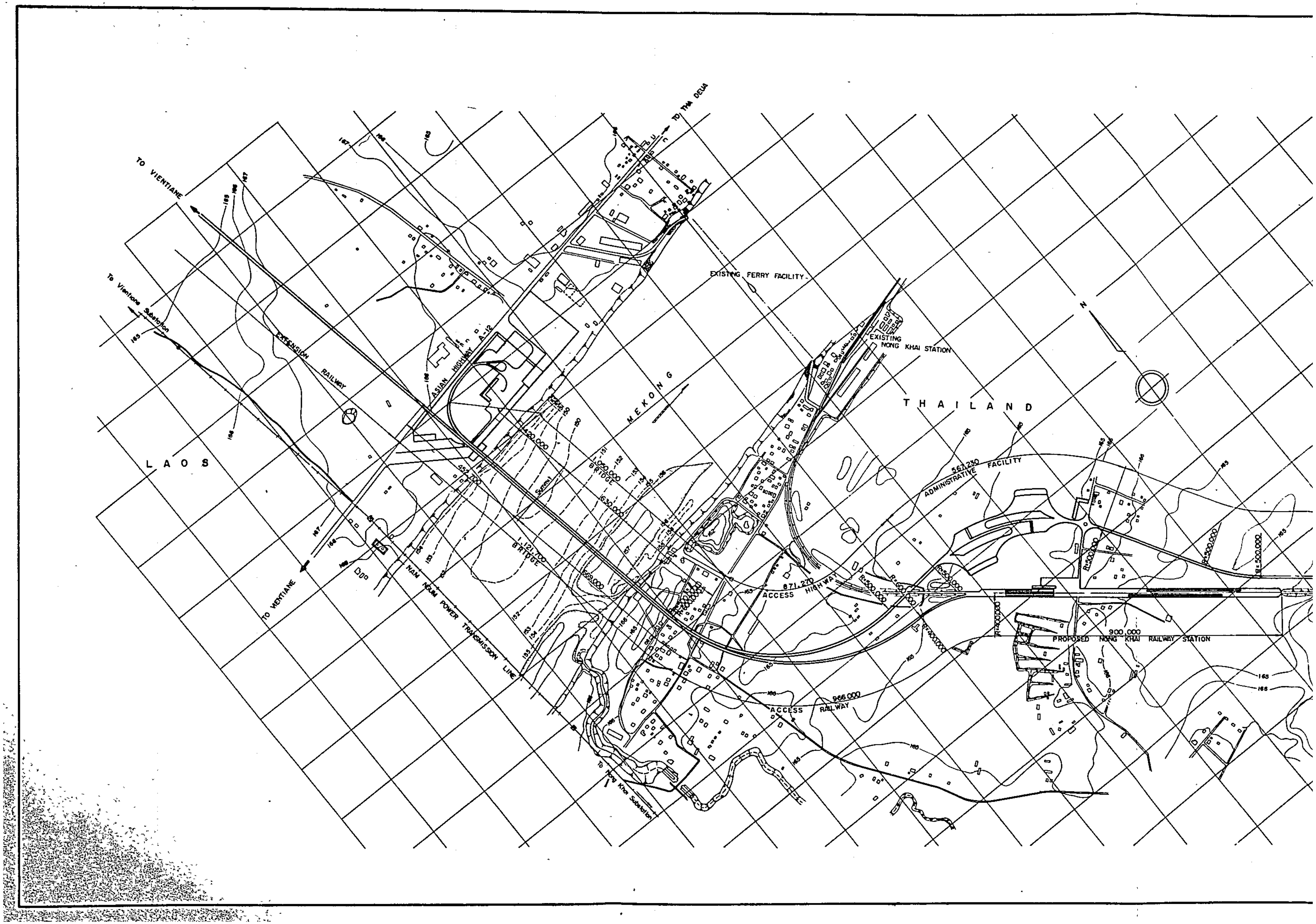
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

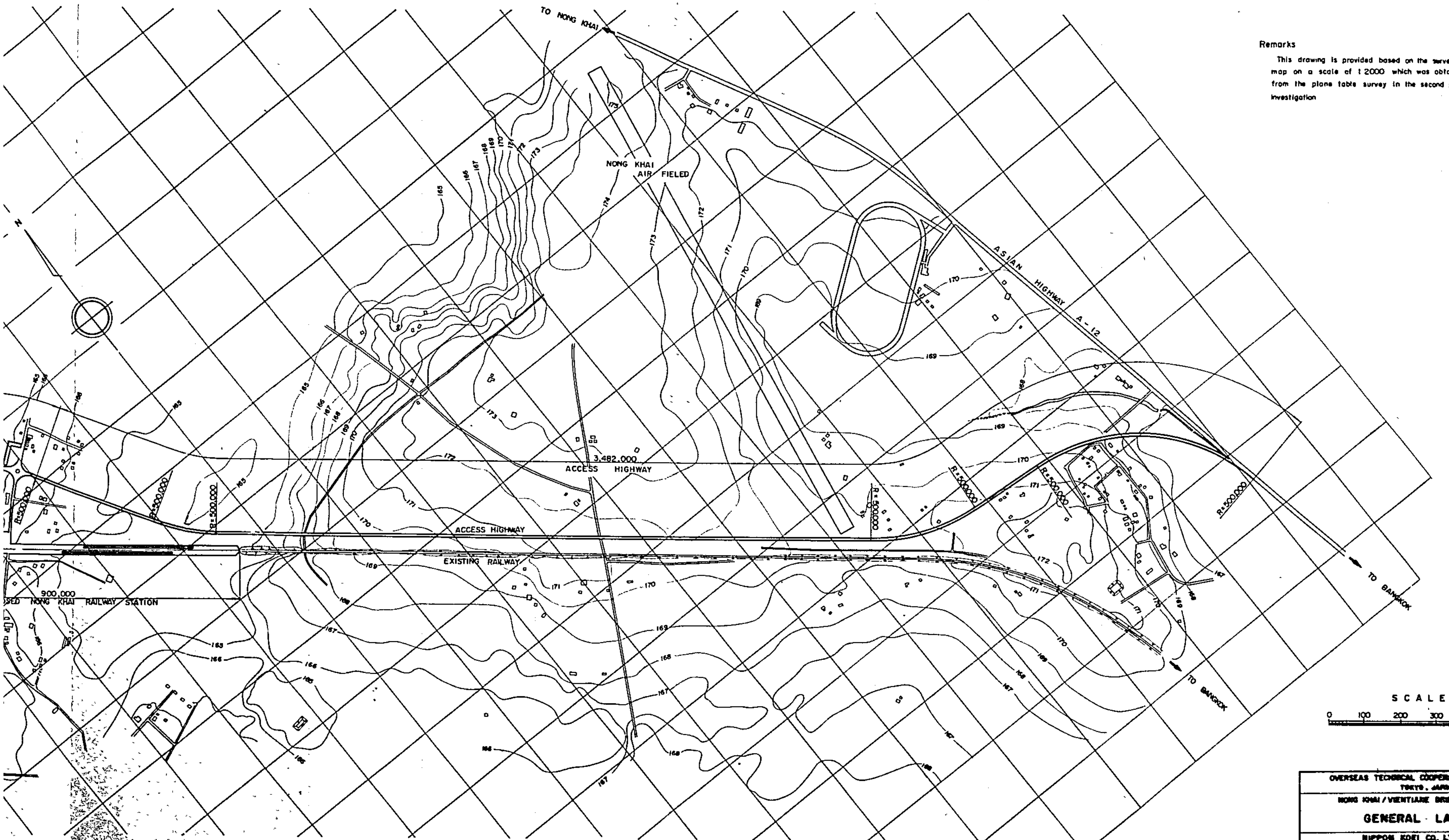
NONG KHAI / VIENTIANE BRIDGE PROJECT

GENERAL MAP

NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	M. Shimizawa	DATE Oct 14, 1968
CHECKED	Y. Tokunaga	
SUBMITTED	Y. Nucus	PLATE 1
APPROVED	R. Yoshida	


TO VIENTIANE
To Vientiane Substation
EXTENSION RAILWAY
ASIAN HIGHWAY A-12
L A O S
TO VIENTIANE
NAM NGUM POWER TRANSMISSION LINE
To Nong Khai Substation
TO THA DEUA
EXISTING FERRY FACILITY
MEKONG
BRIDGE
EXISTING NONG KHAI STATION
T H A I L A N D
N
ADMINISTRATIVE FACILITY
ACCESS HIGHWAY
ACCESS RAILWAY
PROPOSED NONG KHAI RAILWAY STATION
420.000
452.700
1,040.000
1,121.700
1,630.000
563.230
671.270
900.000
966.000



Remarks

This drawing is provided based on the survey map on a scale of 1:2000 which was obtained from the plane table survey in the second phase investigation

SCALE

0 100 200 300 400 500m

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

GENERAL LAYOUT

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

DRAWN
CHECKED
SUBMITTED
APPROVED

DATE Oct. 14, 1969

PLATE 2

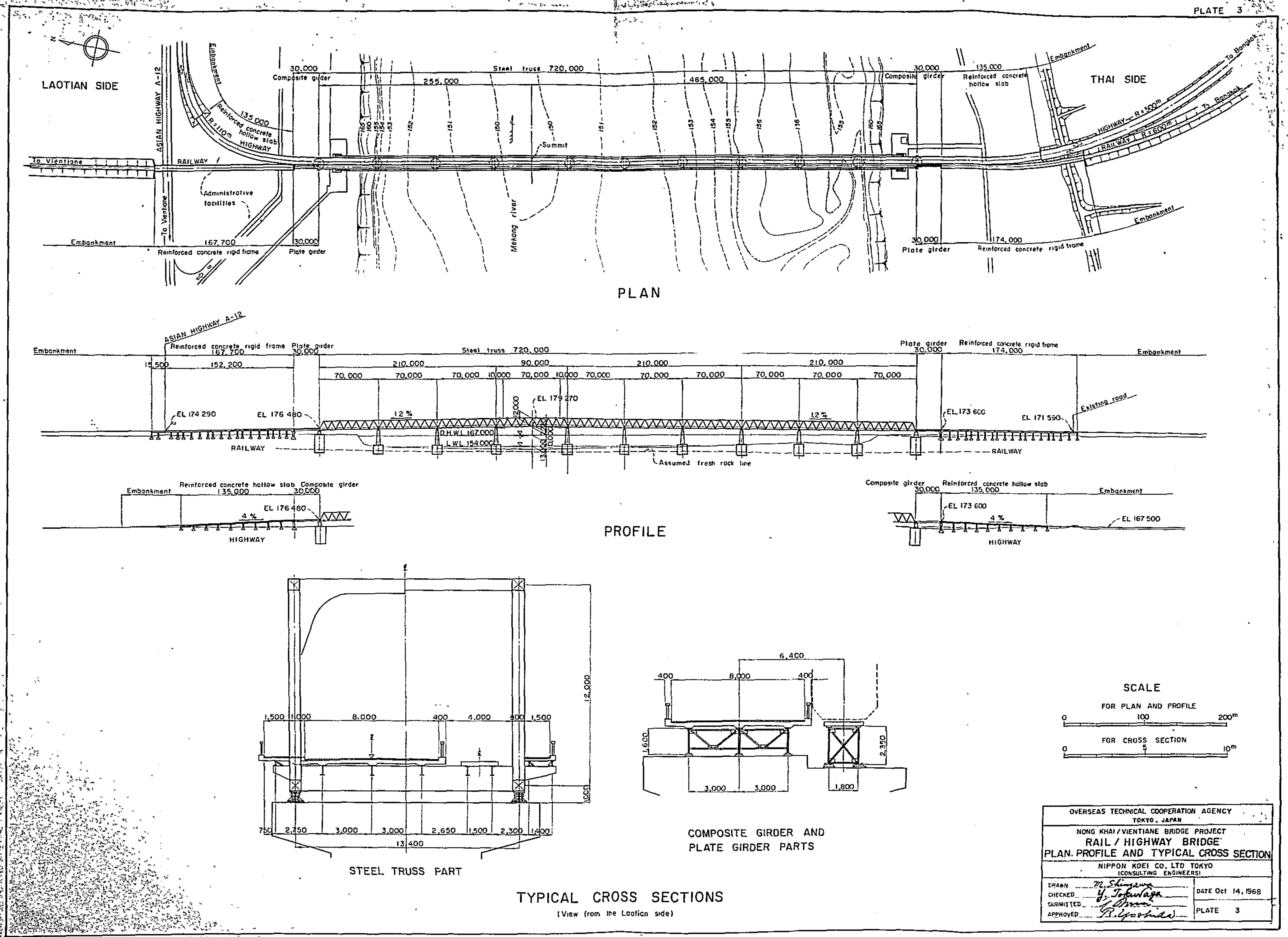
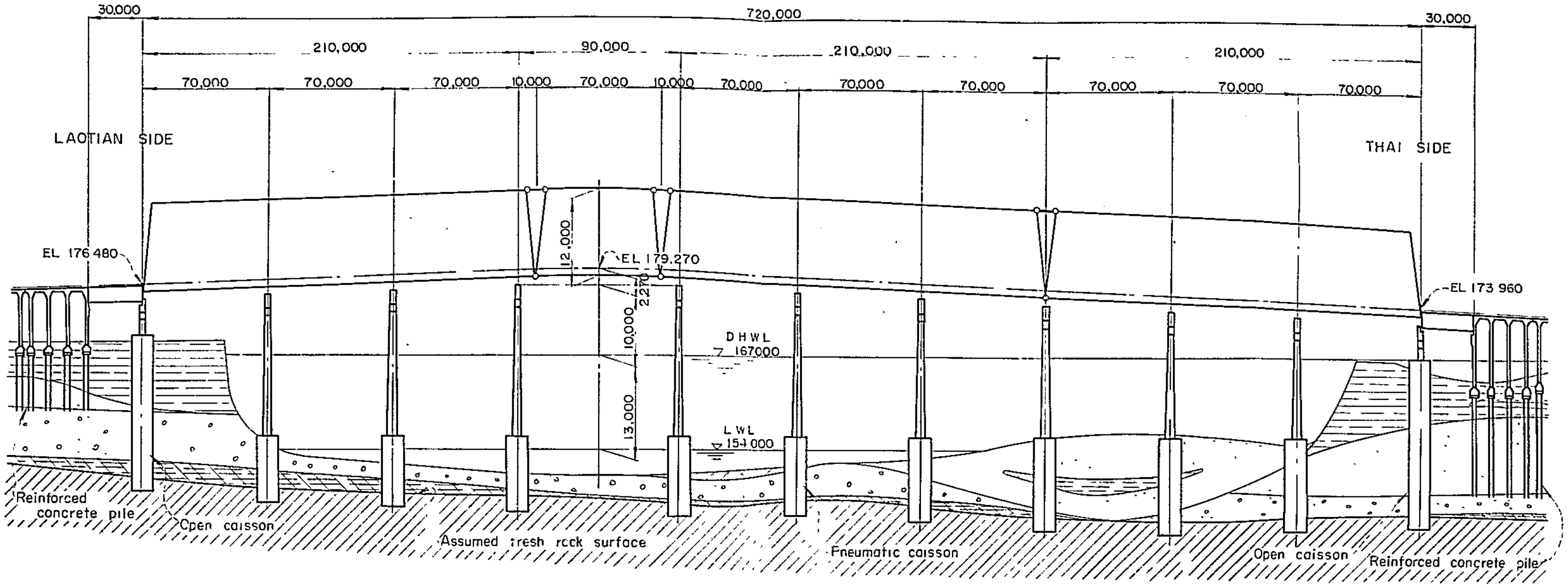


PLATE 3
LAOTIAN SIDE
THAI SIDE
ASIAN HIGHWAY A-12
To Vientiane
RAILWAY
HIGHWAY
Embankment
Reinforced concrete hollow slab
135,000
R=110m
Composite girder
30,000
Steel truss 720,000
255,000
465,000
Reinforced concrete hollow slab
135,000
To Bangkok
HIGHWAY R=500m
RAILWAY R=600m
Summit
Mekong river
Administrative facilities
167,700
Reinforced concrete rigid frame
Plate girder
174,000
PLAN
Reinforced concrete rigid frame
Plate girder
152,200
15,500
210,000
90,000
70,000
EL 174 290
EL 176 480
EL 179 270
EL 173 600
EL 171 590
12 %
H.H.W.L 167,000
L.W.L 154,000
Assumed fresh rock line
Existing road
4 %
EL 167 500
PROFILE
12,000
1,500
1,000
8,000
400
4,000
750
2,750
3,000
2,650
2,300
1,400
13,400
STEEL TRUSS PART
6,400
1,600
2,350
1,800
COMPOSITE GIRDER AND PLATE GIRDER PARTS
TYPICAL CROSS SECTIONS
(View from the Laotian side)
SCALE
FOR PLAN AND PROFILE
0 100 200m
FOR CROSS SECTION
0 5 10m
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN
NONG KHAI / VIENTIANE BRIDGE PROJECT
RAIL / HIGHWAY BRIDGE
PLAN, PROFILE AND TYPICAL CROSS SECTION
NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)
DRAWN M. Shimizu
CHECKED Y. Tokunaga
SUBMITTED
APPROVED
DATE Oct 14, 1968
PLATE 3



