REPORT ON FEASIBILITY SURVEY
OF
SRI RACHA SEA BERTH CONSTRUCTION PROJECT
IN
THAILAND

March 1975

JAPAN INTERNATIONAL COOPERATION AGENCY

75

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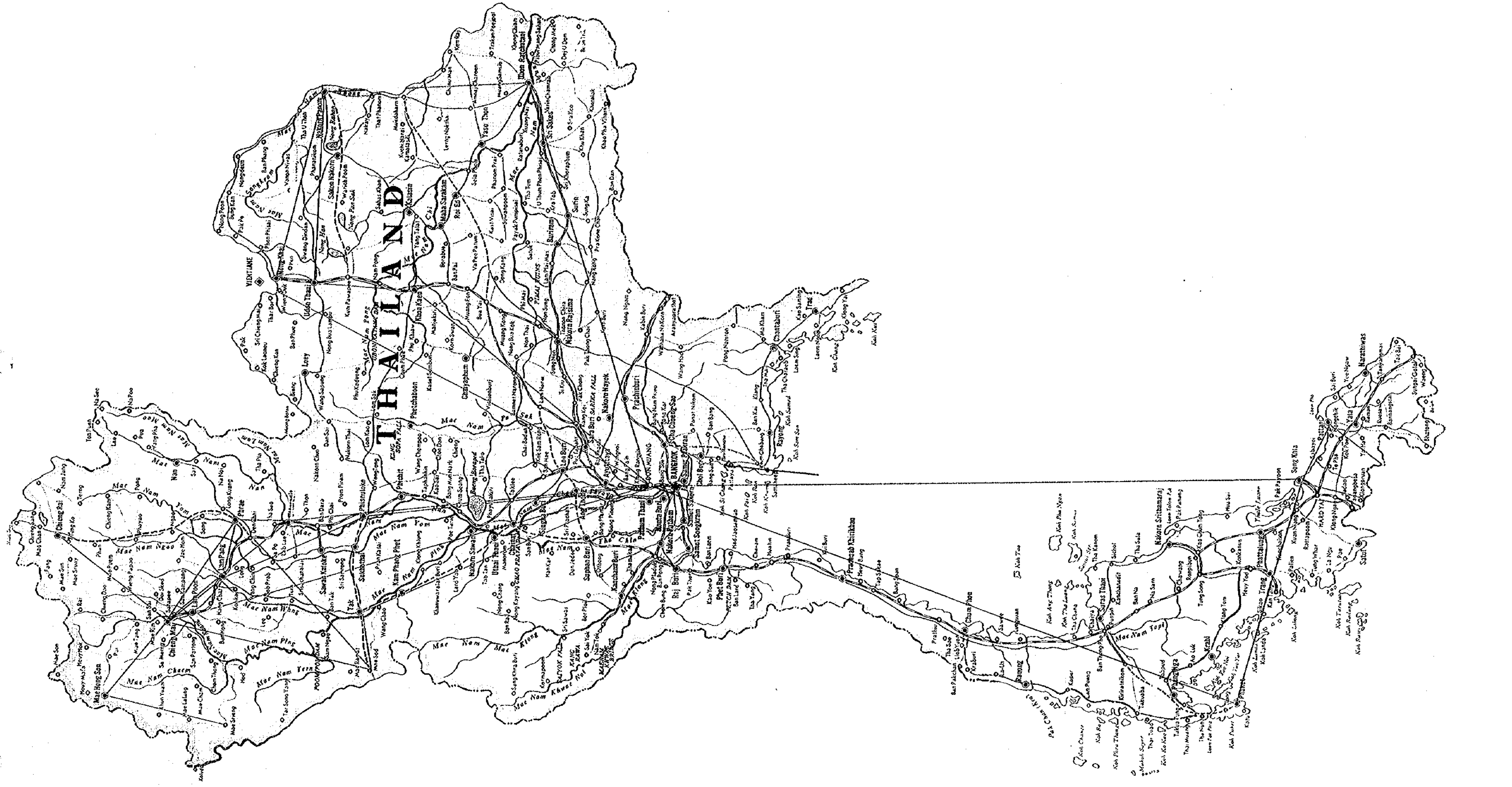

THAILAND

Preface

At the request of the Government of the Kingdom of Thailand, the Government of Japan has decided to conduct a feasibility study for the Sea-Berth Construction Project at the Sri-Racha of Thailand as part of Japan's overseas technical cooperation programmes, and entrusted its execution to the Overseas Technical Cooperation Agency, the predecessor of the Japan International Cooperation Agency (J I C A).

The JICA sent the survey team of 8-members, headed by Mr. Osamu Harada, Director-General of the Fifth Ports and Harbours Bureau of the Ministry of Transport, to Thailand and carried out the feasibility study on the project from February 13 to January 17, 1974.

During its study in Thailand, the team prepared and submitted an interim report to the Government of the Kingdom of Thailand. After its return to Japan, the team continued to devote its efforts to complete the final report by studying the project carefully and reviewing the collected data.

It gives me a great pleasure if this report, which I am submitting here with to the Government of the Kingdom of Thailand, will contribute to promote the progress of the project and, at the same time, serves to enhance the economic development of Thailand and the friendly relations now existing between Thailand and Japan.

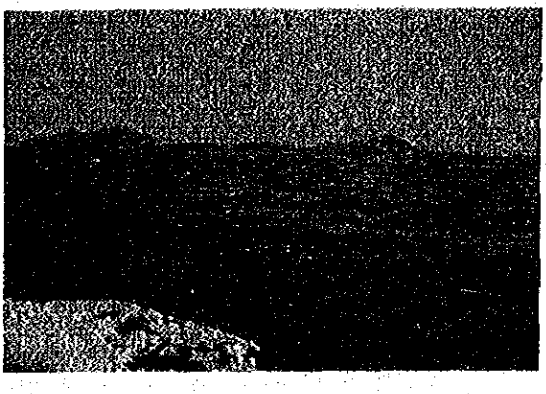
I take this opportunity to express my heatfelt gratitude to the Government of the Kingdom of Thailand and the staffs of the Thai Authorities concerned for the helpful cooperation extended to the team.

Shinsaku Hogen

President

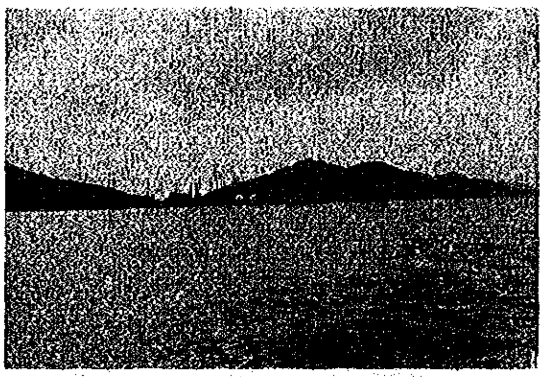
Japan International Cooperation Agency

March 1975

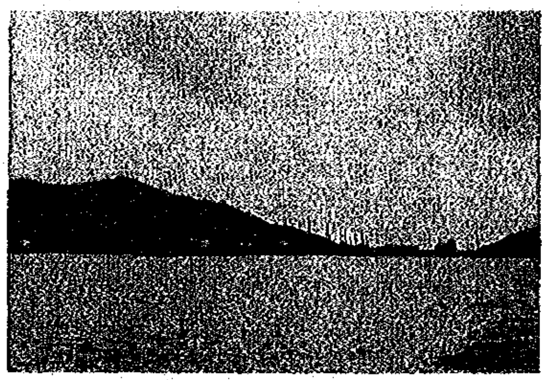


Ko Shi Chang Island

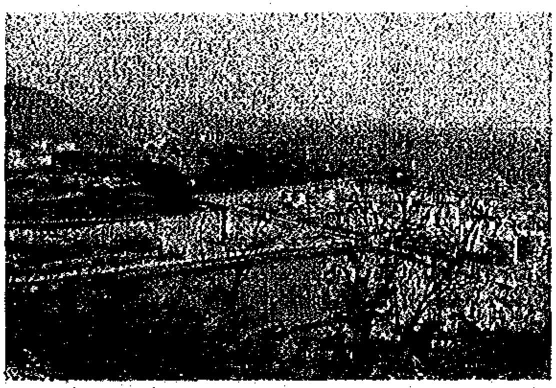
Cape Laem Chabang



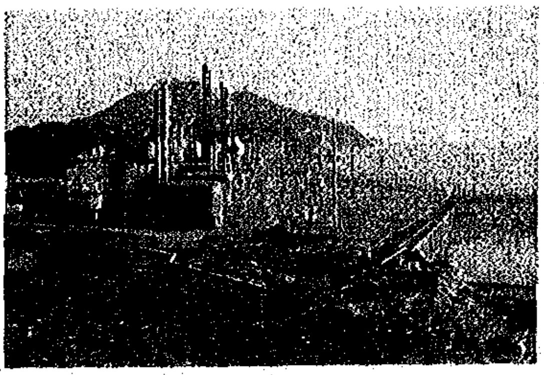
Remote view of TORC Refinery



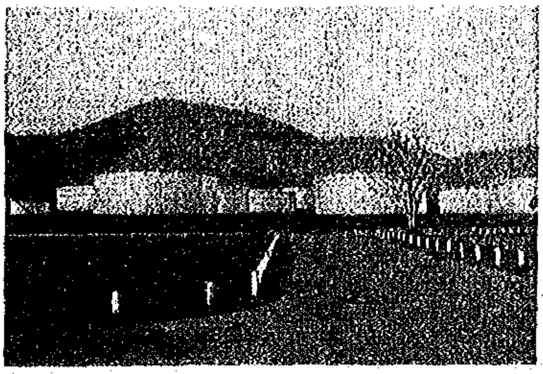
Remote view of ESSO Refinery



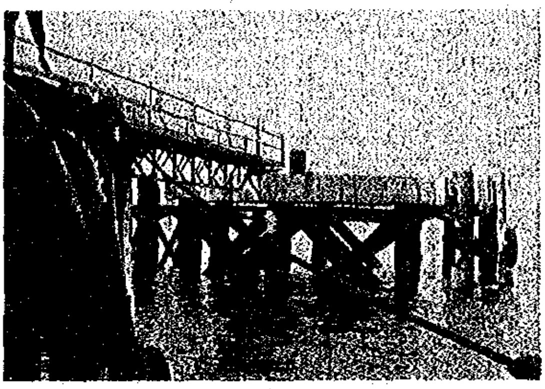
Oil tanks (ESSO on the right, SUMMIT on the left, and TORC in the left back)



ESSO Refinery (Mooring buoy seen on the right)



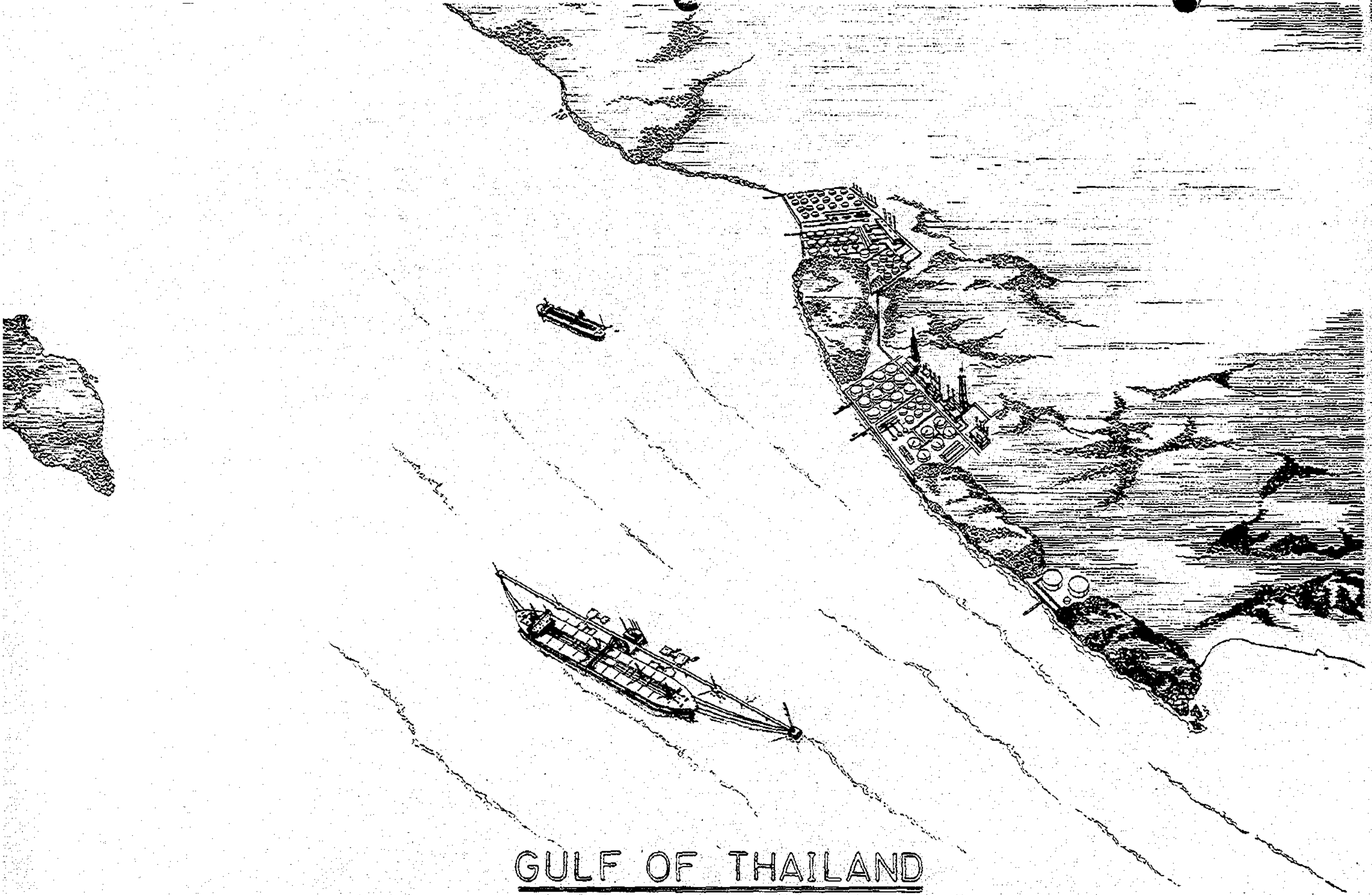
SUMMIT tanks



SUMMIT dolphin for 60,000 DWT tankers

Manifold of SUMMIT dolphin
for 60,000 DWT tankers

Ban Phra Reservoir


GULF OF THAILAND

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I. SUMMARY, CONCLUSIONS AND PROPOSALS

I. SUMMARY, CONCLUSIONS AND PROPOSALS

Various studies were made with an emphasis on the period between 1980 and 1985 in this report.

1. Imported crude oils in Thailand

(1) Basic standpoint

The demand for petroleum was predicted on the basis of the following standpoint.

1) The Third National Economical Plan of the Thai Government was basically used for setting an economic frame. However, some adjustments were made on the basis of the past records.

2) It is quite difficult to make a long-range and accurate prediction of demand for petroleum in this period of oil crisis. Under this project, the prediction was made by obtaining the demand for petroleum for accomplishing the economic plan within the adopted economic frame.

3) The period was divided into two terms, namely, 1980 ~ 1985 (first term) and 1985 ~ 1990 (second term). The prediction for the second term may not necessarily be highly accurate for the given reason, but the prediction for the first term seems quite accurate in view of the trends of enterprises.

(2) Future economic frame

The estimated population, GNP and GNP per capita in 1975, 1980, 1985 and 1990 are given below.

	1975	1980
Population	42.2 million	49.1 million
GNP	150.4 billion ฿	182.6 billion ฿
GNP per capita	3.6 thousand ฿	3.7 thousand ฿

	1985	1990
Population	56.4 million	64.1 million
GNP	217.5 billion ฿	254.0 billion ฿
GNP per capita	3.9 thousand ฿	4.0 thousand ฿

(Note) The actual price of 1962 was adopted for GNP and GNP per capita.

(3) Future demand for energy

The following figures show the estimated demand for total energies, demand for petroleum energy, demand for imported crude oil energy and their ratio in 1975, 1980, 1985 and 1990.

	Total Energies	Petroleum Energy	Imported Crude Oil Energy
1975	90.6 10^{12}K-Cal (100.0%)	74.9 10^{12}K-Cal (82.6%)[100.0%]	63.6 10^{12}K-Cal [85.0%]
1980	129.2 10^{12}K-Cal (100.0%)	103.0 10^{12}K-Cal (79.4%)[100.0%]	92.7 10^{12}K-Cal [90.0%]
1985	178.1 10^{12}K-Cal (100.0%)	145.5 10^{12}K-Cal (81.7%)[100.0%]	136.7 10^{12}K-Cal [94.0%]
1990	236.8 10^{12}K-Cal (100.0%)	197.0 10^{12}K-Cal (83.2%)[100.0%]	187.1 10^{12}K-Cal [95.0%]

(4) Import of crude oils

Thailand's estimated import of crude oils in 1975, 1980, 1985 and 1990 is given below.

	1975	1980
Import of crude oils	8,800 thousand KL	12,800 thousand KL

	1985	1990
Import of crude oils	18,900 thousand KL	25,900 thousand KL

2. Natural conditions and navigation conditions in Sri Racha Region

(1) Natural conditions

1) South-west wind prevails in summer and north-east wind prevails in winter. The maximum wind speed through a year is 20m/sec. Wind speed is below 8m/sec. for 95.4% of a year.

2) Fog is light. The annual mean visibility is 11 km.

3) The monthly mean temperature is 26 ~ 30°C. The difference between the maximum temperature and the minimum temperature is 5 ~ 7°C.

4) The annual amount of rainfall is 1235mm. Rain falls are at least 15 days per month during the rainy season (May ~ October) and are 6 days or less during the dry season (November ~ April).

5) Thunder storm is frequent in April ~ May and September ~ October. It is extremely heavy.

6) With regard to tides, H.H.W.L. is 1.80m above M.S.L. and L.L.W.L. is 2.48m below M.S.L.

7) The tidal current is N020° in the case of ebb tide and N215° in the case of flood tide. (Max. 1.5 knot)

8) The maximum wave height is 3.6m. The wave height is 50cm or below for 330 days per year. There is no swell.

9) No earthquake occurs.

10) Silt, sandy silt or silty sand is found in the subsurface. Basement is exposed on the east and the west coasts of Sichang Island and near the southern seaside of Sri Racha. The hill district of Leam Chabang has good soil condition, but the rear district has alluvium Ko Sichang Island is a platform consisting of stiff foundation.

(2) Navigation conditions

1) Tankers of 250 thousand DWT class (max.) can enter Sri Racha. (The draft is assumed to be 20m.)

2) The navigation channel is shown in Fig. IV-15.

3) The navigation aids that shown in Fig. IV-15 are required.

4) The water depth of 21 ~ 22m is secured.

5) Tidal current should desirably be below 1 knot.

6) Wave Height must be below 3m.

7) Wind speed must be below 15m/sec.

8) A fixed type or multiple buoy type sea berth requires 5L long water area, while a single buoy type sea berth requires 5L ~ 7L long water area.

9) The points A, B, C in Fig. IV-16 are most promising as the sea berth construction site.

10) Tag boats must be ready.

(3) Comparision of construction sites

1) The point C has the best natural conditions.

2) The point C has the worst navigation conditions.

3) The points A, B, C are almost equal except a few conditions.

3. Sea berth system

(1) Sea berth system

1) A common sea berth system is assumed. The scope of the feasibility investigation comprises a sea berth, a submarine pipe line, and a ground or submarine pipe line to a primary crude oil storing facility and a petroleum enterprise.

2) A sea berth system at the points A, B, C is set as below.

Point A
- Sea berth - West of Ko Sichang Island
- Buffer tank - Ko Sichang Island
- Pipe line - Sea berth ~ Ko Sichang Island ~ Leam Chabang

Point B
- Sea berth - South of Ko Sichang
- Buffer tank - Leam Chabang
- Pipe line - Sea berth ~ buffer tank

Point C
- Sea berth - East of Ko Sichang Island
- Buffer tank - Leam Chabang
- Pipe line - Sea berth ~ buffer tank

(2) Scale of system

1) One berth can handle 16 million KL of crude oils.
Two berths will be necessary after 1985.

2) A buffer tank has the capacity of 150 thousand KL/unit.
Two buffer tanks will be necessary in Ko Sichang Island in the case of Point A. One tank is necessary in the case of Point B and C. Another tank will become necessary after 1985 at all of the three sites.

4. Land and water

(1) Land

1) Land of 1,340 ha is available on Leam Chabang side, and land of 65 ha is available in Ko Sichang Island.

2) The cost of land reclamation is 6 ~ 10 times as high as purchase price.

(2) Water

Multi-purpose use of Bampra Reservoir must be planned. A closed system based on water circulation must be adopted at refineries for efficient use of water.

5. Facility design and construction schedule

(1) Facility design

1) A fixed type dolphine sea berth is adopted for this project for its navigational, safety and long-range economic advantages.

2) The berth layout is shown in Fig. VII-3.

(2) Construction schedule

1) Two years are allowed for the construction of the first one berth. The first one year will be used for designing and purchasing materials and the second year will be used for actual construction works. Works are to begin in 1976.

2) One year is allowed for the second sea berth. Construction works are to begin in 1984.

6. Construction costs and maintenance costs

(1) Construction costs

The construction costs at the three sites (A, B, C) are estimated as below for plans X, Y, Z, separately.

(Unit: Million ¥)

Site \ Stage \ Plan		X	Y	Z	W
A	1st	1,153 (921)	1,212 (965)	1,212 (965)	1,212 (965)
	2nd	0	0	459 (361)	459 (361)
	Total	1,153 (921)	1,212 (965)	1,671(1,326)	1,671(1,326)
B	1st	946 (759)	1,005 (803)	1,005 (803)	1,005 (803)
	2nd	0	0	611 (474)	611 (474)
	Total	946 (759)	1,005 (803)	1,616(1,277)	1,616(1,277)
C	1st	931 (769)	990 (813)	990 (813)	990 (813)
	2nd	0	0	605 (491)	605 (491)
	Total	931 (769)	990 (813)	1,595(1,304)	1,595(1,304)

Note: The figures in the parentheses indicate foreign funds.

(2) Maintenance costs

The estimated maintenance costs at the sites A, B, C under plans X, Y, Z are given below.

(Unit: Million ฿)

Site \ Stage \ Plan		X	Y	Z	W
A	1st	47.9	48.6	48.3	48.4
	2nd	0	0	64.9	65.4
B	1st	43.7	44.4	44.1	44.3
	2nd		0	62.1	62.6
C	1st	42.5 (53.8)	43.2 (54.5)	42.9 (54.2)	43.1 (54.4)
	2nd	0	0	59.7 (85.4)	60.1 (85.9)

Note: The figures in the parentheses indicate the maintenance cost at every five years.

7. Transportation costs of crude oils

(1) Appearance of large tankers

The transportation cost is 41.4 ฿/KL with a 200 thousand DWT tanker. It is cheaper than a 90 thousand DWT tanker by 16.5 ฿/KL.

(2) Loss due to demurrage

If all the currently available sea berths are used for importing 12,800 thousand KL of crude oils (estimated 1980 import), the demurrage loss will be 1.2 ฿/KL. The demurrage loss will be 2.5 ฿/ KL if one sea berth for 200 thousand DWT is used. The demurrage loss for importing 18,900 thousand KL of crude oils (estimated 1985 import) will be 1.5 ฿/KL in the former case, but 0.5 ฿/KL in the case of two sea berths for 200 thousand DWT.

8. Evaluation of economic advantages

(1) Economic analysis

1) The internal return rate is given below for each plan and each site. X Plan (SUMMIT, TIPCO, TPC), Y Plan (ESSO, TORC, SUMMIT, TIPCO), Z Plan (ESSO, TORC, SUMMIT, TIPCO, TPC) and W Plan (ESSO, TORC, SUMMIT, TIPCO, TPC, others)

	X	Y	Z	W
A	7.8%	13.5%	13.6%	14.1%
B	9.9%	16.3%	15.3%	15.9%
C	10.0%	16.5%	15.5%	16.0%

(Note) One berth is assumed for X Plan and Y Plan

2) The cost-benefit ratio is given below. The discount rate of 12.0% is assumed.

	X	Y	Z	W
A	0.72	1.10	1.11	1.15
B	0.85	1.30	1.22	1.27
C	0.86	1.31	1.23	1.28

(Note) One berth is assumed for X Plan and Y Plan

(2) Financial analysis

1) Profit and loss account

Deficit finance continues until 1984 under X Plan and until 1979 under Y, Z and W Plans. The financial conditions are good at the site C under Y, Z and W Plans.

2) Financial account

The initial finaicial account is poor under any of the plans (X, Y, Z, W). The financial account is the worst under Plan X. The financial account at the site C is far better compared with the other sites.

3) Charge

A charge of 20 ~ 30 ฿/KL is necessary under X Plan. However, 20 ฿/KL seems sufficient under Plans Y , Z and W, especially at the sites B and C.

9. Conclusions

(1) Sea berth construction site

No specially large difference in natural conditions and navigation conditions is found among the sites A, B, C. However, the advantage of the site C was confirmed by the above economic evaluation (national economic analysis, financial analysis). Therefore, the Investigation Mission concludes that the site C is most suitable for sea berth construction.

(2) Economic advantages

The internal return rate of this project is at least 13% under Y, Z and W plans. Since the cost-benefit ratio is at least 1.1 (with the discount rate assumed as 12%), this project has sufficient economic advantages.

(3) Stock

Sixty day stock of crude oils must be secured to the stable supply of petroleum energy. When the site C is adopted for this project, approximately 30 day stock and 60 day stock will be secured in 1980 and 1990, respectively.

(4) Managing organization

The current transactions will be red figures between 1977 and 1979 even in the case of C-Y because of the burden of large intial investments. If charges are assumed to be kept below benefits, the Thai Government must participate in the management in some form. Financial assistances must be given from the general account at the initial stage. The Investigation Mission considers that a third sector consisting of the Thai Government and the participating enterprises is a suitable managing organization.

10. Proposals

(1) On overall development plan for Sri Racha ~ Leam Chabang District

Sri Racha ~ Leam Chabang District has been considered as a promising industrial development zone in Thailand. Various large projects are planned for this district in addition to the oil refining industry that is directly related to this sea berth project. Such projects include petroleum chemistry, a steel plant, atomic power plant, Deep Sea Port.

If four or five large projects are planned for this district, it will be faced with land problems, water problems, land and marine transportation problems, environmental maintenance and pollution problems, city planning problems etc. Overall adjustments will have to be made among these projects. Such a situation is expected to occur during the second term of this sea berth project.

Therefore, this district requires an overall development and investigation for evaluating and adjusting these projects from a higher standpoint.

With regard to the transportation of petroleum products, a pipe line plan must be studied to provide a means of transporting products to Bangkok. A plan should also be made to improve the port functions, including unloading facilities of petroleum products at Bangkok Port.

(2) On rationalization and growth of oil related enterprises

It has already been reported that this sea berth project is feasible, including the petroleum enterprises in the rear. However, there will be required the growth and rationalization of an oil refining plants, including stable chartering of large 200 DWT class tankers and "Kombinat" formation with related industries. The demand for petroleum increases yearly. Stable and cheap supply of petroleum for economic development requires the growth and rationalization of petroleum related enterprises.

II. INTRODUCTION

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1. Purpose of investigation and background for dispatching investigation mission

Thailand drew the First 6 Year Social and Economic Development Plan in 1961 and the Second 5 Year Economic Plan in 1967. She has made steady advancements to national prosperity through the promotion of agricultural developments, the expansion of education system, the elimination of regional differences and the active promotion of industrialization. She started the Third National Economic and Social Plan in October of 1971 in attempts to increase national product and income, to promote export to maintain adequate foreign currency reserve, to expand education system and to promote the population policy. Industrialization is the nucleus of national economic development. However, various problems have arisen because of her dependence on petroleum products for energies, which are driving forces of industrialization.

The international energy crisis, which began with the Middle East War in November of 1973, spread throughout the world and gave a serious shock to crude oil importing countries in the world. Thailand is not an exception. She is currently faced with extremely important problems of finding a way for stable supply of petroleum energy and for coping with sharply increased import price of crude oils.

In Thailand, most of the oil refineries exist in Bangchak (South of Bangkok City) and Sri Racha District of Chonburi Province, although some exist in Amphon Farng oil field zone of Chiengmai Province. The first two districts produce about 99% of the total refined oils and about 80% of the demand for petroleum products.

The scale of oil refineries (ESSO, TORC and SUMMIT) is 165,000 PBSD at the beginning of 1974. For this reason, relatively small berthing facilities for 90,000 DWT class or smaller tankers are available as crude oil unloading facilities. Larger tankers are internationally favored since larger tankers sharply cut down crude oil transportation costs. Currently, 250,000 DWT class tankers seem most widely used. This tendency is expected to continue in the future.

It is predicted that crude oil consumption in Thailand will rise sharply from approximately 6,300 thousand KL of 1971 to approximately 70,000 thousand KL in 1975. In view of such circumstances, the Thai Government has made studies for inexpensive and stable supply of crude oils through the construction of larger crude oil unloading facilities and adequate crude oil stock. The Sri Racha Sea Berth construction project was proposed as a part of the series of these studies. The Thai Government is to make independent planning and investigation on this project, but also requested the Japanese Government to carry out a feasibility survey on this project.

In answer to this request, the Japanese Government discussed with the Thai Government on the investigation items and methods etc. and determined to dispatch an investigation mission. The works were assigned to the Overseas Technical Cooperation Agency belonging to the Japanese Government. As a result, the First Investigation Mission was dispatched in September, 1972 and the Second Investigation Mission was also planned for these investigation activities.

The history of the investigation missions on this project and the accomplishments of the First Investigation Mission are summarized here. Various circumstances between the First and the Second Investigation Missions are described.

(1) November, 1971

The Thai Government requested the Japanese Government to send a feasibility investigation mission.

(2) December, 1971

The Thai Government presented A-1 form of Columbo Plan to the Japanese Government.

(3) January, 1971

Secretary General Nitipat and Department Director Triratana of NEA of the Thai Government came to Japan. They visited the related Japanese organs and requested to dispatch feasibility investigation mission. They inspected Nippon Steel Corporation, Toyo Kanetsu K.K., Nippon Oil Co., Ltd. etc.

(4) May, 1972

A private investigation team conducted a field investigation before the Japanese Government's feasibility investigation mission.

1) Purposes of investigation

1. Grasping of conditions for this project in Thailand
2. Field investigation of construction site and collection of related materials for designing and construction

2) Members of investigation team

Director:	Yasumaru Ishii	Nippon Steel Corporation (Director)
Members:	Yoshio Miyashita	Nippon Steel Corporation (Iron & Steel Development Division)
	Yoshiyuki Uemasu	Nippon Steel Corporation (Sagamihara Laboratory)
	Kazuo Furukawa	Nippon Steel Corporation (Iron & Steel Development Division)
	Masao Ganke	Nippon Steel Corporation (Sagamihara Laboratory)
	Akihiko Nitta	Nippon Steel Corporation (Iron & Steel Development Division)
	Junichi Yano	Nissho-Iwai Co., Ltd. (Iron & Steel Development Group)
	Shigenori Takahashi	Nissho-Iwai Co., Ltd. (Iron & Steel Development Department)

Shiro Nakada	Nissho-Iwai Co., Ltd. (Bangkok Office)
Takeji Shiomi	Nissho-Iwai Co., Ltd. (Metal Department)

3) Investigation period

May 11, 1972 ~ May 27.

(5) September, 1972

The Japanese Government dispatched the First Investigation Mission.

1) Purposes of investigation

1. Sounding was conducted in Sri Racha and Ko Sichang Sea Area and a map was drawn. The results were confirmed with the available sea chart.

2. The Japanese Government discussed with the Thai Government with regard to the contents of the Terms of Reference of the Second Investigation Mission.

The accomplishments of the First Investigation Mission are attached as reference materials in this report.

2) Members of Investigation Mission

Director:	Ken Terao	(Deputy Director of Construction Division of Bureau of Ports & Harbors of the Ministry of Transport)
Members:	Tsunehiro Inoue	Kokusai Kogyo
	Takeyasu Kikuta	"
	Hiroo Hara	"
	Yoshiho Saito	"
	Masanori Yamaguchi	"
	Niibara	O.T.C.A.

3) Investigation period

September 29, 1972 ~ October 22.

(6) December, 1972

The Thai Government sent the Terms of Reference for the Second Investigation Mission.

(7) January, 1972

The Japanese Government made comments on (6).

(8) April, 1972

Secretary Nitipat of NEA of the Thai Government came to Japan and unofficially exchanged opinions on the Terms of Reference of the Thai Government.

(9) May, 1973

The Japanese Government presented a corrected version of the Terms of Reference based on the Thai Government's draft.

(10) May ~ December, 1973

The two governments continued to adjust the Terms of Reference and reached an agreement in December. The Terms of Reference is attached to this report as reference materials.

(11) January, 1974

The Japanese Government dispatched the Second Investigation Mission.

2. Scope of Investigations

The Terms of Reference shows the scope of the investigations which were requested to the Second Investigation Mission. They are summarized below.

(1) Forecast of petroleum & crude oil demand of Thailand.

