UNITED NATIONS

COMMITTEE FOR COORDINATION OF INVESTIGATIONS

OF THE LOWER MEKONG BASIN

NONG KHAI / VIENTIANE BRIDGE PROJECT

LAOS — THAILAND

FEASIBILITY REPORT

PART II

ENGINEERING, ECONOMIC AND FINANCIAL STUDIES

OVERSEAS TECHNICAL COOPERATION AGENCY

Japan, September 1969

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OVERSEAS TECHNICAL COOPERATION AGENCY

Japan, September 1969

Tokyo, 29 September 1969

LETTER OF SUBMITTAL

His Excellency Mr. Kiichi Aichi
Minister of Foreign Affairs
Tokyo, Japan

Excellency,

I have the honor to present herewith to Your Excellency the Feasibility Report comprising three parts on the Nong Khai/Vientiane bridge project for which the works have been entrusted to the Overseas Technical Cooperation 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 a team of engineers for two different periods of about two months from August to October 1967 and about four months from February to June 1968. Besides, an advisory party consisting of three members was concerned in technical advices for the feasibility study of the project.

The project envisages to construct a rail/highway bridge across the Mekong, to extend the existing railway from Nong Khai up to Vientiane, and to build a highway to connect the two parts of the Asian Highway A-12 now existing in Laos and Thailand.

In this report it was made clear that the Nong Khai/Vientiane bridge project is technically, economically and financially feasible and will play the most important role in the socio-economic development of both Laos and Thailand. Therefore, the implementation of the project is strongly required, and above all it is advisable that following the feasibility study the detailed design is immediately carried out.

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

Respectfully submitted,

Keiichi Tatsuke

Director General

Overseas Technical Cooperation Agency

NIPPON KOEI CO., LTD.
Consulting Engineers
TELEX: TK4557 (KOEICO)
CABLES. NIPPONKOEI TOKYO
1-11, UCHISAIWAICHO 2CHOME, CHIYODA-KU,
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TEL. TOKYO 502-7571

REFERENCE

DATE 27 September 1969

LETTER OF TRANSMITTAL

Mr. Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency
Tokyo, Japan

Dear Sir,

I have the great pleasure to submit herewith to you the Feasibility Report comprising three parts 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.

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 April 14, 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.

Second phase: To draw a conclusion as to which should be taken up, a rail/highway bridge or a highway bridge, from engineering, economic and financial points of view.

Third phase: To provide a draft feasibility report regarding the selected bridge site and the selected kind of bridge.

Fourth phase: To finally print the draft feasibility report in accordance with the decisions of the Mekong Committee based on the first, second and third phase reports.

NIPPON KOEI CO., LTD.
TOKYO, JAPAN

We are very happy to state that all of these works have been completed. The first-phase operation was carried out in 1967 and the second-phase operation in 1968. As a result, the following matters have already been decided by the Mekong Committee in accordance with the conclusions and recommendations given in the First-and Second-Phase Reports: (1) the bridge site is Nong Khai, (2) the kind of bridge is a rail/highway bridge and (3) the railway route is Route C/D.

According to the results of the feasibility study presented in this report, the Nong Khai/Vientiane bridge project is technically, economically and financially sound. The benefit-cost ratio is around 6 and the internal rate of return is 16 percent for the case that no toll is charged on the bridge. Even in the case of collecting bridge tolls equaling the current ferry charges the ratio is 1.3 and the internal rate of return is 12.9 percent.

It is advisable to immediately seek for a generous grant or a soft loan to finance the project. If it is difficult to raise a fund for the whole construction cost 21,500,000 U.S. dollars at the earliest moment, it is recommended that an appreciable action be first taken to finance only the detailed design of the project to be successively carried out, which is estimated at about 400,000 U.S. dollars inclusive of the preparation of the tender documents. It is effective to demonstrate the implementation of the project during the period of the execution of the detailed design which will take at least one year or one and a half years.

We wish to express our hearty thanks to the Mekong Committee, the Government authorities of the riparian countries, Laos and Thailand, the Japanese Embassies and other organizations concerned for their kind cooperation rendered to us during the investigations.

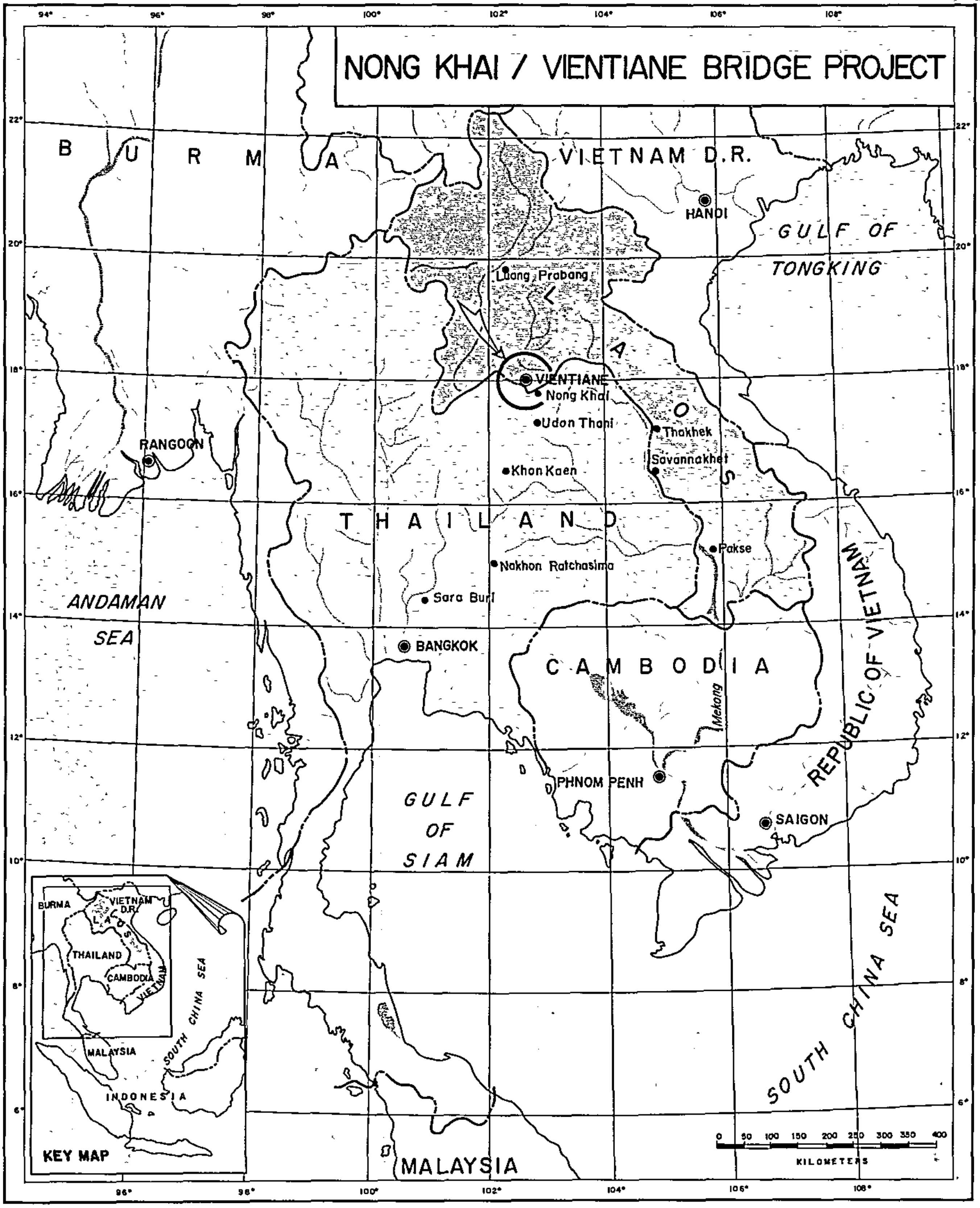
With our heartfelt gratitude for your constant support and encouragement, we remain,

Yours most obediently

R. Komori

for Yutaka Kubota
President

Nippon Koei Co., Ltd.


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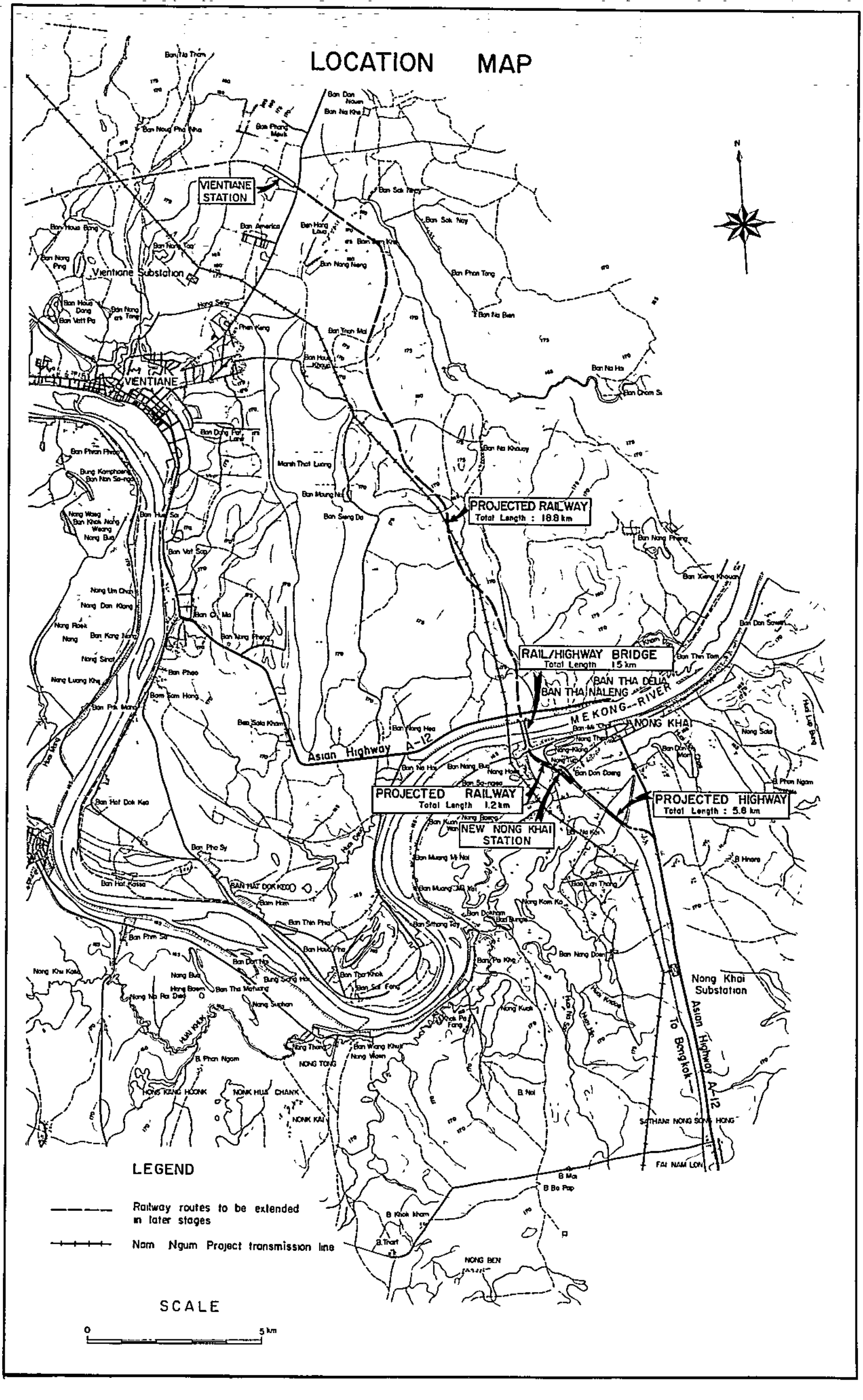
MALAYSIA
KILOMETERS
KEY MAP
BURMA
VIETNAM D.R.
LAOS
THAILAND
CAMBODIA
VIETNAM
SOUTH CHINA SEA
MALAYSIA
INDONESIA

LOCATION MAP



LAOS
VIENTIANE
NAM NGUM PROJECT
TRANSMISSION LINE
ASIAN HIGHWAY, A-12
HIGHWAY, ADMINISTRATIVE
FACILITIES
RAIL / HIGHWAY BRIDGE
MEKONG RIVER
EXISTING
FERRY FACILITY
EXISTING NONG KHAI STATION
NORTH
THAILAND
HIGHWAY, ADMINISTRATIVE
FACILITIES
NEW NONG KHAI STATION

PROJECT FEATURES

Item	Description
I. PROJECT	
1. Location	670 kilometers northeast of Bangkok, 20 kilometers southeast of Vientiane and 3 kilometers upstream of Nong Khai
2. Purpose	To build a rail/highway bridge across the Mekong, a highway, a new railway to be extended from Nong Khai to Vientiane, and two administrative facilities for immigration, customs and plant quarantine.
3. Construction cost	U.S.$ 21,500,000
II. BRIDGE	
1. River width	640 m
2. Type	
(i) Main bridge	Steel Warren truss, two 3-span continuous and one 2-span continuous, besides a suspended span
(ii) Approach viaducts	
Railway part	Plate girder and reinforced-concrete 3-span-continuous rigid frame construction
Highway part	Composite girder and reinforced-concrete 3-span-continuous hollow slab construction
3. Bridge width	17.8 m
(i) Railway part	4.0 m
(ii) Highway part	8.0 m
(iii) Sidewalk	1.5 m
(iv) Gangway	1.5 m
4. Bridge length	
(i) Main bridge	650 m
(ii) Approach viaducts	803.5m
Railway part	473.5m
Highway part	330 m
5. Max. pier spacing	90 m
6. Abutment and pier	2 open caissons on both banks, and 8 pneumatic caissons on the Mekong river-bed
III. RAILWAY	
1. Track	Single
2. Track gauge	1.000 m
3. Length	20 km
4. Station	
(i) Vientiane station	100,000 m^2
(ii) New Nong Khai station	55,000 m^2
IV. HIGHWAY	
1. Length	5.8 km
2. Width	
(i) Roadway	7 m (two lanes)
(ii) Shoulder	2.5 m each
V. ADMINISTRATIVE FACILITIES	48,000 m^2

BENEFITS AND COSTS

Item	Discount rate (%)	Unit	Characteristic value ⊿
I. FUTURE TRAFFIC			
1. Vehicles			
A.D. 1973		vehicles/day	1,353
1990		〃	9,025
2000		〃	13,538
2. Railway freight			
A.D. 1973		tons/day	606
1990		〃	2,737
2000		〃	3,991
3. Railway passengers			
A.D. 1973		persons/day	380
1990		〃	2,045
2000		〃	3,025
II. ANNUAL BENEFIT	3	U.S.$	7,036,300
	7	〃	5,619,100
	10	〃	4,794,800
III. ANNUAL COST	3	U.S.$	1,195,600
	7	〃	1,886,900
	10	〃	2,478,700
IV. BENEFIT-COST RATIO	3		5.9
	7		3.0
	10		1.9
V. INTERNAL RATE OF RETURN		percent	15.9
VI. INDIRECT BENEFIT			
1. Lumber industry		Much expedited	
2. Mining		Much expedited	
3. Urbanization		Rapid, especially around the Vientiane station	
4. Rise in land value		Remarkable	
5. Livestock industry		Self-sustaining expedited	
6. Saving in stock		Much	

⊿: These characteristic values are given for the case that no toll is charged on the bridge.

NONG KHAI/VIENTIANE BRIDGE PROJECT

FEASIBILITY REPORT

PART II

ENGINEERING, ECONOMIC AND FINANCIAL STUDIES

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CURRENCY EXCHANGE RATE

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

CHAPTER I

CONCLUSIONS AND RECOMMENDATIONS

1.1. Conclusions

Mentioned herein as conclusions are the feasibility of the Nong Khai/Vientiane bridge project and the decisions on various items made by the Committee for coordination of Investigations of the Lower Mekong Basin, which will be hereinafter referred to as the Mekong Committee, or derived from studies made in compliance with the comments of the Mekong Committee and by the authorities concerned of the Laotian and Thai governments.

1.1.1. Feasibility

The Nong Khai/Vientiane bridge project is technically, economically and financially feasible. The project involves no serious engineering difficulty and will be of considerable benefit to both Laos and Thailand.

Engineering soundness of a bridge in general depends primarily upon its foundation. The test drilling carried out at the bridge site during the second-phase investigation revealed that underneath the alluvial river-bed lies a stratum of unweathered siltstone firm enough for supporting the bridge structures. The bridge substructures shall, of course, be founded on this siltstone stratum. The pneumatic caisson foundation was adopted in this report considering that, though it might be a little expensive, the job would be better controlled and would be executed exactly because it will enable one to visually inspect the bearing surface and ascertain satisfactory bearing of the caisson on the firm siltstone stratum. Wooden mattresses loaded with lumps of laterite will be placed around midstream piers to protect the river-bed around them from being scoured and thus to safeguard the foundation.

No serious engineering difficulties will occur in the course of the bridge construction, including the underwater works mentioned above.

In implementing the whole project, however, there are some engineering problems that demand attention: (1) river-bank erosion; (2) a soil-engineering problem that the ground subsoil along the projected highway and railway routes has a tendency to swell when staturated with water and hence is not suited for use in the highway and railway embankments; and (3) to protect the structures against eventual extraordinary floods such as what in 1966 inundated the Vientiane plain and the Nong Khai district.

Although these problems are not so serious as to make the project totally unfeasible and measures to cope with them have been studied and are presented in this report, it is desired that further studies be made when the detailed design would be started.

The essential structures of the project comprise the main bridge across the Mekong with approach viaducts, the railway and highway as well as the administrative facilities, all of which are of ordinary construction.

The total cost of construction is estimated at U.S.$21,500,000, which divides into $9,000,000 for the main bridge and the approach viaducts, $8,500,000 for the railway and $4,000,000 for the highway and the administrative facilities.

When completed, the project will bring forth such a large direct benefit as to amount to about $7,000,000 at a discount rate of 3 percent, even if no toll would be collected. Even in the case of a 10-percent discount rate, the annual benefit will amount to $3,400,000, if tolls of the same amount as the current ferry charges would be collected.

The benefit-cost ratio is 5.9 in the former case and 1.3 in the latter case. The internal rate of return is estimated at 15.9 percent in the former case and at 12.9 percent in the latter case, both exceeding 12 percent, the minimum acceptable rate widely recognized for this kind of project.

The project will accompany various indirect benefits that, though difficult to appraise in monetary value, will contribute to the development and well-being of the region in and around the project area. For instance, the savings in the cost and time of transportation will cause a drop in commodity prices accompanied by an increase in the demand and a decrease in the volume of goods in stock in shops or factories, which in turn will further the price drop.

To be mentioned further as the indirect benefits are the urbanization of the region in and around the project area, the rise in the land value, the rise in the development values of natural resources such as iron, copper, limestone and the like, the development of industry, forestry, stock-raising and so forth.

As regards the financial feasibility of the project, the following can be said as conclusions. If it would be allowed to collect bridge tolls equaling the current ferry charges, it will be quite possible to repay a loan within its amortization period even if the loan would be such a hard one as a loan of 10-percent annual interest rate and 23-year term. However, it is desirable that the bridge tolls be set at a level not higher than half the current ferry charges. In this case, the loan shall be much softer, for example, a 4-percent, 21-year loan or a 3-percent, 20 year loan.

It goes without saying that the most desirable fund hence to be sought first for financing the project is a generous grant. Next comes a loan, the interest rate of which varies at a certain time of the useful life of the project. An example that seems suitable for the present project is a 40-year-term loan, in which the annual interest rate is first set at 3 percent for the period, possibly 10 to 15 years, during which the traffic would remain relatively little as compared with the capacity of the project, and then raised to 10 percent for the remaining period when the traffic would grow to near capacity. Another example recommendable for financing the present project is to borrow a soft loan such as of 3-percent interest rate and 20- to 25-year term on condition that it is replaced in 10 to 15 years with a hard loan such as of 10-percent interest rate and 20-year term.

In conclusion, the Nong Khai/Vientiane bridge project is quite feasible from the economic and financial points of view, if it would be financed with a generous grant or with a suitable loan.

1.1.2. Decisions and Studies Made on Various Items

Concerning and based on the studies on the feasibility of the Nong Khai/Vientiane bridge project as presented in the First-Phase Report of December 1967 and the Second-Phase Report of November 1968, the Mekong Committee and the government authorities of Laos and Thailand have not only made decisions on key items such as the bridge site and the kind of the bridge but also presented useful comments and suggestions. The following are the decisions and the gist of studies made on various items.

(1) Bridge Site

The comparative study on three alternative locations of the bridge site, Nong Khai, Vientiane, and Pa Mong, has been described in detail in the First-Phase Report and is outlined in Chapter IV in this report. The Mekong Committee, after deliberation, decided that the bridge be located at the Nong Khai site.

(2) Kind of Bridge

Whether the main bridge shall be a highway bridge or a dual-purpose rail/highway bridge had been a key point of the project and detailed studies were made in the course of the first-phase and second-phase investigations as reported in the Second-Phase Report and outlined also in Chapter IV of the present report.

The Mekong Committee, to which the choice was committed, has finally made its choice of the rail/highway bridge, considering that it will be more advantageous in respect of the socio-economic development of both countries concerned.

(3) Bridge Floor Layout

Five types of bridge floor layout shown in Fig.5.3 were studied as described in Subparagraph 5.2.1 (and also in the Second-Phase Report) and choice was made of the type shown in PLATE 3, in which a two-lane roadway and a single-track railway track are laid separately on the bridge floor between the main bridge trusses.

(4) Protection of River-Bed Against Scouring

Wooden mattresses filled with lumps of laterite will be placed around the bridge piers to guard the river-bed therearound from being scoured, as described in Subparagraph 5.2.2 and shown in PLATE 6.

In sinking pneumatic caissons for the pier foundations, temporary islands will be built enclosed by steel sheet-piles and filled with fine sand of the river. These islands will be left as they stand after the construction of the foundation so that they will contribute to the stability of the foundation.

(5) Bank Protection

To protect banks at the bridge ends against erosion, gabions will be laid over the bank slopes and concrete blocks will be dumped at their toes as shown in PLATE 6 and described in Subparagraph 5.2.3. The protection shall stretch about 120 meters on the Laotian bank and 150 meters on the Thai bank.

(6) Influence on the Shipyard Under Construction at Nong Khai

A shipyard is now under construction on the Thai side about 150 meters downstream from the proposed bridge site. Whether or not, or in what way or in what degree the shipyard would be affected by the bridge construction has become a matter of concern among those concerned.

The Mekong makes a bend, convex toward the Laotian side, a little upstream from the bridge site and hence there lies a sand-bar in front of the shipyard, which makes its appearance during the low-water season. Consequently, to judge the influence on the shipyard reduces to study the effect on the sand-bar, namely, to study how the sand-bar would be affected by the scouring action of the current that would be caused by the bridge piers and how and in what extent silt deposit would result in the vicinity of the shipyard.

During the second-phase investigation, the Japanese team has surveyed the sand-bar and has also made an echo-sounding of the river bottom around the intake tower of the Vientiane waterworks to find some clues to the river-bed scouring. If judged from the results of these investigations reported in detail in the Second-Phase Report, it seems most likely that the shipyard would not be affected by the bridge construction. However, it is desirable that a hydraulic model test be carried out to reach a more decisive judgement at the stage of the detailed design of the project.

(7) Railway Route

As mentioned in detail in Chapter IV and also in the Second-Phase Report, the so-called combined route C/D shown in Fig.4.1 has been selected by the Mekong Committee as the railway route on the Laotian side. This route, after crossing the Mekong, passes through the highlands covered with dense jungle east of the That Luong marsh and reaches the proposed Vientiane terminal located some 7 kilometers from the civic center of Vientiane.

(8) Change-Over of Traffic Direction

The traffic in Laos keeps to the right, whereas in Thailand it keeps to the left. It is therefore necessary to provide a site where the direction of the traffic shall be changed from the right to the left, and vice versa.

As described in Subparagraph 5.2.1, the problem of change-over was studied with relation to the layout of the administrative facilities to be built in the vicinity of both ends of the bridge and to the layout of the bridge floor. It has so far been concluded that at the present stage the change-over shall be provided on the Laotian side with at-grade intersection, though a grade separation would become necessary sometime in the future to cope with the increased traffic.

(9) Traffic Growth

To obtain basic data for estimating the possible future traffic on the bridge, an origin-destination traffic survey was carried out in 1967 in the course of the first-phase investigation, supplemented by another survey made in the second-phase investigation.

Judging from the accuracy of the origin-destination survey, the possible extent of the period for which reliable volumes of traffic can be predicted would be 20 years at the longest. Accordingly, although the future traffic has been estimated for the period of 40 years from 1973 when the bridge is assumed to be opened for traffic, it can be said that the estimates for the period after some 20 years from 1967 when the traffic census was taken, say after 1990, would be less reliable than those for the preceding period.

For the period from 1973 to 1990, as shown in Table 6.6, the traffic has been estimated to increase at a constant annual rate of 10.3% for buses, 13.1% for personal cars, 13.5% for taxis, 8.4% for heavy trucks, 8.7% for light trucks, 10.4% for motorcycles, 9.3% for railway freight, and 10.4% for railway-passengers.

A comparatively conservative estimate has been made for the period after 1990, Namely, it has been assumed that the traffic would increase after 1990 linearly at an average rate of 4 percent a year and remain constant after 2000, as shown in Fig.6.3.

The above estimates of the possible future traffic may be said not over-estimated if it is considered that, according to the Thai Government Highway Department's information, the traffic on main interurban highway routes in Thailand has been growing at a rate of about 20 percent a year over the last five years and that the data collected at site during the first-phase investigation show that the vehicular traffic between Udon Thani and Nong Khai has increased ten times in the last four years.

(10) Discount Rate

The economic feasibility of the project has been comparatively evaluated based on three different discount rates, 3%, 7% and 10%. It has been also studied by means of the internal rate of return.

(11) Cost of Transshipment

The cost of transshipment at the Tha Naleng car ferry will be saved when the project would be implemented and, consequently, has been counted in the benefit of the project.

The Mekong Committee Advisory Board has commented that the possible present cost of intermediate trade might dissappear in case a railway would be laid up to Vientiane, and that in case direct shipment could be made from Bangkok to Vientiane either by rail or by road, the drop in the prices of imported commodities in Vientiane should be of much more importantce than the savings in transportation and transshipment which would result from the use of the bridge. The survey team has been well aware of these benefits, but in the present report, they have been counted as indirect benefits.

1.2. Recommendations

It shall be recommended that the detailed design for executing the project be started as soon as possible and that a reasonable fund be sought for to finance the project. Besides, it is desired that measures be taken for some relevant items that have become to be noticed as indispensable in the course of the present feasibility study.

1.2.1. Financing

As already noted in Subparagraph 1.1.1, it is advisable for financing the project to get a generous grant or a soft loan of favorable condition at the earliest stage.

It is most desirable to raise at one time the fund needed for the whole cost of the project, U.S.$21,500,000, at the outset of the project. But it will take much time and such loss of time should be avoided.

Accordingly, it is recommended to start at the earliest moment the detailed investigations and the detailed design necessary for initiating the project at about 400,000 U.S. dollars inclusive of the preparation of tender documents. These preliminaries will take at least about one year and during this period, it is hoped, measures should be taken to raise the necessary fund. Anyway, the survey team strongly hopes that the detailed design be started as soon as possible because the present project will be of much benefit to both Laos and Thailand.

1.2.2. Detailed Investigations and Design

The following are needed for the detailed design.

(1) Detailed Topographic Survey

The plane-table survey made on a scale of 1:2,000 during the second-phase investigation is not sufficient for designing the details of the project structures. Therefore, a more detailed topographic survey of the whole project area shall be made on a scale of 1:500 or so.

It is first of all necessary to adjust the elevations of bench-marks located in and around the project area. For instance, the elevation of a bench-mark located in the compound of the Thai Hydrographic Office at Nong Khai as surveyed during the second-phase investigation based on the bench-mark V-636 in Vientiane, registered to lie at El.170.105m, showed a discrepancy of 18 centimeters as compared with the elevation adopted by the Thai government. Such discrepancies in the elevations of bench-marks must be adjusted as they cause serious mistakes and unnecessary troubles in planning and construction of the project structures.

(2) Detailed Material Survey

Although detailed surveys regarding concrete aggregates, embankment materials and the like have been made as reported in the Second-Phase Report, more studies on these materials are required for making the detailed design of the project structures.

(i) Concrete Aggregates – To decide the design mix of concrete for different design compressive strengths and to make plans for supplying cement and aggregates, it is required to know the physical characteristics of the aggregate materials that lie in the pits to be finally selected.

(ii) River Sand and Gravel for Pavement Use – In general, crushed stone is preferred for use in wearing, base and subbase courses of highway pavement. But crushed stone is not obtainable in the vicinity of the project area. Accordingly, it is planned to use the Mekong's sand and gravel as described in the Second-Phase Report on the assumption that they would meet the requirements of the CBR test. It is therefore necessary to carry out the CBR test at site.

(iii) Embankment Materials – A survey on embankment materials made during the second-phase investigation revealed that the subsoil of the ground in the project area is not suited for highway or railway embankments for it has a tendency to swell when saturated with water.

As a measure to cope with the swelling, the use of soil-cement mix has been considered as noted in this report. Accordingly, it is necessary to make further studies on this problem and also to seek embankment materials of better quality from other sources.

The data of the soil test made in the second-phase investigation are listed in the Feasibility Report Part III: "ENGINEERING AND ECONOMIC DATA".

(iv) Ballast Material — Material of sufficient hardness suitable for railway ballast cannot be found in the vicinity of the project area. It shall be supplied from the district around Sara Buri or Loei in Thailand. Further studies shall be made on the source and supply of railway ballast.

(v) Laterite and Stone — Further studies shall also be made on these materials.

(3) Test Drilling

Test drilling of the river-bed shall be carried out at the planned location of bridge piers.

(4) Hydraulic Model Test

It is recommended that a hydraulic model test be done to know the pattern of bank erosion and also to make clear the problem noted in (6) of Subparagraph 1.1.2.

(5) Preparation of Design Drawings, Design Report, Data Book and Specifications

(6) Exact Estimation of Work Quantities, Unit Prices and Construction Cost

(7) Preparation of Tender Documents

1.2.3. Pending Items

The following shall be projected or undertaken at the earliest stage for implementing the present project:

(1) To map out the course of the socio-economic development of the Vientiane plain, and to formulate the city planning of Vientiane taking into account the urbanization around the projected railway terminal.

(2) Widening of the Asian Highway A-3 (Laotian National Highway Route 13) on the stretch from Vientiane to the envisaged railway terminal. At present the road is 7 meters wide with no shoulders and is much inferior to the Asian Highway A-12 in its traffic capacity. Therefore, it is at least necessary to provide 2.5-meter shoulders on both sides of the roadway.

(3) To establish an organization for the operation, maintenance and replacement of the project after its completion. It is proposed that the organization be established under the direct jurisdiction of the Laotian and Thai governments and be authorized to assume the overall responsibility of administrating the operation and management of the project.

The organization shall be called the "Nong Khai-Vientiane Bridge Authority" and shall comprise a secretariat and various departments and sections to handle the operation and management, maintenance and improvements, financing, statistics, personnel affairs and general affairs.

The operation and maintenance of the project are recommended to be done under the guidance of qualified foreign engineering organizations.

(4) To establish an organization for the operation and maintenance of the railway on the Laotian side. At present, there is in Laos no railway and naturally no governmental section concerned in railway. Therefore, when the railway would be extended into Laos, it is absolutely necessary to

establish a new organization that should be called, for example, the "Royal State Railway of Laos". The new organization shall have a far-reaching ideal of extending the railway toward Luang Prabang and further north as well as toward the southern part of Laos and ultimately to realize a railway network all over Laos with rolling stocks of its own.

(5) To settle the problem of the ownership of the Nong Khai/Vientiane bridge before its completion.

CHAPTER II

INTRODUCTION

2.1. Necessity of the Project

The Kingdom of Laos is a landlocked country surrounded by Thailand, Cambodia, South Viet-Nam, North Viet-Nam, China and Burma. Owing to this geography, Laos's exports and imports are compelled to pass through the territories of neighboring countries.

Before World War II, Laos, along with Cambodia and Viet-Nam, had been a constituent of Indochina under French rule. In those days, all means of transport in Laos were linked with Viet-Nam and Cambodia. Several long highways connected principal cities in Laos with Hanoi, Hai Phong, Hue and Da Nang in Viet-Nam. And, an artery road along the Mekong connected Vientiane with Thakhek, Savannakhet and Paksé in Laos and entered into Cambodia toward Phnom Penh and Saigon. Therefore, most of the foreign trade to and from Laos was being made through Hanoi or Saigon or Phnom Penh and almost none through Bangkok in Thailand.

With the change in the situation in this part of the world after World War II, Laos is now making most of her foreign trade through the route from Bangkok. It is natural that Laos has chosen this route as it is the shortest among the conceivable routes. The route from Bangkok to Vientiane measures about 690 kilometers as compared with 800 kilometers from Hanoi or 1,200 kilometers from Phnom Penh. Moreover, the route from Hanoi or Saigon has virtually been shut off since the outbreak of hostilities in Viet-Nam.

The navigation on the Mekong from its mouth to Vientiane, a stretch of about 1,600 kilometers, at present cannot be expected as a means of transport. There are certain reaches on the way such as the Sambor rapids, Khone Falls, the Khemarat rapids and so on, where the river is not navigable, or is navigable only with difficulty.

Thus, the route from Bangkok is most advantageous and hence is being fully utilized. At present, most of the freight destined for Laos is carried from the port of Bangkok to Nong Khai either by trucks on the Asian Highway A-12 or by rail on the northeastern line of the Royal State Railway of Thailand. Both routes ensure smooth and speedy transportation. However, the rail freight must be transshipped at Nong Khai to trucks to be carried, after crossing the Mekong by the ferry, on the Asian Highway A-12 extension that runs about 20 kilometers from Tha Naleng to Vientiane on the Laotian side.

The crossing of the Mekong by the ferry constitutes a bottleneck to the traffic to and from Laos. The existing vehicular ferry is no more able to serve the growing traffic. In these days, a long row of trucks awaits the ferry on the Nong Khai side.

It is a long-cherished desire of the people in these areas to replace the ferry with a bridge. The bridge will not only warrant a smooth and speedy flow of traffic but also greatly contribute to the promotion of the Laotian foreign trade and give stimulus to the socio-economic development of Laos as well as of the northeastern region of Thailand.

2.2. History of the Project

The project of bridging the Mekong in the Nong Khai-Vientiane area dates back to 1956, when the United States Operation Mission in Thailand first undertook a study for a favorable bridge site. And a little later, the Royal State Railway of Thailand has also made a similar survey.

The project was highlighted in 1965 when the Mekong Committee took it up at its 29th Session as one of the first priority projects in the Ten-Year Development Program of the Lower Mekong Basin.

In May 1966, at the Third Seminar on Navigation Improvement, discussions were made on three possible bridge sites – Nong Khai, Vientiane and Pa Mong – that had been considered promising at that time, and a resolution was made that a study on these three sites should be started.

In February 1967, the Mekong Committee requested assistance of friendly countries to the execution of the feasibility study of the bridge project. In response to the Mekong Committee's request, the Japanese government offered at the 32nd Session in April 1967 to undertake the study. This offer was consented to by the Laotian and Thai representatives and the Plan of Operation was immediately provided and signed between the Mekong Committee and the Government of Japan. The Japanese Government Ministry of Foreign Affairs has entrusted the task of the said study to the Overseas Technical Co-operation Agency, which, in turn, assigned the execution of the study to Nippon Koei Co., Ltd.

The Plan of Operation stipulates that the feasibility study be made in four phases. The first-phase investigation was carried out during the period from August to October 1967 and the First-Phase Report was submitted to the Mekong Committee in December 1967. The Mekong Committee, at its 34th Session held in January 1968, requested the Advisory Board to review the report and, following the Advisory Board's advice, decided to choose the Nong Khai site in accordance with the conclusions and recommendations stated in the First-Phase Report.

As soon as the bridge site had thus been decided, the Japanese survey team started the second-phase study, making field investigations from February through June 1968. One major purpose of the second-phase investigation was to make study on, and to obtain data for deciding, the kind of the bridge, a rail/highway bridge vs. a highway bridge, to be built at the Nong Khai site. The Second-Phase Report was submitted to the Mekong Committee in November 1968. The Mekong Committee, at its 38th Session held in January 1969, decided to select a rail/highway bridge as the kind of the bridge to be built at the Nong Khai site, according to the conclusions and recommendations stated in the Second-Phase Report.

The Plan of Operation stipulates that a draft feasibility report be submitted in the third phase, which will summarize the results of the first-and second-phase investigations. Part I: Summary and Recommendations of the Draft Feasibility Report was submitted to the Mekong Committee in April 1969. Part II: Engineering, Economic and Financial Studies, and Part III: Engineering and Economic Data of the Draft Feasibility Report were submitted to the Mekong Committee in May 1969.

The Mekong Committee approved Part I of the said report at its 39th Session held in Singapore in April 1969, and also approved Parts II and III at its 40th Session held in Geneva in July 1969.

Prior to approval of Parts II and III, the Thai National Mekong Committee commented that the change-over of the traffic direction from the left to the right, and vice versa should be provided on the Laotian side with at-grade intersection, and if it will be made on the Thai side the change-over should be made with grade separation.

As regards this problem, the Japanese survey team suggested as follows. Whether on the Thai side or on the Laotian side, at the present stage it is not economical to make the change-over with grade separation. In so far as it is made with at-grade intersection, it is possible to locate the change-over point on the Laotian side, and there is no room enough for providing grade-separated structures on the Laotian side. These suggestions were understood and accepted by the Mekong Committee in the 40th Session.

The Plan of Operation provides that the draft feasibility report be printed in the fourth phase. Part I: SUMMARY AND RECOMMENDATIONS, Part II: ENGINEERING, ECONOMIC AND FINANCIAL STUDIES, that is the present volume, and Part III: ENGINEERING AND ECONOMIC DATA of the final feasibility report were submitted to the Mekong Committee in September 1969.

Table 2.1 inserted at the end of Paragraph 2.5 presents the chronology of the project.

2.3. Plan of Operation

This report is prepared and submitted in accordance with the Plan of Operation that was signed on April 14, 1967 by the Governments of Laos, Thailand and Japan, the Economic Commission for Asia and the Far East, the Mekong Committee and the Asian Highway Transport Technical Bureau.

The Plan of Operation provides that the Government of Japan should make the feasibility investigation and study of the Nong Khai/Vientiane bridge project. The main purposes of the project are to link the two segments of the Asian Highway A-12 entirely separated by the Mekong and to make research into the possibility of extending the northeastern trunk line of the Royal State Railway of Thailand from Nong Khai to Vientiane, by constructing a bridge over the Mekong.

The scope of work to be carried out by the Government of Japan is provided in detail in Part III of the Plan of Operation as reproduced in Table 2.2. The main items to be carried out in compliance with the provisions are:

(1) To study the engineering, economic and financial feasibility of linking the two segments, which are cut off at present by the Mekong, of the Asian Highway A-12 and of extending the existing railway on the Thai side into Laos up to Vientiane;

(2) To offer data for selection by the Mekong Committee of the most favorable bridge site from among three promising sites, namely, the Nong Khai site, about one kilometer upstream from the existing vehicular ferry between Nong Khai and Tha Naleng; the Vientiane site, located in the western part of the city of Vientiane; and the Pa Mong site, about 18 kilometers upstream from Vientiane in the vicinity of the projected Pa Mong dam site;

(3) To make a comparative study on the merits and demerits of the two kinds of bridge⚠, a rail/highway bridge v. a highway bridge; and

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

Of the above, the investigation on the second item has been carried out in the first-phase investigation and reported in the First-Phase Report. The studies on the first and third items have been made in the second-phase investigation and reported in the Second-Phase Report. The volumes of the report now presented are what are prepared to meet the fourth, and the last, requirement.

2.4. Organization of the Japanese Survey Team

A survey team of 12 members was organized to carry out the first-phase investigation and three advisers were appointed to make advices and suggestions on the investigation.

The first-phase field study was carried out during a period of about two months from August to October 1967. The survey team, first in Bangkok, exchanged views and discussed on the project with staff members concerned of the Thai government and the Mekong Committee and gathered engineering and economic data for its further study, and then proceeding to the project area, made necessary field investigations around Vientiane, Nong Khai, Tha Deua, Sri Chieng Mai and Pa Mong.

While the survey team was making the field investigations, the advisory party stayed at the site for about two weeks, giving advices to the survey team and making its own study.

As regards the second-phase study, a survey team of 15 members was despatched to the site in February 1968 immediately after the Mekong Committee's selection of the Nong Khai site. The field investigation lasted about four months. The advisory party has stayed in Japan during this period but has given advices and suggestions on the execution of the field investigations and has helped the survey team in preparing the reports by reviewing, and by rewriting some part of, the manuscripts of the reports.

The survey team was headed by Mr. Tsuda in the first-phase investigation and by Mr. Yoshida in the second-phase investigation. The advisory party was headed by Prof. Fukuda throughout the study. Members of the survey team and advisers are listed in Table 2.3.⚠

On the other hand, a survey team of 5 members was organized to carry out the feasibility investigation of the projected railway to be extended from Nong Khai to Vientiane and to make a comparative study of the two cases that the railway is constructed along Route C or Route C/D. The team was headed by Mr. Nakajima. The field investigation was continued for three months from November 1968 to February 1969. A report recommending to take up Route C/D as the most

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⚠ : In this report, "the kind of bridge" means the classification of a bridge from the kind of traffic that the bridge is to carry, i.e., a highway bridge, rail/highway bridge, etc., and "the type of bridge" the classification according to the structural characteristics such as a girder bridge, truss bridge, continuous bridge, and so forth.

⚠: Operations in the third - and fourth-phases were mostly office works in Japan. Accordingly, participants in the work of these phases are not listed in the table.

favorable railway route as the results of the feasibility study was prepared in March 1969 in Japanese version. The English version of the report was submitted to the Mekong Committee in July 1969.

2.5. Acknowledgements

Throughout the whole period of its field study, the survey team has maintained close relation with the Governments of Laos and Thailand as well as with the Mekong Committee for all engineering and administrative matters. Much data and informations referred to in the First - and Second-Phase Reports are what have been supplied by various sections of the Laotian and Thai governments, the Mekong Committee and the United States Agency for International Development-Laos.

The Japanese survey team wishes to express its appreciation of the cooperation and assistance offered by the said authorities and to express thanks to a number of persons or agencies concerned, particularly to:

LAOTIAN GOVERNMENT

S.E. Mr. Ngon Sananikone	Ministre des Travaux Publics et des Transports
S.E. Mr. Inpeng Suryadhay	Ministre du Plan et de la Coopération
Mr. Oukeo Souvannavong	Secrétaire Exécutif du Comité National Lao du Mékong
Mr. Phak Savan	Directeur Général, Ministère des Travaux Publics et des Transports
Mr. Somphavanh Inthavong	Directeur des Ponts & Chaussées, Ministère des Travaux Publics et des Transports
Mr. Issara K. Sasorith	Directeur de l'Hydraulique et de la Navigation, Ministère des Travaux Publics et des Transports
Mr. Sisouphanh Choummanivong	Directeur des Services Techniques du Comité National Lao du Mékong
Mr. Ngeun Sivisay	Chef du Laboratoire d'Essai des Sols et Matériaux de Construction
Mr. Ny Phommachan	Chef du Bureau de la Navigation, Direction de l'Hydraulique et de la Navigation
Mr. L.G. Doolaege	Capitaine au Long Cours E.S.N., Direction de l'Hydraulique et de la Navigation
Mr. Stewart	Programme Section, U.S.A.I.D.

THAI GOVERNMENT

Dr. Boonrod Binson	Under-Secretary of State Ministry of National Development, Bangkok
Mr. Nitipat Jalichan	Secretary General, National Energy Authority
Mr. Vibul Taweesup	Chief of the Mekong River Project, Officer in charge of the Nong Khai/Vientiane bridge project, National Energy Authority
Mr. Chairat Ritvirool	Liaison Engineer, National Energy Authority
Mr. Prasaan Vandhanakom	Liaison Engineer, National Energy Authority
Mr. Wichian Sirisoontorn	Chief of Nong Khai Hydrographic Office
Mr. Ahtorn Peetathawatchai	Planning Division, Department of Highways
Mr. Yong Chantrangkul	Deputy Chief Civil Engineer (Construction), Royal State Railway
Mr. Siri Pipitsombat	Construction Planning Engineer, Royal State Railway
Mr. Yongyut Pisalsarakit	Attached to the General Manager, Royal State Railway

Mr. Uem Sanasen	Police Colonel of Immigration Division, Police Department
Mr. Pleak Sundarakumara	Police Colonel of Immigration Division, Police Department
Mr. Chan Mingkwan	Customs Supervisor Region 4, Nong Khai
Mr. Vichit Satravaha	Chief of Nong Khai Customs House

ECAFE

Mr. U Nyun	Executive Secretary

MEKONG SECRETARIAT

Dr. C. Hart Schaaf	Executive Agent
Mr. Kanwar Sain	Director, Division of Engineering Services
Mr. I.S. Macaspac	Director, Division of Economic and Social Studies
Mr. Samarom Bunnag	Officer-in-Charge, Division of Navigation Improvement
Mr. B.J. Wohlwend	Navigation Legal Officer

ASIAN HIGHWAY TRANSPORT TECHNICAL BUREAU

Mr. M.S. Ahmad	Director

Table 2.1. Chronology

Calendar Year	Month	Description
1956		Preliminary survey for a bridge across the Mekong in the Vientiane area made by the United States Operation Mission to Thailand.
1959		Reconnaissance made as a series of comprehensive Thailand transportation survey by Transportation Consultants, Inc.
1965	Aug.	Mekong Committee took up the bridge project as one of the first priority projects in its 10-year Development Program.
1966	May	The three promising bridge sites were examined and discussed at the Mekong Committee's Third Regional Seminar on Navigation Improvement.
1967	Feb.	Mekong Committee requested assistance of friendly countries to the execution of a feasibility study of the bridge project.
	Apr.	Japan offered to undertake the study of the bridge project to the Mekong Committee. The project Plan of Operation signed between the Mekong Committee and Japan, hereupon the Nong Khai/Vientiane bridge project was formally established.
	Aug.	First-phase investigation carried out until October.
	Dec.	First-Phase Report submitted to the Mekong Committee.
1968	Jan.	Mekong Committee decided to finally select the Nong Khai bridge site.
	Feb.	Second-phase investigation carried out until June.
	Nov.	Second-Phase Report submitted to the Mekong Committee.
	Nov.	Survey on the projected railway started as an additional investigation of the bridge project.
1969	Jan.	Mekong Committee took up the rail/highway bridge and adopted Route C/D as the route of the projected railway.
	Apr.	Part I: SUMMARY AND RECOMMENDATION of the Draft Feasibility Report submitted to the Mekong Committee.
	May	Part II: ENGINEERING, ECONOMIC AND FINANCIAL STUDIES and Part III: ENGINEERING AND ECONOMIC DATA submitted as integral parts of the Draft Feasibility Report to the Mekong Committee.
	July	An additional report of the Second-Phase Report was submitted to the Mekong Committee, which reports the results of the feasibility investigation of the projected railway and the results of the comparative study of the benefits and costs between Routes C and C/D.
	Sep.	Part I: SUMMARY AND RECOMMENDATIONS, Part II: ENGINEERING, ECONOMIC AND FINANCIAL STUDIES, and Part III: ENGINEERING AND ECONOMIC DATA of the final Feasibility Report were submitted to the Mekong Committee.

Excerpt from 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 leveling, 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.
(11) 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.

Table 2.3. List of Survey Team Members and Advisers

First-phase investigation

Member	Speciality	Investigation period
A. Advisory Party		
1. Dr. FUKUDA, Takeo Doctor of Engineering; Professor Emeritus of the Univ. of Tokyo; President, Kozo-Keikaku Consultant Co., Ltd.	Bridge Construction	15
2. Dr. SATO, Hiromasa Doctor of Engineering; Vice-President, Mitsui Kyodo Kensetsu Consultant Co., Ltd. (Former Vice-President, Japan Highway Public Corp.)	Highway Engineering	16
3. Dr. MURAKAMI, Eiichi Dorctor of Engineering; Director, Japan Public Highway Corp.	Bridge and Highway	14
B. Survey Team		
1. Mr. TSUDA, Makoto Authorized Engineer; Chief of Projects Dept., Nippon Koei Co., Ltd.	Head, Survey Team	40
2. Mr. SAKAITA, Masanobu Authorized Engineer; Director, Chief of Geological Dept., Nippon Koei Co., Ltd.	Geology	21
3. Mr. NOGUCHI, Yutaka Authorized Engineer; Technical Advisor, Nippon Koei Co., Ltd.	Highway Planning	15
4. Mr. TOKUNAGA, Yuzo Authorized Engineer; Projects Dept., Nippon Koei Co., Ltd.	Highway Engineering and Survey	45
5. Mr. NAKAJIMA, Tooichi Authorized Engineer; Deputy-chief, Overseas Dept., Japan Transportation Consultants, Inc./1	Railway Planning	21
6. Mr. AOYAMA, Masaki Deputy-chief, Designing Dept., Japan Transportation Consultants, Inc.	Bridge	30
7. Mr. KOBAYASHI, Yaichi Institute of Behavioral Sciences/1	Economics	54
8. Mr. FUKUSHIMA, Chisato Institute of Behavioral Sciences	Economics	54
9. Mr. KAMIJO, Etsuji Institute of Behavioral Sciences	Economics	54
10. Mr. KUWABARA, Masao Development Survery Dept., Overseas Technical Cooperation Agency	Liaison and Accounting	40
11. Mr. TANIGUCHI, Isoo Civil Engineering Dept., Nippon Koei Co., Ltd.	Survey	45
12. Mr. SUZUKI, Isamu Civil Engineering Dept., Nippon Koei Co., Ltd.	Survey	45

/1 : Cooperative body of Nippon Koei Co., Ltd.
* : Team members of the first-phase investigation.
** : Team members of the first-and second-phase investigations.

Second-phase investigation

Member	Speciality	Investigation period
A. Survey Team		
1. Mr YOSHIDA, Ryozo Authorized Engineer; Deputy-Chief Engineer, Chief of Projects Dept., Nippon Koei Co., Ltd.	Head, Survey Team	17
*2. Mr. SAKAITA, Masanobu Authorized Engineer; Director, Chief of Geological Dept., Nippon Koei Co., Ltd.	Geology	29
*3. Mr. NOGUCHI, Yutaka Authorized Engineer; Technical Advisor, Nippon Koei Co., Ltd.	Highway Planning	15
*4. Mr. TOKUNAGA, Yuzo Authorized Engineer; Projects Dept., Nippon Koei Co., Ltd.	Highway Engineering and Survey	89
5. Mr. ITO, Tohru Projects Dept., Nippon Koei Co., Ltd.	Bridge Engineering and Hydrology	90
*6. Mr. NAKAJIMA, Tooichi Authorized Engineer; Deputy-Chief, Overseas Dept., Japan Transportation Consultants, Inc.	Railway Planning	30
7. Mr. SASAKI, Tsuneichi Representative Director, Institute of Behavioral Sciences	Economics	10
*8. Mr. KOBAYASHI, Yaichi Institute of Behavioral Sciences	Economics	45
9. Mr. OGAWA, Tetsuo Institute of Behavioral Sciences	Economics	45
10. Mr. KIMURA, Hiroshi Development Survey Dept., Overseas Technical Cooperation Agency	Liaison and Accounting	15
11. Mr. OHYAMA, Hiroyoshi Development Survey Dept., Overseas Technical Cooperation Agency	Liaison and Accounting	15
*12. Mr. TANIGUCHI, Isoo Civil Engineering Dept., Nippon Koei Co., Ltd.	Survey	129
13. Mr. IKEDA, Hiroshi Projects Dept., Nippon Koei Co., Ltd.	Survey	104
14. Mr. SHIRAYAMA, Kikuo Geological Dept., Nippon Koei Co., Ltd.	Test drilling	129
15. Mr. ONOUE, Takashi Geological Dept., Nippon Koei Co., Ltd.	Test drilling	129

Additional railway investigation

Member	Speciality	Investigation period
A. Advisory Party		
1. Dr. FUKUDA, Takeo Doctor of engineering; Professor Emeritus of the Univ. of Tokyo; President, Kozo-Keikaku Consultant Co., Ltd.	Bridge Construction	15
2. Dr. SATO, Hiromasa Doctor of engineering; Vice-President, Mitsui Kyodo Kensetsu Consultant Co., Ltd. (Former Vice-President, Japan Highway Public Corp.)	Highway Engineering	15
B. Railway Team		
**1. Mr. NAKAJIMA, Tooichi Authorized Engineer; Deputy-Chief, Overseas Dept., Japan Transportation Consultants, Inc.	Head, Railway Team Railway Planning	10
2. Mr SHIMURA Takuya Development Survey Dept., Overseas Technical Cooperation Agency	Survey, Liaison and Accounting	15
**3. Mr. TANIGUCHI, Isoo Civil Engineering Dept., Nippon Koei Co., Ltd.	Survey	97
4. Mr. ISHIZAKI, Haruya Civil Engineering Dept., Nippon Koei Co., Ltd.	Survey	63
5. Mr. IDE, Yushichi Civil Engineering Dept., Nippon Koei Co., Ltd.	Survey	88
C. Bridge Team		
1. Mr. YOSHIDA, Ryozo Authorized Engineer; Deputy-Chief Engineer, Chief of Projects Dept., Nippon Koei Co., Ltd.	Head, Bridge Team	23
**2. Mr TOKUNAGA, Yuzo Authorized Engineer; Projects Dept., Nippon Koei Co., Ltd.	Highway Engineering and Survey	23

CHAPTER III

GENERAL DESCRIPTION

3.1. Project Area

The Kingdom of Laos occupies an area of about 236,800 square kilometers in the Indo-Chinese Peninsula. It is a landlocked country situated between 14°N and 22°30'N and between 100°E and 107°30'E, forming a long and slender land extending from north to south. On the north and east, it is bounded by China, North Vietnam and South Viet-Nam. To the west and south, it borders on Burma, Thailand and Cambodia.

No census has been taken of the Laos's population. But it has been estimated at some 2.3 million as of 1966, with a density of 10 on the average per square kilometer. Most of the population centers in the flat land along the Mekong. The principal cities and towns in Laos are Vientiane, the capital, Luang Prabang, Thakhek, Savannakhet and Paksé. Vientiane has a population of about 140,000 and Luang Prabang 42,000. The annual growth rate of the population in Laos was about 2.3 percent in 1964.

Thailand lies between 6°N and 20°30'N and between 97°30'E and 105°30'E. It borders on Burma on the west and on Laos and Cambodia from the south to the east. Its land extends southward to reach Malaysia, embracing the Gulf of Siam on the east. Thailand's total area is about 514,000 square kilometers, about half of which is covered by forests. Land under cultivation is about 20 percent of the total land area.

The Thailand's population has been estimated at 31.8 million as of 1966 with a density of about 60 per square kilometer. The annual growth rate of the population is about 3 percent. Bangkok, the capital, has a population of about 1.9 million.

The Nong Khai/Vientiane bridge project is located within a circle with a radius of about 20 kilometers from the city center of Vientiane. This area spreads over Laos and Thailand. On the Laotian side, the area belongs to Vientiane Province, and on the Thai side to Nong Khai Province. Nong Khai is an important commercial center in the northeastern region of Thailand, with a population of 15,000. Nong Khai is serving as the most important gateway to and from Laos for the last two decades.

The bridge site is located in the western suburbs of Nong Khai not far from the terminal of the Thai State Railway Northeast Line. It also lies in the vicinity of the end of the highway that runs about 670 kilometers from Bangkok.