VERTICAL SCALE

0 10 20 30m

HORIZONTAL SCALE

0 50 100 150m

LEGEND

- Loam, clay or silt and clay
- Silt
- Mud and sand
- Sand
- Sand and gravel
- Weathered siltstone
- Siltstone or shale

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

RAIL / HIGHWAY BRIDGE
GEOLOGICAL PROFILE

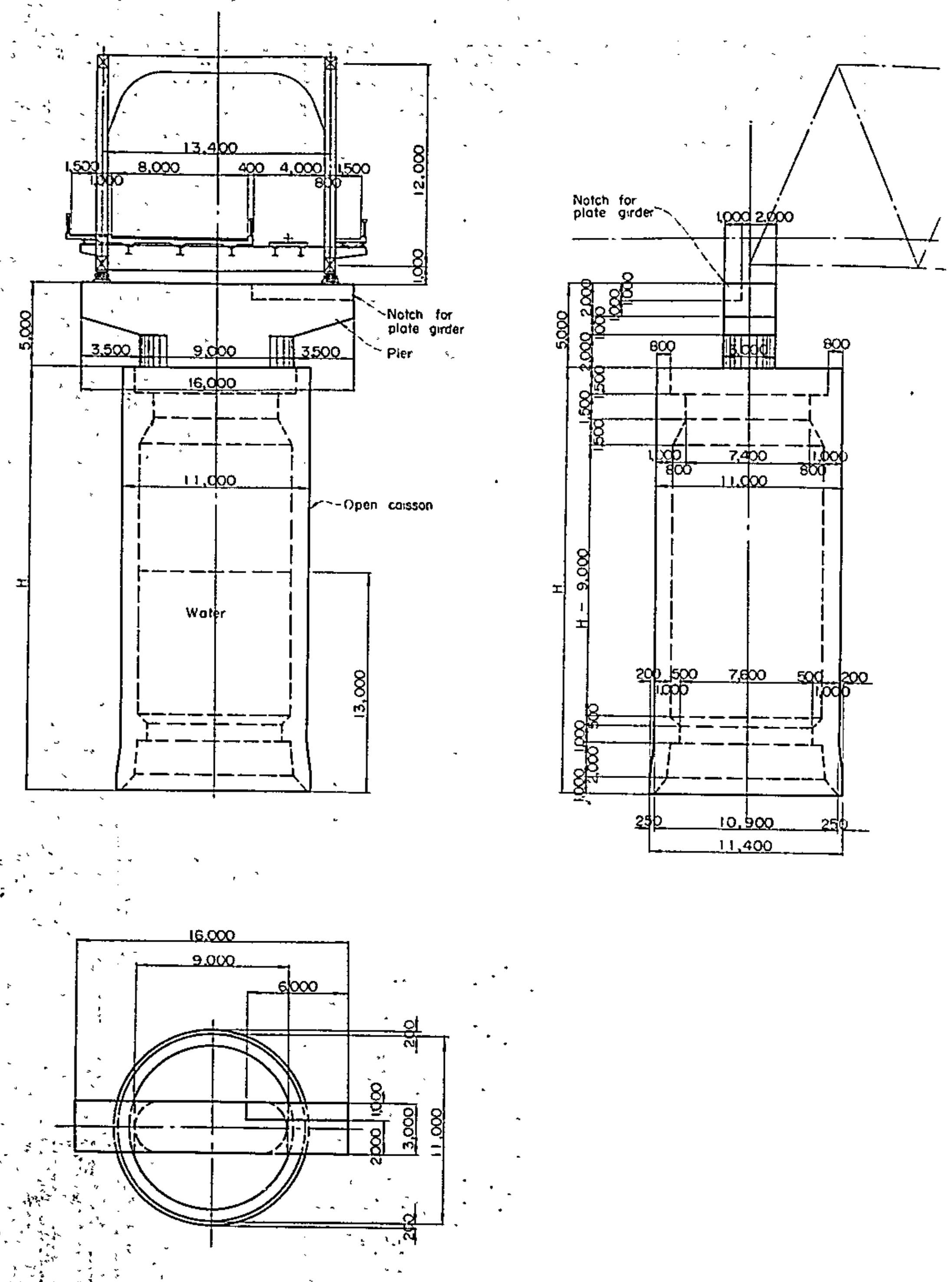
NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN
CHECKED
SUBMITTED
APPROVED

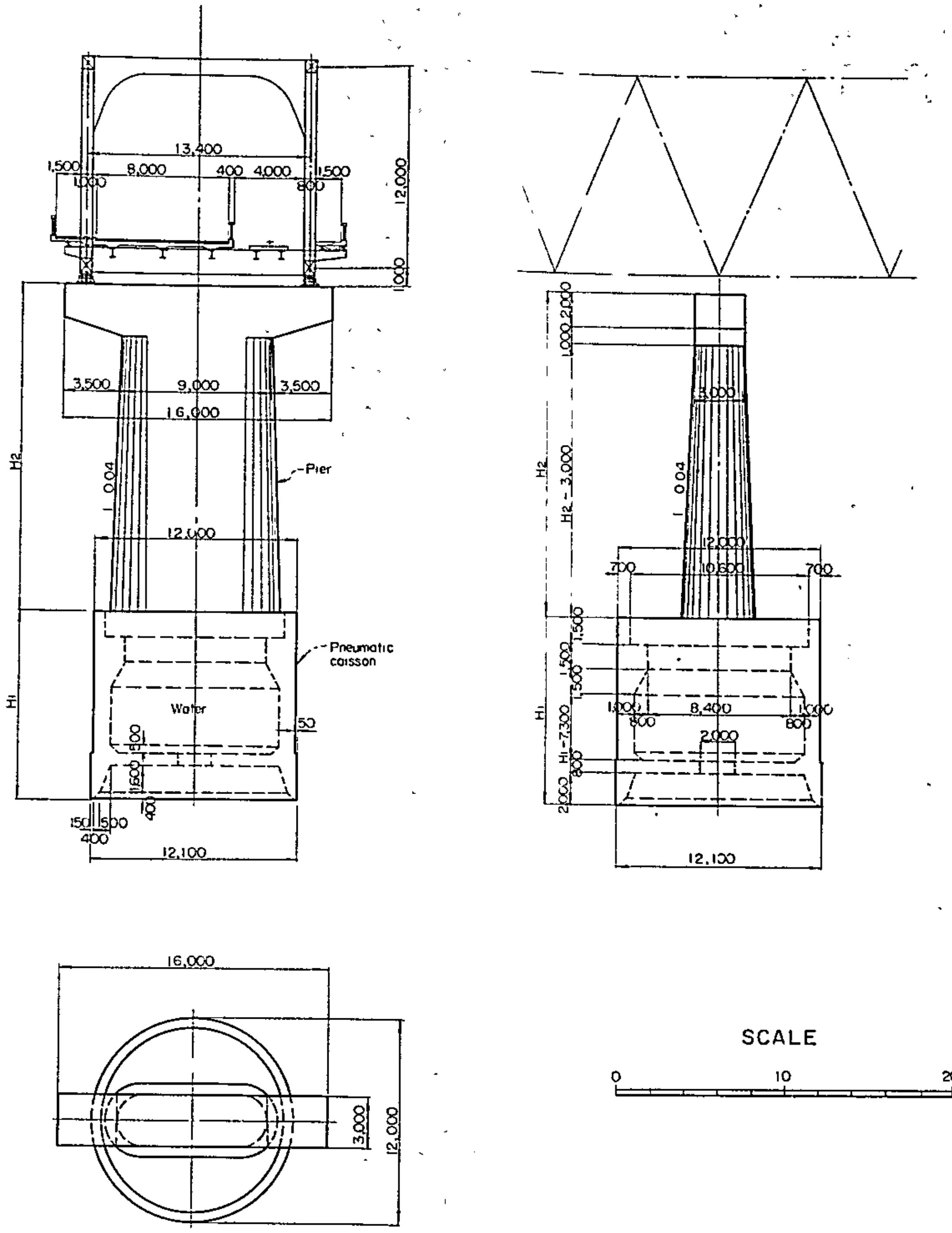
DATE Oct 14, 1968

PLATE 4

PIER AND OPEN CAISSON



PIER AND PNEUMATIC CAISSON



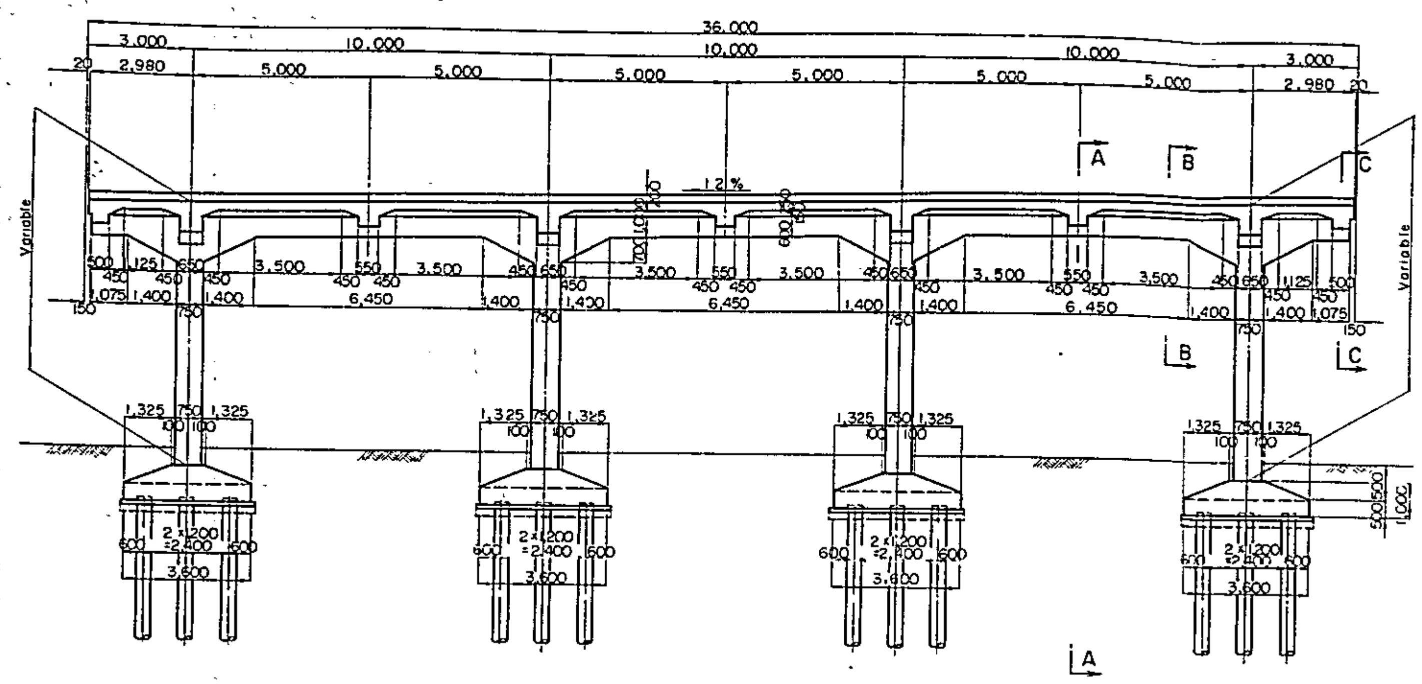
SCALE

0 10 20^{m}

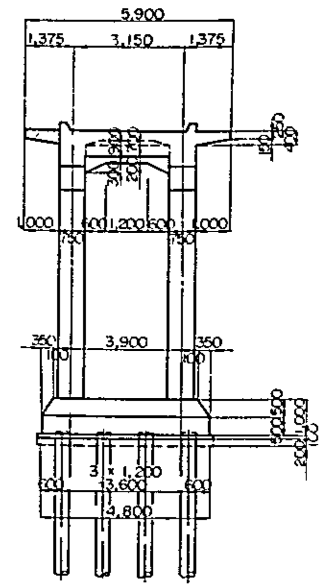
Remarks

Both open and pneumatic caissons are planned to be founded on the fresh siltstone layer, after excavation, at the depth of two meters from its top surface

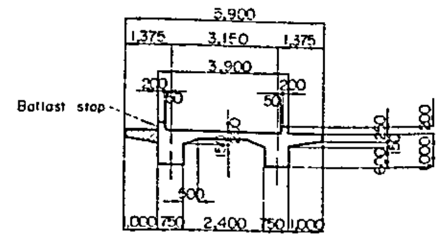
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT RAIL / HIGHWAY BRIDGE SUBSTRUCTURE NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN M. Shingawa CHECKED Y. Tokyshiga SUBMITTED APPROVED R. Yoshida	DATE Oct 14, 1968 PLATE 5



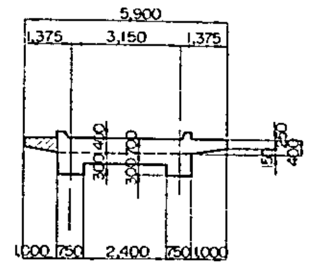
PROFILE (INTERMEDIATE PART)



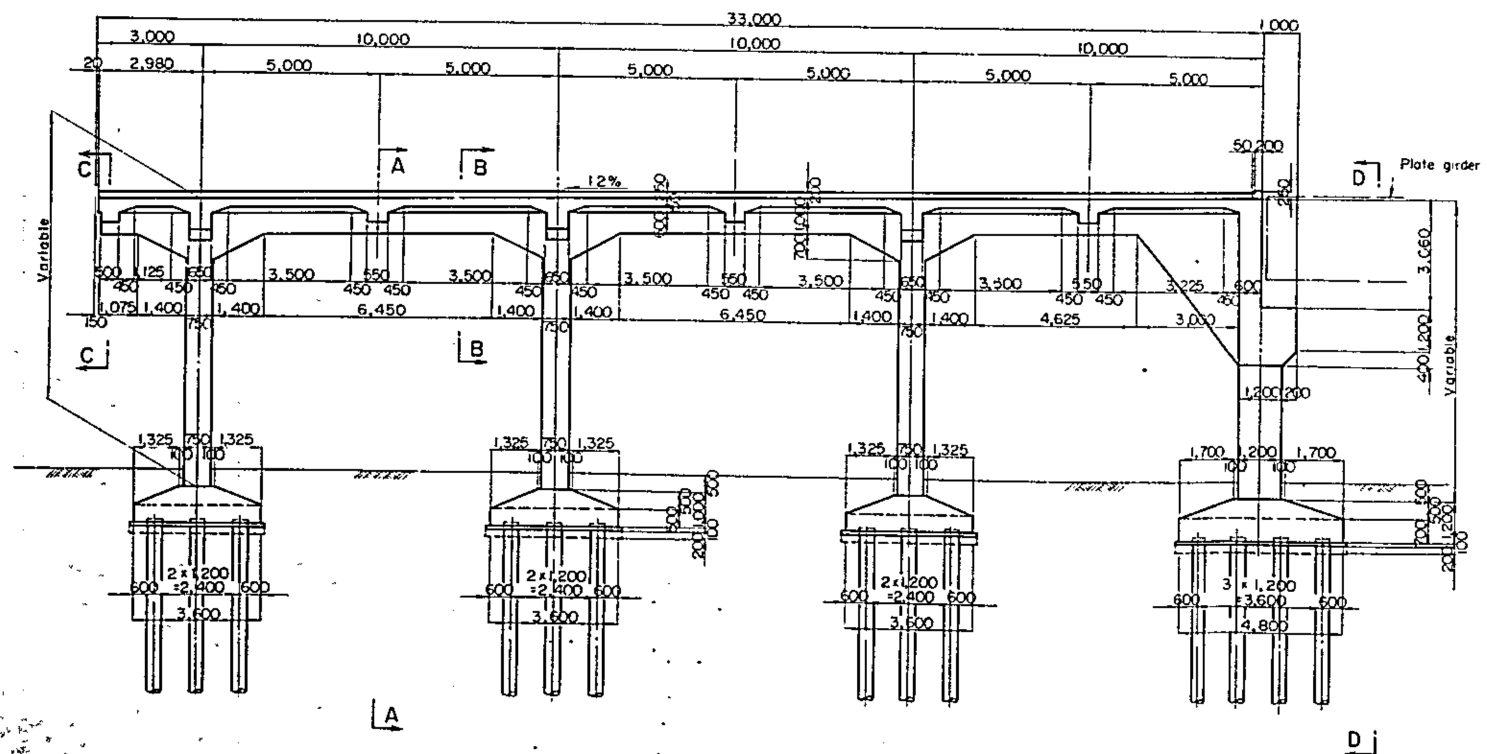
SECTION A – A



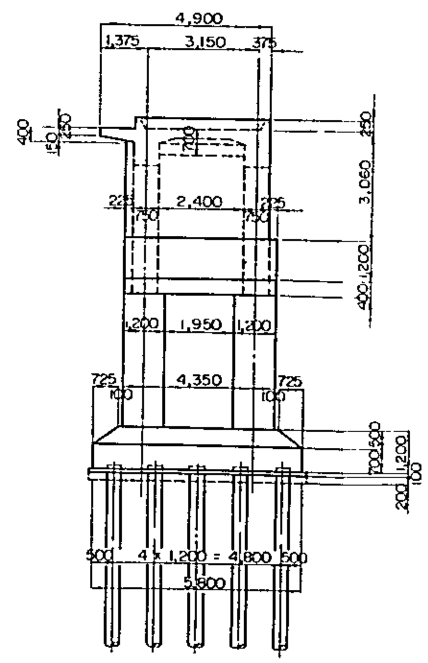
SECTION B – B



SECTION C – C



PROFILE (END PART)