(2) Forecast of crude oil to be unloaded in Laem Chabang area.

(3) Study of transport system & costs.

(4) Study of storage requirement at Laem Chabang.

(5) Study of navigation channel improvement.

(6) Physical and geographical conditions of project area.

(7) Land uses in Laem Chabang.

(8) Navigation in Gulf of Thailand & Laem Chabang area.

(9) Present unloading facilities at Laem Chabang.

(10) Site Investigation.

(11) Structures and facilities to be provided at sea berth.

(12) Acquisition of land and compensation of land facilities.

(13) Justification for project selection for various alternatives.

(14) Project description.

(15) Preliminary design.

(16) Cost estimate.

(17) Economic justification, B/C, internal rate of return.

(18) Financial analysis.

(19) Construction plan & schedule.

(20) Studies the effect of other related projects which bear the influent on this project.

3. Members of Investigation Mission

The Investigation Mission consisted of the following eight members. Their title at the time of field investigation is given below.

Director:	Osamu Harada	Director-General of The Fifth District Port Construction Bureau of the Ministry of Transport
Consultant:	Tomio Shinohara	Nippon Steel Corporation (Head of Iron & Steel Development Division)
Members:	Kan Hirata	Asahi Giken (President)
	Shohei Yuasa	Toyo Kanetsu K.K. (Head of Design Division)
	Isao Ikeda	Head of Navigation Department of the Institute for Sea Training of the Ministry of Transport
	Tsutomu Kumakura	Deputy Director of Construction Division of Bureau of Ports & Harbors of the Ministry of Transport
	Tadanori Asada	Deputy Director of Disaster Prevention Division of Bureau of Ports & Harbors of the Ministry of Transport
	Yasuyuki Nakayama	Construction Specialist of Design Group of the Fifth District Port Construction Bureau of the Ministry of Transport

4. Schedule of Investigation Mission

The investigation period is to begin on January 17, 1974, and to end on February 13. (28 days) The Mission carried out reconnaissance, exchanged opinions with related organizations and enterprises and collected various important data. It made an interim report before its return to Japan.

(1) Schedule and works

January 17: Departure from Tokyo and arrival in Bangkok (Harada, Shinohara, Ikeda, Kumakura, Asada, Nakayama)

18: Visit to the Japanese Embassy and O.T.C.A. (morning)
Visit to N.E.A. (afternoon)

19: Internal works

20: Holiday

January	21:	Explanation of report of the First Investigation Mission to N.E.A. and discussion on the schedule of the Second Investigation Mission (morning) Collection of data (afternoon)
	22:	Reconnaissance of Sri Racha Districts by all the Mission members in Thailand
	23:	Same as above Meeting at the Japanese Embassy (Harada and Shinohara)
	24:	Collection of data Visit to D.T.E.C. (Harada and Shinohara)
	25:	Same as above
	26:	Analysis of collected data
	27:	Holiday
	28:	Collection and analysis of data
	29:	Same as above
	30:	Same as above Departure from Bangkok and return to Japan (Ikeda and Kumakura)
	31:	Collection and analysis of data, visit to Industrial Estate Authority of Thailand by Harada and Shinohara (morning) Explanation of investigations to N.E.A. (afternoon)
February	1:	Collection and analysis of data departure from Bangkok and return to Japan (Shinohara), arrival in Bangkok (Yuasa)
	2:	Collection and analysis of data
	3:	Holiday
	4:	Collection and analysis of data, visit to the Ministry of Industry by Harada
	5:	Collection and analysis of data arrival in Bangkok (Hirata)
	6:	Visit to ESSO, TORC, SUMMIT in Sri Racha by all the members in Thailand
	7:	Analysis of collected data
	8:	Collection and analysis of data, visit to the Ministry of Communication by Harada

February 9: Analysis of collected data, reconnaissance of Ko Shichang Island by Hirata and Yuasa, arrival in Bangkok (Shinohara)

10: Preparation of interim report

11: Same as above (morning)
Explanation of interim report to N.E.A. (afternoon)

12: Meeting at the Japanese Embassy, departure from Bangkok and return to Japan (Harada, Asada, Nakayama)

13: Departure from Bangkok and return to Japan (Shinohara, Hirata, Yuasa)

(2) Related organizations in Thailand

The Mission's field investigation was helped by the related organizations of the Thai Government. Several members of N.E.A. joined the Japanese Investigation Mission during the investigations. Large accomplishments were possible only with their assistance. Such organizations are listed below and their assistances are deeply appreciated.

1) National Energy Administration (N.E.A.)

2) Ministry of Industry (M.O.I.)

3) Ministry of Communication (M.O.C.)

4) Industrial Estate Authority of Thailand (I.E.A.T.)

5) Hydrographic Department, Thai Royal Navy

III. ECONOMIC FACTORS RELATED TO SEA BERTH PROJECT

III. ECONOMIC FACTORS RELATED TO SEA BERTH PROJECT

1. Predicted import of crude oils

(1) Economic frame

The following basic standpoint was taken for predicting the import of crude oils.

- o The Thai Government's Third National Economic Plan was followed as closely as possible for setting the economic frame. Although its major indices were respected, some adjustments were made to adopt rather moderate figures in view of the recent trend so that excessive investments might be avoided.
- o Various complicated factors are involved for the adequate ultra long range prediction of the demand for petroleum under the current oil crisis. It seems more important to base such prediction on the national policy. Therefore, Thailand's demand for energy and for petroleum was predicted on the basis of the target of the national economic plan.
- o The period of the project was divided into two terms, namely, 1980 ~ 1985 and 1990. However, the prediction for 1990 will be subject to some fluctuation in the future. The prediction for 1980 ~ 85 will be quite accurate in view of the trends of existing enterprises.

For this reason, the prediction of the demand is to be made with the major emphasis laid on the first term (1980 ~ 1985). The facility planning, economic analysis and financial analysis in the subsequent chapters are directed mainly to this term. With regard to the predictions and analyses for the term between 1985 and 1990, some increases over the first term may be assumed for economic and financial analysis since the import of crude oils will increase yearly with certainty.

1) Population

The population of Thailand was 25.6 million in 1960, 30.6 million in 1965 and 35.6 million in 1970. In other words, it has been increasing at the yearly rate of at least 3%. The rate of increase was 3.6% between 1970 and 1971 and 4.2% between 1971 and 1972. The rate of population growth in Thailand is quite high in view of the fact that the average annual growth rate in the entire South East Asia is 2.8%. (See Table III-1 for reference.)

Under the Third 5 Year Economic and Social Development Plan (to be abbreviated as the Third Plan) started in October, 1971, the rate of population growth is to be lowered to 2.5% by 1976. However, the records of population increase during the past 16 years show that the growth rate was always above 2.5% except 1966 ~ 1967 (2.3%). The average annual growth rate during these 16 years is as high as 3.3%.

If the Third Plan is accomplished, the population is estimated to be 42.3 million in 1975, 47.9 million in 1980, 54.2 million in 1985 and 61.3 million in 1990. If the average annual growth rate predicted by the Mission is assumed, the population is estimated to be 42.2 million, 49.1 million, 56.4 million and 64.1 million. (See Fig. III-1 for reference.)

Results of Estimates

(Unit: thousand)

Year	Estimate		The Third Plan	
	Population	Ratio to 1972	Population	Ratio to 1972
1972*	38,359	1,000	38,359	1,000
1975	42,220	1,101	42,330	1,104
1980	49,100	1,280	47,890	1,248
1985	56,430	1,471	54,190	1,413
1990	64,140	1,672	61,310	1,598

(Note) 1. The records are marked with * .

2. The growth rate of Fig. III-2 was assumed for the estimates.

Table III-1 Transition of Population

(Unit: thousand)

Year	Population	Growth rate over preceding year
1956	22,812	
1957	23,596	3.44%
1958	24,238	2.72
1959	24,891	2.69
1960	25,644	3.03
1961	26,507	3.37
1962	27,437	3.51
1963	28,312	3.19
1964	29,552	4.38
1965	30,582	3.49
1966	31,756	3.84
1967	32,469	2.25
1968	33,552	3.34
1969	34,648	3.27
1970	35,550	2.60
1971	36,820	3.57
1972	38,359	4.18

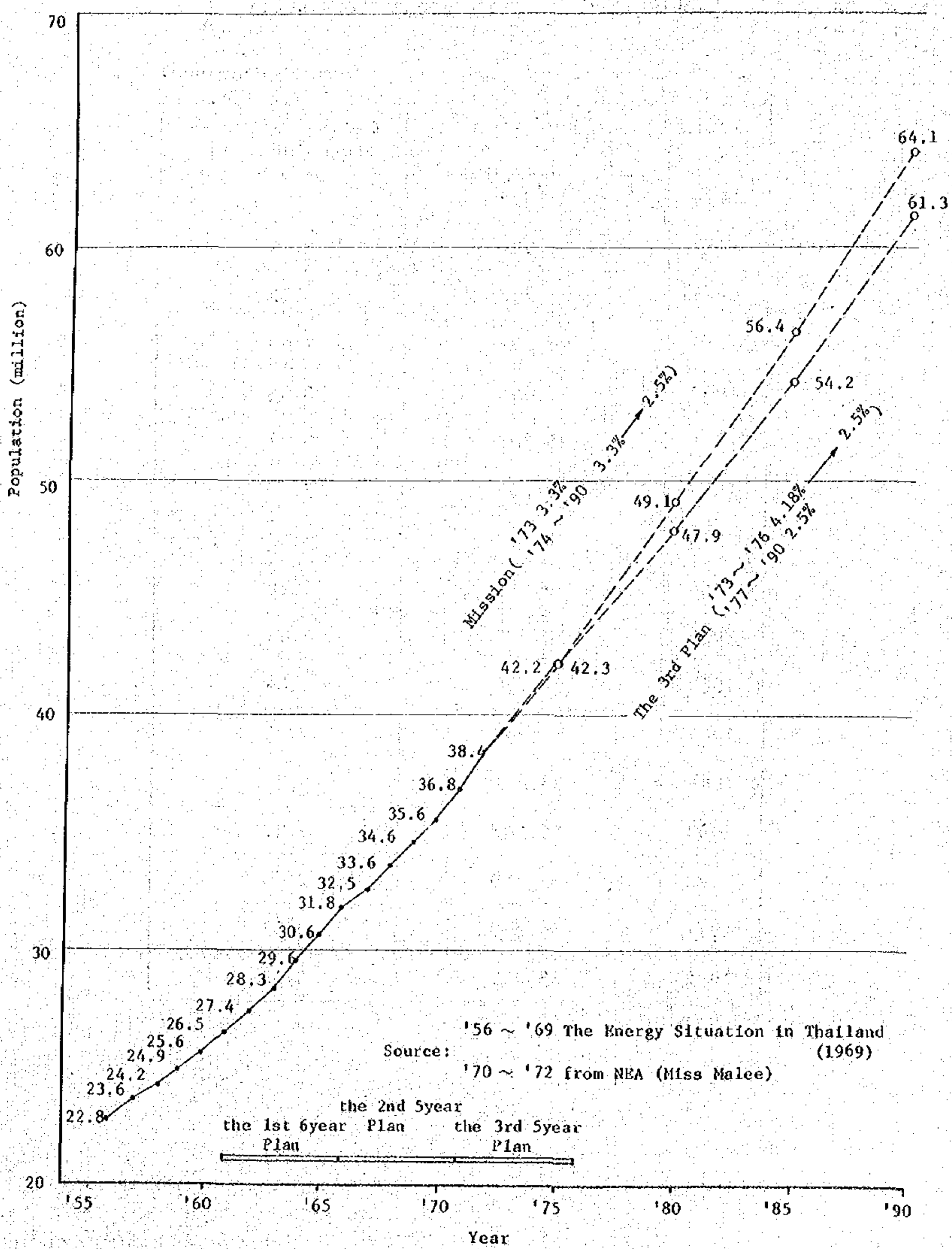


Fig. III-1 Tendency and Forecast of Population

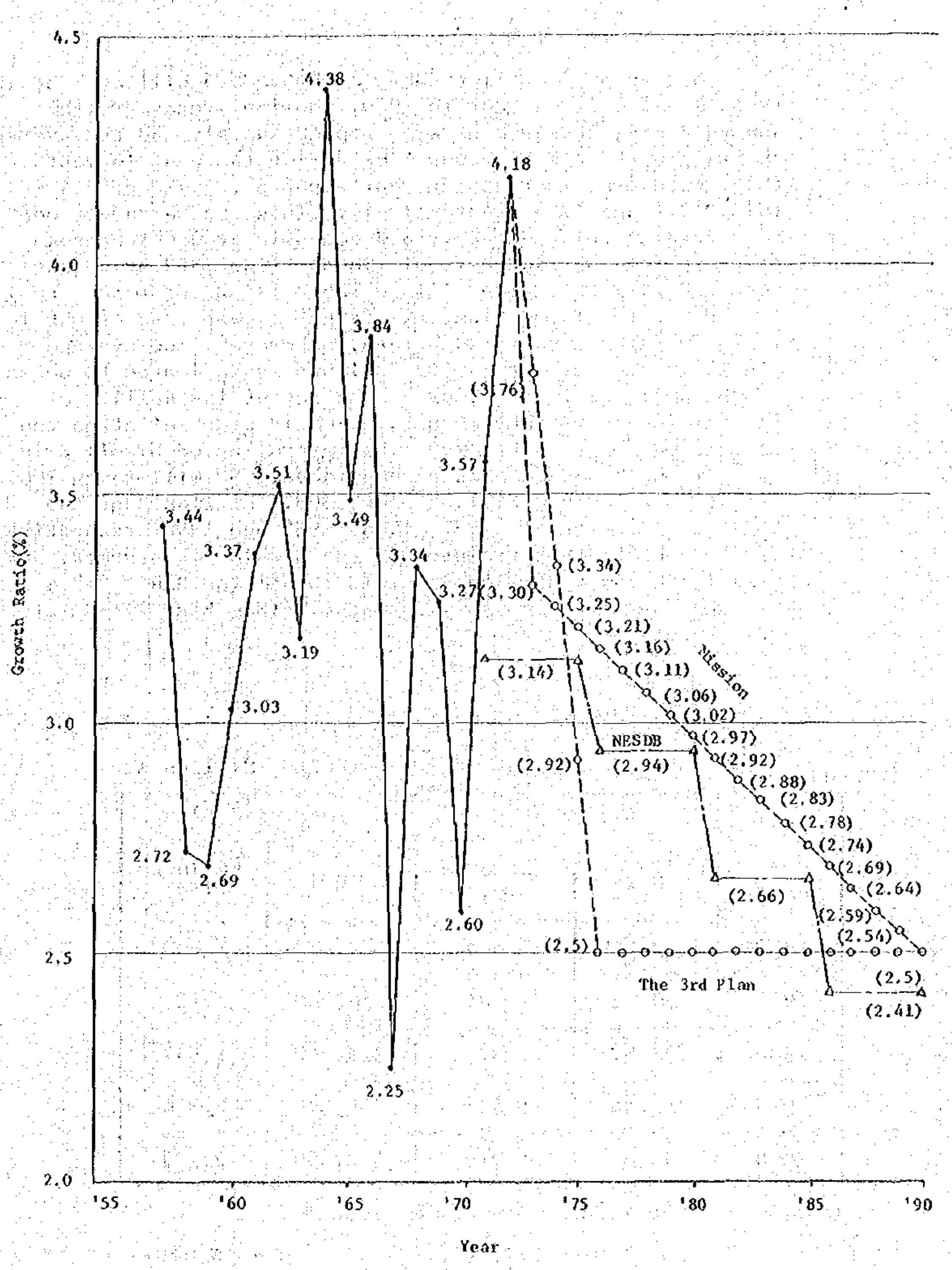


Fig. III-2 Growth Ratio of Population

2) GNP

GNP was 56.0 billion Baht in 1960, 79.5 billion Baht in 1965, 119.8 billion Baht in 1970, showing steady growth. Subsequently, the growth rate dropped sharply and the average annual growth rate has been 6.6% during the past 16 years. The growth over a preceding year was 6.6%, 6.1% and 4.4 in 1970, 1971 and 1972, respectively. This can be understood as a turning point of the rapid economic grow which took place during the last half of 1960s. (The 1962 price has been and will be adopted.) (See Table III-2 for reference.)

Under the Third Plan, the target growth rate of GNP is 7.0% (average annual growth rate.) However, the average annual growth rate of GNP in Thailand is estimated to be as shown in Fig. III-4 in view of the recent instability of international currency situation, world-wide inflation and unbalanced demand & supply of energy reflected by oil crisis.

If the Third Plan is accomplished, GNP will reach 156.8 billion Baht, 219.9 billion Baht, 308.4 billion Baht and 432.5 billion Baht in 1975, 1980, 1985 and 1990, respectively. If the growth rate predicted by the Mission is assumed, GNP will reach 150.4 billion Baht, 182.6 billion Baht, 217.4 billion Baht and 254.0 billion Baht. (See Fig. III-3 for reference.)

Results of Estimates

(Unit: Million ฿)

Year	Estimate		The Third Plan	
	GNP	Ratio to 1972	GNP	Ratio to 1972
1972*	132,689	1,000	132,689	1,000
1975	150,420	1,134	156,760	1,181
1980	182,570	1,376	219,860	1,657
1985	217,450	1,639	308,370	2,324
1990	254,040	1,915	432,490	3,259

(Note) 1. The records are marked with * .

2. The growth rate of Fig. III-4 was assumed for the estimates.

Table III-2 Transition of GNP (1962 price)

(Unit: Million ฿)

Year	GNP	Growth rate over preceding year
1956	47,712	
1957	48,196	1.01%
1958	48,572	0.78
1959	53,628	10.41
1960	55,979	4.38
1961	58,943	5.29
1962	63,695	8.06
1963	69,082	8.46
1964	73,602	6.54
1965	79,455	7.95
1966	89,120	12.16
1967	94,171	5.67
1968	102,719	9.08
1969	112,421	9.45
1970	119,796	6.56
1971	127,056	6.06
1972	132,689	4.43

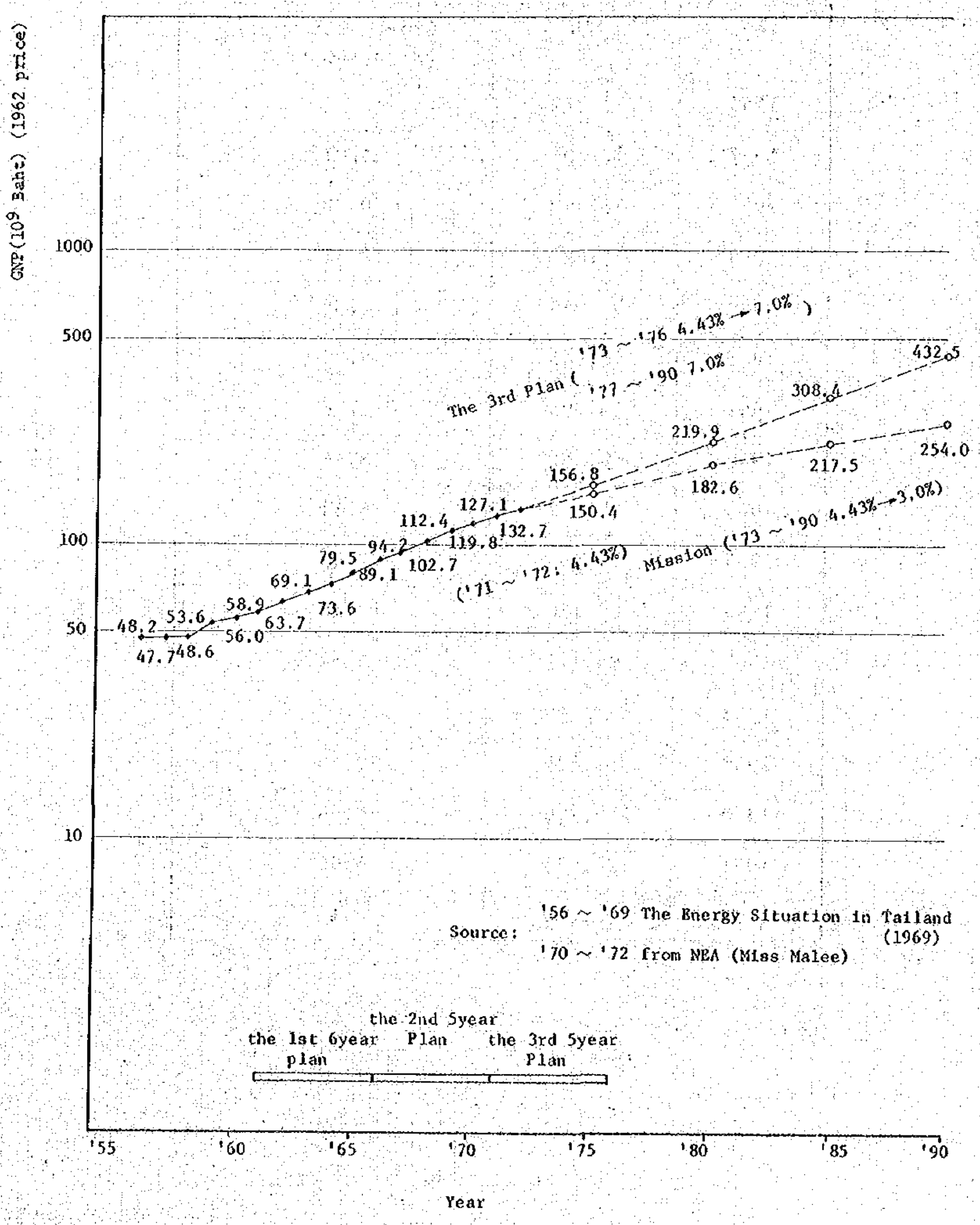


Fig. III-3 Tendency and Forecast of GNP (1962 price)

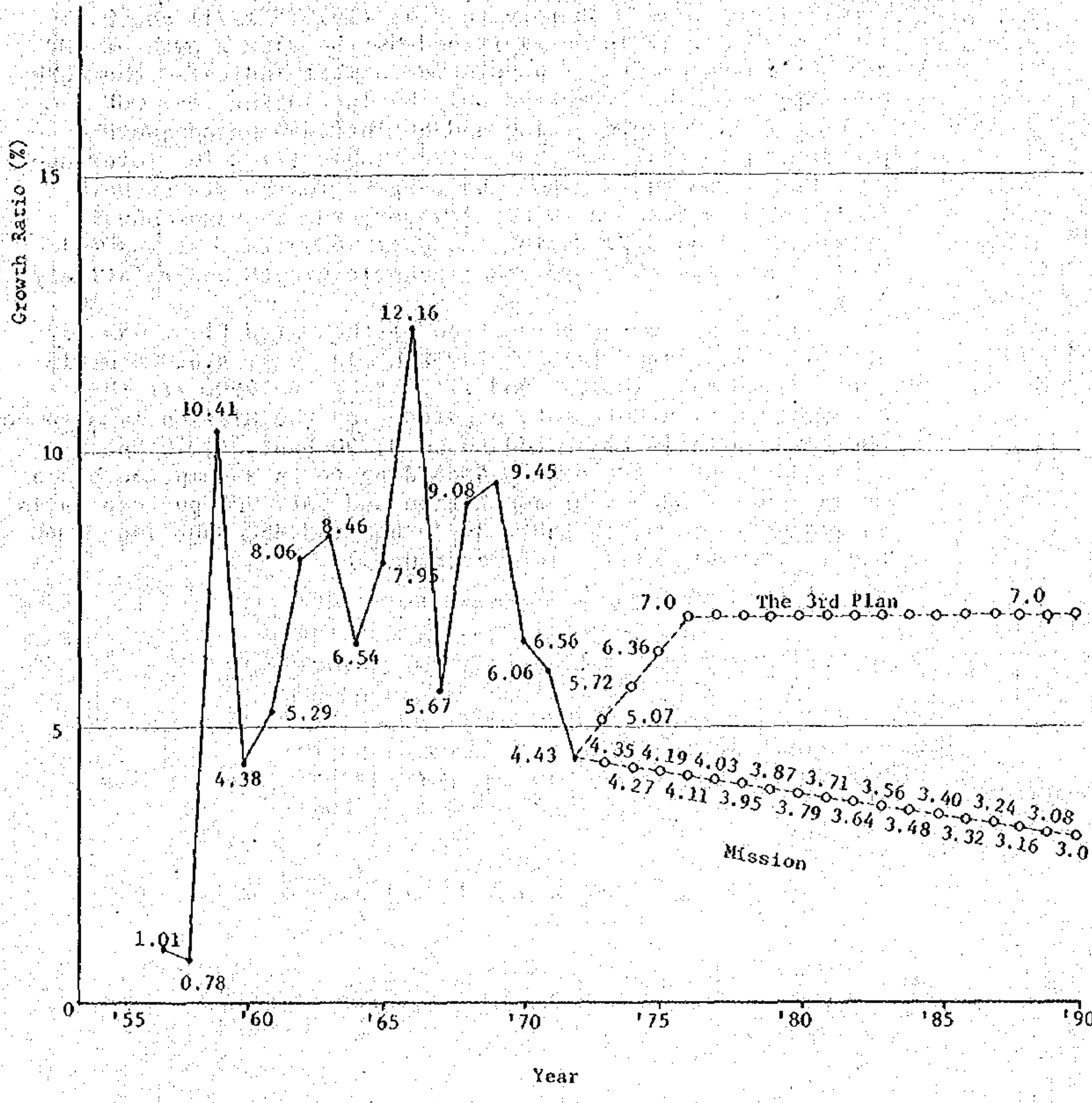


Fig. III-4 Growth Ratio of GNP

3) GNP per capita

GNP per capita was 2,180 Baht in 1960, 2,600 Baht in 1965, and 3,370 Baht in 1970, showing the average annual growth rate of 4.1% during the past 10 years. However, the growth rate dropped sharply to 2.4% (1970 ~ 1971) and 0.2% (1971 ~ 1972). This is explained by the slow growth of GNP and the sharp growth of population. This indicates that GNP per capita can be increased only by increasing real GNP through expanded production and by introducing adequate population control measures. (See Table III-3 for reference.)

Under the Third Plan, the target growth rate of per capita GNP is 4.5% in 1976. However, the average annual growth rate was 3.2% during the past 16 years. It was 4.1% during the past 10 years when economic growth was relatively rapid.

According to the assumption of the Third Plan, GNP per capita is estimated to be 3,700 Baht in 1975, 4,610 Baht in 1980, 5,750 Baht in 1985 and 7,170 Baht in 1990. If the average annual growth rate predicted by the Mission is assumed, GNP per capita is estimated to be 3,790 Baht, 4,370 Baht, 4,940 Baht and 5,490 Baht. According to an assumption based on the past tendency of population and GNP, GNP per capita is estimated to be 3,560 Baht, 3,720 Baht, 3,850 Baht and 3,960 Baht. (See Fig. III-5 for reference.)

Results of Estimates

(Unit: ฿)

Year	Estimate		The Third Plan		Reference	
	GNP/Capita	Ratio to 1972	GNP/Capita	Ratio to 1972	GNP/Capita	Ratio to 1972
1972*	3,459	1,000	3,459	1,000	3,459	1,000
1975	3,560	1,029	3,700	1,070	3,790	1,096
1980	3,720	1,075	4,610	1,333	4,370	1,263
1985	3,850	1,113	5,750	1,662	4,940	1,428
1990	3,960	1,145	7,170	2,073	5,490	1,587

(Note)
1. The records are marked with * .
2. The growth rate of Fig. III-6 was assumed for the estimates.
3. The following four types of predictions can be made.
   1) Prediction based on the growth rate of GNP/Capita given by the Third Plan.
   2) Prediction based on the growth rate of GNP and population given by the Third Plan.
   3) Prediction based on the trend of GNP/Capita (Given in the table in the Reference column.)
   4) Prediction based on GNP and population estimated by the Mission.

   1) > 2) > 3) > 4)

   The prediction 4) was adopted for safety.

Table III-3 Transition of GNP per capita
(1962 price)

(Unit: ฿)

Year	(A) GNP/Capita	Growth Rate
1956	2,092	
1957	2,043	△ 2.34
1958	2,004	△ 1.91
1959	2,155	7.53
1960	2,183	1.30
1961	2,227	2.02
1962	2,322	4.27
1963	2,440	5.08
1964	2,491	2.09
1965	2,598	4.30
1966	2,806	8.01
1967	2,900	3.35
1968	3,062	5.59
1969	3,245	5.98
1970	3,370	3.85
1971	3,451	2.40
1972	3,459	0.23

△ shows minus

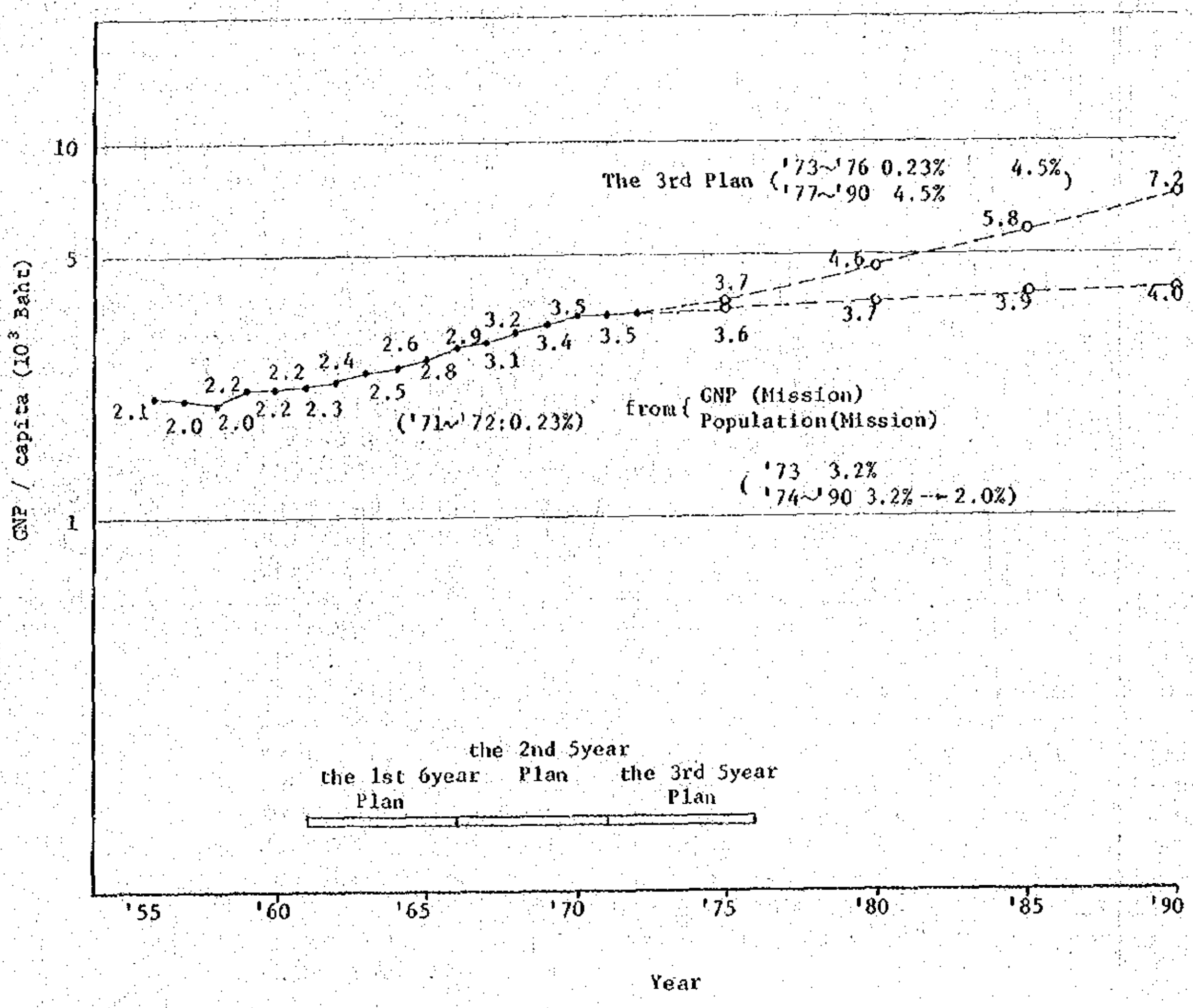


Fig. III-5 Tendency and Forecast of GNP Per Capita (1962 price)

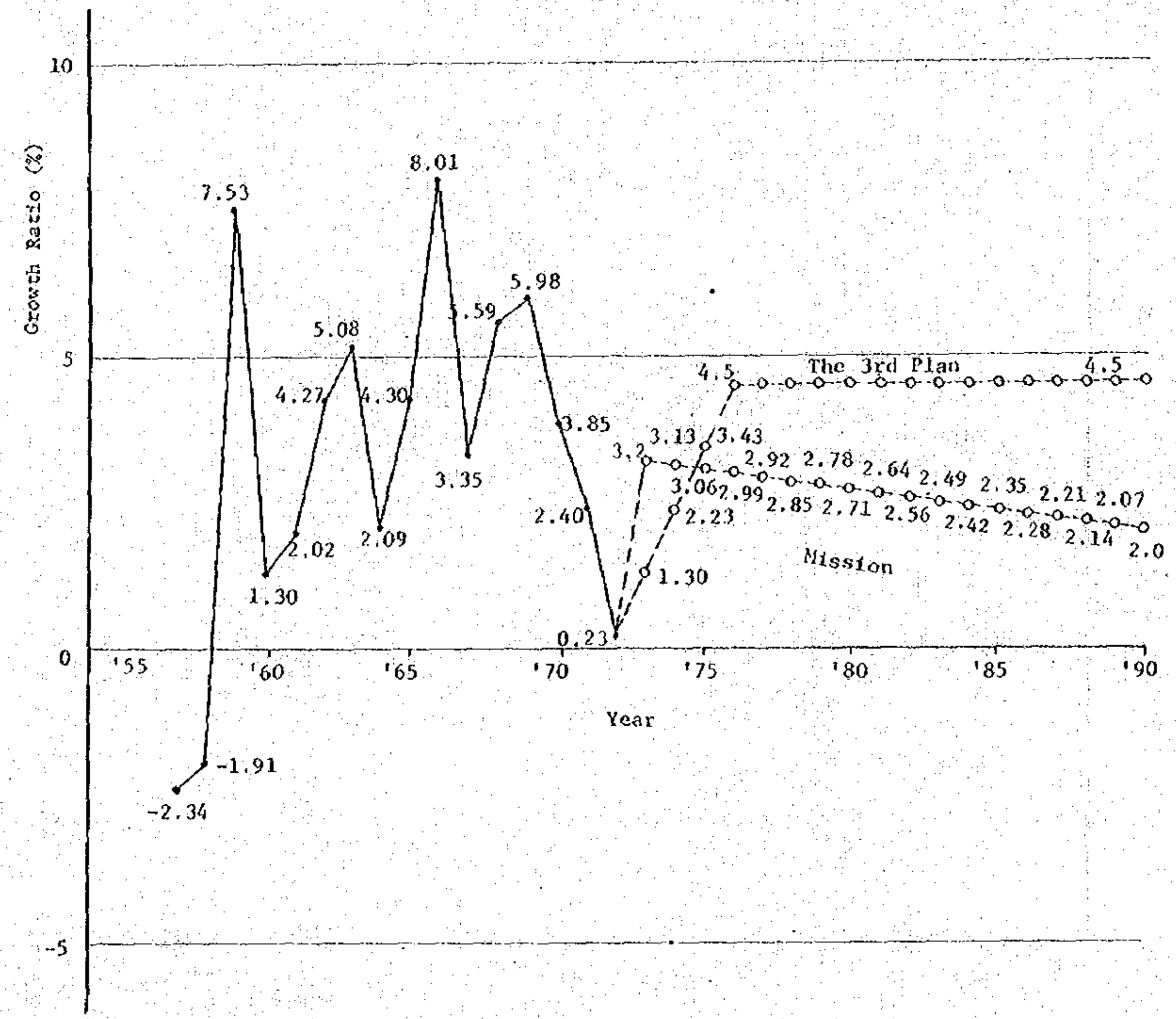


Fig. III-6 Growth Ratio of Per Capita GNP

On the basis of the above results, the economic frame of this project was set as shown in Table III-4.