A passenger ferry is now operating across the Mekong between Nong Khai and Tha Deua, a small town on the Laotian side with a population of 3,000. This ferry handles, besides passengers, small cargoes. A little downstream from the projected bridge site, there is a vehicular ferry to Tha Naleng, a small village on the Laotian side situated about 2 kilometers upstream from Tha Deua. All the heavy cargoes from Thailand are landed from the ferry at Tha Naleng, from where a newly constructed, asphalt-paved two-lane highway runs about 20 kilometers to Vientiane.

3.2. Climate

The climate in Laos is characterized by two seasons, the dry season and the rainy or wet season. The dry season lasts from November to March and the northeast monsoon prevails during this season. The rainy season begins in late April and ends in October. In the rainy season, often called the monsoon season, the southwest monsoon prevails, sometimes accompanying a torrential rainfall that temporarily reduces the activity of the whole country. The climate in the project area is essentially the same as noted above.

The temperature in the project area falls to its lowest in January every year, starts to rise to reach its highest in April and then gradually falls until next January. The highest temperature ever observed in Vientiane is 40.7°C recorded in April 1960 and the lowest 3.1°C recorded in February 1955. The annual mean temperature is 26.1°C.

The relative humidity in the Vientiane area remains high during the rainy season. It reaches its peak as high as 100 percent in September and drops in the dry season, sometimes falling as low as to 12 percent in February or March. The annual mean is 72.5 percent.

The annual rainfall in the Vientiane area ranges from 1,200 to 2,000 millimeters, almost all of which, about 97 percent, comes in the rainy season. The monthly rainfall varies much according to the season. During the rainy period, it is around 300 millimeters on the average, the maximum being 600 millimeters or more. The combined rainfall in August and September accounts for about 40 percent of the annual total, and there is hardly any rainfall in December and January.

3.3. The Mekong's Flow

The water-level of the Mekong at Vientiane starts to rise following the onset of the monsoon in May and reaches its peak in August or September. It gradually recedes from October and reaches its lowest in April before the onset of the monsoon.

The flood water-levels and peak discharges recorded in the past at the Vientiane gaging station are listed in Table 3.1.

Table 3.1. Flood Water-Level and Peak Discharge
At Vientiane Gaging Station

Year	Flood Water-Level (m.)	Peak Flood Discharge (m^3/sec)
1929	EL. 171.36	25,300
1942	EL. 170.84	23,200
1945	EL. 170.84	23,200
1966	EL. 170.75	22,700

If judged from a probability study made on the Mekong's water-level, the water-level of the 1966 flood corresponds to the 20-year probable high-water level, and a discharge of 20,000 cubic meters per second, which is the minimum to inundate the Vientiane plain, corresponds to the 7-year probable high-water discharge.

Computed probable high-water levels at the bridge site are shown in Table 3.2.

Table 3.2. Probable High-Water Level At the Bridge Site

Period of Occurrence, In Years	Probable High-Water Level, In meters above mean sea level
2	165.53
10	167.45
50	168.99
100	169.64
200	170.24

According to the measurements made in the rainy season of 1967 during the first-phase investigation, the Mekong's surface slope in the stretch between the bridge site and the RID gaging station at Nong Khai was about 1/10,000 to 1/9,000. In September 1966, Vientiane and its environs were inundated by a disastrous flood, listed in Table 3.1, that left behind traces of its highest water-level at many places along the river. Leveling of these traces revealed that the surface slope of the flood water was about 1/11,000 to 1/10,000.

The feasibility study made in 1961 on the Nam Ngum project showed that the Mekong carries about 800 milligrams per liter of suspended load in the rainy season and 50 milligrams per liter in the dry season. As compared with this, a relatively large amount, about 2,200 millimeters per liter, of suspended load was observed when a measurement was done cursorily during the first-phase investigation. This is perhaps due to the fact that the measurement was done in the midst of a flood season.

It is also reported in the Nam Ngum project feasibility report that the Mekong's water is slightly alkaline with a pH-value that ranges between 7.0 and 7.9, rising in the dry season and falling in the rainy season.

3.4. Topography and Geology

The topography of Laos is controlled by two major components. One is the mountain ranges extending southward from the Tran Ninh plateau toward Thailand. The other is the Annam Cordillera that runs southeastward along the Laotian-Vietnamese border. The Vientiane plain lies between these mountain ranges and the Mekong's mainstream. It extends southward across the Mekong to join the Korat plain in Thailand.

The Vientiane plain forms roughly a shape of a triangle with its base of about 80 kilometers along the Mekong. The Nam Ngum river flows through this plain, first toward the south and then, making a turn to the east, joins the Mekong at about 55 kilometers east of Vientiane. The Vientiane plain is highly promising in its potential productivity. The Korat plain in Thailand extends from north to south and from east to west slightly undulating over a vast area of about 400 kilometers square. Both plains lie on comparatively flat bedrock of Jurassic shale and sandstone overlain by silty sediment carried by the Mekong.

The Mekong flows through mountainous gorges of Paleozoic-Mesozoic Indosinian formations for a distance of about 600 kilometers in Laos. At about 30 kilometers upstream from Vientiane, it debouches from a series of narrow gorges into the open plain. The mean surface slope of the Mekong is

1/4,000 in the mountainous stretch and 1/13,000 in the plain stretch.

At the bridge site, there lies an extensive deposit of loam and silt. A conglomerate layer is observed on the Laotian side of the Mekong, but none on the Thai side. No rock outcrop can be found around the bridge site.

The geological survey of the riverside terrain in the vicinity of the bridge site made by the survey team revealed that the surface soil is underlain by layers of loam, sand, gravel, weathered siltstone and unweathered siltstone that lie in this order. The firm bedrock of unweathered siltstone can be reached at a depth of 15 to 20 meters from the ground surface on the Laotian side and at a depth of about 20 meters on the Thai side. The bedrock surface is assumed to slope gently from an elevation of El.149m. to El.153m. on the Laotian side to El.144m. on the Thai side.

The river-bed at the bridge site consists of a sand-and-gravel layer 3 to 5 meters thick on the Laotian side and of a fine sand layer 7 to 13 meters thick on the Thai side. Underneath these layers lies a thin layer of weathered siltstone underlain by firm bedrock of reddish Jurassic siltstone which extends over a vast tract in Laos and Thailand.

3.5. Traffic and Transportation

3.5.1. Roads

The roads in Laos measures about 3,000 kilometers in total length, of which about one-third is all-weathered. They are asphalt-paved in urban areas but laterite-surfaced in most other parts.

In Thailand, the total length of the road network as of 1964 amounted to about 11,600 kilometers that divides into 9,400 kilometers of national roads and 2,200 kilometers of provincial roads. They are fairly well maintained and the construction of new roads is well in progress.

The northern trunk road from Bangkok to Chieng Mai via Ayudhya and the southern trunk road from Bangkok to Songkhla via Nakorn Pathom have been the two main roads in Thailand. In recent years, however, efforts have been made on the development of other routes in the northern and northeastern parts of the country. The 600-kilometer Friendship Highway between Sara Buri and Nong Khai, a major section of the Asian Highway Route A-12, was completed in 1966. Besides, the Thai government has started in 1967 the Five-Year Plan of Road Construction that will cost about U.S.$800 million in total.

The Thai-side section of the Asian Highway Route A-12 terminates at Nong Khai. On the Laotian side, a 19-kilometer section of Route A-12 was constructed in 1962 between Tha Naleng and Vientiane. This is an asphalt-paved, two-lane road providing a 7-meter roadway sided with 2-meter shoulders. If a bridge would be built across the Mekong as planned, Route A-12 would be open to uninterrupted through traffic between Bangkok and Vientiane, and would become the first completed route among many routes of the Asian Highway network.

3.5.2. Railway

The railway in Thailand is operated by a public corporation, the Royal State Railway of Thailand. The lines under operation as of September 1966 is reported to total about 4,200 kilometers in length.

Trunk lines run from Bangkok in various directions. The North Line connects Bangkok with Chieng Mai and the Northeast Line runs from Bangkok to Nong Khai passing on the way Nakhorn Ratchasima, Khon Kaen and Udon with a line branching from Nakhorn Ratchasima toward Ubon. The East Line runs between Bangkok and Poipet, and the South Line connects Bangkok with Ban Hat Yai.

Around Bangkok, trains are operated fairly frequently. Between Nakhorn Ratchasima and Udon, there are 7 passenger trains and 6 freight trains a day, and between Udon and Nong Khai, 6 passenger trains and 2 freight trains are operated daily.

The railway traffic in Thailand is increasing annually in recent years. Most of the passengers and freight arriving at Nong Khai are destined for Laos. If a rail/highway bridge would cross the Mekong, passengers and freight would become to move, without transfer or transshipment, to and from Laos.

No railway system exists in Laos.

3.5.3. Mekong-Crossing Facilities

Local travel and light cargo transport across the Mekong are being rendered to some extent by sampans or small motorized boats available at various places along the river. But, most of passenger traffic is handled by the ferry operating between Nong Khai and Tha Deua, where immigration procedures and customs formalities are performed. The ferry charges 5 Bahts per person.

The only Mekong-crossing facility for vehicles and heavy cargoes is the existing ferry between Nong Khai and Tha Naleng, owned and operated by the Public Equipment Management Company (SOGOV). The present facility on the Laotian side comprises two ferries, a ramp, a parking area, repair shops, warehouses and offices. Each ferry measures 7 by 20 meters with a capacity of 80 tons. But the load is limited to about 50 tons in total and 20 tons per vehicle. On the Nong Khai side, there are a ramp and warehouses. These facilities have now become inadequate to cope with the increased traffic, and vehicles are often compelled to wait for a long time in a queue at the Nong Khai side.

The present capacity of the car ferry is 50 to 60 tons per crossing. The net crossing time is about 20 minutes but actually it takes more than 20 minutes including the time required for loading and unloading. The ferry is operated 6 hours per day.

3.5.4. Other Transportation

In Laos, the Mekong plays an important role in the transport of cargoes and passengers between Vientiane and Savannakhet. In Thailand, numerous canals and streams are being utilized for short haul on small boats of farm produce, commodities, livestocks and the like.

As regards air transport, the state-owned Royal Air Laos operates the airline business in Laos. Regular flights link Vientiane with Bangkok, Saigon, Hong Kong and Taipei. Frequent domestic flights are being operated between Vientiane and principal cities of Laos such as Luang Prabang, Savannakhet and Paksé. Bangkok is a pivot not only of international flight but also of some 20 domestic routes to Chieng Mai, Udon, Sakolnakorn, Sawankhalok and so on.

The port of Bangkok is not only the main port of Thailand but also at present the gateway of Laos's foreign trade. If the estuary of the Chao Phya river would be dredged, Bangkok would become to be reached by seagoing vessels larger than what are now calling at the port. In Thailand, there are many other ports of smaller scale such as Songkhla, Pattani, Narathiwat, Phuket Kantang and so forth.

3.6. Economic Condition

3.6.1. Economic Condition in Laos

Laos is essentially an agricultural country. In spite of the fact that the land under cultivation accounts for only 4 percent of the total area of the country, 90 percent of the population is engaged in agriculture.

In Laos, rice is the most important product. Laos's annual production of rice is 727,000 tons as of 1965. It is mostly consumed in the production area. The Laos's main crop that ranks next to rice is corn, raised mostly in mountainous areas. The corn crop in 1966 amounted to about 20,500 tons. other agricultural products to be mentioned are tobacco, coffee, cotton, tea, cassava, etc.

If adequate measures would be taken to improve the farming technique, Laos's agricultural production would be much increased, because the fertile land, undulating topography and the temperature in this country seem favorable to cultivation of various crops.

Rich forests cover about two-thirds of Laos, but they have not yet been exploited on any significant scale mainly because of transport difficulties. At present, forest produce is one of the main items of Laos's export and supports the country's economy. Lumber production has increased rapidly from 23,000 tons in 1960 to 77,000 tons in 1966. Such a rapid increase is attributable to the increase in the demand for use in construction works and also to the improved technique of lumbering.

Mining, with the exception of tin, is yet undeveloped in Laos. Although no detailed investigation or prospecting has been done so far, it is reported that there are at different places in Laos various minerals such as gold, copper, lead, iron, limestone, manganese, tangsten and others. Among these, an iron ore deposit in Xieng Khouang district, with an estimated reserve of several hundred million tons, is now considered the most promising. The ore is said to be of 60 to 70 percent iron content, and would be exploited and exported profitably, if a railway would be constructed. In any case, the exploitation of these mineral resources depends mainly on the improvement and development in transportation.

The most important item of Laos's mining industry is tin that is being mined in Khammouane province. The annual output of tin before World War II was about 1,300 tons. It dropped to 192 tons in 1954, but rose to 878 tons in 1966. If the exploitation of tin deposits that are reported in some places but lie so far unexploited would be accelerated by improved transportation and cheap power, it may be expected that Laos's tin output would reach 2,000 to 3,000 tons a year.

Industries in Laos have not yet developed beyond the scope of small-scale consumer-goods-manufacturing industry and home industry. Tobacco, beverage, cement and other like items are manufactured in the Vientiane area, and rice-cleaning mills and sawmills are also located mostly in this area. Excepting tobacco, the above-mentioned items are produced mostly for domestic use. Silks, cotton goods and hardwares are items of home industry.

In any case, the undeveloped, inadequate transport system in Laos constitutes a grave bottleneck to the industrial development of the country.

As regards foreign trade, Laos is suffering from a chronic adverse balance of trade. Main items of imports are foodstuff, petroleum, machinery, metal goods, etc., foodstuff accounting for about 30 percent in value of the total. Tin is the main item of the Laotian export, accounting for about 70 percent of the total value, and is followed by lumber, coffee and hide. But the export amounts to only 3 to 4 percent in value of the import, and consequently, Laos has to depend on foreign aids.

The fatal bottleneck that restrain Laos's economic activity is the fact that Laos does not possess any seaport for foreign trade. Accordingly, it can be considered that the Nong Khai/Vientiane bridge would contribute to the improvement of transportation to and from Laos and hence to the promotion of Laos's foreign trade, though it might not be so effective as a seaport.

3.6.2. Economic Condition in Thailand

Agriculture is the main industry of Thailand. Agricultural production constitutes approximately 35 percent of the gross national product and about 80 percent of the total export. About 80 percent of labor population is engaged in agriculture.

Rice is the most important crop in Thailand. Rice production in Thailand in 1964, 1965 and 1966 are reported to have amounted to 10, 9.6 and 11 million tons, respectively, of which about 15 percent was exported every year. But, since Thailand had adopted a policy of diversified farming in 1958, agricultural production other than rice such as corn, coconuts, tapioca, jute, cane-sugar and rubber has increased remarkably. Annual rubber production in Thailand is estimated at about 200,000 tons and rubber has become an important item of Thai export. And, after the completion of the Asian Highway A-12, corn outcrop has increased to 6.5 times from 186,000 tons of 1958 to 1,200,000 tons of 1966.

The forest area in Thailand is about 310,000 square kilometers. The annual teak production on an average for 4 years after World War II was mere 89,000 cubic meters. It had increased to 359,000 cubic meters in 1954, but decreased to about one-third, 106,000 cubic meters, in 1966. This decrease in teak production seems to have resulted from the fact that teak has become to be lumbered in forest areas in the far northern regions of the country and to be carried a long way, with increased costs, to markets or to sea ports for export because the forests located in areas suited for lumbering and for shipping had become all but exhausted.

Thailand is one of the main tin-producing countries, and tin constitutes an important export item of the country. Thai tin production has increased remarkably from 11,000 tons in 1958 to 31,000 tons as of 1966. Other mineral resources so far exploited in Thailand include manganese, fluorite and lignite, the production of which, though not on large scale, is in the increasing trend.

With the exception of cement, matches and some processing goods of agricultural products, the manufacturing industry in Thailand was mostly on small scale. In order to better her national economy, the government has established a plan of promoting medium-scale manufacturing industries throughout the country. As the result of the plan, the nation's industry has shown recently a remarkable progress. The number of factories has increased from 10,409 in 1957 to 38,394 as of 1965, and the industrial production in 1966 has increased about 1.8 times as compared with that in 1961 with an increase in value by about 260 million U.S. dollars. Some of the main industrial production in the last 6 years is listed in Table 3.3.

Table 3.3. Thailand's Main Industrial Production

Year	Cement, in tons	Fiber, in thousand square meters	Tobacco, in tons
1961	800,284	79,176	9,739
1962	967,475	100,061	10,525
1963	997,231	128,058	10,148
1964	1,059,136	156,803	10,409
1965	1,247,998	216,774	10,057
1966	1,482,730	237,744	11,123

Nearly half of Thailand's agricultural produce is being exported. Her foreign trade is of a typical pattern in which raw materials and foodstuff are exported in exchange for import of manufactured goods. In the past, rice, rubber, tin and teak had been the four main export items of Thailand which composed 70 to 80 percent of the total export. However, following the enforcement in 1957 of a policy of encouraging the export of more items, the export of corn, kapok, tapioka, jute and oil seeds have gradually increased. The export of these items in 1957 was a mere 3 percent of the total export, but it has increased to 17 percent in 1962. Rice accounted for 47 percent of the total export in 1957, but its share declined to 35 percent in 1964. Nonetheless, rice is still the top export item.

About 70 percent of Thailand's import is accounted for by petroleum, cars and industrial equipments and machinery such as needed for light industries and mining. In 1966, Thailand's import amounted to 1,120 million U.S. dollars as compared with 640 million U.S. dollars of export, bringing in an adverse trade balance of 480 million U.S. dollars. Of this, 300 million U.S. dollars has been balanced through the United States' financial aid, which Thailand is not obliged to repay in foreign currency.

3.7. Pa Mong Project

The first-phase investigation on the Pa Mong project was started in July 1963. The feasibility report will be presented after the third-phase investigation, scheduled to be completed in about three years. Accordingly, it is most likely that the project would not be completed before 1980.

The Pa Mong project involves construction of a gravity-type concrete dam on the Mekong at a site about 30 kilometers upstream of Vientiane, at an estimated cost of U.S.$1,000 million. Principal features of the project as considered at present are shown in Table 3.4.

Table 3.4. Principal Features of Pa Mong Dam

Catchment area	305,000 sq. km.
Height of dam	100 to 120 m.
Volume of dam	2,000,000 cu.m.
Storage capacity	73,700,000,000 cu.m.
Available discharge	3,500 cu.m. per sec.
For power generation	2,500 cu.m. per sec.
For irrigation	1,000 cu.m. per sec.
Installed capacity	3,000,000 kw

3.8. Nam Ngum Project

The Nam Ngum project now being actualized in Laos involves construction of a gravity-type concrete dam on the Nam Ngum river about 70 kilometers from Vientiane. The projected dam height is 65 meters. The power that will be generated by two units of 15,000-kw generators will be distributed not only to the Vientiane area but also into Thailand as far as to regions lying farther south of Udon.

CHAPTER IV

BASIC STUDIES

4.1. Selection of Bridge Site

When the Government of Japan undertook in 1967 the task of the present feasibility study, the following three sites were already under consideration as the possible bridge sites: (1) the Nong Khai site between Nong Khai and Tha Naleng; (2) the Vientiane site between Vientiane and Sri Chieng Mai; and (3) the Pa Mong site, about 18 kilometers upstream from Vientiane.

In the present feasibility study, therefore, it was aimed first to make study for selecting the most favorable bridge site from among the above three sites. The first-phase investigation was carried out to this effect, including topographic survey as well as engineering and geological reconnaissance of the proposed bridge sites and highway and railway routes, material survey, cost survey, and collection of engineering and general economic data/1.

The Japanese survey team consisting of nine engineers and three economists was dispatched to make the first-phase field investigations for the period from August to October 1967. And also an advisory party of three members visited the site. The party not only gave the survey team advices and suggestions but also made its own investigation.

Preliminary designs of bridges, highways and railways were made for the three sites based on the data obtained during the first-phase investigation. Salient features of these preliminary designs are listed in Table 4.1.

Surveys of existing traffic in the project area, including origin-destination surveys, were conducted during the first-phase investigation, and by analyzing the data obtained by these surveys, the possible future traffic was estimated.

Based on the preliminary designs of the project structures and on the estimated possible future traffic, benefit-cost study was made for the proposed three sites. The gist of the benefit-cost study, reported in detail in the First-Phase Report, is shown in Table 4.2.

Based on the comparative benefit-cost study made on the three proposed sites and considering the topography and geology of the sites, the relative easiness in the construction and the existing and possible future traffic, it has been concluded, as was recommended in the First-Phase Report, that the bridge shall be built at the Nong Khai site in either case of a rail/highway bridge or a highway bridge.

The Mekong Committee, following this recommendation as well as the Advisory Board's advice, has decided to select the Nong Khai site at its 34th Session held in Bangkok in January 1968.

/1: The results of studies made and engineering and general economic data obtained during the first-phase investigation are included in the Feasibility Report Part III "ENGINEERING AND ECONOMIC DATA".

4.2. Selection of Kind and Type of Bridge

As regards the type of the bridge, it was concluded as a result of the first-phase investigation, as reported in the First-Phase Report, that, for the proposed three sites alike, through-truss construction is suited for the rail/highway bridge and box-girder construction for the highway bridge.

Immediately following the Mekong Committee's selection of the Nong Khai site, the second-phase investigation was started with a chief object of obtaining data for deciding the kind of the bridge, i.e., the rail/highway bridge or the highway bridge.

A survey team consisting of twelve engineers and three economists was dispatched to the project site and stayed there about four months from February to June 1968, making topographic survey, test drilling, material survey, route reconnaissance, economic study and other necessary investigations. The findings obtained were presented in Appendices of the Second-Phase Report and also are given in the Feasibility Report, Part III "ENGINEERING AND ECONOMIC DATA".

For the Nong Khai site, the bridge, railway, highway and other project structures were tentatively designed for either case of the rail/highway-bridge project and the highway-bridge project, based on the data obtained by the field investigation. The details of these tentative designs were presented in the Second-Phase Report. The principal features of the project structures thus designed are summarized in Table 4.3.

The construction cost as well as the direct and indirect benefits that would be brought about by the project after its implementation were estimated in detail as reported in the Second-Phase Report.

As can be seen from Table 4.4 in which the results of the benefit-cost study are summarized, the highway-bridge project will bring about a much higher benefit-cost ratio and a slightly larger capitalized net benefit as compared with the rail/highway-bridge project. However, it has been reported in the Second-Phase Report submitted to the Mekong Committee in November 1968 that it would be preferable to extend railway into Laos by building a rail/highway bridge at the Nong Khai site, when various indirect benefits that might result from the railway extension would be taken into consideration and if the necessary fund would be available.

In effect, the decision has been committed to the Mekong Committee, which, after studying the Second-Phase Report and following the Advisory Board's recommendation, decided at its 38th Session held in Saigon in January 1969 that a rail/highway bridge of through-truss type be built at the Nong Khai site and railway be extended into Laos.

4.3. Selection of Railway Route

Basically, it has not been purported by the Plan of Operation to carry out a feasibility study particularly on the railway extension of about 20 kilometers from Nong Khai to Vientiane. Accordingly, the field investigations in the first and second phases had been confined to the extent of a reconnaissance of possible routes envisaged for the three proposed project sites.

However, now that the Mekong Committee has selected the rail/highway-bridge project at the Nong Khai site, there has arisen the necessity of carrying out a detailed study on the railway route around the bridge site and its extension up to Vientiane. To make this study, the Japanese government has organized and sent to the project site a railway survey team consisting of five engineers. The team stayed at the site from November 1968 to February 1969 and made topographic survey and necessary investigations on the possible routes including the location of stations and other facilities.

In the stage of the first-phase investigation, five railway routes, designated as A, B, C, D and C/D as shown in Fig.4.1, were considered feasible and were studied. And as reported in the Second-Phase Report, it was found that Route C or Route C/D will be the most feasible and advantageous among the envisaged five routes. Consequently, the field study on the railway route was focussed on Route C and Route C/D.

Based on the data obtained from the field study, tentative designs were made of the railway extension including the Vientiane station and necessary structures for both Route C and Route C/D. The salient features of these designs, together with the construction costs, are given in Table 4.5, and the benefits and costs of both routes are compared in Table 4.6.

Although Route C will bring about a slightly higher benefit-cost ratio at a little less cost than Route C/D as can be seen from Table 4.6, Route C/D seems preferable in view of the following points concerning the location of the station in Vientiane.

(1) The station in Route C is located about 4 kilometers from the civic center of Vientiane and it will not be easy to acquire a sufficient tract for the station yard. Besides, the station will face just opposite to the Nam Ngum project substation.

As compared with the above, the station in Route C/D is located about 7 kilometers from the civic center, where no obstruction can be envisaged in locating the station and the station yard.

(2) The station site of Route C lies on a land that slopes from neighboring highlands and directly faces a low-lying land that will become a passage of flood water when such a flood as the 1966 flood would come. Such concern is not necessary in Route C/D, because the station in this route is located on the highlands free from inundation.

(3) If Route C/D would be adopted, the station will become an effective incentive to Vientiane's future expansion toward inland in a greater degree than in the case of Route C. And,

(4) In Route C, the station is located just at the outskirts of the present Vientiane. Consequently, it will soon become surrounded by commercial, industrial or residential quarters when judged from the recent trend of Vientiane's expansion. It is generally not desirable in the light of the city planning in the future that a big station such as the Vientiane station, along with its yard, lies in or near the congested area of a city. In this point, Route C/D is preferable to Route C.

From the above consideration, Route C/D was taken up for the economic evaluation of the present project as reported in the Second-Phase Report. The Mekong Committee has decided at its 38th Session held in Saigon in January 1969 to select Route C/D for extending railway into Laos.

Table 4.1. Salient Features of the Project Envisaged in the First-Phase Investigation

Description	Unit	Nong Khai site		Vientiane site		Pa Mong site	
		Rail/highway bridge	Highway bridge	Rail/highway bridge	Highway bridge	Rail/highway bridge	Highway bridge
I. BRIDGE							
1. River width	m	640	640	930	930	320	320
2. Design high-water level	m	EL. 167	EL. 167	EL. 170.5	EL. 170.5	EL. 172.5	EL. 172.5
3. Type of bridge		Truss	Box girder	Truss	Box girder	Truss	Box girder
4. Length of bridge	m	1,135	735	1,345	993	410	410
5. Maximum pier spacing	m	85	85	85	85	90	90
II. HIGHWAY	Km	3.4	3.4	0.4	0.4	27.6	27.6
III. RAILWAY	Km	18.7	18.7	38.2	38.2	58.9	58.9

Remarks:– The above figures were quoted from the First-Phase Report and those pertaining to the Nong Khai site have been modified at the last stage of the feasibility study of the project, as given in Chapter V of this Report.

Table 4.2. Benefits and Costs of the Project Envisaged in the First-Phase Investigation

	Description	Unit	Nong Khai site		Vientiane site		Pa Mong site	
			Rail/highway bridge	Highway bridge	Rail/highway bridge	Highway bridge	Rail/highway bridge	Highway bridge
1.	Construction cost	US$	15,100,000	8,900,000	20,800,000	10,300,000	22,500,000	10,000,000
2.	Annual benefit	US$	5,767,000	5,163,000	4,342,000	2,146,000	1,942,000	- 417,000
3.	Annual cost	US$	1,022,700	602,300	1,371,000	630,300	1,847,200	739,600
4.	Benefit-cost ratio		5.64	8.57	3.17	3.41	1.05	- 0.56
5.	Capitalized net benefit	US$	98,208,000	93,750,000	63,464,000	31,916,000	6,635,000	-22,341,000

Remarks:–

(1) The annual benefit is the sum of the direct benefits of two kinds: the savings in travel time and vehicular operating cost, estimated by comparing the traffic through the present car ferry and on the projected bridge.

The negative annual benefit means that the existing ferry is more advantageous than the projected bridge.

(2) The above figures were quoted from the First-Phase Report, and some of them have been modified in the final Feasibility Reports, as shown in Chapter VI, due to the subsequent advanced studies.

Table 4.3. Salient Features of the Project for the Nong Khai Site envisaged in the Second-Phase Investigation

Item	Unit	Rail/highway-bridge Project	Highway-bridge Project
I. BRIDGE			
1. River width	m	640	640
2. Navigation requirements			
(i) Vertical clearance	m	10	10
(ii) Horizontal clearance	m	78	78
3. Design high-water level	m	EL. 167	EL. 167
4. Type			
(i) Main bridge		Steel Warren truss bridge	Steel box girder bridge
(ii) Access bridge			
Railway part		Plate girder, and reinforced concrete rigid frame construction	
Highway		Composite girder, and reinforced concrete hollow slab construction	
5. Bridge width	m	17.8	11.6
(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	
6. Bridge length			
(i) Main bridge	m	720*	710
(ii) Access bridge			
Railway part	m	401.7*	
Highway part	m	330	
7. Max. pier spacing	m	90	90
II. HIGHWAY			
1. Length	km	5.0*	5.4
2. Width			
(i) Roadway, two lanes	m	7	7
(ii) Shoulder on both sides	m	2.5	2.5
3. Administrative facilities	m^2	185,000*	125,000
III. RAILWAY			
1. Length	km	20.1*	
2. Track gauge	m	1.000	
3. Station			
(i) Vientiane station	m^2	107,900*	
(ii) New Nong Khai station	m^2	32,200*	

Remarks:– The figures asterisked have been modified at the final stage of the feasibility study, as shown in the Feasibility Report PART II "ENGINEERING, ECONOMIC AND FINANCIAL STUDIES", Chapter V.

Table 4.4. Comparison of Benefits and Costs Between Rail/Highway-Bridge and Highway-Bridge Projects at the Nong Khai Site Envisaged in the Second-Phase Investigation

Item	Unit	Rail/highway-bridge Project	Highway-bridge Project
I. CONSTRUCTION COST	US$	20,000,000*	12,000,000
II. FUTURE TRAFFIC			
(i) Vehicles			
1973 (year)	cars/day	1,273	1,640
1990	"	8,317	10,140
2000	"	12,459	15,146
(ii) Railway freight			
1973	tons/day	609	
1990	"	2,664	
2000	"	3,873	
(iii) Railway passengers			
1973	persons/day	361	
1990	"	1,922	
2000	"	2,840	
III. DIRECT BENEFIT			
1. Annual benefit	US$	9,281,000*	8,994,000
2. Capitalized benefit	"	289,644,000	280,161,000
IV. COST			
1. Annual cost	US$	1,177,600*	665,700
2. Capitalized cost	"	26,659,000*	15,823,000
V. BENEFIT-COST RATIO		7.9*	13.5
VI. CAPITALIZED NET BENEFIT	US$	262,985,000*	264,338,000
VII. INTERNAL RATE OF RETURN	%	16.1*	18.7
VIII. INDIRECT BENEFIT			
1. Stock saving		Much	Much
2. Urbanization		Rapid, especially around Vientiane station	Expected
3. Rise in land value		Remarkable	To some extent
4. Agricultural development		Expedited	Expedited
5. Livestock industy		Self-sustaining expedited	Self-sustaining expedited
6. Mining		Much expedited	Expedited
7. Lumber industry		Much expedited	Expedited

Remarks:— The figures asterisked have been modified at the final stage of the feasibility study, as shown in the Feasibility Report PART II "ENGINEERING, ECONOMIC AND FINANCIAL STUDIES", Chapter VI.

Table 4.5. Salient Features of Route C and Route C/D

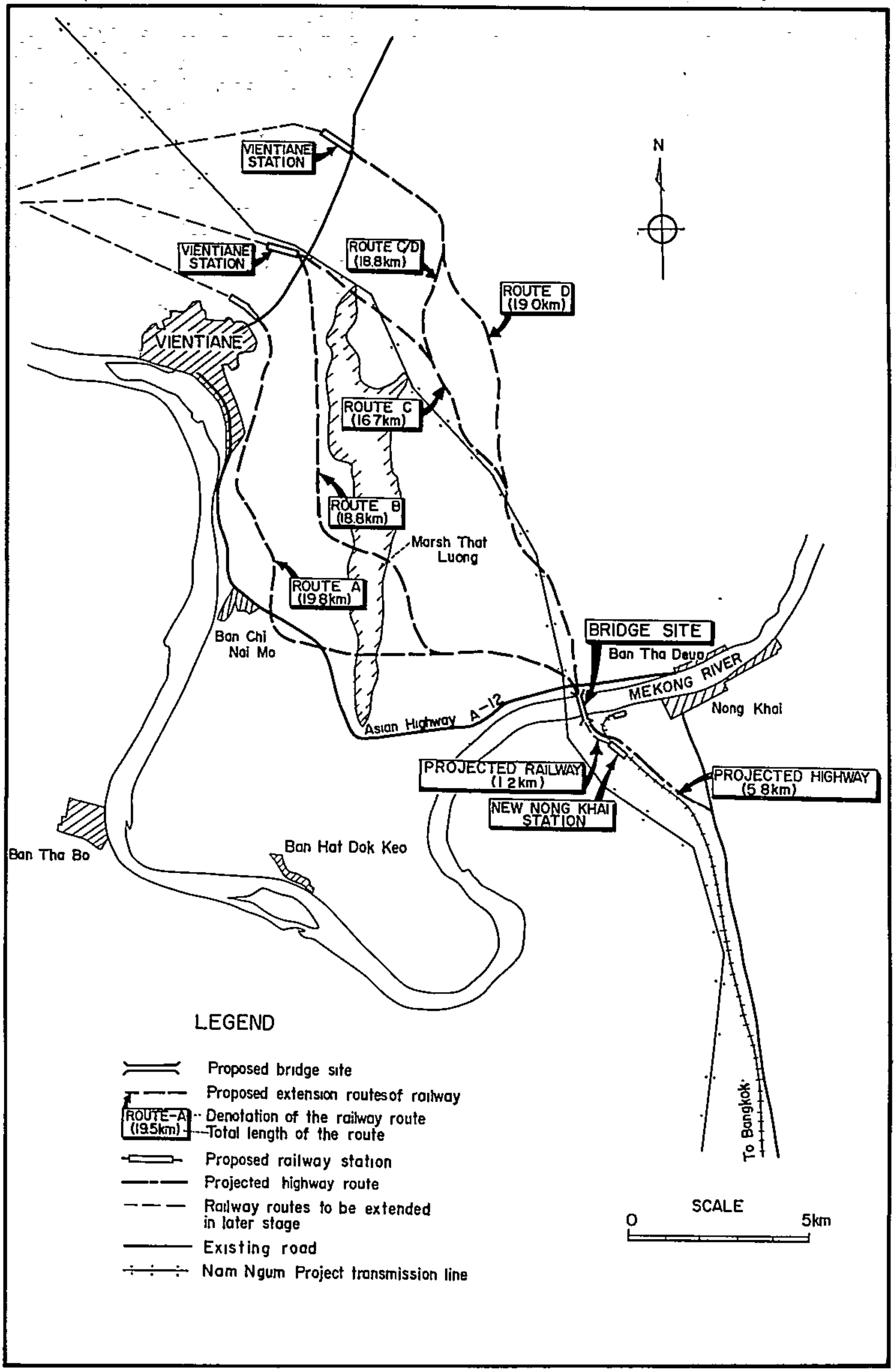
Item	Unit	Route C	Route C/D
I. RAILWAY TRACK			
1. Rail	lbs/yd	80	80
2. Rail gauge	m	1.000	1.000
3. Track		Single	Single
4. Route length	km	17.9	20
II. VIENTIANE STATION			
1. Station yard	m^2	100,000	100,000
2. Station building	m^2	1,000	1,000
3. Platform	m^2	3,000	3,000
4. Station plaza	m^2	14,000	14,000
III. BRIDGES AND CULVERTS			
1. Flood bridge	sites	6	5
2. Overpass	"	2	1
3. Bridge	"	3	1
4. Culvert	"	9	13
IV. COST			
1. Construction cost (1	US$	5,450,000 (1	5,550,000 (1
2. Unit cost	US$/km	310,000	280,000

Remarks:– (1 These costs do not include the expense for engineering service, Governments' administrative expense, and interest during construction.

Table 4.6. Comparison of Benefits and Costs Between Route C and Route C/D

Item	Unit	Route C	Route C/D
1. Annual benefit	US$	4,676,900	4,594,300
2. Capitalized benefit	US$	46,770,000	45,940,000
3. Annual cost	US$	2,449,300	2,478,700
4. Capitalized cost	US$	24,490,000	24,790,000
5. Benefit-cost ratio		1.91	1.85
6. Capitalized net benefit	US$	22,280,000	21,150,000

Fig. 4.1. RAILWAY ROUTES



CHAPTER V

CONSTRUCTION

5.1. General

The Nong Khai/Vientiane bridge project involves as its main project structures (1) a rail/highway bridge across the Mekong and its approach viaducts; (2) a railway line of 20 kilometers between Nong Khai and Vientiane including the new Nong Khai and the Vientiane stations, yards and necessary structures; (3) a 6-kilometer highway to connect the Asian Highway Route A-12 in Thailand with the Laotian section of the same route; and (4) administrative facilities for immigration and customs procedures.

Judged from the studies made in the first and the second phases and subsequently, it may be said that the construction of the project structures itself will be practically feasible in engineering point of view. But there are some problems that shall be solved or coped with beforehand. At the present moment, the following three items are considered as such:(1) scouring of the river-bed around piers; (2) bank erosion; and (3) the use in embankment of soil that swells when saturated with water. These problems, however, are solved or can be coped with as will be mentioned later and are in no way so serious as to make the project unfeasible.

The 650-meter main bridge that spans the Mekong will be a through truss bridge that divides into nine spans, of which one measures 90 meters and the rest 70 meters. The 90-meter span conforms to the navigation requirements. A single-track railway line and a two-lane roadway will be laid between the main trusses, and a pedestrian sidewalk and an inspection gangway will be provided on brackets that outstand from either side of the main truss as shown in Fig.5.3.

The bridge superstructure will rest on reinforced concrete piers founded on the firm siltstone layer in the river-bed with pneumatic caissons, excepting the two piers to be built on the riverside land, for which open caissons will be used.

Although the railway and roadway will be laid in parallel on the same floor of the main bridge, they will be separated in the approach sections because they shall be located conforming to respective specifications that differ much, for instance, in the limitation of grades and curves. The railway approach will run over reinforced concrete viaducts, consisting of a series-of-three-span rigid frames and measuring 210 meters on the Thai side and 203.5 meters on the Laotian side. The roadway will be laid on reinforced concrete approach viaducts of hollow-slab construction, measuring 135 meters each on both Thai and Laotian sides. At each end of the main bridge, a 30-meter span will connect the viaducts to the main bridge. This 30-meter span will be crossed by a steel plate girder to carry the railway and by a steel-concrete composite girder to support the roadway.

The rail line on the Thai side is not planned to extend from the present Nong Khai terminal. Instead, it will branch off from the existing route at a point a little distant from the present terminal, where the existing line makes an eastward curve. The new station will be built also at this site. The offices and facilities for immigration and customs procedures will be built in the premises of both the new Nong Khai and the Vientiane stations.

To guard the rail line against extraordinary floods, the formation level will be located so that it would not be overtopped by a 40-year probable flood. Besides, embankment slopes will be adequately protected and flood bridges will be provided where the line would be exposed to violent streams of flood water.

The new highway route on the Thai side branches off from the existing Asian Highway route at about 500 meters north of the Na Tha railway station in the suburbs on Nong Khai and runs about 4.5 kilometers to reach the Mekong bridge. The administrative facilities on the Thai side, including the immigration office, customhouse, plant quarantine, warehouses and others, will be installed neighboring the new Nong Khai railway station as shown on Plate 2. The administrative facilities on the Laotian side will be located at a riverside site where the new highway route joins the existing Asian Highway route.

The salient features of the project structures are listed in Table 5.1.

Most regions in Southeast Asia are generally affected much by monsoons accompanied by heavy rainfall that will give rise to floods and the present project site is in no way an exception. Therefore, the construction shall be carried out concentrically in the dry season that lasts from November to next April. Considering this circumstance, the construction is estimated to take about two years. In addition, the period required for preparatory works including the detailed designing, preparation of tender documents and the decision of a contractor or a joint venture of contractors to whom the job shall be awarded is estimated at about one year and a half as shown in Fig.5.12.

Based on the data so far obtained and the work quantities of the tentative design, the costs of various construction items have been estimated as listed in Table 5.6. The construction cost totals an amount equivalent to U.S.$21,500,000 that divides into U.S.$10,900,000 in foreign currency and U.S.$10,600,000 in domestic currency, that is, in Thai and Lao currencies. Of this total, the direct cost of the bridge accounts for about 30 percent, or U.S.$6,200,000, and the railway and highway inclusive of administrative facilities U.S.$5,550,000 and U.S.$2,440 000, respectively.

Table 5 Project Features

Item	Unit	Characterization
I. Project		
1. Location		670 kilometers northeast of Bangkok, 20 kilometers south-east of Vientiane and 3 kilo-meters upstream of Nong Khai
2. Purpose		To build a rail/highway bridge across the Mekong including the construction of a highway, a railway to be extended to Vientiane, and two administrative facilities for immigration, customs and plant quarantine.
3. Construction cost	US$	21,500,000
II. Bridge		
1. River width	m	640
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 bridge		Steel Warren truss bridge, two 3-span continuous and one 2-span continuous, besides a suspended span
(ii) Approach viaducts		
Railway part		Plate girder and reinforced-concrete 3-span-continuous rigid frame construction
Highway part		Composite girder and rein-forced-concrete 3-span-continuous hollow slab construction
5. Bridge width	m	17.8
(i) Railway part	m	4.0
(ii) Highway part	m	8.0
(iii) Sidewalk	m	1.5
(iv) Gangway	m	1.5
6. Bridge length		
(i) Main bridge	m	650
(ii) Approach viaducts	m	803.5
Railway part		473.5
Plate girder	m	60
Rigid frame	m	413.5
Highway part		
Composite girder	m	60
Hollow slab	m	270
7. Abutment and pier	m	2 open caissons on both banks 8 pneumatic caissons on the Mekong river-bed.
8. Span		
(i) Main bridge	m	(70-70-70)x2+2(70+70)x1+90
(ii) Approach viaducts		
Railway part		
Plate girder	m	(30) + (30)
Rigid frame		
Laotian side	m	(8-15-8-3)+(3-10-10-10-3)x4 +(3-7.5-7.5-7.5)
Thai side	m	(10-10-10-3)x2+(3-10-10-10-3)x4
Highway part		
Composite girder	m	(30) + (30)
Hollow slab	m	(15-15-15)x6
9. Summit of formation	m	EL. 179.270
10. Longitudinal grade		
(i) Main bridge	%	1.2
(ii) Approach viaducts		
Railway part		
Plate girder	%	1.2
Rigid frame	%	1.2
Highway part		
Composite girder	%	1.2
Hollow slab	%	4.0
III. Railway		
1. Length		
(i) Laotian side	km	18.8
(ii) Thai side	km	1.2
2. Track gauge	m	1.000
3. Radius of curvature	m	400 at min.
4. Station		Including administrative facilities
(i) Vientiane station	m^2	100,000
(ii) New Nong Khai station	m^2	55,000
IV. Highway		
1. Length		
Laotian side	km	1.3
Thai side	km	4.5
2. Width		
Roadway	m	7 (two lanes)
Shoulder	m	2.5 (each on both sides)
3. Radius of curvature	m	500
V. Administrative facilities		
1. Laotian side	m^2	22,000
2. Thai side	m^2	26,000

5.2. Main Bridge

The Mekong bridge has two objectives: to extend the existing railway from Nong Khai to Vientiane; and to consummate the Asian Highway A-12 that lies at present cut off by the Mekong.

The Nong Khai site has been selected by the Mekong Committee, but the exact location is not yet decided, for which the following situations must be taken into account.

(1) No favorable site can be conceivable on the stretch downstream from the Thai Government Hydrographic Office that lies about one kilometer upstream of Nong Khai, because the riverside land on the Thai side becomes the more densely inhabited the nearer it gets to the town of Nong Khai.

(2) Although the Mekong flows in a straight channel from a point about one kilometer upstream of the Hydrographic Office, the center of stream does not lie in the channel center but lies deviated toward the Laotian side, because the river on the upstream reach flows in a curve deviated toward the Laotian side. Therefore, it is desirable to locate the bridge as downstream as possible from the said point.

(3) The Nam Ngum project transmission line crosses the Mekong at a point about 600 meters upstream from the Hydrographic Office.

(4) A small tributary on the Thai side joins the Mekong at a point about 400 meters upstream from the Hydrographic Office and often causes inundation in the rainy season. And,

(5) The Shipyard Training Center of Thailand is now under construction at a site just downstream of the Hydrographic Office.

Considering the above situations, it has first been concluded that the bridge shall be located within a stretch between the Hydrographic Office and the estuary of the said tributary. And, after making studies on the geology, soil conditions, the relationship to the rail and highway routes as well as to the shipyard under construction and other circumstances, the bridge center line has finally been located as shown in Plate 2 in this report, and in Fig.2.1 in Part III.

The tentative design of the bridge has been made conforming to the Specifications for the Supply of Steel Superstructure of Railway Bridge of the Royal State Railway of Thailand as well as to the Standard Specifications for Highway Bridges of the American Association of State Highway Officials.

The railway and roadway clearance limits on bridges stipulated by these specifications are shown in Fig.5.1 and the specified railway and highway live loads are shown in Fig.5.2.

5.2.1. Superstructure

Prior to the design of the bridge superstructure, studies were made on the following three items: (1) the type of the bridge; (2) the layout of the railway and roadway on the bridge; (3) the elevation of the bridge in relation to navigation requirements. In the following are described the gists of the studies made on these items.

(1) Type of Bridge

The structural type of a bridge is to be decided not only from the engineering and economic points of view but also from the viewpoints of local conditions and esthetics. A bridge shall first suit local conditions and render the greatest service at a least cost. It is required also to be durable, easy for maintenance and agreeable in appearance.

With these in view, a comparative study on the bridge superstructure was carried out considering the following five types for the main bearer elements: (1) continuous box girders with battledeck floors; (2) simply-supported box girders; (3) continuous through trusses; (4) simply-supported through trusses; and (5) tied arches.

In a multispan bridge with spans of 60 to 80 meters, the greatest saving in steel weight is effected, in general, by the use of continuous through trusses. As compared with this type, simply-supported through trusses, continuous box girders, tied arches and simply-supported box girders require about 10, 25, 30 and 35 percent more steel, respectively.

On the other hand, truss bridges, continuous or simply supported, require much more work in shop fabrication and field assembly and a higher cost of maintenance as compared with girder bridges. Besides, through bridges, of truss type or of any other type, will present inconvenience when the roadway would be widened in the future. On through bridges, car drivers'sight will be narrowed and travelers will be hindered from commanding a vast view from the bridge.

Although girder bridges may seem preferable from the above viewpoints, if loaded with heavy and fast-running train loads, continuous girder bridges will undergo large deflections and severe vibrations due to a relatively small depth-span ratio of the girder. Besides, as it is natural that girder bridges are designed as deck bridges, the bridge floor in a girder bridge will become to lie at a higher level than in the case of a through bridge, if the same vertical clearance shall be provided underneath the bridge. The floor level in a deck girder bridge can be lowered to some extent by using battledeck floors, or steel deck-plates. But, battledeck floors are inconvenient for track laying.

Thus, from the above considerations and especially considering that it is most desirable to reduce the length and the height of approach structures by laying the bridge floor as low as possible, a continuous through truss bridge has been selected as the most recommendable type of the bridge.

As an alternative for a through truss bridge, a bridge consisting of a series of tied arches is well conceivable. But, an arch bridge of this type, each span of which in its nature shall be built as a single-span structure, generally requires about 30 percent more steel for a span of about 60 or 70 meters than a three-span continuous through truss bridge. Moreover, tied arches lack rigidity. Therefore, tied-arch construction was left out of consideration.

It goes without saying that a bridge must be planned not only from the viewpoint of its superstructure but also in relation to its substructures. At sites where it is almost impossible or extremely difficult to construct midstream piers or a very large channel opening is required, a suspension bridge is a solution. At the Nong Khai site, however, though some difficulties might arise in the work during the flood season, there seem to exist no unfavorable conditions that would hinder the construction of midstream piers. Hence, a suspension bridge is out of the question.

Prestressed-concrete construction was also studied. A bridge of this kind with a span of 70 meters or more, a span required for navigation in the present project, involves many problems in its construction. And, because prestressed-concrete girders generally weigh much heavier than steel girders, a much greater cost is required in their substructures and foundations. Besides, prestressed-concrete structures require much more time in construction than steel structures. From these reasons, the adoption of prestressed-concrete bridges was left out of consideration.

(2) Layout of Bridge Floor

In order to find out the most desirable and economical way of providing the vehicular roadway and the railway track on the bridge, comparative studies were made on the five conceivable types shown in Fig.5.3.

1) Type 1

In this type, the main trusses will be spaced 13.4 meters on centers. Between these trusses will be laid the two-lane, 8-meter-wide roadway on one side and the railway track on the other side, both on the same floor. Foot-paths of 1.5-meter width will be provided one each on either outside of the main trusses for use of pedestrians or for inspection.

In this layout, the main truss on the side of the railway track will be subjected to a greater load than the one on the side of the roadway because the railway loading is greater than the roadway loading. The discrepancy in the stresses in the truss members, however, does not, in the present case, become so large as one might suppose, because the unbalance in the live loads will mostly be offset by the heavier dead load of the roadway deck. It will present no serious problem whatsoever in designing.

Although they are large as compared with the highway loading, the train loads act on floorbeams relatively near their ends so that the bending moments that will arise in the floorbeams due to the train loads do not amount to much. Besides, the floor system will be of a simple design and no much material is required for the floor system as well as for the lateral and sway bracings. The total steel weight required for the Type-1 construction, including adjoining approach viaducts, has been estimated at about 3,500 tons as compared with the 3,700 tons for Type 2.

In Type 1, as the roadway and railway will be laid separated and in parallel on the same floor, the approach structures that shall be constructed on different routes and in different grades for the roadway and for the railway can be located and designed independently and most easily. Type 1 will require the least construction cost among the envisaged types not only in the main bridge but also in the total including the approach structures, as shown in Table 5.2.

Table 5.2. Comparison of Direct Construction Costs
of Bridges of Five Types Shown in Fig.5.3

Floor Layout	Main Bridge	Approach Viaducts	Total
Type 1	5,330,000	870,000	6,200,000
Type 2	5,490,000	1,050,000	6,540,000
Type 3	7,600,000	500,000	8,100,000
Type 4	5,500,000	1,800,000	7,300,000
Type 5	5,700,000	1,050,000	6,750,000

Note: The costs are given in U.S. dollars, not including the expense for engineering service, Governments' administrative expenses and interests during construction.

2) Type 2

In this type, the railway track will be laid at the middle of the bridge floor, and the roadway will be divided into two single-lane parts that lie separately on either side of the railway track. Each divided parts of the roadway will be made 5 meters wide in order that eventual passing may be done or the traffic might not be stopped by disabled cars. Accordingly, the main trusses must be spaced wider, 16.0 meters on centers, requiring longer floor-beams than in Type 1.

In this construction, both main trusses will receive the same load. But, as the heavy train loads act at the midspan of the floorbeams, a much greater bending moment will be caused in the floorbeams, requiring much more steel in the floor system than in Type 1. Likewise, as the main trusses will be spaced wider, the lateral and sway bracings will also require more steel and piers must be made wider. These circumstances cause a rise in the cost of the main bridge.

Because the roadway in Type 2 is divided into two one-way parts by the in-between-lying railway track, either one must be led, crossing the railway with a grade separation, to join the other one and then to merge in the normal two-lane roadway on the approaches. This necessitates a very complicated design and construction of access structures and, consequently, an increased cost as can be seen in Table 5.2. Furthermore, the divided roadway is somewhat inconvenient and uneconomic in carrying out its maintenance and administration.

3) Type 3

Type 3 is a commonplace solution in which a highway bridge and a railway bridge will be built in parallel. In the viewpoint of the approach structures, this solution is the most convenient and requires the least cost as shown in Table 5.2. However, to construct two bridges separately, one each for sole use of railway and highway, generally requires a much greater cost than to build a dual-purpose rail/highway bridge. In the present case, the main bridges of Type 3 will cost by about U.S.$2.3 million more than the dual-purpose bridge of Type 1. Type 3 requires the greatest total construction cost among the envisaged types.

However, Type 3 has a distinctive advantage that it can be implemented in two steps in a way that at the first step only the highway bridge will be constructed and the railway bridge will be built at a later stage when it would become needed. Type 3 has also another advantage that the administration, operation, maintenance and financing of both bridges can be done independently.

4) Type 4

This type is a double-deck construction, in which the 8-meter-wide, two-lane roadway will be placed on the upper deck and the railway track on the lower deck, with a 1.5-meter footpath on either side. In this type, because the roadway lies at a high elevation, the roadway approach structures must be constructed higher and consequently must extend longer than in other types, involving many engineering difficulties and costing a large amount, about double as compared with Type 2.

In this type, the main trusses can be spaced closer, 8 meters on centers, and hence piers can be made less wide. But, two floor systems must be provided, one for the roadway and another for the railway, causing a cost increase. Moreover, as it is a top-heavy construction, due attention must be paid in designing to ensure the lateral stability of the bridge. Type 4 requires the second greatest cost.

5) Type 5

Type 5 differs from Type 2 in that the divided roadway parts and footpaths are laid outside of the main trusses as shown in Fig.5.3. The footpaths take the form of sidewalks. In this type, the main trusses might be spaced narrow to the extent that the required track clearance can be afforded, and consequently the piers might be made also less wide than in Type 2. But they shall be made a little wider than necessary in order to ensure the lateral stiffness of the structure. Namely, the main trusses will be spaced 6.5 meters on centers instead of 4.8 meters that would suffice for the railway track.

One merit of this type may be that it can afford car drivers or passengers a wide and uninterrupted view from the bridge. But Type 5 has the same disadvantages as Type 2 in respect of the approach roadway layout. Besides, as the roadway parts will be laid on long cantilever floorbeams that outstand from the main structure, large deflections and vibrations of the outstanding parts cannot be avoided and it shall be expected that the main structure will be subjected to tortion due to the unbalanced roadway loading. From the structural point of view, Type 5 cannot be said recommendable.

6) Conclusion

From the viewpoint of the structural dynamics and in consideration of the total construction costs of the main bridge and approach viaducts mentioned above, the layout of Type 1 is the most desirable.

The Mekong Committee, however, requested the Japanese survey team to make further comparative study of Types 1 and 2, because the difference of construction costs between both types is not so much as expected, in connection with the layout of the administrative facilities and the problem that the direction of traffic flow has to be changed on or in the proximity of the bridge because in Thailand the highway traffic keeps to the left, and in Laos to the right.

Although many plans can be conceivable for the further study, nine plans shown in Fig.5.4 have been envisaged and studied. As a result, the following are concluded:

(i) Traffic flow is comparatively simple in each of five plans from (a) to (e) for Type 1 shown in Fig. 5.3, while that in each plan for Type 2 is a little more complicated.

(ii) Administrative facilities on the Laotian side are inevitably divided into two according to the direction of traffic in Type 2. As a result a special bypass connecting the two separate administrative facilities is required to deal with the vehicles violating the immigration law. Such layout is very inconvenient from the viewpoint of administration as compared with the case that the administrative facilities are provided at a place like in Type 1.

(iii) As compared with each plan in Plans (a) to (e) for Type 1 excepting Plan (d), each plan in Plans (f) to (i) for Type 2 requires an increased cost of about U.S.$260,000 for the construction of the projected highway, because a divided roadway necessarily takes a roundabout way on the Thai side, in addition to the increase of U.S.$340,000 in the cost of the main bridge with approach viaducts as shown in Table 5.2.

Thus, all things considered, it was concluded that Type 1 is the most recommendable type of the floor layout of the rail/highway bridge to be built in the present project. And, further studies and designs have been made assuming the adoption of this type.

(3) Elevation of Bridge

At and around the bridge site, the Mekong flows relatively deep on the Laotian side and shallow on the Thai side. The navigation course at this site lies therefore deviated toward the Laotian side.