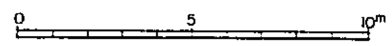


SECTION D – D

Remarks

The gangway for inspection purpose hatched on the above drawings is not provided partly on one side of the rigid frame part near the joint with the highway bridge due to the construction gage of highway

SCALE



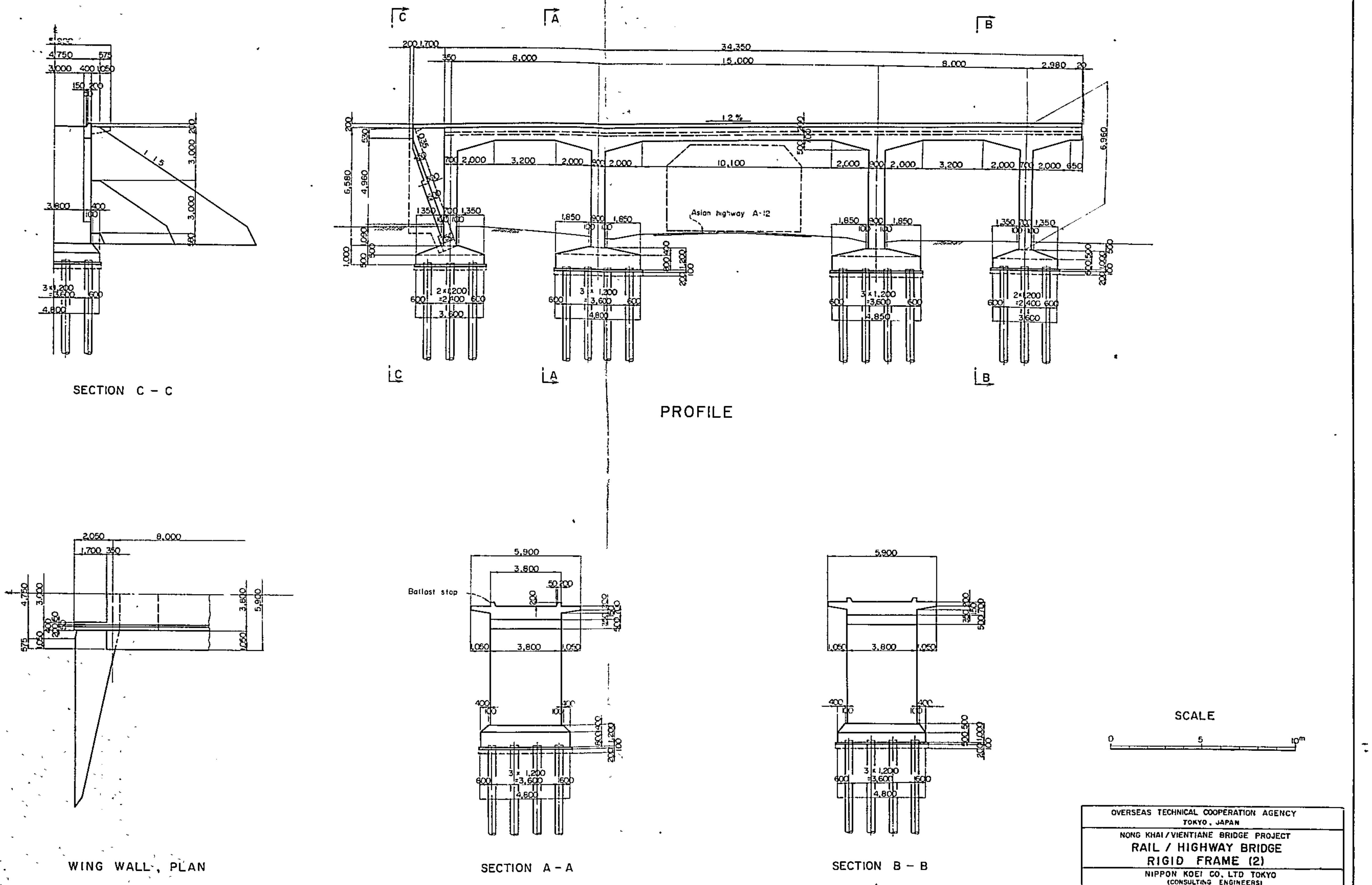
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

RAIL / HIGHWAY BRIDGE
RIGID FRAME (I)

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	M. Shingawa	DATE Oct 14, 1968
CHECKED	Y. Takeuchi	
SUBMITTED	Y. Amai	
APPROVED	R. Yoshida	PLATE 6



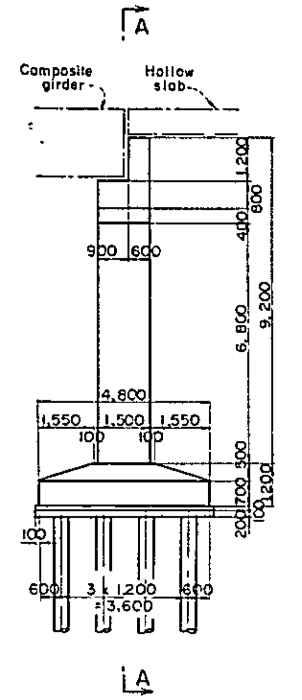
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

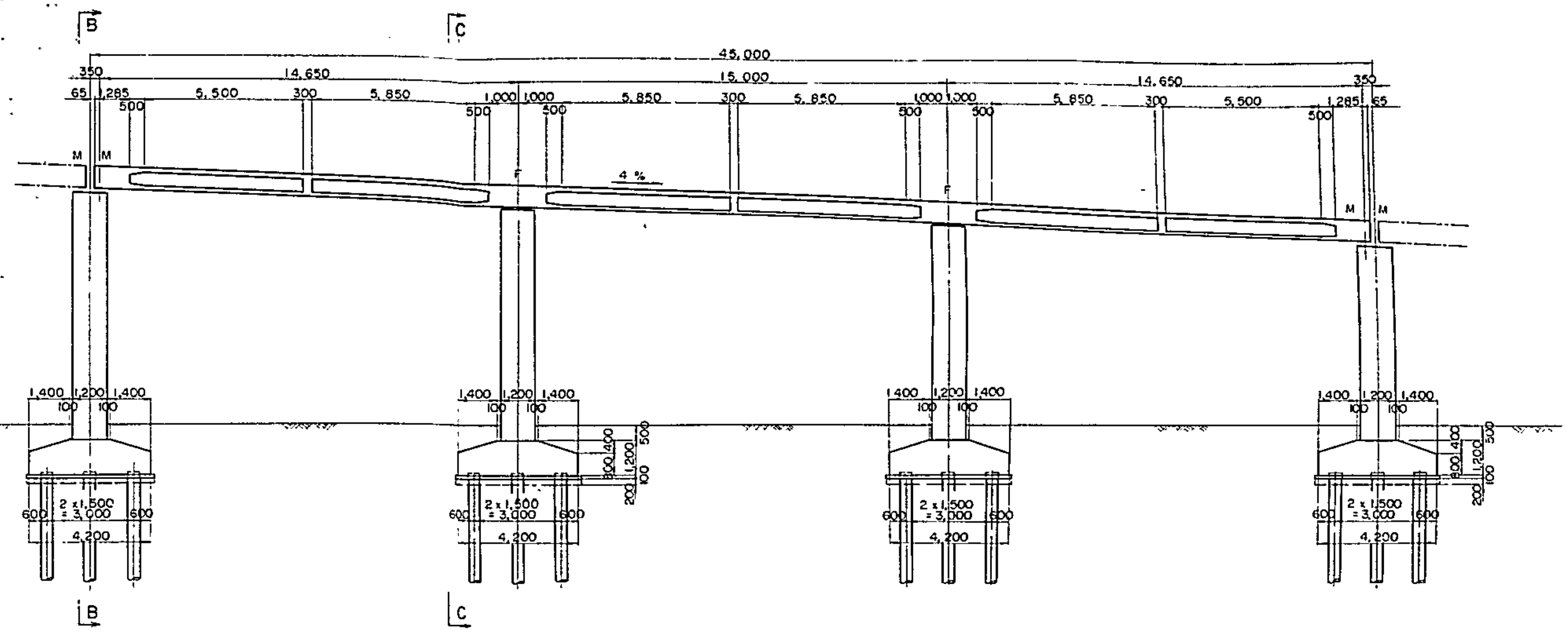
RAIL / HIGHWAY BRIDGE
RIGID FRAME (2)

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

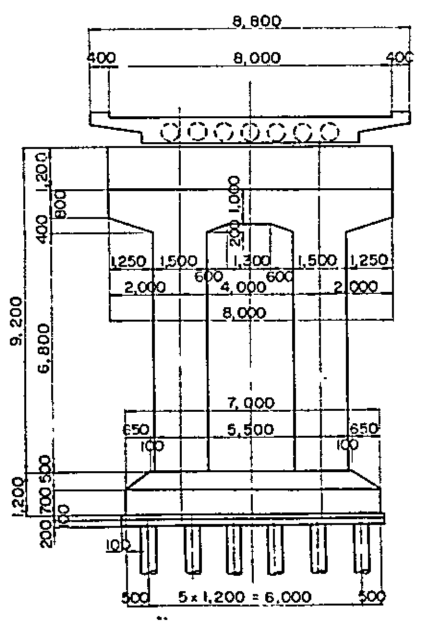
DRAWN	N. Shingawa	DATE Oct 14, 1968
CHECKED	Y. Tokushige	
SUBMITTED	U. Naoai	PLATE 7
APPROVED	R. Yoshida	



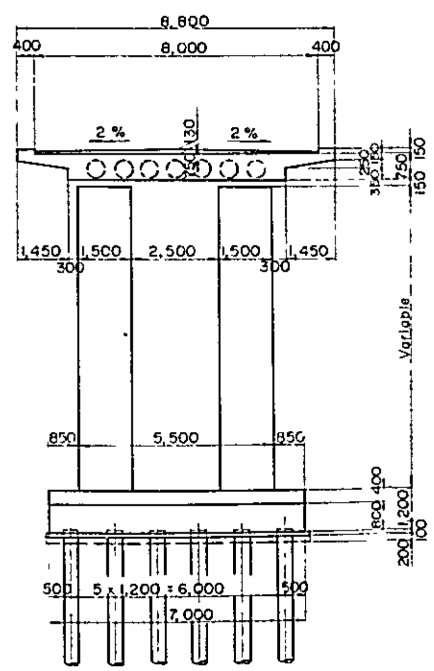
END PIER



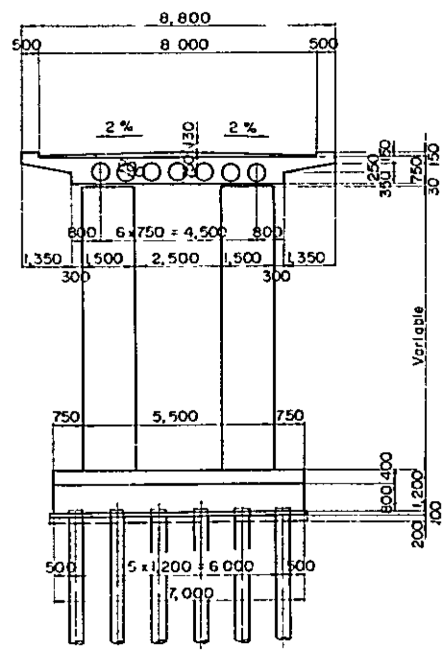
TYPICAL PROFILE



SECTION A – A

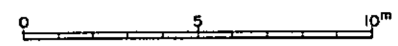


SECTION B – B



SECTION C – C

SCALE



OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

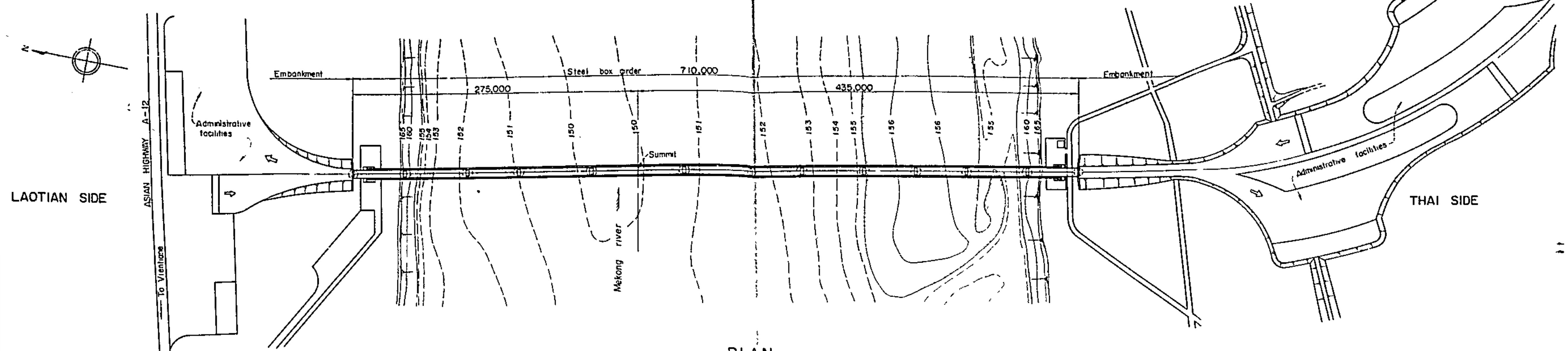
NONG KHAI / VIENTIANE BRIDGE PROJECT

RAIL / HIGHWAY BRIDGE

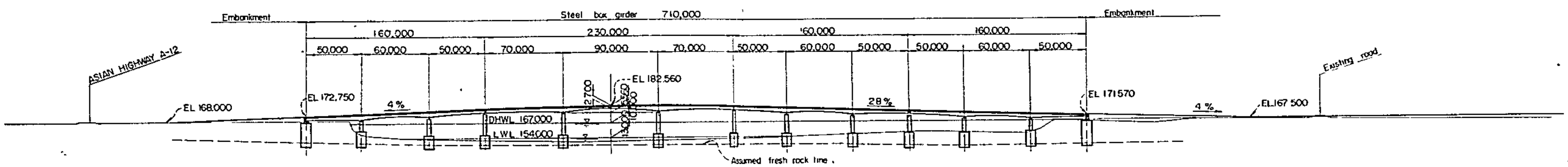
HOLLOW SLAB

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

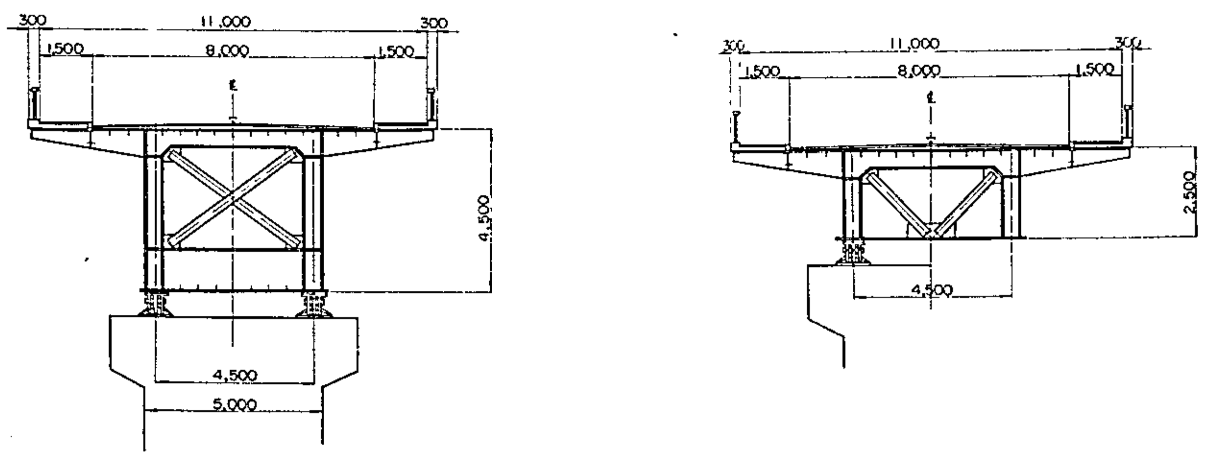
DRAWN	M. Shingawa	DATE Oct. 14, 1968
CHECKED	Y. Tokunaga	
SUBMITTED	[illegible]	PLATE 8
APPROVED	K. Yoshida	