Table III-4 Economic Frame

Economic index	Unit	1975	1980	1985	1990
Population	Million	42.2	49.1	56.4	64.1
GNP (1962 price)	Billion ฿	150.4	182.6	217.5	254.0
GNP per capita (1962 price)	Thousand ฿	3.6	3.7	3.9	4.0

(2) Estimated demand for energy

1) International comparision of domestic energy consumption

Study of the national income per capita and energy consumption per capita in various countries in 1967 and 1970 reveals positive relation in all of these countries. Positive relation is also found between the two obtained by such a cross section. In other words, energy consumption per capita is 2,000 ~ 10,000 kg (in terms of coal) in those countries where NI/capita is above 1,000 U.S.$. The energy consumption per capita is between 100 kg and 1,000 kg in those countries where NI/capita is below 100 U.S.$. In Thailand, NI/capita was 150 U.S.$ and the energy consumption was 173 kg/capita in 1967. They rose to 172 U.S.$ and 245 kg/capita in 1970, respectively. These figures indicate that the energy consumption pattern in Thailand is an internationally standard development pattern. Therefore, an ordinary prediction technique will be applicable. (The national income is given in nominal price.) (See Table III-5 and Fig. III-7 for reference.) It is worth noting that energy consumption is increasing at an extremely high rate in Thailand compared with other countries.

Table III-5 Energy Consumption in Various Countries

Country	1967		1970	
	Consumption	National income	Consumption	National income
U.S.A.	9,880	3,661	11,144	4,274
Canada	8,061	2,609	9,072	3,214
United Kingdom	4,893	1,848	5,362	1,993
West Germany	4,171	1,844	5,112	2,698
France	3,163	2,105	3,794	2,606
Japan	2,253	1,050	3,210	1,658
Taiwan	724	255	925	364
Singapore	638	628	818	921
Korea	570	146	796	241
Philippines	229	255	279	342
Thailand	173	150	245	* 172
Indonesia	96	83	111	107

(Note) 1. Consumption is indicated by kg/capita by coal conversion.

2. National income is nominal price. It is indicated U.S.$/capita.

3. The figure marked with * shows per capita GNP converted by 21.0฿

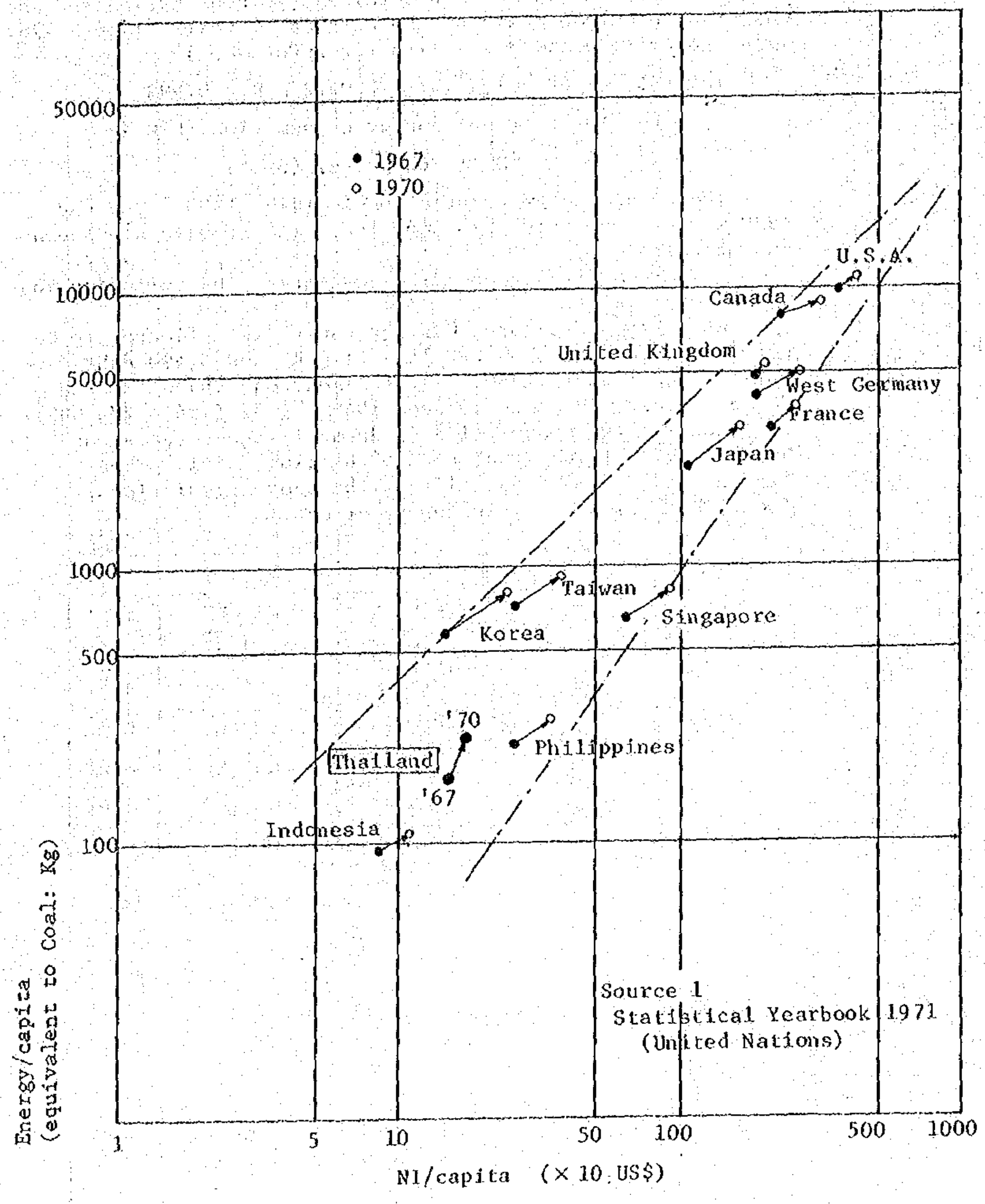


Fig. III-7 Energy Consumption Per Capita by Cross Section Data (1967 and 1970) according to NI Per Capita

2) Domestic total energy consumption

The correlation between total energy consumption and GNP was studied on the basis of the data of 14 years (1956 ~ 1969). (See Table III-6 and Fig. III-8 for reference.)

$$\log (Y) = 1.8323 \log (X) - 2.0322 \quad R = 0.998$$

$Y \times 10^{12}$: Total energy consumption (K-Cal)

$X \times 10^{9}$: GNP (1962 price) (Baht)

The total energy consumption in 1975, 1980, 1985 and 1990 was estimated by this equation. The results are shown in Table III-7.

With regard to these merco estimates, the following confirmation is given.

As discussed before, GNP per capita is estimated to be between 3,960 Baht (189 US$ 1$ = 21.0 ฿) and 5,490 Baht (261 US$) in Thailand in 1990. It is almost equivalent to the GNP per capita in Japan between 1949 ~ 1952 (194 ~ 278 US$). The total energy consumption in Japan in those years was between 193 billion K-Cal and 288 billion K-Cal. These figures indicate the validity of the above prediction. (See Table III-8 ~ III-10 for reference.)

Table III-6 Transition of Energy Consumption

(Unit: 10^9 K-Cal)

Year	Inland Consumption	Petroleum Product	Indigenous Source	Foreign Source	Import Product
1954	3,084	895	-	-	895
1955	6,864	4,608	-	-	4,608
1956	10,548	8,289	-	-	8,289
1957	11,618	9,252	-	-	9,252
1958	11,964	9,460	-	-	9,460
1959	13,168	10,395	42	-	10,353
1960	14,649	11,799	56	-	11,743
1961	16,226	12,714	30	-	12,684
1962	18,910	15,526	15	-	15,511
1963	20,619	16,768	17	-	16,751
1964	25,558	20,444	20	3,515	16,909
1965	29,374	22,757	19	11,857	10,881
1966	33,544	26,808	26	17,812	8,970
1967	38,376	29,741	52	20,128	9,561
1968	48,232	39,243	60	24,040	15,143
1969	50,501	42,547	46	28,009	14,492
1970	59,700	48,700	100	36,500	12,100
1971	66,500	54,400	100	42,400	11,900
1972	72,000	59,000	100	47,800	11,100

(Note) Petroleum products include L.P.G., but do not include gas.

Table III-7 Results of Estimates

(Unit: 10^9 K-Cal)

Year	Inland Consumption	Petroleum Product	Indigenous Source	Foreign Source	Import Product
1975	90,630	74,860	150	63,630	11,080
1980	129,240	103,000	210	92,700	10,090
1985	178,050	145,470	290	136,740	8,440
1990	236,760	196,980	390	187,130	9,460

(Reference)

Table III-8 Comparison of Japan and Thailand by GNP per Capita

	Year	GNP (nominal)	Deflater	GNP (real)	Population	GNP per Capita	US$
Japan	1949	billion yen 3,375	59.16	billion yen 5,705	thousand 81,780	yen 69,760	$ 194
	1950	3,947	58.20	6,782	83,200	81,514	226
	1951	5,444	71.05	7,662	84,541	90,631	252
	1952	6,051	70.57	8,574	85,808	99,921	278
Thailand	1990					3,960 ~ 5,490	189 ~ 261

(Note) 1. 1 US$ = 360 yen, 1962 real price is used for Japan.

2. 1 US$ = 21฿

Table III-9 Petroleum Consumption in Japan (1950, 1951)

	Imported Crude Oils	Production of Petroleum Products	Imported Petroleum Products
1950	10^3 KL 1,541	10^3 KL 1,498	10^3 KL 796
		(65.3)	(34.7)
1951	2,844	2,713	1,160
		(70.0)	(30.0)

(Note) Lubricants are excluded.

Table III-10 Share of Demand and Supply of Energy (Japan)

Year	Division	Total	Electric Power	Coal	Lignite	Petroleum	Natural Gas	Charcoal	Firewood
1949	Supply	100.0	24.6	56.4	0.9	9.3	0.1	3.2	5.5
	Demand	100.0	28.9	51.6	1.0	9.3	0.1	3.3	5.8
1950	Supply	100.0	26.1	53.6	0.9	10.9	0.1	3.0	5.4
	Demand	100.0	30.5	48.8	1.0	10.7	0.1	3.2	5.7
1951	Supply	100.0	29.7	48.8	0.8	12.5	0.1	2.8	5.3
	Demand	100.0	34.3	44.2	0.9	12.1	0.1	2.9	5.5
1952	Supply	100.0	25.5	51.7	0.8	14.1	0.1	2.6	5.2
	Demand	100.0	31.5	46.1	0.9	13.5	0.1	2.6	5.3

(Note) The share was calculated by calory conversion.

Calory conversion 9×10^{6} K-Cal/KL

1950 $(1{,}498 + 796) \times 10^{3}$ KL $\times (9 \times 10^{6}$ K-Cal/KL$) = 20.6 \times 10^{12}$ K-Cal

1951 $(2{,}713 + 1{,}160) \times 10^{3}$ KL $\times (9 \times 10^{6}$ K-Cal/KL$) = 34.9 \times 10^{12}$ K-Cal

Estimated total calories

1954 $20.6 \times 10^{12} \div 0.107 = 192.5 \times 10^{12}$ K-Cal

1955 $34.9 \times 10^{12} \div 0.121 = 288.4 \times 10^{12}$ K-Cal

They are almost equal to the estimate for 1990 (236.8×10^{12} K-Cal) in Thailand.

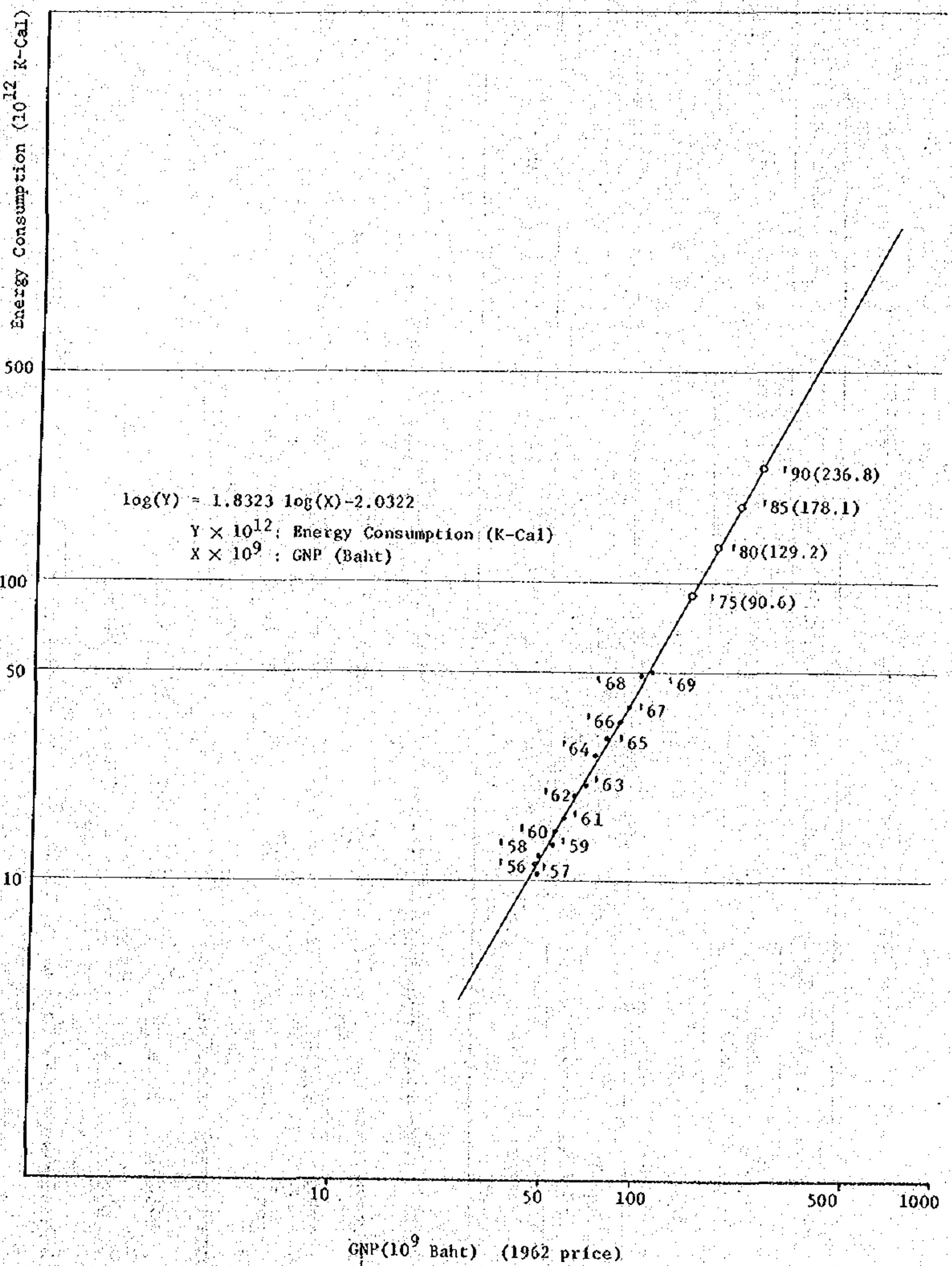


Fig. III-8 Relation between GNP and Energy Consumption

3) Petroleum product energy consumption

The correlation between GNP and petroleum product energy consumption was obtained. (See Table III-6 and Fig. III-9 for reference.)

$$\text{Log (Y)} = 1.8613 \log (X) - 2.1806 \qquad R = 0.997$$

$Y \times 10^{12}$: Petroleum energy consumption (K-Cal)

$X \times 10^{9}$: GNP (1962 price) (Baht)

The petroleum energy consumption in Thailand in 1975, 1980, 1985 and 1990 was estimated from this equation. The following table shows the estimates. It reveals that the ratio of petroleum energy consumption to total energy consumption is 82.2%, 82.6%, 83.1% and 83.4% in these years.

Petroleum energy consumption

Year	Petroleum energy (10^9 K-Cal)
1975	74,480
1980	106,810
1985	147,890
1990	197,540

It must be pointed out that the difference between total energy and petroleum energy must be filled by electric power energy (hydraulic and atomic) and lignite energy etc. Therefore, the extent of the dependence or petroleum energy is largely determined by the Thai Government's policy. It must establish energy policy for stable energy supply and determine adequate distribution of energy sources within this policy.

The Investigation Mission assumed the ratio of energy consumption in consideration of NEA's energy policy. (See Table III-11 and Fig. III-10.) It estimated petroleum consumption on the basis of this assumption. The results are shown in Table III-7.

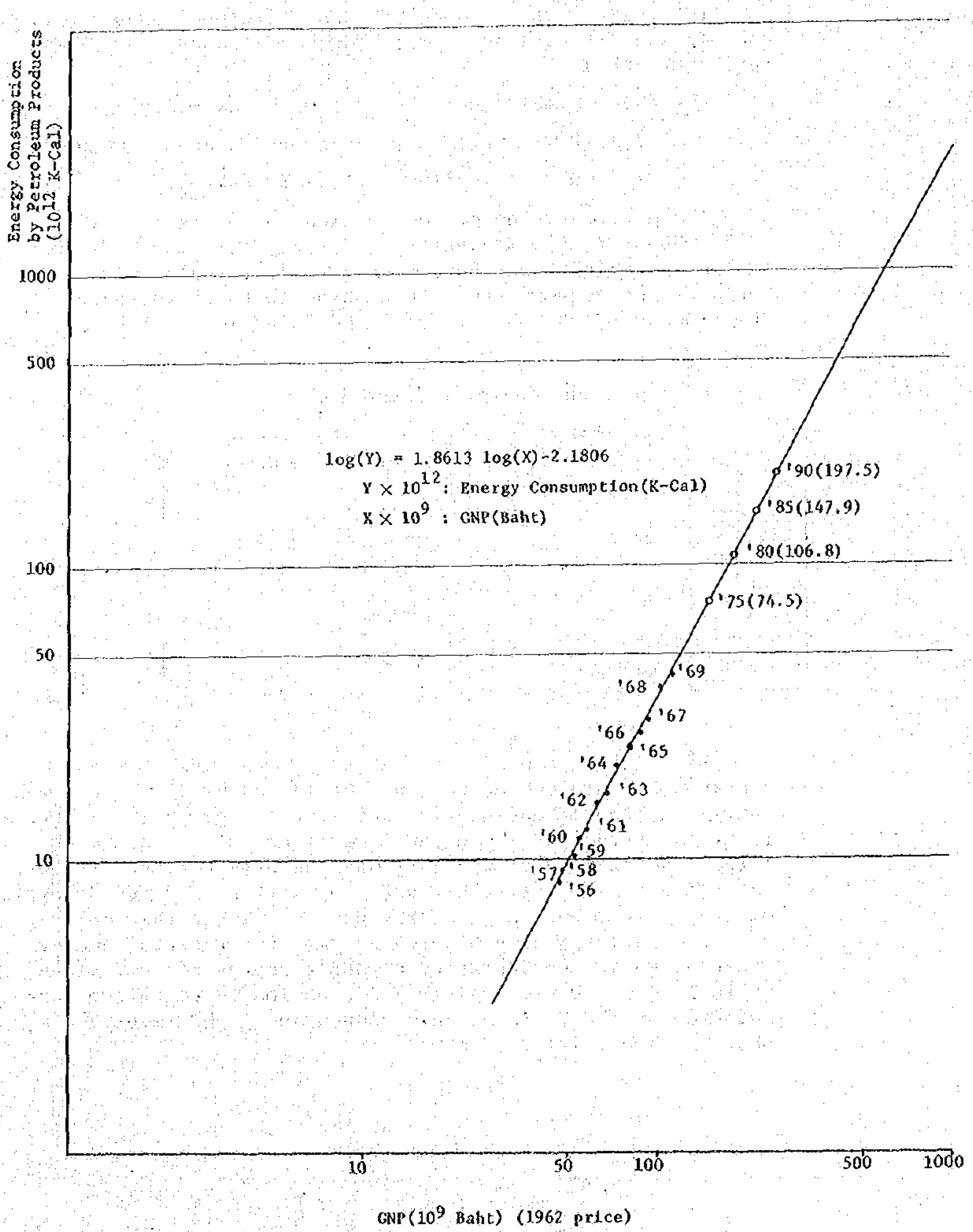


Fig. III-9 Relation between GNP and Energy Consumption by Petroleum Products

Table III-11 Share of Energy Sources

(Unit: %)

Year	Domestic demand	Petroleum Products		Domestic Crude oils	Imported crude oils	Imported products
1954	100.0	29.02	100.0			100.0
1955	100.0	67.13	100.0			100.0
1956	100.0	78.58	100.0			100.0
1957	100.0	79.64	100.0			100.0
1958	100.0	79.07	100.0			100.0
1959	100.0	78.94	100.0	0.4		99.6
1960	100.0	80.54	100.0	0.5		99.5
1961	100.0	78.36	100.0	0.2		99.8
1962	100.0	82.10	100.0	0.1		99.9
1963	100.0	81.32	100.0	0.1		99.9
1964	100.0	79.99	100.0	0.1	17.2	82.7
1965	100.0	77.47	100.0	0.1	52.1	47.8
1966	100.0	79.92	100.0	0.1	66.4	33.5
1967	100.0	77.50	100.0	0.2	67.7	32.1
1968	100.0	81.36	100.0	0.1	61.3	38.6
1969	100.0	84.25	100.0	0.1	65.8	34.1
1970	100.0	81.60	100.0	0.2	75.0	24.8
1971	100.0	81.80	100.0	0.2	78.0	21.8
1972	100.0	81.90	100.0	0.2	81.0	18.8
1975	100.0	82.60	100.0	0.2	85.0	14.8
1980	100.0	79.80	100.0	0.2	90.0	9.8
1985	100.0	81.70	100.0	0.2	94.0	5.8
1990	100.0	83.20	100.0	0.2	95.0	4.8

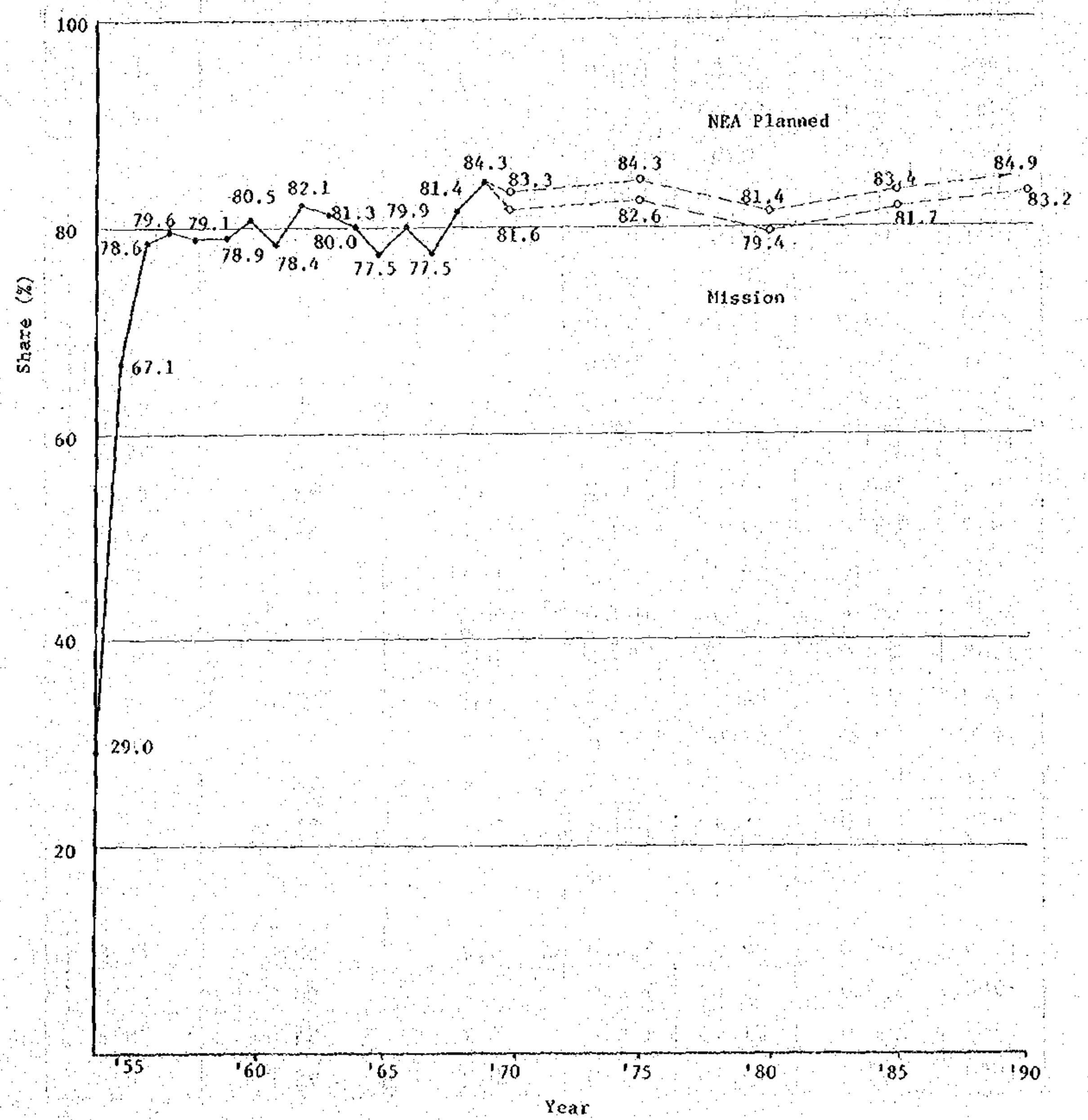


Fig. III-10 The Share of Petroleum Products in Total Energy Consumption

A study on the sources of petroleum energy reveals that the share of domestic crude oils, the share imported crude oils and the share imported petroleum products have been changing, as shown in Table III-11. For these estimates, the share of imported crude oils is assumed to be 95.0%, that of imported petroleum products as 4.8% and that of domestic crude oils as 0.2% for 1990 according to the share trend of Table III-11. Therefore, the petroleum energy consumption by imported crude oils in 1975, 1980, 1985 and 1990 will be as given in Table III-7.

4) Results of estimates

The demand for energy, the demand for petroleum product energy and the demand for imported crude oil energy in 1975, 1980, 1985 and 1990 in Thailand will be assumed as Table III-12.

Table III-12 Demand for Energy

(Unit: 10^{12} K-Cal)

Year	Domestic Energy Consumption	Petroleum Products		Share: Domestic Crude Oils		Share: Imported Crude Oils		Share: Imported Petroleum Products	
			%		%		%		%
1975	90.6 (100.0)	74.9 (82.6)	100.0	0.2	0.2	63.6	85.0	11.1	14.8
1980	129.2 (100.0)	103.0 (79.4)	100.0	0.2	0.2	92.7	90.0	10.1	9.8
1985	178.1 (100.0)	145.5 (81.7)	100.0	0.3	0.2	136.7	94.0	8.4	5.8
1990	236.8 (100.0)	197.0 (83.2)	100.0	0.4	0.2	187.1	95.0	9.5	4.8

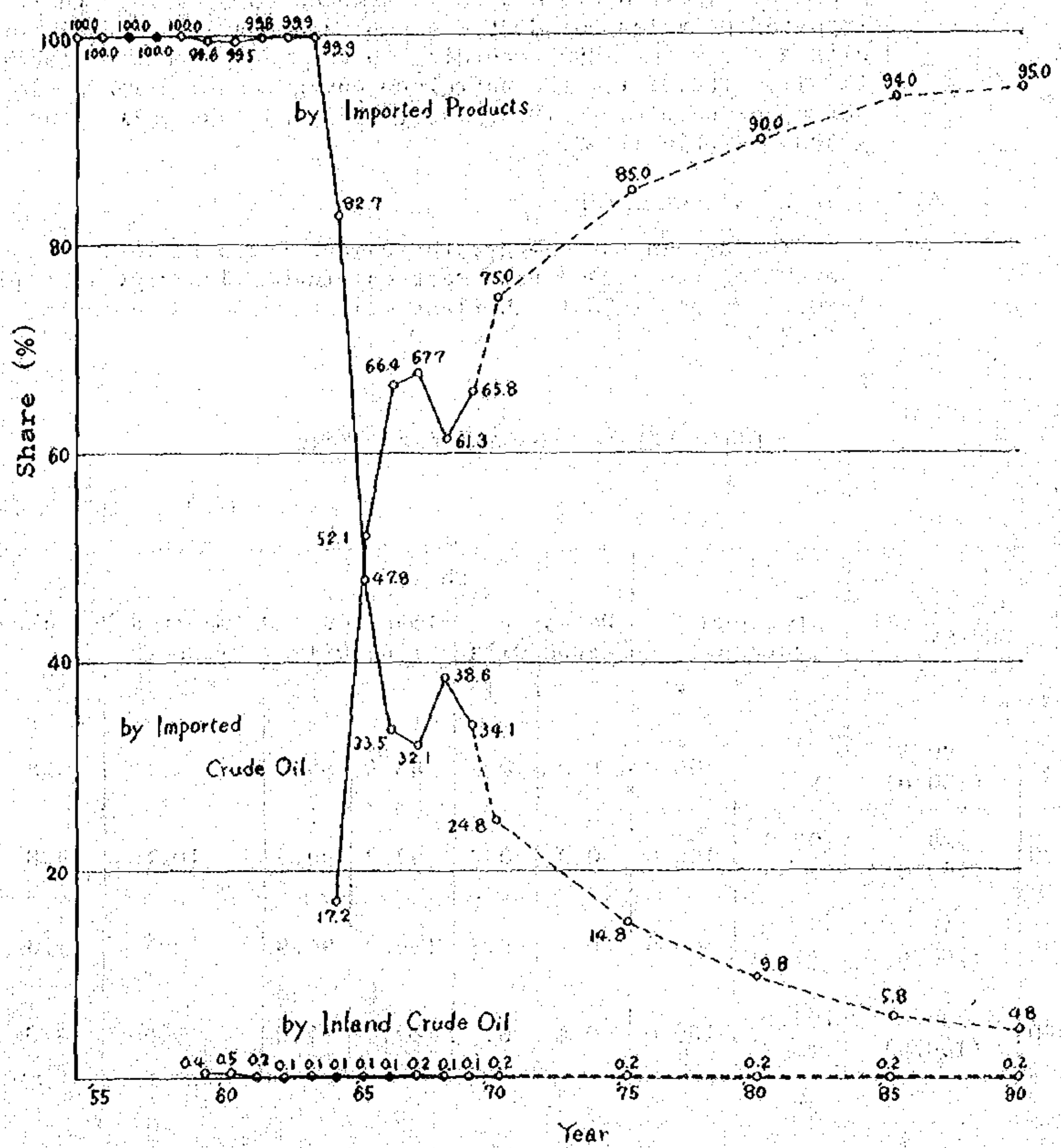


Fig. III-11 The Structure of Source in Petroleum Products
(by indigenous, foreign source and imported products)

(3) Macro estimate on import of crude oils

The relation between the quantity of imported crude oils and the energy of petroleum products depends on the share of various products. No fixed tendency is found from the transition of the energy conversion rate of crude oils in Thailand. (See Table III-13 and Fig. III-12.) For the present estimate, 7230 K-Cal/L will be adopted.