The Plan of Operation states in regard to the Mekong's navigation that:

"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 waterway traffic on the Mekong around the project area has so far been limited to small-scale, regional services on the reach upstream from Savannakhet, because certain sections in the downstream reach, such as the rapids at Khemarat and Sambor and Khone Falls[/1], are not navigable or navigable only with difficulty. In recent years, however, pusher-barge fleets have come to be used increasingly in regional river traffic. Operator's cabins of pusher tugs are built as high as 8 to 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 for navigation will be required than what may suffice for the existing river traffic. Accordingly, the Advisory Board's recommendation of the 10-meter clearance can be considered appropriate.

The problem lies in the selection of the preponderant high-water level. With a view of obtaining data for this selection, the high-water levels probable to occur at the bridge site were estimated based on the records observed at gaging stations located in the project area and are shown in Table 5.5 in Part III. The high-water levels listed in this table are what were estimated from the 30-year (1937–67) data observed at the R.I.D. gaging station located at Wat Hai Sok in Nong Khai and the 4-year (1964–67) records at the Hydrographic Office at Nong Khai.[/2] The details of the probability calculation for the above are described in Paragraph 5.2 in Part III.

/1: Khone Falls is a series of rapids extending from Kinak to Voeun Khane near the Lao-Cambodian border over a distance of about 20 kilometers with a total head of about 30 meters.

/2: The hydrographs of these water-level records are shown in Paragraph 5.1 in Part III.

The number of days in which the water level at the bridge site in the past was above the estimated 2-, 5-, 10- and 20-year probable high-water levels and the maximum durations in days during which the water level in the past continuously remained above the probable high-water levels were computed from the 30-year water-level records at the R.I.D. gaging station and are given in Table 5.5 in Part III.

As can be seen from this table, the water-level at the bridge site remained in the past above the 2-year probable high-water level at a rate of one in 50 days on the average. The corresponding figures for the 5- and 10-year probable high-water levels are very small, i.e., 1 in 310 and 1 in 700, respectively.

Of the floods recorded so far, what had remained longest above the estimated probable high-water levels is the one that in 1966 inundated the Vientiane plain. The flood-water level of this flood corresponds to the 20-year probable high-water level, and had remained continuously 29, 20 and 14 days above the 2-, 5- and 10-year probable high-water levels, respectively. In the floods that occurred in other years, the number of days per year in which the flood-water levels were above the 5-year probable high-water level is about 5 days on an average.

From the above consideration, the 5-year probable high-water level of an elevation of 166.7 meters above mean sea-level was considered appropriate to be chosen as the preponderant high-water level. Consequently, making a margin of 0.3 meters, the design high-water level at the bridge site to be based upon in designing the bridge structures was set at E1.167.0.

In the tentative design of the main bridge, the top face of the piers of the 90-meter main span that provides a horizontal clearance of not less than 78 meters as stipulated in the Plan of Operation was set at E1.177.0. Then, if it is assumed that the bridge bearings will stand about 0.6 meters high, the bottom of the bridge members will become to lie at E1.177.6, 10.6 meters above the design high-water level and 10.9 meters higher than the 5-year probable high-water level, well meeting the requirement of a minimum vertical clearance of 10 meters above the preponderant high-water level.

The main bridge that will measure 650 meters in total length will be divided into nine spans, one 90-meter span and eight 70-meter spans. The 90-meter span that will provide the main navigation course is not located at the center of the bridge. Instead, it constitutes the fourth span from the Laotian side conforming to the condition of the river channel previously noted. On both sides of the 90-meter span, the bridge will slope toward both ends at a straight-line grade of 1.2 percent, the maximum grade specified by the Thai Royal State Railway.

The formation level on the railway approach structures will also make a straight-line profile of 1.2 percent. But, the approach roadway will be laid at a grade of 4 percent in order to save the construction cost. The railway must provide a vertical clearance of not less than 4.5 meters when it crosses the existing Asian Highway A-12 on the Laotian side and shall not constitute an obstacle to the local land traffic on the Thai side.

All these circumstances considered, the elevation of the bridge floor surface, assumed to lie 2 meters above the top of each pier, was set at E1.176.48 at the Laotian end and at E1.174.80 at the Thai end as shown in Plate 4. The highest point, or summit, of the roadway surface lies at the midspan of the 90-meter span at an elevation of E1.179.27.

5.2.2. Substructure

The piers of the main bridge will be built of reinforced concrete and will be founded on the firm siltstone layer underlying the alluvial river-bed by pneumatic caissons, excepting the two at the bridge ends, for which open caissons will be used. The substructures of the approach structures are also of reinforced concrete construction and will be founded on precast reinforced-concrete piles that shall be driven into firm sand or gravel layers.

The substructures of the approach structures are all of conventional construction and require no special mention. However, the main bridge piers involve some engineering problems, which will be dealt with in the following.

(1) Kind of Piers

Unless there is a particular reason or necessity, to construct bridge piers of reinforced concrete is a long-established practice, especially when they shall be built in water. If steel or prestressed concrete is used in piers, there will arise a problem in joining the pier body with the foundation, whether it may be built of piles or a caisson, and the cost will increase. Besides, if steel piers will be built in the water, corrosion becomes a serious problem. In the present project, the piers will of course be built of reinforced concrete.

The piers will have an elliptical section to reduce the pressure and the back-water phenomenon of the river stream. The pier head will be enlarged to support the superstructure.

(2) Pier Spacing

In a steel truss bridge in general, the length of each member and the total steel weight increase with the increase in the span. Consequently, the total cost of the superstructure increases as the span becomes longer. On the other hand, in a bridge to cross a wide river such as the Mekong, the number of piers and consequently the construction cost of the substructure will increase when the span becomes shorter. This correlation is a problem of great importance to be studied carefully in any bridge project.

Accordingly, a comparison was made chiefly in respect of the total cost of construction, including the super- and substructures, between the cases of 50-, 60-, 70-, 80- and 90-meter spans, assuming that the foundation caissons will be founded on the bedrock of firm siltstone by excavating it about 2 meters deep and assigning a constant bearing value for the bedrock. The result is graphed in Fig. 5.5 that shows clearly that the most economical span will lie around 70 meters. Consequently, it has been decided to divide the bridge into eight 70-meter spans and a 90-meter span, the last being provided for the sake of navigation, as shown in Plates 3 and 4.

(3) Pier Foundations

Bridge foundations are so important a problem as would decide the engineering feasibility of the project. Unsuitable foundations will cause an unnecessary increase in the construction cost and inadequate foundations may lead to damages or destruction of the superstructures. For the foundations of the Mekong bridge to be built at the Nong Khai site, pile foundations, footings to be built with cofferdams, open caissons and pneumatic caissons are conceivable and studies were made on these four types of foundations.

1) Pile Foundations

Pile foundations, at first, were thought economical and suitable for the present project, considering that pile driving will require no special skill and can be done easily in a short time and that the variety and number of equipments required for the job would not amount to much as compared with the case of foundations of other types. At the Nong Khai site, however, the alluvial soil layer that constitutes the river-bed is thin and necessarily the piles become end-bearing piles that bear on the underlying siltstone layer. But, in the present case, piles must be driven into the siltstone layer deep enough not to be affected by the scouring action of the river stream. To drive piles, whether they may be of steel, reinforced concrete or prestressed concrete, deep into a firm siltstone stratum is practically impossible. Therefore, pile foundations were left out of consideration.

2) Footings With Cofferdams

Footings are most simple and economical when used in foundations that shall be built on a sufficiently firm ground layer on land. However, to construct them in water, and that in a river like the Mekong where the current is rapid and floods shall be expected, is in no way practical. For the Mekong bridge, very large footings are required to sustain large loads that will be transmitted from the superstructures. Accordingly, cofferdams that shall be built in the river to permit work to be carried out on a nearly dry state will become to enclose large areas in the river. Then, as the river channel will be greatly narrowed and the flows around the cofferdams will become turbulant and rapid accompanied by backwaters, the cofferdams should be built to withstand the dynamic effect of the flowing water. Besides, the height of the cofferdams should be adequate to keep out floods that might occur during the period of construction.

Furthermore, if steel sheetpiles will be used, as is usually the case, to enclose the cofferdams, there will arise a leakage problem. When the inside of a cofferdam will be excavated and dried, water would leak not only at sheetpile interlocks but also excessively at the bottom, unless the sheet-piles will be driven deep into a thick, impervious layer. If such a leakage would occur, it will cause much troubles and will affect the cost and time of construction most adversely. It cannot be guaranteed that such would never occur in the present project. In conclusion, from the above-noted technical reasons as well as from the viewpoint of completing the job within a limited period, to construct footing foundations by building cofferdams and by open-cut excavation was concluded unsuitable for the Mekong bridge in the present project.

3) Open Caissons

An open caisson on land can be constructed without any difficulty. But, should it be built in water, it involves many problems. Because an open caisson will be sunk under its own weight with some aids such as overlaid weights, water or compressed-air jets, it will take much time to reach the bearing stratum. If it is assumed that the foundation work cannot be done in the high-water season, and if the whole project should be implemented in three years as scheduled, the time available for the foundation work amounts to only two dry seasons[/1]. And, to sink all of the large-size open caissons of the main bridge into the Mekong's bed within such a limited period seems no easy a task.

Soils that lie inside the caisson are usually dredged with clamshells or orange-peel buckets. But, it would be very difficult to excavate the firm siltstone to make caissons reach 2 meters deep into the

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/1: It is meant here the period, during which the Mekong's water-level at the bridge site stays below El.154.00. This period usually lasts from November to next May.

siltstone layer. Moreover, it will be almost impossible in open caissons to ascertain whether caissons have reached and settled well in place on the prescribed bearing stratum.

The job of caisson sinking through water can be converted to a land job by constructing a temporary island or a cofferdam. In this case, however, all the engineering problems noted in regard to footing foundations must be taken into consideration.

4) Pneumatic Caissons

Pneumatic caissons in general cost more than open caissons because they must be provided with equipments for compressed-air work and require technical skill and experienced engineers. In the present project, assuming that the job will be implemented without any serious problem, a pneumatic caisson is estimated to cost about U.S.$240,000 as compared with U.S.$230,000 of an open caisson. But this difference is very trifle when compared with the total cost of the project, even if ten foundations are taken into account. Besides, if pneumatic caissons would be adopted, their sinking will be better controlled and the condition of the bearing bedrock as well as whether the caissons will have settled well in place on the bedrock can be visually ascertained.

Therefore, though they may cost a little more than open caissons, considering the important meaning of the Mekong bridge, it was decided to use pneumatic caissons for the foundations of the midstream piers and open caissons for piers that will be built on land at both ends of the bridge. Principal features of these caissons are shown in Plate 5.

(4) Pier Protection Against Scouring

From the test drilling carried out in the second-phase investigation, the geological formation of the river-bed at the bridge site can be assumed as shown in Fig.5.6. The river-bed is composed of alluvial deposit of sand and gravel, 7 to 13 meters thick on the Thai side and 3 to 5 meters thick from the midriver toward the Laotian side. Underneath the alluvial layer lies a firm bedrock of siltstone, covered by a thin layer of weathered siltstone, at an elevation ranging from El.145.0 to El.150.0. The river-bed is subject to scouring in the high-water season, and when the bridge would be built, it is most certain that the river-bed around the piers would suffer severe scouring. And, the following measures were planned to cope with the scouring.

To sink caissons of the five midstream piers at sites that will lie always in water, temporary islands will first be built by enclosing the job sites by steel sheetpiles and filling the inside with the river's fine sand. Each island will be 16 meters square and will stand about 5 meters from the river bottom to an elevation of El.156.5 to El.157.0. The temporary islands will be left as they will have been built even after the foundation work will have been ended for the protection of the foundations. In addition, the river-bed around each pier will be covered with wooden mattresses that will extend about 6 meters from four sides of the island and will be weighted with lumps of laterite not less than 20 centimeters in size, as shown in Plate 6.

Three piers near the Thai side are located on a large sandbar that comes into appearance above the water surface in the low-water season. For these piers, instead of temporary islands, earth mounds will be built on the sandbar for the caisson-sinking job. When the foundations will be completed, these mounds will be leveled off and wooden mattresses will be laid around the caissons in the same manner as noted above. The mattresses at each site will shape a square of about 36 meters as shown in Plate 6.

As for the two end piers that will be built on land, there will be no fear of scouring in ordinary times. Nevertheless, as a precaution against eventual scouring from extraordinary floods, the ground around the piers will be riprapped with laterite, extending about 5 meters from the circumference of the caissons and about 50 centimeters thick.

Furthermore, all caissons will be founded about two meters deep into the bedrock so that the piers would not lose their stability even if the riverbed soil, together with the islands, would all be washed away.

5.2.3. Bank Protection

The Mekong makes a bend, convex towars the Laotian side, in a stretch just upstream of the bridge site as shown in Plate 1. From a point about one kilometer upstream from the bridge site, the river becomes nearly straight but the stream flows still deviated toward the Laotian side. Consequently, while silt deposition is growing on the Thai side, the river bank on the Laotian side is being incessantly eroded. At present, the erosion is estimated to proceed about 20 centimeters a year.

The two end piers are located on land several meters away from the bank-slope shoulders on both Laotian and Thai sides as shown in Plate 6. It is therefore necessary to protect the bank slopes against erosion. There are many ways of bank-slope protection. In the present project, considering the cost and the stream flow and other conditions at the site, it has been planed to cover the slopes with gabions.

Gabions of a dimension of 50-centimeter diameter by 6 meters will be laid over the bank slopes, extending along the slopes about 40 meters on the Laotian side and about 30 meters on the Thai side. The gabions will be anchored with wooden piles that will be driven in two rows along the slopes and at an interval of about 10 meters in the direction of the river. On and beyond the toes of the gabion covering, concrete blocks of 50-centimeter cube will be riprapped 1.5 meters thick to a width of about 5 meters as shown in Plate 6.

The gabion covering will stretch on the Laotian side from 40 meters upstream to 80 meters downstream from the bridge center-line, and on the Thai side from 40 meters upstream to 110 meters downstream from the bridge center-line up to the compound of the Nong Khai Hydrographic Office.

Fig. 5.1 CLEARANCE DIAGRAMS FOR BRIDGES

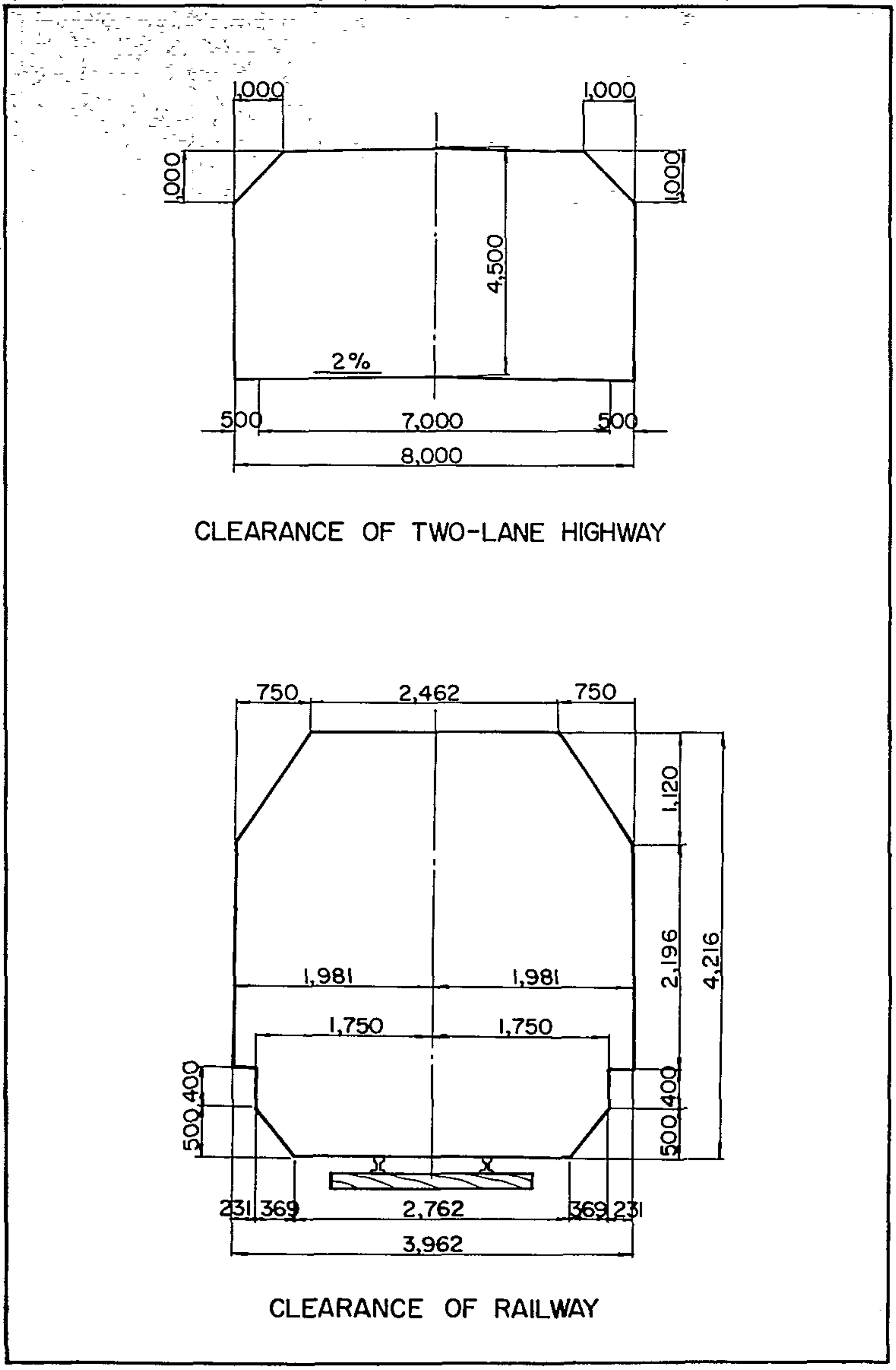
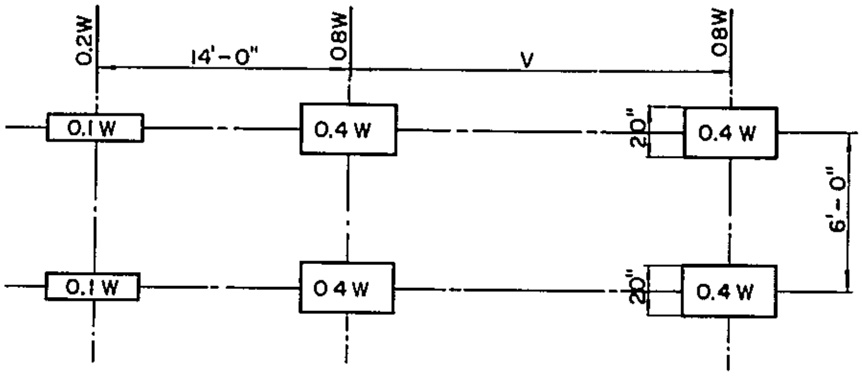


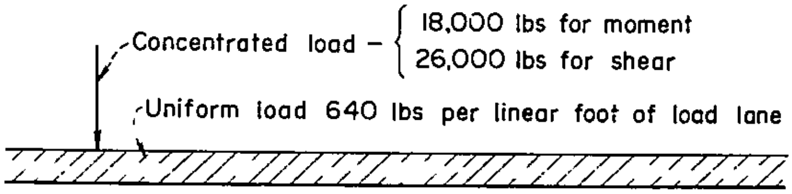
Fig. 5.2. ROADWAY AND RAILWAY LIVE LOADS



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

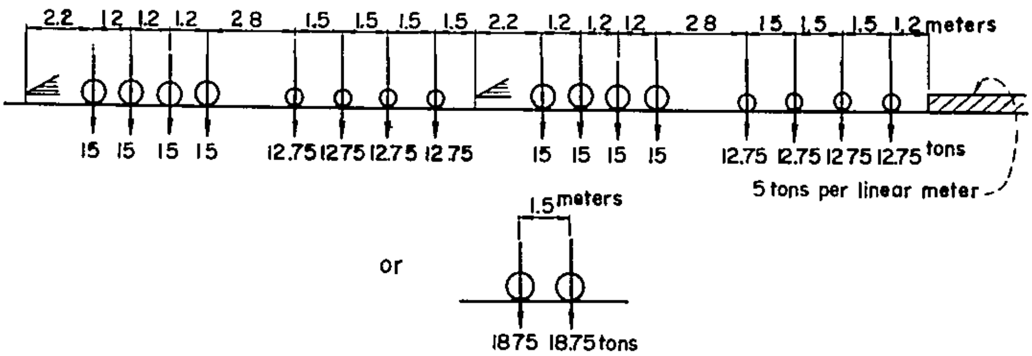
V = Variable spacing – 14 feet to 30 feet inclusive
Spacing to be used is that which produces maximum stresses.

Standard HS20-44 truck



HS 20-44 lane loading

HS 20-44 LOADING FOR HIGHWAY



STANDARD 15-TON LOADING FOR RAILWAY

Fig. 5.3. VARIOUS LAYOUTS OF BRIDGE FLOOR

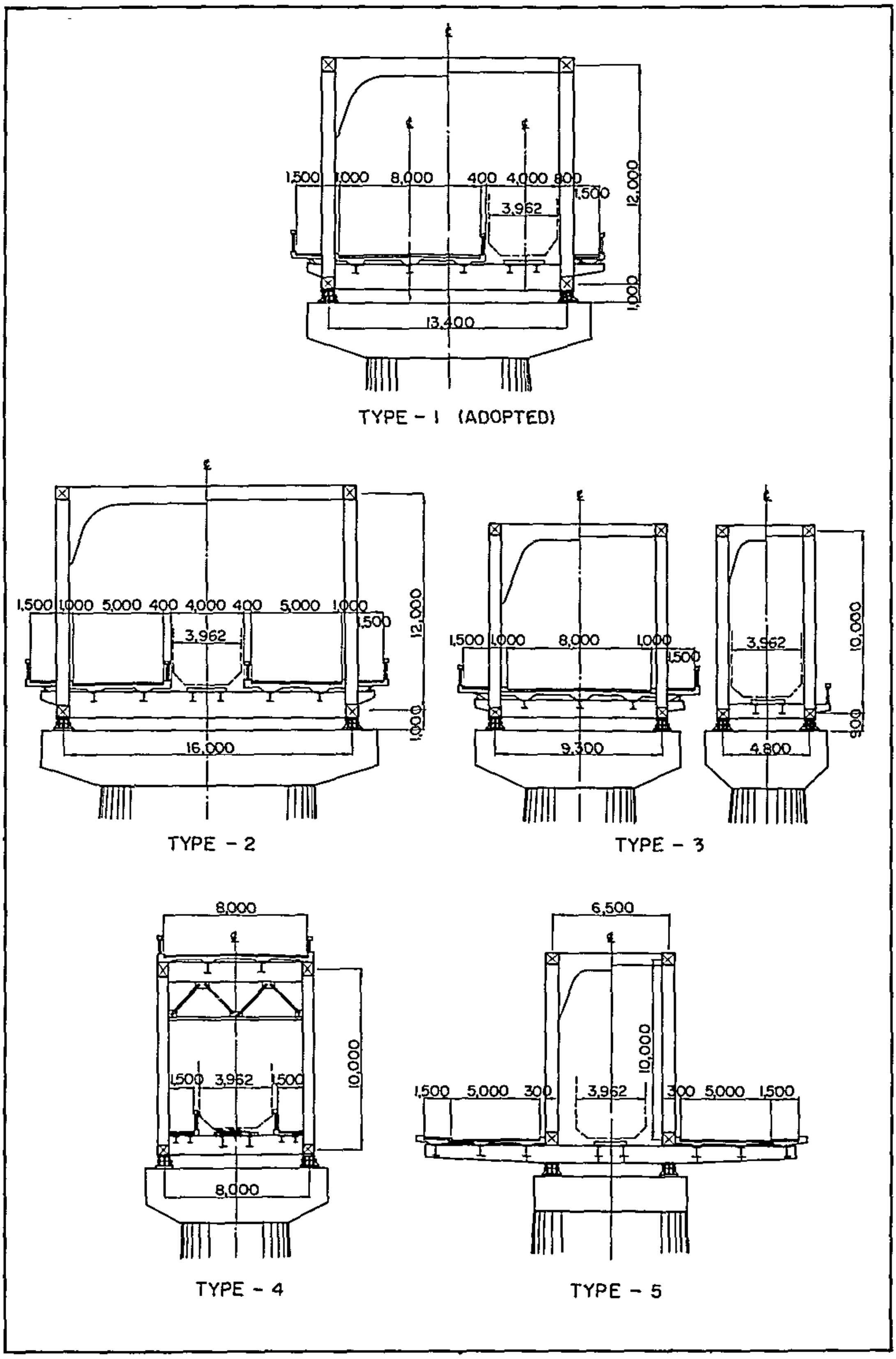


Fig. 5.4. LAYOUT PLANS OF ADMINISTRATIVE FACILITIES AND A CHANGE-OVER POINT IN RELATION TO THE BRIDGE-FLOOR LAYOUTS OF TYPES 1 AND 2

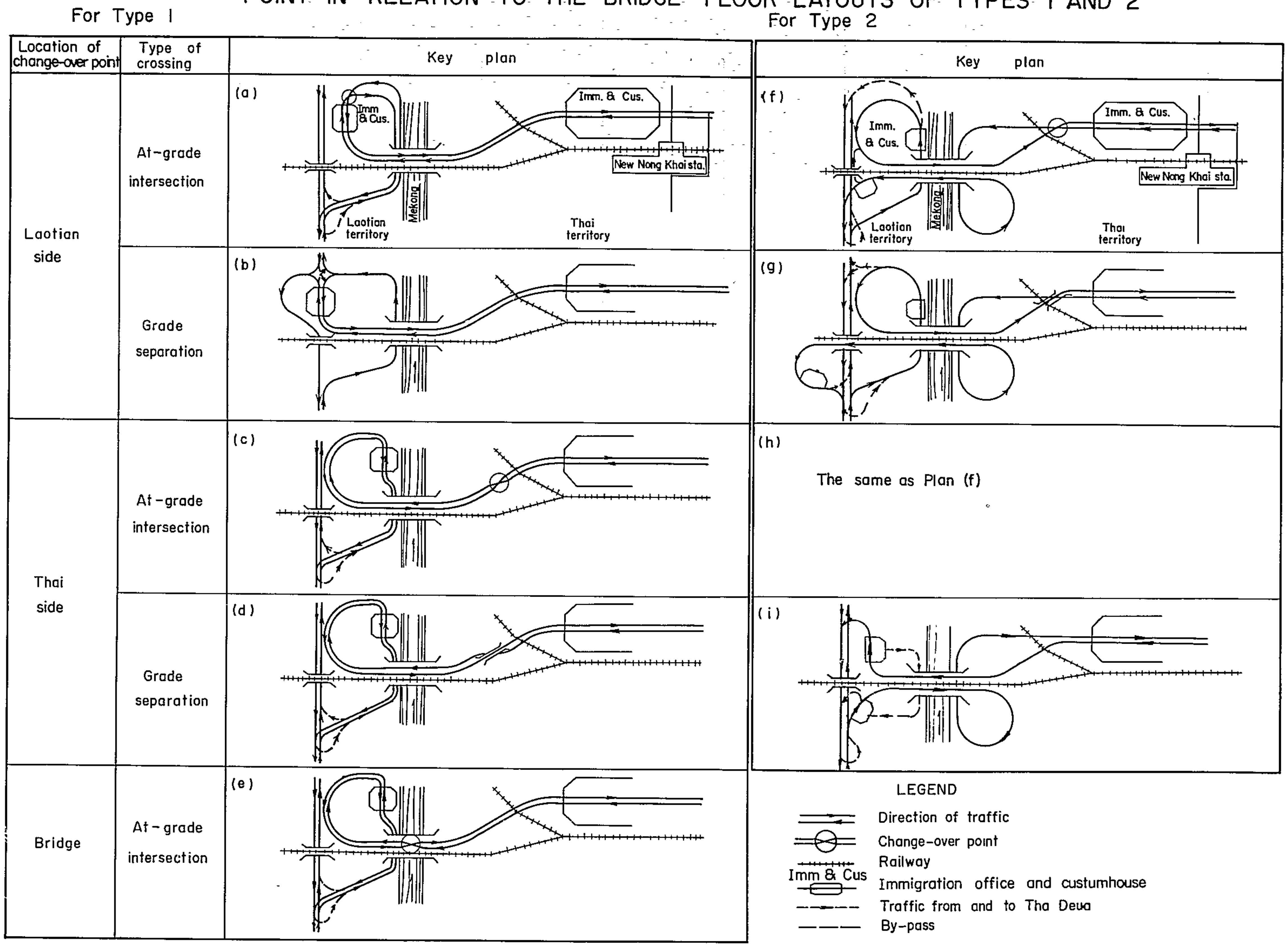
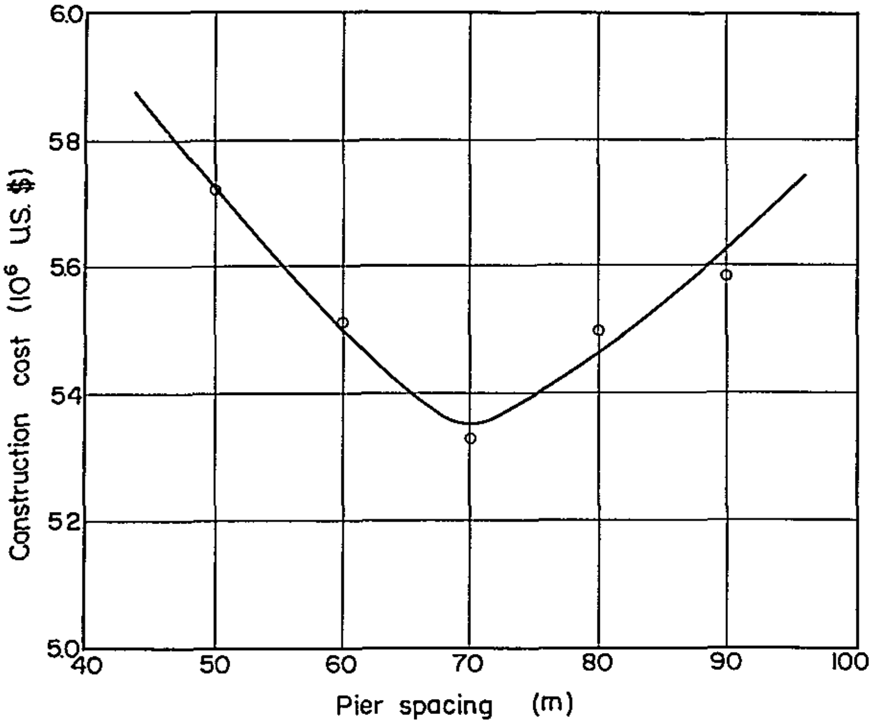


Fig. 5.5. SPAN VS. COST OF BRIDGE



Pier spacing (m)	Numbers of pier	Steel weight (tons)	Construction cost (US.$)		
			Substructure	Superstructure	Total
50	14	2,800	3,570,000	2,160,000	5,730,000
60	12	3,100	3,120,000	2,400,000	5,520,000
70	10	3,300	2,780,000	2,550,000	5,330,000
80	9	3,700	2,640,000	2,860,000	5,500,000
90	8	4,100	2,420,000	3,170,000	5,590,000

Remarks :

(1) Cost of approach structures is not included

(2) The above construction costs do not include such indirect costs as expenses for engineering services, Government's administrative expenses and interests during construction

Fig. 5.6. GEOLOGICAL PROFILE OF BRIDGE SITE

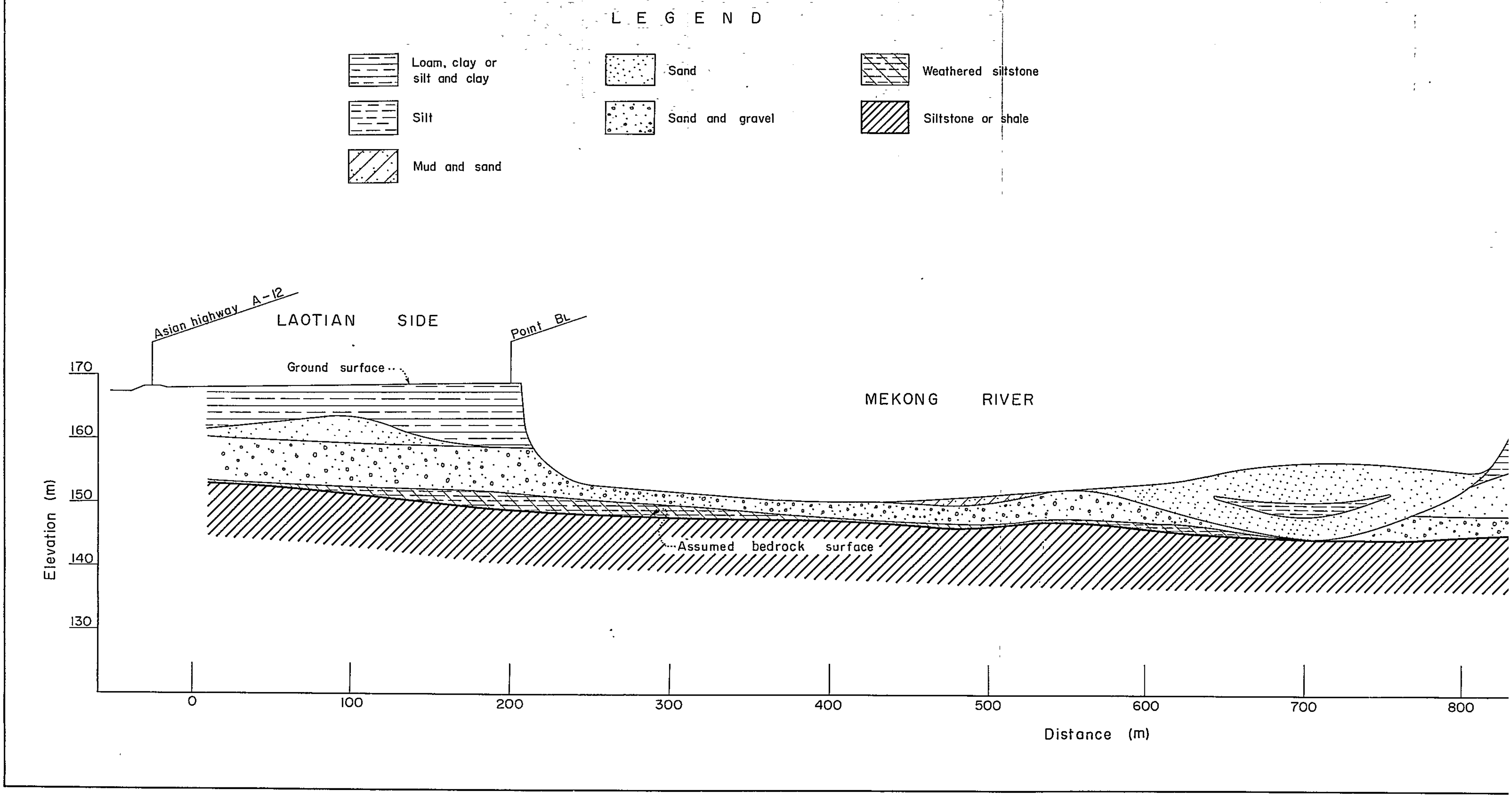
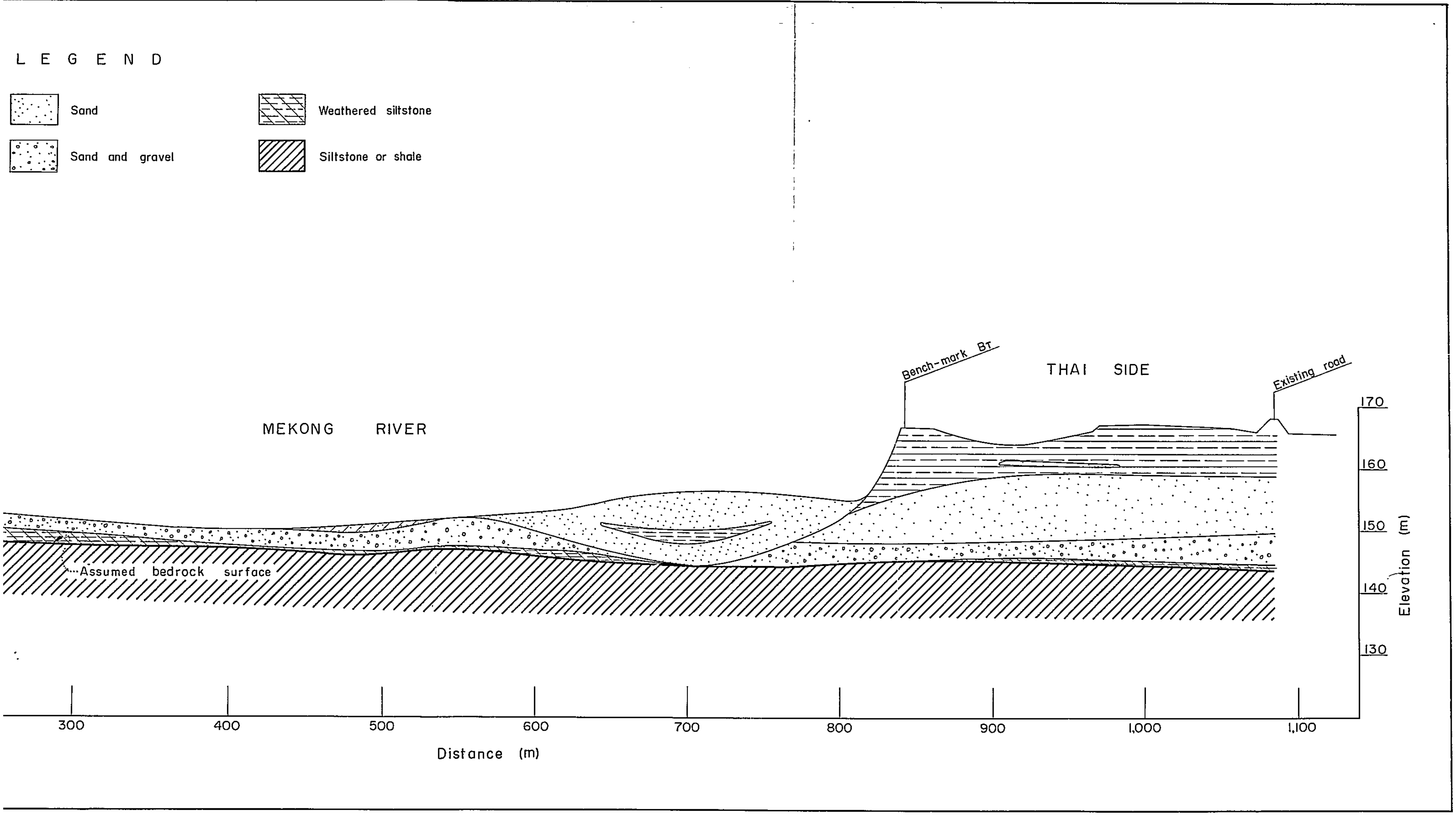


Fig. 5.6. GEOLOGICAL PROFILE OF BRIDGE SITE



5.3. Railway

When a rail/highway bridge would be completed across the Mekong as planned, the Northeastern Trunk Line of the Royal State Railway of Thailand will be extended 20 kilometers from Nong Khai to Vientiane. The construction itself of the railway will scarcely give rise to any serious engineering problem, because the topography of the project area is relatively flat and the ground will provide a comparatively good foundation.

No comparative study is needed for the railway route on the Thai side, because it would measure relatively short and its route would be fixed more or less automatically when the bridge site would be determined.

On the contrary, five promising routes were studied on the Laotian side as reported in the Second-Phase Report and Route C/D was finally selected by the Mekong Committee as noted in Paragraph 4.3, and the present paragraph deals with the details of this route.

The tentative design of the railway was made conforming to the Design Standards of the Royal State Railway of Thailand, main provisions of which are epitomized in Table 5.3.

Table 5.3. Main stipulations of Thai Railway Design Standards

1. Maximum design speed	90 km/hr
2. Gage	One-meter gage
3. Rail	80 lbs/yd (40 kg/m)
4. Tie	Hardwood of 15 x 20 x 190 cm, 65-cm spacing
5. Ballast	Crushed stone, not greater than 6 cm in size, with a hardness not less than that of limestone
6. Minimum curve radius	400 m: in transition curve: not less than 700 times of superelevation
7. Maximum grade	1.2 %; in station: 0.11 %
8. Right of way	40 m on both sides from track center

Note: The clearance diagram for tracks and structures is shown in Fig. 5.7.

In the following are reported the studies and plans made on the railway construction.

(1) Track and Roadbed Construction

At present, rails of 50, 60 and 70 lbs/yd are being used on the lines of the Thai Royal State Railway but they are scheduled to be replaced with rails of 80 lbs/yd in the future. The Northeast Line running from Bangkok to Nong Khai is of single-track. Consequently, the new line to be laid up to Vientiane will also be a single-track line and 80-lb rails will be used. Wooden ties will be laid in 65-centimeter spacing on 15-centimeter thick, crushed-stone ballast. Typical track and roadbed cross sections are shown in Plate 10.

As regards embankment, it is a common practice to use as far as possible the excavated material on the job site. But, as noted before, the soil that can be excavated at the job site has an undesirable nature to swell when saturated with water. After making studies to cope with this difficulty, it has been decided to use the so-called "composite section" in embankments that will stand high and will often be exposed to floods. Namely, the inner part of embankments will be built of fine sand of the Mekong and in the outer part will be used half-and-half mixture of the river sand and the soil from the job site, as shown in Plate 10. The sand-filled inner part will serve for inside drainage, reducig the adverse effect of the soil in the outer part, and thus will greatly contribute to the soundness of embankments. Embankments must of course be well compacted, and desirably to the extent that a CBR-value of greater than 10 percent can be obtained.

When embankments are not high, they can be built wholly with soil lying in the job area, as the effect of soil swell would not amount to much on account of the small height of the embankments and as it can be thought that part of lumps of laterite of track sub-ballast would sink into the soil and would reduce the adverse effect of the soil to some extent. In this case, however, it is a matter of course that soils of the best possible quality should be sought for and be used.

A typical roadbed cross-section in cutting is shown in Plate 10. Instead of laying the crushed-stone ballast directly on the surface of excavated ground, a 40-centimeter-thick layer of sub-ballast will be laid under the top-ballast with a view to prevent the underlying ground soil from jamming up into the ballast of crushed stone. Lumps of laterite will be used for the sub-ballast.

Embankment slopes in areas where inundation in the flood season shall be anticipated will be protected with lumps of laterite dumped into latticed timber frames or with concrete-block pitching. Slopes of cutting and of embankment on highlands will be sodded.

The formation level profile is shown in Plates 11 to 16. This profile has been so decided that the rail track would not be submerged by an abnormal flood that might occur once in 40 years, considering that the useful life of the railway is estimated at 40 years.

The railway route on the Laotian side passes lowlands that form the eastern and northern periphery of the That Luong marsh. But, roadbed construction will be done without any serious difficulty as the ground in these areas was found to be relatively firm contrary to prior presumption.

(2) Stations

Although it is the terminal of the northeastern trunk line of the Thai Royal State Railway, the present Nong Khai station is not provided with a switchyard and car-sorting is now being carried out at the Na Tha station located about 6 kilometers south of the Nong Khai station. The Na Tha station had been the terminal until the line was extended to Nong Khai, but car-operation is still being carried out at the Na Tha station with facilities such as a switchyard, an engine shed and repair shops located there as shown in Fig.5.8.

Considering the above and other situations, the line to reach the bridge has been planned, instead of extending it from the present Nong Khai station, to branch off from the existing line at a point where, a little short of the Nong Khai terminal, it makes a turn toward there.

The new Nong Khai station, the layout of which is shown in Plate 10, is located at this point. It will be provided with offices of immigration and customs as well as a plant quarantine station to handle necessary immigration procedures. Four side tracks will be laid to facilitate the customs procedures, two each for traffic to and from Laos. It is planned that the immigration and customs procedures of transit passengers can be done in cars.

When the extension line and the new station would have been completed, the section between the new station and the present Nong Khai station and the station itself will possibly be abolished and freight destined for the town of Nong Khai will be carried by trucks from the new station.

Various railroad operations in the future will be carried out at the Na Tha station supplementing and improving the facilities now located there.

The Vientiane station, the terminal of the extension line, is located about 7 kilometers northeast of the civic center. As shown in Plate 10, it will be provided with a station building, two passenger platforms, a freight platform, tracks for petroleum, a classification yard, an engine shed and other necessary facilities.

(3) Bridges and Culverts

Besides the main Mekong bridge, many bridges shall be built at sites where the rail line crosses roads and streams and culverts are also required for drainage. They comprise an overpass, five bridges to cross marshy lowlands (called flood bridges), a bridge to cross a stream and thirteen culverts. All these structures will be built of reinforced concrete and their tentative designs are shown in Plates 17 and 18.

The overpass has been designed as a simple T-beam bridge and the flood bridges as three-span-continuous rigid-frames when they stand high and as a simple slab bridge or a simple T-beam bridge when they stand not so high. For the culverts, two types have been designed: box culverts and slab culverts. The former will be used when the opening is relatively high and wide, and the latter for culverts, to which a small vertical clearance is required.

Fig. 5.7. CLEARANCE DIAGRAM OF RAILWAY FOR TRACK AND BUILDING

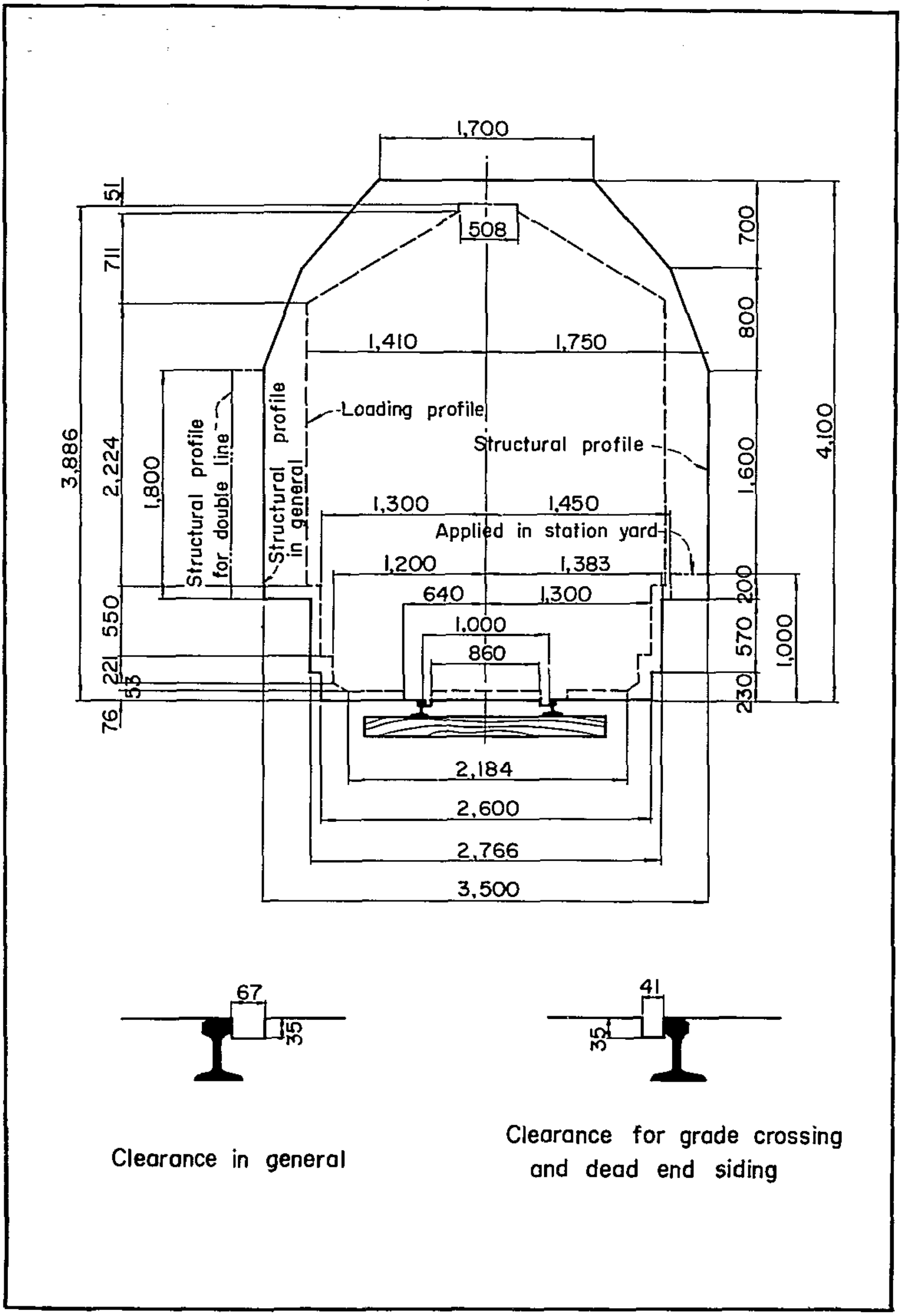
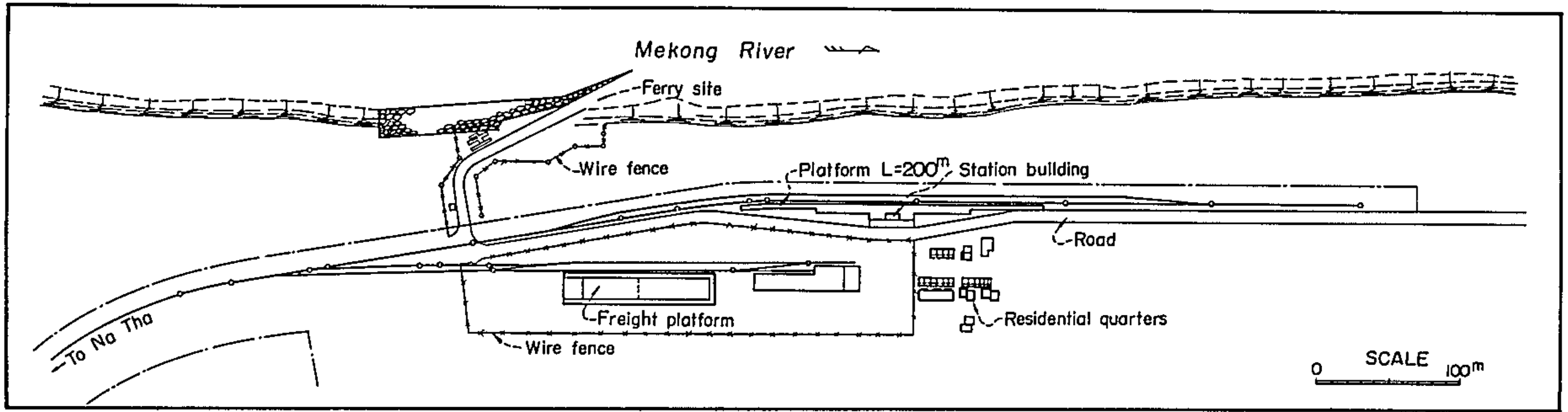
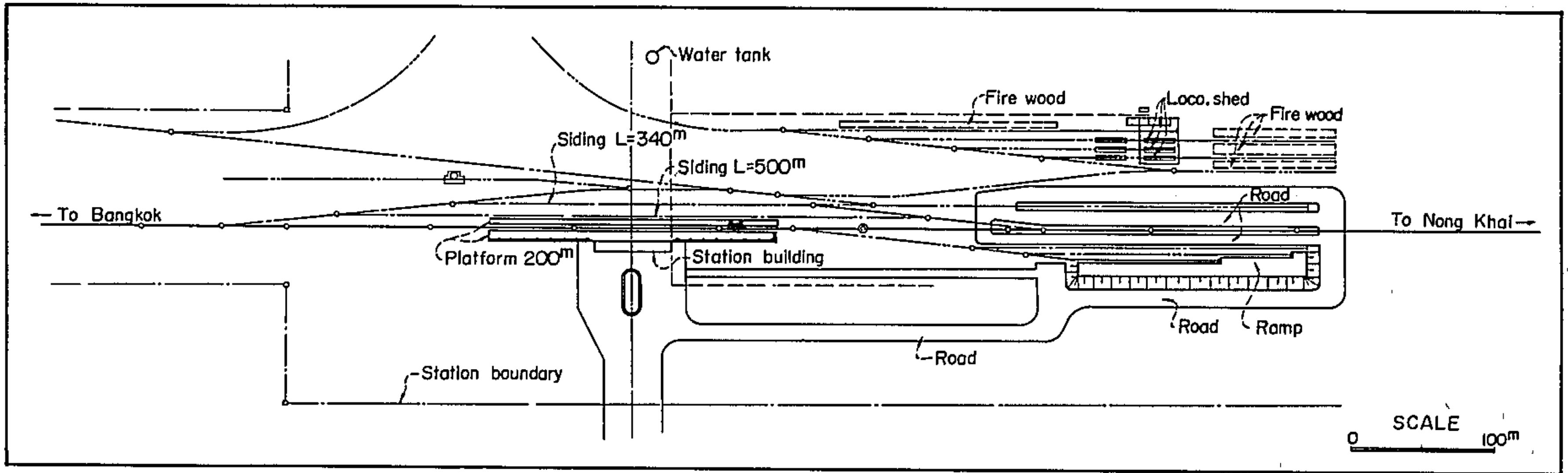


Fig. 5.8. EXSTING NONG KHAI AND NA THA RAILWAY STATIONS



NONG KHAI STATION



NA THA STATION

5.4. Highway

5.4.1. Route

At present, the Asian Highway Route A-12 runs from Sara Buri to Nong Khai in Thailand, and from Tha Naleng to Vientiane in Laos, interrupted by the Mekong. Of the route to connect these two separated sections, there is no need, or rather no freedom, of choice on the Laotian side, because here the end of the Mekong bridge is located in the proximity of the existing route. Therefore, what comes into question is the location of the route that shall connect the bridge with the existing route on the Thai side.

For selecting the most appropriate route on the Thai side, a comparative study was made on three possible routes shown in Fig.5.9. The first route branches off from the existing route in the vicinity of the town of Nong Khai. The second and third routes branch off from the existing route at a point about 3 kilometers from Nong Khai and run along the existing railway line, the second on the downstream side and the third on the upstream side. The following can be said from the study.

1) Route Length

The first route measures about 3.4 kilometers as compared with 4.9 kilometers of the second and third routes, not including the sections on the bridge and on the Laotian side.

2) Foundation

In the first route, a good foundation cannot be expected as it passes undesirable swampy areas. The second and third routes are preferable, because they for the most part pass through paddy fields and shrubby lands.

3) Compensation

The first route will require more compensation for land expropriation than the other two.

4) Environmental Conditions

The first and second routes can afford an easier direct access to the town of Nong Khai than the third. In the third route, the direct access road from the town of Nong Khai to the bridge, if ever it would become needed in future, must cross the rail line, most likely with a grade separation.

The third route itself crosses the existing rail line. Therefore, when in the future the traffic on the highway as well as on the railway would increase and exceed the limit specified by the Thai Highway Department, given in Table 5.4, a grade separation will have to be constructed.

There is a fear that the first route would become an obstacle to the expansion of the town of Nong Khai in the future or it might become to pass through the middle of the expanded town. The prefectural authorities of Nong Khai have expressed their opinion that a highway like the Asian Highway should still be outside of the town even after a few decades.

In the third route, the roadway will enter into Laos on the upstream side of the bridge end, and there is no enough space here to provide the Laotian administrative facilities as this site is surrounded by the Mekong, the existing Asian Highway and the Nam Ngum Project transmission line with its tower.