PLAN



PROFILE



TYPICAL CROSS SECTIONS

SCALE

FOR PLAN AND PROFILE
0 100 200m

FOR CROSS SECTION
0 5 10m

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

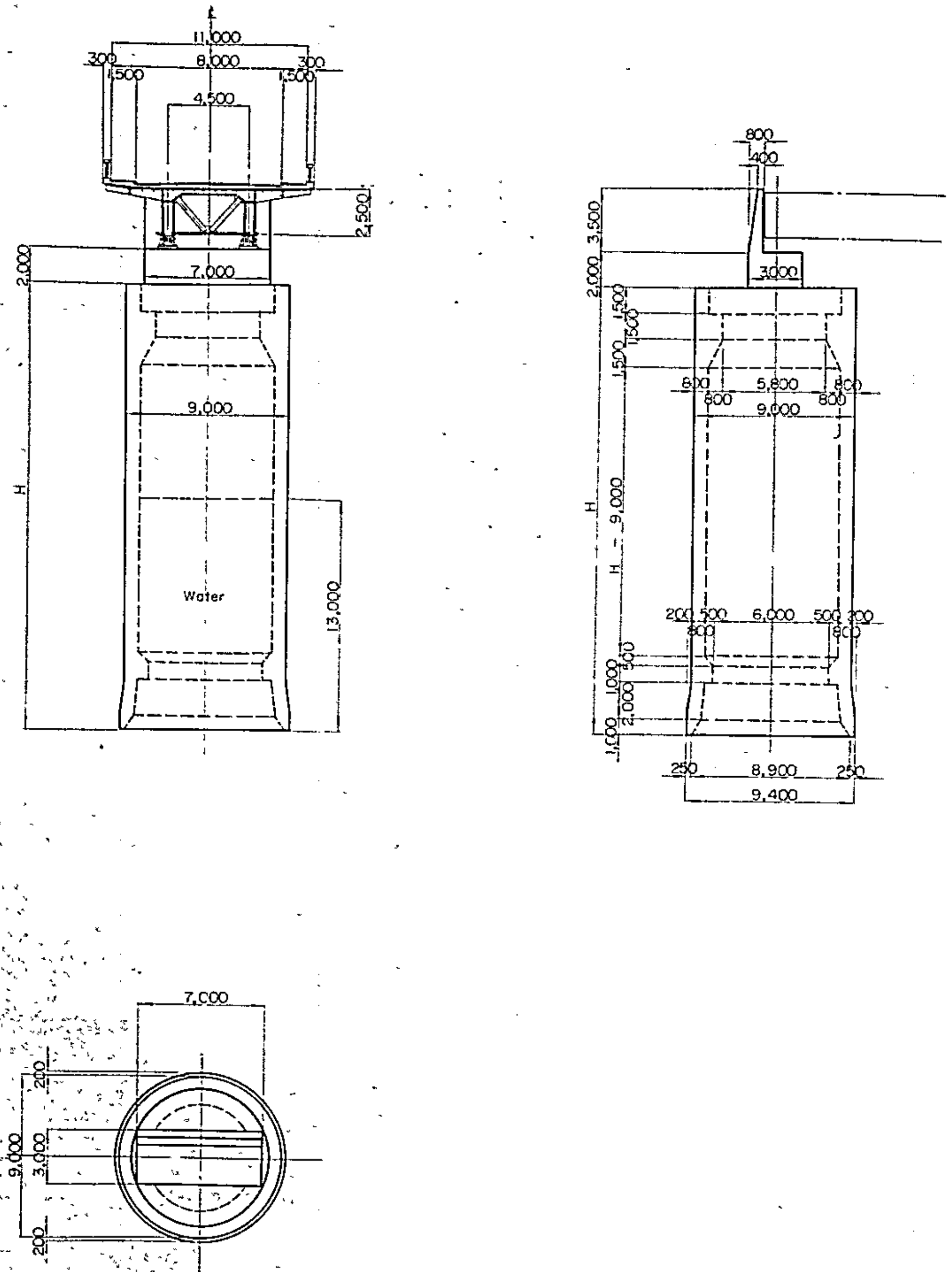
NONG KHAI / VIENTIANE BRIDGE PROJECT

HIGHWAY BRIDGE
PLAN, PROFILE AND TYPICAL CROSS SECTION

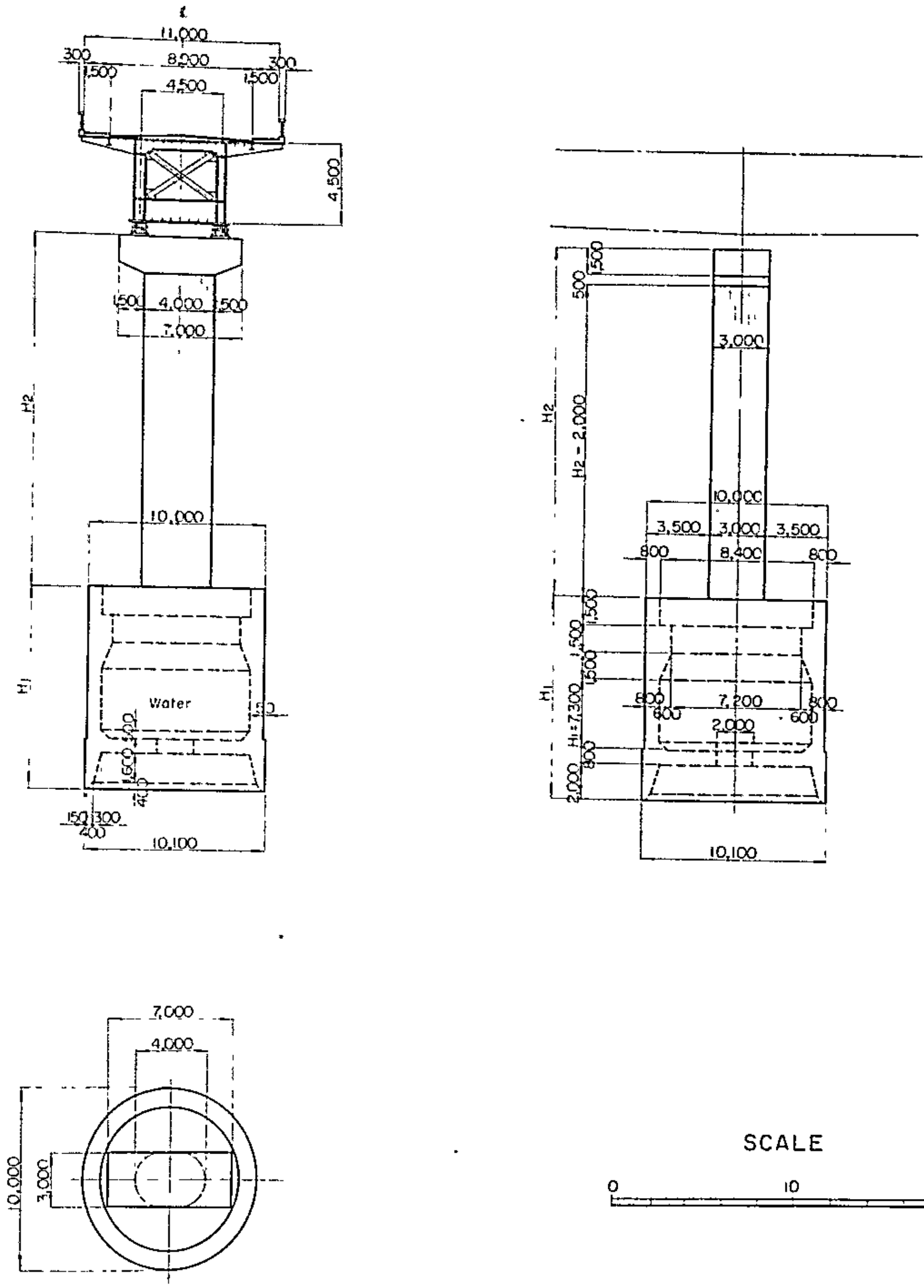
NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	M. Shingawa	DATE Oct 14, 1968
CHECKED	Y. Tokudaga	
SUBMITTED		PLATE 9
APPROVED	R. Yoshida	

PIER AND OPEN CAISSON



PIER AND PNEUMATIC CAISSON



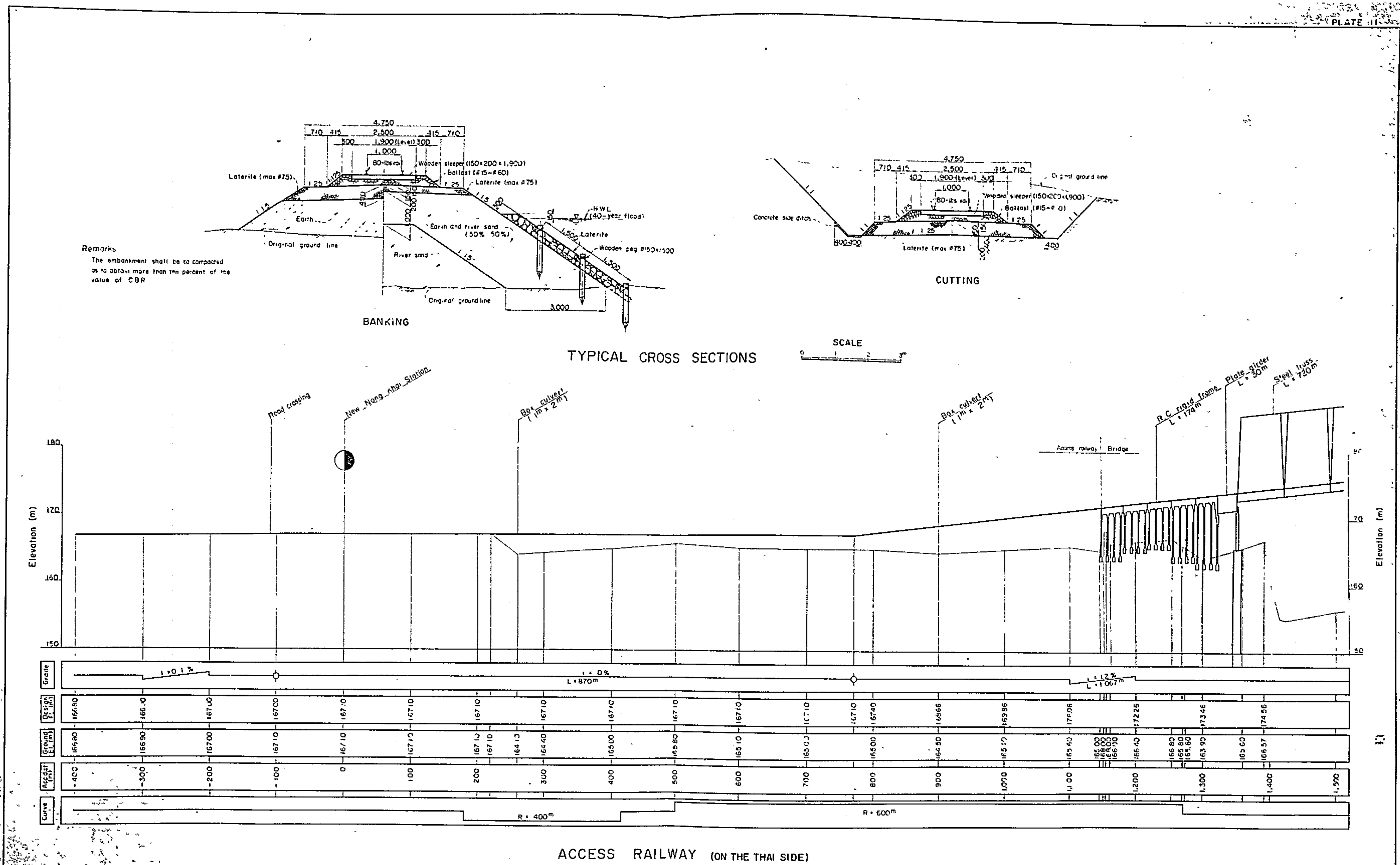
SCALE

0 10 20m

Remarks

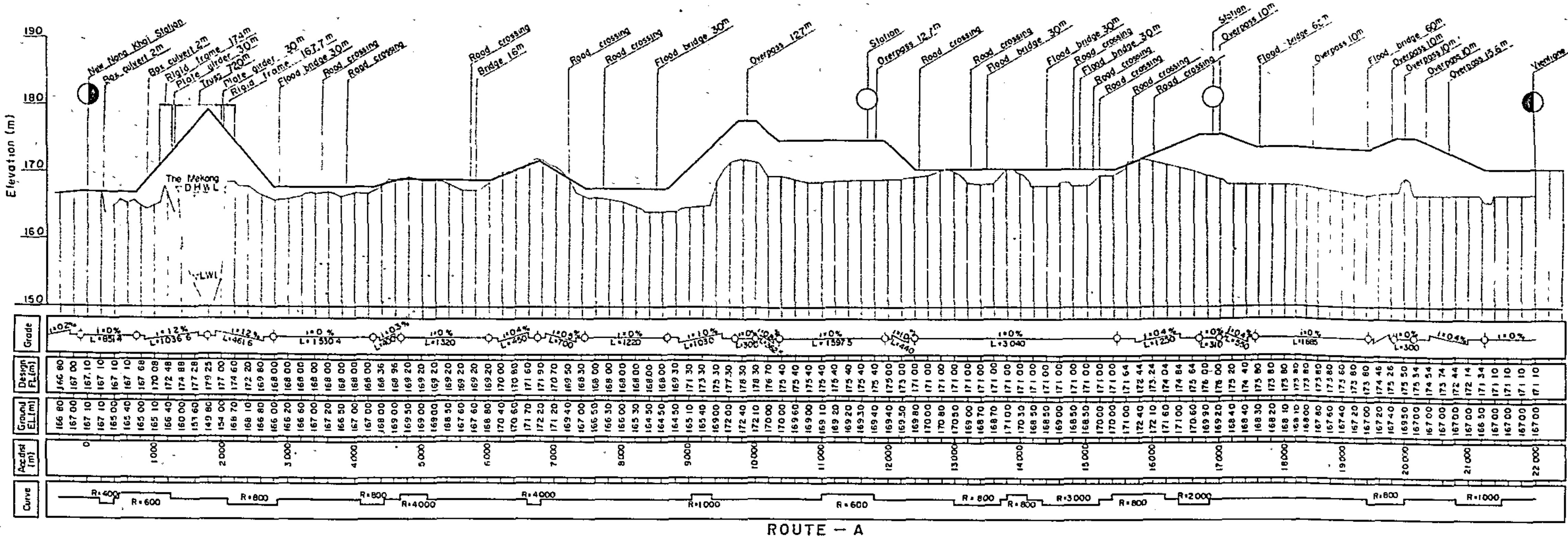
Both open and pneumatic caissons are planned to be founded on the fresh siltstone layer, after excavation, at the depth of two meters from its top surface

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI/VIENTIANE BRIDGE PROJECT HIGHWAY BRIDGE SUBSTRUCTURE	
NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN / CHECKED / SUBMITTED / APPROVED	DATE Oct. 14, 1968
	PLATE 10

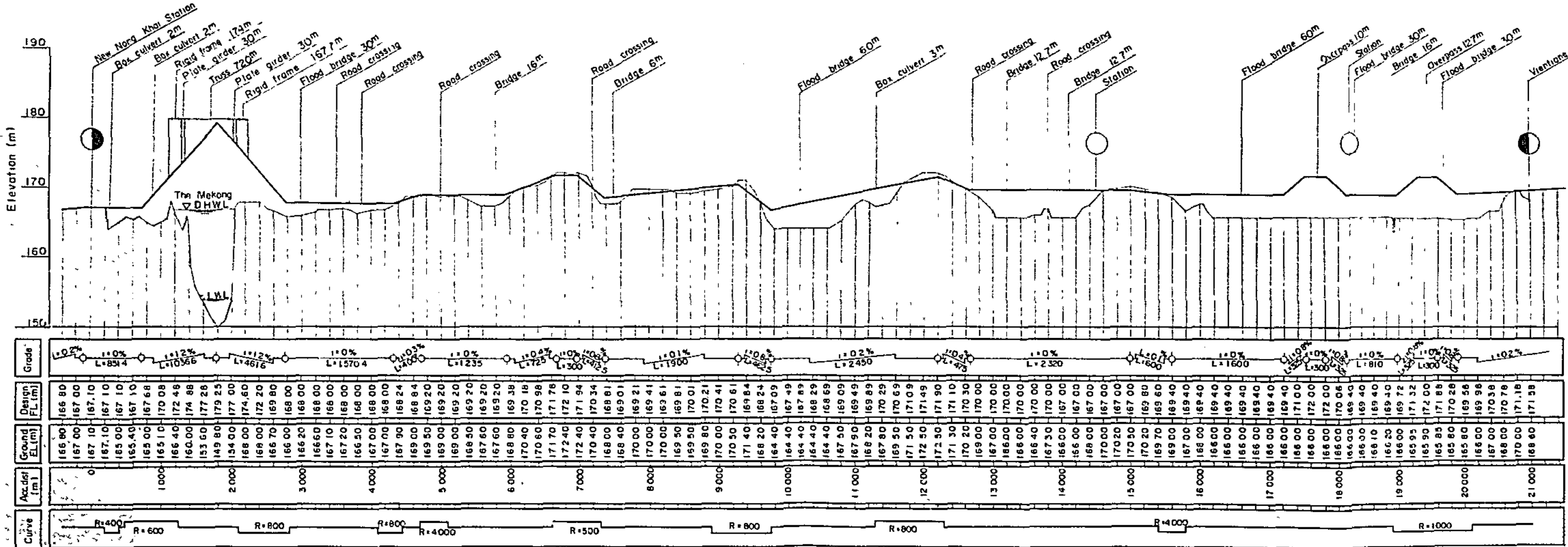


OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN
NONG KHAI / VIENTIANE BRIDGE PROJECT
RAILWAY TYPICAL CROSS SECTION AND PROFILE (1)
NIPPON KOEI CO. LTD TOKYO (CONSULTING ENGINEERS)