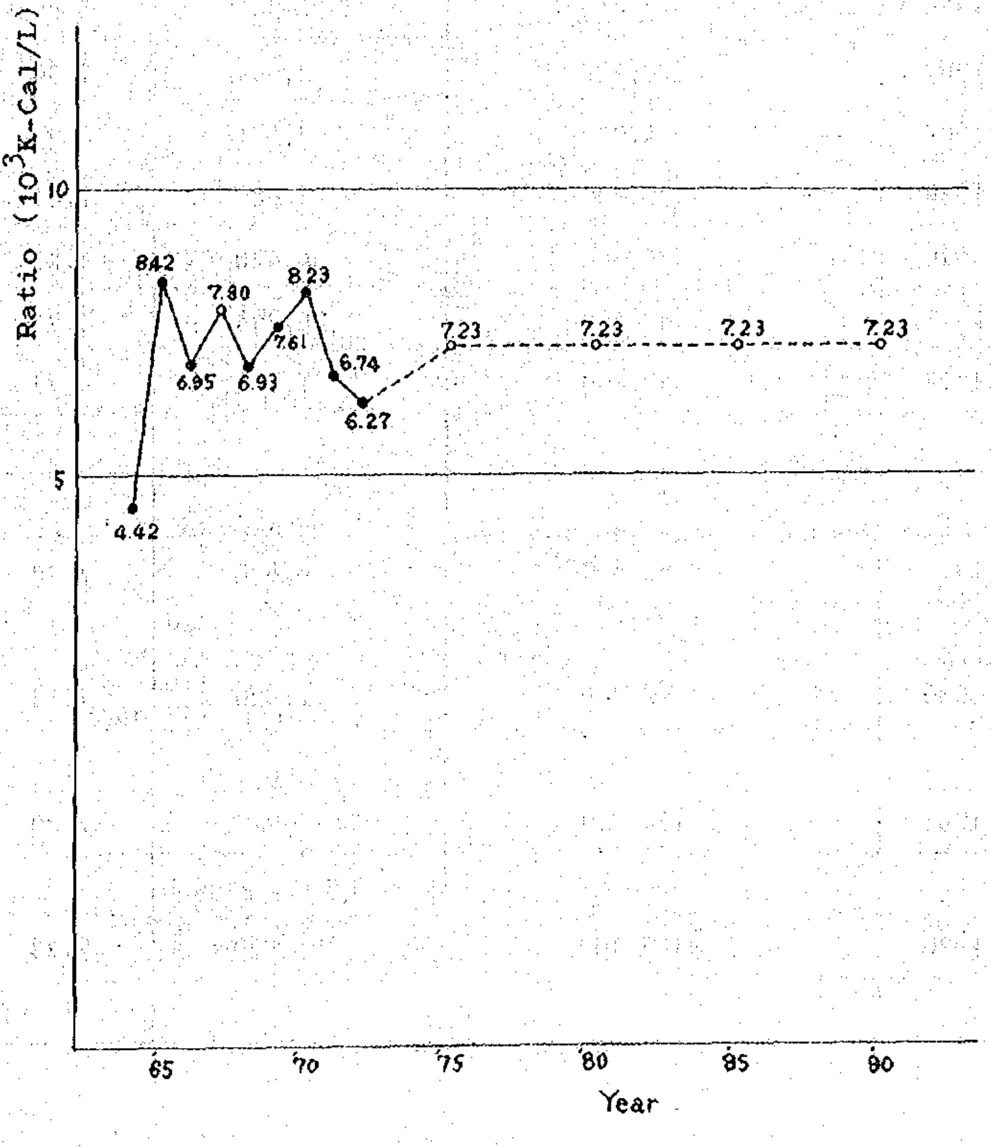


Fig. III-12 Energy Conversion Rate

Table III-13 Energy Conversion Rate

(Unit: 10^9 K-Cal, thousand KL, 10^6)

Year	(A) Energy Consumption by Imported Oil	(B) Imported Crude Oil	(A)/(B)
1964	3,515	795	4.42
1965	11,857	1,409	8.42
1966	17,812	2,564	6.95
1967	20,128	2,549	7.90
1968	24,040	3,471	6.93
1969	28,009	3,680	7.61
1970	36,500	4,420	8.23
1971	42,400	6,294	6.74
1972	47,800	7,624	6.27
1975	63,630	8,800	7.23
1980	92,700	12,820	7.23
1985	136,740	18,910	7.23
1990	187,130	25,880	7.23

This energy conversion rate was used to convert the demand for energy by imported crude oils (obtained in (2)) into the quantity of crude oils. The results are shown below. (See Fig. III-13 for reference.)

Results of Estimates

(Unit: thousand KL)

Year	Quantity of Imported Crude Oils	Ratio to 1972	Annual Average Growth Rate Over 1972
1972*	7,620	1,000	-
1975	8,800	1,155	4.9%
1980	12,800	1,680	6.7%
1985	18,900	2,480	7.2%
1990	25,900	3,399	7.0%

(Note) The records are marked with * .

(For reference) Direct correlation between GNP and quantity of imported crude oils

Direct correlation between GNP and imported crude oils was used for the explanation of predictions in the interim report. The following estimates can be obtained from this result. (See Fig. III-13 for reference.)

1980 15.7 million KL

1990 38.2 million KL

However, this technique lacks precision, especially for long-range predictions. Therefore, the technique that was discussed previously was adopted for the present report.

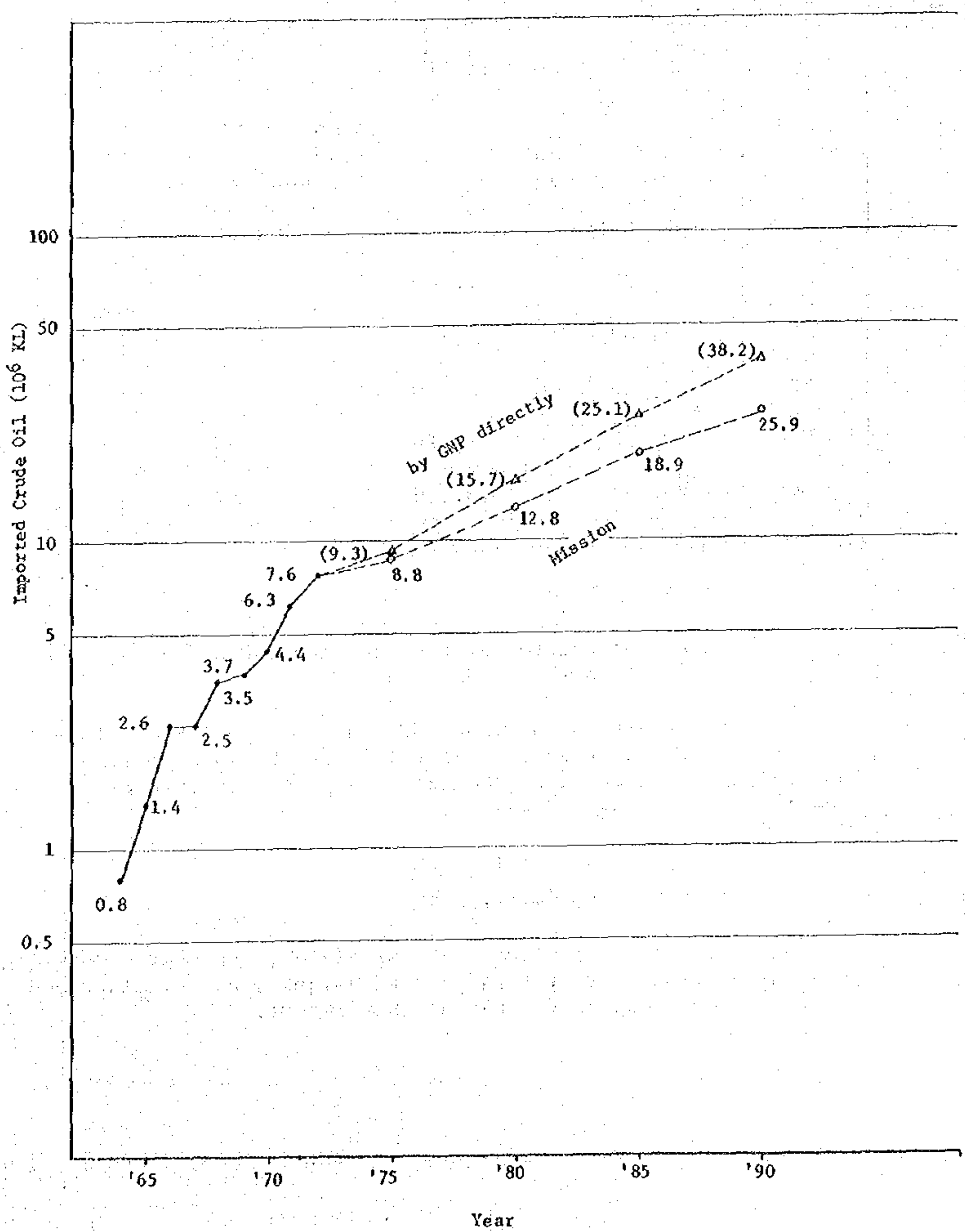


Fig. III-13 The Forecasting of Imported Crude Oil

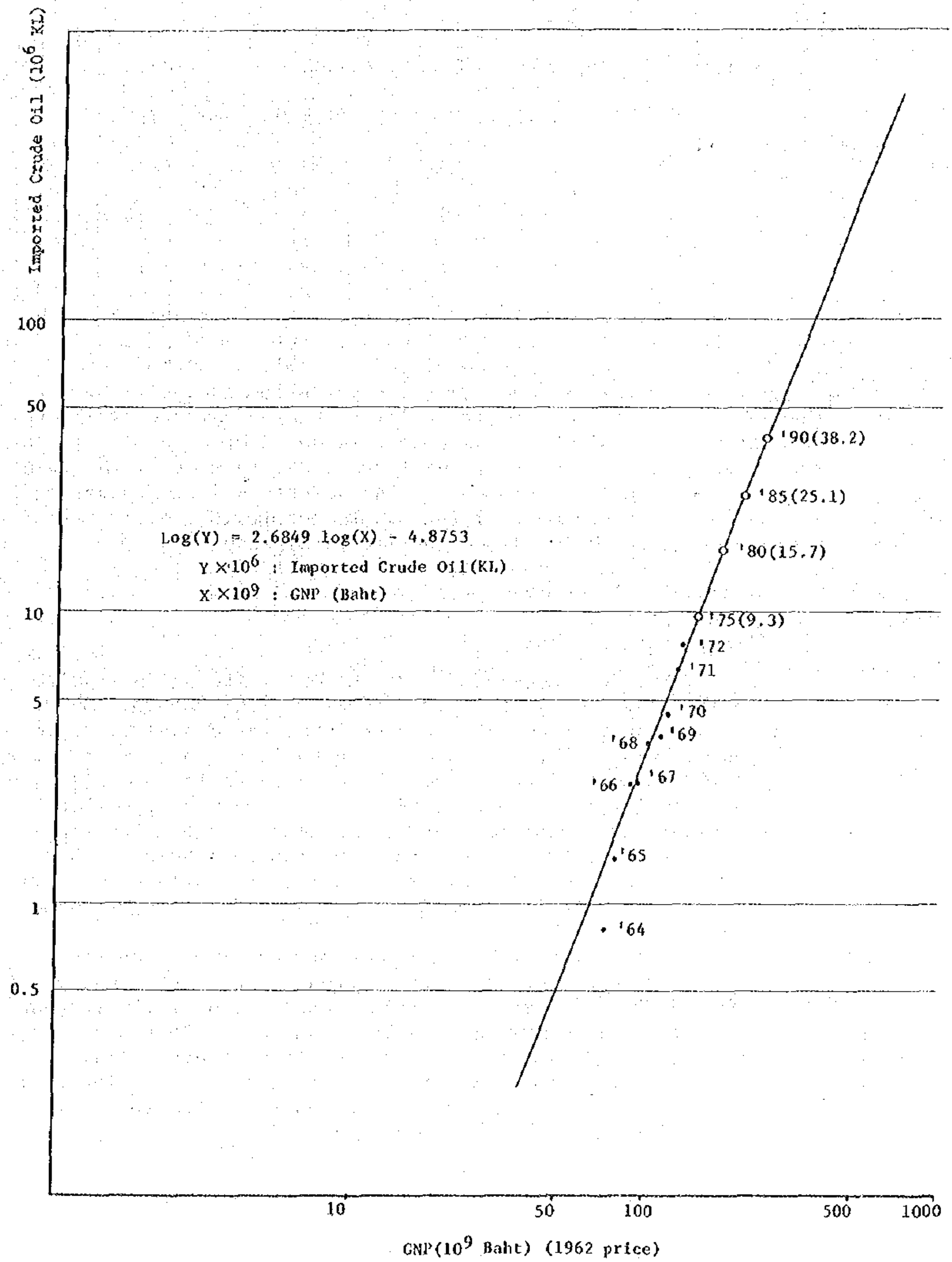


Fig. III-14 Relation between GNP and Imported Crude Oil

The estimates on imported crude oils made by ESSO and TORC (SHELL) are given below.

(Unit: million KL)	ESSO	SHELL	Ours
1975	9.3	9.7	8.8
1980	13.6	13.3	12.8
1985	19.1	16.7	18.9
1990	27.0	(not available)	25.9

The estimates of the two companies differ slightly from those of the mission. However, the mission's estimates seem adequate in consideration of refining capacity of petroleum related enterprises. According to some view, the petroleum energy's share of the demand for all the energies will decrease from the 1974 level. However, the dependence on petroleum is not decreasing in view of the international situation, the further development of the transportation by means of automobiles is expected and the industrialization policy is actively promoted. Therefore, the estimates of the Investigation Mission seem sufficiently safe.

(4) Trends of oil related enterprises

1) Oil refining capacity

ESSO, TORC and SUMMIT are the oil refining enterprises in Thailand. Their refining capacity is 65 thousand BPSD, 65 thousand BPSD and 35 thousand BPSD, respectively, at the end of 1973. TORC and SUMMIT plan to increase their capacity to 100 thousand BPSD in the near future, while ESSO plans to increase it to 65 thousand BPSD. A new refinery, called TIPCO, is to be constructed in the near future. Its final refining capacity will be about 100 thousand BPSD.

In sum, the oil refining capacity of Thailand is to rise from the current level of 165 thousand BPSD to 260 thousand BPSD by 1980.

Currently, Thailand has no petro-chemical industry. According to unconfirmed information, a petro-chemical plant (called TPC) with annual ethylene production of 200 thousand tons is to be constructed in Thailand in 5 ~ 10 years. Annual ethylene production of 200 thousand tons is equivalent to crude oil refining capacity of 100 thousand tons. Therefore, oil refining capacity must be increased by 1985 for petrochemical industry. (See Table III-14 for reference.)

Table III-14 Trends of Petroleum Related Enterprises

Year	Oil refining capacity (thousand BPSD)							Import of crude oils (thousand KL)
	ESSO	TORC	SUMMIT	TIPCO	TPC	Others	Total	
1974	35	65	65	0	0	0	165	8,860
1975	35	65	65	0	0	0	165	8,800
1980	65	65	80	50	0	0	260	12,800
1985	65	80	100	80	50	0	375	18,900
1990	65	100	100	100	100	50	515	25,900

According to the Mission's survey, the expansion plans of the oil related enterprises almost coincide with the estimates until 1980, as Table III-14 shows, indicating the adequacy of the predictions. However, the enterprises' behavior after 1985 is unknown. New expansion of several thousand BPSD and that of 50 thousand BPSD will be necessary in 1985 and 1990, respectively. Such expansions seem essential for meeting the demand for energy in Thailand, regardless of the policies of the existing enterprises and a new enterprise.

2) Participating enterprises and amount of crude oils handled by Sri Racha Sea Berth

The amount of crude oils to be handled by Sri Racha Sea Berth depends on the enterprises that participate in this project. The following four plans are set for this plan.

X Plan - SUMMIT, TIPCO and TPC participate.

Y Plan - ESSO, TORC, SUMMIT and TIPCO participate.

Z Plan - ESSO, TORC, SUMMIT, TIPCO and TPC participate.

W Plan - ESSO, TORC, SUMMIT, TIPCO, TPC and other enterprises required for obtaining the refining capacity equal to macro estimates participate.

Table III-15 and Fig. III-15 show the amount of crude oils to be handled by the Sea Berth under these plans.

Table III-15 Crude Oils to be handled by Sea Berth

(Unit: thousand KL)

Item / BPSD / Year	Oil Refinery and Petro-Chemical Industry						X Plan	Y Plan	Z Plan	W Plan	Imported Crude Oil	
	1 ESSO	2 TORC	3 SUMMIT	4 TIPCO	5 TPC	6 Others	③+④+⑤	①+②+③+④	①+②+③+④+⑤	①+②+③+④+⑤+⑥	Summation	Macro-esti-mation
Year	65×10^3 BPSD	100×10^3 BPSD	100×10^3 BPSD	100×10^3 BPSD	100×10^3 BPSD	153×10^3 BPSD	300×10^3 BPSD	365×10^3 BPSD	465×10^3 BPSD	620×10^3 BPSD		
1975	(35) 1,750	(65) 3,250	(65) 3,250	-	-	-	3,250	8,250	8,250	8,250	8,250	8,800
1980	(65) 3,250	3,250	(80) 4,000	(50) 2,500	-	-	6,500	13,000	13,000	13,000	13,000	12,800
1985	3,250	(80) 4,000	(100) 5,000	(80) 4,000	(50) 2,500	-	11,500	16,250	18,750	18,750	18,750	18,900
1990	3,250	(100) 5,000	5,000	(100) 5,000	(100) 5,000	(50) 2,500	15,000	18,250	23,250	25,750	25,750	25,900

(Note) The figures in the parentheses show oil refining capacity.
($\times10^3$ BPSD)

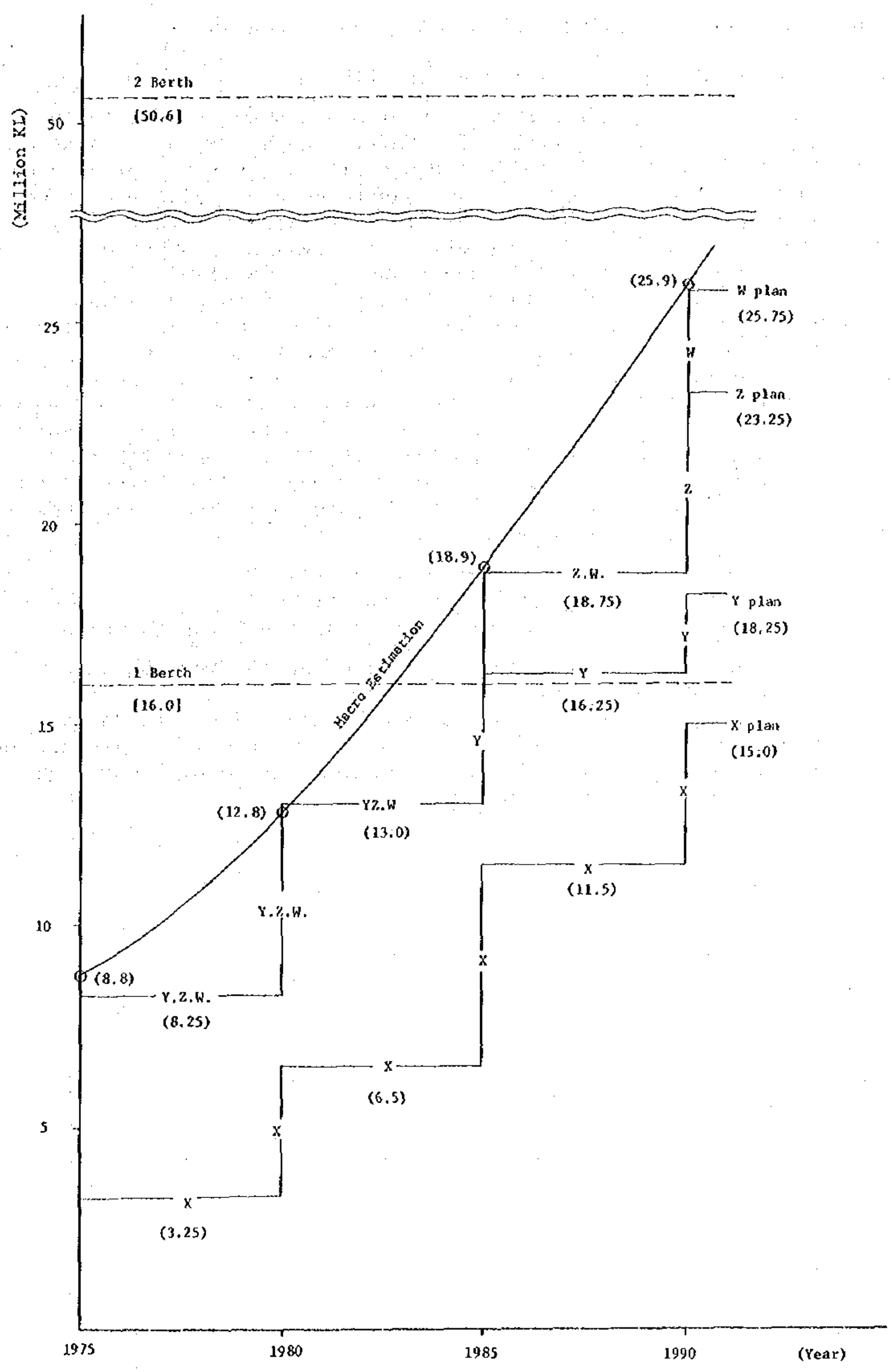


Fig. III-15 Crude Oils to be handled by Sea Berth

2. Types and stock of crude oils and petroleum products

(1) Classification of imported crude oils

An extremely large variety of crude oils are available, but all of them are a mixture of paraffin, naphthene and aromatic hydrocarbon etc. Individual crude oils are roughly classified into paraffin base crude oils, naphthene crude oils and mixed base crude oils. Crude oils of Middle East (Arabia, Iran, Iraq, Kuwait etc.) are mixed base crude oils. The typical properties of these three types of crude oils are shown in Table III-16.

Crude oils are occasionally classified into high sulfur type, medium sulfur type and low sulfur type on the basis of sulfur content. This classification is often necessary in those regions where de-sulfurization process and scale are important for preventing pollution by sulfurous acid gas. Crude oils of high pour point (Libya, Cabinda, Minas, Duri, Seria etc.) require heating or thermal insulation, a special tank must be used for them. Most of crude oils with high pour point belong to low sulfur type.

If several types of crude oils are to be imported, they must be stored in three groups.

A Group ... High sulfur crude oils
B Group ... Medium sulfur crude oils
C Group ... Low sulfur and high pour point crude oils

One tank can be shared by A Group and B Group by keeping the mixture rate below 10%.

Currently, all of the crude oils handled by Sri Racha Sea Berth come from Middle East. This situation will remain unchanged for quite some time. Neither low sulfur crude oils nor high pour point crude oils are imported.

Table III-16 Classification of Crude Oils and Typical Properties

Property \ Classification	Paraffin base crude oil	Naphthene base crude oil	Mixed base crude oil
Sulfur content	Usually small	Usually large	Medium
Gasoline content	Low octane number (34 ~ 53)	High octane number (55 ~ 70)	Low octane number Around 50
Kerosene content	Good	Heavy soat generation	Ordinary
Light oil content	Good (Cetane number 51 ~ 76)	Ordinary	Ordinary
Lubricant content	Good, high viscosity index (90 ~ 106), unsatisfactory at high temperature	Low viscosity index, good purifying property, low pour point	Ordinary
Wax content	Large, large dewaxing cost	Small, no need for dewaxing	Medium, large dewaxing cost
Asphalt	Not contained	Good	Ordinary
Origin	North America (Pensylvania)	North America (California State) U.S.S.R. (Baku)	Middle East
Paraffin hydrocarbon Naphthene hydrocarbon Aromatic hydrocarbon	45 ~ 97% 2 ~ 31% 3 ~ 31%	15 ~ 60% 38 ~ 76% 3 ~ 24%	25 ~ 79% 17 ~ 45% 3 ~ 29%

(2) Share of petroleum products

The following table shows the share of petroleum energy products that are consumed in Thailand. (1969). Diesel oil accounts for 48.6%, heavy oil accounts for 27.7%, benzine accounts for 12.6 %, fuel jet accounts for 6.3%, kerosene accounts for 4.1% and LPG accounts for 0.7%. (See Table III-17 for reference.)

In other words, the fuel oils (diesel oil and benzine) for transportation (automobiles, small ships etc.) account for more than 60%. Naphtha, which is a raw material for petro-chemistry, has no share. A study of the trend reveals that the share of heavy oils and LPG is increasing sharply.

The large consumption of diesel oil and benzine especially for the transportation by means of automobiles is accounted by the sharp increase of motor vehicles. (See Table III-18 for reference.) During the five years between 1965 and 1970, the number of buses and trucks (including vans) increased from 76 thousands to 146 thousand (190%), while that of passenger cars increased from 67 thousands to 213 thousands (321%) and the number of motor cycles increased from 105 thousands to 334 thousands (320%). It is assumed that such large increases took place in Bangkok and other urban districts. Therefore, the future development of regional cities and the improvements of inter-city roads will bring about further increases.

Heavy oils are used as industrial fuels. The industrial production of Thailand has increased sharply. It rose from the 1960 level of 7.3 billion ฿ to 13.8 billion ฿ in 1966 and 24.4 billion ฿ in 1972. For this reason, the consumption of heavy oils has been increasing sharply. (See Table III-19 for reference.)

Heavy oils are partly used for thermal power generation. Since Thailand has large potential water resources for water power generation, the consumption of heavy oils may change in the future according to the government's energy policy.

No naphtha is currently produced because of the absence of petro-chemical industry. In European and American countries and in Japan, naphtha production is important since plastic products etc. are used instead of expensive wooden products because of poor forestry resources. Thailand has had no need for petro-chemical industry since agricultural and forestry products are sufficiently available. For example, jute bags are used for packing in Thailand. However, petro-chemical products will become popular in the future along with rises of personnel expenses, developments of mass production and improvements of living standard. Naphtha production will be started accordingly. The consumption and the origin of petroleum products in Japan are shown as reference. (See Table III-20 for reference.)

Table III-17 Transition of Energy Consumption by Oil Categories

(Unit: 10^9 K-Cal)

Year	Banzine	%	Kerosene	%	Diesel	%	Fuel Jet	%	Heavy Oil	%	LPG	%	Total	%
1954	425	47.5	47	5.2	423	47.3	0		0		0		895	100.0
1955	1,762	38.2	934	20.3	1,912	41.5	0		0		0		4,608	100.0
1956	2,725	32.9	1,081	13.0	2,669	32.2	0		1,814	21.9	0		8,289	100.0
1957	3,295	35.6	957	10.3	3,050	33.0	0		1,950	21.1	0		9,252	100.0
1958	3,083	32.6	1,032	10.9	3,769	39.8	0		1,576	16.7	0		9,460	100.0
1959	3,587	34.5	1,124	10.8	3,673	35.3	0		2,011	19.4	0		10,395	100.0
1960	4,242	36.0	1,286	10.9	4,976	42.2	38	0.3	1,257	10.6	0		11,799	100.0
1961	4,215	33.2	1,189	9.4	4,647	36.5	13	0.1	2,650	20.8	0		12,714	100.0
1962	4,434	28.6	1,329	8.5	5,677	36.6	437	2.8	3,649	23.5	0		15,526	100.0
1963	4,541	27.1	1,431	8.5	6,503	38.8	50	0.3	4,243	25.3	0		16,768	100.0
1964	4,546	22.2	1,037	5.1	8,505	41.6	1,193	5.8	5,153	25.2	10	0.1	20,444	100.0
1965	3,297	14.5	616	2.7	9,800	43.1	5,113	22.5	3,899	17.1	32	0.1	22,757	100.0
1966	4,911	18.3	860	3.2	12,312	45.9	3,166	11.8	5,498	20.5	61	0.3	26,808	100.0
1967	5,146	17.3	1,295	4.3	13,986	47.0	2,307	7.8	6,897	23.2	110	0.4	29,741	100.0
1968	5,047	12.9	1,628	4.1	20,064	51.1	2,572	6.6	9,712	24.7	220	0.6	39,243	100.0
1969	5,348	12.6	1,747	4.1	20,680	48.6	2,688	6.3	11,768	27.7	316	0.7	42,547	100.0

Table III-18 Transition of number of motor vehicles

(Unit: vehicle)

Classification / Year	Bus	Van & Truck	Passenger Car	Motor Cycle
1964	9,099	55,108	14,897	61,106
1965	17,638	58,098	67,261	105,379
1966	17,256	80,389	90,923	159,168
1967	17,662	81,875	115,394	212,808
1968	17,609	84,788	125,574	248,028
1969	17,369	102,385	167,714	282,915
1970	19,562	126,590	212,881	333,708

Table III-19 Industrial Production

(Unit: Million ฿)

Year	Production
1960	7,320
1966	13,795
1967	15,465
1968	16,594
1969	18,609
1970	20,622
1971	22,621
1972	24,400

Table III-20 Petroleum Products in Japan

	1969	1970	1971
	10^3KL	10^3KL	10^3KL
Volatile oils	18,385	20,803	22,595
Production	18,480	20,888	22,676
Import	10	2	2
Export	105	87	83
Naphtha	21,636	28,317	30,002
Production	17,148	21,860	24,965
Import	4,492	6,460	5,042
Export	4	3	5
Kerosene	12,126	17,369	17,351
Production	12,912	17,497	17,567
Import	-	61	156
Export	786	189	372
Light oil	10,243	12,030	13,076
Production	10,440	12,097	13,250
Import	-	-	-
Export	197	67	174
Jet fuel oil	915	1,033	1,133
Production	3,348	2,397	2,688
Import	-	-	-
Export	2,433	1,364	1,555
Heavy oil	91,608	110,991	120,735
Production	89,844	101,575	114,638
Import	11,395	16,832	16,493
Export	9,631	7,416	10,396
Total	154,913	190,543	204,892

(3) Stock

1) Quantity of Stock

It is obvious that petroleum is the basic resource for the economy of one country, as a source of energy and a raw material of petro-chemistry and that it is produced only in some countries. Reserving of crude oils is an important theme for every country in these days when international situation is extremely unstable. When crude oil supply becomes unstable because of charges in international situation, reserved crude oils must be depended on until a diplomatic solution is reached or domestic adjustments are made.

One country's stock is economically limited and extremely large reserve is difficult. Since the maximum reserve in Europe and America is 100 days and that in Japan is 35 days, 60 day reserve of crude oils and 25 ~ 30 day reserve of petroleum products must be assumed in the future. (See Table III-21 for reference.)

When crude oil supply becomes unstable due to a change of international situation, a diplomatic solution must be attempted and domestic energy consumption must be controlled at the same time. The time one country can spare for a solution depends heavily on its petroleum stock.

Table III-21 Current and Target Stock of Crude Oils in Europe and America

Country	Stock
England	Target stock: 90 days or more
France	100 days
West Germany	Crude oils: 75 days, products: 55 days
Italy	65 days

2) Current tank capacity and future expansion plan

The following table shows the capacity of the crude oil tanks for the refineries in Sri Racha District.

Division / Company	Capacity of the tank			Crude oil tanks for future installation			Total capacity
	Capacity of one tank	Number of tanks	Stock	Capacity of one tank	Number of tanks	Stock	
ESSO	KL 130,000	2	KL 260,000	KL 130,000	4	KL 520,000	KL 780,000
	100,000	1	100,000	-	-	-	100,000
	Sub-total	3	360,000			520,000	880,000
SUMMIT			320,000	Unknown	-	-	320,000
TORC	78,000	2	156,000	Unknown	-	-	
	55,000	2	110,000				
	34,000	4	136,000				
	27,600	4	110,400				
	Sub-total	12	512,400				512,400
Total		15	1,192,400		4	520,000	1,712,400

(Note) 1. ESSO's future plan was estimated from its plottage.

2. SUMMIT's and TORC's future plan is unknown. Since their plottage is small, they must purchase additional land for installing additional tanks.

3) Optimum use of current tanks of refineries as a part of reserving capacity

The capacity of the crude oil tanks at the refineries was given above. Their potential reserving capacity was calculated on the basis of the current oil refining capacity.