At present, there is no noteworthy obstructive object that would make trouble in or hinder the construction of the highway, whether it be located on the first route or on the second or third route.

5) Influence on Nong Khai Airfield

The second and third routes pass near the Nong Khai airfield. The Thai Civil Aviation Department has officially approved the construction of the highway through the area lying between the existing railway line and the airfield. Besides, if the national regulation provided by the department will be applied to this airfield, the take-off climb surface of the runway will have some allowance in height above the necessary clearance of the highway as shown in Fig.5.10.

6) Conclusion

From the above consideration, the choice was made on the second route.

5.4.2. Design

The design of the highway was made conforming to the provisions of "Geometric Design Standards For Two-Lane Primary Highways (Rural)" of the Thai Highway Department. "A Policy on Geometric Design of Rural Highways" of the American Association of State Highway Officials as well as Japan Highway Standards were also referred to. Table 5.4 shows the principal items provided by the above-cited Thai Standards, and Fig.5.11 the clearance diagram adopted in the design.

Table 5.4. Geometric Design Standards For Two-Lane Primary Highways (Rural) of Highway Department of Thailand

Item	Description
1. Access control:	Required when daily traffic exceeds 3,000 vehicles.
2. Intersection:	Intersection at grade permitted.
3. Railroad crossing:	Grade separation is required when daily traffic exceeds 4,000 with six or more trains per day. Automatic signal is required when daily highway traffic multiplied by trains per day exceeds 3,500.
4. Design speed:	80 to 100 kilometers per hour.
5. Maximum grade:	4 percent.
6. Right of way:	60 to 80 meters.
7. Clearance:	See Fig.5.11.
8. Roadway Width:	

Classification	Class I	Class II	Class III
Annual average daily traffic	8,000-4,000	4,000-1,500	Less than 1,500
Pavement, in m	7.00-6.50	7.00-6.00	6.00
Shoulder, in m	2.75-2.50	2.50-2.25	2.00

(1) Cross-Section

The Asian Highway A-12 is a two-lane primary highway in both Thailand and Laos. The road to be built is nothing other than what will become a section of the highway. Therefore, it shall be designed as a two-lane highway with the same cross-section as that of the highway. Thus, the basic features of the design cross-section, shown in Plate 19, have been fixed as follows.

Roadway:	7 meters, with two lanes;
Shoulder:	2.5 meters on both sides of the roadway;
Cross-slope:	2 % in roadway, 3 % on shoulders;
Side slope:	1 to 1 in cut, 2 to 1 on banking.

The roadway will be composed of a 5-centimeter cold-mix wearing course, 15-centimeter base course and 30-centimeter subbase. In shoulders will be used soil-cement mix, which in cuts measures 20 centimeters thick and on embankments extends downwards along the slopes and forms the outer parts of embankments.

Embankments will be made as far as possible from the excavated soil in the job site. But the soil lying along the projected route on the Thai side has, besides the nature of swelling when saturated with water as noted in regard to railway embankments, an undesirable characteristic that while it shows a considerably high shearing strength in the state of the optimum water content, it loses its shearing strength almost to nil when saturated with water. Therefore, it is necessary to build the roadway subgrade with soil of the best possible quality in the state of the optimum water content. The use of soil-cement mix, as noted, in shoulders and in the outer parts of banking has been so planned with a view of protecting the inner part of the subgrade from infiltration of rain or flood water and keeping the subgrade always in or nearby the state of the optimum water content.

It is an established practice to use crushed stone in pavements. But, if crushed stone should be used in the present project, it will amount to about 45,000 cubic meters and will hardly be obtained in or around the project area. In the present project, it seems practical to make use of sand and gravel from the Mekong. Therefore, it shall be recommended or rather seems necessary to make a study on whether the river sand and gravel will show a desirable CBR value[/1] when mixed adequately and hence can be used in pavement courses. In case they should be found unsuitable, some measures should be taken such as to crush large-sized river gravel or to admix thin cement milk.

(2) Profile of Roadway

When a flood that would probably occur once in ten years comes to the project area, the existing Asian Highway on the Laotian and Thai sides gets partly submerged and loses its function for a time. In order that the same shall not be repeated in the new road that will be built with much effort, the formation level of the roadway has been designed, in the tentative plan, to lie above the 10-year-probable high-water level at the project site, estimated at an elevation of 167.5 meters above mean sea level.

On the Mekong bridge, the grade is made 1.2 percent, the maximum allowable grade for railway, and on the adjoining approach structures the maximum grade of 4 percent is used in order to make the

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/1: The desirable modified CBR value, of which the method of testing is stipulated in the Japanese Industrial Standards, is 80 to 90 percent for base courses, 20 to 30 percent for subbases, and 5 to 10 percent for subgrades.

length of these structures as short as possible. Excepting these sites, the roadway will be laid almost level as the topography is generally flat and gentle. Only at two sites, a grade of 1 % is used. Surface drainage will be effectuated by side ditches. But in level sections or in sections of very small grade, side ditches will be sloped sufficiently to drain water on the roadway.

(3) Horizontal Curves

A radius of 500 meters of curves has been adopted as a standard in the tentative roadway alignment on the Thai side as shown in Plate 20, as there is no situation that will hinder the alignment. Although it is at present well possible to run the Asian Highway on the Thai side at a speed of 120 kilometers per hour or more, should the design speed be fixed at 80 kilometers per hour, curves of 500-meter radius will require neither roadway widening nor superelevation.

On the Laotian side, curves of 70- to 200-meter radius have been adopted, because there is no enough space and, besides, no need for providing curves of a larger radius as the roadway is located in and around the administrative premises and there is no need for vehicles to run fast at this site. A curve of 110-meter radius is located at the bridge end on the Laotian side. If a 6-percent roadway superelevation will be provided, vehicles will be able to run this curve safely at a speed of 50 kilometers per hour.

(4) Traffic Capacity

There are three classifications of highway traffic capacity: basic capacity, possible capacity and practical capacity.

The basic capacity means a possible capacity under ideal traffic and roadway conditions. It is estimated at 2,500 passenger cars, total in both directions, per hour for a two-lane, two-way primary highway with a 7-meter roadway.

The possible capacity is the product of the basic capacity and reduction factors that depend on traffic composition and restrictive lateral clearances. Traffic composition is usually expressed by the ratio, in percent, of trucks during a design hour to the total traffic during the same design hour, the design hourly volume (DHV). In the present project, the percentage of trucks in the future has been assumed to approximate to 25 percent, and consequently the reduction factor due to traffic composition becomes 0.8. Excepting on the bridge[⊿1], 2.5-meter shoulders will be provided on both sides of the roadway, the reduction factor due to restrictive lateral clearances can be taken at unity. Consequently, the possible capacity becomes 2,500 x 0.8 x 1.0, or 2,000 passenger cars per hour.

The practical capacity of a two-lane primary highway is estimated to range from 900 to 1,200 cars per hour. In the case of uninterrupted traffic flow, the practical and the design capacities have essentially the same meaning. Therefore, the above practical capacity has been adopted as the design capacity of the projected road.

⊿1: On the bridge, the clearance on either side of the pavement will amount to 0.5 meter, so that the reduction factor due to lateral clearances may be assumed at 0.85. Then, the possible capacity on the bridge becomes 1,700 cars per hour.

When the aforesaid possible capacity of 2,000 cars per hour is converted into a capacity on daily basis assuming a conversion rate of 0.12, the daily possible capacity becomes about 17,000 cars. On the other hand, the annual-average daily traffic (ADT) after 40 years from the present is roughly estimated at about 14,000 cars. As the useful life of the road and the bridge is estimated at 40 years, it may be said that they will be serviceable to highway traffic throughout their useful life of 40 years.

(5) Railroad Crossing

The roadway on the Thai side crosses the existing railway line at a site midway between the present and projected Nong Khai stations. Although the future highway traffic will exceed 4,000 cars per day, specified in the provision of the Thai Highway Design Standards given in Item 3 in Table 5.4, there will be no need of providing a grade separation, because after the completion of the present project the railway traffic on the existing line wil markedly diminish or the line itself will be most likely abolished. Accordingly, the crossing has been planned as a level crossing.

5.4.3. Change-Over of Traffic Direction

The vehicular traffic in Thailand keeps to the left, and in Laos to the right. Therefore, it is necessary to change the direction of traffic on or in the proximity of the bridge on the Mekong, which constitutes the Thai-Laotian border. Hereafter in the present report, changing of traffic direction will be called "change-over" for brevity's sake.

Change-over has a close relation to the roadway layout on the bridge floor and the location of administrative facilities. It is especially influenced by whether the roadway on the bridge is undivided or divided into two one-way parts by the middle-lying railway track. Although many plans of change-over can be conceivable, nine plans shown in Fig.5.4 have been envisaged and studied in connection with the layout of the bridge floor and of the administrative facilities. Of these, plans (a) to (e) are those for the case of undivided roadway, and (f) to (i) for the case of divided roadway.

Comparative studies have been made of these two groups of plans for Types 1 and 2 in Subparagraph 5.2.1, (2), and the bridge-floor layout of Type 1, with an undivided roadway, has been adopted. Therefore, the study as to how and where to make change-over is made of Plans (a) to (e) shown in Fig.5.4.

(1) Comparative Study

(i) Plans (a) and (b)

The change-over will be implemented on the Laotian side, and that with a weaving intersection at grade in Plan (a) and with loops in Plan (b). Weaving is not suited for brisk traffic. In Plan (a), therefore, should traffic increase in the future, a grade separation will become necessary. But, to provide a grade separation in place of the weaving intersection will be very difficult as there is no enough space between the Mekong and the existing Asian Highway.

In Plan (b), the traffic will flow much smoothly, the traffic on the Asian Highway will be hindered from running straight. The highway is at present one of the most important roads in Laos to join with the Asian Highway A-3 via Tha Deua and to lead to Thakhek, Savannakhet and Paksé in the near future. That such a primary highway makes an unnecessary roundabout is not desirable. Besides, Plan (b) will cost a little more than Plan (a).

(ii) Plans (c) and (d)

The change-over site is located on the Thai side. The difference between (c) and (d) lies in that the change-over will be done with a weaving intersection at grade in (c) and with a grade separation in (d). On the Laotian side, the roadway makes a simple loop to reach the existing Asian Highway that lies about 9 meters lower than the level of the bridge floor at the bridge end. As compared with other plans, Plans (c) and (d) have least disadvantages. It is therefore recommendable to implement Plan (c) in the initial stage of the project and afterward, when it would become necessary due to the traffic increase, to substitute a grade separation for the weaving intersection at grade, which is nothing but Plan (d). There lies on the Thai side a wide area enough for it.

(iii) Plan (e)

In this plan, the change-over is planned to be done on the bridge, and that with weaving. In case change-over is made on land with weaving, the pavement may be widened or two or more lanes can be provided at the intersection in both directions and thus traffic congestion will be much relieved. On the bridge, however, this is naturally impossible and hence much trouble and inconvenience would surely arise in traffic as well as in operation. Plan (e) seems in no way practical.

Plan (b) is not recommendable because of such a demerit that the primary highway makes an unnecessary roundabout. Plan (e) also is not recommendable because there is an apprehension that the plan may involve much trouble and inconvenience in traffic in the future.

Plan (a) is better than plans (b) and (e), but is costly as compared with plan (c). Namely, on the Laotian side the highway to be provided between the administrative facilities and the existing Asian Highway A-12 becomes unnecessarily long, because the space lying between the Mekong and the said Highway is too narrow.

Plan (d) is much better than plans (a), (b) and (e), but it is not economical to take up plan (d) because the future highway traffic, which has been estimated in next Chapter VI, is not so much as to necessitate to provide at the outset a grade-separation change-over.

From the above considerations, Plan (c) seems to be the most recommendable among the five plans (a) to (e). The Japanese Survey Team recommended in the draft Feasibility Report that the Mekong Committee should take up plan (c).

2) Further Study

Lao National Mekong Committee accepted the above recommendation, but Thai National Mekong Committee commented as follows.

> "For the change-over with at - grade intersection type of crossing, we propose to select plan (a) because its location is very near to the Immigration and Custom Office, the traffic control at the intersection can be easily made" and "If the change-over point will be made on the Thai side, we propose to use the change-over plan with grade-separation over the railway tracks similar to the layout in Fig. 2.3 in the draft Feasibility Report Part I in order to provide more safety on traffic accident as well as to facilitate the smooth flow of the traffic."

The Japanese Survey Team immediately made further study of the change-over problem according to the instructions made in the comment. The study is presented below.

What are mentioned in the comment are in a word to find a solution as to how and where to carry out the change-over between the left hand driving in Thailand and the right hand driving in Laos.

The study as to how to carry out the change-over has drawn a conclusion that the change-over should be made with at-grade intersection, and traffic should be controlled by means of an automatic interlocking signal system at the most appropriate change-over site.

If automatic interlocking signals are installed at an interval of 30 meters as shown on PLATE 19, and so operated that the green and red signals may alternate with each other every 30 seconds, such a signal system has a capacity to handle five vehicles/1 for 30 seconds.

In this bridge project, the two-lane highway is to be enlarged by one more lane each on both sides over the length of 170 meters at the change-over site, as given on PLATE 19. In this case, the signal system can deal with nine trucks for 30 seconds, that is, 18 trucks for a cycle of 1 minute. The hourly handling capacity totals 1,080 trucks equivalent.

On the other hand, it is estimated that the future traffic volume will reach 13,538 vehicles/2 per day in 40 years after the project is completed, provided that no toll is imposed on the bridge users. The traffic growth in the future is the largest in the case of a non-toll bridge. The traffic volume of 13,538 vehicles per day are equivalent to 6,980 trucks per day when it is converted to the truck-equivalent according to the rates mentioned in the footnote/1. Hourly peaking traffic volume is figured out at 838 trucks assuming that a coefficient of conversion is taken at 0.12/3.

The traffic volume of 838 trucks equivalent is less than the handling capacity of 1,080 trucks equivalent. Consequently, the automatic interlocking signal system is quite serviceable throughout the useful life of the project, 40 years.

In addition, the at-grade intersection will not give rise to traffic congestion. The administrative facilities have to be provided on both sides of the Mekong so that all the transit vehicles can go through the immigration and customs formalities. It is expected that a lot of vehicles rushing at the administrative facilities are adjusted naturally in the course of the formalities and go out there with a certain stream of traffic.

Traffic congestion will therefore not occur at the change-over site by reason of such steady traffic flow as well as from the viewpoint of considerably less peaking traffic volume after 40 years than the handling capacity of the said signal system.

/1: This figure is represented with the truck-equivalent, i.e., the total number of heavy trucks to which all the vehicles are converted at the rate of 1 vehicle unit for buses, 2 for personal cars, taxis and light trucks, and 4 for motorcycles. The multiplication factor is 1 for buses, 0.5 for personal cars, taxis and light trucks, and 0.25 for motorcycles, respectively.

/2: See Table 6.8 in Chapter VI.

/3: This figure means that daily peaking hours are approximately 8 hours.

Another reason why we recommend to make the change-over with at-grade intersection is that the at-grade intersection is much more economical than the grade-separation. In this bridge project, the at-grade intersection requires only a total of 30,000 U.S. dollars equivalent inclusive of the cost of the automatic interlocking signal system, while the grade-separation costs about 250,000 U.S. dollars equivalent.

If future traffic would remarkably grow up beyond our estimate, it may be necessary to replace the at-grade intersection with the grade-separation. But, such replacement should be made when the necessity would arise. At the present stage, it is indispensable to allocate the project structures so that enough space may be made available when the grade-separated structures will be constructed in the future.

The solution of the problem as to where to carry out the change-over lay in Plan (c) as mentioned before, namely, to make the change-over on the Thai side. The major reasons why it was recommended were that it can offer smoother traffic flow, less traffic congestion and less construction cost than any other plans.

On the contrary, Thai National Mekong Committee proposed to select plan (a). Plan (a) aims at making the change-over with at-grade intersection on the Laotian side. But, in this plan the space lying between the Mekong and the existing Asian Highway A-12 is so narrow that the projected highway will become unnecessarily long. In addition, when the necessity would arise to provide the facilities for grade separation in the future, it is difficult to obtain enough space for the facilities. Plan (a) is therefore not recommendable.

Then it was recommended by the Japanese Survey Team to modify Plan (a) as follows. It is to locate the change-over site at appropriate place on the projected highway connecting the administrative facilities with the bridge on the Laotian side, as shown on PLATE 19. This is a modified plan of Plan (c), too. Functionally this modified plan can bear comparison with Plan (c). In this plan, however, it is impossible to provide the grade-separated facilities at the same place as the change-over is made with at-grade intersection on the occasion that the necessity may occur in the future. By this reason, the modified plan was not taken up in the draft Feasibility Report. However, in so far as the future grade-separation is made on the Thai side, the modified plan is as fine as plan (c). The Mekong Committee accepted to finally take up the modified plan.

3) Conclusion

The problem of the change-over is concluded as follows.

(i) The change-over should be made with at-grade intersection. At the present stage, it is not economical to carry out the change-over with grade-separation.

(ii) In so far as the change-over is made with at-grade intersection, it is possible to decide its location on the Laotian side. It is recommended to locate the change-over site at appropriate place on the projected highway connecting the administrative facilities with the bridge, as shown on PLATE 19.

(iii) An automatic interlocking signal system should be installed at the change-over site for traffic control with at-grade intersection. The signal system under consideration can have a capacity to handle the estimated future traffic throughout the useful life of the project, 40 years.

(iv) If the future traffic would grow up beyond the estimate made in next Chapter VI, the grade-separation should be provided on the Thai side when the necessity arises.

5.4.4. Administrative Facilities

The bridge is an international bridge that shall form the boundary between Laos and Thailand. All the traffic that will pass the bridge are therefore required to go through due procedures of immigration and customs. Accordingly, administrative facilities for the procedures must be provided at appropriate sites on either side of the bridge, which shall include an immigration office, a customshouse, a plant quarantine, warehouses, check booths for immigration and customs or to collect tolls if necessary, and so forth.

The layout of the administrative facilities was studied in connection with the problem of the bridge floor layout and of the change-over system, as described in Subparagraphs 5.2.1 and 5.4.3, and finally located and designed as shown in Plate 19.

The facilities on the Thai side will require an area of 140 by 330 meters, and those on the Laotian side an area of 110 by 410 meters. On the Thai side as well as on the Laotian side will be built two warehouses, each measuring 15 by 50 meters, and two office buildings, each for joint use of immigration and customs procedures, one for handling truck traffic and the other for traffic other than trucks. These offices will be so designed that business can be transacted at a rate of five minutes or less per vehicle with a capacity enough for handling increasing traffic for the first fifteen years. Besides, ample spaces will be provided for the future extension.

The driveways in the compounds of the administrative facilities will be paved with asphalt in the same way as in the roadway of the highway. Five check booths will be provided at the exit of the compounds on the Thai side as well as on the Laotian side.

Fig. 5.9. PROPOSED ROUTES OF PROJECTED HIGHWAY

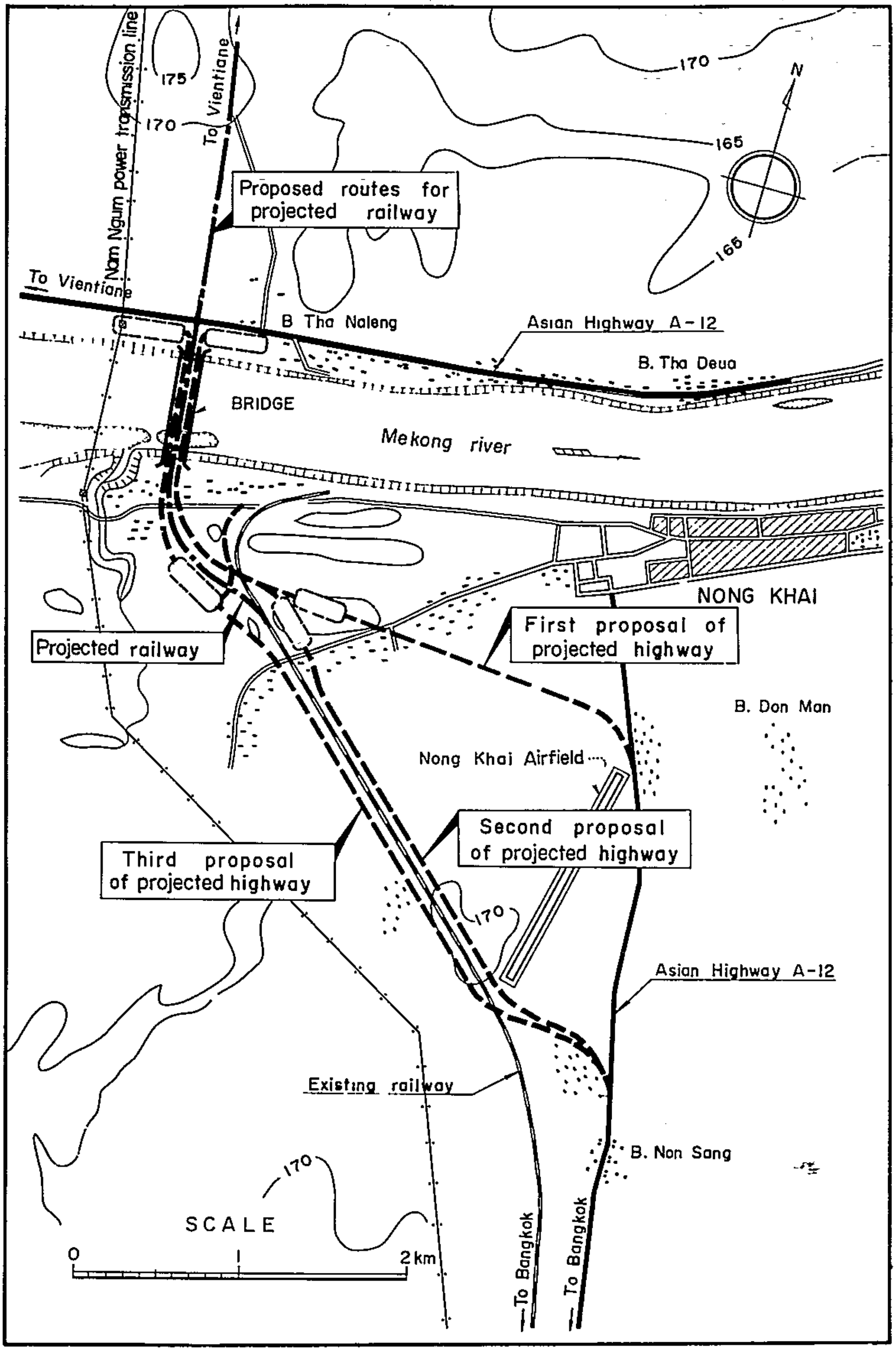
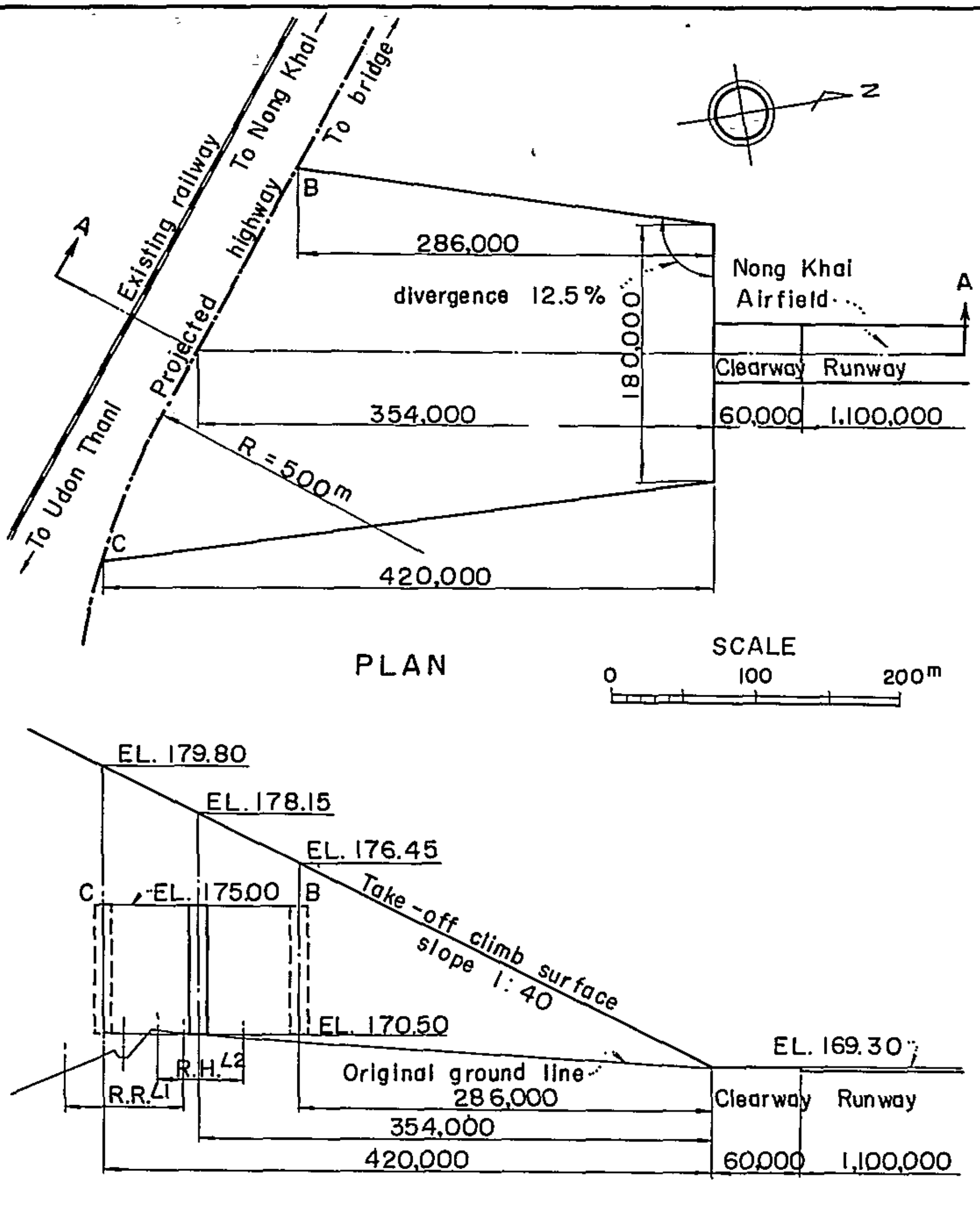


Fig. 5.10. RELATION BETWEEN THE TAKE-OFF CLIMB SURFACE OF THE RUNWAY AND THE NECESSARY VERTICAL CLEARANCE FOR THE PROJECTED HIGHWAY

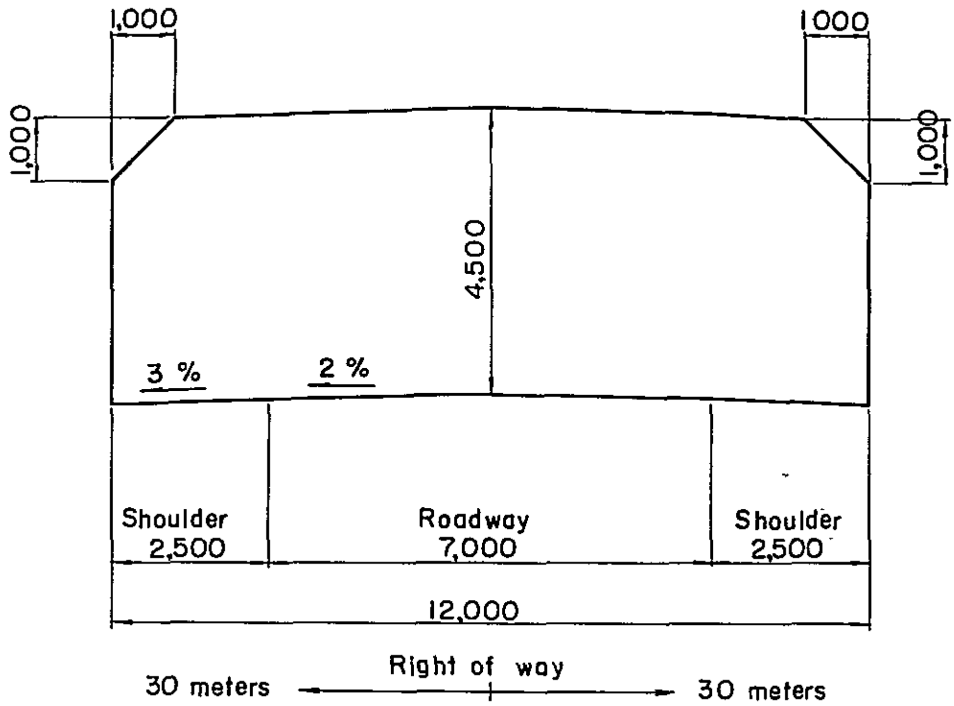


Remarks

∠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.

Fig. 5.11. CLEARANCE DIAGRAM OF THE PROJECTED HIGHWAY



Remarks :

This is a modified clearance diagram adopted for the design of the projected 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.

5.5. Construction Plan

Construction jobs in Southeast Asia are with almost no exception affected by monsoons characteristic of this region. The present project will not of course be an exception. The job will probably be often disturbed by heavy rains in the rainy season and will be subjected to sweltering heat of the sun in the dry season.

The construction plan of the present project therefore should be scheduled conforming to such local climate. The time schedule shown in Fig. 5.12 is what has been prepared under such consideration. It is intended that the job be done concentrically in the dry season that usually lasts from November to April of the next year. The construction is estimated to take net two years. The period required for detailed designing, preparation of tender documents and decision of a contractor or a joint venture of contractors to whom the job shall be awarded is estimated at about one year and a half.

The substructure of the main bridge comprises ten piers that shall be founded on bedrock of siltstone with caissons. Construction of these caissons will be carried out in two dry seasons, namely, five on the Thai side in the first dry season and the remaining five on the Laotian side in the next dry season.

Pneumatic caissons will be used in foundations of eight midstream piers, and open caissons in two end piers that will be built on land. In sinking caissons, the so-called "floating method", in which caissons are fabricated on land, towed into position and sunk through water, cannot be used in the present case, because the Mekong's water level at the bridge site drops in the dry season too low to tow caissons. In the present project, as already stated in Subparagraph 5,2,2, the caissons will be constructed on temporary islands to be built of steel-sheetpile cofferdams or on earth mounds to be built on a large sandbar on the Thai side and sunk in the same way as on land. In this way, the underwater work can be converted to a land job.

Temporary bridges shall be provided from the Thai and Laotian banks to the job sites to carry materials and machinery and for use of workmen. These bridges cannot be united to provide a through come-and-go over the river, because a clear opening for navigation shall be provided.

No decisive recommendation can be made at the present time regarding the method of erecting the superstructure of the main bridge. It must be selected by considering various factors, such as the structural type of the bridge, conditions around the job site and the availability of machinery, labor and power.

There is nothing to be specifically mentioned regarding the construction of the railway excepting that ballast material of a satisfactory quality can scarcely be found in or around the project area. It may be supplied from the Sara Buri district in Thailand but will cost much in transportation. And, should it be carried onto the Laotian side by the car ferry, the transport had better be done during the high-water season, because in the low-water season ferries have to take a roundabout course as sandbars come into appearance on the regular course and it takes much time for ferries to cross the river.

Railway and highway embankments shall preferably be finished about one month before the onset of the rainy season in order to minimize the adverse effect of soil swell due to the infiltration of rainwater.

Various installations necessary for the construction, such as field offices, lodgings and camps, concrete plants, material storage yards, machine shops, power-supply systems and water-supply systems, shall be provided on either bank of the river, as shown in Fig. 5.13 for instance.

Near the bridge site on the Laotian side, although in the near future power will become available from the Nam Ngum hydroelectric power project, at present no power-supply facilities are available. On the Thai side, however, abundant power can be obtained from the Pong Neeb power station.

Sand and gravel shall be excavated from the river during the dry season to the extent that they can meet the demand of concrete job through the year and aggregate plants shall have a capacity enough for that amount.

Two means of transportation are available for the construction machinery, equipments and materials that shall be carried from abroad via Bangkok to the job site, namely, the Asian Highway and the northeastern trunk line of the Royal State Railway of Thailand. At the present moment, there lies no bridge on these routes to be strengthened for the transportation of these heavy loads. But the present Nong Khai station should be strengthened in many aspects. Especially it should be equipped with large-capacity gantry cranes and a sufficient unloading yard.

The machinery, equipments and materials that shall be installed or used on the Laotian side and shall be carried from the Thai side should preferably be carried in the high-water season by the car ferry from Nong Khai to Tha Naleng as the capacity of the ferry sharply drops in the low-water season.

5.6. Construction Cost

During the first- and second-phase investigations, a cost survey was made mainly in the Vientiane-Nong Khai area on various items, such as materials, labor and freight. Based on the results of the survey and the work quantities estimated from the tentative designs, the construction cost has been estimated, being divided into two parts that shall be paid in domestic currency and in foreign currency, as shown in Tables 5.5. and 5.6. In this estimate, duties and taxes are not included, and an exchange rate of one U.S. dollars to 20.5 Bahts or 500 Kips has been adopted. Regarding the unit prices of various items, due account has been taken of the future price rise.

The net construction cost has been estimated at U.S. $14,390,000, dividing into U.S. $7,520,000 in foreign currency and U.S. $6,870,000 in domestic currency. The total cost has been estimated at U.S. $21,500,000, which divides nearly into halves in foreign and domestic currencies, namely, U.S. $10,900,000 in foreign currency and U.S. $10,600,000 in domestic currency.

Fig. 5.12. CONSTRUCTION TIME SCHEDULE

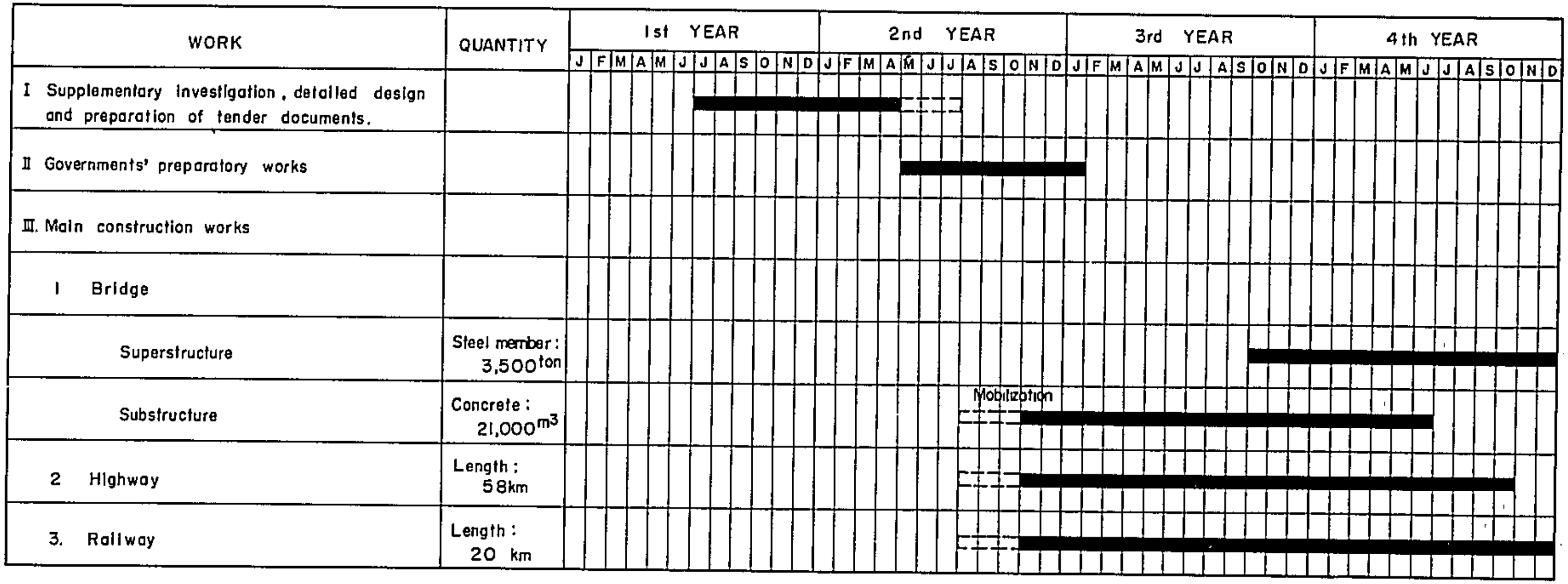


Fig. 5.13. CONSTRUCTION FACILITIES

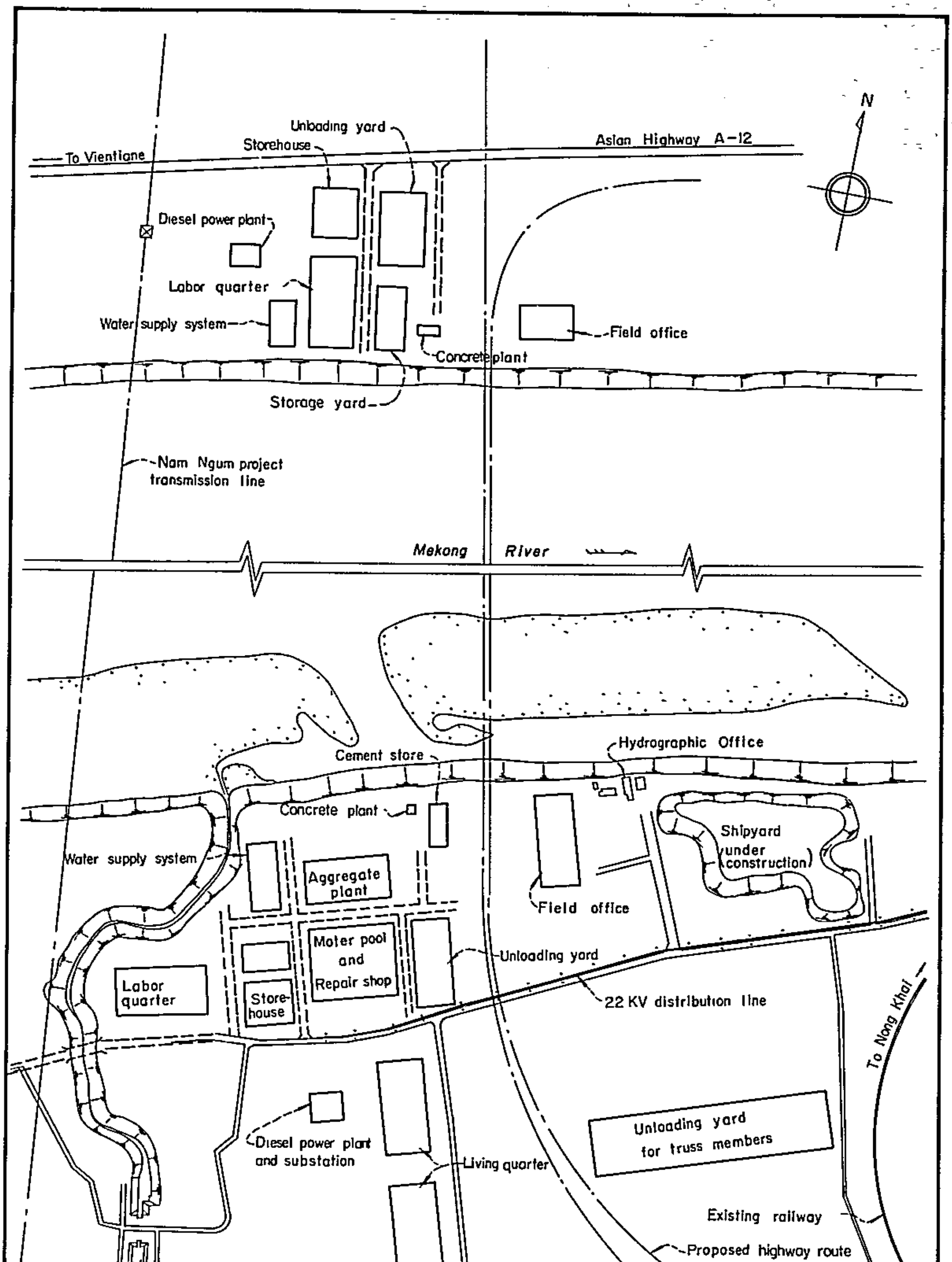


Table 5.5. Construction Cost (Summary)

Work	Construction cost (US$) Foreign currency	Domestic currency	Total
I. GOVERNMENTS' PREPARATORY WORKS	240,000	720,000	960,000
1. Construction facilities	240,000	135,000	375,000
2. Land and rights	-	585,000	585,000
II. MAIN CONSTRUCTION WORKS	7,520,000	6,870,000	14,390,000
1. Bridges	3,900,000	2,300,000	6,200,000
(a) Main truss bridge			
(i) Superstructure	2,000,000	550,000	2,550,000
(ii) Substurcture	1,500,000	1,280,000	2,780,000
(b) Approach viaducts	400,000	470,000	870,000
2. Railways	2,730,000	2,820,000	5,550,000
3. Highway	460,000	530,000	990,000
4. Administrative facilities	400,000	1,050,000	1,450,000
5. Permanent residential buildings	30,000	170,000	200,000
III. CONTINGENCY AND RESERVE	1,400,000	1,300,000	2,700,000
IV. ENGINEERING SERVICE	900,000	400,000	1,300,000
V. GOVERNMENTS' ADMINISTRATIVE EXPENSE	240,000	710,000	950,000
VI. INTEREST DURING CONSTRUCTION	600,000	600,000	1,200,000
Total	10,900,000	10,600,000	21,500,000

Table 5.6. Itemized Construction Cost

Item No.	Work	Unit	Quantity	Foreign currency (US$) Unit price	Foreign currency (US$) Amount	Domestic currency (US$) Unit price	Domestic currency (US$) Amount	Total (US$)	Remarks
I.	GOVERNMENTS' PREPARATORY WORKS				240,000		720,000	960,000	
1.	Construction facilities				240,000		135,000	375,000	
(a)	Temporary buildings	m^2	1,500	20	30,000	40	60,000	90,000	
(b)	Water supply system	L.S.			20,000		10,000	30,000	
(c)	Electric power supply system								
c-1	Substation and 22 kV distribution line	L.S.			75,000		40,000	115,000	One 1,250 KVA trans. and a distr. line 500 m. long.
c-2	Diesel power plants	L.S.			100,000		20,000	120,000	
(d)	Communication system	L.S.			15,000		5,000	20,000	
2.	Land and rights	km^2	1.3			450,000	585,000	585,000	
II.	MAIN CONSTRUCTION WORKS				7,520,000		6,870,000	14,390,000	
1.	Bridges				3,900,000		2,300,000	6,200,000	650 m. long
(a)	Main truss bridge				3,500,000		1,830,000	5,330,000	
	(Superstructure)				(2,000,000)		(550,000)	(2,550,000)	
a-1	Steel for truss members	ton	3,320	530	1,759,600	120	398,400	2,158,000	
a-2	Concrete	m^3	2,250	10	22,500	30	67,500	90,000	Cement 300 kg/m^3
a-3	Reinforcement Steels	ton	500	160	80,000	90	45,000	125,000	
a-4	Asphalt pavement	m^2	7,150	0.5	3,575	1.5	10,725	14,300	
a-5	Rails for track	m	650	30	19,500	10	6,500	26,000	Including wooden sleepers
a-6	Miscellaneous	L.S.			114,825		21,875	136,700	5%
	(Substructure)				(1,500,000)		(1,280,000)	(2,780,000)	
a-7	Excavation, all classes, for piers	m^3	15,500	20	310,000	10	155,000	465,000	10 piers
a-8	Concrete for caissons	m^3	8,200	60	492,000	55	451,000	943,000	Cement 300 kg/m^3
a-9	Concrete for piers	m^3	6,700	30	201,000	30	201,000	402,000	Cement 250 kg/m^3
a-10	Reinforcement steels	ton	1,100	160	176,000	90	99,000	275,000	Floor slab: 25cm thick
a-11	Steel sheetpiles	ton	750	235	176,250	115	86,250	262,500	
a-12	Structural steels for temporary bridge	ton	200	210	42,000	110	22,000	64,000	H-shape
a-13	Wooden mattresses for pier protection	m^2	6,200	1	6,200	20	124,000	130,200	
a-14	Gabions for bank protection	m^2	1,000	25	25,000	75	75,000	100,000	
a-15	Miscellaneous	L.S.			71,550		66,750	138,300	5%
(b)	Approach viaducts				400,000		470,000	870,000	
	(Composite girder bridges for highway)				(60,000)		(30,000)	(90,000)	2 x 30 m. long
b-1	Steel for composite girders	ton	90	530	47,700	120	10,300	58,500	
b-2	Concrete	m^3	200	10	2,000	30	6,000	8,000	Cement 300 kg/m^3
b-3	Reinforcement steels	ton	50	160	8,000	90	4,500	12,500	
b-4	Asphalt pavement	m^2	500	0.5	250	1.5	750	1,000	
b-5	Miscellaneous	L.S.			2,050		7,950	10,000	5%
	(Concrete hollow slab bridges for highway)				(120,000)		(180,000)	(300,000)	2 x 135 m. long
b-6	Excavation, common, for piers	m^3	900	1.5	1,350	1.0	900	2,250	
b-7	Concrete for superstructure	m^3	1,500	10	15,000	30	45,000	60,000	Cement 300 kg/m^3
b-8	Concrete for substructure	m^3	1,200	5	6,000	30	36,000	42,000	Cement 250 kg/m^3
b-9	Reinforcement steels	ton	380	160	60,800	90	34,200	95,000	
b-10	Concrete piles for piers	No.	380	70	26,600	130	49,400	76,000	
b-11	Asphalt pavement	m^2	2,200	0.5	1,100	1.5	3,300	4,400	
b-12	Miscellaneous	L.S.			9,150		11,200	20,350	5%
	(Plate girder bridges for railway)				(50,000)		(20,000)	(70,000)	2 x 30 m. long
b-13	Steel for plate girders	ton	90	530	47,700	120	10,800	58,500	
b-14	Rails for track	m	60	30	1,800	10	600	2,400	Including wooden sleepers
b-15	Miscellaneous	L.S.			500		8,600	9,100	5%
	(Concrete rigid frame bridges for railway)				(170,000)		(240,000)	(410,000)	413.5 m. long
b-16	Excavation, common, for piers	m^3	2,300	1.5	3,450	1.0	2,300	5,750	
b-17	Concrete	m^3	2,860	10	28,600	30	85,800	114,400	Cement 300 kg/m^3
b-18	Reinforcement steels	ton	490	160	78,400	90	44,100	122,500	
b-19	Concrete piles for piers	No.	610	70	42,700	130	79,300	122,000	
b-20	Ballast for track	m^3	420	3	1,260	20	8,400	9,660	
b-21	Rails for track	m	420	30	12,600	10	4,200	16,800	Including wooden sleepers
b-22	Miscellaneous	L.S.			2,990		15,900	18,890	5%
2.	Railways				2,730,000		2,820,000	5,550,000	
(a)	Railway track				(1,590,000)		(1,680,000)	(3,270,000)	
a-1	Clearing for track	m	15,000			1.6	24,000	24,000	80 m wide
a-2	Excavation, common, for track	m^3	48,700	1.0	48,700	0.5	24,350	73,050	
a-3	Excavation, common, for flood bridges	m^3	1,700	1.5	2,550	1.0	1,700	4,250	
a-4	Embankment, earth	m^3	137,500	1.0	137,500	1.0	137,500	275,000	

– Continued –

Item No.	Work	Unit	Quantity	Foreign currency (US$) Unit price	Foreign currency (US$) Amount	Domestic currency (US$) Unit price	Domestic currency (US$) Amount	Total (US$)	Remarks
a-5	Embankment, soil-sand mix	m^3	187,300	2.0	374,600	1.5	280,950	655,550	
a-6	Ballast for track	m^3	19,500	3	58,500	20	390,000	448,500	
a-7	Subballast for track	m^3	36,450	3	109,350	6	218,700	328,050	Laterite
a-8	Rails for track	m	19,500	30	585,000	10	195,000	780,000	Including wooden sleepers
a-9	Concrete for bridges and culverts	m^3	4,170	10	41,700	30	125,100	166,800	Cement 280 kg/m^3
a-10	Reinforcement steels	ton	445	160	71,200	90	40,050	111,250	
a-11	Concrete piles for piers	No.	450	70	31,500	130	58,500	90,000	
a-12	Dumped riprap for slope protection	m^2	31,890	2	63,780	3	95,670	159,450	Wooden latticed frames with laterite
a-13	Miscellaneous	L.S.			65,620		88,480	154,100	
(b)	New Nong Khai Railway Station				(380,000)		(400,000)	(780,000)	
b-1	Embankment	m^3	51,000	1	51,000	1	51,000	102,000	
b-2	Rails for track including ballast	m	2,100	25	52,500	25	52,500	105,000	
b-3	Station building	m^2	540	50	27,000	100	54,000	81,000	71.5m x 8m
b-4	Platforms	m^2	2,750	15	41,250	55	151,250	192,500	
b-5	Points and crossings, and safety appliances	L.S.			153,000		7,000	160,000	
b-6	Warehouses	m^2	500	10	5,000	50	25,000	30,000	
b-7	Station plaza	m^2	6,600	13	19,800	4	26,400	46,200	Asphalt-paved, including approach
b-8	Underpasses	m	20	280	5,600	400	8,000	13,600	roads
b-9	Miscellaneous	L.S.			24,850		24,850	49,700	5%
(c)	Vientiane Railway Station				(760,000)		(740,000)	(1,500,000)	
c-1	Excavation, common, for station	m^3	45,500	1	45,500	0.5	22,750	68,250	
c-2	Embankment	m^3	20,400	1	20,400	1	20,400	40,800	
c-3	Rails for track including ballast	m	5,200	25	130,000	25	130,000	260,000	
c-4	Station building	m^2	1,000	50	50,000	100	100,000	150,000	100m x 10m
c-5	Platforms	m^2	7,000	7	49,000	30	210,000	259,000	
c-6	Points and crossings, and safety appliances	L.S.			250,000		20,000	270,000	
c-7	Warehouses, engine shed and others	m^2	1,800	10	18,000	50	90,000	108,000	
c-8	Station plaza	m^2	10,000	3	30,000	4	40,000	70,000	Asphalt-paved
c-9	Approach road	m	1,400	90	126,000	50	70,000	196,000	
c-10	Miscellaneous	L.S.			41,100		36,850	77,950	5%
3.	Highway				460,000		530,000	990,000	5.6 km long
3-1	Clearing and stripping	m^2	72,500	0.2	14,500	0.1	7,250	21,750	
3-2	Excavation, common	m^3	26,500	1.0	26,500	0.5	13,250	39,750	
3-3	Embankment, earth	m^3	59,800	1.0	59,800	1.0	59,800	119,600	
3-4	Embankment, soil-cement mix	m^3	44,300	2.0	88,600	4.0	177,200	265,800	
3-5	Subbase course	m^2	47,450	2.0	94,900	1.0	47,450	142,350	
3-6	Base course	m^2	38,850	1.0	38,850	0.5	19,425	58,275	
3-7	Asphalt pavement	m^2	44,520	0.5	22,260	1.5	66,780	89,040	
3-8	Concrete for box culverts	m^3	2,300	10	23,000	30	69,000	92,000	Cement 280 kg/m^3
3-9	Reinforcement steels	ton	230	160	36,800	90	20,700	57,500	
3-10	Guardrail	m	3,840	10	38,400	5	19,200	57,600	
3-11	Miscellaneous	L.S.			16,390		29,945	46,335	
4.	Administrative facilities				400,000		1,050,000	1,450,000	
4-1	Clearing and stripping	m^2	50,300	0.2	10,060	0.1	5,030	15,090	
4-2	Embankment	m^3	73,900	1.0	73,900	1.0	73,900	147,800	
4-3	Subbase course	m^2	39,700	2.0	79,400	1.0	39,700	119,100	
4-4	Base course	m^2	41,600	1.0	41,600	0.5	20,800	62,400	
4-5	Asphalt pavement	m^2	39,650	0.5	19,825	1.5	59,475	79,300	
4-6	Immigration offices and customhouses	m^2	6,500	20	130,000	100	650,000	780,000	
4-7	Warehouses, booths and others	m^2	3,000	10	30,000	50	150,000	180,000	
4-8	Miscellaneous	L.S.			15,215		51,095	66,310	5%
5.	Permanent residential buildings	m^2	2,000	15	30,000	85	170,000	200,000	
III.	CONTINGENCY AND RESERVE	L.S.			1,400,000		1,300,000	2,700,000	18% of (I) and (II)
IV.	ENGINEERING SERVICE	L.S.			900,000		400,000	1,300,000	
V.	GOVERNMENTS' ADMINISTRATIVE EXPENSE	L.S.			240,000		710,000	950,000	6% of (I) and (II)
VI.	INTEREST DURING CONSTRUCTION	L.S.			600,000		600,000	1,200,000	6% of (I) to (V)
	Total				10,900,000		10,600,000	21,500,000	

CHAPTER VI

ECONOMIC JUSTIFICATION

6.1. General

Economic justification is essential to the feasibility study of a project. It is usually studied by evaluating direct and indirect benefits that will be brought about by the project and the cost that will be required for the project.

In the present report, the economic justification begins with the estimation of the future traffic on the bridge and of the unit benefit that will arise in the traffic on the highway as well as on the railway. The benefits were obtained as the product of the unit benefit and the traffic, and the costs were computed from the total construction cost and the annual working expense of the project. And then, from the benefits and costs thus obtained, the benefit-cost ratio, capitalized net benefit and internal rate of return were estimated for judging the economic feasibility of the project. Furthermore, studies have been done on various indirect benefits that might accrue from the project.

For estimating the future traffic, at first an origin-destination traffic survey was conducted at selected sites in the project area and then the initial traffic that shall be assumed at the time when the bridge would be open to traffic[/1] was estimated by analyzing the result of the survey. Then the future traffic was estimated based on the initial traffic, assuming that the bridge tolls would be set at the same level as the current ferry charges. However, it is natural that the traffic volume will be influenced by the toll rate, and so the relationship between the future traffic volume and the toll rate was studied.

In estimating the future traffic from the data of a traffic survey, the possible extent of the period, for which the estimation can be considered to hold, may be some 20 years at the longest. Therefore, the future traffic estimated in the present report for the period from 1973[/1] to 1990 may be considered to hold with passable accuracy.

The traffic will grow from the initial volume at a certain growth rate in the period from 1973 to 1990. However, as for the traffic growth in the period after 1990, a conservative estimate was made as compared with in the period before 1990. Namely, it has been assumed that the traffic will grow linearly from 1990 to 2000, and will remain constant after 2000.[/2] The mode of the future traffic growth thus assumed is shown in Fig. 6.3, and the volumes and the annual growth rates of traffic in the years 1973, 1990 and 2000 are listed in Table 6.6. According to these figure and table, the rate of the annual traffic growth is nearly 10 percent on the average for the period from 1973 to 1990, and about 4 percent for the period from 1990 to 2000.

The direct benefit comprises savings in the cost and time of travel, less chance of accidents, comfortable traveling, the increase in carrying capacity and so forth. In the present report, however,

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/1: It is assumed that the bridge will be open to traffic in 1973.

/2: The useful life of the project is estimated at 40 years. When the project would be completed in 1973, the end of the useful life falls on 2012.

only the savings in the cost and time of travel have been taken into the estimation of the direct benefit as the other benefits can hardly be evaluated in monetary value. The annual benefit is given as the product of the unit benefit and the annual traffic. The annual equivalent benefit has been computed for the period of 40 years, which nearly corresponds to the mean useful life of the project, for three different discount rates, 3, 7 and 10 percent.

The benefit-cost ratio, the ratio of the annual equivalent benefit to the annual equivalent cost, exceeds unity in all cases computed, as shown in Table 6.12. Especially, it will amount to 5.9, when no toll would be collected and the discount rate would be set at 3 percent. Even in a most unfavorable case in which the bridge tools that equal the current ferry charges would be collected and a high discount rate of 10 percent would be applied, the benefit-cost ratio is 1.3, still greater than unity, and a capitalized net benefit of about U.S. $9 million can be expected.