DRAWN	M. Shinzawa	DATE Oct. 14, 1968
CHECKED	Y. Tokudaga	
SUBMITTED	[illegible]	PLATE 11
APPROVED	R. Yoshida	



ROUTE — A



ROUTE — B

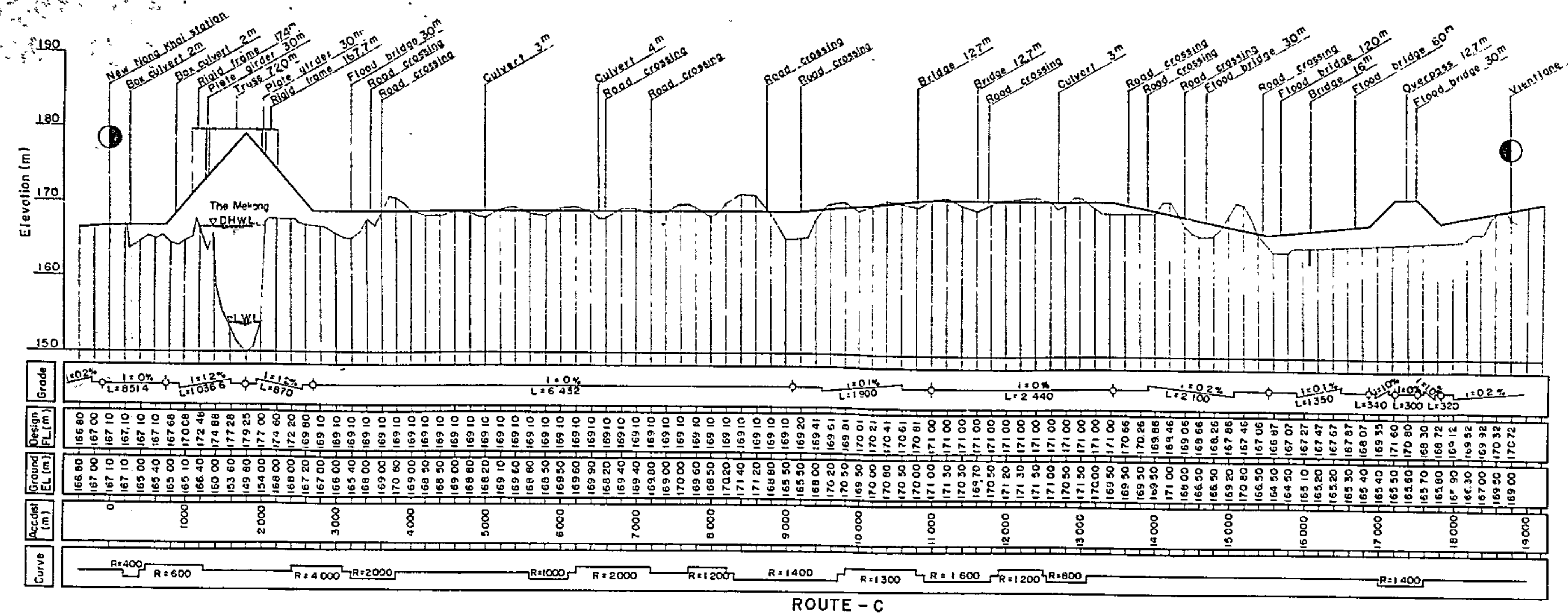
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

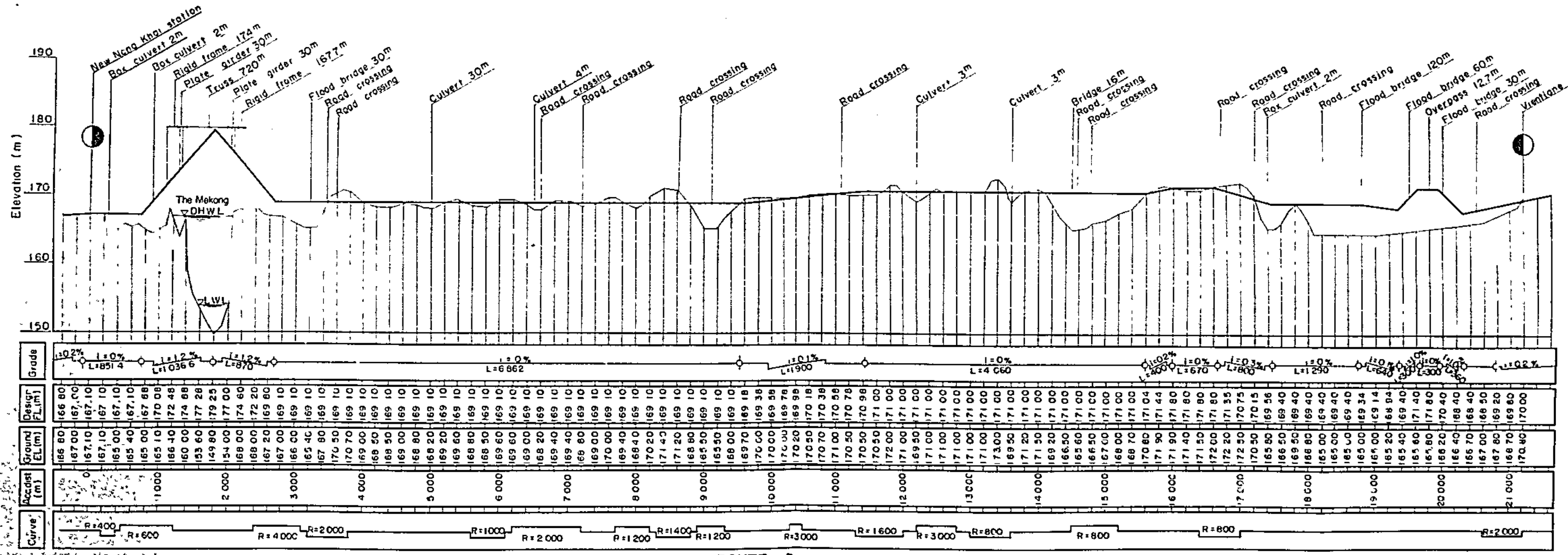
RAILWAY, PROFILE (2)

NIPPON KOEI CO LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	M. Shimizu	DATE Oct 14, 1968
CHECKED	Y. Tokunaga	
SUBMITTED	Y. Imai	PLATE 12
APPROVED	R. Yoshida	

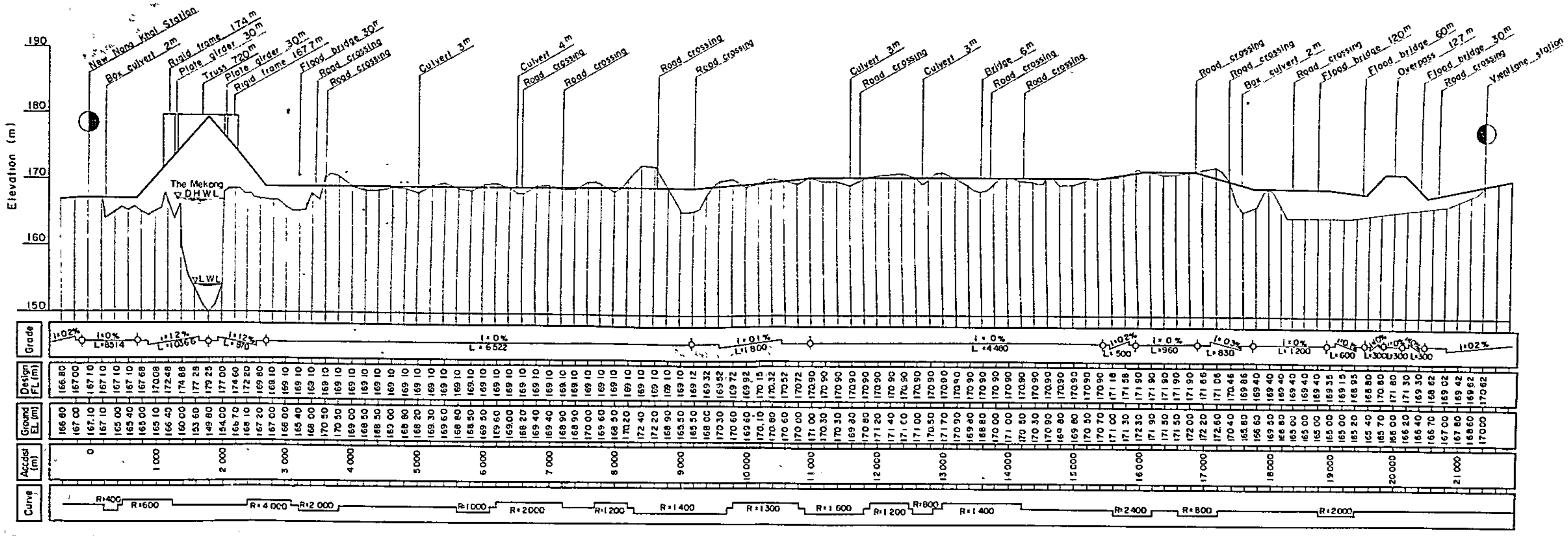


ROUTE - C



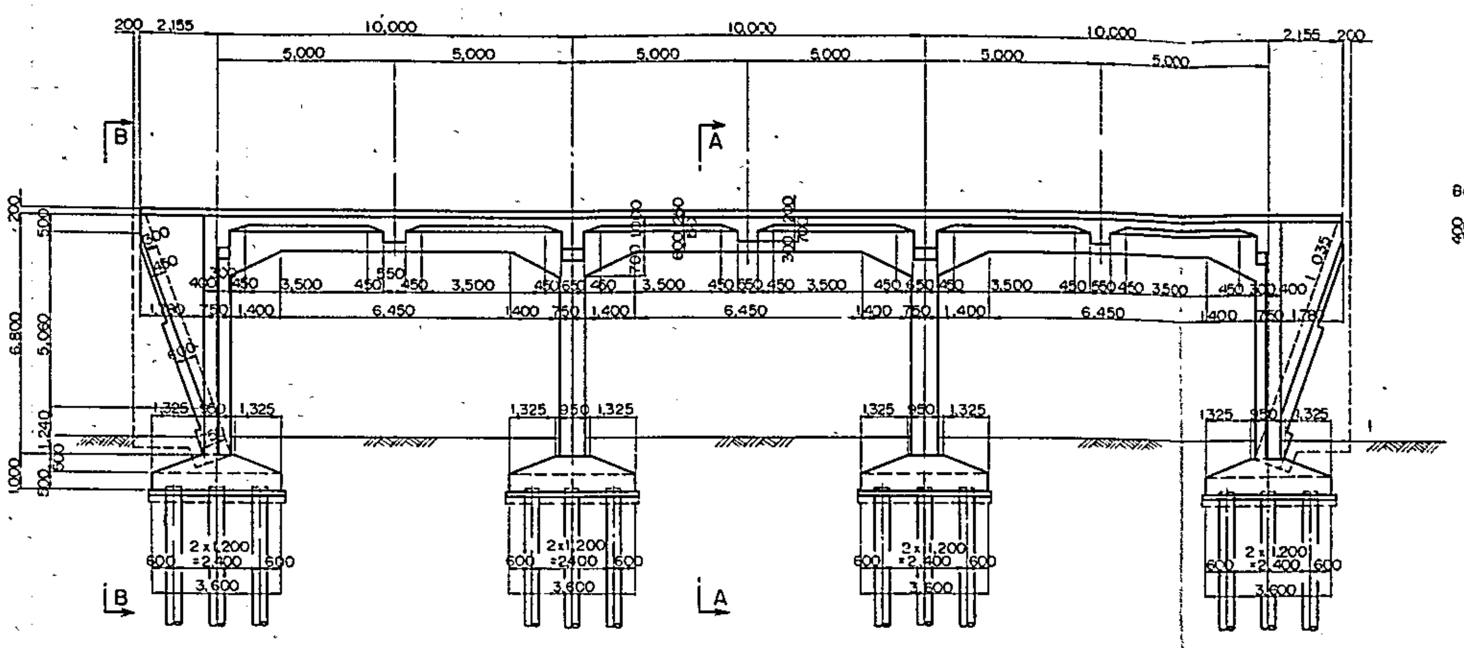
ROUTE - D

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
RAILWAY, PROFILE (3)	
NIPPON KOEI CO. LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN M. Shingawa	DATE Oct 14 1968
CHECKED Y. Takashige	
SUBMITTED [illegible]	PLATE 13
APPROVED R. Yoshida	



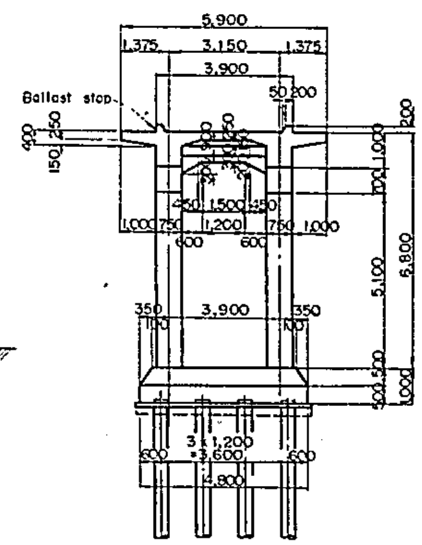
ROUTE — C·D

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN
NONG KHAI / VIENTIANE BRIDGE PROJECT
RAILWAY . PROFILE (4)
NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)
DRAWN M. Shinzawa
CHECKED Y. Tokunaga — DATE Oct 14, 1968
SUBMITTED Y. [signature]
APPROVED R. Yoshida — PLATE 14

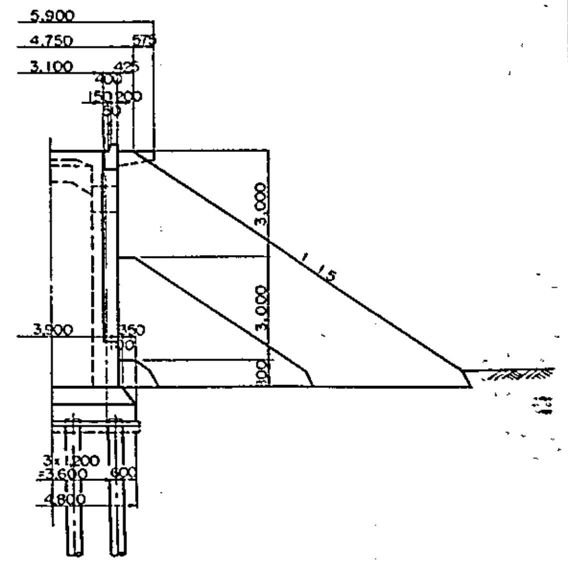


PROFILE

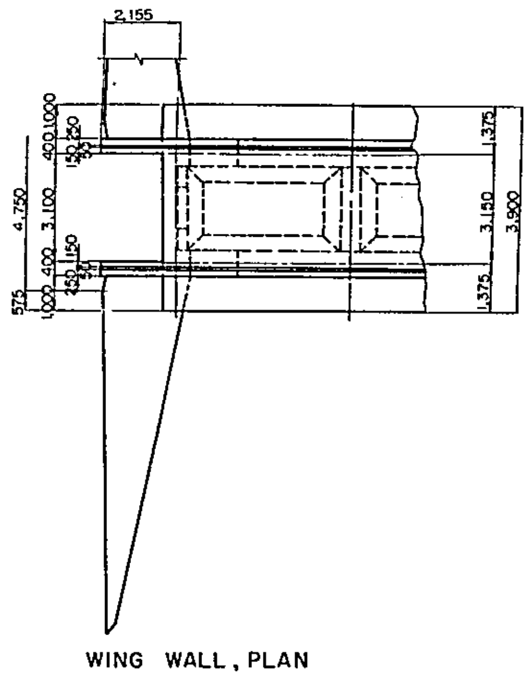
RIGID FRAME



SECTION A - A



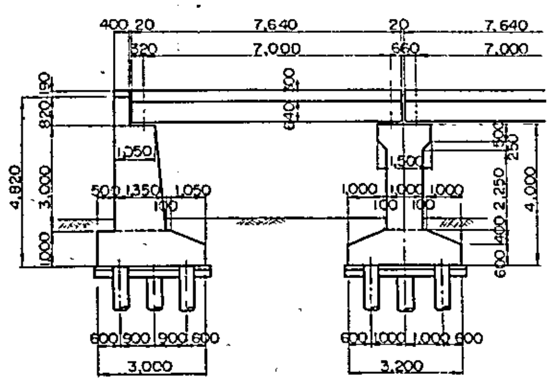
SECTION B - B



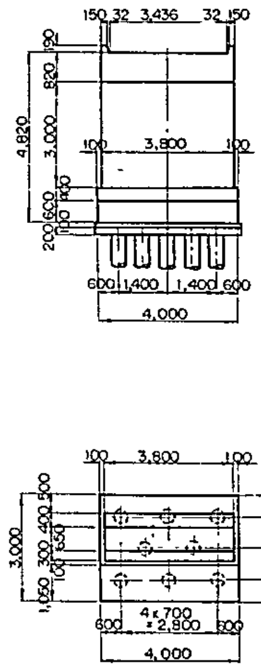
WING WALL, PLAN

SCALE

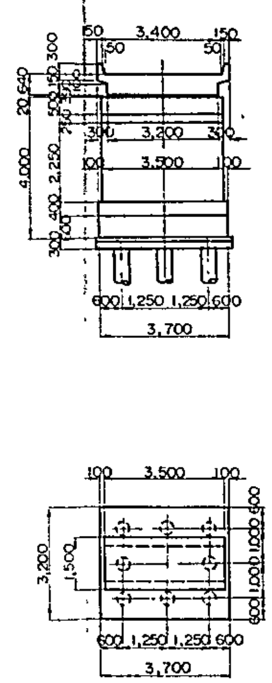
0 5 10m



PROFILE



ABUTMENT



PIER

SLAB BRIDGE

Remarks

In the case that a flood bridge spans over 60 meters or 120 meters in total, the design of typical rigid frame shown on PLATE 6 will be applied to the flood bridge making level the longitudinal slope instead of 12%