Division / Company	Refining capacity		Total capacity of all current crude oil tanks Kℓ	Stock (day)	Remark
	BPSD	Kℓ/day			
ESSO	35,000	6,000	360,000	30 days	Presence in tank is assumed to be 50%.
SUMMIT	65,000	10,000	320,000	16 days	The capacity of refinery's tanks is unknown.
TORC	65,000	10,000	512,000	25 days	
Total	166,000	26,000	1,192,000	Average 23 days	

The above table shows that each of the companies has the reserving capacity of 20 ~ 30 days (23 days on average), but this seems rather insufficient in view of the unstable crude oil supply and larger reserve in other countries.

4) Economic analysis

Crude oil handling cost can be lowered by raising the rate of use of tanks. However, oil reserving will lower the rate of use and raise costs. Further more, reserving of crude oil requires not only additional investments, but additional interest for the crude oil. Such burdens will give considerable difficulties to the management of petroleum enterprises. The country must pay for equipment construction costs and interests for reserved crude oils in view of the fact that stable petroleum supply in essential for national economy. Sufficient reserve will not be realized without governmental assistances.

Crude oil tanks are shared by two or more enterprises without serious problem in various countries.

Such a system can be easily realized in Sri Racha District with many petroleum enterprises. This will be an efficient reserving system.

IV. NATURAL CONDITIONS AND NAVIGATION CONDITIONS OF SRI RACHA REGION

IV. NATURAL CONDITIONS AND NAVIGATION CONDITIONS OF SRI RACHA REGION

1. Natural Conditions

(1) Meteorological conditions

This region is located at about 13° North Latitude. It belongs to the monsoon zone. SW wind prevails in summer (June ~ September), while NE wind prevails in winter (November ~ February). One year is divided into a rainy season (May ~ October) and a dry season (November ~ April). The amount of rainfall is about 1,200 mm ~ 1,400 mm/year. The highest atmospheric temperature is recorded in April. However, it remains relatively unchanged throughout a year. Monthly mean temperature is 26 ~ 30°C.

1) Wind

In the region around Sri Racha District, an observation station belonging to the Meteorological Department of the Ministry of Communications exists in Chonburi and Ko Sichang. The observation results are shown in Fig. IV-1 and Fig. IV-2. According to the data at Chonburi, S wind prevails in February ~ September, NE wind prevails in October ~ December and E wind prevails in January. The mean wind speed of S wind is slightly larger than that of NE wind. The mean wind speed was highest in March (3.7m/s.) S wind generally has high wind speed. The highest wind speed (31.5m/s.South) of the year was recorded in November.

According to the data at Ko Sichang, SW ~ W wind prevails in March ~ September and N ~ NE wind prevails in October ~ February. The mean wind speed is 3.5 ~ 4.5m/s. slightly larger than that at Chonburi. However, the maximum wind speed is generally smaller than that at Chonburi. The highest wind speed (20.0m/s.W) of the year was recorded in July. The differences between the data at these two places are attributable to the topographic effects, different obsevation period and the fact that Chonburi is located in the inland, while Ko Sichang is on an island.

According to TORC's data, mild wind conditions and 2 ~ 8m/s account for 12.8% and 82.6%, respectively, while 8.5 ~ 13.5m/s. and 13.5m/s. account for 4.4% and 0.2%, respectively. In other words, wind below 8m/s. accounts for 95.4%. In sum, wind conditions are satisfactory.

With regard to typhoons, the remaining force of a typhoon occasionally comes accross the Indo-China Peninsula as cyclone. However, they will hardly give any problem.

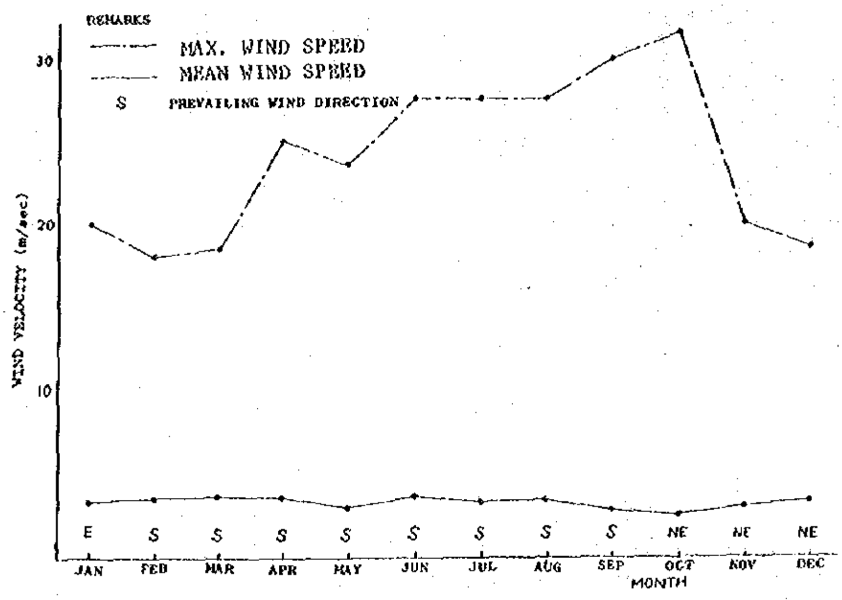


Fig. IV-1 Records of Wind (Chonburi)

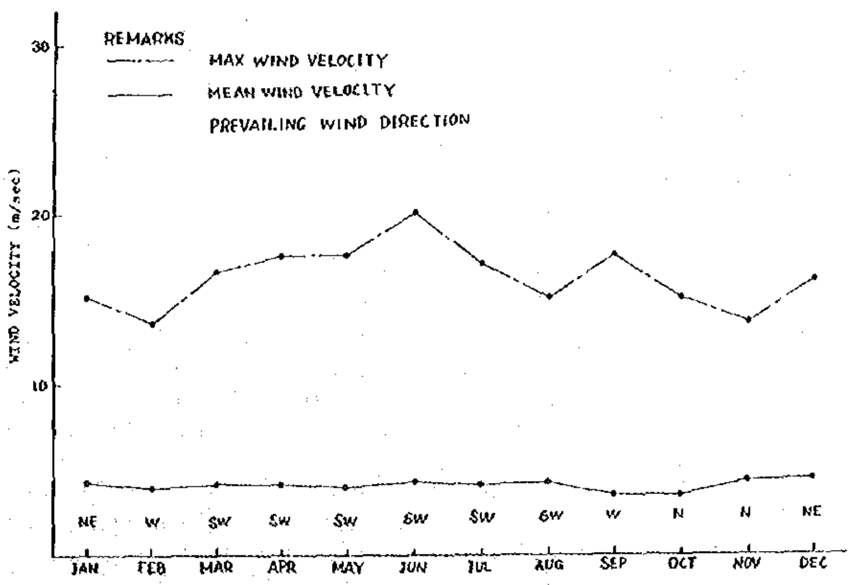


Fig. IV-2 Records of Wind (Ko Sichang) 1958 ~ 1970

2) Fog

Fog appears early in mornings in December ~ January, but disappears almost completely by eight o'clock. According to the data at Ko Sichang (Fig. IV-3), the lowest visibility at 7 o'clock is 7.3km recorded in February. Low visibility is recorded in October ~ April. Visibility is above 10km in the other months. The annual mean visibility is 11km.

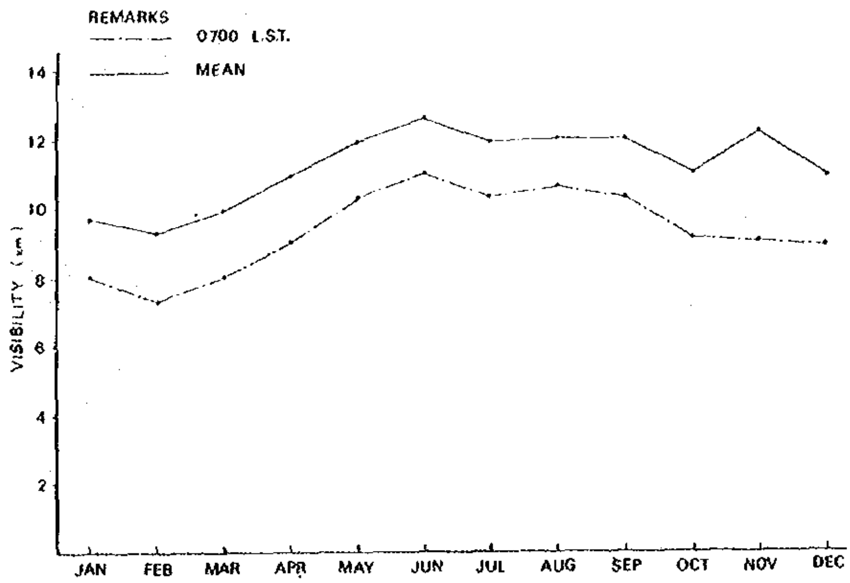


Fig. IV-3 Visibility (Ko Sichang) 1958 ~ 1970

3) Atmospheric temperature

Fig. IV-4 shows the atmospheric temperature change throughout a year. Mean atmospheric temperature shows little change. The lowest (26.3°C) was recorded in January and the highest (30.1°C) was recorded in April. The annual mean air temperature is 28.2°C. The mean maximum air temperature is lowest (29.9°C) in December and January and highest (33.3°C) in April. The mean minimum air temperature is lowest (22.7°C) in January and highest (27.0°C) in April. The maximum ~ minimum difference is 5 ~ 7°C.

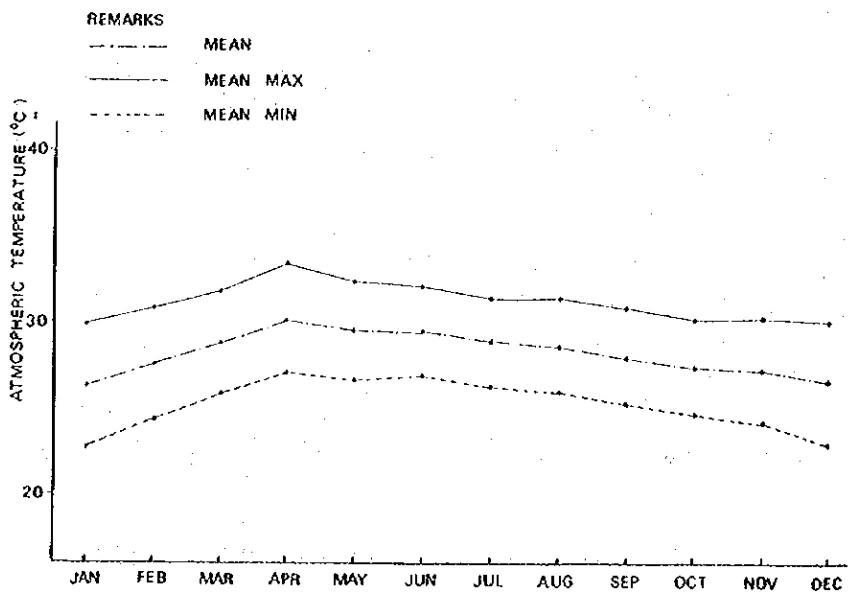


Fig. IV-4 Atmospheric Temperature (Ko Sichang) 1958 ~ 1970

4) Rainfall

Fig. IV-5 shows the mean rainfall and the mean number of rainy days. The data on the number of rainy days, show an obvious distinction between a rainy season and a dry season. The number of rainy days exceeds 15 dsys/month in May ~ October, except June (11.8 days/month). September has the largest number of rainy days (17.9 days/month). On the other hand, the number of rainy days is 6 days/month or less in November ~ April. January has the smallest number of rainy days (1.3 days/month). The data on the amount of rainfall also show a similar tendency. September has the largest amount of rainfall (304.5 mm/month), while January has the smallest amount of rainfall (5.7 mm/month). The annual mean number of rainy days is 114.2 days and the annual mean rainfall is 1235.0mm.

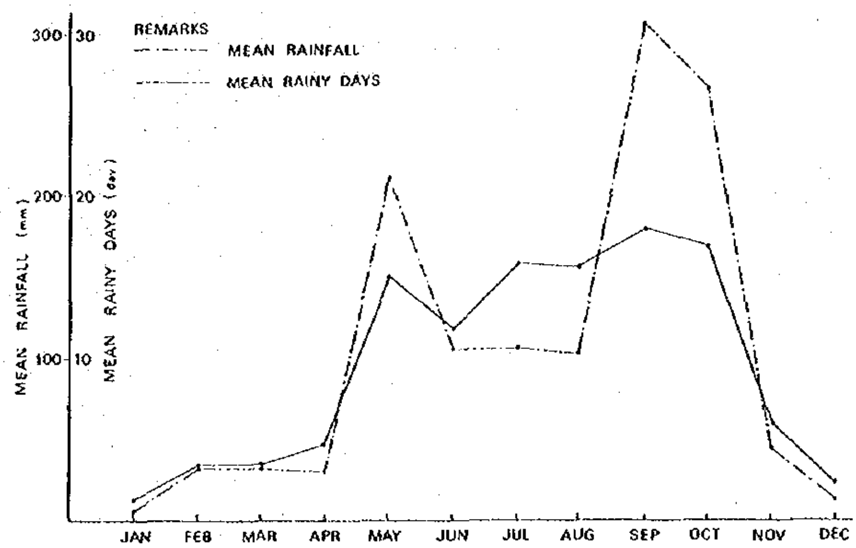


Fig. IV-5 Rainfall and Rainy Days
(Ko Sichang) 1958 ~ 1970

5) Thunderstorm

Thunderstorms in this region are said to be extremely heavy. Fig. IV-6 shows the number of days with thunderstorm. It reveals that thunderstorms are frequently recorded in April ~ May and September ~ October, namely, at monsoon changing. A thunderstorm visits this region on 108 days in one year. Since thunderstorms restrict outdoor works, they must be considered in a work schedule.

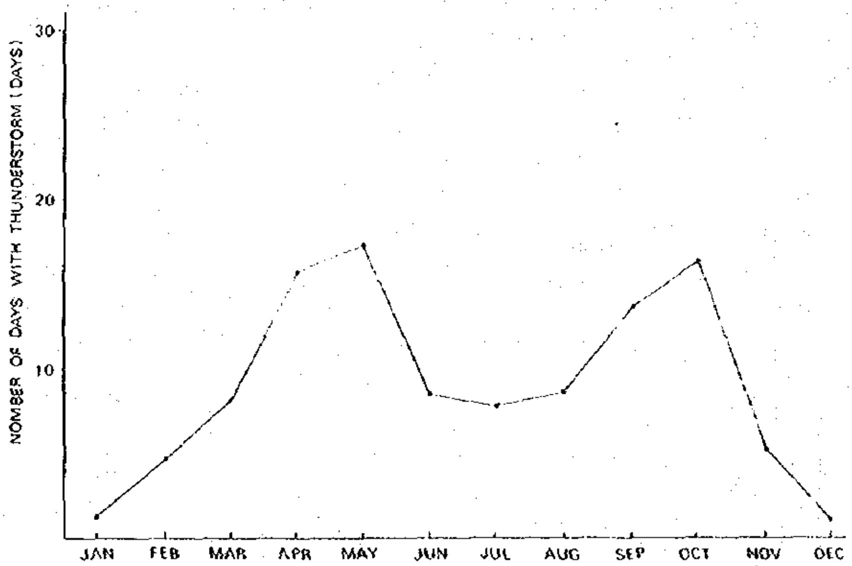


Fig. IV-6 Days of Thunderstorm
(Ko Sichang) 1958 ~ 1970

(2) Marine conditions

1) Tide

The Gulf of Thai is generally shallow, and even more shallow in the inner part. This accounts for the development of a shallow water tide. The tidal difference exceeds 3.5m at Bangkok Bar. Both diurnal tide and semi-diurnal tides are recorded in the inner part of the Gulf of Thai. The records of tides obtained at the tide-gage station of Ko Sichang are given below.

H.H.W. = +1.80m

H.W. = +0.94m

M.S.L. = ±0.00m

L.W. = -0.97m

L.L.W. = -2.48m

2) Current

The ocean current in the Gulf of Thai is generally weak. Tidal current is said to be dominant. (Hydrographic Department, Thai Royal Navy).

According to the observation made (near Ko Sichang Island) by Hydrographic Department in April, 1972, the maximum flood tide was 1.3kt (northern flow) and the maximum ebb tide was 0.8kt (southern flow) at the time of a spring tide. On the other hand, the maximum flood tide was 1.0kt (northern flow) and the maximum ebb tide was 0.5kt at the time of a neap tide.

According to ESSO's observation, the maximum flood tide is N.020° 1.5kt and the maximum ebb tide is N.215° 1.5kt near ESSO Berth. Locational differences must also be considered in view of topographic effects and diurnal inequality. However, it may be safe to assume the maximum flood tide and ebb tide as 1.5kt.

3) Waves

According to the data of Hydrographic Department of Thai Royal Navy, the wave height reaches 1.2 ~ 1.5m in the west of Ko Sichang Island during the NE monsoon period and 1.8 ~ 2.4m during the SW monsoon period. The maximum wave height is said to be 3.6m during the SW monsoon period. It is not clear weather maximum waves or 1/10 maximum waves or significant waves are meant. However, 1/10 maximum waves seem to be meant because of their visual inspection technique.

TORC has data on sea surface conditions throughout a year. (Table IV-1) The period of the statistics is unknown. According to these data, the sea surface is calm on 212 days per year and smooth (0.1 ~ 0.5m) on 118 days per year.

In other words, the wave height is below 50cm on 330 days per year. Since the allowable wave height for sea berth operation is said to be 0.5 ~ 0.7m, a sea berth will be physically operatable on 330 days (85%) in a year.

Of the three proposed sea berth construction sites, A and B are under similar conditions, while C has better wave conditions because of the sheltering effect of Ko Sichang Island.

Some affirm the presence of swells, while other negate it. Waves outside a fetch seem to exist. However, such waves (swells) seem to have the cycle of 6 ~ 7 sec. and the height of 0.2 ~ 0.3m.

Table IV-1

(Unit: day)

Season	Month	Calm	Smooth	Slight	Mod	Rough	Very bad	Swell
NE monsoon period	Nov ~ Feb	72	30	17	1			115
Transitional period	Mar ~ May	62	26	4				89
SW monsoon period	Jun ~ Sep	59	52	9	2			118
Transitional period	Oct	19	10	2				28
Year	Jan ~ Dec	212	118	32	3			350

(3) Geological Conditions

1) Earthquake

No numeric data on earthquake are available. Since this region is generally said to be without earthquake, there seems to be no need of the consideration for earthquake.

2) Submarine geology

Fig. IV-7 ~ Fig. IV-8 show the results of the submarine geological sound wave investigation by the First Investigation Mission.

Base is exposed at the center both on the east coast and the west coast of Ko Sichang Island. Base is exposed or present at a shallow place near the seashore of the south of Sri Racha Refinery.

Silt, sandy silt or silty sand exist on the base at the other places.

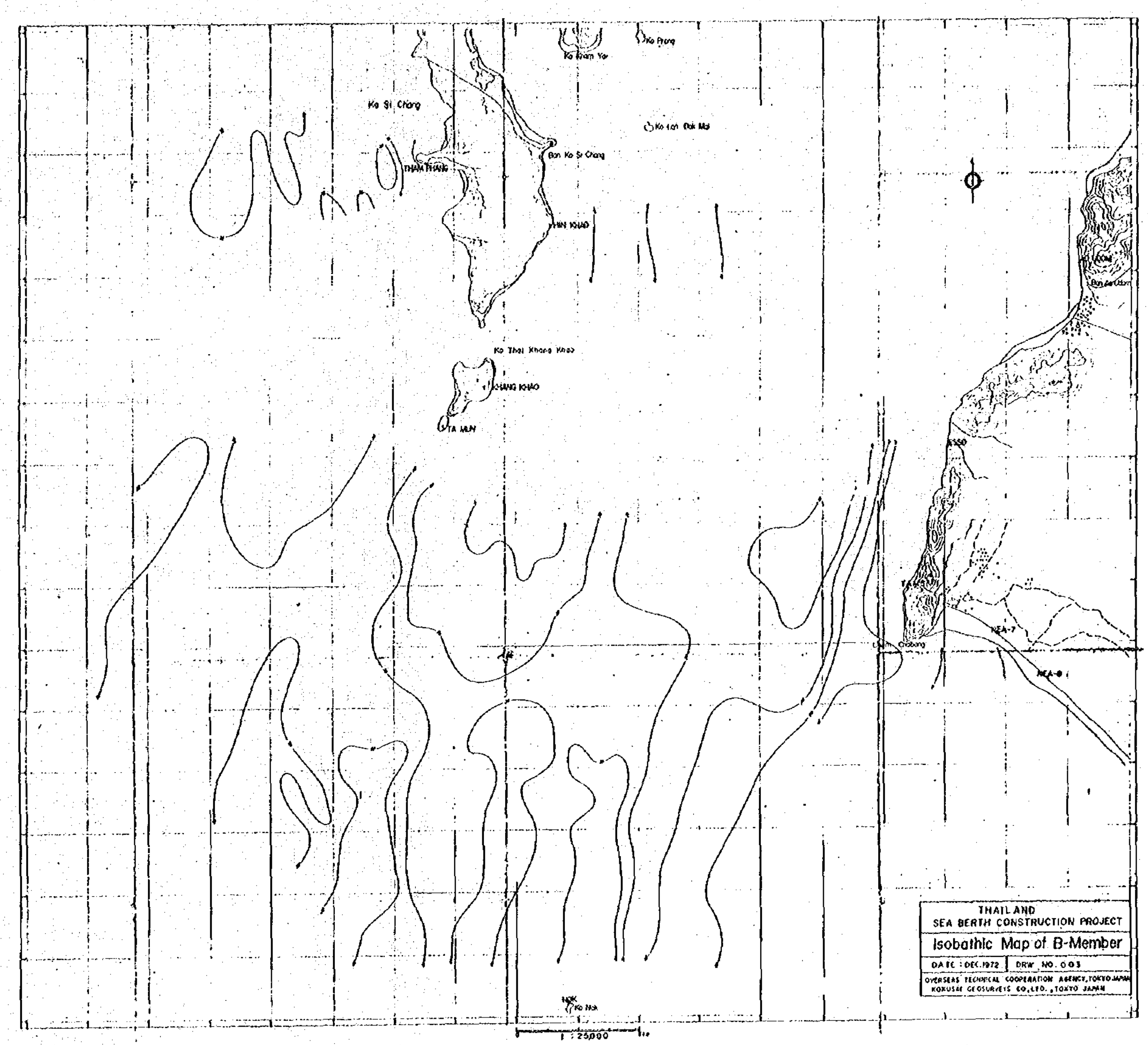


Fig. IV-7 Isobathic Map of B-member
(Report of First Investigation Mission, Attached Drawing-3)

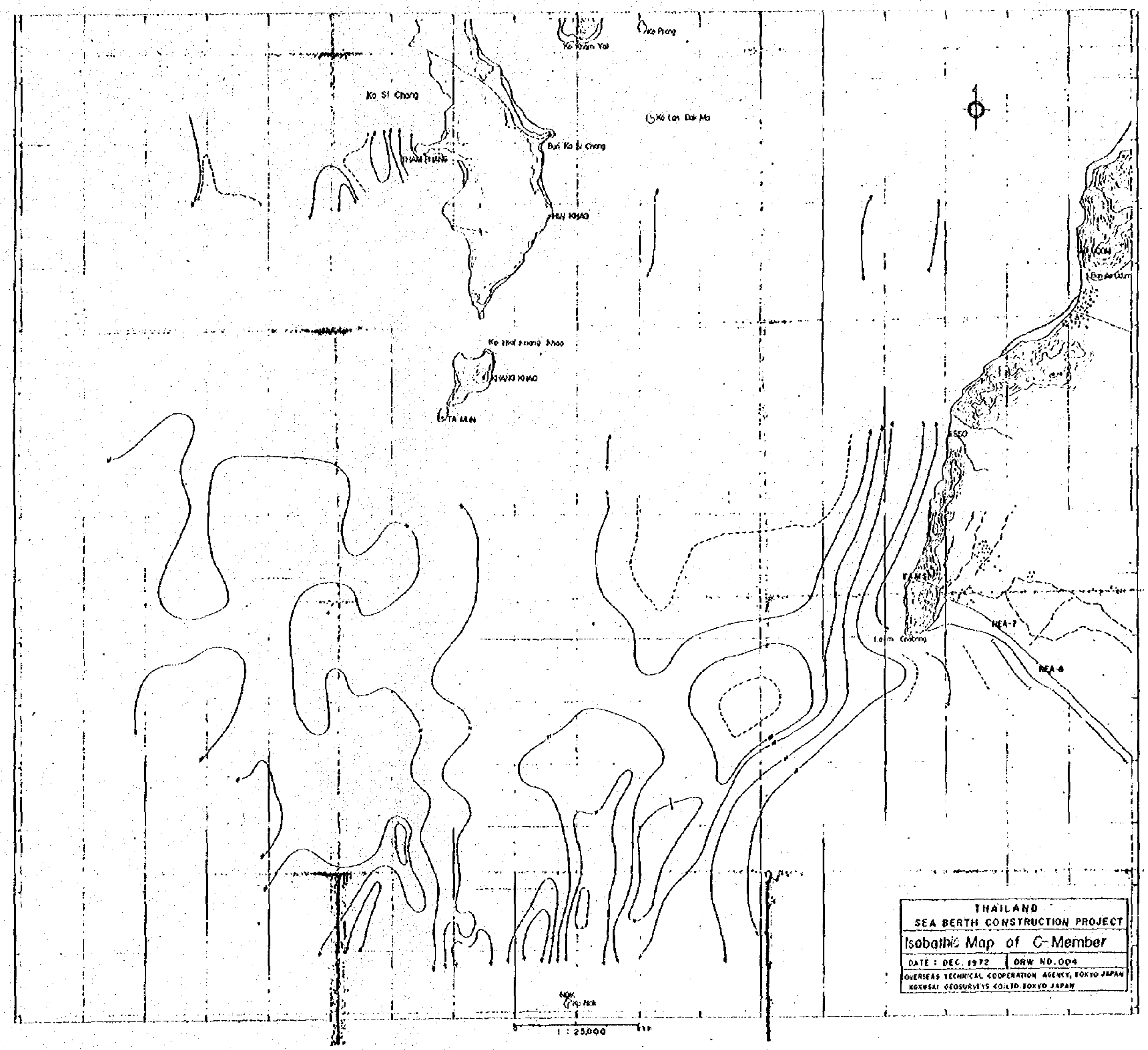
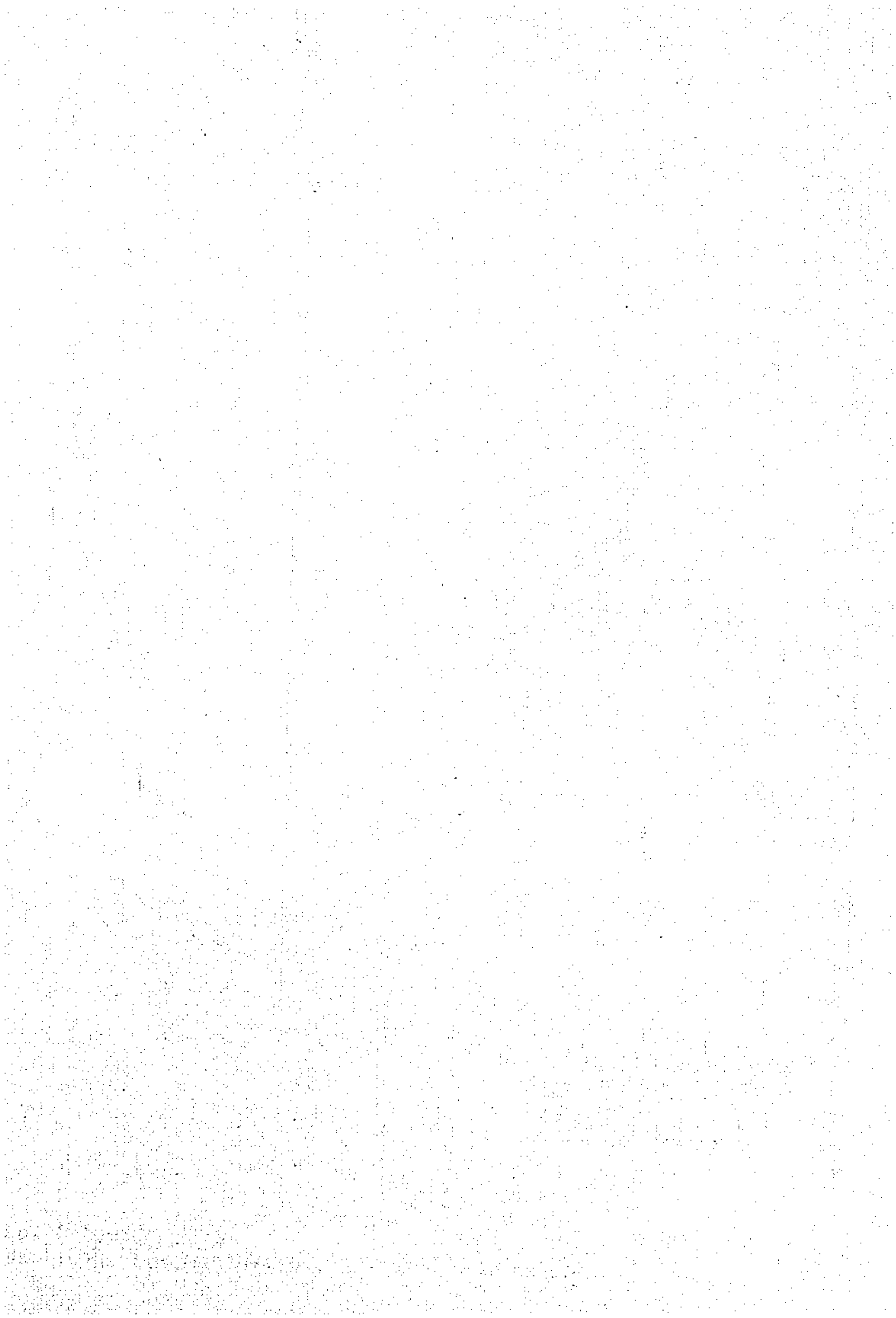


Fig. IV-8 Isobathic Map of C-member
(Report of First Investigation Mission, Attached Drawing-4)



3) Ground geology

As Fig. IV-9 shows, Sri Racha District seems to have good ground conditions. Hills run in the north-south direction on the main land side coast and sand or gravel is found in the adjacent region. However, alluvial bed of 2 ~ 2.5m high above sea level is found in the back of the hills. Soft materials seem to be deposited on the bed.

On the other hand, Ko Sichang Island has mountains in the north and about 60m high flat plateau in the south. Its stiff foundation is especially suitable for a tank yard. Sharp cliffs with exposed base are found on the west of the island. Similar conditions are assumed in the sea and they will present problems for the laying of submarine pipeline.

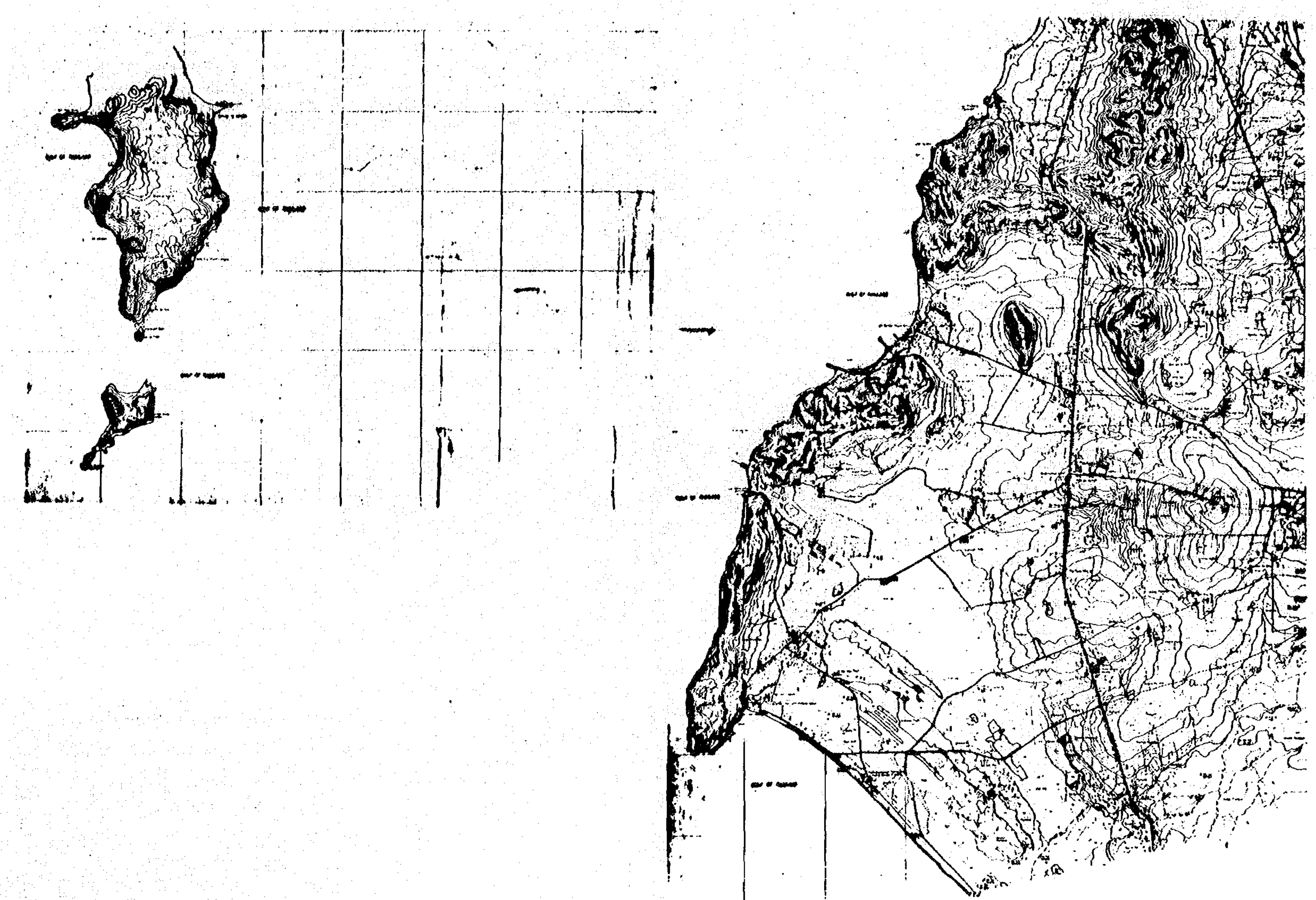


Fig. IV-9 Topographic Map of Sri Racha District

2. Navigation Conditions

(1) Navigatable ships in the water area of Sri Racha

Oil tankers from ports of the Persian Gulf enter the project water area via Malacca Strait because of water depth problems. This is because the maximum allowable draft is 10m for the northbound route via Sunda Strait.