The internal rate of return will amount to a high figure of 15.9 percent when the bridge tolls would not be collected, and still to 12.9 percent even if the bridge tolls would equal the current ferry charges, as shown in Fig. 6.5.

It can be concluded from the above consideration that the present project is quite feasible from the economic point of view.

6.2. Future Traffic

Prior to the estimation of the future traffic, the imaginary initial traffic, defined in (2) in this paragraph, will first be estimated from the data that shall be obtained by the survey of the existing traffic. Then, after assuming possible growth rate, the possible future traffic will be estimated based on the imaginary initial traffic.

(1) Present Traffic

An origin-destination traffic survey was carried out during the first-phase investigation in 1967. It was conducted at ten selected sites lying within the project area as listed in Table 6.1 on highway traffic as well as on waterway traffic.

Table 6.1. Site and Date of Origin-Destination Survey

	Survey Point	Date	
1.	7 km from Vientiane toward Luang Prabang ...	12 Sep. '67	(Tues.)
2.	11 km from Vientiane toward Paksé	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.)

N. B. The locations of the survey points are shown in Fig. 6.1.

The survey was conducted at each site for 12 hours from 6 a.m. to 6 p.m. in the daytime, considering the fact that the night traffic is everywhere very scarce on account of insecurity. However, to find a clue to 24-hour traffic, a 24-hour survey was carried out at Point 7 and it was found that the 24-hour traffic at this site was 1.23 times the 12-hour daytime traffic. And this multiplier was applied to other sites for estimating the 24-hour traffic from the observed 12-hour traffic.

From the data thus obtained, the flows of freight, passengers and vehicles between possible zonal pairs were computed and are shown in Fig.6.1.

(2) Imaginary Initial Traffic

It is necessary for estimating the future traffic on the bridge to assume an imaginary traffic that would be initiated on the new bridge, if the bridge would be open to traffic at the time when the "present" traffic is estimated, namely, in 1967 in the present case. This traffic is in no way the actual traffic in 1967, but an imaginary traffic to be expected in 1967 under the above assumption.

The imaginary initial traffic was estimated from the present traffic based on some assumptions. For instance, it was assumed that the present highway traffic that are now handled by the existing ferries will all be diverted to the bridge traffic and that the present railway traffic to and from the Nong Khai station may all be included in the imaginary railway traffic.

The estimated volumes of the imaginary initial traffic are listed in Table 6.2.

Table 6.2. Imaginary Initial Traffic On the Bridge In 1967[a]

Kind of Traffic	(A)	(B)	Total
Highway Traffic, in vehicles per day			
Buses	2	12	14
Personal Cars	23	56	79
Taxis	1	57	58
Heavy Trucks	93	2	95
Light Trucks	3	0	3
Motorcycles	0	62	62
(Total)	122	189	311
Railway Traffic, in persons or tons per day			
Passengers	6	135	141
Freight	254	—	254

Note: a: On the assumption that the bridge will be open to traffic in 1967.
(A): Traffic that will be diverted from the car ferry.
(B): Traffic that corresponds to passengers and freight to be diverted from ferries other than the car ferry.

(3) Traffic Growth Index

The growth of traffic in the future may be considered to consist of the natural growth of the present traffic and the sudden increase that will arise due to the impact of the opening of a new bridge.

In general, the natural growth of traffic can be estimated correlating to the growth of the gross national product, because traffic activity in an area is closely related to the production activity in the area, which, in turn, is influenced by the national production activity. And the relationship between the traffic and the gross national product is usually assumed linear. In the present case, the ferry passengers, the ferry freight and the railway arrival freight at Nong Khai were assumed to be expressed in terms of the gross national product by the following equations:

$$A_F = 2{,}324.7\,P_L - 253{,}313.4 \quad \ldots\ldots (1)$$

$$A_P = 1{,}713.4\,P_L - 240{,}543.7 \quad \ldots\ldots (2)$$

$$A_R = 2{,}255.2\,P_L - 253{,}750.0 \quad \ldots\ldots (3)$$

in which A_F, A_P and A_R denote the annual ferry freight in tons, the number of ferry passengers per year, and the annual railway arrival freight at Nong Khai, respectively, and P_L denotes the Laotian gross national product in terms of U.S. $1 million. The above equations are what have been derived based on the past data of the Laotian gross national product and of the volumes of traffic listed in Table 6.5 in Part III.

In order to compute A_F, A_P and A_R for a future time point, it is necessary to estimate P_L for that time point. As shown in Table 6.5 in Part III, it has increased in the period from 1961 to 1965 at an average annual rate of about 5 percent. In Burma and Cambodia, there were the times in the past when the annual growth rate of their national products was about 6 percent. Therefore, when the future exploitation of undeveloped resources and the promotion of social welfare would be considered, it may be assumed that the Laotian gross national product would increase in the future at an annual rate of 6 to 7 percent.

Accordingly, it has been assumed in the present report that the Laotian gross national product would increase at an average annual rate of 5 percent from 1965 to 1970, at 6 percent from 1970 to 1975, at 6.5 percent from 1975 to 1985, and at 7 percent after 1985. Based on this assumption and the data in 1965, A_F, A_P and A_R were computed from Eqs. 1 to 3 and are listed in Table 6.3 (Table 6.6 in Part III). And, indices of natural growth of traffic based on 1967 traffic are shown in Table 6.3 (Table 6.7 in Part III).

The traffic volumes given in Table 6.3 are what shall be expected from the natural increase of the traffic. The sudden traffic increase that would be touched off by the completion of the Mekong bridge can be considered to be what would be induced by the reduction in the so-called economical distance of traffic due to the improvement that in the present case means the bridge. Such traffic increase can be estimated by the method of gravity model[/1] as described in detail in Chapter VI in Part III. The computation was made for the case in which tolls of the same amount as the current ferry charges would be levied on the bridge and a conclusion was drawn that a sudden increase in traffic at rates shown in Table 6.4 should be expected in 1973 after the completion of the bridge.

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

Table 6.3. Natural Growth of Traffic

Year	Gross National Product (P_L) In US. $ one million	Annual Growth Rate in Percent	Ferry Freight (A_F) In Tons	Growth Rate	Ferry Passenger (A_P) In Persons	Growth Rate	Arrival Railway Freight at Nong Khai (A_R) In Tons	Growth Rate
1966	175.50							
1967	184.28	5	175,080	1.00	75,200	1.00	161,840	1.00
1970	213.32	5	242,590	1.39	124,960	1.66	227,330	1.40
1973	254.07	6	337,320	1.93	194,780	2.59	319,230	1.97
1975	285.47	6	410,320	2.34	248,580	3.31	390,040	2.41
1980	391.12	6.5	655,920	3.75	429,600	5.71	628,300	3.88
1985	535.87	6.5	992,420	5.67	677,620	9.01	954,740	5.90
1990	751.59	7	1,493,910	8.53	1,047,230	13.93	1,441,240	8.91

Table 6.4. Rate of Sudden Traffic Increase Due to Completion of Bridge

Vehicles for passenger use and railway passengers	26 %
Trucks and railway freight	13 %

From Tables 6.3 and 6.4 and by taking account of the riding and loading efficiency, the growth indices of the possible future traffic on the bridge were estimated on the basis of the 1967 traffic, as described in Subparagraph 6.3.2 in Part III, for the case when the same tolls as the current ferry charges would be collected on the bridge. The estimated indices are shown in Table 6.5 (Table 6.8 in Part III).

Table 6.5. Growth Indices of Possible Future Traffic

	Kind of Traffic	Growth Indices of the Traffic Diverted from Passenger Ferry			Growth Indices of the Traffic Diverted from Car Ferry		
		1967	1973	1990	1967	1973	1990
I.	Highway Traffic						
	1. Buses	1.00	2.59	13.93	1.00	3.26	17.55
	2. Personal Cars	1.00	2.59	20.90	1.00	3.26	26.33
	3. Taxis	1.00	2.59	22.29	1.00	3.26	28.08
	4. Heavy Trucks	1.00	1.93	7.65	1.00	2.18	8.64
	5. Light Trucks	1.00	1.93	8.53	1.00	2.18	9.64
	6. Motorcycles	1.00	2.59	13.93	1.00	3.26	17.55
II.	Railway Traffic						
	1. Passengers	1.00	2.59	13.93	1.00	3.26	17.55
	2. Freight	1.00	1.97	8.91	1.00	2.23	10.07

Note: Tolls of the same level as the current ferry charges would be collected on the bridge.

(4) Possible Future Traffic on the Bridge

The possible volumes of traffic that should be envisaged on the bridge in 1973 and 1990, i.e., after one year and 18 years after the completion of the bridge, respectively, when the bridge tolls would be set at the same level as the current ferry charges, can be obtained by multiplying the imaginary initial traffic given in Table 6.2 by the growth indices listed in Table 6.5 and the results are listed in Table 6.6.

The traffic in the period from 1973 to 1990 was assumed to increase exponentially at a constant annual growth rate that shall be determined for each traffic from the estimated 1973 and 1990 volumes. From 1990 to 2000, the traffic was assumed to increase linearly at a rate that equals the average increase rate from 1973 to 1990. The annual growth rates for the period from 1973 to 1990 and the average increase rate for the period from 1990 to 2000 are shown in Table 6.6. Beyond 2000, the traffic was assumed to remain constant at the level as of 2000. The possible future traffic for each year from 1973 to 2000, as estimated, are listed in Table 6.7.

(5) Relationship Between Bridge Tolls and Traffic

The above estimation is based on the assumption that the bridge tolls would equal the current ferry charges. The traffic growth in the future, however, will largely be influenced by the level of the tolls. This problem has been studied, as described in Subparagraph 6.3.3 in Part III, based on the following equations.

$$Q_{ij} = Q_{if} \cdot \alpha_i^{\,1 - \frac{C_{ij}}{C_{if}}} \quad \text{.......... (4)}$$

$$\alpha_i = \frac{Q_{in}}{Q_{if}} = \left(\frac{C_{ir} + C_{if}}{C_{ir}} \right)^{K_i} \quad \text{.......... (5)}$$

in which

C_{ij}, C_{if} and C_{ir}	:	bridge toll, current ferry charge, and the operation cost between a typical zonal pair, respectively, for a traffic "i";
Q_{ij},Q_{if} and Q_{in}	:	volumes of traffic "i", when the toll would equal C_{ij}, C_{if} and nought, respectively;
K_i	:	a constant pertinent to traffic "i"; and
α_i	:	a coefficient of traffic variation.

In these equations, C_{ij}, C_{if} and C_{ir} are given values and Q_{if} is nothing but the traffic volume listed in Table 6.7. The constant K_i has been estimated, as shown in Table 6.9 in Part III, from the data observed before and after the release for free-of-charge traffic of several toll highways in Japan. Once K_i is known, the ratio α_i, called the coefficient of traffic variation, can be computed from Eq. 5. The relationship between the ratios C_{ij}/C_{if} and Q_{ij}/Q_{if} as well as the values of α_i are shown in Fig. 6.2.

Once α_i is known, possible future traffic, Q_{ij}, for various levels of the tolls, that is, for various values of C_{ij}/C_{if}, can be computed from Eq. 4 by substituting the traffic volumes listed in Table 6.7 for Q_{if}. The results are graphed in Fig. 6.3, which shows clearly that while the railway traffic will scarcely be affected by the bridge tolls, the highway traffic will largely be influenced by the tolls. Table 6.8 presents the possible volumes of traffic that should be envisaged on the bridge in 1973, 1990 and 2000, when no toll would be collected, the growth indices of the estimated 1990 and 2000 volumes to the estimated 1973 volume, the annual growth rates of the traffic in the period from 1973 to 1990 and the annual growth volumes of the traffic in the period from 1990 to 2000.

Fig. 6.1. ORIGIN-DESTINATION SURVEY POINTS AND TRAFFIC FLOW AS OF 1967

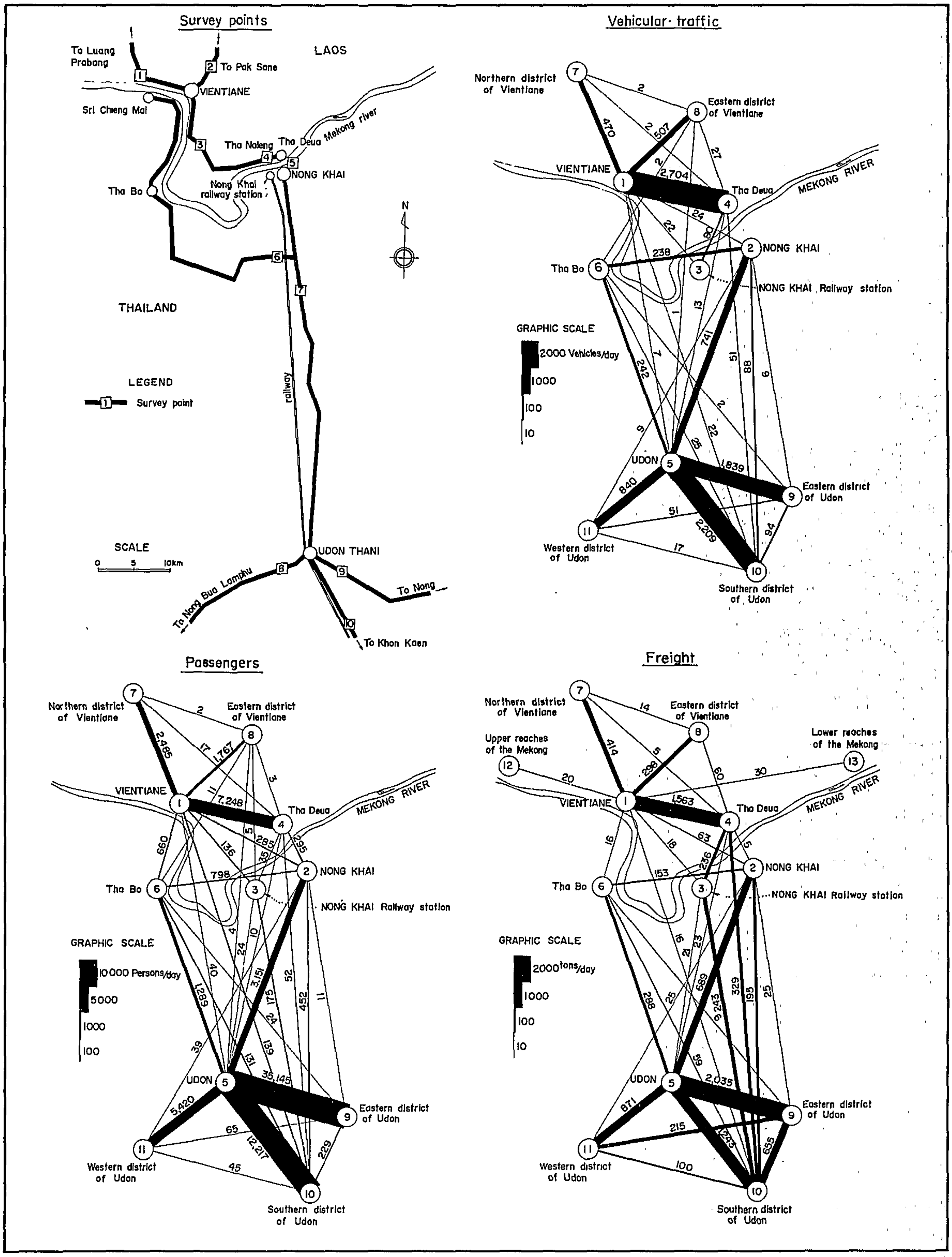


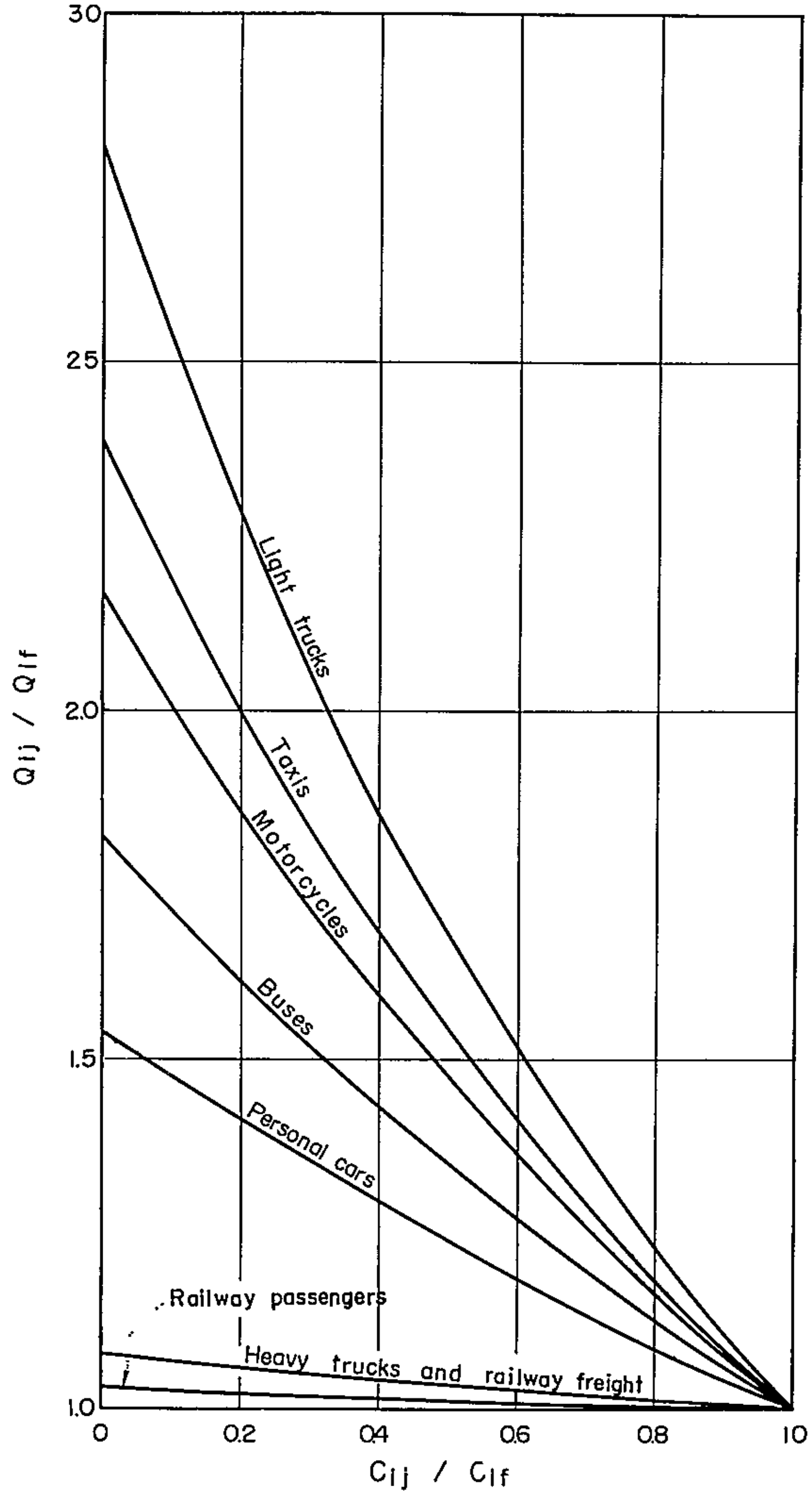
Table 6.6 Estimated Future Traffic, When Bridge Tolls Equal Current Ferry Charges

Items			Unit	Imaginary Initial Traffic	Future Traffic			Growth Index			Annual Growth Rate (%)	Annual Growth Volume	
				1967	1973	1990	2000	1973	1990	2000	1973 to 1990	1990 to 2000	
Highway Traffic	Vehicles diverted from car ferry	Buses	vehicles/day	2	7	35	52	1.00	5.00	7.43	9.9	1.7	vehicles/day
		Personal cars	"	23	75	606	918	1.00	8.08	12.25	13.1	31.2	"
		Taxis	"	1	3	28	43	1.00	9.33	14.33	14.4	1.5	"
		Heavy trucks	"	93	203	804	1,158	1.00	3.96	5.71	8.4	35.4	"
		Light trucks	"	3	7	29	42	1.00	4.14	6.00	8.7	1.3	"
		Motorcycles	"	0	0	0	0	0	0	0	0	0	
		Sub-total	"	122	295	1,502	2,213	1.00	5.09	7.50	10.1	71.1	"
	Vehicles diverted from passenger ferries	Buses	vehicles/day	12	31	167	247	1.00	5.39	7.97	10.4	8.0	vehicles/day
		Personal cars	"	56	145	1,170	1,773	1.00	8.07	12.23	13.1	60.3	"
		Taxis	"	57	148	1,270	1,930	1.00	8.58	13.04	13.5	66.0	"
		Heavy trucks	"	2	4	15	21	1.00	3.75	5.25	8.1	0.6	"
		Light trucks	"	0	0	0	0	0	0	0	0	0	
		Motorcycles	"	62	161	864	1,278	1.00	5.37	7.94	10.4	41.4	"
		Sub-total	"	189	489	3,486	5,249	1.00	7.13	10.73	12.2	176.3	"
	Total traffic	Buses	vehicles/day	14	38	202	299	1.00	5.32	7.87	10.3	9.7	vehicles/day
		Personal cars	"	79	220	1,776	2,691	1.00	8.07	12.21	13.1	91.5	"
		Taxis	"	58	151	1,298	1,973	1.00	8.60	13.06	13.5	67.5	"
		Heavy trucks	"	95	207	819	1,179	1.00	3.96	5.69	8.4	36.0	"
		Light trucks	"	3	7	29	42	1.00	4.14	6.00	8.7	1.3	"
		Motorcycles	"	62	161	864	1,278	1.00	5.37	7.94	10.4	41.4	"
		Sub-total	"	311	784	4,988	7,462	1.00	6.36	9.51	11.5	247.4	"
Railway Traffic	Freight diverted from car ferry		tons/day	254	566	2,558	3,730	1.00	4.52	6.50	9.3	117.2	tons/day
	Passengers diverted from car ferry		persons/day	6	20	105	155	1.00	5.25	7.75	10.3	5.0	persons/day
	Passengers diverted from passenger ferries		"	135	350	1,881	2,782	1.00	5.37	7.96	10.4	90.1	"
	Total railway passengers		"	141	370	1,986	2,937	1.00	5.37	7.94	10.4	95.1	"

Table 6.7 Estimated Future Traffic For Each Year From 1973 to 2000, When Bridge Tolls Equal Current Ferry Charges

Calendar year	Ordinal year	Highway Traffic (vehicles/day)							Railway Traffic	
		Buses	Personal cars	Taxis	Heavy trucks	Light trucks	Motor-cycles	Total	Railway freight (tons/day)	Railway passengers (persons/day)
1973	1	38	220	151	207	7	161	784	566	370
1974	2	42	249	171	224	8	178	872	619	408
1975	3	46	281	194	243	8	196	968	676	451
1976	4	51	318	221	264	9	217	1,080	739	498
1977	5	56	360	250	286	10	239	1,201	807	549
1978	6	62	407	284	310	11	264	1,338	882	607
1979	7	69	460	323	336	12	291	1,491	964	670
1980	8	76	520	366	365	13	322	1,662	1,053	739
1981	9	83	588	416	396	14	355	1,852	1,151	816
1982	10	92	665	472	429	15	392	2,065	1,258	901
1983	11	102	751	535	465	16	433	2,302	1,375	994
1984	12	112	850	607	504	18	478	2,569	1,502	1,098
1985	13	124	961	689	547	19	527	2,867	1,642	1,212
1986	14	136	1,086	782	593	21	582	3,200	1,794	1,337
1987	15	150	1,228	888	643	23	642	3,574	1,960	1,476
1988	16	166	1,389	1,008	697	25	709	3,994	2,142	1,630
1989	17	183	1,570	1,144	756	27	783	4,463	2,341	1,799
1990	18	202	1,776	1,298	819	29	864	4,988	2,558	1,986
1991	19	212	1,867	1,365	855	30	906	5,235	2,675	2,081
1992	20	221	1,959	1,433	891	32	947	5,483	2,792	2,176
1993	21	231	2,050	1,500	927	33	988	5,729	2,910	2,271
1994	22	241	2,142	1,568	963	34	1,030	5,978	3,027	2,366
1995	23	250	2,233	1,635	999	36	1,071	6,224	3,144	2,461
1996	24	260	2,325	1,703	1,035	37	1,112	6,472	3,261	2,556
1997	25	270	2,416	1,770	1,071	38	1,154	6,719	3,378	2,652
1998	26	279	2,508	1,838	1,107	39	1,195	6,966	3,495	2,747
1999	27	289	2,599	1,905	1,143	41	1,236	7,213	3,613	2,842
2000	28	299	2,691	1,973	1,179	42	1,278	7,462	3,730	2,937

Fig. 6. 2. RELATION BETWEEN BRIDGE TOLLS AND TRAFFIC



Values of α_i

Traffic components	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. Railway passengers	1.030
8 Railway freight	1.070

Remarks

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

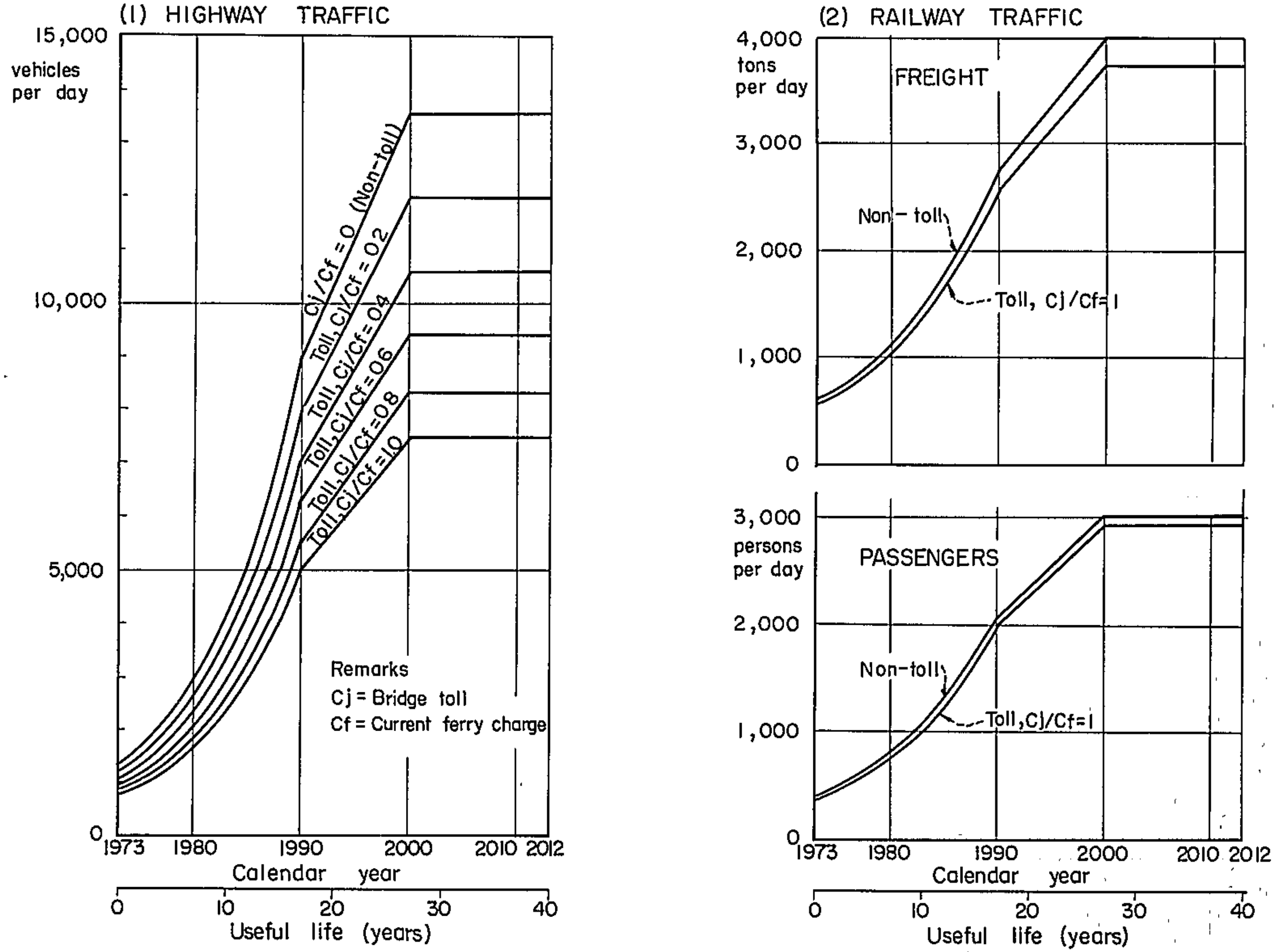
$Q_{ij} / Q_{if} = \alpha_i^{(1-\frac{C_{ij}}{C_{if}})}$

(See Eqs. (4) and (5).)

Table 6.8. Estimated Future Traffic, When No Toll Would Be Collected

Kind of Traffic	Unit	1973	1990	2000
Highway Traffic				
Buses	Vehicles/day	69	368	544
Personal Cars	"	338	2,735	4,145
Taxis	"	359	3,091	4,698
Heavy Trucks	"	221	876	1,261
Light Trucks	"	18	81	118
Motorcycles	"	348	1,874	2,772
Total		1,353	9,025	13,538
Railway Traffic				
Freight	tons/day	606	2,737	3,991
Passengers	passengers/day	380	2,045	3,025

Fig. 6.3. FUTURE TRAFFIC VOLUMES, AS RELATED TO BRIDGE TOLLS



6.3. Direct Benefit

As noted in Paragraph 6.1, the direct benefits that would be brought forth by the implementation of the present project comprise savings in the cost and time of travel, less chance of accidents, comfortable traveling, the increase in carrying capacity and so forth.

The saving in the cost of travel is called the operation benefit, and the saving in the travel time the time benefit. While these two benefits can be estimated more or less reasonably, other benefits can hardly be evaluated even in a rough estimate. In the present report, therefore, only the operation and time benefits are counted in the direct benefit.[/1]

6.3.1. Unit Benefit

The annual benefit can be obtained by multiplying the benefit per unit of traffic, called "unit benefit", by the annual traffic volume.

A unit benefit comprises the operation and time benefits per unit of traffic in a zonal pair, and the unit benefit to be used in estimating the annual benefit shall be the average of the unit benefits in given zonal pairs. In the present report seven zonal pairs shown in Table 6.10 in Part III have been considered. The average unit benefit can be computed generally by

$$B_{mn} = (C_0 - C_1) + a(T_0 - T_1) \quad \cdots\cdots \quad (6)$$

$$B_i = \frac{\Sigma f_{mn} B_{mn}}{\Sigma f_{mn}} \quad \cdots\cdots \quad (7)$$

in which

B_{mn}	:	unit benefit of traffic between two zones, "m" and "n";
C_0 and C_1	:	operating costs of traffic in a zonal pair m-n on the existing route and on the improved route, respectively;
T_0 and T_1	:	time of travel in a zonal pair m-n on the existing and improved routes, respectively;
a	:	coefficient for converting travel time into monetary value;
f_{mn}	:	traffic volume in a zonal pair m-n; and
B_i	:	unit benefit of traffic "i".

Details of computation are described in Paragraph 6.4 of Part III, and the results are shown in Tables 6.10 and 6.11 in Part III and also given in the following table.

/1: Hereinafter, unless needed, "direct" will be omitted.

Table 6.9. Unit Benefits

Kind of Traffic	Unit Benefit	
Highway Traffic		
Buses	117.1	Bahts per vehicle
Personal Cars	39.4	"
Taxis	39.2	"
Heavy Trucks	111.0	"
Light Trucks	55.6	"
Motorcycles	5.3	"
Railway Traffic		
Freight	26.6	Bahts per ton
Passengers	7.4	Bahts per person

6.3.2. Annual Equivalent Benefit and Capitalized Benefit

The annual equivalent benefits and capitalized benefits can be computed by the following equations.

$$B_a = \frac{r(1+r)^n}{(1+r)^n - 1} \cdot \sum_{k=1}^{n} \sum_{i=1}^{l} \left[365 Q_{(if)k} \cdot (\alpha_i)^{1-\frac{C_{ij}}{C_{if}}} \cdot B_i \frac{1}{(1+r)^{k-1}} \right] \quad \cdots\cdots (8)$$

$$B_c = \frac{B_a}{r} \quad \cdots\cdots (9)$$

in which

- B_a : annual equivalent benefit;
- B_c : capitalized benefit;
- B_i : unit benefit of traffic "i";
- C_{if} : current ferry charge of traffic "i" (cf. Table 6.17 in Part III);
- C_{ij} : bridge toll "j" of traffic "i";
- $Q_{(if)k}$: daily volume of traffic "i" in year "k", in the case when bridge tolls equal the current ferry charges (cf. Table 6.8);
- l : number of traffic "i";
- n : period of analysis in years;
- r : discount rate; and
- α_i : coefficient of traffic variation of traffic "i" (cf. Fig. 6.2).

The traffic volume, as noted, varies with the level of the bridge tolls. Consequently, the benefit will be influenced by the tolls. In computing the benefits, the following three cases were considered: (1) the case of free-of-charge (non-toll); (2) the case that half the current ferry charges will be collected (half-toll); and (3) the case that bridge tolls the same as the current ferry charges will be collected (full-toll). The level of the tolls is expressed by the factor C_{ij}/C_{if} in Eq. 8, and the above three cases correspond to 0, 0.5 and 1 of C_{ij}/C_{if}.

The annual benefits were computed for the period of 40 years from 1973 to 2012 (namely, n = 40), because the average useful life of the project is assumed about 40 years and the present worth of the benefits after 40 years from now would be very small.

Three different discount rates, 3%, 7% and 10%, were considered because the opportunity rate is not clearly defined in Laos and Thailand, and eight kinds of traffic ($\ell = 8$) were taken up. The annual volumes of various traffic were computed beforehand and are graphed in Fig. 6.4 as related to C_{ij}/C_{if}. The computation was made by using these graphs and the result is shown in Table 6.10 and also in curves in Fig. 6.4.

Table 6.10. Annual Equivalent Benefit and Capitalized Benefit, In U.S. Dollars

Bridge Toll	Discount Rate, r	Annual Equivalent Benefit, B_a	Capitalized Benefit, B_c
Non-Toll	3 percent	7,036,300	234,540,000
	7 "	5,619,100	80,270,000
	10 "	4,794,800	47,950,000
Half-Toll	3 percent	5,780,700	192,690,000
	7 "	4,635,500	66,220,000
	10 "	3,969,400	39,690,000
Full-Toll	3 percent	4,874,400	162,480,000
	7 "	3,924,300	56,060,000
	10 "	3,371,800	33,720,000

6.4. Benefit-Cost Ratio and Capitalized Net Benefit

6.4.1. Annual Equivalent Cost and Capitalized 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 life. As regards the fixed cost, the costs of the three major items of the project, the bridge, railway and highway, were estimated separately and were added together, because the useful lives of these structures are not the same.

The annual movable cost means the annual working expense for operation, maintenance and replacement of the project structures and facilities. In addition, office expenses for toll collection also are necessary in the case of a toll bridge. The annual working expenses were estimated in Part III and are shown in Table 6.13, Part III.

The equations, by which the annual equivalent cost and the capitalized cost were computed, are:

$$C_a = \sum_{t=t_1}^{t_n} C_t \cdot \frac{r(1+r)^t}{(1+r)^t - 1} + E \qquad \text{(10)}$$

$$C_c = \frac{C_a}{r} \qquad \text{(11)}$$

in which

C_a : annual equivalent cost;
C_c : capitalized cost;
C_t : construction cost of a project structure of t-year useful life (cf. Table 6.12, Part III);
E : annual working expense (cf. Table 6.13, Part III);
r : discount rate; and
t : useful life in years.

Computations were made for three discount rates, 3, 7 and 10 percent. The results are listed in Table 6.11.

Table 6.11. Annual Equivalent Cost and Capitalized Cost, In U.S. Dollars

Bridge Toll	Discount Rate, r	Annual Equivalent Cost, C_a	Capitalized Cost C_c
	3 percent	1,195,600	39,850,000
Non-Toll	7 "	1,886,900	26,960,000
	10 "	2,478,700	24,790,000
	3 percent	1,216,600	40,550,000
Half-and	7 "	1,907,900	27,260,000
Full-Tolls	10 "	2,499,700	25,000,000

6.4.2. Benefit-Cost Ratio and Capitalized Net Benefit

The benefit-cost ratio of a project is the ratio of the annual equivalent benefit to the annual equivalent cost, and the capitalized net benefit is the difference between the capitalized benefit and the capitalized cost. These indices were computed from the values given in Tables 6.10 and 6.11, and are listed in Table 6.12.

Table 6.12. Benefit-Cost Ratio and Capitalized Net Benefit

Bridge Toll	Discount Rate	Benefit-Cost Ratio, B_a/C_a	Capitalized Net Benefit, $B_c - C_c$ In U.S. Dollars
	3 percent	5.9	194,690,000
Non-Toll	7 "	3.0	53,310,000
	10 "	1.9	23,160,000
	3 percent	4.8	152,140,000
Half-Toll	7 "	2.4	38,960,000
	10 "	1.6	14,690,000
	3 percent	4.0	121,930,000
Full-Toll	7 "	2.1	28,800,000
	10 "	1.3	8,720,000

As can be seen from the above table, the benefit-cost ratio is greater than unity in any case. Even if the annual benefits would be discounted by a high rate of 10 percent and the bridge tolls would be set at the same level as the current ferry charges, it will still amount to 1.3. In case the discount rate would be set at 3 percent and no toll would be collected, the benefit-cost ratio will become as high as 5.9.

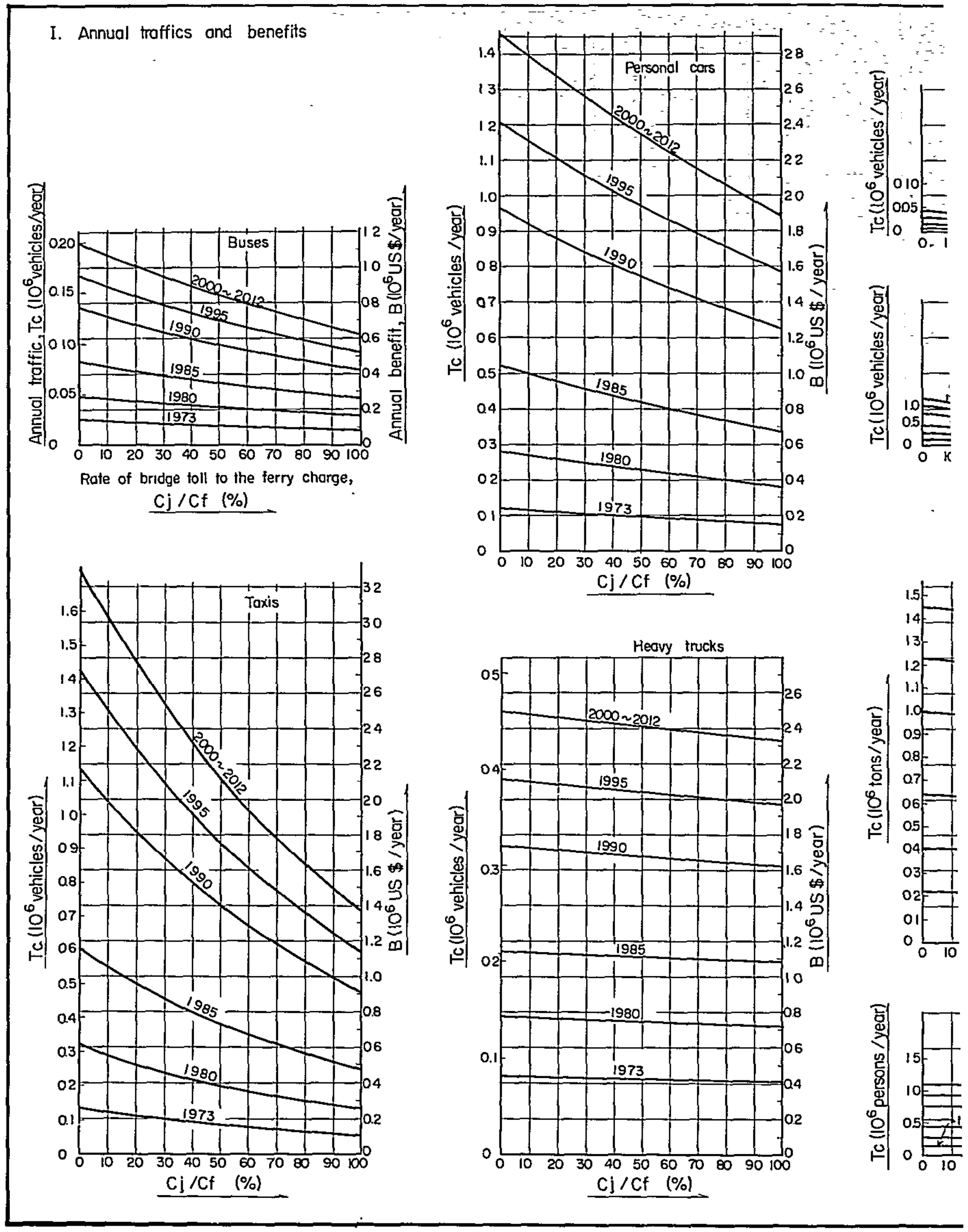
In the last mentioned case, the highest capitalized net benefit, about 195 million U.S. dollars, would be yielded.

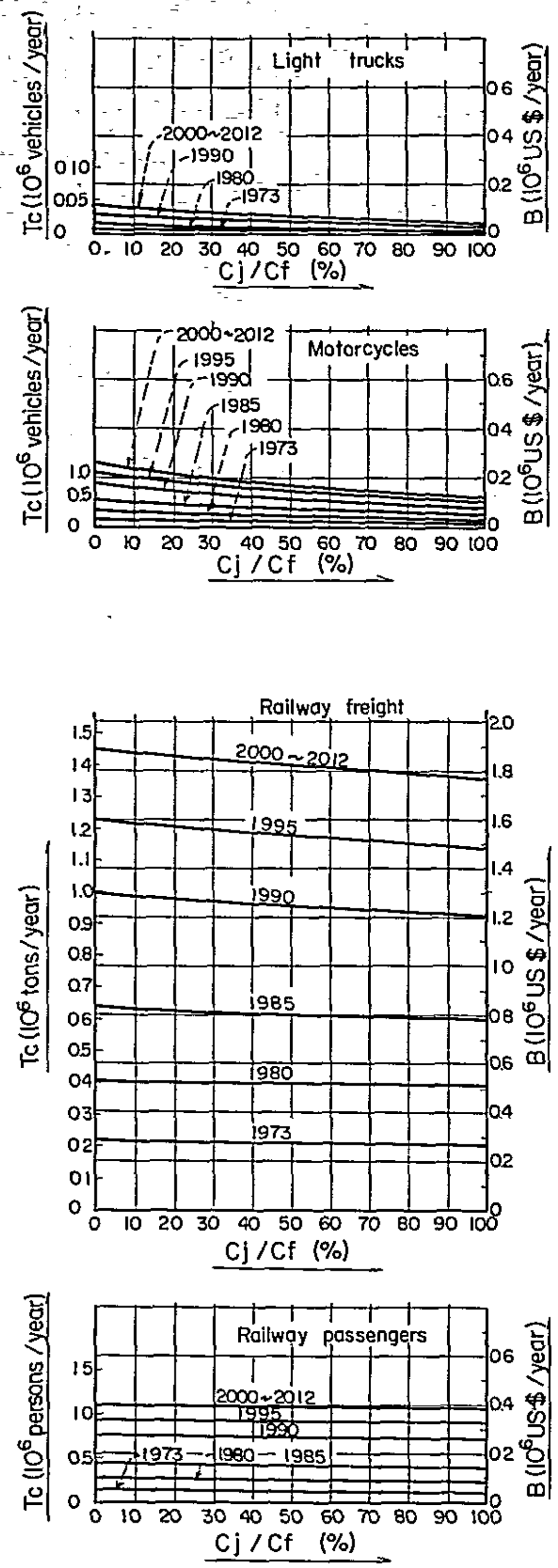
6.5. Internal Rate of Return

The internal rate of return is a discount rate that would make the total present worth of benefits to equal that of costs, and it is generally recognized that the minimum acceptable rate in a project like the present one is about 12 percent. The internal rate was computed for the three cases noted in Subparagraph 6.3.2. regarding the level of the bridge tolls.

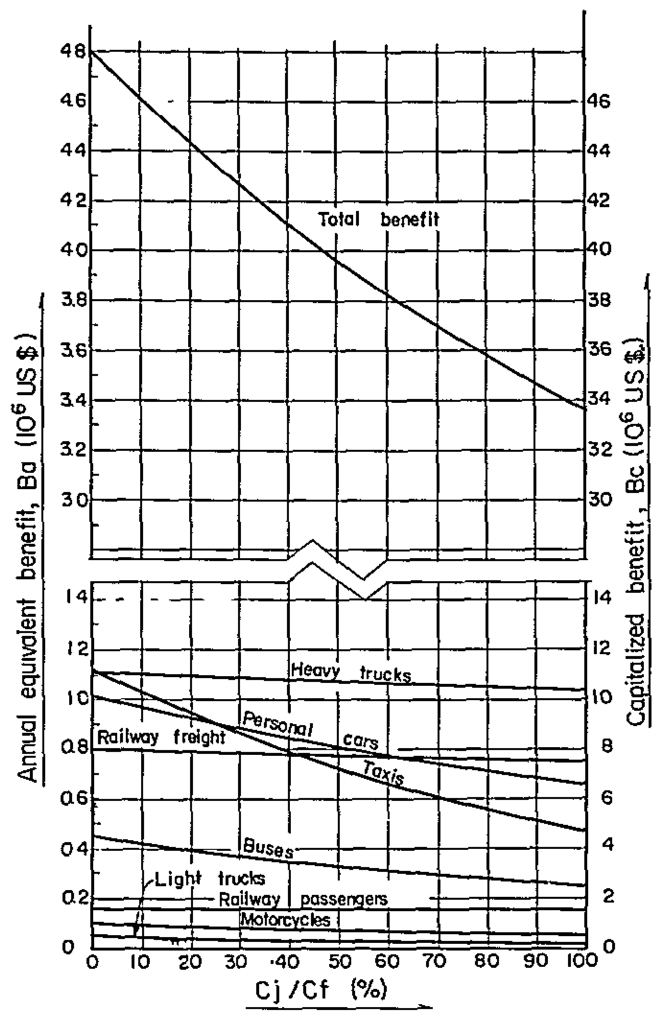
In determining the rate, both the annual benefits and costs were discounted to the present worths for a series of forty years, the mean useful life of the project. The rate was determined graphically as shown in Fig. 6.5. It was found that the rate would amount to 15.9 percent in the case of a non-toll bridge, to 14.1 percent when the bridge tolls would be set at half the current ferry charges and to 12.9 percent when the bridge tolls would equal the ferry charges. These rates exceed the minimum acceptable rate of 12 percent and therefore suggest that the project is economically feasible and worth developing.

Fig. 6.4. TRAFFICS AND B





II. Annual equivalent benefit and capitalized benefit (Discount rate = 10%)



Remarks :

$Tc = 365\, Q_f \alpha^{(1 - Cj/Cf)}$

$B = Tc\ Bi$

$Ba = \{r(1+r)^n / \{(1+r)^n - 1\}\} \sum_{K=1}^{n} B/(1+r)^{K-1}$

$Bc = Ba / r$

where

Q_f = Daily traffic in the case that the bridge tolls equall the current ferry charges,

α = Coefficient of traffic variation,

Cj = Bridge toll,

Cf = Current ferry charge,

Tc = Annual traffic,

Bi = Unit benefit,

B = Annual benefit,

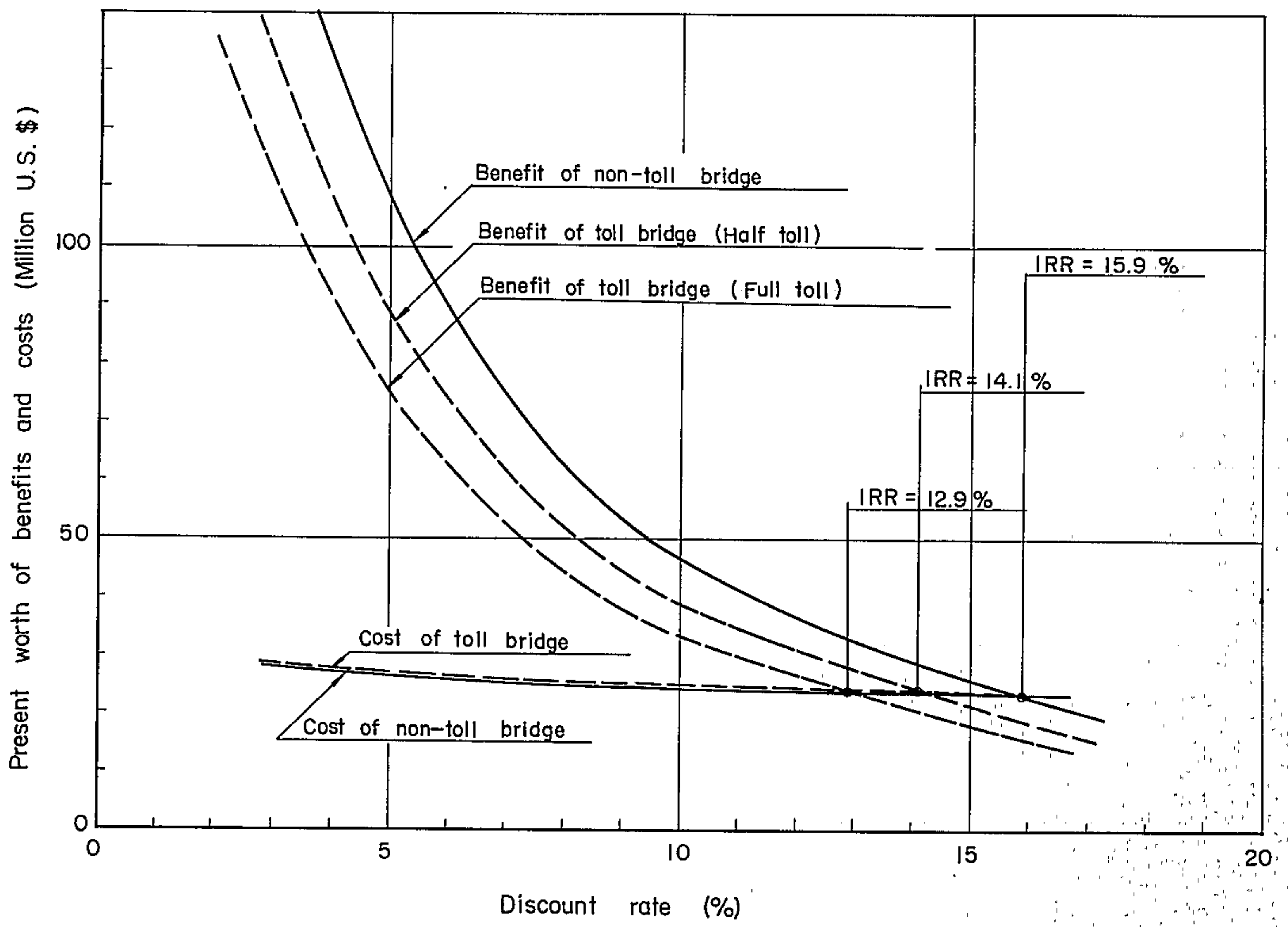
r = Discount rate

n = Analysis period, n = 40 years,

Ba = Annual equivalent benefit,

Bc = Capitalized benefit.

Fig. 6.5. INTERNAL RATE OF RETURN



6.6. Indirect Benefits

Besides the direct benefits, the project would effect many kinds of indirect benefits. The following are the major indirect benefits considered in the economic evaluation of the project.

(1) Contribution to the socio-economic development:
(2) Effect of reducing the volume of goods in stock; and
(3) Benefit in the field of consumption and production.

A brief description is given below of the above three.

(1) Contribution To the Socio-Economic Development

It is obvious that the project would remarkably promote the socio-economic development not only of the project area but also of Laos and Thailand. This effect will, however, be effectuated in the long course of time.

(a) Lumber Industry
Laos is rich in lumber resources, about two-thirds of her land being covered with dense forests. So, the lumber industry in Laos can be expected to develop remarkably when the transportation would be improved. It is especially significant for the Laotian lumber industry that a mass transportation system of railway would be introduced for the first time into Laos and would likely be extended farther inland. The Laotian lumber export is expanding being supported by the fact that Thailand is becoming short of forest resources and also by the favorable economic growth in Thialand. Therefore, the Laotian lumber export without fail will be promoted by the implementation of the project. Besides, new lumber industries of manufacturing secondary lumber products such as plywood will also develop.

If it could be assumed that the Laotian lumber export would increase at an annual rate of 10 percent on the average, it will increase from 32,400 tons in 1966 to about 300,000 tons in 1990.

(b) Mining
Mining, with the exception of tin, has not been developed in Laos, and no reliable survey nor prospecting has been carried out so far. Although the information is incomplete, there are some reports of the occurrence in Laos of gold, copper, lead, iron, limestone, gypsum, manganese, tungsten, antimony, graphite and salt. Among these, the most promising is the iron ore deposit in Xieng Khouang district, with an estimated reserve of several hundred million tons. These mineral resources, of great potential, have so far remained unexploited because Laos has no port for foreign trade as well as because of the lack of adequate transportation.

Accordingly, if a through rail route would be open from Bangkok to Vientiane by the construction of a rail/highway bridge over the Mekong, and moreover, if the rail route would be extended in the future farther inland to the sites of promising mineral resources, mined ores would become to be carried easily to Bangkok, at present the main gateway for the Laotian foreign trade, and as a result the development of the Laotian mining industry would be much accelerated.

(c) Rise of Land Value
After the completion of the project, the utility value of land will increase in areas lying along the

highway and railway and around the bridge site. Particularly, it is anticipated that the district around the Vientiane railway station, which lies almost undeveloped at the present time, will be rapidly developed.

The demand for land in and around the project area for construction of factories, shops and residences will bring about a rise in land prices, which in turn will benefit landowners in the form of increased rentals. This can be considered an indirect benefit of the project.

To appraise the landowners' income increase due to the rise of rentals, the following were assumed.

1. An area within a radius of one kilometer from the new railway station, totaling 3.14 square kilometers, will be influenced by the project;
2. The land price will rise from 1,000 Kips per square meter as of 1973 at an annual growth rate of 10 percent until 1990, and at 5 percent thereafter.
3. The rental is 5 percent of the land price throughout and the annual interest is 4 percent.

Based on the above assumptions, the land price in 1990 will become 5,000 kips per square meter, just the present average land price in Vientiane, and the landowners' income from the increased rentals will total U.S.$16 million for the period of 40 years, the useful life of the project.

(d) Agriculture and Stock-Raising

At present, most of foodstuffs such as rice, vegetables and meat consumed in the Vientiane area are imported from the Sri Chieng Mai-Tha Bo district on the opposite side of the Mekong. The bridge will place the economy of the Vientiane area in a much closer relation with the economy of the northeastern district of Thailand, and this will promote the development of agriculture and stock-raising in this area. For instance, it is said that the production of corn in northeastern Thailand has increased from 186,000 tons in 1958 to 1,200,000 tons in 1966, corresponding to 6.5 times, after the completion of the Asian Highway A-12. Thus, access to additional markets and reduction in transportation costs, which will result from the implementation of the project, will bring about an increase in the yield of farm produce as well as in farm income.