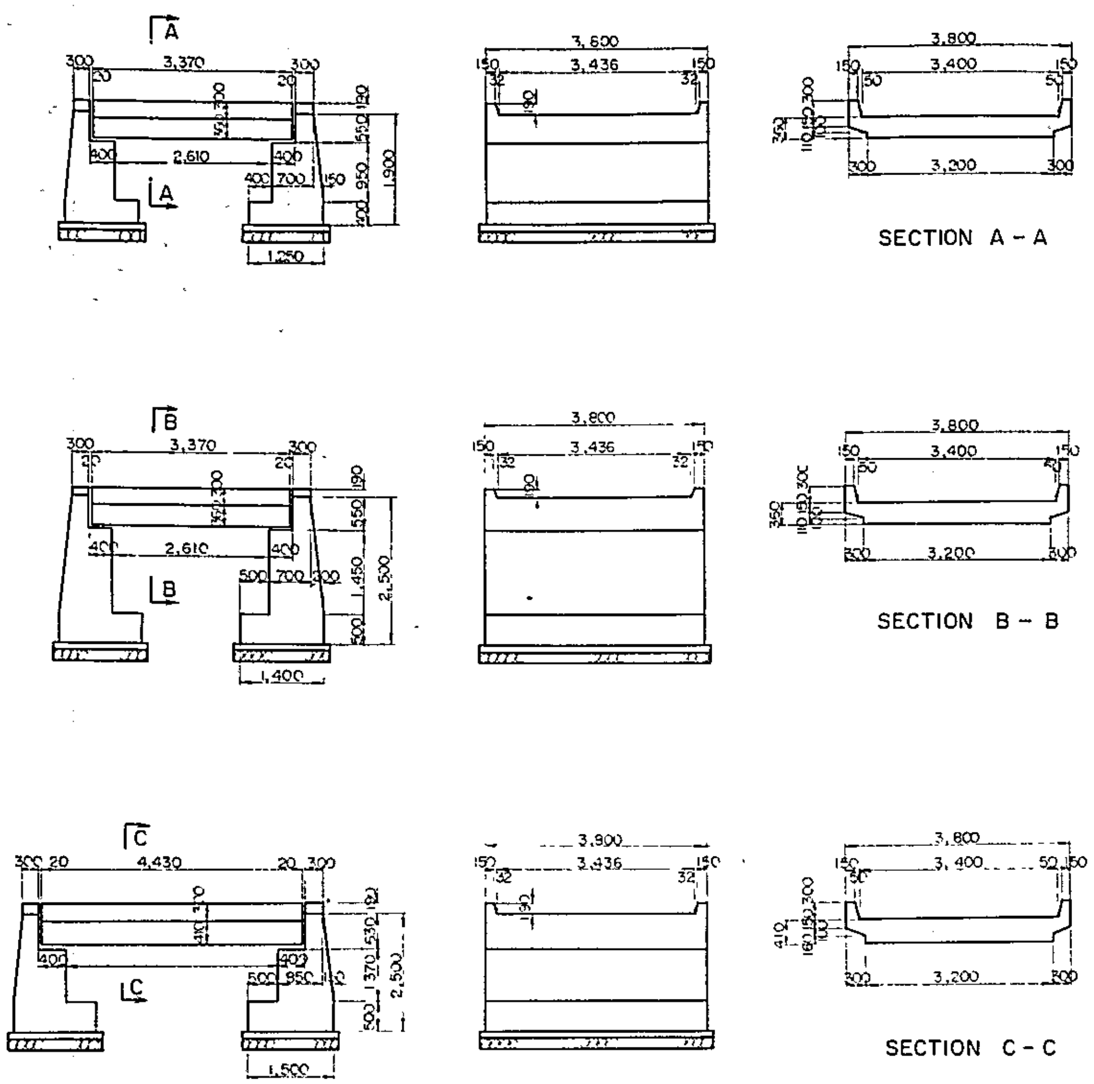
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

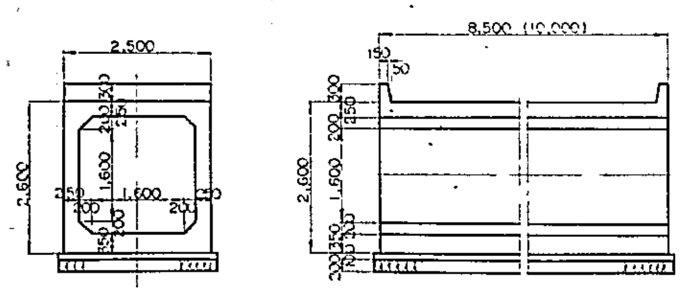
RAILWAY FLOOD BRIDGES

NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

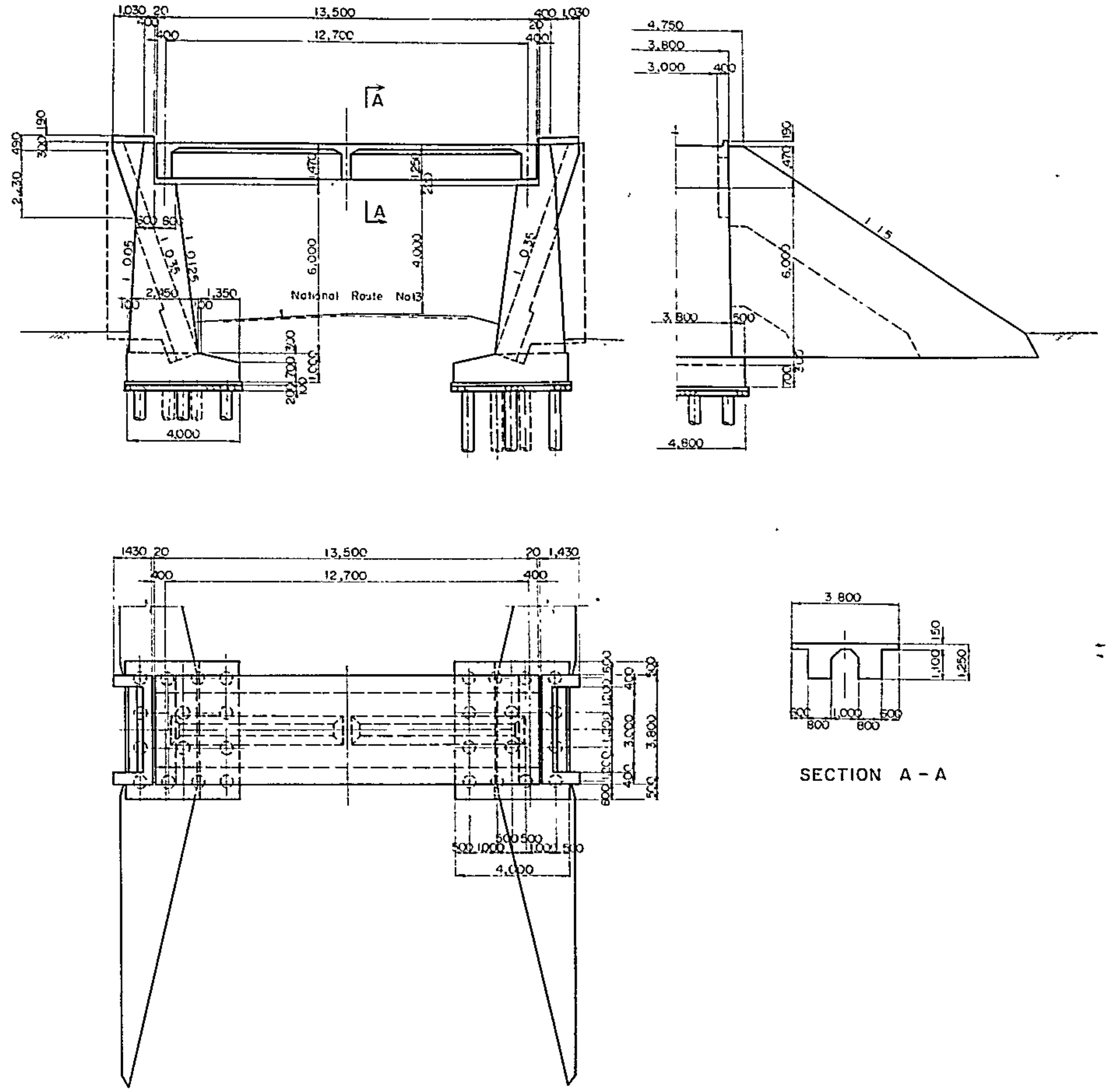
DRAWN	M. Shinzawa	DATE Oct. 14, 1968
CHECKED	Y. Tokunaga	
SUBMITTED	[illegible]	PLATE 15
APPROVED	R. Yoshida	



CULVERT



BOX CULVERT



OVERPASS

SCALE

FOR CULVERT 0 5m

FOR OVERPASS 0 5 10m

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO , JAPAN

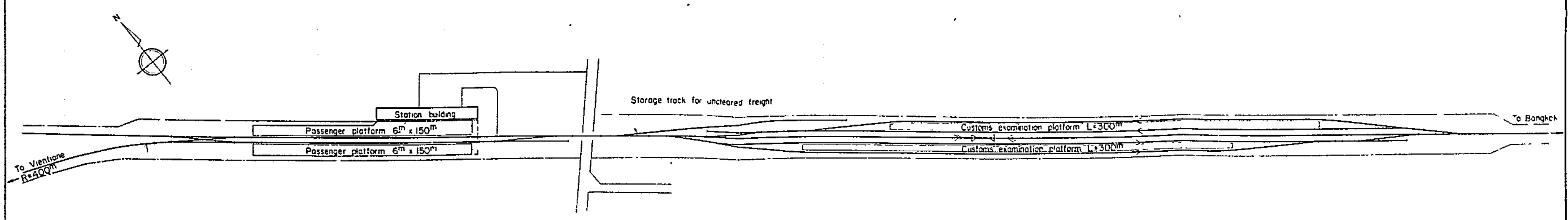
NONG KHAI / VIENTIANE BRIDGE PROJECT

RAILWAY

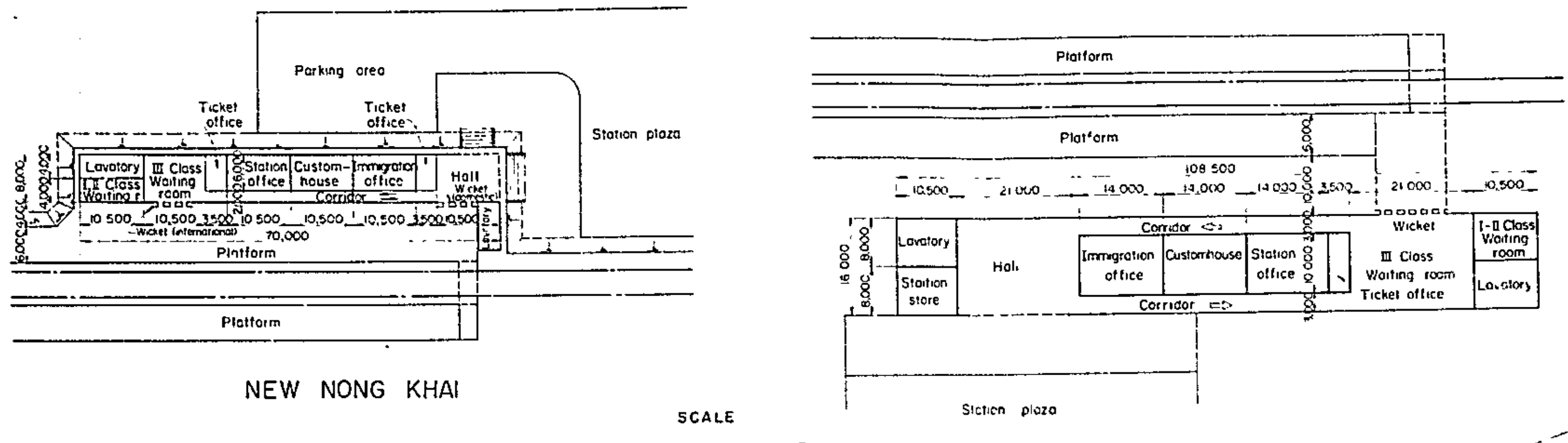
CULVERT AND OTHERS

NIPPON KOEI CO LTD TOKYO
(CONSULTING ENGINEERS)

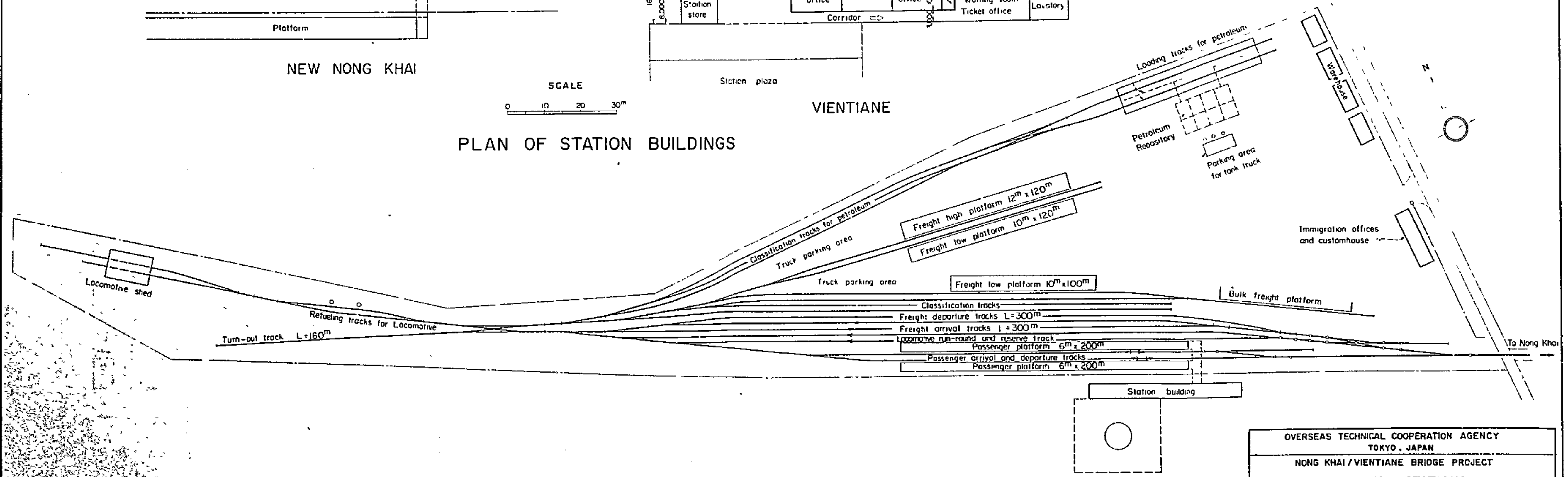
DRAWN	M. Shimizu	DATE Oct 14, 1968
CHECKED	Y. Tokunaga	
SUBMITTED	Y. Okusai	PLATE 16
APPROVED	B. Yoshida	