Currently, the maximum allowable draft for navigating Malacca Strait is 20m. There is no plan for dredging this strait to improve the navigation channel.

Therefore, the maximum draft of 20m may be assumed for ships entering the water area of Sri Racha.

Fig. IV-10 ~ Fig. IV-14 show the principal specifications of the VLCC and the ULCC that were recently constructed in Japan.

Table IV-2 shows the average principal dimensions of these tankers.

In view of the fact that efforts are being made to increase D.W.T. and to increase the draft below 20m at the same time, tankers of 25 thousand DWT (maximum) will enter the water area of Sri Racha.

Table IV-2 Principal Dimensions of Tankers

(Unit: m)

D.W.T.	Overall length (LOA)	Width (Breadth)	Depth (D)	Full Draft (d)
200,000 DWT Model	315	50	26	19.0
230,000 DWT Model	325	51	27	19.5
250,000 DWT Model	330	53	27	20.5
270,000 DWT Model	330	55	27	21.0

(For reference)

Idemitsu Maru constructed in 1966

206,000 D.W.T.	344	49.8	23.2	17.7

Recently constructed 128 Japanese ships of at least 150 thousand DWT

(From 1972 Edition of Japanese Ship Specifications, "Ships" (1972, 1973))

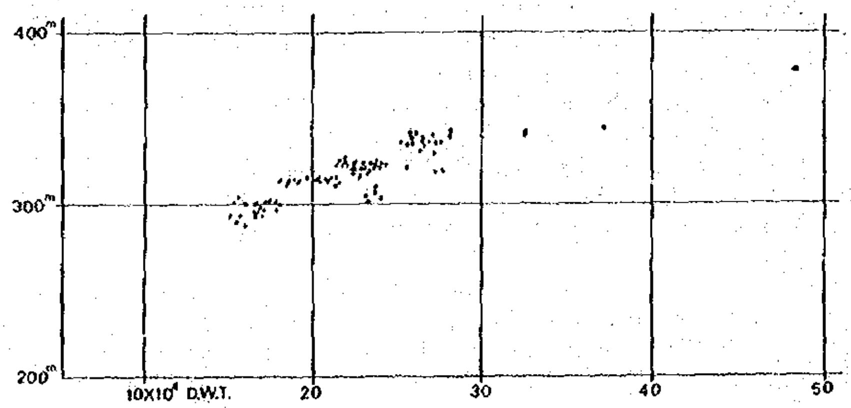


Fig. IV-10 Relation between Dead Weight Tonnage and Overall Length

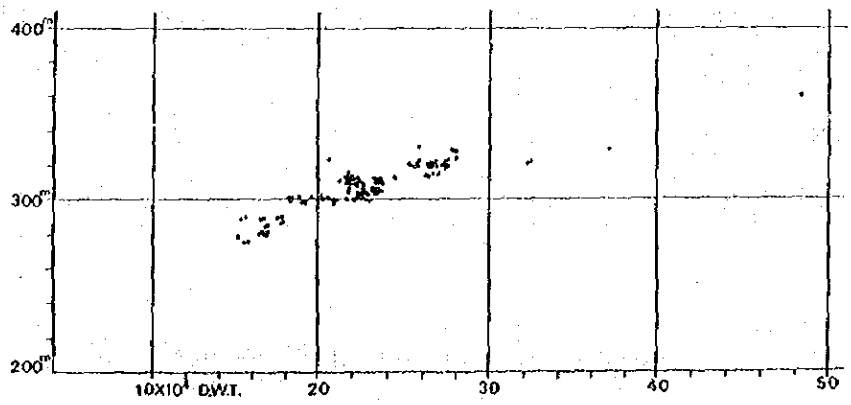


Fig. IV-11 Relation between Swad Dead Weight Tonnage and Lpp

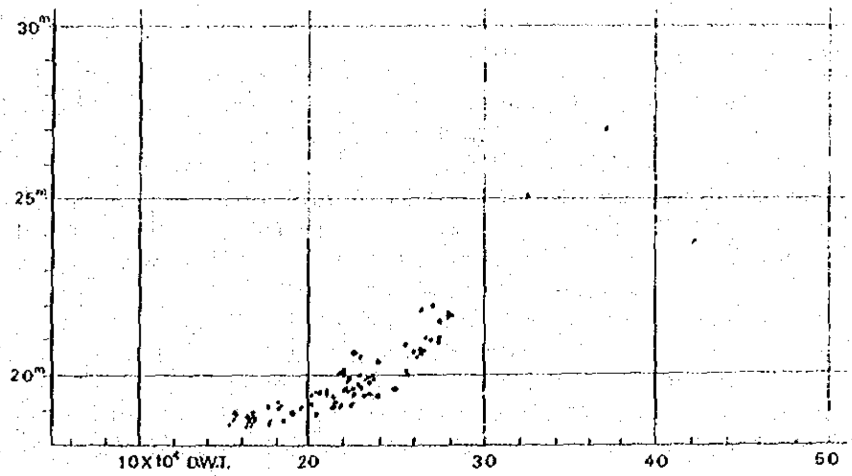


Fig. IV-12 Relation between Dead Weight Tonnage and Max. Draft

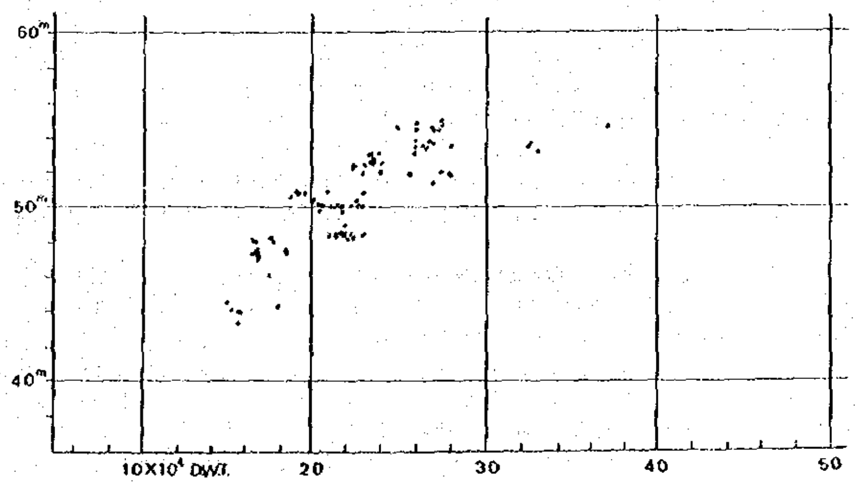


Fig. IV-13 Relation between Dead Weight Tonnage and Breadth

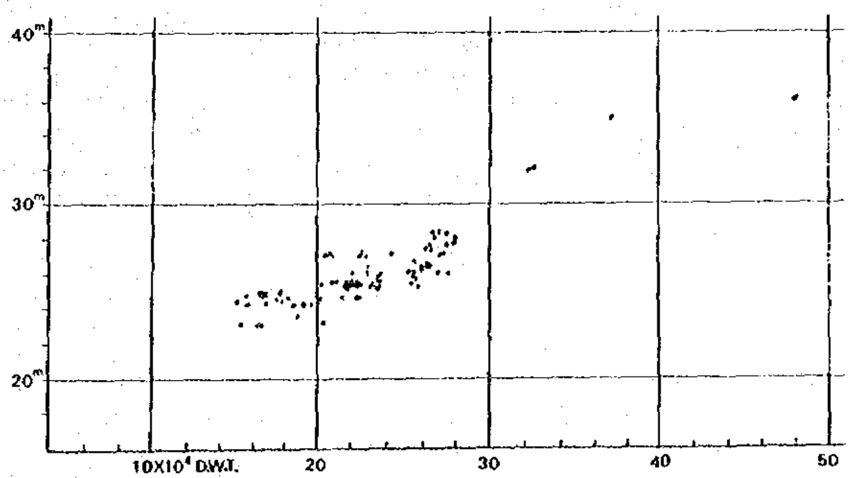


Fig. IV-14 Relation between Dead Weight Tonnage and Depth

(2) Setting of navigation channel

As discussed in the previous section, ships with the draft of 20m are assumed for the water area of Sri Racha since such ships alone can pass Malacca Strait.

The South China Sea from the east end of Singapore Strait to the Gulf of Thai has the water depth ranging between 50m and 70m. The water depth of the Gulf of Thai is less than 40m in the north of 12° North Latitude.

Gigantic ships (approximately 230 thousand D.W.T.) with the draft of 20m can navigate at the normal service speed until 12° North Latitude. However, they must lower the service speed to 12 knots within the Gulf of Thai in the north of 12° North Latitude, at 40 miles south of Sattahip. The reasons for this are listed below.

1) When a gigantic ship of approximately 200 thousand DWT navigates at the full speed of 16 knots, squat becomes 1.6m in a shallow water area where the ratio of water depth to draft (h/d) is 1.5.

2) The draft of a ship is changed by pitching and rolling due to wind waves, swells etc.

3) The maneuvering performance, including steering performance and turning performance, goes down when h/d is below 2.0.

Ordinary commerical ships (10 thousand GT class) travel toward the north from the east end of Singapore Strait and reach the point about 5 miles southwest of the lighthouse of Ko Chuang Island in the south of Sattahip. Then they pass the west of Kokram Island, besides either side Ko Rin Island or Ko Phai Island, and go to Bangkok Bar.

For the previously given reasons, gigantic oil tankers (U.L.C.C.) with the draft of 20m require the keel clearance of 4m in open sea and the keel clearance of 2m in maneuvering water area as "under keel clearance."

A navigation channel to be selected from the south of Sattahip to Ko Sichang must satisfy the following conditions. It must have the water depth of at least 23m and the course change it requires must be less than 30° in view of the maneuvering performance of gigan ships. A ship's position must be easy to check. The navigation channel shown in Fig. IV-15 satisfies these conditions. (Sea Chart No. 1 published by Hydrographic Department of Thai Royal Navy.)

The starting point is at 7.8 miles on the 205° of the lighthouse of Ko Chuang Island in the south of Sattahip. Ships are to navigate about 20 miles at the course of 330° until they reach the point at 3.8 miles on the 270° of the 233m high mountain top of Ko Khram Island. At this point, they change the course to 000° and navigate about 14.5 miles until they reach the point at 3.6 miles on the 090° of Ko Phai Island Lighthouse. Then, they change the course to 021° and head to Ko Thai To Mun Island Lighthouse at the south edge of Ko Sichang Island and navigate about 8 miles until they reach the berth. This is set as the standard course and one mile wide bands along it are set as the navigation channel. A buoy is installed at the starting point and at each course change point for indicating the navigation channel center.

Service speed must be kept below 12 knots on this navigation channel. Water depth of 25m ~ 30m is secured for most of the channel, but a shallow part (21m) exists at about 3 miles SSE of Ko Rin Island. Ships with the draft of 19m (namely 200 thousand D.W.T. or less) can navigate the route between Ko Khram Island and Ko Rin Island at 6 knots or below. It is desirable to remove the shallow part by dredging in view of the fact that tankers with the draft of 20m (230 thousand D.W.T. class) enter the port. If it is impossible, a buoy must be installed at this shallow part to secure the safety of ships.

In any event, further hydrographic surveying is required for the final selection of a navigation channel from the Gulf of Thai to a berth near Ko Si Chang Island.

(3) Improvements of navigation channel and navigation facilities

1) A buoy must be installed at the starting point of the navigation channel and at each course changing point.

Buoy lights with radar reflector which are visible at the distance of 5 miles must be used.

Starting point of navigation route

Approximate location

(12° 24'N
100° 54.2'E

Course changing point, west of Ko Kram Island

Approximate location

(12° 41.1'N
100° 44.1'E

Course changing point, east of Ko Phai Island

Approximate location

(12° 55.8'N
100° 44.1'E

2) A buoy must also be installed to indicate the shallow part (water depth of 20m or less) near the navigation channel. A buoy of the type described before should be used.

1. The following two locations for indicating the south edge and the north edge of the shallow part located at about 4 miles northeast of Ko Rim Island.

Approximate location (12° 48.4'N
100° 45.7'E

Approximate location (12° 51.6'N
100° 45.4'E

2. The following four locations indicating the shallow part on the both sides of the navigation channel between Ko Phai Island and Ko Khangkhao Island.

Approximate location (13° 06.0'N
100° 44.4'E

Approximate location ($13°$ 02'7N, $100°$ 48'2E)

Approximate location ($13°$ 5'2N, $100°$ 47'2E)

Approximate location ($13°$ 04'4N, $100°$ 48'0E)

The islands near the navigation channel are about 100 ~ 200 m high. They can be caught by a radar from the distance of at least 20 miles. Therefore, they do not require any additional shore beacon (light house etc.).

However, the lighthouse of Ko Thai Ta Mun Island, which serves as the heading target for a ship travelling to the sea berth, must be improved. Its light reaching distance must be improved from the current level of 9 miles to at least 15 miles. Since it is not clearly visible during day time, its structure must also be improved.

The paint color of the buoy lights must comply with the international standards. (See Fig. IV-15 for reference.)

The navigation channel from the southwest of Sattahip to a sea berth coincides with the navigation channel of ordinary commercial ships travelling to Bangkok Port or Ko Si Chang Port. If oil tankers continue to travel to the existing sea berths of TORC, ESSO and SUMMIT, traffic problems will arise. In such a case, strict navigation control must be provided for safe navigation.

Fishing is said to be prohibited along the coast from Sri Racha and Sattahip. Numerous fishing boats occasionally seem to be engaged in fishing in the west and the south of Ko Si Chang Island.

If numerous sea berths for gigantic tankers are constructed in the water area of Sri Racha in the future, fishing boats will have to be controlled from frequent traffics.

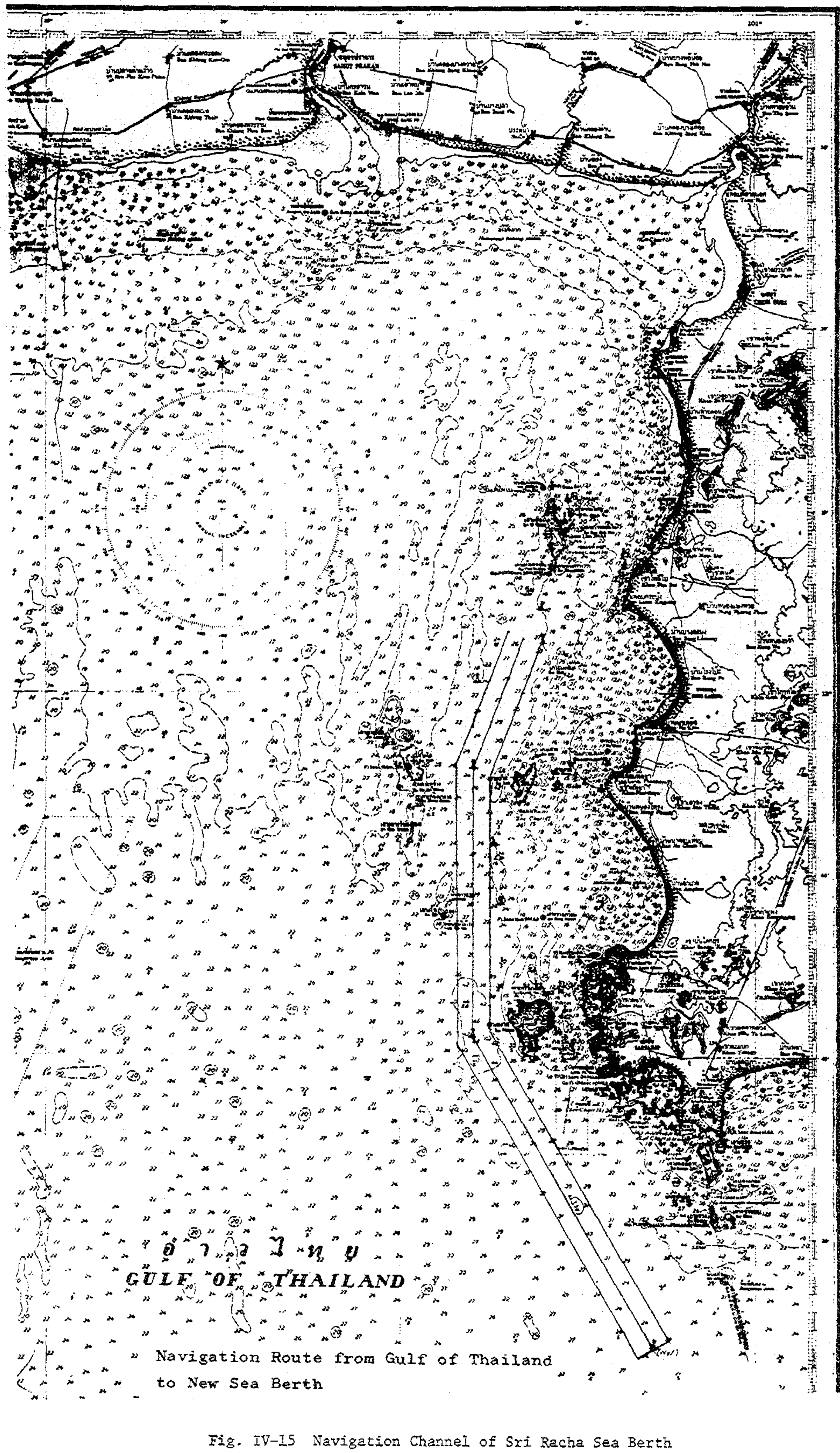
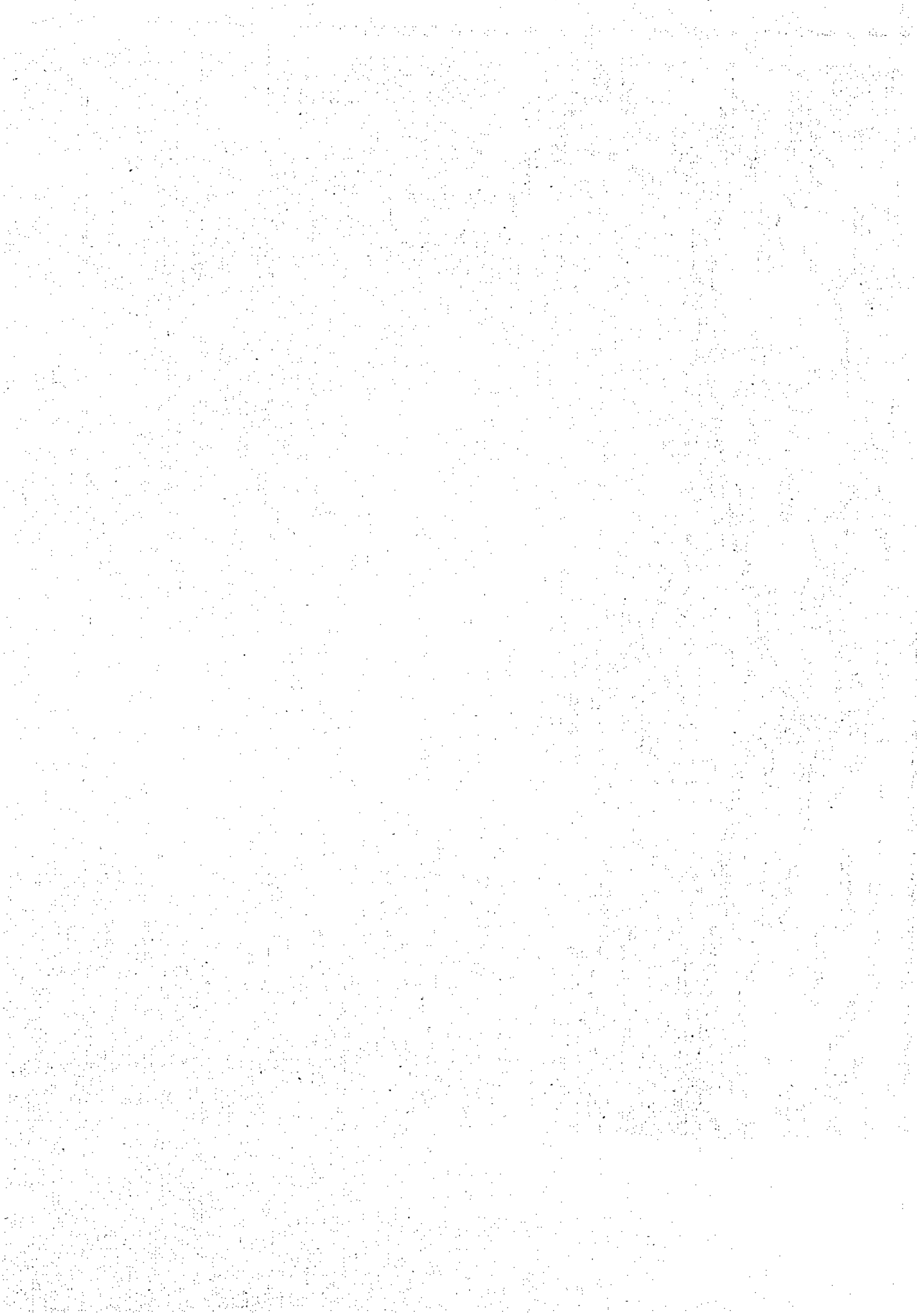


Fig. IV-15 Navigation Channel of Sri Racha Sea Berth



(4) Selection of sea berth construction site

1) General conditions for selection of sea berth site for gigantic ships above 200 thousand D.W.T.

1. Water depth

Gigantic ships of course should not touch the sea bottom. Furthermore, they must have sufficient under keel clearance to maintain good maneuvering performance.

Generally speaking, the following under keel clearance is essential in view of squant during navigation, the pitching and rolling caused by oscillation, tidal level, meteorological condition, marine phenomena, bottom material, shoaling by sediments and littoral drift, allowance for the bottom's cooling water inlet, water depth accuracy of marine chart etc.

$h/d \geq 1.2$ in open sea

$h/d \geq 1.15$ in channel outside the port

$h/d \geq 1.1$ in port

(h = water depth; d = draft)

In other words, water depth of at least 21 ~ 22 m must be secured since ships with the draft of 19 ~ 20 m will enter the Sri Racha sea berth.

2. Marine phenomena

(a) Tidal flow

Since a gigantic ship has large draft, a fully loaded ship is subjected to larger fluid pressure attributable to tidal current than wind pressure. Fluid pressure attributable to tidal current can be compared with wind pressure attributable to wind in the following manner. If identical area is assumed, the tidal flow of 2 knots is equivalent to the wind speed of 28 m/sec. When a ship receives tidal current of the stem or the stern, it is subjected to its 1/6 ~ 1/7 of the fluid pressure compared with a ship receiving the same tidal current at side. Therefore, the face line of a berth must coincide with the direction of tidal current.

Tidal current should desirably be below 1 knot for good maneuvering.

(b) Swell

The hull is moved by swell when the wave-length exceeds 1/3 of the hull length. It is difficult to maintain safety with current berthing facilities when the wave height exceeds 3m. Therefore, it is important to select a site without swell.

(c) Wind waves

When constant wind prevails, waves are formed and make berthing operation difficult. It is said that the maximum allowable wave height for tug boat operation is 1.5m.

3. Meteorological condition

(a) Wind

A large fully loaded ship is not much affected by wind since its wind pressure area is small. A berth should desirably allow ship to receive wind from the stem or the stern. If a ship receives wind in another direction, transverse pressure produces rotary moment and makes maneuvering difficult.

An empty ship is subjected to larger wind pressure. However, it can be maneuvered because of the smaller mass as long as wind speed is below 15 m/sec. The maximum allowable mean wind speed for docking and undocking is 15 m/sec.

(b) Visibility

When visibility is below 1 mile because of rain etc., it is safer to delay port entry and departure operations. The frequency of narrow field of visibility must also be considered in the selection of a berth site.

4. Necessary water area for maneuvering

Gigantic ships of 200 thousand DWT class must lower their speed to 4 knots in approaching a berth. Since their maneuvering performance becomes extremely poor, sufficient water area must be secured for docking and undocking.

In the case of a fixed sea berth, a fully loaded gigantic ship enters a port with the stem in the front. When empty, it undocks and makes a turn in front of a berth and leaves the port. Therefore, a water area with the length of 5L (L is the hull length) must be allowable almost in parallel to a berth's face line. For undocking and turning, a space with the diameter of 2L (minimum) must be allowed in front of the berth. The same water area is necessary for a multi buoy mooring type sea berth.

In the case of a single buoy mooring type sea berth, a water area with the radius of 3L ~ 4L is necessary around a berth in consideration of a ship's whirling during mooring. Furthermore, a water area of 5L - 7L is necessary around a buoy to allow approaching against tidal current at the stem.

5. Navigation channel

A navigation channel leading to a sea berth should desirably be without any bent. It should have good wind, tidal current and wave conditions and be used exclusively.

The width of a navigation channel is determined on the basis of wind pressure, fluid pressure, water depth and traffic situation etc. The width of 1.2L is necessary under the assumption of wind speed below 15 m/sec., no transverse current, water depth h/d = 1.3 or higher. Additional 2B (B is a ship's width) is necessary when a current of 0.5 knot due to tidal flow etc. exists.

6. Water area for safety

Since dangerous cargoes, such as oils, are handled at a sea berth, it must be sufficiently far from the berthing facilities, navigation routes and anchorages for ordinary ships for the sake of safety. Marginal water area must be allowed to prevent pollution due to oil leakage and to prevent danger, such as fires.

Therefore, a sea berth must be constructed at least 1500m from the above facilities.

2) Sri Racha Sea Berth construction site

The three sites A, B, C shown in Fig. IV-16 were selected as proposed sea berth sites on the basis of Sea Chart No. 1 published by Hydrographic Department of Thai Royal Navy and the water depth chart prepared by the First Investigation Mission as well as in consideration of the above conditions.

These three sites were selected with the assumption of a fixed sea berth and double mooring.

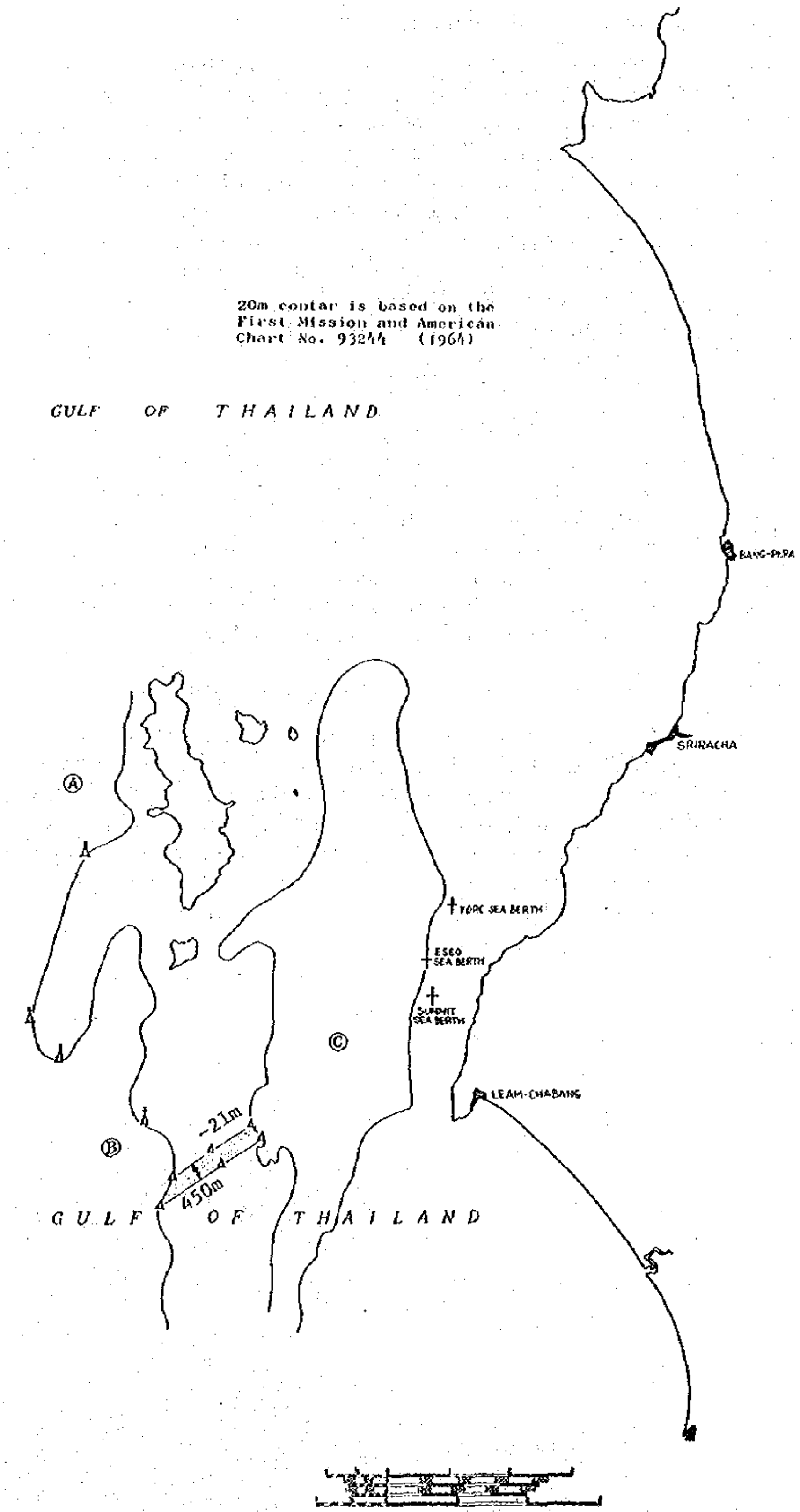


Fig. IV-16 Proposed Sites for Sea Berth Construction

(5) Tug boats

Gigantic ships above 200 thousand DWT are difficult to maneuver because of their large inertia attributable to large weight as well as extremely low steering effect attributable to deep draft. Gigantic ships require the assistance of tug boats for passing through a narrow channel and for docking and undocking at a sea berth since their navigation speed must be kept below 4 knots and since they cannot be maneuvered by their own rudder and engines near a berth.

The maneuvering pattern which a gigantic ship follows for docking at a fixed sea berth can be summerized as below. A gigantic ship is attended by two tug boats from the entrance of a channel leading to a berth. They assist the navigation through a narrow channel. Then it is attended by all the tug boats at 1 ~ 1.5 miles from the berth. Its hull is stopped in parallel with the berth's normal line at 2 ~ 3B (B = beam) from the berth. Then, the ship is laid alongside the berth by tug boats.

The required thrust and number of the tug boats used for undocking depend on the geographical conditions, weather and marine conditions. Table IV-3 and Table IV-4 show approximate figures.

The tug boat requirements for undocking at a fixed sea berth and a multi-buoy mooring type sea berth has been discussed. However, two tug boats are usually required for mooring and unmooring at a single buoy mooring type sea berth.

Naturally, a mooring facility for these tug boats must also be constructed.