(e) Expected Contribution to Pa Mong Project

The Pa Mong project will need much cement for construction in the near future, and Laos is now planning to exploit limestone near the Nam Ngum project for manufacturing cement. If the railway would have been laid to Vientiane, it would be easy to extend the railway to Pa Mong along the Mekong (it should be understood that it is at present not easy to reach Pa Mong on the Thai side).

The railway, if realized, will contribute much to the transportation of cement and various other construction materials and machinery that shall be carried from abroad at the time of construction of the Pa Mong project.

(2) Effect of Reducing Goods in Stock

Time saving in transportation to be effectuated by the use of the Mekong bridge will reduce to some extent the volumes of goods and products to be stored in stock in shops or factories in Vientiane.

Articles for which such savings can be expected are agricultural produce, petroleum, electrical appliances and construction materials.

(3) Benefit in the Field of Consumption and Production

Cost saving in transportation will induce a drop in the cost prices of imported goods, an increase in production profit in manufacturing, and a drop in selling prices accompanied by a rise in demand and the resultant increase in sale.

Cost saving in transportation has already been counted in the direct benefit. It was appraised, item by item, for the Laotian imports and exports as of 1966 and are given in Table 6.14, Part III. This table shows that if all the imports and exports would have been carried from or to Bangkok via a non-toll bridge over the Mekong, a total of about U.S. $530,000 would have been saved. If it is assumed that the imports and exports would increase at an annual growth rate of 5 percent, the saving in the cost of transportation will almost triple in 1990.

Furthermore, to know the extent of the effect of cost saving in transportation to the Laotian imports and export, the ratio of the former to the cost prices of the imports and exports was appraised as listed in Table 6.15, Part III. As can be seen from the table, the rate is comparatively high in such items as watermelon, cement, lumber, petroleum, steel bars, household electrical appliances, beer, and raw materials for polyethylene.

Table 6.14, Part III, also shows that an amount of about U.S. $84,000 would be saved in the transportation of the Laotian imported consumer goods of 1966. Although most of the saving should go to dealers, consumers would still be benefited in the form of a price drop. This will stimulate a new demand and will also contribute much to the improvement of the living standard in Laos.

The amount that would be saved in the transportation of imported production goods was estimated at about U.S. $400,000 in 1966. This saving would directly benefit industry, contributing much to the economic and industrial growth of Laos.

CHAPTER VII

FINANCIAL FEASIBILITY

7.1. General

If the construction cost of the project should be financed wholly by a loan, it is desirable that the project be self-liquidating. From this point of view studies were made on the kind of loan and the rate of the bridge tolls, as described in this chapter. As regards amortization, it was considered to repay the loan annually from the revenue expected to exceed the interest on the invested capital plus the working expense, instead of repaying on the equal annual repayment basis.

First, assuming that the bridge tolls would equal the current ferry charges, studies were made on loans of three different annual rates of interest, namely, 3-, 7- and 10-percent annual rates of interest, and it was found that these loans would be amortized in 14, 18 and 24 years, respectively, as shown in Table 7.1. However, it was also found that in the case of loans of 7-percent and 10-percent annual rates of interest, a working capital amounting to about 11 percent and 58 percent, respectively, of the total construction cost would have to be provided.

Next, considering the bridge tolls variable, the relationship between the bridge tolls and the rate of interest and repayment period of loans was studied as described in Subparagraph 7.2.2. Fig. 7.1 shows the result, from which it can be judged what kind of loan should be sought for the selected bridge tolls.

Finally, Table 7.2 shows the optimal rate of tolls that would give the users of the bridge a maximum benefit in the cases of a 3-percent, 40-year loan and a 7-percent, 25-year loan, on condition that a working capital to the extent of 30 to 50 percent of the construction cost would be allowed.

The following are the conclusions of the financial study.

Should no working capital be allowed, it is desirable to obtain a loan not harder than a loan of 4-percent annual rate of interest and 15-year amortization period and to set the bridge tolls at the level of the present ferry charges. If it would be allowed that the necessity of working capitals totaling about 15 percent of the total construction cost arises for a period of the first 7 years, it will be possible to borrow a loan of 7-percent annual rate of interest and 18-year amortization period in the case of collecting bridge tolls equaling current ferry charges.

7.2. Financial Study

In the present study, it is assumed that the total investment of the project would be amortized with the revenue from the bridge tolls. And it was considered that the loan will be repayed annually with the surplus of the revenue expected to exceed the expenditure that comprises the interest on the loan and the working expense.

The annual revenue from the bridge tolls was computed as the product of the bridge tolls and the annual traffic, related closely each other as noted in Paragraph 6.2.

7.2.1. Repayment Plan

The repayment was studied on loans of 3-percent, 7-percent and 10-percent annual rate of interest on condition that the bridge tolls would equal the ferry charges. The results are shown in Table 7.1.

In the case of a 3-percent loan, while expenditures will amount to about 954,100 U.S. dollars in the first year, the bridge tolls will total 1,164,800 U.S. dollars in the same year. Accordingly, it is possible to start the amortization by repaying 210,700 U.S. dollars in the first year after the bridge would be open to traffic and to complete it in 14 years.

In the case of a 7-percent loan, an interest of 1,505,000 U.S. dollars must be paid in the first year as shown in Table 7.1. And, as the project will entail every year 309,100 U.S. dollars of working expense for operation, maintenance and replacement, an expenditure of 1,814,100 U.S. dollars is required in the first year. On the other hand, the income from the bridge tolls in the first year is estimated at 1,164,800 U.S. dollars, bringing on a deficit of 649,300 U.S. dollars. The deficit will gradually decrease after the second year to vanish in the sixth year. Accordingly, the substantial repayment will first begin in the seventh year. The outstanding amount of the capital and interest that will be caused by the unbalance during a period of six years after the opening of the bridge will amount to 23,963,500 U.S. dollars by the end of the sixth year (1978). This is 2,463,500 U.S. dollars or about 11 percent more than the initial investment of 21,500,000 U.S. dollars. This means that a working capital equivalent to about 11 percent of the construction cost will be required in addition to the construction cost. The loan will be fully amortized in 18 years.

In the case of a 10-percent loan, the project will keep on creating deficits, amounting to 1,294,300 U.S. dollars in the first year, for 13 years thereafter. The outstanding capital and interest will amount to 34,077,300 U.S. dollars which means a working capital of 12,577,300 U.S. dollars or about 58 percent of the initial investment is required.

In case no working capital should be allowed, a loan of 4-percent interest and 15-year amortization period or softer would have to be sought. Should a working capital of about 15 percent of the total construction cost be allowed for an initial period of 7 years, a loan of 7-percent interest would be repaid in 18 years.

7.2.2. Favorable Loans For Selected Toll Rates

This subparagraph deals with the study made on loans that will be fully amortized with the income from the bridge tolls, when they would be set different from the current ferry charges. In the study, it was assumed that the bridge tolls for various kinds of traffic, irrespective of their level, will remain in the same proportion as in the current ferry charges.

The study was made based on the following equation:

$$U_n = C(1+i)^n + E\sum_{j=0}^{n-1}(1+i)^j - R\sum_{k=0}^{n-1}(1+r)^k(1+i)^{n-1-k} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

in which

U_n : outstanding amount in n-th year;
C : amount of capital investment;
E : annual working expense;

R : total toll income in the initial year;
i ; annual rate of interest;
j, k : variable integers to denote the range of summation;
n : number of years; and
r : annual growth rate of toll income, no other than the annual growth rate of traffic given in Table 6.6.

If U_n becomes nought for a pair of n and i, it means that a loan of an annual interest rate of i would be fully amortized in n years. In the present study, computation was made on the values of n and i, which will make U_n vanish for ten different levels of the bridge tolls. The result is shown in curves in Fig. 7.1.

It can be said from Fig. 7.1, for instance, that a loan of 5-percent interest can be repaid within 21 years by bridge tolls if they would not be less than 60 percent of the current ferry charges. Fig. 7.1 also shows that if the bridge tolls would equal the ferry charges, a loan of 8.5-percent interest would be fully amortized in 20 years, half the useful life of the project and that if a loan should be amortized in 40 years by bridge tolls of 40 percent of the ferry charges, a loan of 6.7-percent interest will suffice..

7.2.3. Optimal Tolls

The optimal tolls, as dealt with herein, are what would give the users of the bridge the maximum residual benefit on condition that the total capital invested in the project should be fully amortized by the tolls.

The last condition means that the present worth of the total amount of the tolls in the period of repayment should equal the present worth of the invested capital and can be expressed by

$$\sum_{k=1}^{n} \left[\frac{1}{(1+r)^{k-1}} \sum_{i=1}^{\ell} Q_{(ij)k} C_{ij} \right] = C \quad \ldots\ldots (14)$$

in which
C : the present worth of the invested capital;
C_{ij} : a toll rate "j" of traffic "i", considered variable;
$Q_{(ij)k}$; volume of traffic "i" in a year "k", when the toll is set at C_{ij} (cf. Eq. 4, Paragraph 6.2);
i : variable integer to denote the range of summation;
ℓ : number of traffic "i";
n : period of repayment in years; and
r : annual rate of interest.

The users' residual benefit means the benefit minus the toll and the condition that the total present worth of the residual benefits in the period of repayment should become maximum can be expressed by

$$\sum_{k=1}^{n} \left[\frac{1}{(1+r)^{k-1}} \sum_{i=1}^{\ell} Q_{(ij)k} (B_i - C_{ij}) \right] = \text{maximum} \quad \ldots\ldots (15)$$

in which
B_i : unit benefit of traffic "i" (cf. Table 6.9).

Thus only two equations have been derived in respect of three variables, C_{ij}, n and r, C_{ij} involving innumerable combinations of toll build-up. Hence, it is impossible to decide these unknowns once for all by the two equations. Therefore, after selecting three combinations of n and r, the optimal toll rates have been appraised for each combination. The selected combination of n and r, i.e., the kind of loans, are a 3-percent, 40-year loan (Loan I), a 7-percent, 25-year loan (Loan II), and a 10-percent, 20-year loan (Loan III). In computing, no particular consideration was given to the working capital. And optimal tolls were estimated in 5-Baht units and so as not to exceed the current ferry charges.

Table 7.2 shows the result of the study. No optimal tolls can be conceivable for Loan III, because the loan cannot be amortized in its term of 20 years even if the tolls would equal the current ferry charges.

The total revenue from the optimal tolls exceeds the required toll income as shown in Table 7.2, and hence the repayment of either loan can be said warranted. The present worths of residual benefits given in the table are the maximums that can be expected in either case.

Table 7 1 Financial Statements in the Case of Collecting Bridge Tolls Equaling Current Ferry Charges

1. Annual rate of interest: 3 percent

Unit: U.S.$

Ordinal Year	Calendar Year	Outstanding amount	Interest	Annual working expense	Total expenditure	Toll revenue	Balance
1	1973	21,500,000	645,000	309,100	954,100	1,164,817	210,717
2	1974	21,289,283	638,678	309,100	947,778	1,280,628	332,850
3	1975	20,956,433	628,693	309,100	937,793	1,406,987	469,194
4	1976	20,487,239	614,617	309,100	923,717	1,550,586	626,869
5	1977	19,860,370	595,811	309,100	904,911	1,705,123	800,212
6	1978	19,060,158	571,805	309,100	880,905	1,877,571	996,666
7	1979	18,063,492	541,905	309,100	851,005	2,068,378	1,217,374
8	1980	16,846,119	505,384	309,100	814,484	2,278,753	1,464,270
9	1981	15,381,849	461,455	309,100	770,555	2,511,007	1,740,451
10	1982	13,641,398	409,242	309.100	718,342	2,767,342	2,049,000
11	1983	11,592,397	347,772	309,100	656,872	3,050,130	2,393,258
12	1984	9,199,139	275,974	309,100	585,074	3,363,902	2,778,828
13	1985	6,420,311	192,609	309,100	501,709	3,712,667	3,210,958
14	1986	3,209,354	96,281	309,100	405,381	4,096,150	3,690,770

2. Annual rate of interest: 7 percent

1	1973	21,500,000	1,505,000	309,100	1,814,100	1,164,817	-649,283
2	1974	22,149,283	1,550,450	309,100	1,859,550	1,280,628	-578,922
3	1975	22,728,205	1,590,974	309,100	1,900,074	1,406,987	-493,087
4	1976	23,221,291	1,625,490	309,100	1,934,590	1,550,586	-384,005
5	1977	23,605,296	1,652,371	309,100	1,961,471	1,705,123	-256,348
6	1978	23,861,644	1,670,315	309,100	1,979,415	1,877,571	-101,844
7	1979	23,963,488	1,677,444	309,100	1,986,544	2,068,378	81,834
8	1980	23,881,654	1,671,716	309,100	1,980,816	2,278,753	297,938
9	1981	23,583,716	1,650,860	309,100	1,959,960	2,511,007	551,046
10	1982	23,032,670	1,612,287	309,100	1,921,387	2,767,342	845,956
11	1983	22,186,714	1,553,070	309,100	1,862,170	3,050,130	1,187,960
12	1984	20,998,754	1,469,913	309,100	1,779,013	3,363,902	1,584,889
13	1985	19,413,865	1,358,971	309,100	1,668,071	3,712,667	2,044,596
14	1986	17,369,269	1,215,849	309,100	1,524,949	4,096,150	2,571,202
15	1987	14,798,067	1,035,865	309,100	1,344,965	4,522,485	3,177,520
16	1988	11,620,547	813,438	309,100	1,122,538	4,995,492	3,872,954
17	1989	7,747,593	542,332	309,100	851,432	5,518,964	4,667,533
18	1990	3,080,060	215,604	309,100	524,704	6,097,913	5,573,208

3 Annual rate of interest: 10 percent

Ordinal Year	Calendar Year	Outstanding amount	Interest	Annual working expense	Total expenditure	Toll revenue	Balance
1	1973	21,500,000	2,150,000	309,100	2,459,100	1,164,817	-1,294,283
2	1974	22,794,283	2,279,428	309,100	2,588,528	1,280,628	-1,307,900
3	1975	24,102,183	2,410,218	309,100	2,719,318	1,406,987	-1,312,331
4	1976	25,414,514	2,541,451	309,100	2,850,551	1,550,586	-1,299,966
5	1977	26,714,480	2,671,448	309,100	2,980,548	1,705,123	-1,275,425
6	1978	27,989,905	2,798,990	309,100	3,108,090	1,877,571	-1,230,520
7	1979	29,220,424	2,922,042	309,100	3,231,142	2,068,378	-1,162,764
8	1980	30,383,188	3,038,319	309,100	3,347,419	2,278,753	-1,068,665
9	1981	31,451,854	3,145,185	309,100	3,454,285	2,511,007	-943,279
10	1982	32,395,132	3,239,513	309,100	3,548,613	2,767,342	-781,271
11	1983	33,176,403	3,317,640	309,100	3,626,740	3,050,130	-576,611
12	1984	33,753,014	3,375,301	309,100	3,684,401	3,363,902	-320,499
13	1985	34,073,513	3,407,351	309,100	3,716,451	3,712,667	-3,784
14	1986	34,077,297	3,407,730	309,100	3,716,830	4,096,150	379,321
15	1987	33,697,977	3,369,798	309,100	3,678,898	4,522,485	843,587
16	1988	32,854,389	3,285,439	309,100	3,594,539	4,995,492	1,400,953
17	1989	31,453,436	3,145,344	309,100	3,454,444	5,518,964	2,064,521
18	1990	29,388,915	2,938,892	309,100	3,247,992	6,097,913	2,849,921
19	1991	26,538,994	2,653,899	309,100	2,962,999	6,387,369	3,424,369
20	1992	23,114,625	2,311,463	309,100	2,620,563	6,678,160	4,057,598
21	1993	19,057,027	1,905,703	309,100	2,214,803	6,968,241	4,753,438
22	1994	14,303,589	1,430,359	309,100	1,739,459	7,259,120	5,519,661
23	1995	8,783,928	878,393	309,100	1,187,493	7,548,488	6,360,996
24	1996	2,422,933	242,293	309,100	551,393	7,839,280	7,287,887

Fig. 7.1. INTEREST RATE AND REPAYMENT PERIOD OF LOAN THAT CAN BE AMORTIZED BY TOLLS

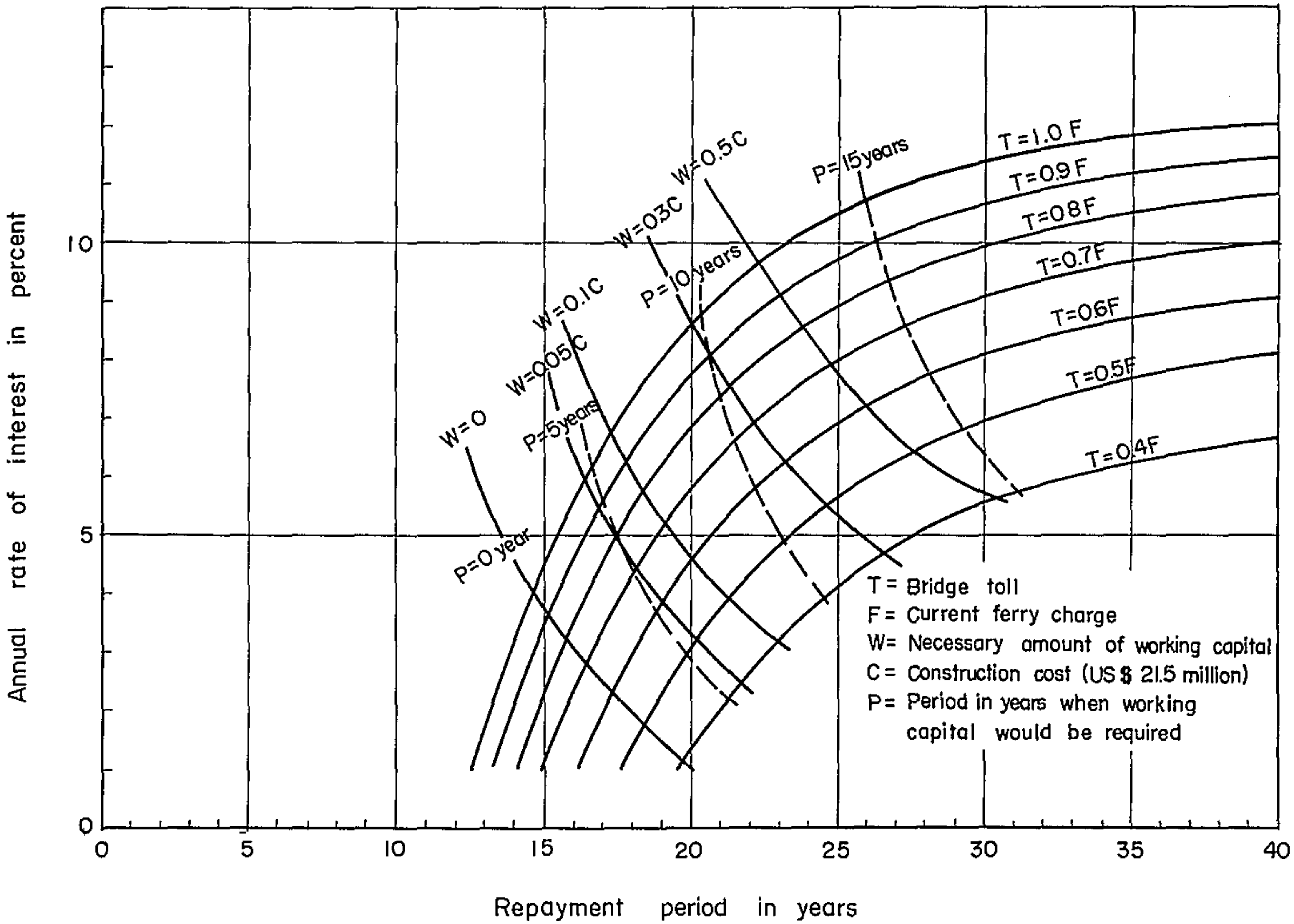
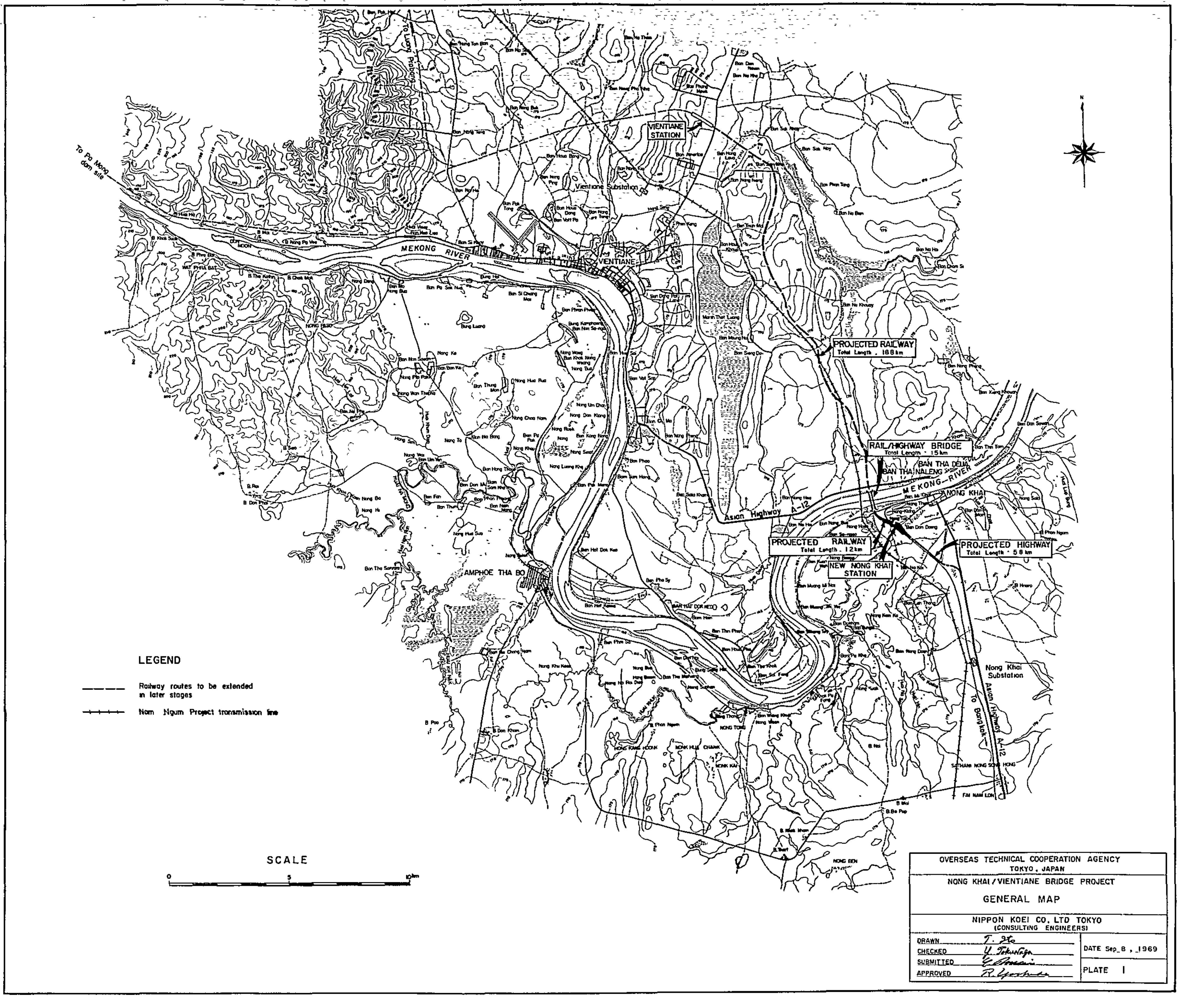
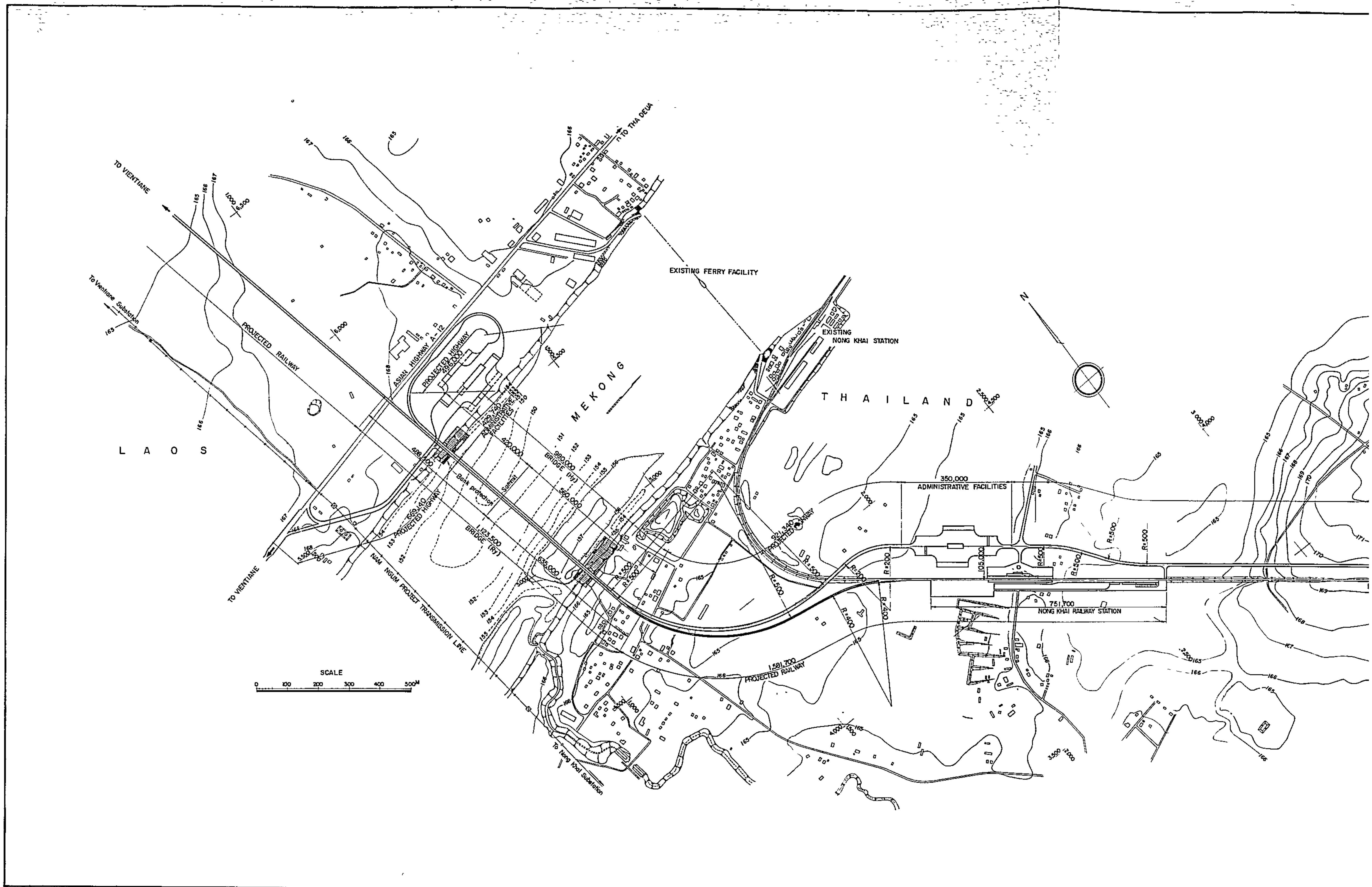


Table 7.2. Optimal Tolls, In Bahts

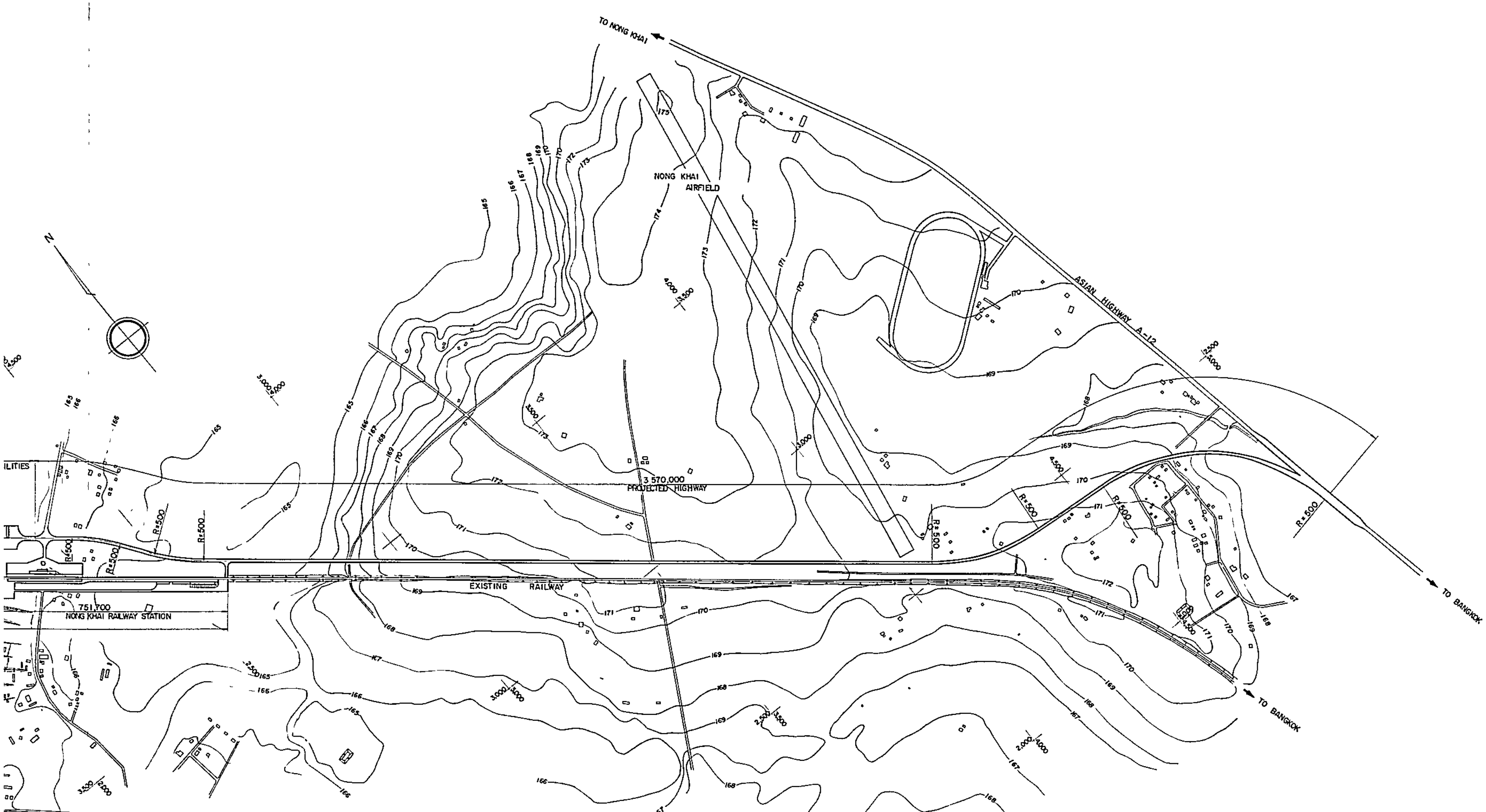
Kind of Traffic	Current Ferry Charges	Optimal Toll Loan I (r=0.03, n=40)	Optimal Toll Loan II (r=0.07, n=25)
Bus	40	5	25
Personal Car	40	5	15
Taxi	40	5	15
Heavy Truck	110	35	110
Light Truck	57	5	15
Motorcycle	5	5	5
Railway Passenger	5	5	5
Railway Freight, per ton	17	5	15
Present worth of required toll income		587,000,000	525,000,000
Present worth of total revenue from optimal tolls		607,000,000	527,000,000
Present worth of residual benefits		2,521,000,000	404,000,000

PLATE


To Luang Prabang
To Pa Nong dam site
VIENTIANE STATION
Vientiane Substation
MEKONG RIVER
VIENTIANE
PROJECTED RAILWAY
Total Length . 168 km
RAIL/HIGHWAY BRIDGE
Total Length · 1.5 km
BAN THA DEUA
BAN THA NALENG
MEKONG-RIVER
NONG KHAI
Asian Highway A-12
PROJECTED RAILWAY
Total Length . 12 km
NEW NONG KHAI STATION
PROJECTED HIGHWAY
Total Length · 5.8 km
AMPHOE THA BO
Nong Khai Substation
Asian Highway A-12
To Bangkok
LEGEND
Railway routes to be extended in later stages
Nam Ngum Project transmission line
SCALE
0
5
10 km
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN
NONG KHAI / VIENTIANE BRIDGE PROJECT
GENERAL MAP
NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)
DRAWN
CHECKED
SUBMITTED
APPROVED
DATE Sep. 8 , 1969
PLATE I



TO VIENTIANE
To Vientiane Substation
TO THA DEUA
LAOS
THAILAND
MEKONG
N
EXISTING FERRY FACILITY
EXISTING NONG KHAI STATION
PROJECTED RAILWAY
ASIAN HIGHWAY A-12
PROJECTED HIGHWAY
ADMINISTRATIVE FACILITIES
BRIDGE (Hy)
BRIDGE (Ry)
Bank protection
350,000 ADMINISTRATIVE FACILITIES
751,700 NONG KHAI RAILWAY STATION
1,581,700 PROJECTED RAILWAY
NAM NGUM PROJECT TRANSMISSION LINE
To Nong Khai Substation
SCALE
0 100 200 300 400 500M



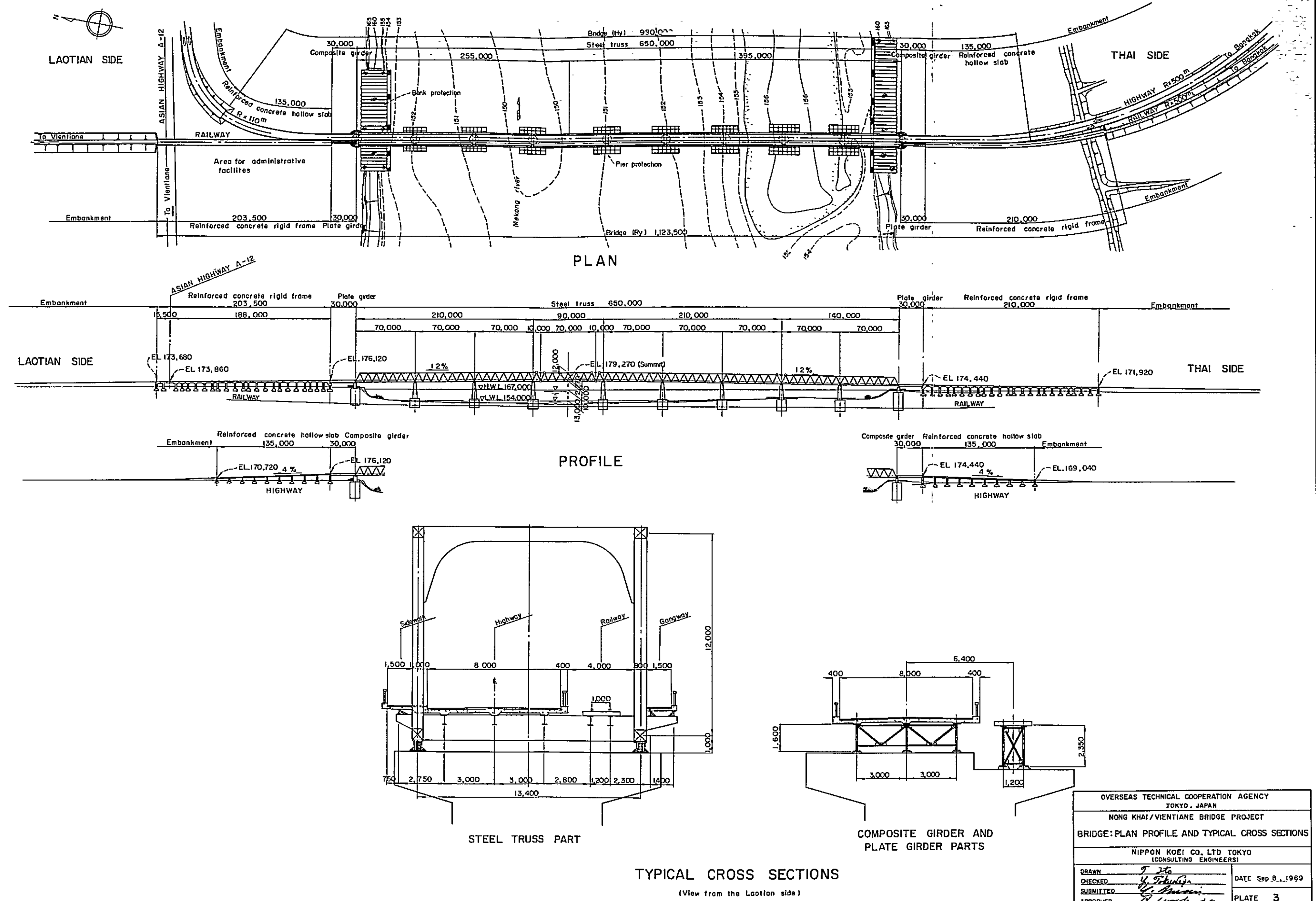
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

GENERAL LAYOUT

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN		DATE Sep. 8, 1969
CHECKED		
SUBMITTED		PLATE 2
APPROVED		



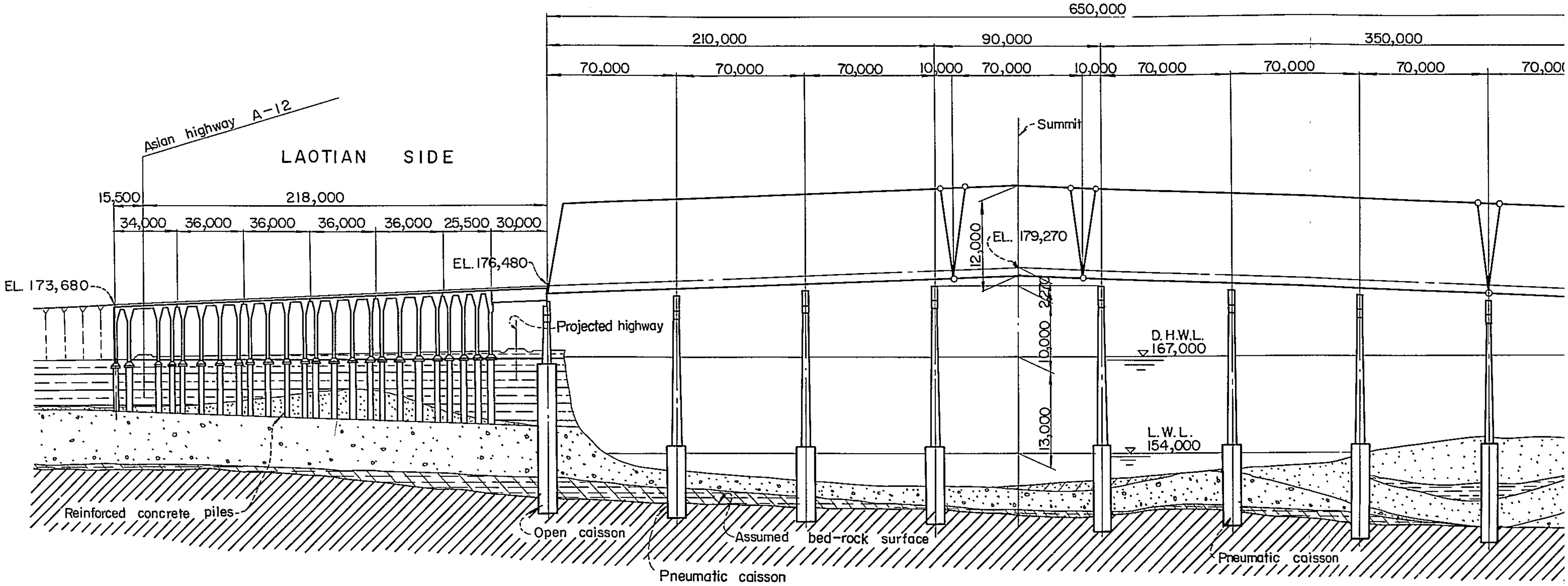
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

BRIDGE: PLAN PROFILE AND TYPICAL CROSS SECTIONS

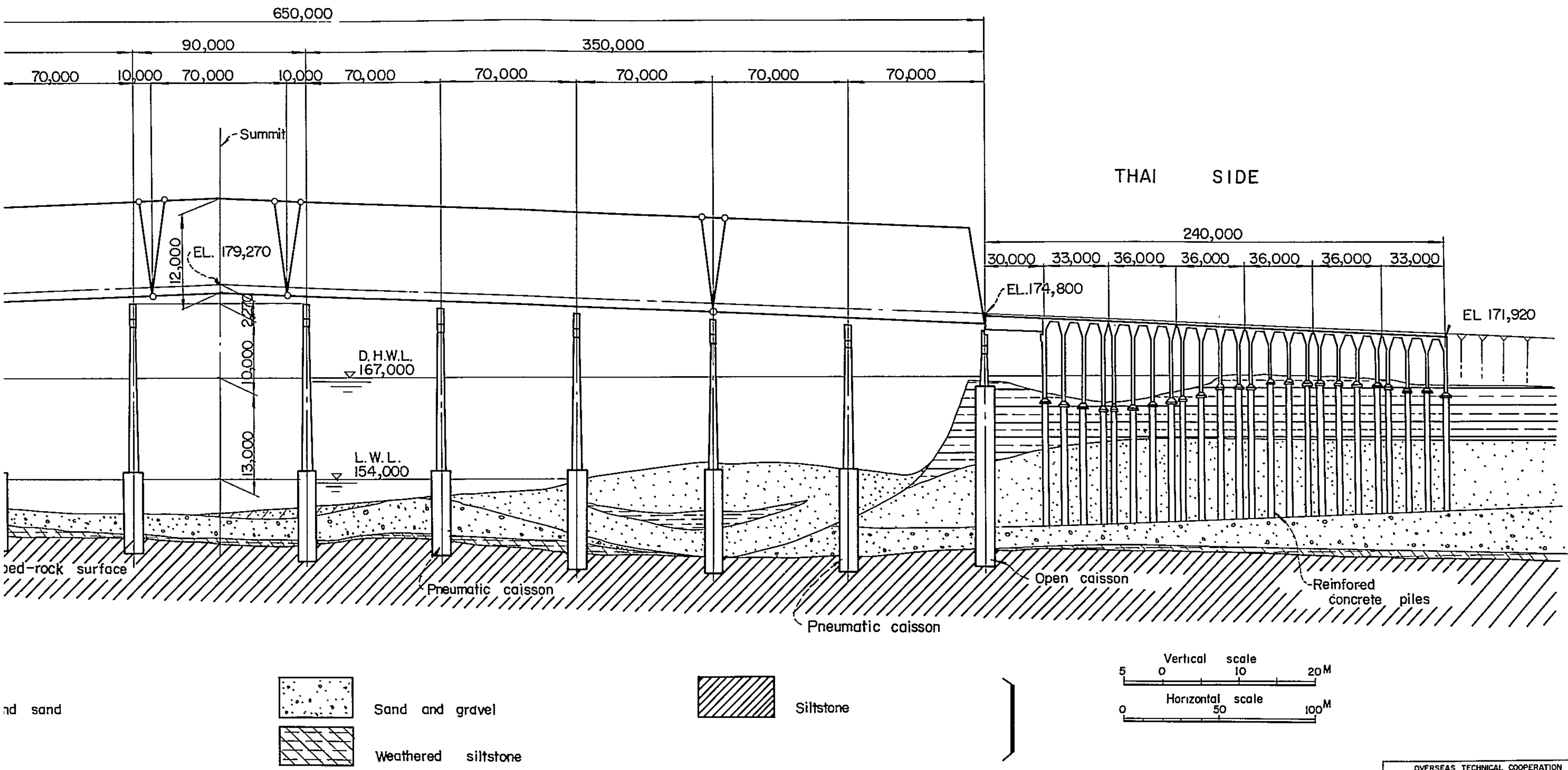
NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	DATE Sep 8, 1969
CHECKED	Y. Tokunaga	
SUBMITTED	[illegible]	PLATE 3
APPROVED	R. Yoshida	



LEGEND

- Loam, clay or silt and clay
- Silt
- Mud and sand
- Sand
- Sand and gravel
- Weathered siltstone



OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

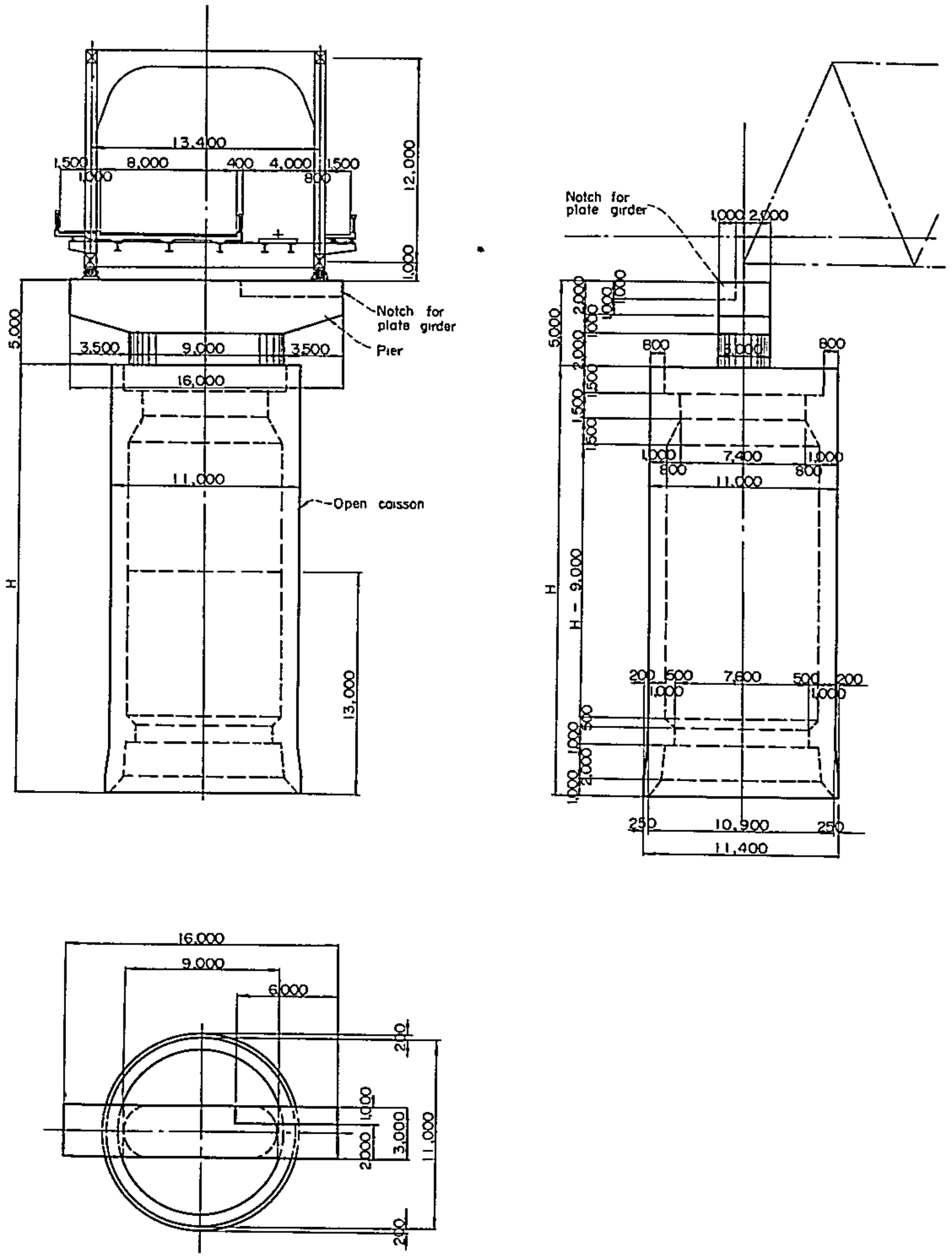
NONG KHAI / VIENTIANE BRIDGE PROJECT

BRIDGE : PROFILE

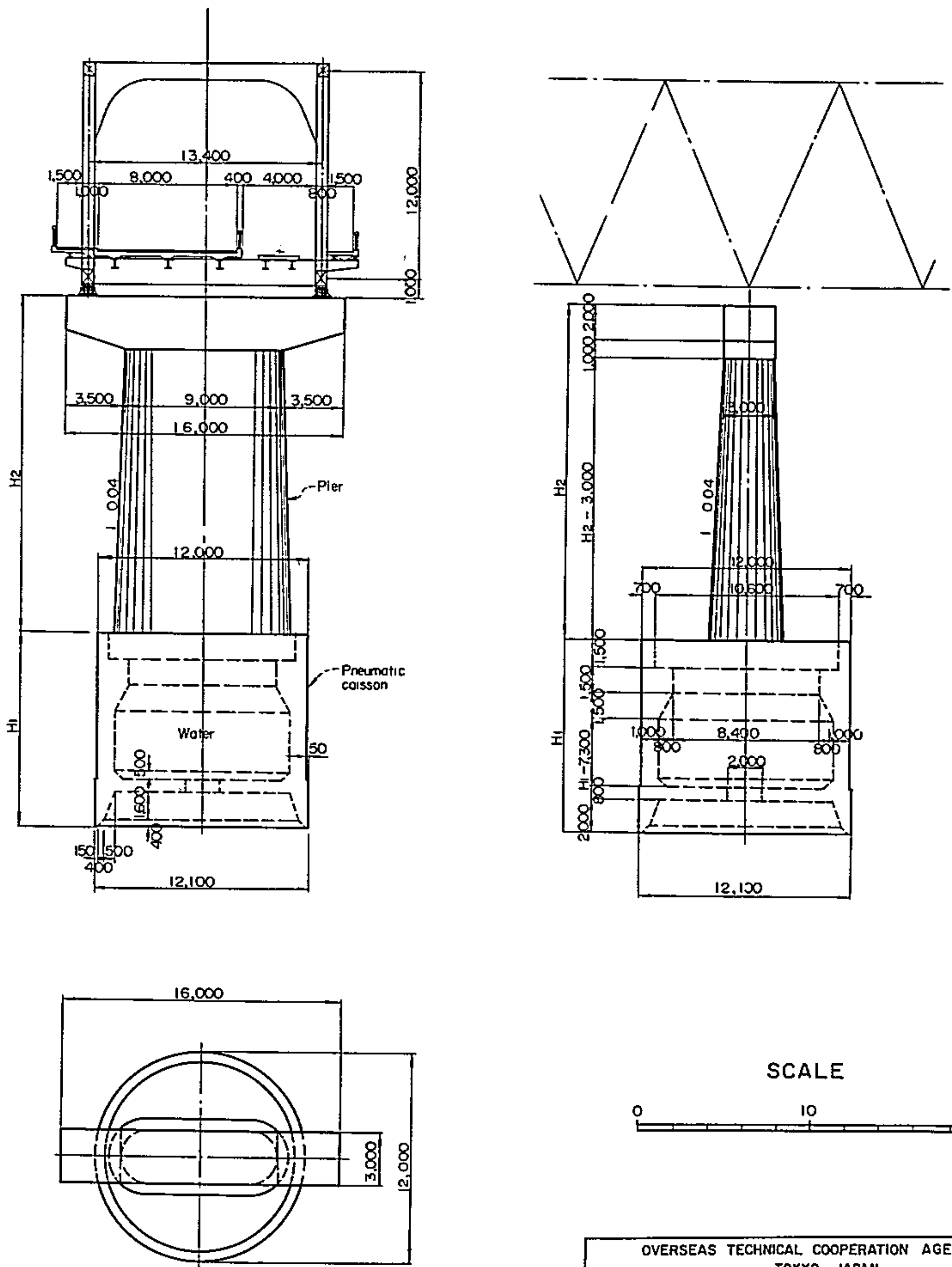
NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	DATE Sep. 8, 1969
CHECKED	Y. Tokudiga	
SUBMITTED	[illegible]	PLATE 4
APPROVED	[illegible]	