LAYOUT OF NEW NONG KHAI STATION



PLAN OF STATION BUILDINGS



LAYOUT OF VIENTIANE STATION

SCALE
0 50 100m

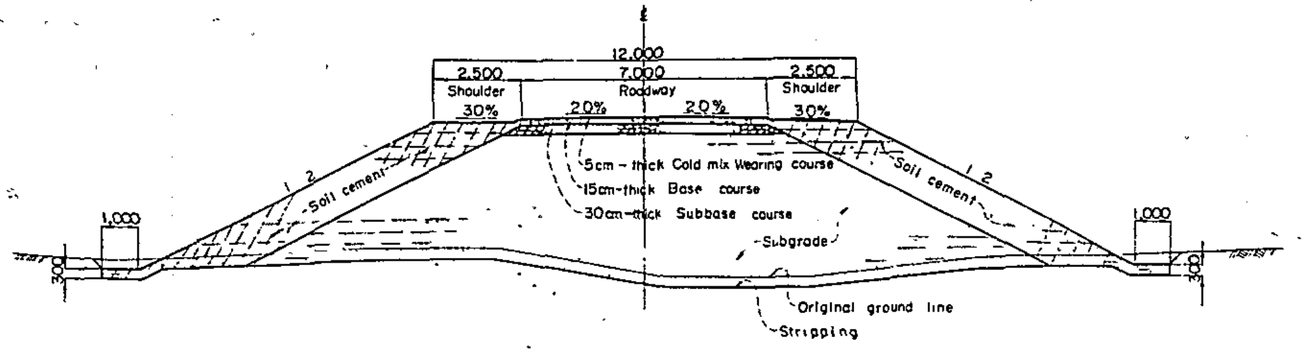
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

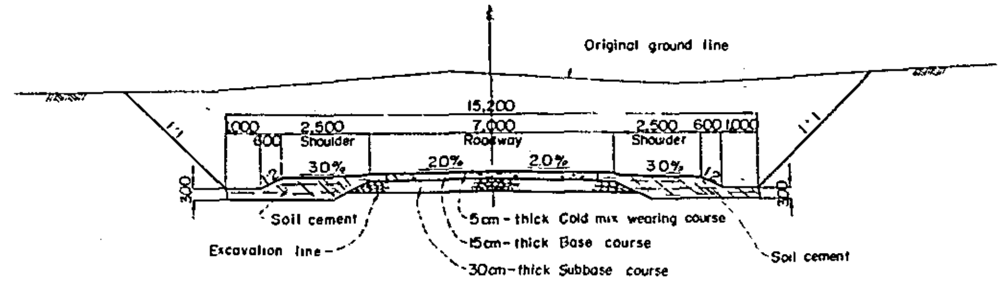
RAILWAY, STATIONS

NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	M. Shinzawa	DATE Oct 14, 1968
CHECKED	Y. Tokunaga	
SUBMITTED	[signature]	PLATE 17
APPROVED	R. Yoshida	



BANKING



CUTTING

SCALE

0 5 10m

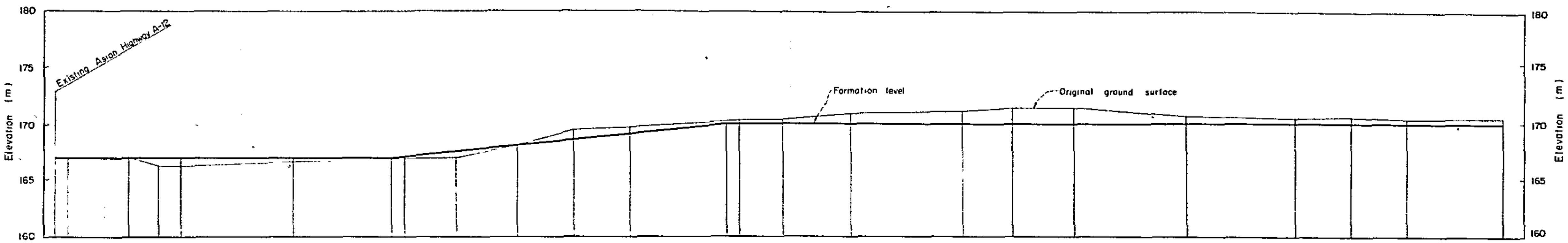
Remarks Each embankment layer shall be so provided as to obtain the value of C B R shown in the following

(1) Base course 80 to 90 (%)

(2) Subbase course 20 to 30 (")

(3) Subgrade 5 to 10 (")

TYPICAL CROSS SECTIONS



Grade: i = 0 %, L = 300; i = 1.0 %, L = 300; i = 0 %, L = 1,900

Station No	Acc. dist (m)	Ground EL (m)	Design FL (m)
T.00	0	167.00	167.00
T 0	1200	167.00	167.00
0-1	6600	167.10	
0-2	9200	166.30	
T 1	11200	166.35	167.00
T 2	21200	166.90	167.00
	30000	166.90	167.00
T 3	31200		167.12
3-1	35600	167.00	
T 4	41200	168.10	168.12
4-1	46200	169.40	
T 5	51200	169.60	169.12
	60000		170.00
T 6	61200	170.35	170.00
6-1	65014	170.40	170.00
T 7	71200	170.88	170.00
T 8	81200	171.15	170.00
8-1	85657	171.40	170.00
T 9	91200	171.41	170.00
T 10	101200	170.71	170.00
T 11	111200	170.51	170.00
11-1	116200	170.60	170.00
T 12	121200	170.49	170.00
	130000		

Curve: R = 500 I A = 74° 30' 00"; R = 500 I A = 35° 00' 00"

PROFILE

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

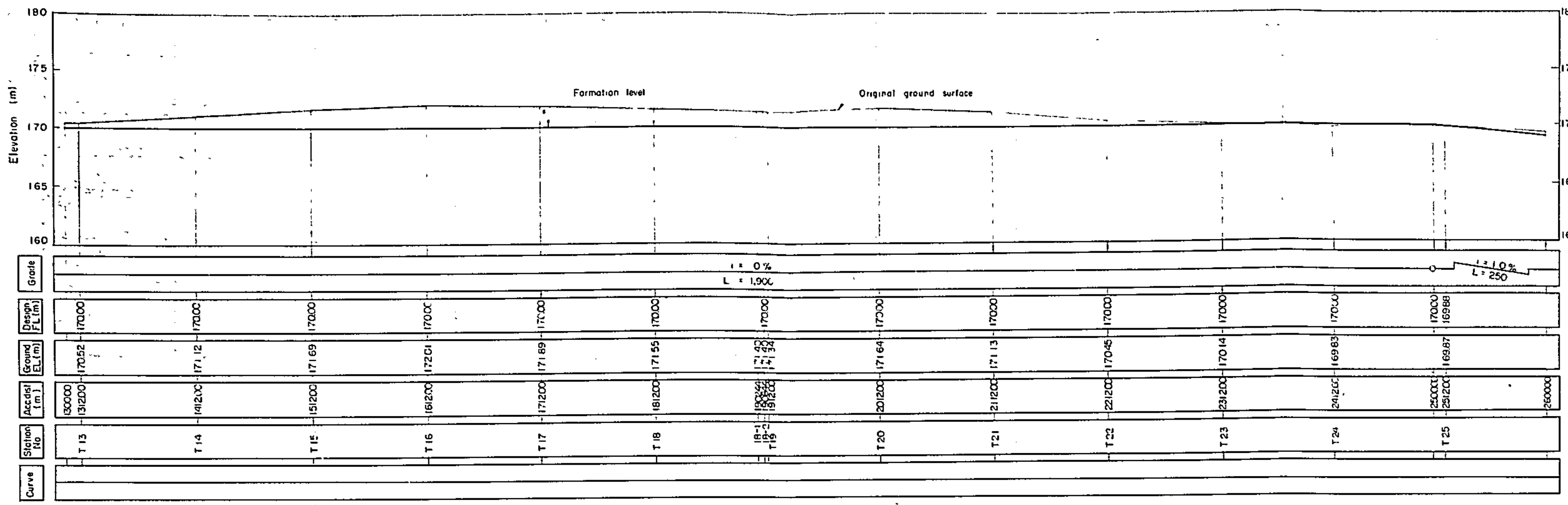
NONG KHAI / VIENTIANE BRIDGE PROJECT

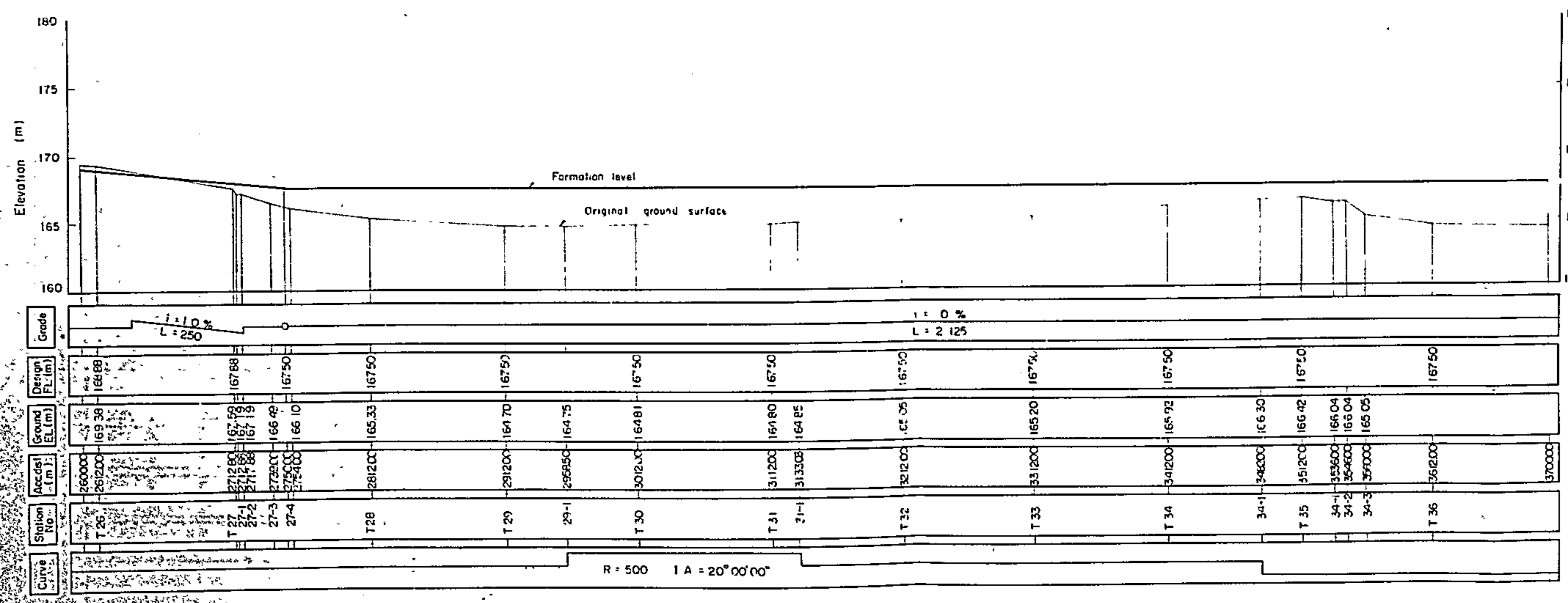
HIGHWAY

TYPCAL CROSS SECTION AND PROFILE (1)

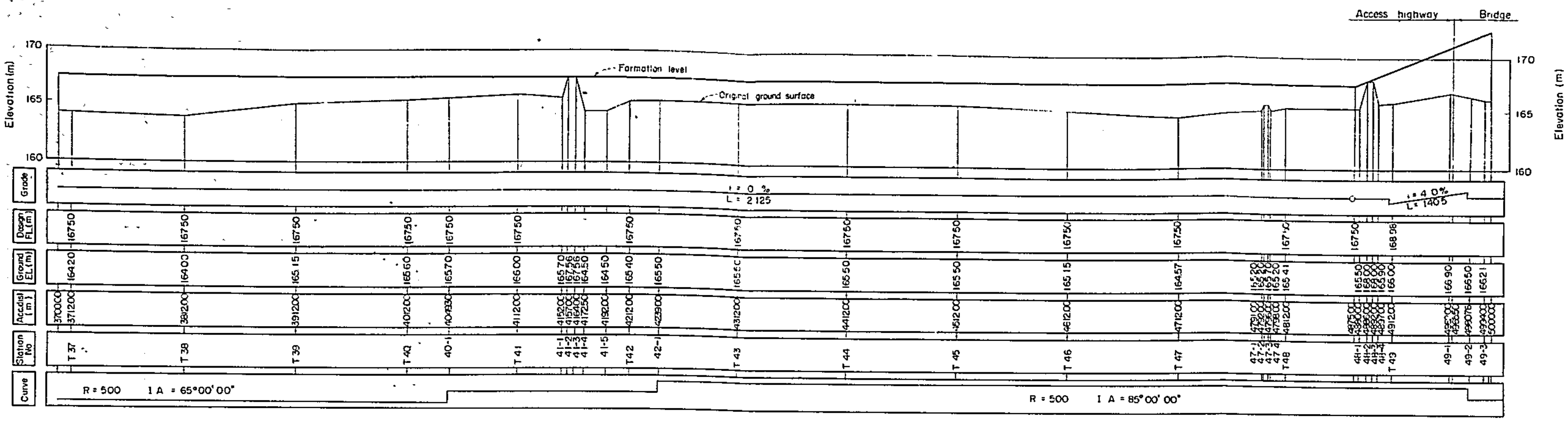
NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

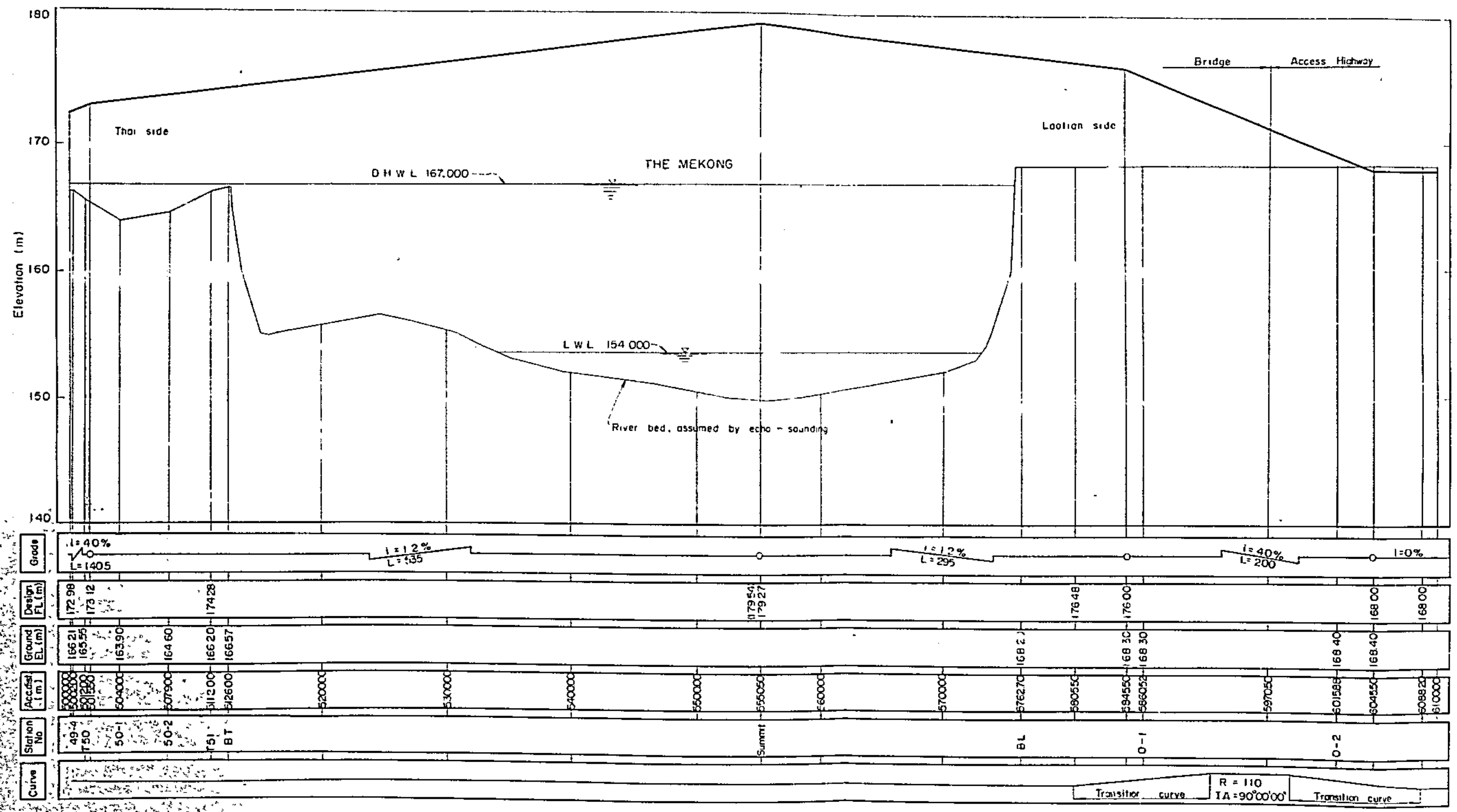
DRAWN	H. Ikeda		
CHECKED	Y. Tokunaga	DATE	Oct 14, 1968
SUBMITTED	[signature]		
APPROVED	K. Yoshida	PLATE	18





OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
HIGHWAY. PROFILE (2)	
NIPPON KOEI CO LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN H. Ikeda CHECKED Y. Tokunaga SUBMITTED [illegible] APPROVED R. Yoshida	DATE Oct 14, 1968 PLATE 19





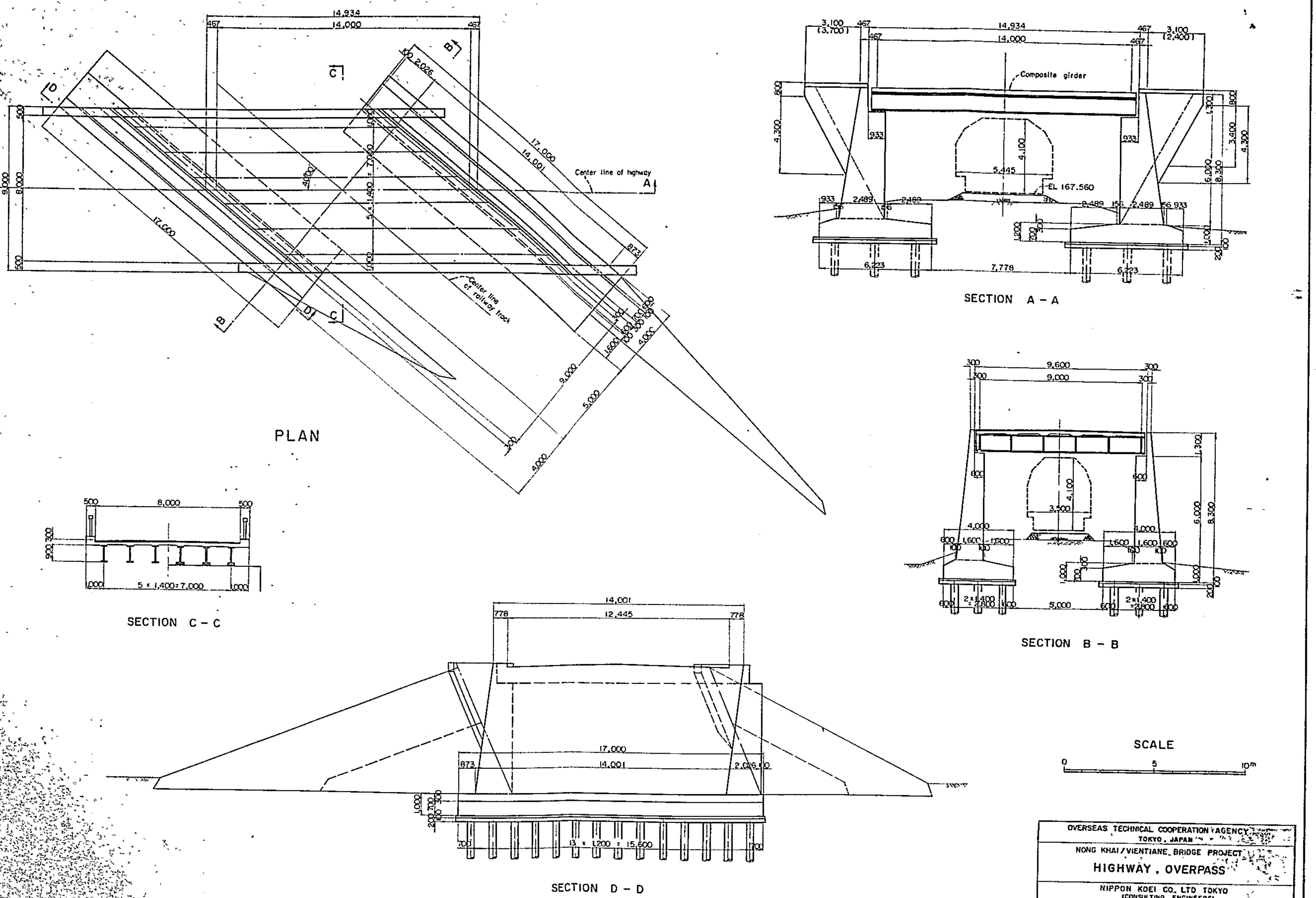
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI/VIENTIANE BRIDGE PROJECT

HIGHWAY, PROFILE (3)

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN		DATE Oct 14, 1968
CHECKED		
SUBMITTED		PLATE 20
APPROVED		



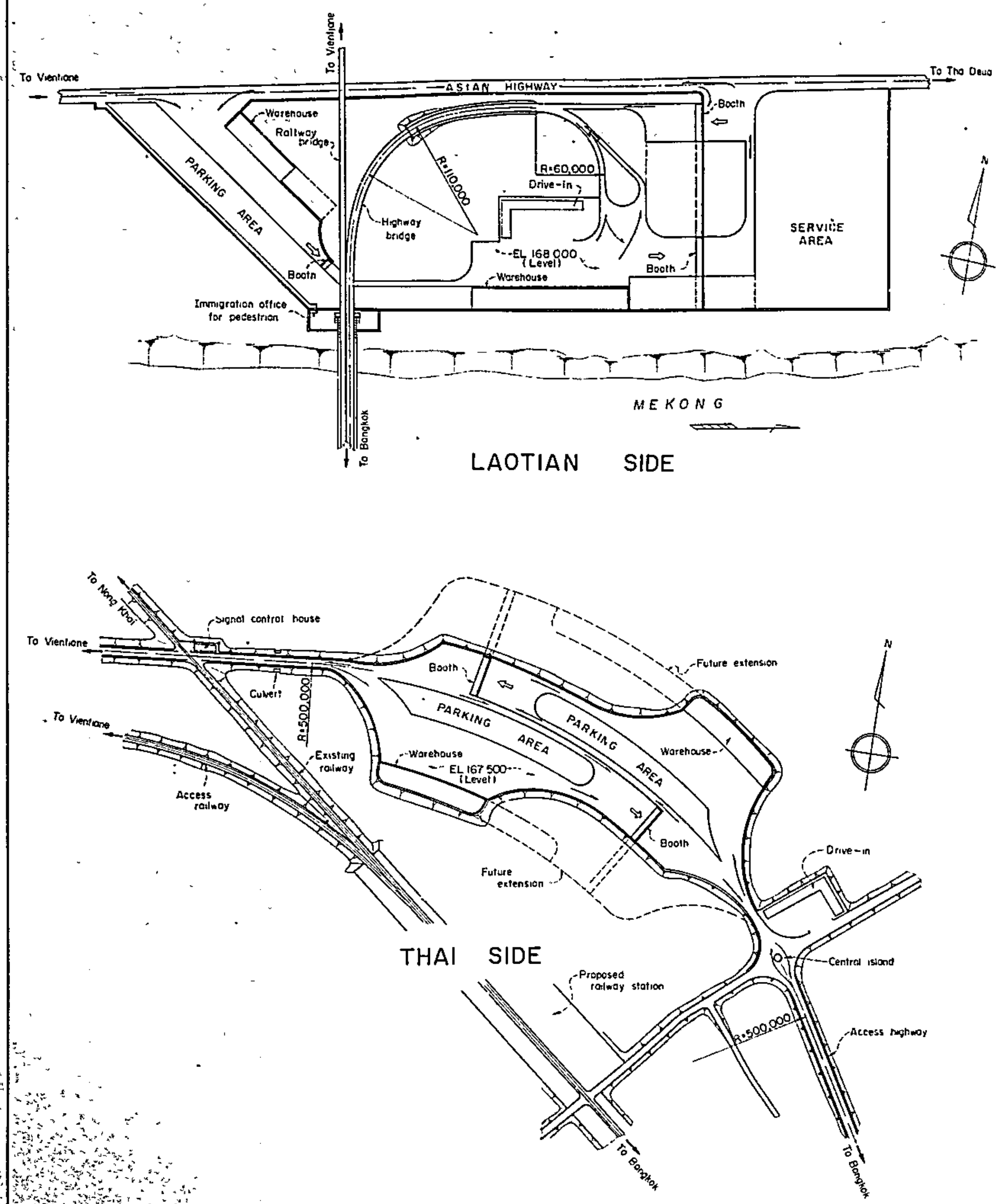
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

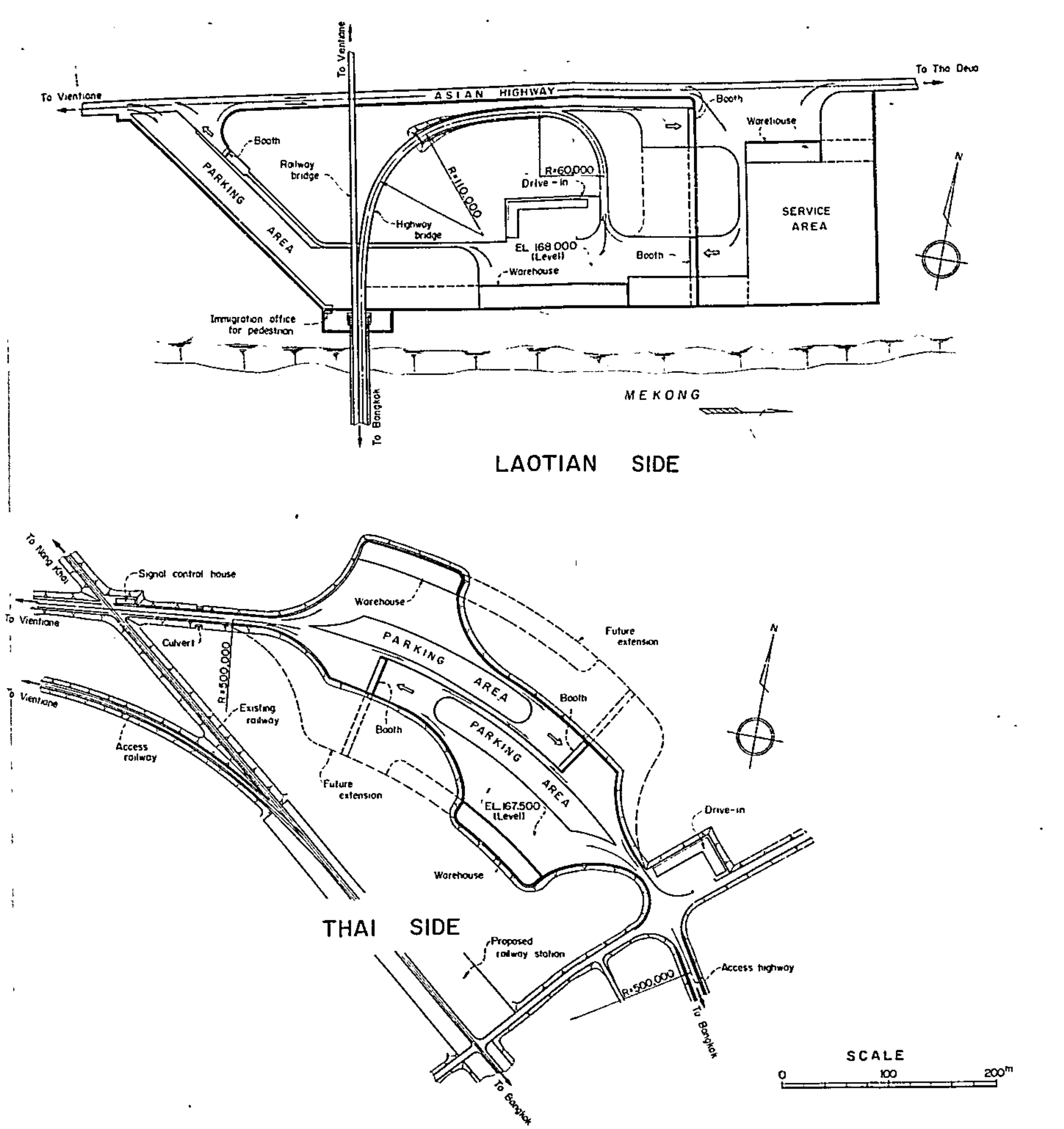
HIGHWAY . OVERPASS

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	M. Shingawa	
CHECKED	Y. Tokudiga	DATE Oct 14, 1968
SUBMITTED	Y. Amai	
APPROVED	T. Yoshida	PLATE 21



RIGHT SIDE PASSAGE



LEFT SIDE PASSAGE

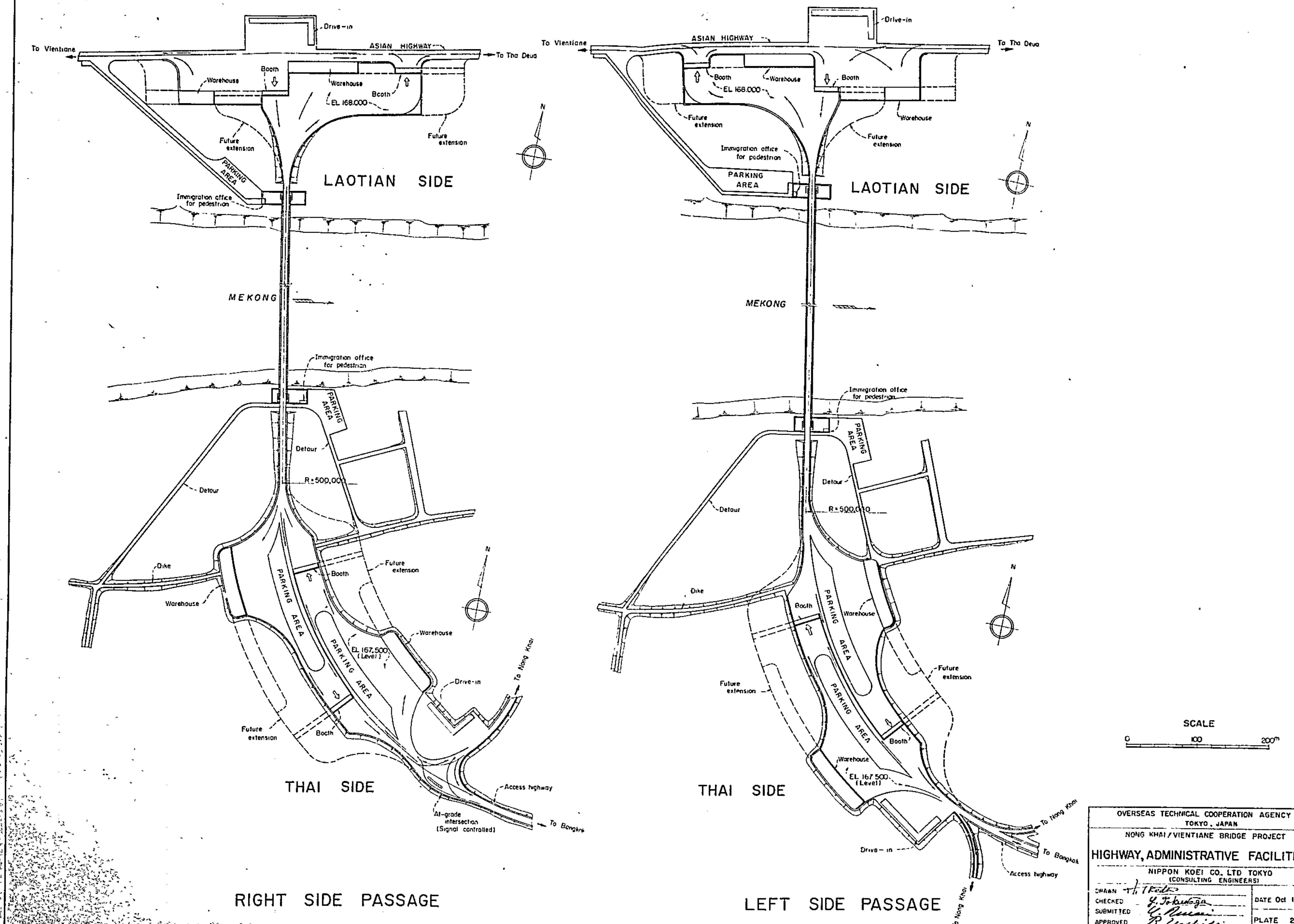
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

HIGHWAY, ADMINISTRATIVE FACILITIES (I)

NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN [signature]	DATE Oct 14, 1968
CHECKED Y. Tokudaga	
SUBMITTED [signature]	PLATE 22
APPROVED R. Yoshida	



OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

HIGHWAY, ADMINISTRATIVE FACILITIES (2)

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	H. Ikeda	
CHECKED	Y. Tokunaga	DATE Oct 14, 1968
SUBMITTED	Y. Kurai	
APPROVED	R. Yoshida	PLATE 23