Table IV-3 Required Thrust of Fleet of Tug Boats

Large tanker (D.W.T.)	Full load status				Ballast status	
	Water depth/draft (h/d)				Wind speed	
	1.1	1.2	1.3	1.5	10 m/sec	15 m/sec
100,000	110t	90t	80t	70t	60t	115t
150,000	140t	120	100	85	70	135
200,000	160t	140	120	100	80	160
250,000	185t	160	140	120	95	185
500,000	210t	180	155	130	115	210

Table IV-4 Number of Tug Boats in Fleet

Large tanker (D.W.T.)	Number of tug boats at port entry	Number of tug boats at port departure
60,000 - 80,000	2 ~ 3	2 ~ 3
80,000 - 100,000	3	3
100,000 - 130,000	3 ~ 4	3
100,000 - 160,000	4	3
160,000 - 200,000	4 ~ 6	3 ~ 4

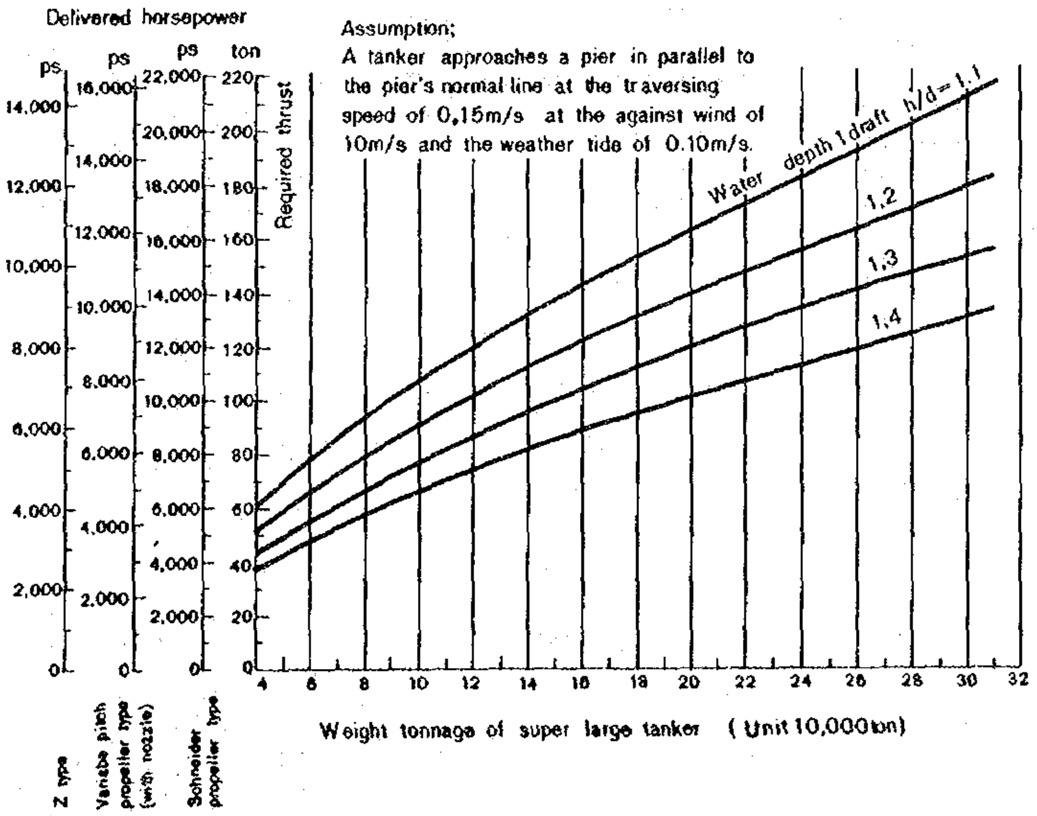


Fig. IV-17 Required thrust of fleet of towboats and delivered horsepower by propulsion types (Full load condition is assumed for super large tanker)

3. Comparison among sea berth construction sites

Table IV-5 compares the three proposed sea berth sites in terms of natural conditions and navigational conditions.

Table IV-5 Characteristic Comparison of Sea Berth Construction Sites

	Site A	Site B	Site C
Approximate location	13°-8.8'N 100°-47.0E	13°-3.8'N 100°-47.9E	13°-5.3'N 100°-51.0E
Wind	SSW ~ SW Mean 4m/sec. Max. 20m/sec. NE Mean 4m/sec. Max. 15m/sec.	Same as left	SSW Mean 3m/sec. Max. 20m/sec. NE Mean 2.5m/sec. Max. 15m/sec.
Wave	Wave Mean wave height 0.5m Mean wave height at SW monsoon 1m No swell	Wave Mean wave height 0.5m Mean wave height at SW monsoon 1m No swell	Wave Mean wave height 0.5m Mean wave height at SW monsoon 1m No swell
Tide	Flood tide flows to north at max. speed of 1.5 knot Ebb tide flows to south at max. speed of 1.0 knot. Max. tide range is 2.0m.	Flood tide flows to NNE at max. speed of 1.5 knot Ebb tide flows to SSW at max. speed of 1.0 knot. Max. tide range is 2.0m.	Same as left
Face line of berth	Direction of tidal flow: North-South	Direction of tidal flow: NNE-SSW	Same as left
Fog	Fog appears early in mornings (1 ~ 2 hours) from December till January. It has hardly any effect.	Same as left	Same as left

	Site A	Site B	Site C
Water depth	25m ~ 27m	22m ~ 27m	22m ~ 25m A guiding channel (shown in Fig. IV-16) must be dredged for entry to C.
Mooring	Waves are slightly higher than at the other sites. Since it is open to wind during SW monsoon period, mooring is restricted for many days. Sufficient mooring basin can be secured, but an empty tanker is subjected to larger wind pressure than at the other sites. Mooring is ordinary. Tidal change must be waited when tidal current is strong.	Waves are smaller than at A because of island in SW. Sufficient mooring basin can be secured. Mooring is easy. Tidal change must be waited when tidal current is strong.	Waves are smallest. Mooring basin is restricted by water depth. Mooring is most difficult among the three sites because of the narrow channel. Mooring is ordinary if sufficient tags are attached. Tidal change must be waited when tidal current is strong.
Trouble with other ships	None	None	It is on the navigation route leading to TORC's sea berth and ESSO's sea berth. It will require navigation rules and necessitate tug boats for tankers entering or leaving from current sea berths. It will have problem with ships entering or leaving from the deep sea port of Laem Chabang in the future. It will require navigation control.

	Site A	Site B	Site C
On entry channel	There is no need for constructing an entry channel.	Same as left	Ships must pass a shallow zone (15 ~ 18m deep) to enter C from Gulf of Thailand. Therefore, an 2800m long and 450m wide entry channel must be dredged at -21m, as shown in Fig. IV-16.
On navigational aids	Entry from Gulf of Thailand requires the navigational aid listed in subparagraph (3) on Pages 93-94. and two buoy lights, as shown in Fig. IV-16	Two additional buoy lights are necessary	In addition to the buoy lights needed for B, eight buoy lights must be installed at the both ends and the both sides of the entry channel (Fig. IV-16.)
On fishing boats	Numerous fishing boats stay in this water area occasionally.	Not many fishing boats stay here.	Fishing is prohibited.
Problems with other ships			It is on the navigation route to other sea berths. If a deep sea port is constructed in Laem Chabang, numerous ships will enter it and leave for Ko Sichang or Bangkok. Adequate navigation control will be required in such event.

	Site A	Site B	Site C
On future expansion	Sea berth expansion will be possible.	Same as left.	Another sea berth can be constructed between Ko Sichang Island (north of C) and the land. However, it requires integrated planning with the current three sea berths. Then, a sea berth with the best wave conditions will be obtained.

V. SEA BERTH SYSTEM

V. SEA BERTH SYSTEM

1. Classification of sea berth systems

Sea berth systems can be roughly classified into private systems and common systems. A study of the international tendency reveals that private systems are overwhelmingly popular at the initial stage, but that common systems increase along with the increase of petroleum enterprises within a country and the decrease of adequate sites. The recent construction of common sea berths is explained by the use of gigantic crude oil tankers used by large enterprises. The necessity of a common sea berth system has been increasing not only for economic reasons, but also for a national policy for stable supply of petroleum energy.

An ordinary sea berth system consists of the following facilities.

Sea berth ... It is used for unloading crude oils or for loading products. (abbreviated as (S))
Tank .... It is used for storing crude oils or products. (abbreviated as (T))
Pipe line ... It is used for transferring crude oils or products. (abbreviated as (P))

The following facilities are related to a sea berth.

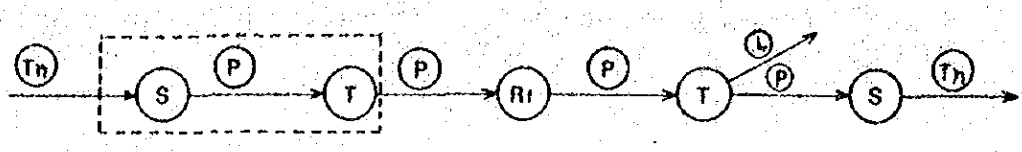
Refinery, petrochemical plant ... Crude oils or petrochemical raw materials are processed. (abbriviated as (R_f))
Tanker, lorry .... They are used for transferring crude oils or products. (abbreviated as (T_n), (L))
Other affiliated facilities ..... They facilitate smooth operation of a system.

(1) Private sea berth system

A private sea berth system is constructed by an enterprise for its production. It is possible to design an optimum system for an enterprise's production system, including plant scale and production forms. However, a large system requires enormous investments (mostly for infra-structure) and raises a question of doubtful profitability.

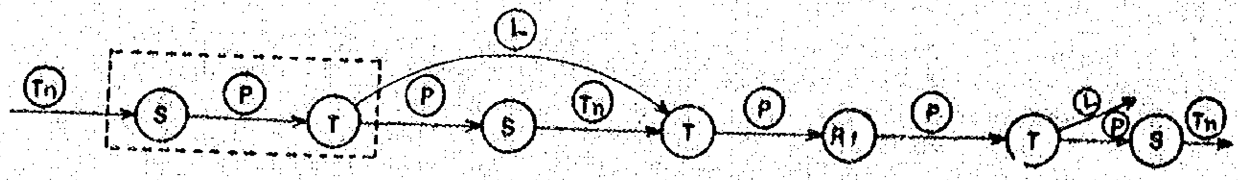
The following forms (including related facilities) are conceivable. (A sea berth system is surround by dotted lines.)

1) Type 1



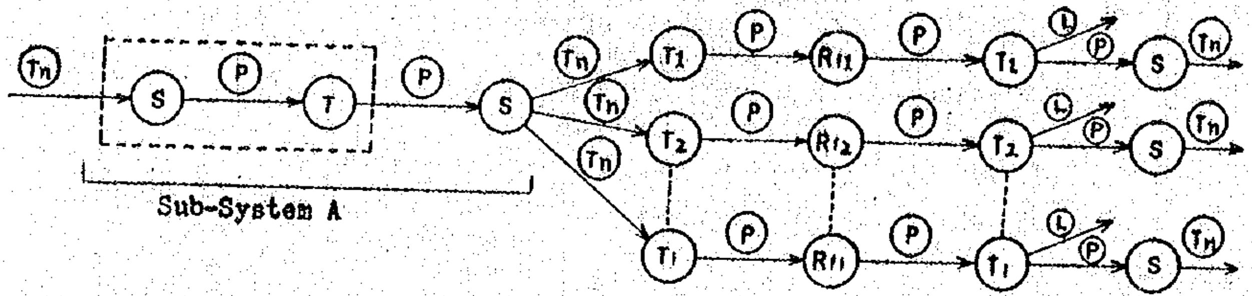
Currently, this is the most popular system. This form has been adopted by ESSO and TORC.

2) Type 2



This form is also relatively popular. This has been adopted by SUMMIT.

3) Type



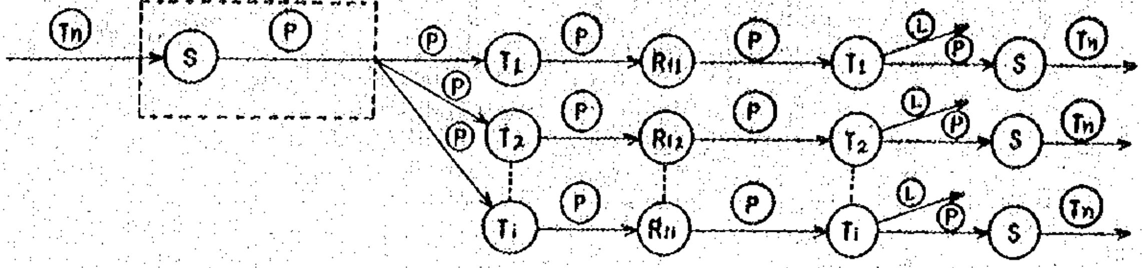
This form has become popular in recent years. Nippon Oil Co., has adopted this form. Its sub-system A is usually called as CTS. The CTS of a private system is characterized by the fact that R_{f1} ... R_{fi} belong to one enterprise or to one family of enterprises. In any event, a private system offers benefits to specific users alone.

(2) Common sea berth system

A common sea berth system offers benefits to several enterprises or to the country or public enterprises. Therefore, investments and financial dangers can be distributed among beneficiaries even in the case of a large system. This is the advantage of a common sea berth system. However, a common sea berth system can be established only when various conditions (users' site conditions, operational conditions and oil types) are satisfied.

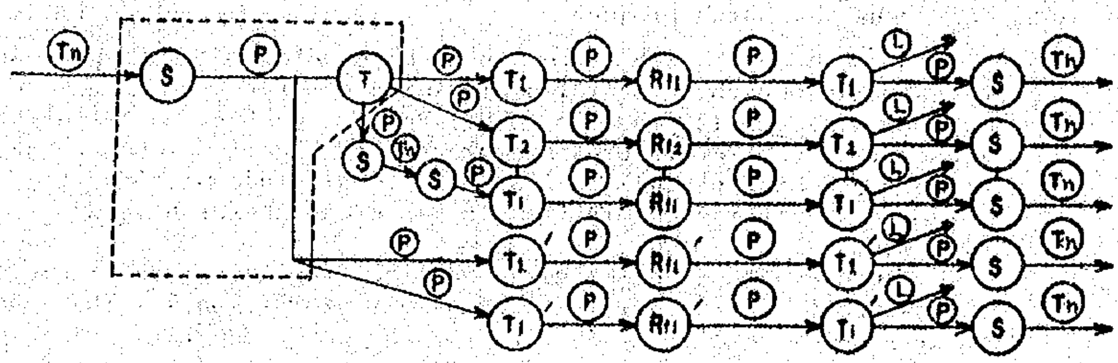
The following forms (including related facilities) are conceivable for a common sea berth. (A sea berth system is surrounded by dotted lines.)

1) Type 1



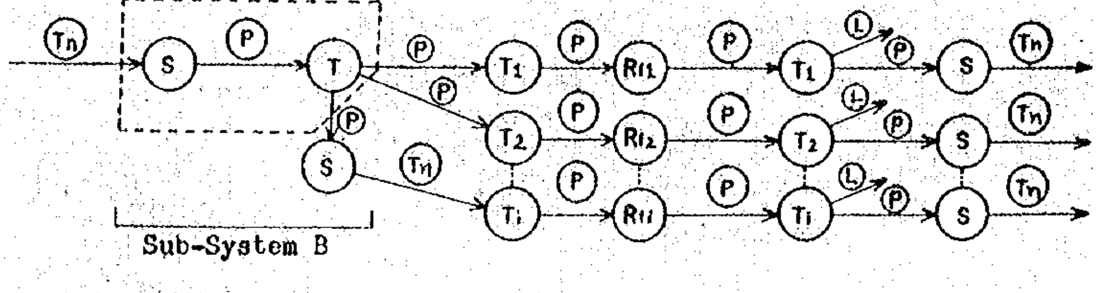
This is the most popular system for a common sea berth. Keiyo Sea Berth belongs to this type.

2) Type 2



This is a transitional system leading to Type 3. This system can be established if SUMMIT participates in this project under the current conditions.

3) Type 3



This is the most completed form. This system is assumed as the target for this project. The sub-system B of a common system is equivalent to CTS in a private system. This system is characterized by the fact that (R_{f1}) ..... (R_{fi}) represent different enterprises, countries or public enterprises.

These system components and the related factors are explained below by taking Type 3 as an example.

(1) Ocean-going crude oil tankers
(2) Crude oil importing sea berth
(3) Crude oil transfer submarine pipe line
(4) 1st stage crude oil storage tank
(5) Crude oil transfer pipe line
(6) Crude oil exporting sea berth
(7) Coastal tanker of crude oil
(8) 2nd stage crude oil tank
(9) Refinery plant pipe line
(10) Refinery plant
(11) Refinery plant pipe line
(12) Oil product tank
(13) Oil product pipe line
(14) Oil product shipping sea berth
(15) Coastal tanker of oil product

(3) Sri Racha sea berth project

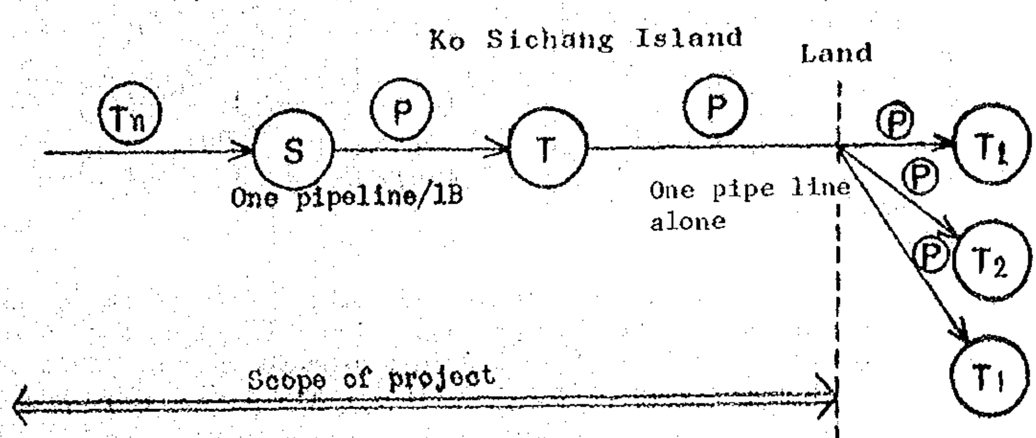
A common sea berth system is to be studied for this project by assuming the three petroleum refining enterprises. A common sea berth system is possible in Sri Racha area for the following reasons. The three enterprises are geographically close to one another and handle similar oils. The total crude oil import volume of the three enterprises is large enough for a large system.

The present project covers the line from the crude oil importing sea berth to the 1st stage crude oil storage tank. The subsequent studies will be limited to this scope. (See Fig. V-1 for reference.)

1) Form of system

Three sites (A, B, C) have been proposed for a common sea berth system for Sri Racha area because of natural conditions and navigational conditions. The form of a sea berth system for each of the proposed sites is shown below. Related factors are also included in the drawings.

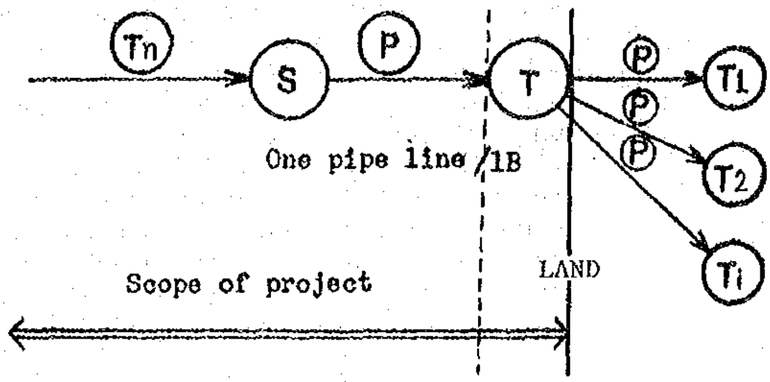
(a) Site A



Type 1 and Type 3 must be mixed for the site A since Ko Sichang Island is to be used as a tank yard. In other words, crude oils are unloaded at the sea berth and transferred to tank on Ko Sichang Island by a submarine pipe line and sent to the land by a submarine pipe line and then transferred to the enterprises tanks.

One pipe line is required for each berth for (S) ~ (T), but one pipe line is sufficient for (T) ~ land regardless of the number of berths.

(b) Site B and Site C



Type 3 is possible at the sites B and C. Crude oils are unloaded at a sea berth, transferred to a land crude oil tank by a submarine pipe line and distributed to the enterprises by land pipe line. These sites require tanks of smaller capacity compared with the site A.

One pipe line is required for each berth for (S) ~ (T).

2) Characteristics of Sri Racha sea berth system

(a) Buffer tank

The common crude oil tanks of this project differ from tanks of ordinary CTS in their role. The Mission named them as "buffer tank". They have the following functions. Basic reserve is to be secured independently by individual enterprises. Buffer tanks are to be used for temporarily storing the crude oils that have been carried by tankers. This leaves considerable room for objections. Tanks equivalent to necessary reserve must be constructed for truely ensuring stable supply of petroleum energy. However, each enterprise has about 23 day reserve, as discussed in III. The concept of buffer tanks was introduced to avoid double investments. Therefore, a buffer tanker should be large enough to store the oils that have been carried by one tanker.

The introduction of this tanker allows the Thai Government to draw an energy policy, especially an oil reserve policy, independently of the enterprises.

(b) Sri Racha sea berth system and SUMMIT

SUMMIT has a special position in this project. Currently, SUMMIT's refinery is located in the south of Bangkok. It has a storage tank mainly in Sri Racha rigion. If a sea berth is constructed at the site A, crude oils can be transferred to Bangkok without using SUMMIT's current storage tank of Sri Racha Region by connecting SUMMIT's existing sea berth and the buffer tank of Ko Sichang Island with a pipe line. If a sea berth is constructed at B or C, SUMMIT's current storage tank can be used as a buffer tank. Therefore, the latter two sites are far more advantageous than A although a selection must be made in consideration of the other participating enterprises.

For the feasibility study of this project, the current systems of the enterprises were assumed and a common sea berth system was considered as an addition to them. Oils are to be temporarily stored in a common buffer tank and then transferred to plant tanks regardless of construction site (A, B or C).

2. Current sea berth systems

ESSO, TORC and SUMMIT are located in Sri Racha Region, as stated before. Their current system is described below.

(1) ESSO

1) Sea berth

It has a multiple mooring type buoy berth. It allows the entry of 90 thousand DWT class tankers. It is the largest sea berth in Thailand.

2) Pipe line

Diameter: 32"
Length: 1.5 km

3) Crude oil tank

It has two 130 thousand KL tanks and one 100 thousand KL tank. (total capacity: 360 thousand KL)

(2) TORC

1) Sea berth

It has a single mooring type buoy berth. It allows the entry of 60 thousand DWT class tankers.

2) Pipe line

Diameter: 24"
Length: 2 km

3) Crude oil tank

It has two 78 thousand KL tanks, two 55 thousand KL tanks, four 34 thousand KL tanks and four 27.6 thousand KL tanks. (total capacity: 512.4 thousand KL)

(3) SUMMIT

1) Sea berth

It has a fixed type dolphin berth. It allows the entry of 60 thousand DWT class tankers. SUMMIT rents ESSO's sea berth for larger tankers.

2) Pipe line

Diameter: 18" and 8"
Length: 1 km

3) Crude oil tank

Its total tank capacity is 320 thousand KL.

(4) Crude oil handling capacity and reserve capacity

When the maximum length of a tanker stay's is assumed to be 5 days, it is estimated that ESSO Sea Berth can handle about 7,800 thousand KL of imported crude oils annually and TORC Sea Berth and SUMMIT Sea Berth can independently handle about 5,200 thousand KL of crude oils annually. (More details will be given in IX). These estimates are based on the assumption that the largest permissible tankers are used and that these sea berths are not shared. The actual figures will be considerably lower than the estimates since tankers of 20 ~ 30 thousand DWT class tankers often go to TORC Sea Berth. Furthermore, SUMMIT uses ESSO Sea Berth. Such a system obviously cut a stay in a port. The storage capacity of these enterprises was discussed in III. The total storage capacity of the three enterprises is 1,190 thousand KL (equivalent to 23 day consumption).

(5) Sea berth of crude oil shipping port

All the crude oils that are imported to Thailand come from Near Middle East. Table V-1 shows the crude oil shipping sea berths in Near Middle East. Note that the list is restricted to those sea berths which permit the docking of 200 thousand DWT or larger tankers. Smaller facilities are not included in the table.

Since the international popularity is directed toward 250 thousand DWT tankers, facilities for 200 ~ 300 thousand DWT class tankers are available at crude oil shipping ports. Therefore, the assumption of larger tankers for this project will not bring up any problem.

Table V-1 Sea Berths in Near Middle East

Country	Port	Water Depth (m)	Allowable tanker (DWT)	Remarks
Iran	Kharg Island	20.8	200,000	
Kuwait	Mena al Ahmadi	27.6	320,000	
Saudi Arabia	Ras Tanura	25.5	200,000	
Oman	Mena al Huharu	22	280,000	
Nigeria	Escravos	22	200,000	
Neutral zone	Khafji	20	250,000	Completed in Feb., 1972

3. Sri Racha sea berth system

The Sri Racha sea berth system is concretely explained below.

(1) Scale of system

1) Sea berth

Tankers of 200 thousand DWT class are assumed for this project. The crude oil handling capacity of the sea berth can be estimated as below.

(a) Assumptions

a. Tanker arrival distribution shall be Poisson distribution.

b. Service time distribution shall be exponential distribution. Average service time is assumed to be 2.5 days/tanker including stay due to weather and tidal current etc.

c. Tankers are to enter the sea berth in the order of arrival.

(b) Handling capacity based on queuing theory

If time unit is assumed to be 1 month = 30 days, the service rate per tanker will be μ = 30 days/2.5 days = 12. If the monthly mean of the number of arriving tankers is known, the traffic density $\rho = \lambda / c\mu$ (C = number of channels, number of berths in this case). An analytic solution has been obtained when $0 < \rho < 1$. The average waiting time $W_d = \frac{1}{c\mu(1-\rho)}$ and the average length of queue $L_d = \frac{1}{1-\rho}$. However note that W_d and L_d are applicable to those tankers whose departure has been delayed. They are not the averages of all the tankers. We must reverse this flow of thinking to obtain the capacity of a 200 thousand DWT class berth. The crude oil handling capacity of a berth is obtained by the following equation. The specific gravity of crude oils is assumed to be 0.83.

$$\text{Capacity (C)} = (200 \text{ thousand DWT} \div 0.83) \times \lambda \times 12 \text{ months}$$

The following table gives the result (capacity) of this equation at W_d = 1 day, 3 days, 5 days.

Number of berths	Demurrage (days)	ρ	λ	Capacity	Remarks
1	1	-	-	-	$\rho < 0$
	3	0.167	2.0	5,780	
	5	0.500	6.0	17,350	
2	1	-	-	-	$\rho < 0$
	3	0.583	14.0	40,480	
	5	0.750	18.0	52,050	
3	1	0.167	6.0	17,350	
	3	0.722	26.0	75,180	
	5	0.834	30.0	86,750	

The capacity of the sea berth in question is to be determined on the basis of these results. The Mission set the crude oil handling capacity for this project by assuming the delay time of 4.6 days on the basis of the data obtained at Japanese sea berths of 200 thousand DWT class.

1 berth	16,000 thousand KL/year (5.53 tankers/month)
2 berths	50,600 thousand KL/year (17.5 tankers/month)
3 berths	86,300 thousand KL/year (29.8 tankers/month)

The above handling capacities are based on the assumption that all the tankers are of 200 thousand DWT class. In reality, however, tankers of various classes enter a sea berth. So that the foregoing capacity figures will have to be reduced to 60 ~ 70%. In any even, the above figures indicate the maximum crude oil handling capacity of a sea berth under the present sea berth system.

(c) Number of required berths

The number of required berths was calculated on the basis of estimated import volume of crude oils at each period and under each plan. The results are shown below. (See Fig. III-15 for reference.)

Plan	1980	1985	1990
X	1	1	1
Y	1	1	2
Z	1	2	2
W	1	2	2

2) Pipe line

The pipe lines must have the diameter of 48' and the oil transferring capacity of 15,000 KL/h because of large tankers (200 thousand DWT class) and their large pumping capacity.

If a sea berth is constructed at the site A, one pipe line must be installed for each berth for the 2.3 km distance from a sea berth to Ko Sichang Island and one submarine pipe line alone is necessary for the 7.9 km distance from Ko Sichang Island to the land. In this case, a booster pump is necessary for transferring oil from Ko Sichang Island to the land side. In this respect, A is less advantageous than B and C. The site A also requires one 1.3 km pipe line for a one-berth system and one 0.7 km pipe line for a two-berth system. If the B is selected, one 9.0 km submarine pipe line must be installed for each berth. Of the three sites, the site B requires the longest pipe line. It also requires a 0.5 km land pipe line for each berth, which requires tunnel excavation. The site C requires a 3.0 km long submarine pipe line for each berth. In other words, the site C requires the shortest submarine piping. The sites B and C are almost equal in terms of land pipe lines and tunnel excavation. The pipe line length required for each site is given below.

(Unit: KM)

Site	1 Berth		2 Berths		Total		Remarks
	Submarine	Land	Submarine	Land	Submarine	Land	
A	10.2	1.3	2.3	0.7	12.5	2.0	Booster pump is required.
B	9.0	0.5	9.0	0.5	18.0	1.0	Tunnel excavation is required.
C	3.0	0.5	3.0	0.5	6.0	1.0	Tunnel excavation is required.

3) Crude oil storage tank and tank yard

(a) Crude oil tank

Crude oil tanks of about 150 thousand KL (max.) can be constructed along with the appearance of large tankers and large refining systems and technological progresses. The permissible size of a new crude oil tank is hardly determined by types of crude oils, but is determined by the bearing force and subsidence of ground. A crude oil tank of 100 thousand KL is adequate for special crude oils (Minas etc.) if tankers of 100 thousand DWT or less are used because of a shipping port's small water depth or small production.

Crude oil tanks of 150 thousand KL are assumed for this project. The number of required tanks is studied here on the basis of this assumption.

(b) Buffer tank

The capacity of a buffer tank should be large enough for temporarily storing crude oils one 200 thousand DWT tanker. Two 150 thousand KL tanks must be constructed at the site A under the one berth system, while one 150 thousand KL tank must be constructed at the sites B and C in consideration of the capacity of the existing tanks. When the system is improved into a two berth system, another 150 thousand KL tank must be constructed to retain the functions of a buffer tank.

(c) Tank yard

The estimates of Thailand's crude oil import are given below.

1975	8,800	thousand KL
1980	12,800	"
1985	18,900	"
1990	25,900	"

Therefore, oil refining capacity must be increased to approximately 515 thousand BPSD by 1990, which mean an increase of 350 thousand BPSD over the current (1974) refining capacity of 165 thousand BPSD. ESSO, TORC, SUMMIT and TIPCO already plan the expansion of 30 thousand BPSD, 35 thousand BPSD, 35 thousand BPSD and 100 thousand BPSD, respectively. Their total is 200 thousand BPSD. The difference 315 thousand BPSD is the target for new expansions. If stage construction is considered for new expansions, 1 set of 150 thousand BPSD and 1 set of 165 thousand BPSD are expected as refineries. The land area that is required for the new facilities is estimated below. (Table V-2).

Table V-2 Required Plottage by Refinery Scale

(Unit: ha)

No.	Item \ Scale	150 thousand BPSD per system	165 thousand BPSD per system	Remark
1	Refinery plant Utility facility	14	15	Roads, office warehouses are included.
2	Oil tank yard including road	69	76	Storage - 60 days, tank occupation - 60%
3	Product tank yard (railway, loading yard)	45	50	The capacity per tank is assumed to be 10 ~ 50 thousand KL. Storage - 30 days, tank occupation - 50%
	Total	128	141	

The above table shows that 270 ha is needed.

(d) Tank layout

The layout of refineries and tank yards must be determined on the basis of natural conditions and the scale of oil refining industry. The following two cases are possible.

Case 1: Crude oil tank yard, refineries and product tank yard etc. are constructed in Laem Chabang District. (See Fig. V-3 for reference.)

Case 2: A part of a crude oil tank yard is constructed on Ko Sichang Island. It is used also as a base for transfer to SUMMIT. The other crude oil tanks are constructed in Laem Chabang District with a refinery and product tanks. (See Fig. V-4 for reference.)

Case 1

The ground for a crude oil tank should desirably be 5 ~ 10m higher than a refinery in view of the flow of petroleum in refining processing and petroleum's characteristics. Tank construction requires good soil conditions. In view of these conditions, a crude oil tank yard should be constructed on the loam ground in the mountain zone or in the southern coastal zone. The previously discussed paddy field zone should probably be used for refining facilities and a product tank yard. It will require adequate ground improvement. Ground improving method should be determined on the basis of thorough geological investigations, the load strength, characteristics and shape of structures etc.

Since all the ground facilities are constructed in Laem Chabang District under Case 2, compensations to residents for the use of their plantation and moving will bring up considerable problems.

The area that is needed for a crude oil tank yard for 315 thousand BPSD is shown below. Sufficient area is obtained in Laem Chabang District for a tank yard, a refinery and a product tank yard.

Refining capacity	Crude oil tank	Number of tanks	Total capacity	Area
thousand BPSD 150	ten thousand KL 15	16	ten thousand KL 240	ha 69
165	15	18	270	76
Total 315		34	510	145

Case 2

Location		Crude oil tank	Number of tanks	Total capacity	Area
Ko Sichang Island		ten thousand KL tank 15	20	ten thousand KL 300	ha 62
Laem Chabang	thousand BPSD 150	ten thousand KL 15	7	105	30
	165	"	7	105	30
Total	315		34	510	122

Under this plan, some crude oil tanks are constructed on Ko Sichang Island, and the other crude oil tanks are constructed in Laem Chabang District. It is possible to construct twenty 150 thousand KL tanks in Ko Sichang Island. This island is a plateau of almost flat basement and its altitude is about 57m. It provides about 65 ha of land for tank construction. Since it is infertile and its height and distance allow direct transfer of crude oils by crude oil tankers' cargo oil pump. Therefore, this island has ideal conditions as a base for crude oil storage tank yard.