PIER AND OPEN CAISSON



PIER AND PNEUMATIC CAISSON



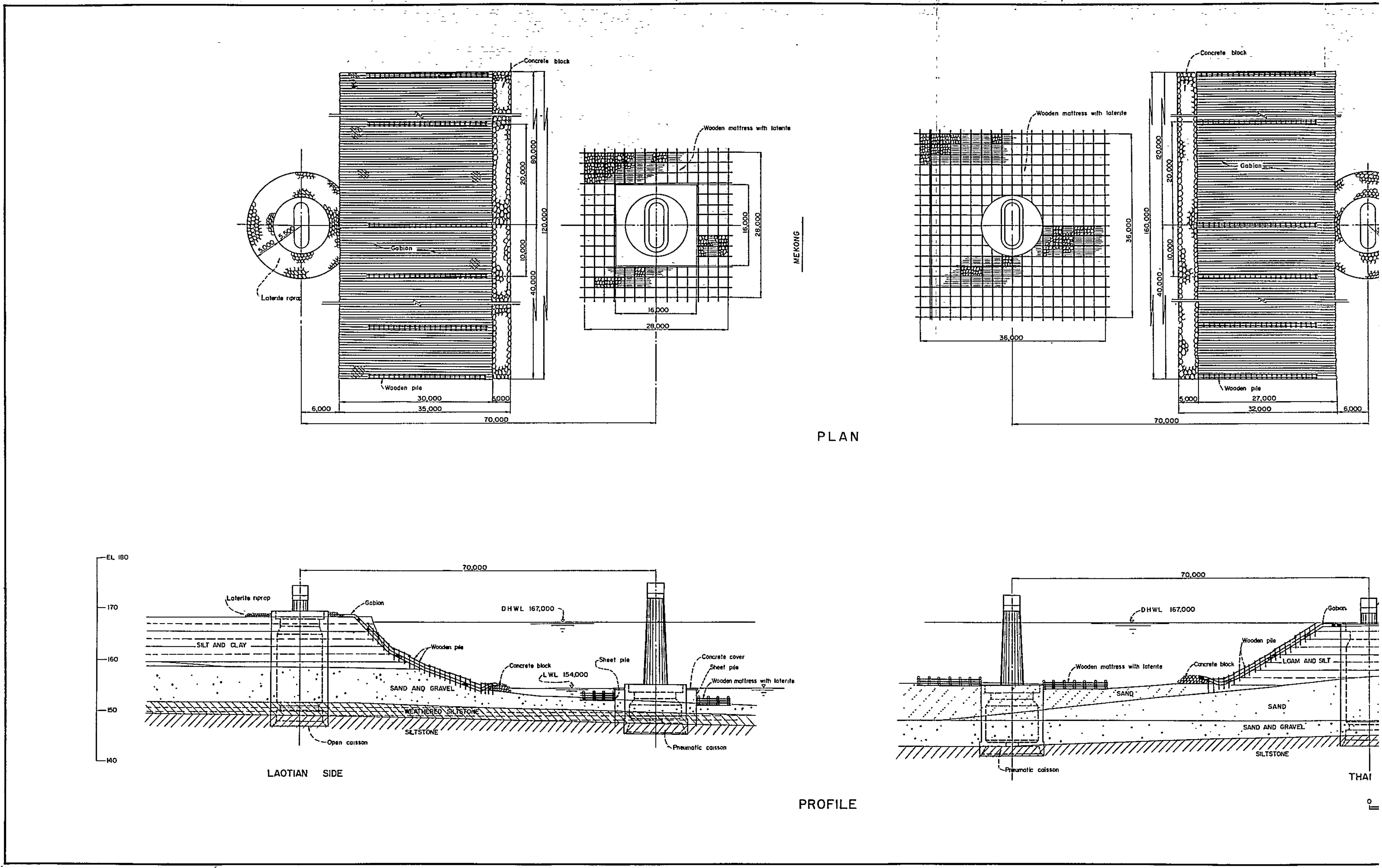
SCALE

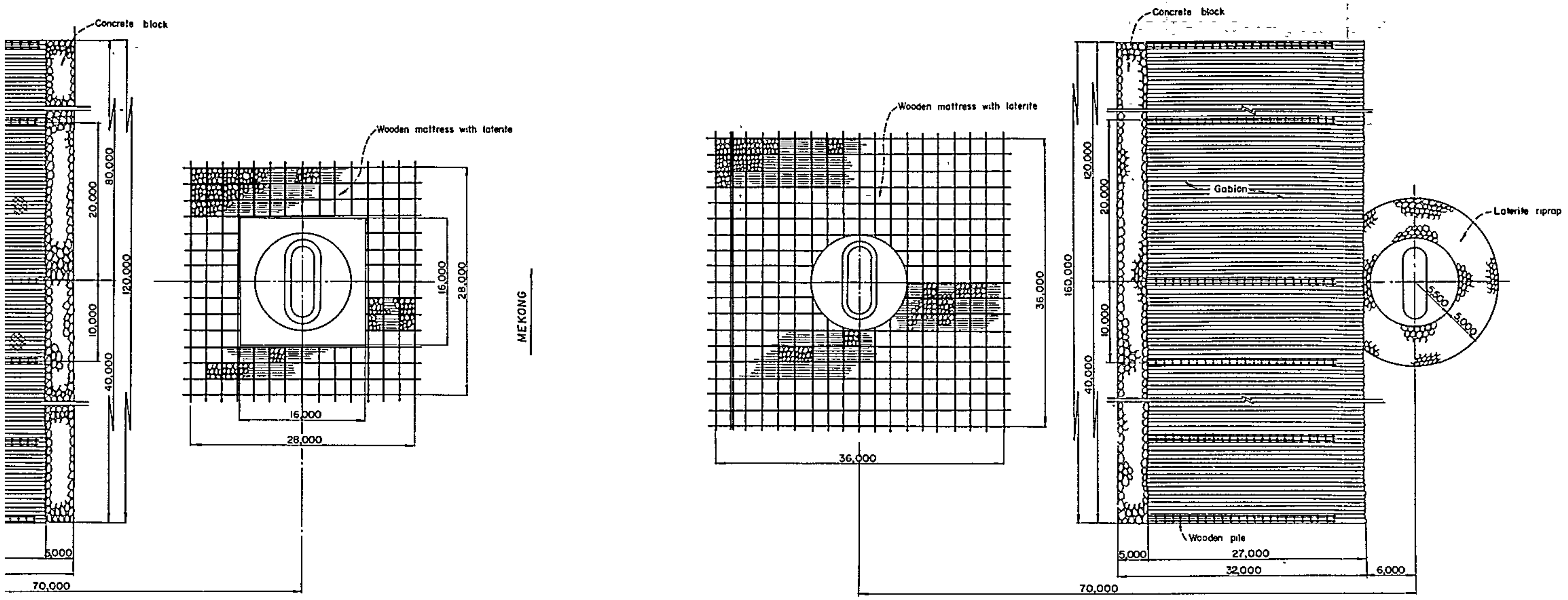
0 10 20m

Remarks

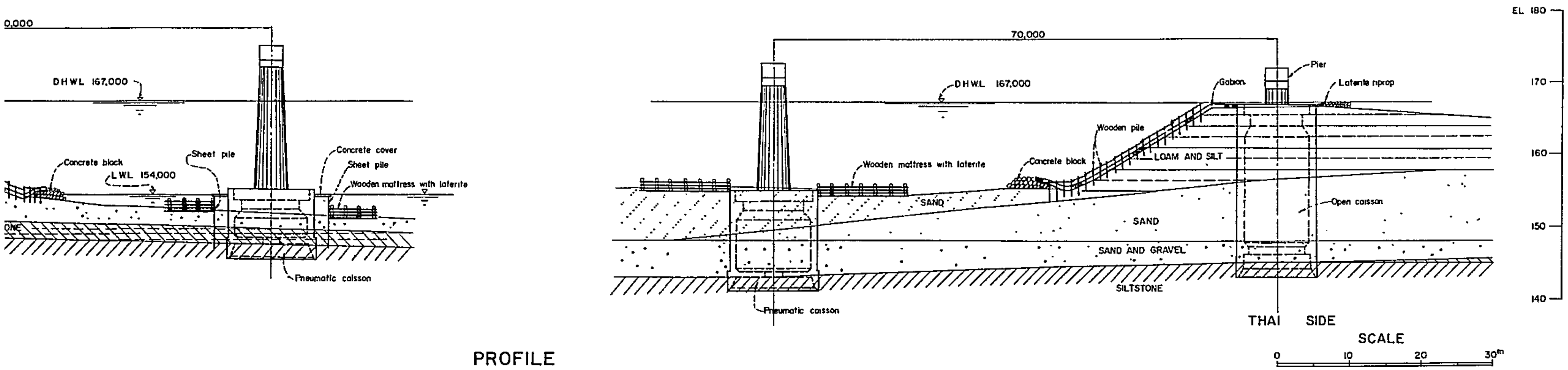
Both open and pneumatic caissons are planned to be founded on the firm siltstone layer, after excavation, at the depth of two meters from its top surface

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
BRIDGE : SUBSTRUCTURE	
NIPPON KOEI CO, LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito CHECKED Y. Tokunaga SUBMITTED APPROVED R. Yoshida	DATE Sep 8, 1969 PLATE 5


PLAN
Concrete block
Wooden mattress with laterite
Gabion
Laterite riprap
Wooden pile
MEKONG
5,000
5,500
20,000
80,000
120,000
10,000
40,000
16,000
28,000
36,000
160,000
30,000
5,000
6,000
35,000
70,000
27,000
32,000
PROFILE
EL 180
170
160
150
140
70,000
Laterite riprap
Gabion
DHWL 167,000
SILT AND CLAY
Wooden pile
Concrete block
LWL 154,000
Sheet pile
Concrete cover
Sheet pile
Wooden mattress with laterite
SAND AND GRAVEL
WEATHERED SILTSTONE
SILTSTONE
Open caisson
Pneumatic caisson
LAOTIAN SIDE
Wooden mattress with laterite
Concrete block
Wooden pile
LOAM AND SILT
SAND
SAND AND GRAVEL
SILTSTONE
Pneumatic caisson
THAI



PLAN



PROFILE

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI/VIENTIANE BRIDGE PROJECT

BRIDGE: PIER AND BANK PROTECTIONS

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	DATE Sep 8, 1969
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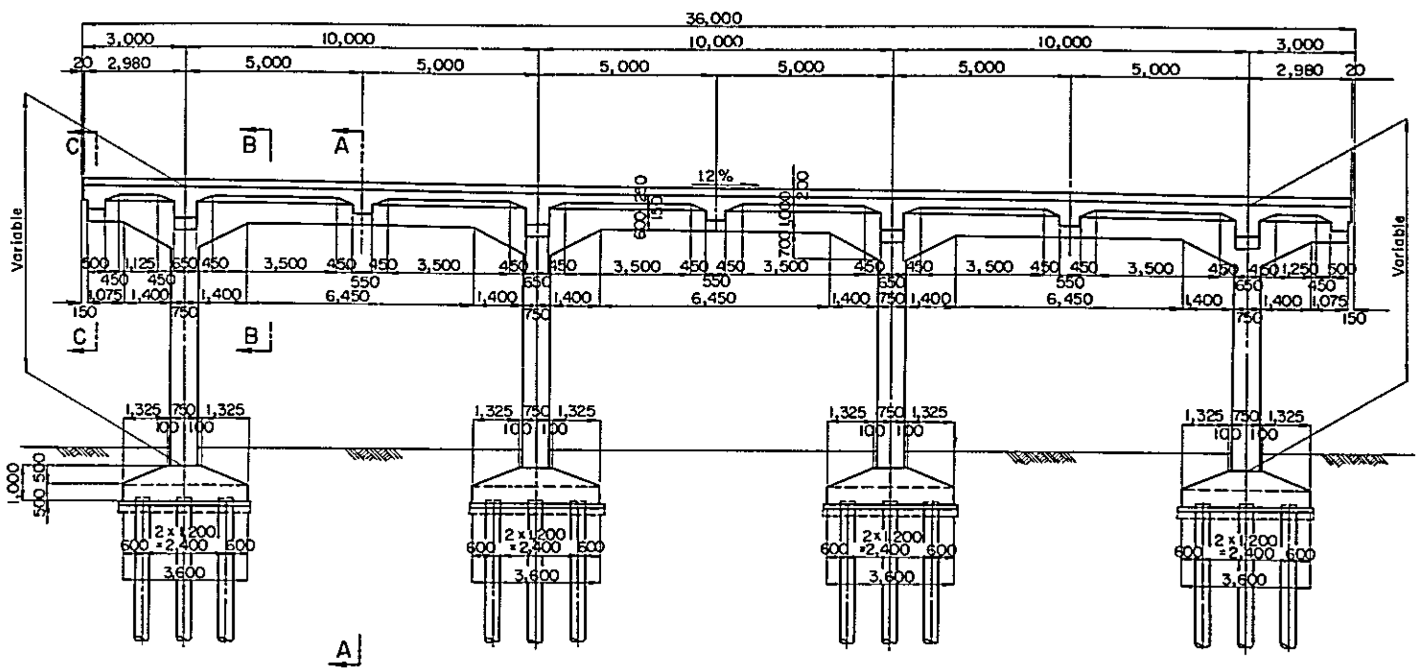
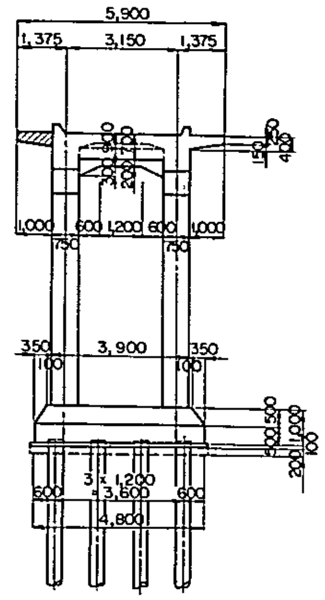
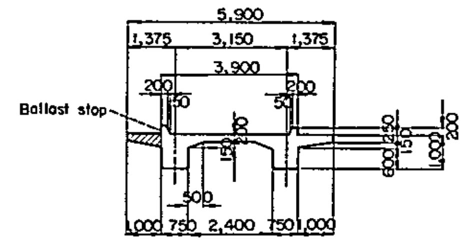
SUBMITTED	[illegible]	PLATE 6
APPROVED	[illegible]	



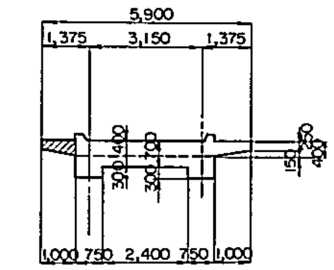
PROFILE (INTERMEDIATE PART)



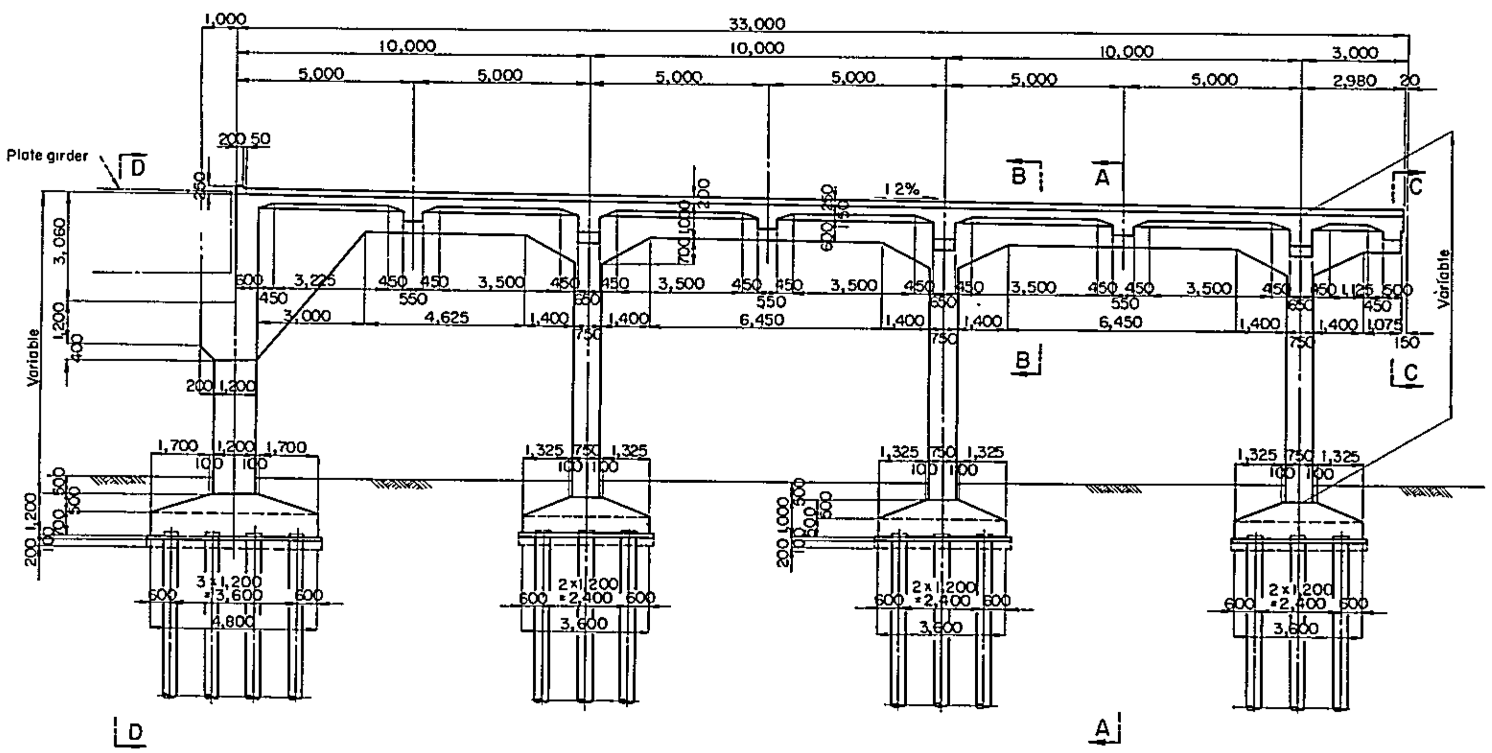
SECTION A – A



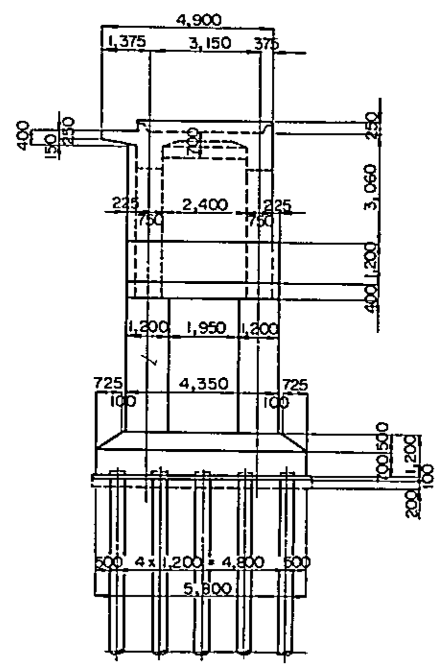
SECTION B – B



SECTION C – C



PROFILE (END PART)



SECTION D – D

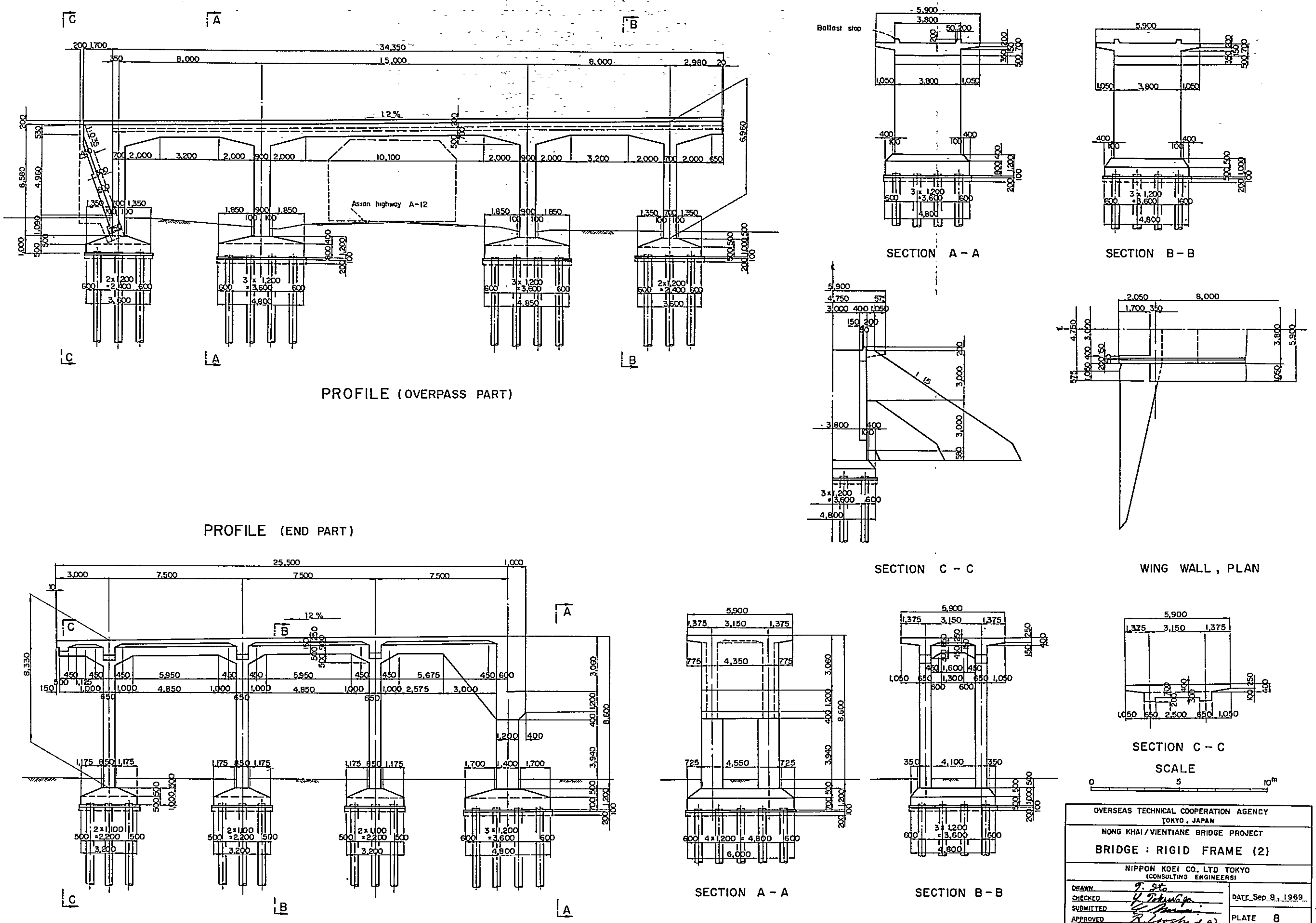
Remarks

The inspection gangway will not be provided in the end part on account of highway clearance limit.

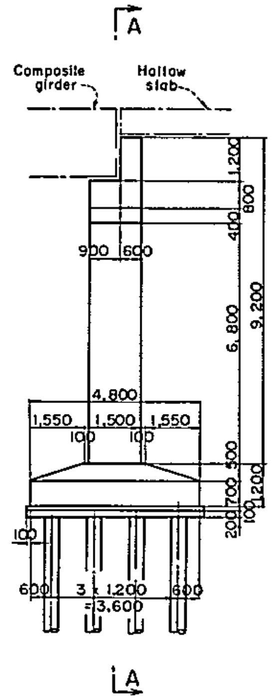
SCALE

0 5 10m

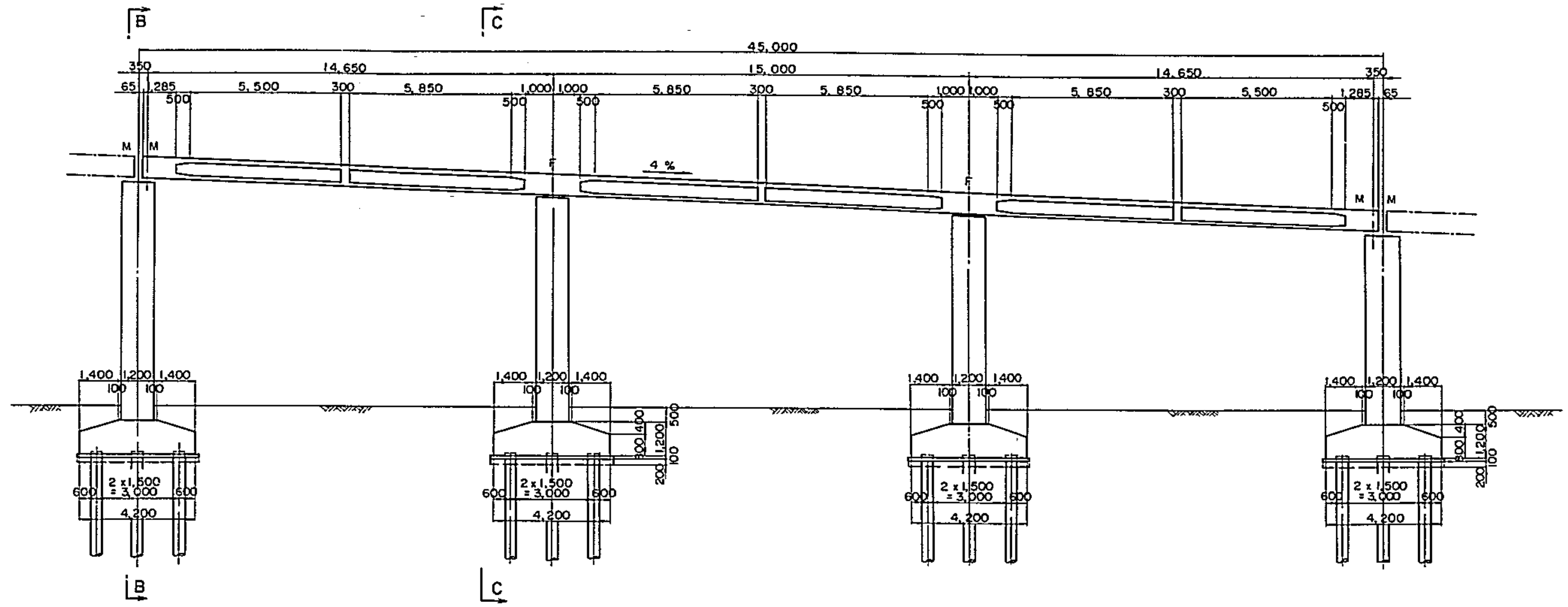
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
BRIDGE : RIGID FRAME (I)	
NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito CHECKED Y. Tokunaga SUBMITTED [illegible] APPROVED R. Yoshida	DATE Sep. 8, 1969 PLATE 7



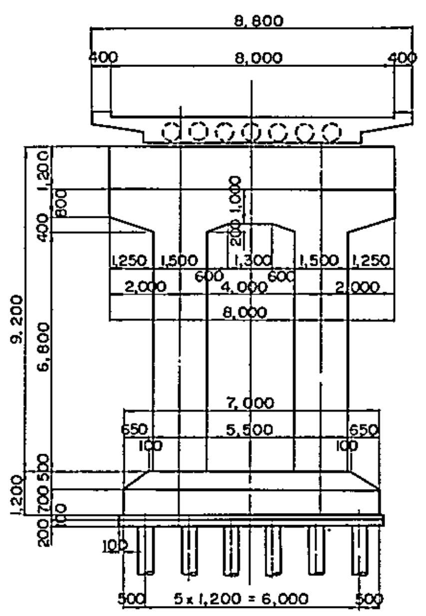
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
BRIDGE : RIGID FRAME (2)	
NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito CHECKED Y. Tokunaga SUBMITTED APPROVED R. Yoshida	DATE Sep 8, 1969
	PLATE 8



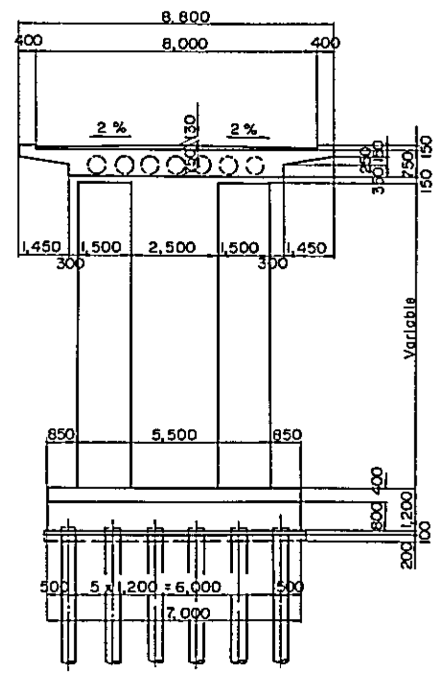
END PIER



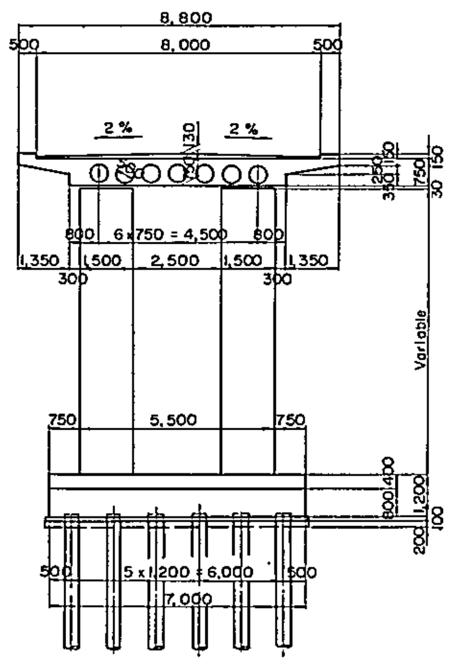
TYPICAL PROFILE



SECTION A - A

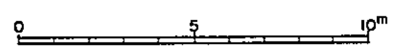


SECTION B - B

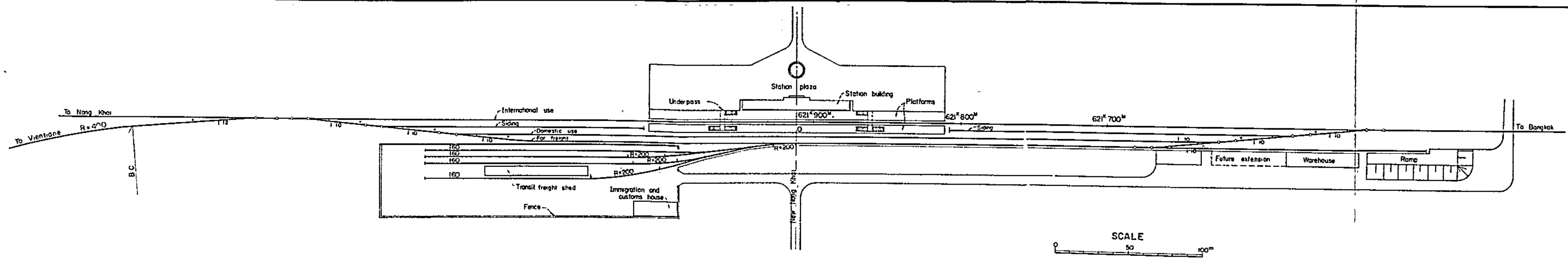


SECTION C - C

SCALE

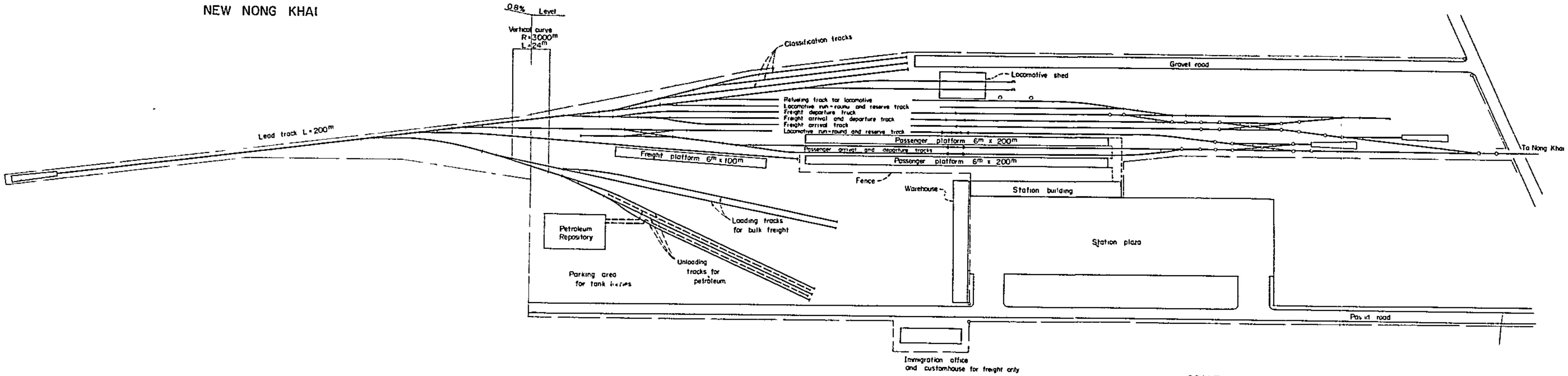


OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
BRIDGE : HOLLOW SLAB	
NIPPON KOEI CO, LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito CHECKED Y. Tokunaga SUBMITTED [signature] APPROVED R. Yoshida	DATE Sep 8, 1969 PLATE 9



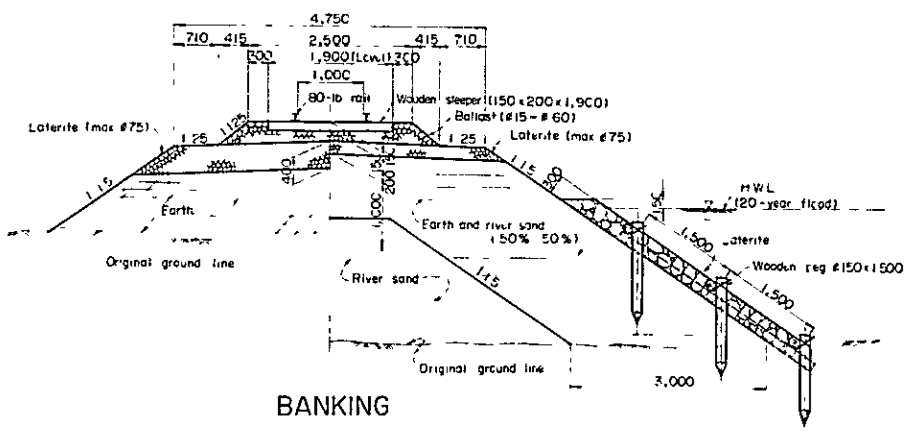
SCALE 0 50 100m

LAYOUT OF NEW NONG KHAI STATION



LAYOUT OF VIENTIANE STATION

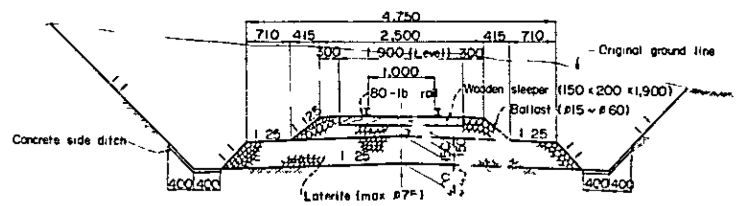
SCALE 0 50 100m



BANKING

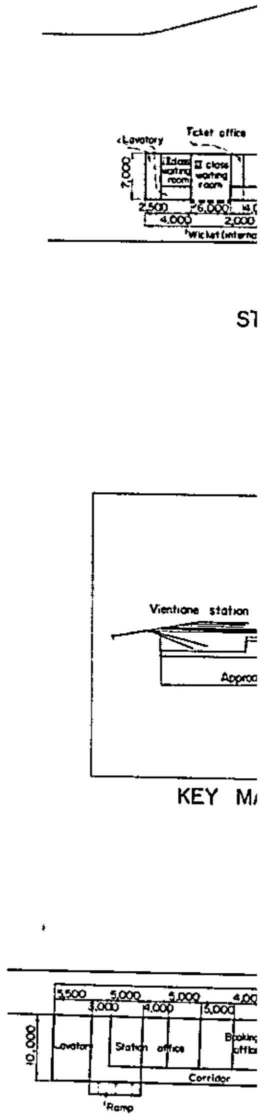
Remarks
The embankment shall be so compacted as to obtain more than ten percent of the value of CBR

SCALE 0 1 2 3m



CUTTING

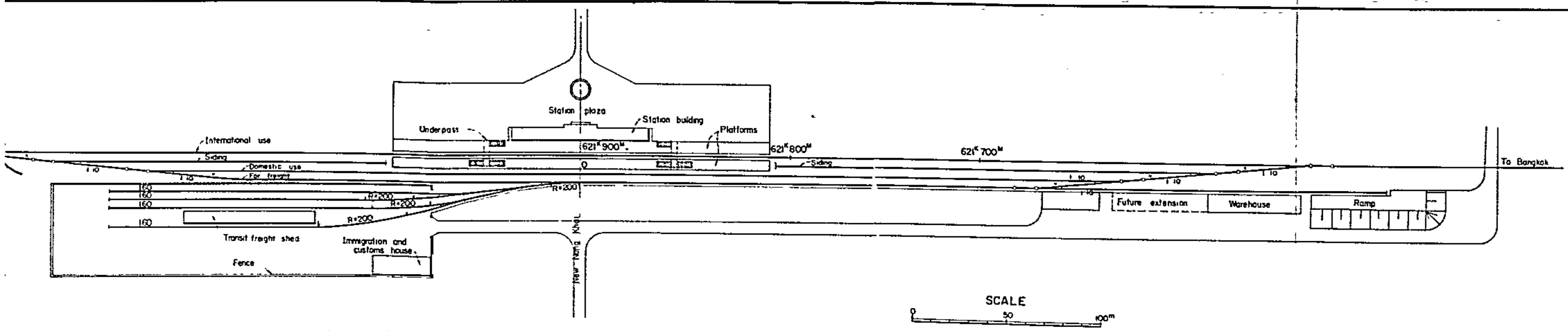
TYPICAL CROSS SECTIONS OF RAILWAY



KEY M

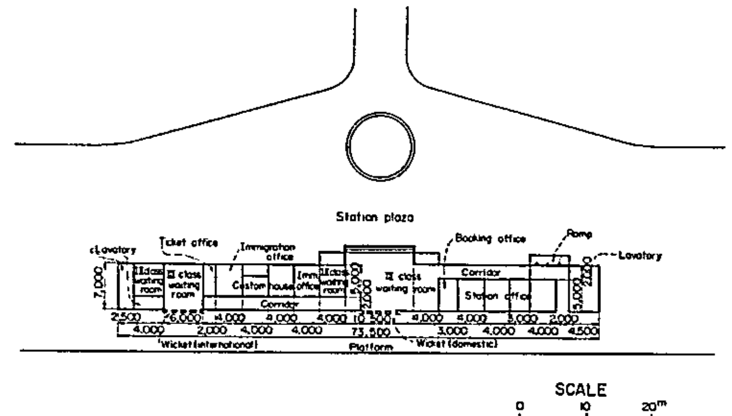
STAT

RA



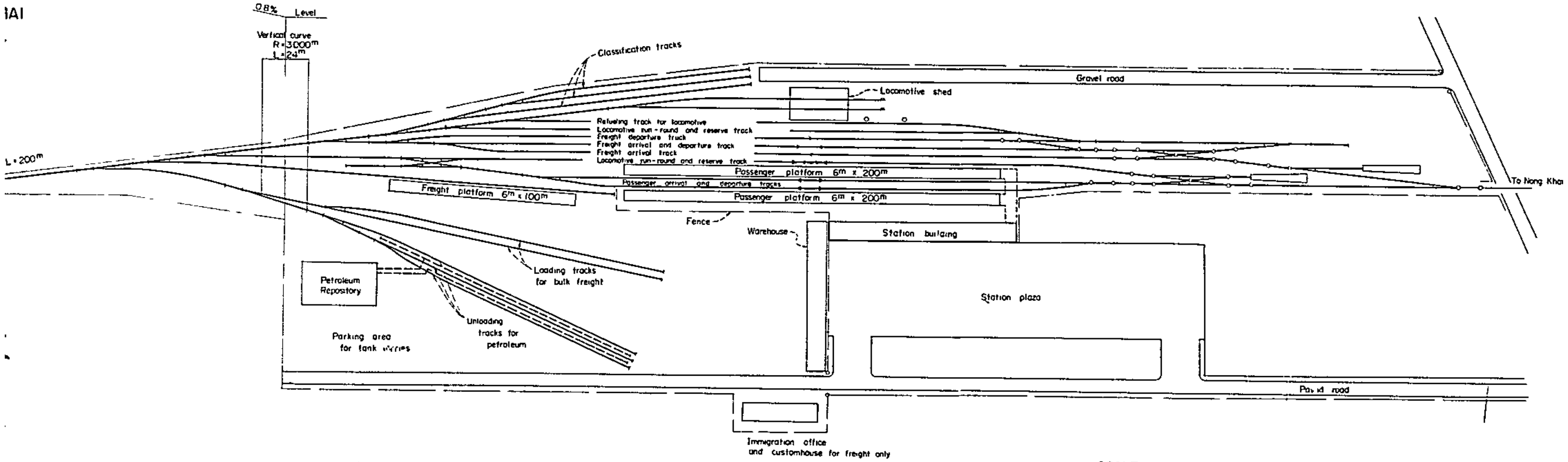
SCALE 0 50 100m

LAYOUT OF NEW NONG KHAI STATION



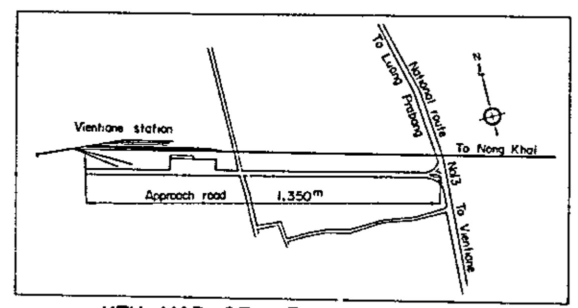
STATION BUILDING

SCALE 0 10 20m

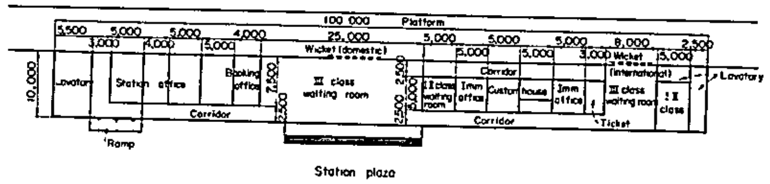


LAYOUT OF VIENTIANE STATION

SCALE 0 50 100m

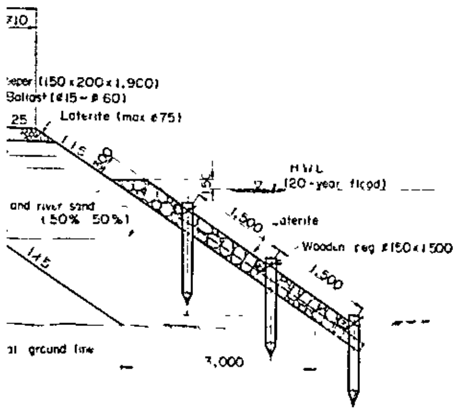


KEY MAP OF VIENTIANE STATION



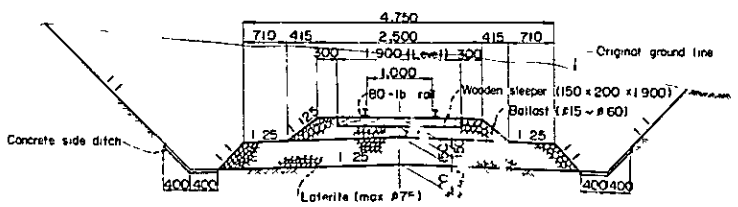
STATION BUILDING

SCALE 0 10 20m



Remarks
The embankment shall be so compacted as to obtain more than ten percent of the value of CBR

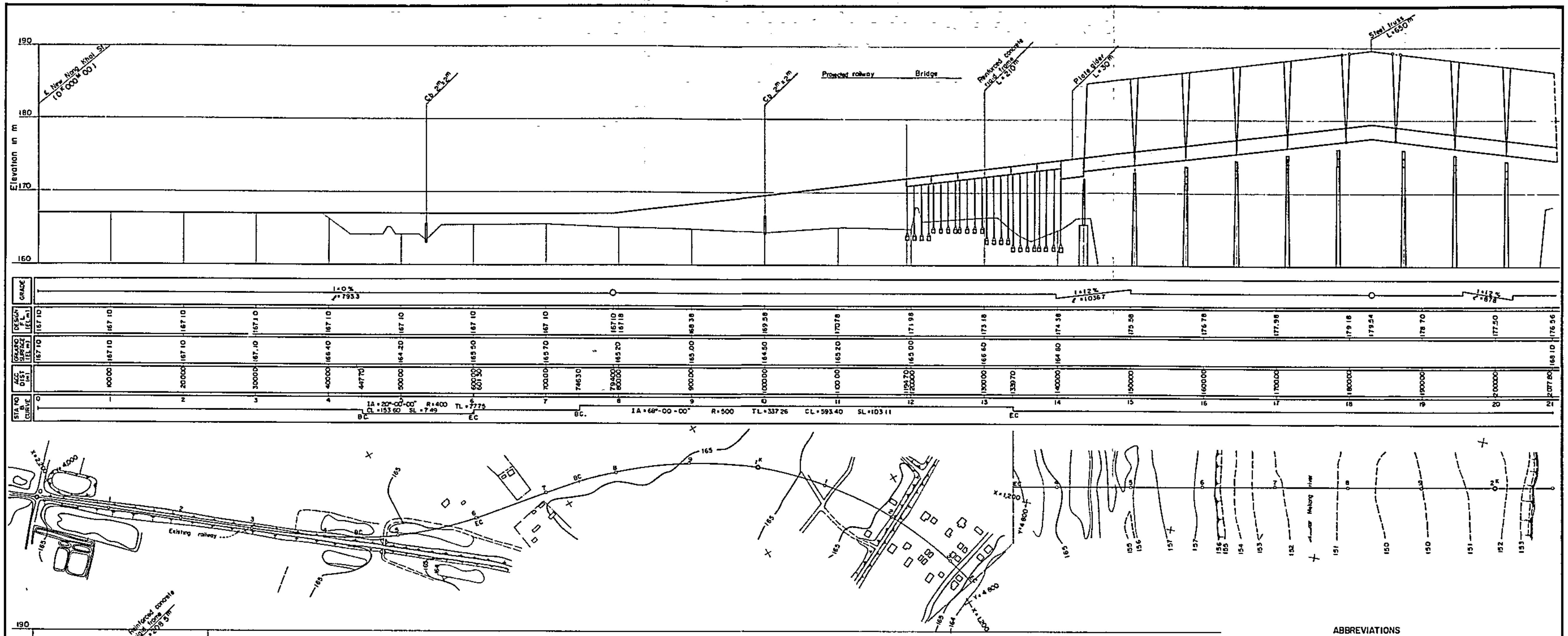
SCALE 0 1 2 3m

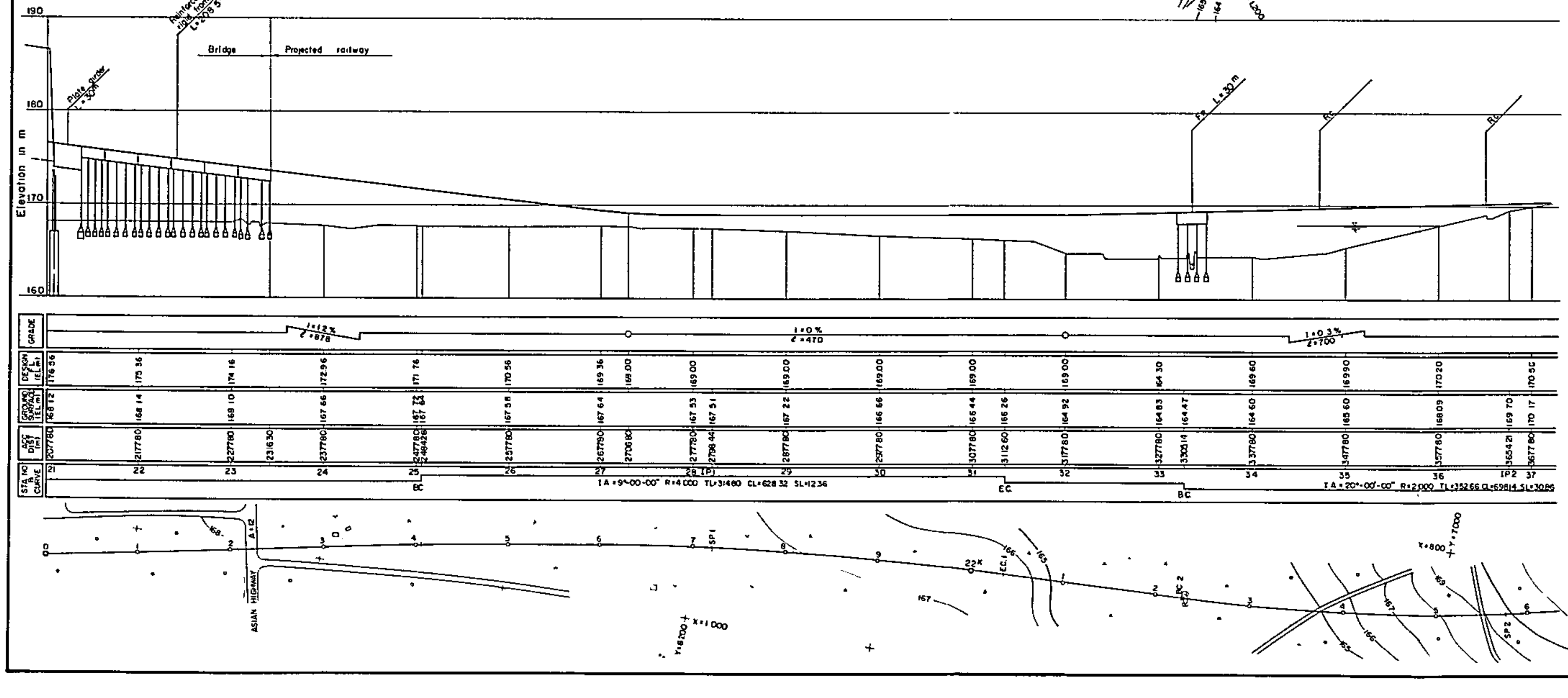


CUTTING

TYPICAL CROSS SECTIONS OF RAILWAY

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT	
RAILWAY : STATIONS AND TYPICAL CROSS SECTIONS	
NIPPON KOEI CO. LTD. TOKYO (CONSULTING ENGINEERS)	
DRAWN	DATE Sep 8 , 1969
CHECKED Y. Tokunaga	
SUBMITTED	PLATE 10
APPROVED	





ABBREVIATIONS

FR	Flood bridge, rigid frame type
FT	Flood bridge, T-beam type
FS	Flood bridge, slab type
O	Overpass
Bs	Bridge, slab type
B1	Bridge, T-beam type
Cs	Culvert, slab type
Cb	Culvert, box type
Rc	Road crossing

SCALE

0 50 100 150 200M

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI/VIENTIANE BRIDGE PROJECT

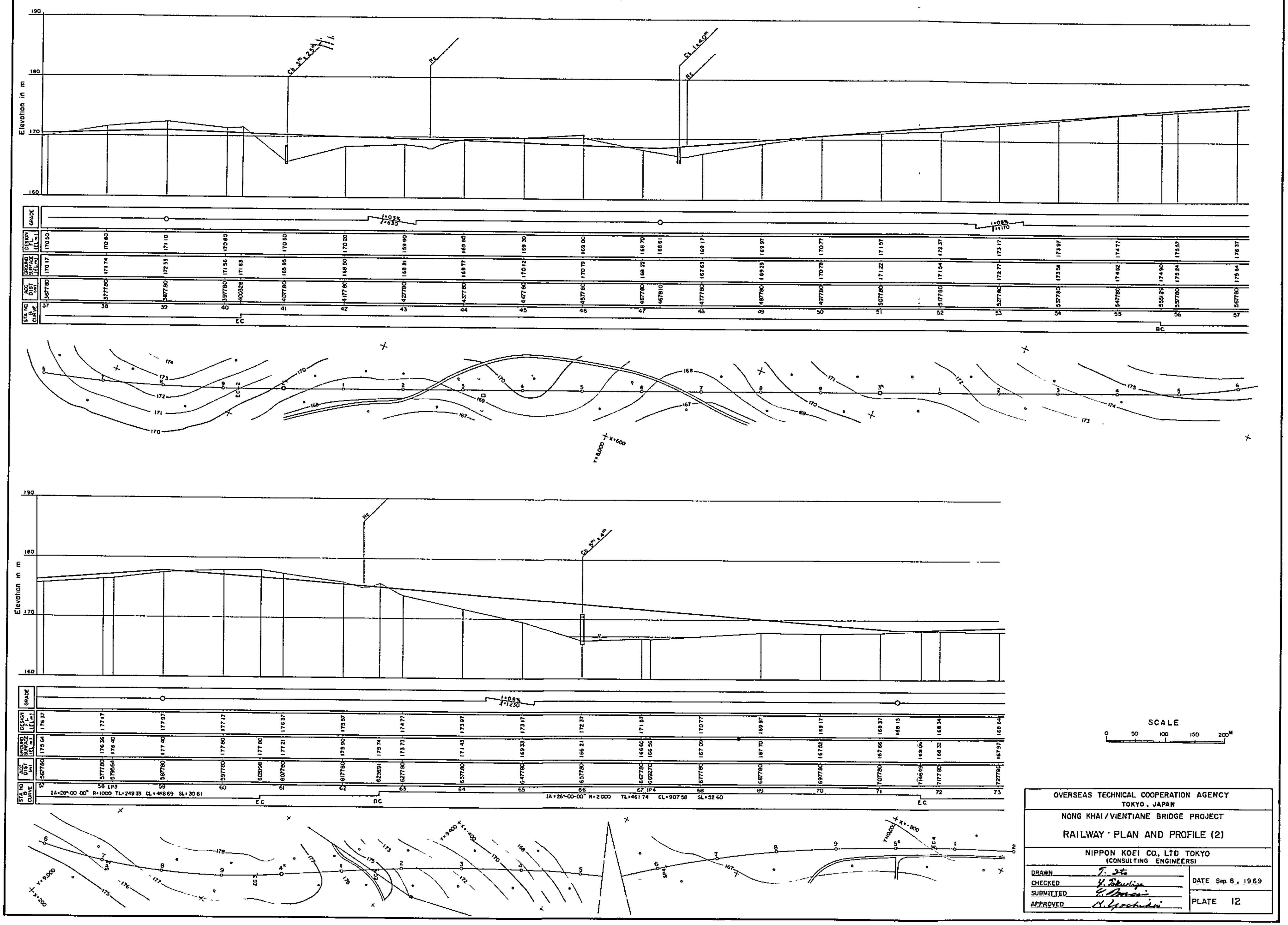
RAILWAY : PLAN AND PROFILE (1)

NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

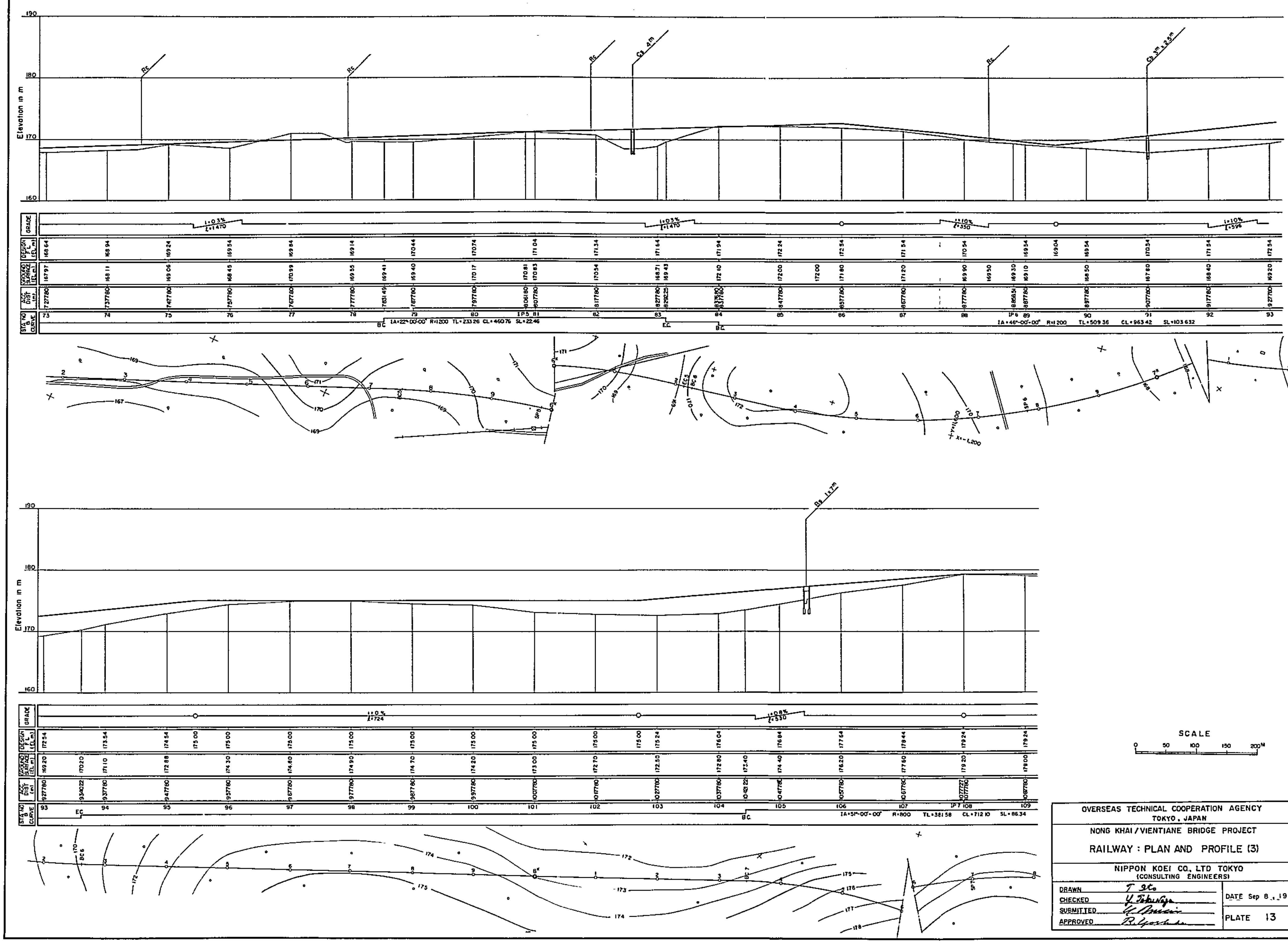
DRAWN T. Ito
CHECKED Y. Tokunaga
SUBMITTED
APPROVED

DATE Sep. 8, 1969

PLATE 11



OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE BRIDGE PROJECT RAILWAY · PLAN AND PROFILE (2)	
NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito	DATE Sep. 8, 1969
CHECKED Y. Tokushiga	
SUBMITTED E. Borai	PLATE 12
APPROVED K. Yoshida	



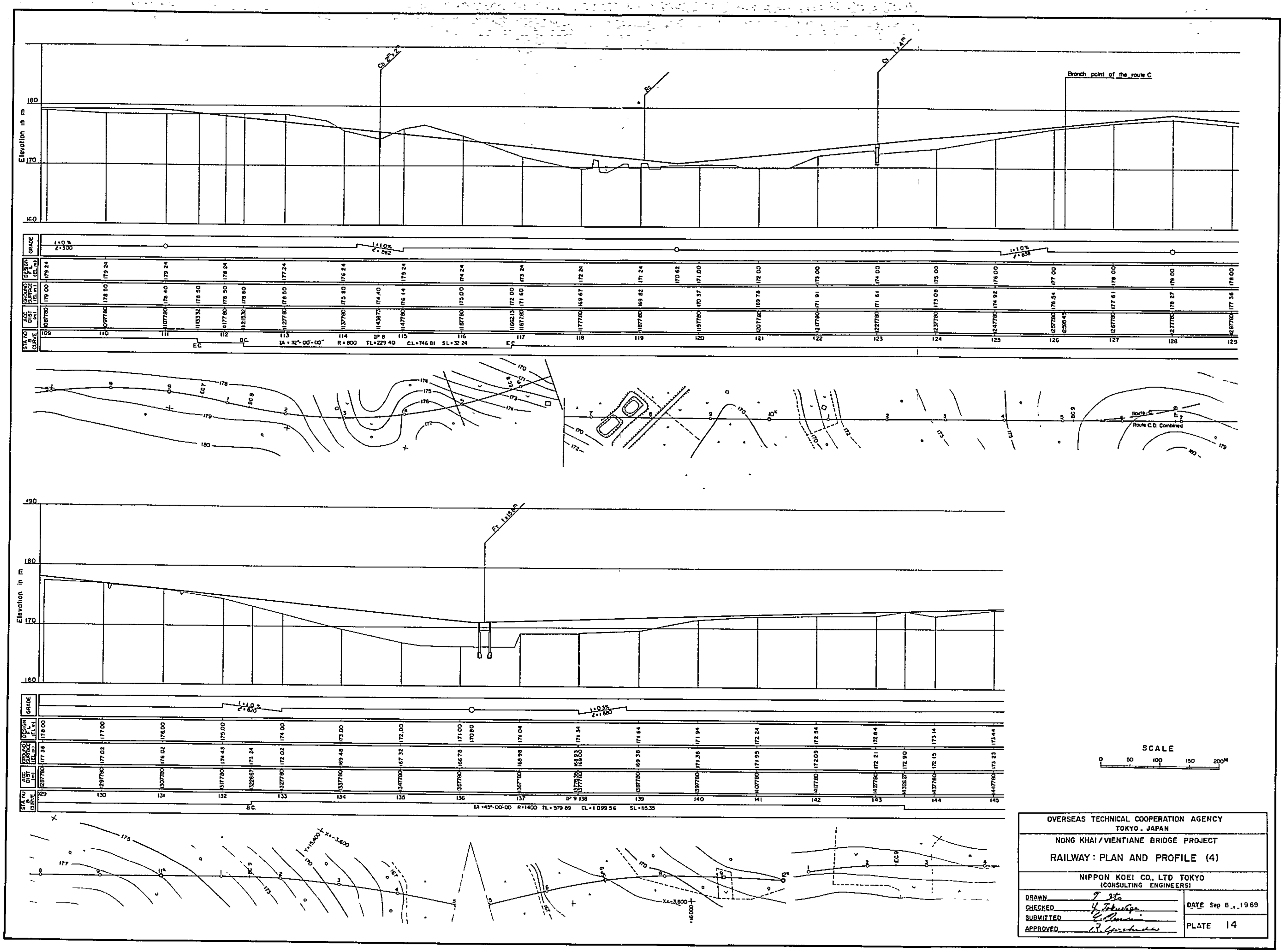
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

RAILWAY : PLAN AND PROFILE (3)

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	DATE Sep 8, 1969
CHECKED	Y. Tokunaga	
SUBMITTED	[illegible]	PLATE 13
APPROVED	[illegible]	



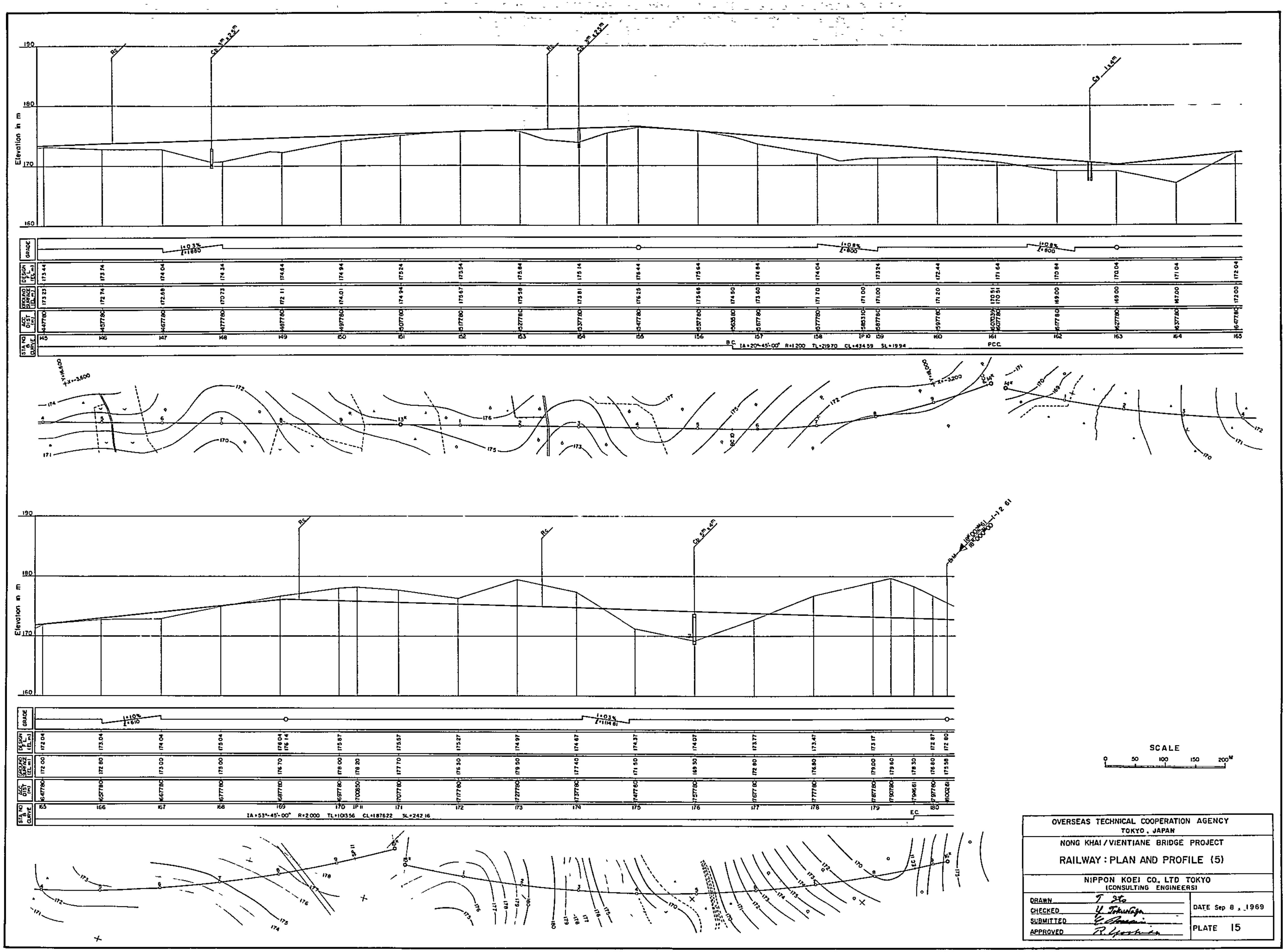
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

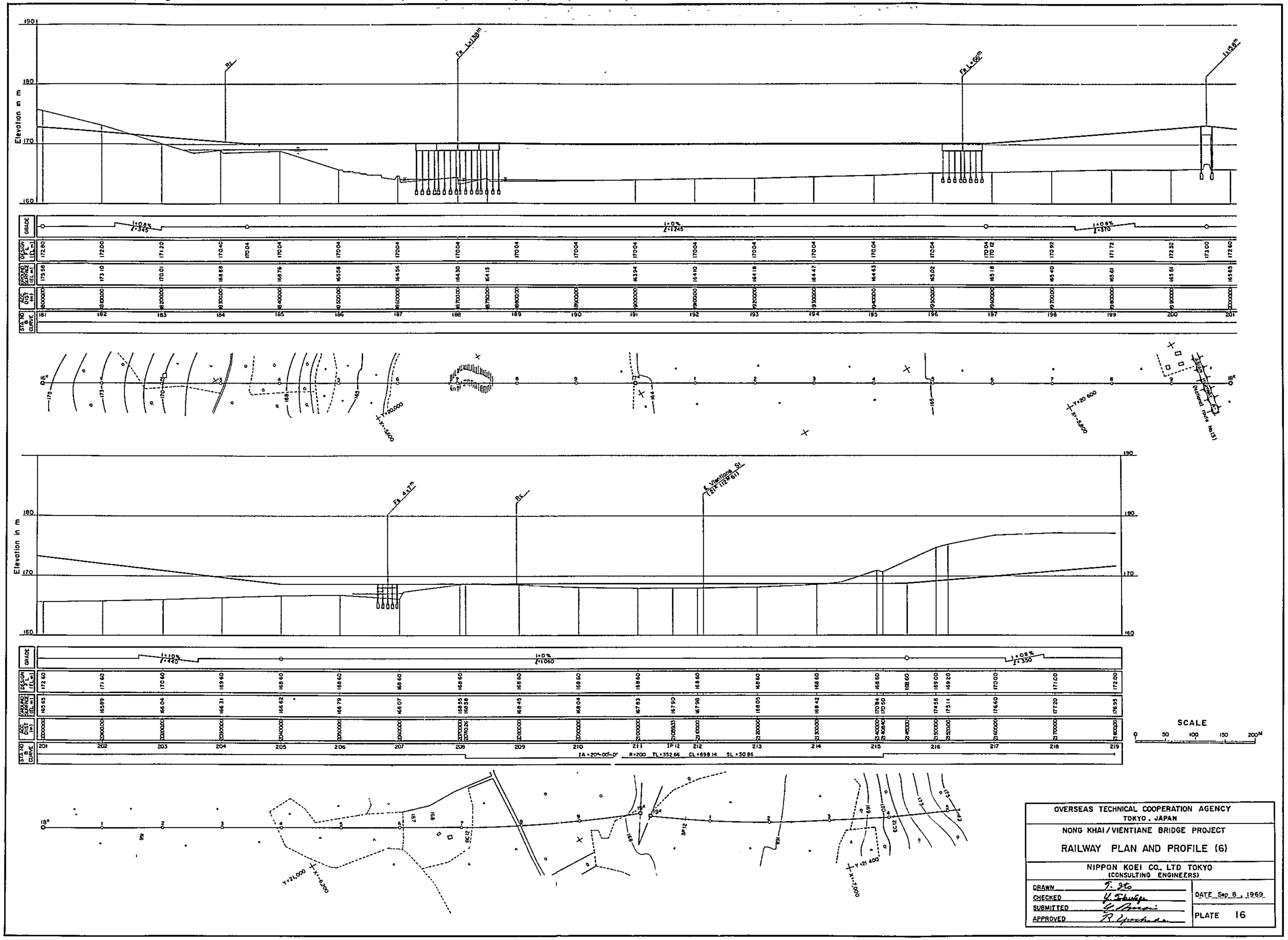
NONG KHAI / VIENTIANE BRIDGE PROJECT

RAILWAY : PLAN AND PROFILE (4)

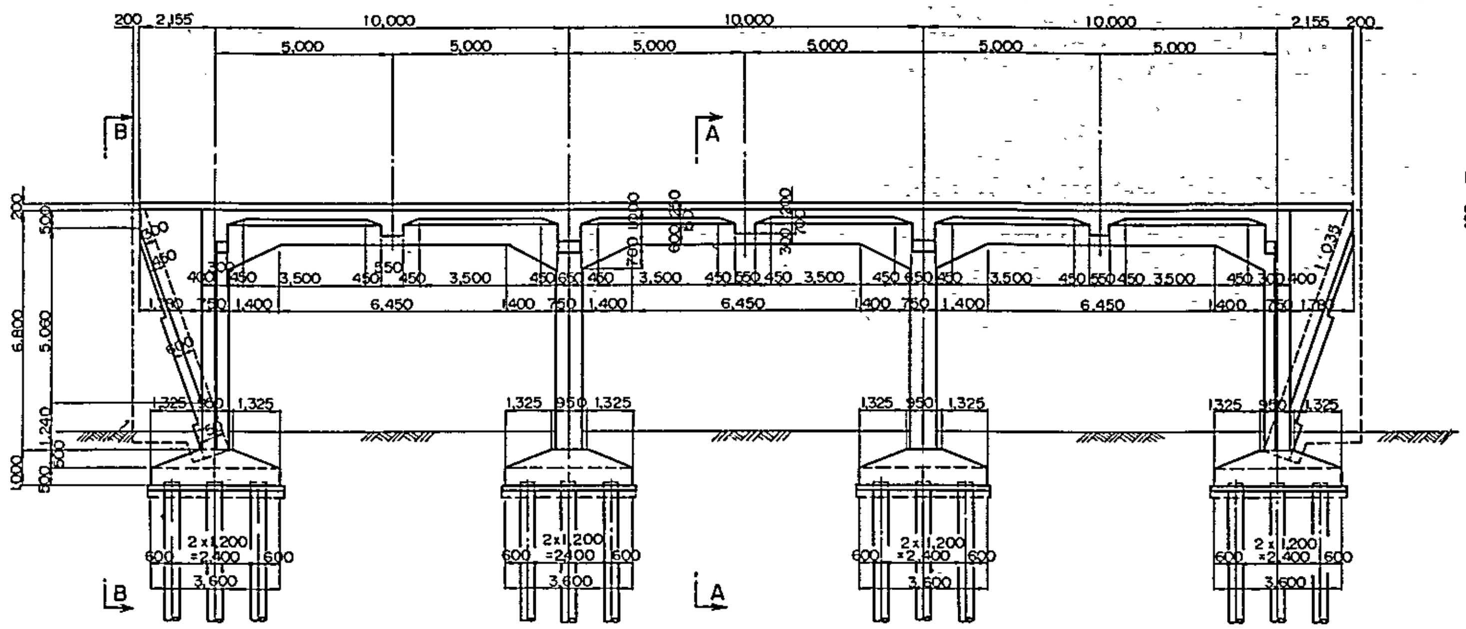
NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	DATE Sep 8., 1969
CHECKED	Y. Tokunaga	
SUBMITTED		PLATE 14
APPROVED		


Elevation in m
GRADE
DESIGN EL (EL m)
GROUND SURFACE (EL m)
ACC. DIST (m)
STA NO & CURVE
IA=20°-45'-00" R=1,200 TL=219.70 CL=434.59 SL=199.4
IA=53°-45'-00" R=2,000 TL=1013.56 CL=1876.22 SL=242.16
SCALE
0 50 100 150 200M
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN
NONG KHAI / VIENTIANE BRIDGE PROJECT
RAILWAY : PLAN AND PROFILE (5)
NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)
DRAWN
CHECKED
SUBMITTED
APPROVED
DATE Sep 8, 1969
PLATE 15

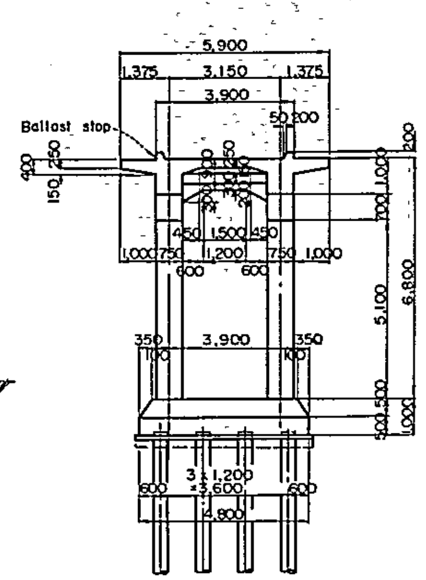


Elevation in m
GRADE
DESIGN F.L. (EL m)
GROUND SURFACE (EL m)
ACC. DIST. (m)
STA. NO. & CURVE
SCALE
0 50 100 150 200M
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN
NONG KHAI/VIENTIANE BRIDGE PROJECT
RAILWAY PLAN AND PROFILE (6)
NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)
DRAWN
CHECKED
SUBMITTED
APPROVED
DATE Sep 8, 1969
PLATE 16

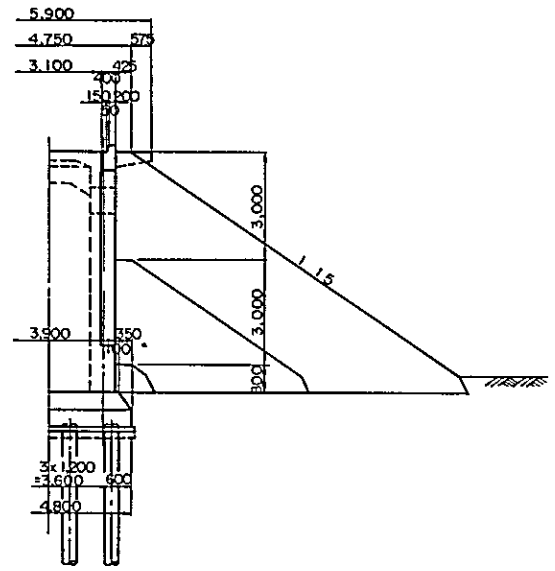


PROFILE

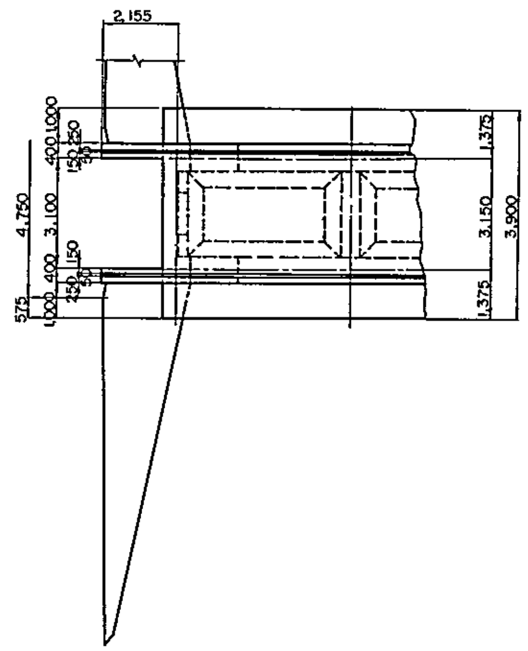
RIGID-FRAME TYPE



SECTION A-A



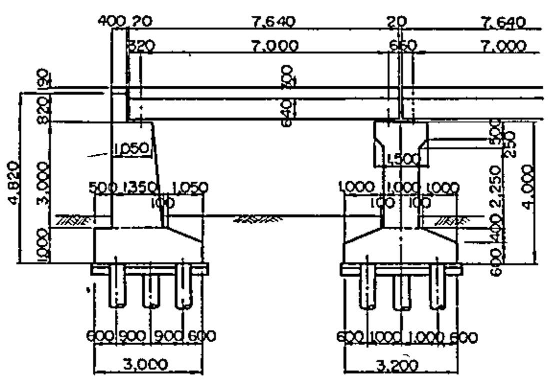
SECTION B - B



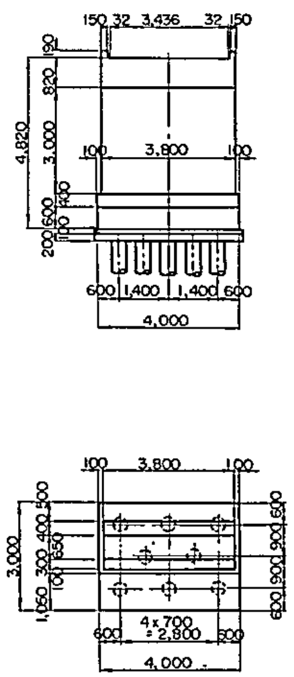
WING WALL, PLAN

SCALE

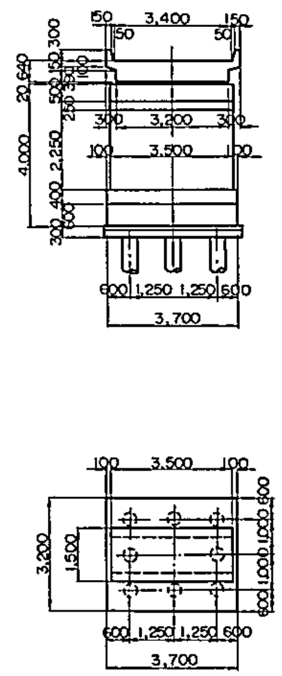
0 5 10m



PROFILE



ABUTMENT



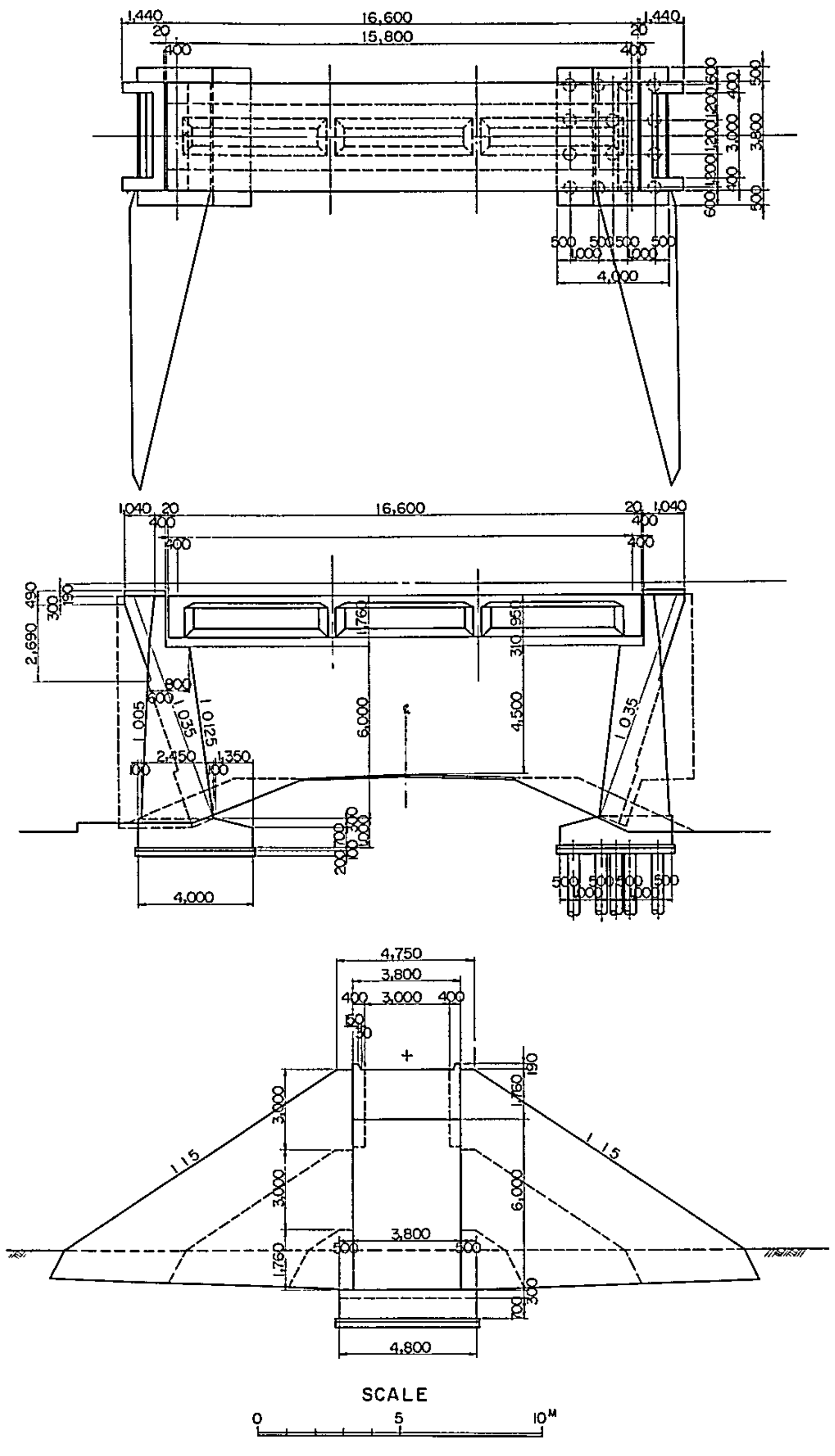
PIER

SLAB TYPE

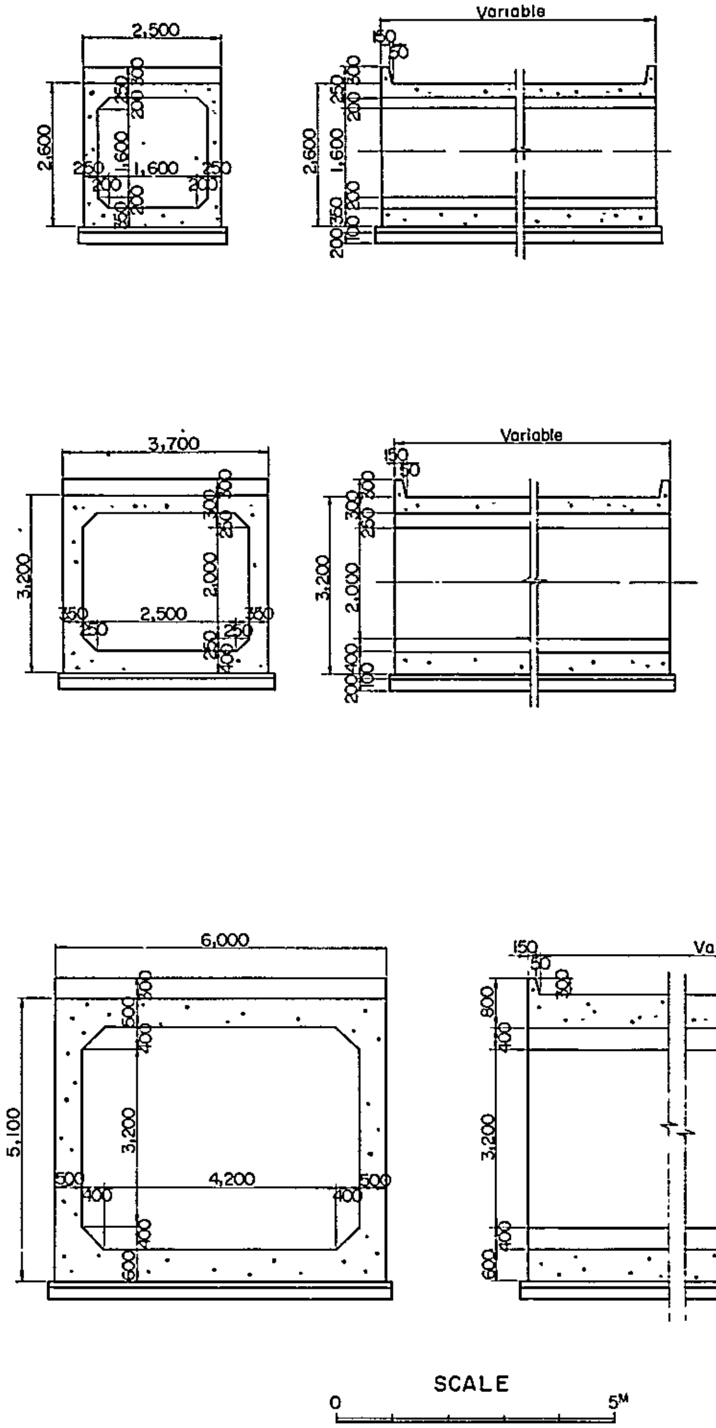
Remarks

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 7 will be applied to the flood bridge making level the longitudinal slope instead of 12%

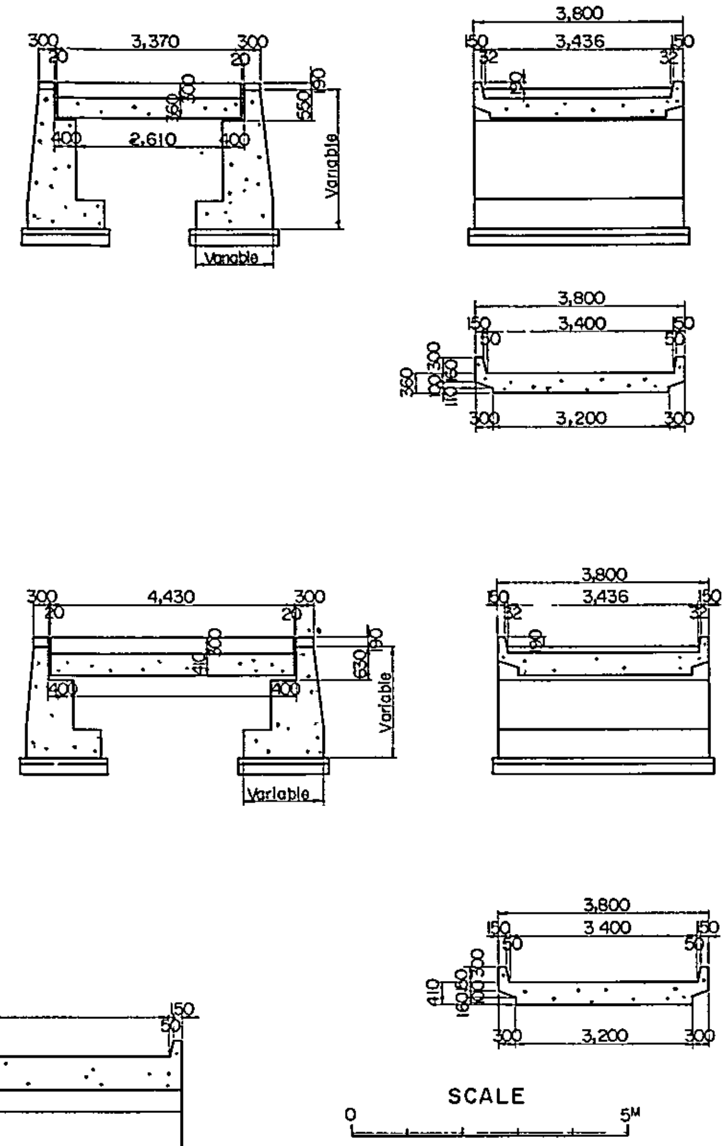
OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI/VIENTIANE BRIDGE PROJECT	
RAILWAY : FLOOD BRIDGES	
NIPPON KOEI CO., LTD., TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito CHECKED Y. Takeuchi SUBMITTED [signature] APPROVED R. Yoshida	DATE Sep 8, 1969 PLATE 17



OVERPASS



BOX TYPE CULVERTS (STANDARD)



SLAB TYPE CULVERTS

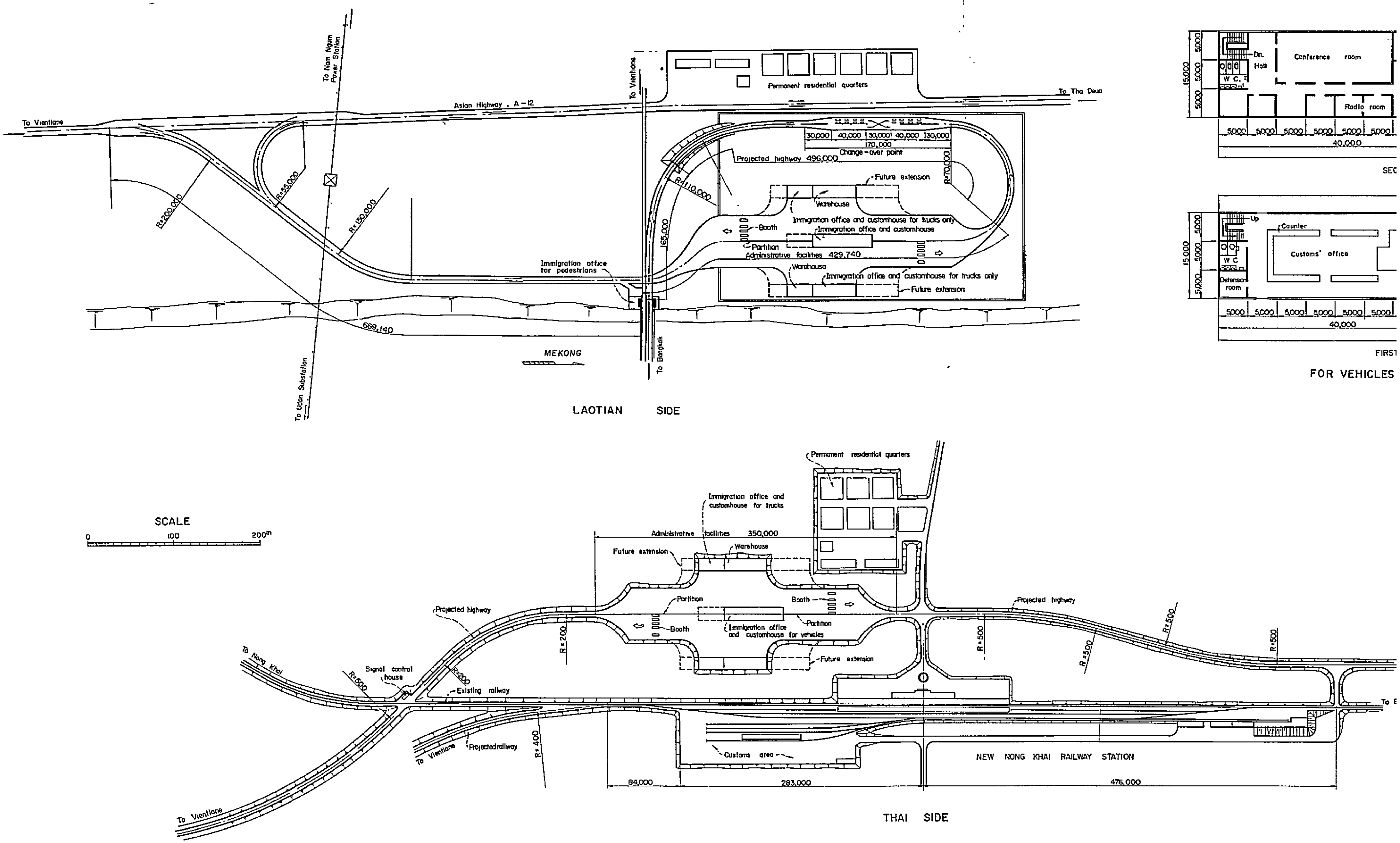
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

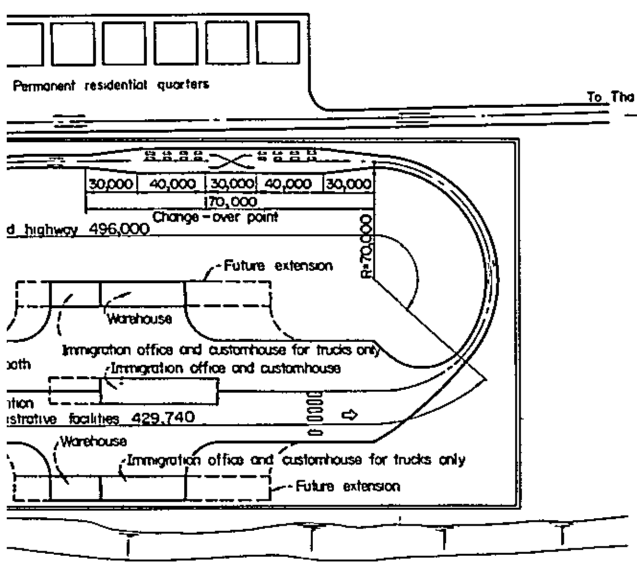
RAILWAY: OVERPASS AND CULVERTS

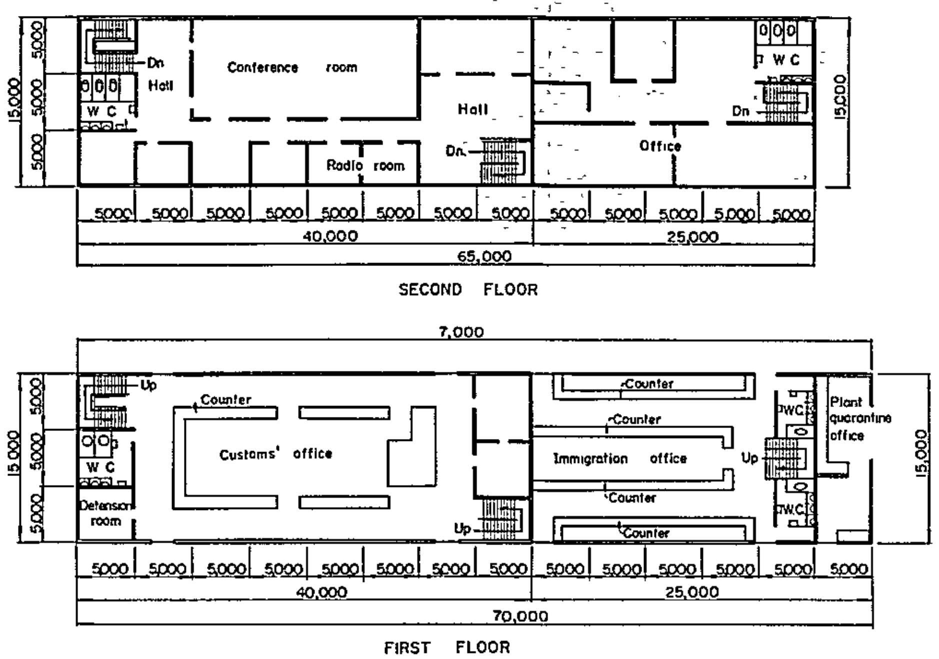
NIPPON KOEI CO. LTD TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	
CHECKED	Y. Tokunaga	DATE Sep. 8, 1969
SUBMITTED	[signature]	
APPROVED	[signature]	PLATE 18

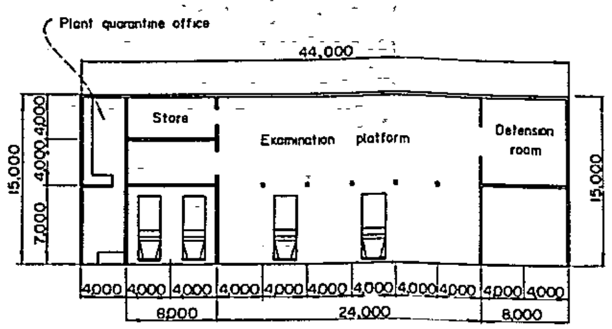


ADMINISTRATIVE FACILITIES





FOR VEHICLES EXCLUDING TRUCKS

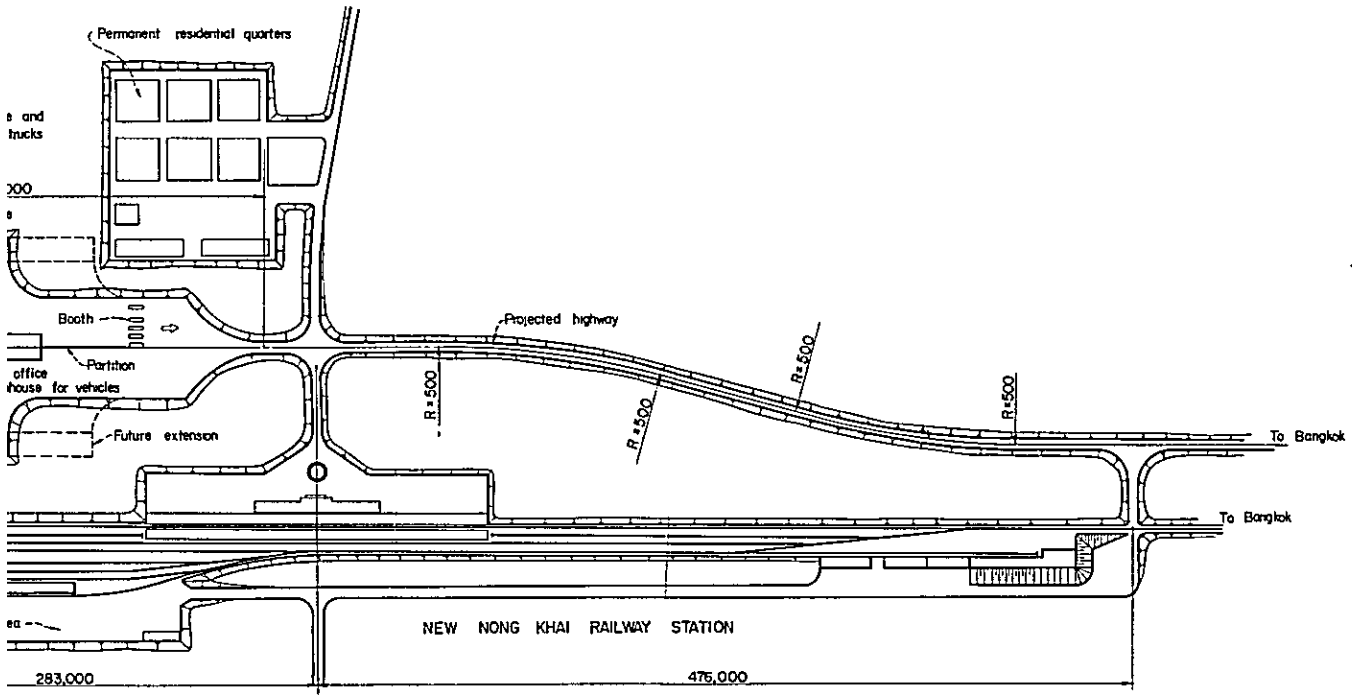


FOR TRUCKS ONLY

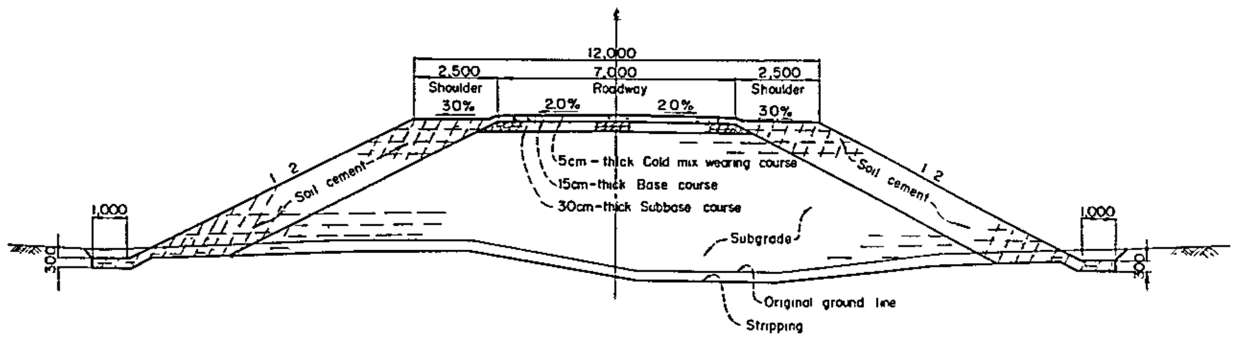
SCALE

0 10 20m

IMMIGRATION OFFICE AND CUSTOMHOUSE



THAI SIDE



BANKING

Remarks

Each embankment layer shall be so provided as to obtain the value of C B R shown in the following

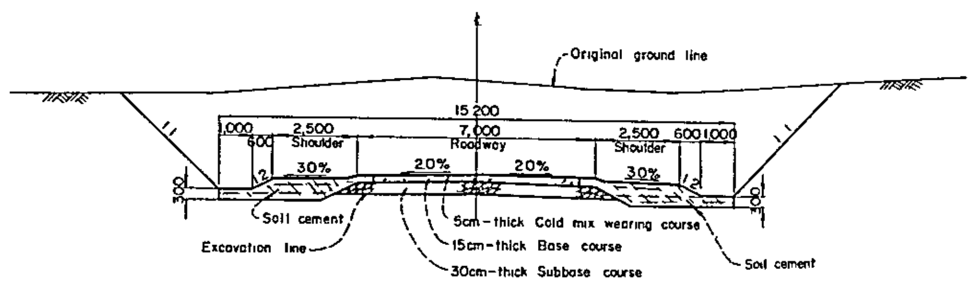
(1) Base course 80 to 90 (%)

(2) Subbase course 20 to 30 (-)

(3) Subgrade 5 to 10 (-)

SCALE

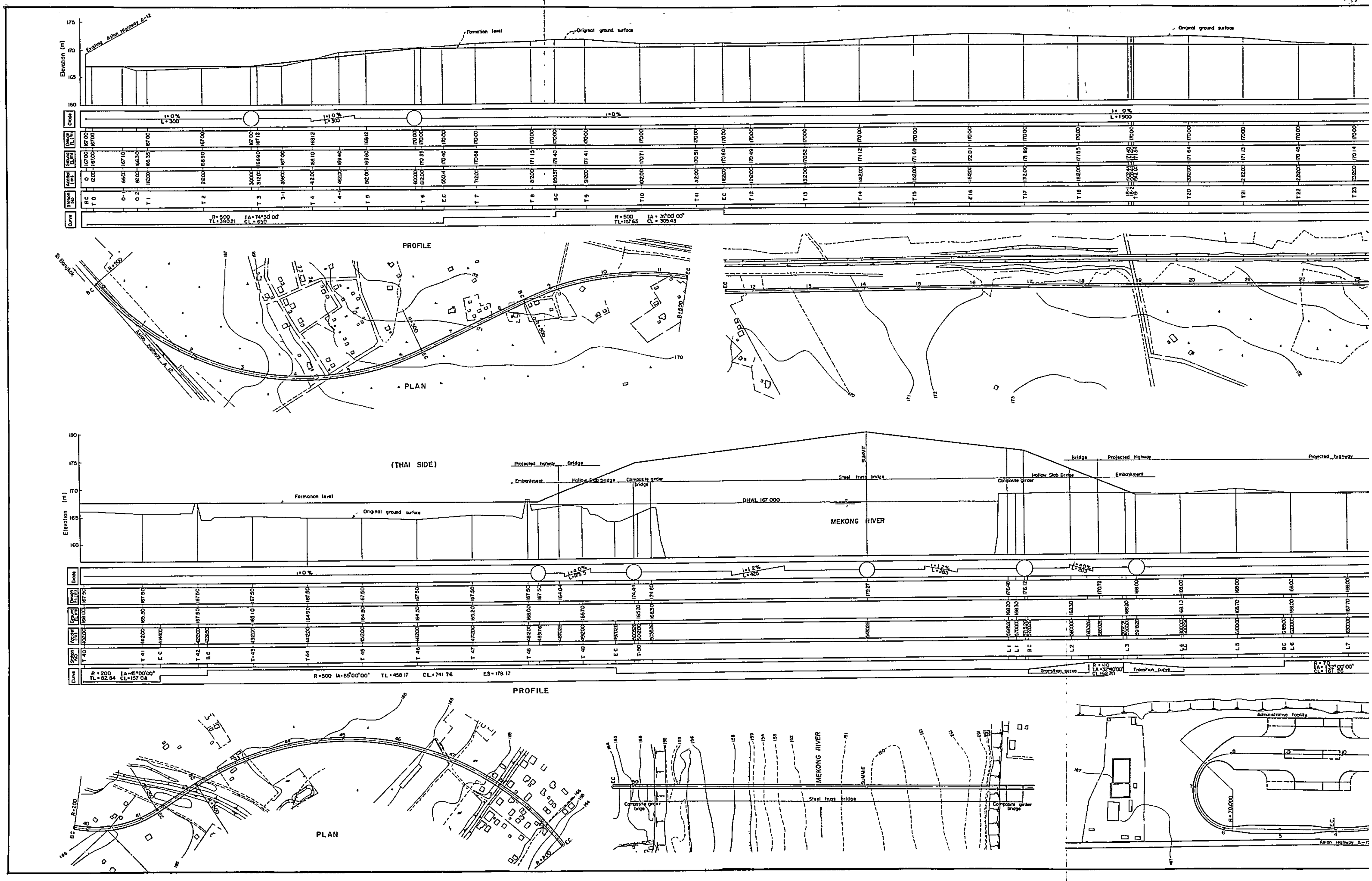
0 5 10m



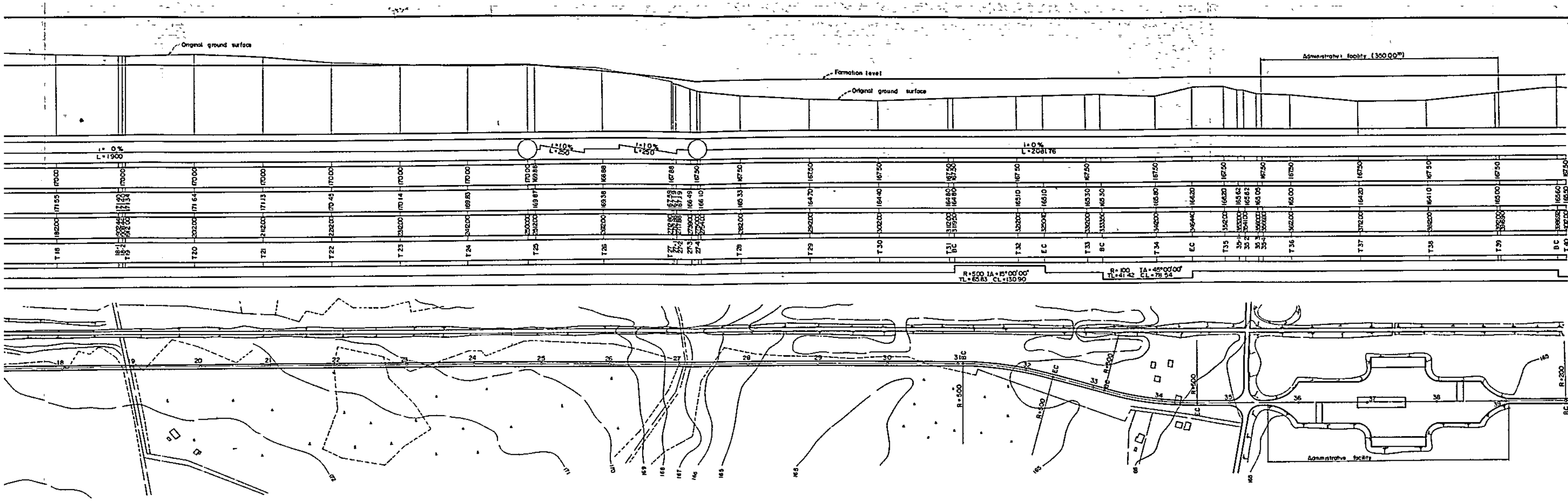
CUTTING

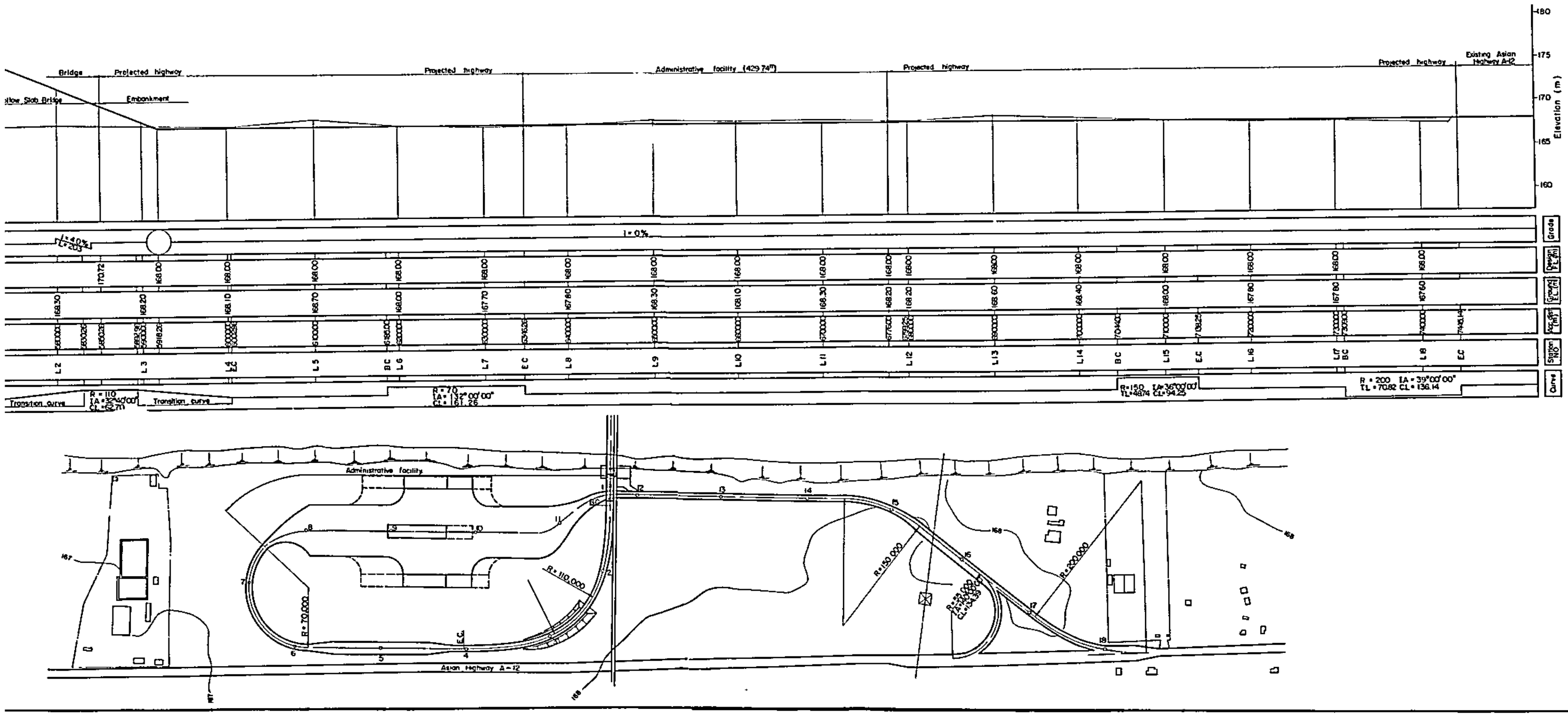
TYPICAL CROSS SECTIONS OF HIGHWAY

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO, JAPAN	
NONG KHAI / VIENTIANE - BRIDGE PROJECT HIGHWAY : ADMINISTRATIVE FACILITIES AND TYPICAL CROSS SECTIONS	
NIPPON KOEI CO., LTD TOKYO (CONSULTING ENGINEERS)	
DRAWN T. Ito CHECKED Y. Tokunaga SUBMITTED [illegible] APPROVED [illegible]	DATE Sep.8, 1969 PLATE 19



Existing Asian Highway A-12
Formation level
Original ground surface
Elevation (m)
Grade
Curve
R = 500 IA = 74°30'00" TL = 380.21 CL = 650
R = 500 IA = 35°00'00" TL = 157.65 CL = 305.43
PROFILE
PLAN
To Bangkok
Asian Highway A-12
(THAI SIDE)
Projected highway
Bridge
Embankment
Hollow Slab bridge
Composite girder bridge
Steel truss bridge
DHWL 167.000
SUMMIT
MEKONG RIVER
Transition curve
R = 200 IA = 45°00'00" TL = 82.84 CL = 157.08
R = 500 IA = 85°00'00" TL = 458.17 CL = 741.76 ES = 178.17
PROFILE
PLAN
Administrative facility
Asian Highway A-12





OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO, JAPAN

NONG KHAI / VIENTIANE BRIDGE PROJECT

HIGHWAY: PLAN AND PROFILE

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

DRAWN	T. Ito	DATE Sep. 8, 1969
CHECKED	Y. Tokunaga	
SUBMITTED	[illegible]	PLATE 20
APPROVED	R. Yoshida	