It has the following advantages to construct crude oil tanks in Ko Sichang Island.

a. Crude oils are transferred to SUMMIT's refinery from Ko Sichang Island by 5,000 DWT class tankers. Therefore, SUMMIT's crude oil tanks in Sri Racha District become unnecessary and can be used by TORC or ESSO.

b. Crude oils can be economically transferred to ESSO and TORC by one submarine pipe regardless of tanker schedule.

The above study leads to the following conclusion. Case 2 requires 85 ha less plantation than Case 1 in Laem Chabang. Case 2 allows to use 62 ha of infertile plateau on the island. Therefore, Case 2 seems for more advantageous since it means far less decrease of agricultural production and far less problems for residents.

It is important to minimize the conversion of plantation and the evacuation of residents under both Case 1 and Case 2.

The present project is based on the assumption that the increase of refining capacity should be 315 thousand BPSD by 1990 (150 thousand BPSD for one enterprises and 165 thousand BPSD for one enterprise) and that this system is to be run by the three enterprises. However, various equipments can be more rationally planned and land requirement can be decreased by running the system by one company established by joint investments.

If the sea berth is constructed at the site A, buffer tanks will be constructed in Ko Sichang Island. If it is constructed at the site B or C, buffer tanks will be constructed in Laem Chabang. Since buffer tanks are a part of crude oil tanks, the both are equal in terms of land occupation. However, their location and layout must be determined in consideration of future expansion.

(2) Products of transportation

The shipment of petroleum products will amount to 10,230 thousand KL/year in 1990. In other words, the daily shipment will amount to 28,000 KL/Dey. The following two methods can possibly be used for product transportation.

1) Tankers are mostly used among tankers, railways and tank lorries.

2) Pipe lines are mostly used among pipe lines, tankers, railways and tank lorries.

Evan if pipe lines are used as the main means of transportation, tankers must also be used to some extent.

They will naturally require sea berths.

Table V-3 shows the number of sea berths that are required for 70% of the products by tankers of various classes (300 ~ 600 DWT, 600 ~ 1,000 DWT, 1,000 ~ 2,500 DWT, 2,500 ~ 5,000 DWT, 5,000 ~ 10,000 DWT).

Table V-3 Number of Shipment Berths by Tanker Classes

Class (DWT)	Staying time near berth from arrival and departure	Average daily operation hours	Number of allowable tankers per day and per berth	Operating ratio of berth	Number of tankers for actual operation per day and per berth	Daily shipment per berth	Number of berth	Number of tankers	Daily shipment
300 ~ 600 (Mean 450)	min. Av. 220 (3.7 hr)	hr 11	tankers 3	% 0.6	tankers 2	KL 900	berths 2	tankers/day 4	KL 1,800
600 ~ 1,000 (Mean 800)	Av. 290 (4.9 hr)	11	2	0.6	1	800	2	2	1,600
1,000 ~ 2,500 (Mean 1,750)	Av. 380 (6.3 hr)	11	1.7	0.5	1	1,750	2	2	3,500
2,500 ~ 5,000 (Mean 3,750)	Av. 660 (11 hr)	12	1	0.5	0.5	1,875	2	1	3,750
5,000 ~ 10,000 (Mean 7,500)	Av. 900 (15 hr)	24	1	0.4	0.4	3,000	3	1.2	9,000
Total							11	10.2	19,650

(Note) 1. The number of berths should be determined by a simulation study by assuming navigation conditions, marine conditions, berth schedule, tanker schedule etc. The operation rate of a berth was assumed to be 0.6 ~ 0.4 here on the basis of the past records.

2. It was assumed that the daily work hours is 11 ~ 12 hours with small tankers and 24 hours with large tankers.

VI. LAND AND WATER

VI. LAND AND WATER

1. Land

(1) Current land utilization

1) Brief description of project region

The present project covers Chonburi Province and Ban Laem Chabang area in Sri Racha Amphur.

Chonburi Province is located in the east of Gulf of Thailand. It adjoins to Chachoengsao Province in the north and to Rayong Province in the south. Chonburi Province consists of seven Amphurs. Sri Racha Amphur is one of them. Sri Racha Amphur is further divided into six communes (called Tambon), namely, Bang Phra, Nong Kham, Sri Racha, Surasak, Buing and Toang Sukher. Each Tambon is divided into villages (called Mooban). Municipalities and sanitation districts are formed in districts with large population. (See Fig. IV-2 and IV-3.)

According to the Thai Government's statistics of 1970, the population in Chonburi Province is about 541,000. Of the amphurs, Amphur Muang has the largest population (130,000). The population of Amphur Sri Racha is 82,000. It is 95,000 if the population of the municipality area is also added. In other words, Amphur Sri Racha is the third in Chonburi in terms of population. About 95% of the residents are engaged in agriculture, while the remaining 5% are engaged in fishery, commerce and industry. Small sugar manufactories and tapioca refineries are the major industries. The most of the developments are limited to the 5 km wide belt zone along the coast and some northern districts with high agricultural productivity. The GNP per capita in the province was 3,744 ฿ in 1970. According to the Thai Government's estimate, it will reach 12,193 ฿ in 1981 (on the assumption of average annual growth rate of 5.4%). The planned growth rate of GNP per capita in Thailand is 4.5%. This reveals that Chonburi Province is considered as rapidly developing province.

Laem Chabang District is close to Bangkok City (about 200 km on ground). Although there is no railway between them, a completely paved highway runs along the east coast of Gulf of Thailand. It runs across Amphur Sri Racha and goes to Sattahip. The traffic of the highway is heavy.

Sri Racha Municipality, which is adjacent to this project area, is a port town with the population of about 13,000. It is the economic and administrative center of Amphur Sri Racha.

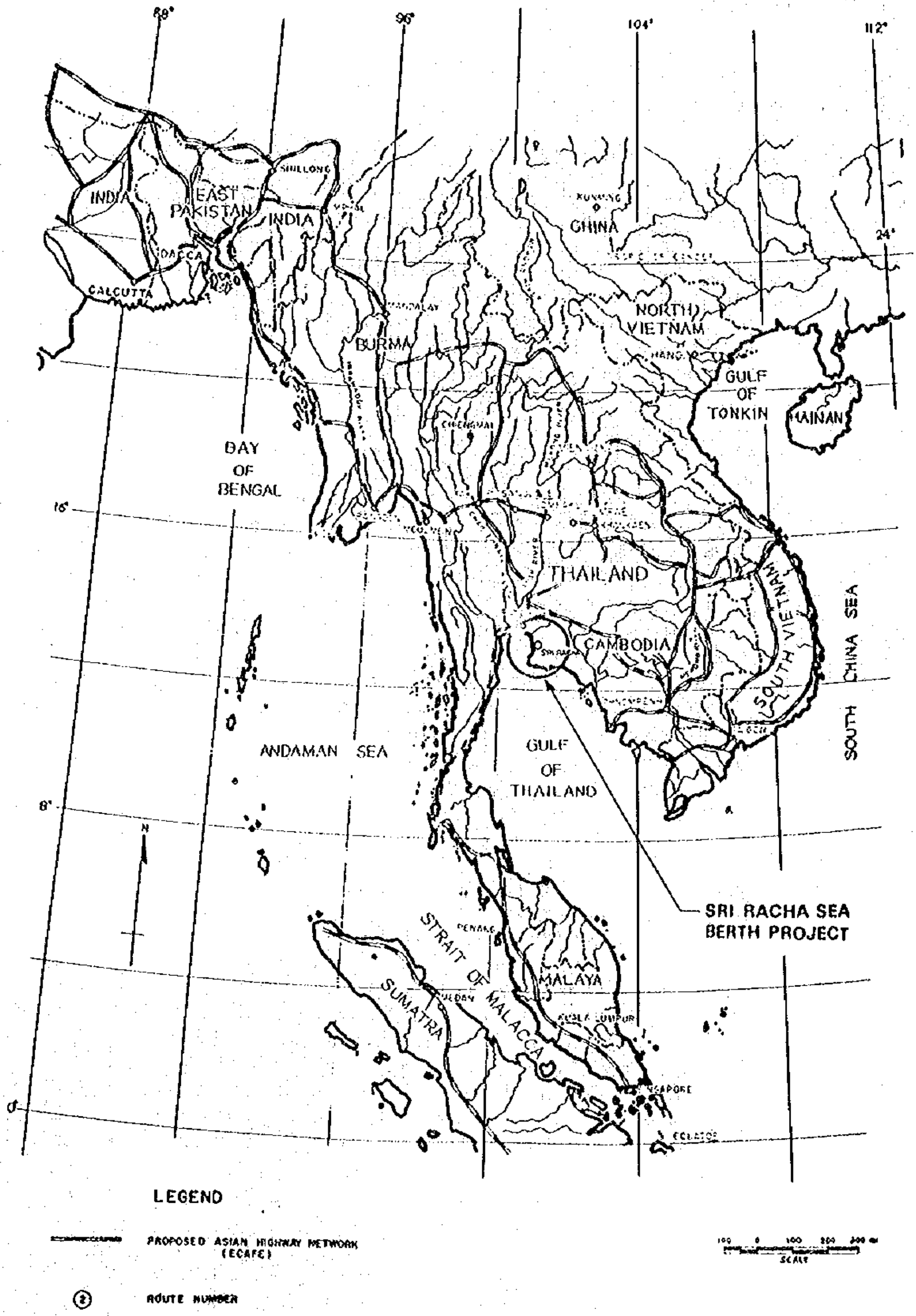


Fig. VI-1 Map of Sea Berth Project

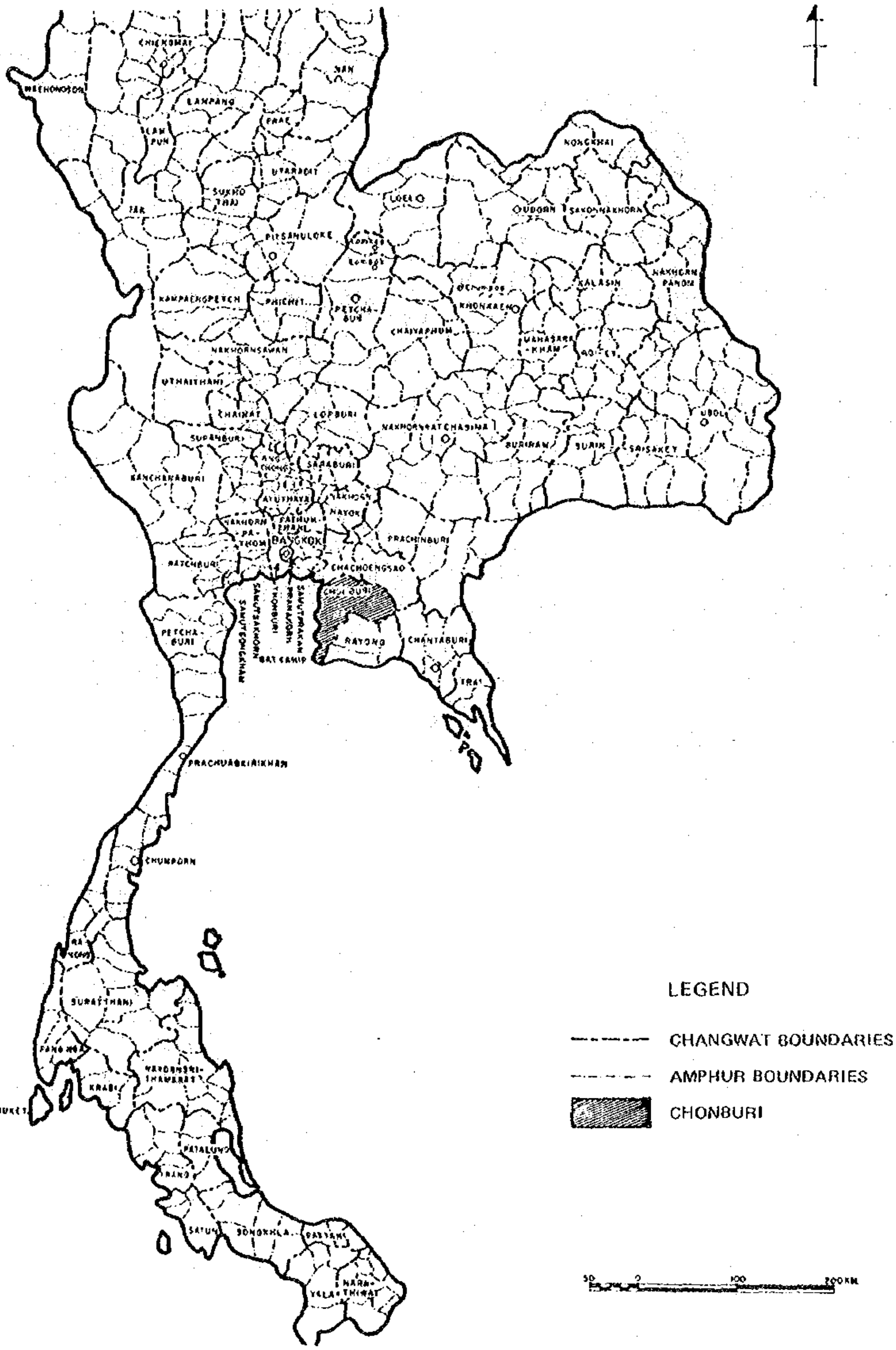


Fig. VI-2 Administrative Divisions

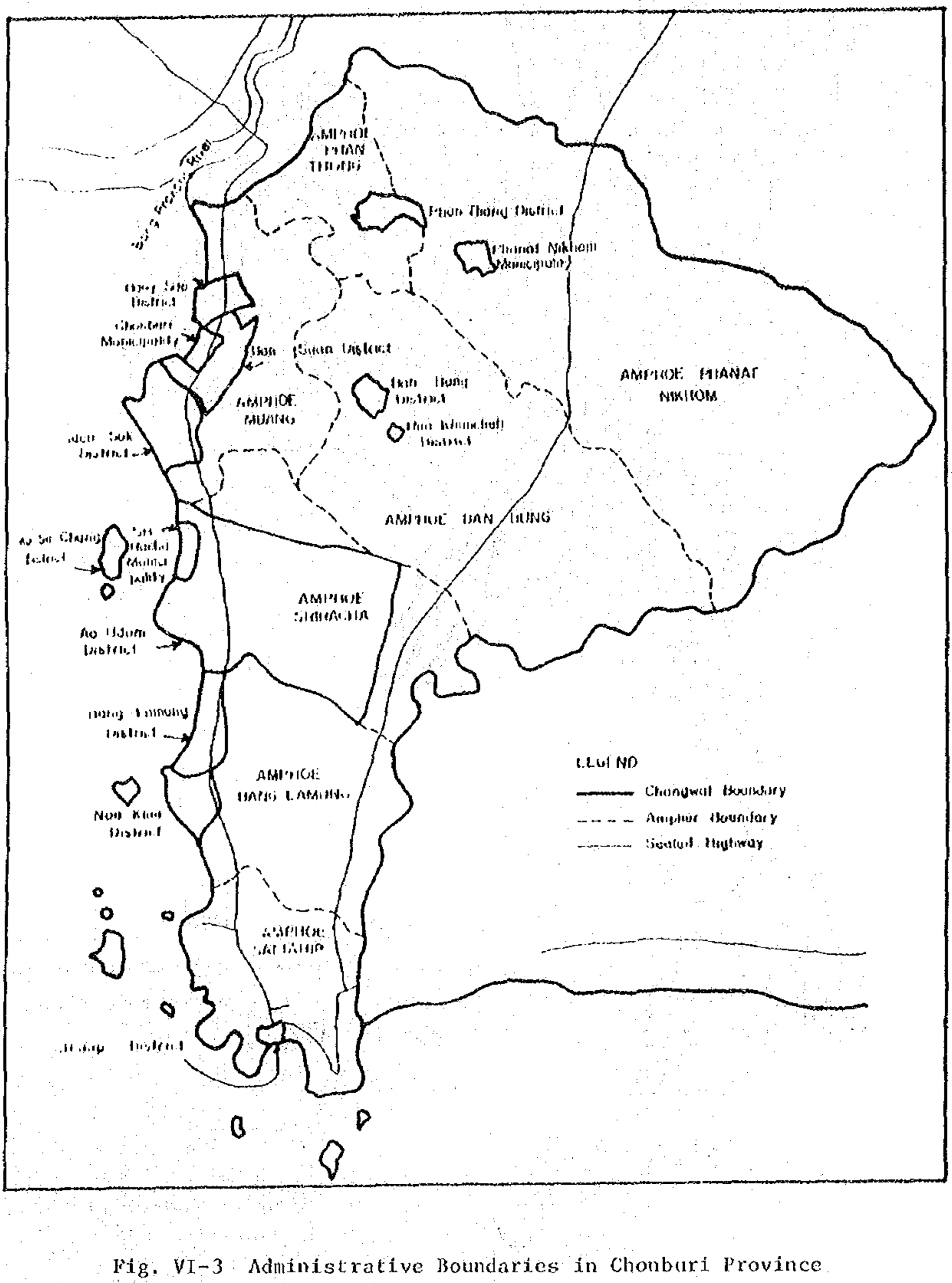


Fig. VI-3 Administrative Boundaries in Chonburi Province

Table VI-1 Total Population by Sex, Total Households by Type, Municipal Area, Sanitary District and Amphoe

	Population			Household			
	Total	Male	Female	Total	Collective Household	Total	Agriculture Household
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Changwat, Total	541,695	277,465	264,230	94,478	615	93,863	40,047
Municipal Area	63,478	31,347	32,131	10,567	48	10,519	329
Sanitary District	128,605	64,424	64,181	22,356	146	22,210	4,890
Non Municipal Area and Outside Sanitary District	349,612	181,694	167,918	61,555	421	61,134	34,828
Amphoe Moang Chon Buri	125,335	63,182	62,153	20,744	148	20,596	3,907
Municipal Area	39,367	19,532	19,835	6,228	33	6,195	60
Sub-Amphoe Ko Sichang	2,097	1,029	1,068	377	1	376	7
Amphoe Bang Lamung	58,034	29,381	28,653	10,219	74	10,145	5,175
Amphoe Ban Bang	77,456	39,984	37,472	13,505	54	13,451	6,807
Amphoe Phanat Nikhom	107,968	53,925	54,043	19,784	97	19,687	13,050
Municipal Area	10,514	4,940	5,574	1,888	4	1,884	193
Amphoe Phan Thong	29,421	14,301	15,120	5,113	26	5,087	3,116
Amphoe Sri Racha	81,620	41,560	40,060	14,519	88	14,431	6,026
Municipal Area	13,597	6,875	6,722	2,451	11	2,440	76
Amphoe Sattahip	59,764	34,103	25,661	10,217	127	10,090	1,959

2) Land utilization in project area

(a) Inland area

The sites A, B, C have been proposed for sea berth construction site. In any event, Ban Laem Chabang area in Amphur Sri Racha is most suitable for constructing tank yards and oil refineries. As Fig. VI-4 shows, this area is surrounded by a line starting from Ban Ao Udom, passing through Ban Pa Ao Udom, going south along Sukhum Wit High Way and reaching Ban Noen Phai (south east) via Ban Noen and by Ban Laem Chabang. Some refineries already exist in this area.

Hills of Khao Pho Bai (altitude: 120m ~ 180m), hills of Khao Nong Ang and Khao Boya (altitude 90m - 110m) are found along the west coast of the project area. These hills reach Laem Chabang Point.

Currently, refineries and tank yards are located along the hilly zone of Mount Kao Pho Bai. They are protected by summer monsoons by the hills. Plantations, such as Orchard and Cassava, are scattered in the east of the hilly zone of Khao Nong Ang and Khao Boya. Flat land with the altitude below 5m is found toward the east in the direction of the highway. It is mostly left as uncultivated land, though it is partly used as rice field. The area around the highway forms mild slope with the altitude of 15m ~ 25m. Many coconut, Orchard and Cassava plantations are found. (See Fig. VI-5)

Almost no house is found in the project area, except along the highway. Therefore, problems related to evacuation of residents will be small. However, the purchase of private land and the compensations for plantations and rice fields must be considered. Few temple exists in this district.

The usable area in this district is shown below. The figures reveal that sufficient land for refinery and tank yard construction for this project can be secured.

Flat land	Altitude	0 ~ 5m	7.8km^2	4.875 Rai
Slope "	"	5 ~ 10m	2.3km^2	1.437 Rai
"	"	10 ~ 15m	1.9km^2	1.187 Rai
"	"	15 ~ 20m	1.0km^2	625 Rai
"	"	20 ~ 25m	0.4km^2	
Total			13.4km^2	

The foundation conditions of the project area were described before. Generally speaking, the flat zone has soft foundation and the hilly zone has good fundation conditions. If plants and tank yards are to be constructed in the flat zone, foundation must be exchanged and foundation piles must be driven.

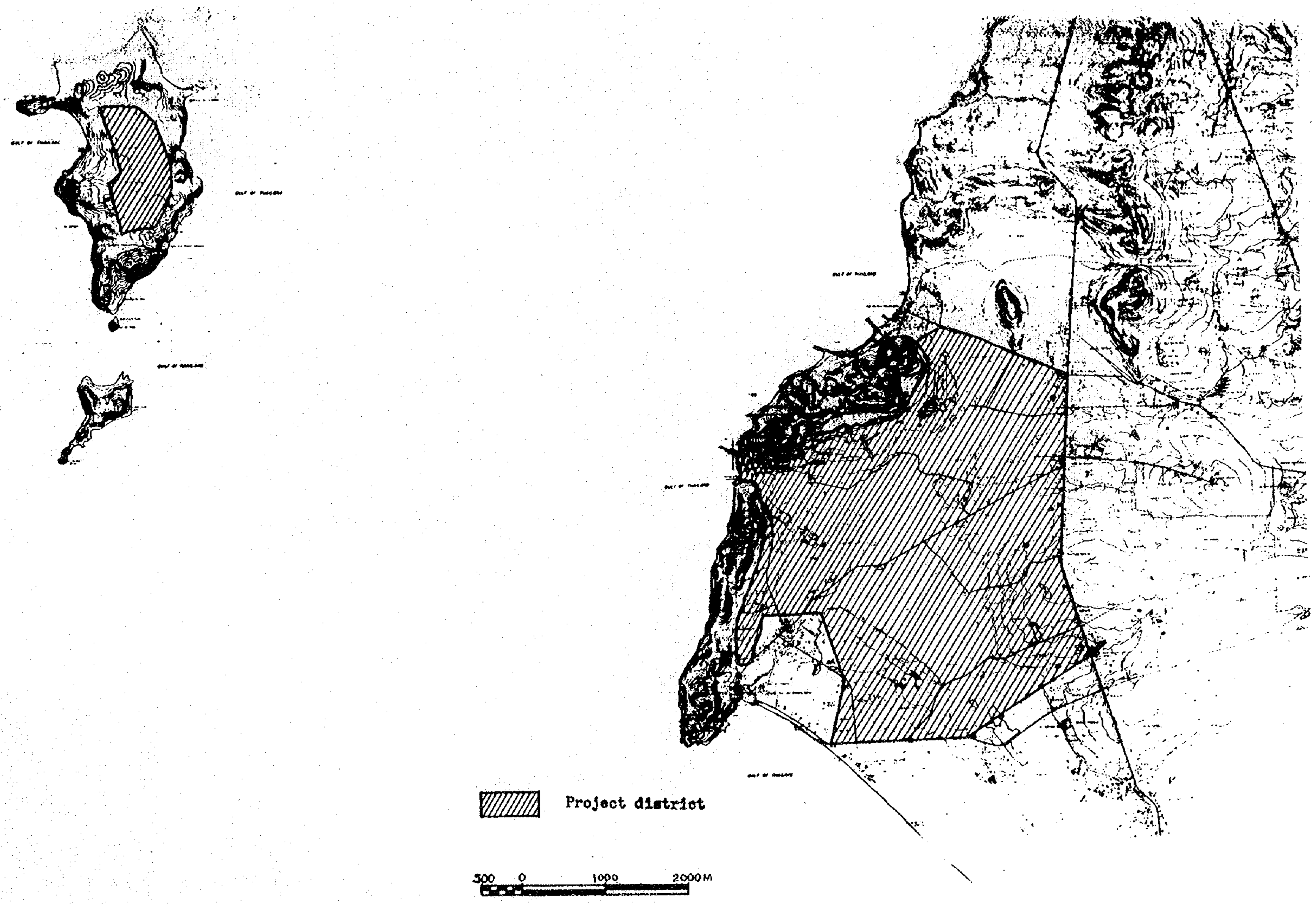


Fig. VI-4 District under Project

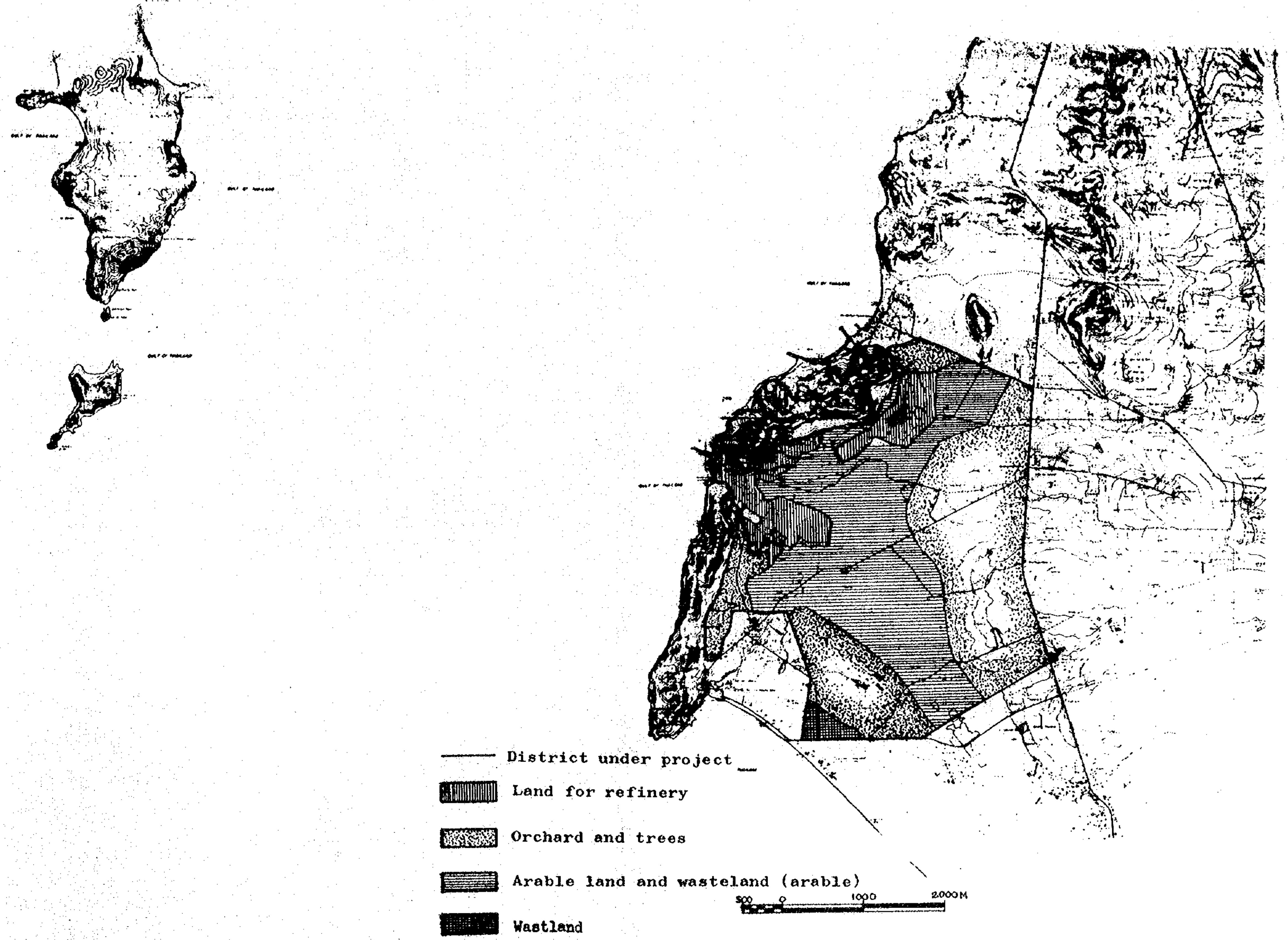


Fig. VI-5 Current Land Utilization

(b) Ko Sichang Island

Ko Sichang Island is located at 12 km in the west of Municipality Sri Racha. Large and small islands exist around it.

Its population is about 2,000. A small number of houses are found in the northeast coast of the island. A small island is found in the northeast sea of the island. The sea is calm and suitable for anchorage. It is used as the bunker base for ships. Therefore, this water area seems most suitable for a base for construction crafts.

The southern part of the island forms relatively flat plateau with the altitude of about 50 m. Hardly any house and tree are found here. Since this area has bedrock beneath the surface soil, it is suitable for tank yard construction. About 650,000 m^2 of land is available here for a tank yard.

3) Existing oil refineries

Currently, oil refineries are located in the east of the coastal hilly zone from Ban Ao Udom to Ban Laem Chabang.

Thai Oil Refinery Co. (TORC) has a submarine pipe line from its sea berth to Ban Ho Udom and a land pipe line around Mountain Khao Pho Bai. Its refinery is located in the east of Mount Khao Pho Bai. It is adjacent to Summit Industrial Corp.'s tank terminal in the southwest.

Mount Pho Bai ends once, but Mount Khao Nong Ang starts soon. ESSO Standard Thailand Ltd.'s submarine pipe line from its sea berth reaches this narrow seashore zone between the two mountains. Its refinery is located in the inland part. The three companies' tanks and plant facilities are located in this area.

The land owned by these companies in given below.

ESSO	0.96 km^2
TORC	0.64 km^2
SUMMIT	km^2

(2) Reclamation and land acquisition

1) Purchase of land

The approximate land prices of the project area and the surrounding area are given below.

In Municipality	About	1,000,000 ฿/Rai
On shore	"	200,000 ฿/Rai
Near highway	"	150,000 ฿/Rai
Flat zone except the above	"	50,000 ฿/Rai~80,000 ฿/Rai
Mountain zone	Below	50,000 ฿/Rai

Therefore, the average purchase price of the project area may be assumed to be 80,000 ฿/Rai (50 ฿/m^2).

Difficulty of land purchase will depend on Thai Government's attitude, namely, on whether it takes legislative measures etc. In view of the current state of land utilization, land purchase will not become the decisive factor for this project. The residential areas must be separated sufficiently from refineries for the safety of residents. Therefore, sufficient land should be purchased in consideration of future facility expansions.

2) Land reclamation

Let's estimate land reclamation costs and compare them with land purchase prices. We assume to reclaim land of 2 km in length and 0.6 km in width along the coastline (water depth below 6 m). See Fig. VI-6.

(a) Reclamation

Height of reclamation	+3.0m
Revetment extension	3.1km
Reclamation area	1,300,000m^2 (810 Rai)
Required soil	7,800,000m^2

(b) Reclamation methods

Case 1:

Assumptions: A sea berth is constructed at C. The sediments obtained from dredging the navigation channel are used for reclamation. The top part (+40m and higher) of Khao Nong Ang and the top part (+50m and higher) of Khao Boya are excavated and used for filling, as Fig. VI-6 shows.

Required soil	7,800,000 m^3
Soil obtained by dredging navigation channel	4,000,000 m^3
(yield rate 80%)	3,200,000 m^3
Shortage of soil	4,600,000 m^3
Soil obtained by excavation	4,600,000 m^3

Dredged soil is carried to the site by suction dredgers. The costs are not given here since they are to be included in dredging costs.

Case 2:

Assumptions: Sediments obtained by dredging the navigation channel are used for reclamation. Additional sediments are to be dredged at the marked place in Fig. VI-6 by suction dredger. Dredgers of 3,000PS class are sufficient for this purpose.

Required soil	7,800,000 m^3
Soil obtained by dredging navigation channel	4,000,000 m^3
(yield rate 80%)	3,200,000 m^3
Shortage of soil	4,600,000 m^3
Soil obtained by dredging (yield rate 80%)	5,750,000 m^3

(Note)
$4,600,000\ m^3 \div 0.8 = 5,750,000\ m^3$

Case 3:

Assumption: A sea berth is constructed at A or B. Since there is no need for dredging the navigation channel in this case, all the soil for reclamation must be obtained by dredging.

Required soil	7,800,000 m^3
Soil obtained by dredging (yield rate 80%)	9,750,000 m^3

(c) Reclamation cost

The costs of land creation by reclamation are shown below.

(Unit: 1,000 ฿)

	Revetment cost	Reclamation soil			Total
		Excavation soil	Navigation channel dredged soil	Reclamation dredged soil	
Case 1	207,000	308,000	-	-	622,000
Case 2	207,000	-	-	203,000	410,000
Case 3	207,000	-	-	390,000	597,000

The following unit prices were used for the calculation.

Ground excavation	67 ฿/m^3
Revetment for reclamation	67,000 ฿/m
Soil obtained by dredging navigation channel	0 ฿/m^3
Soil obtained by dredging	40 ฿/m^3

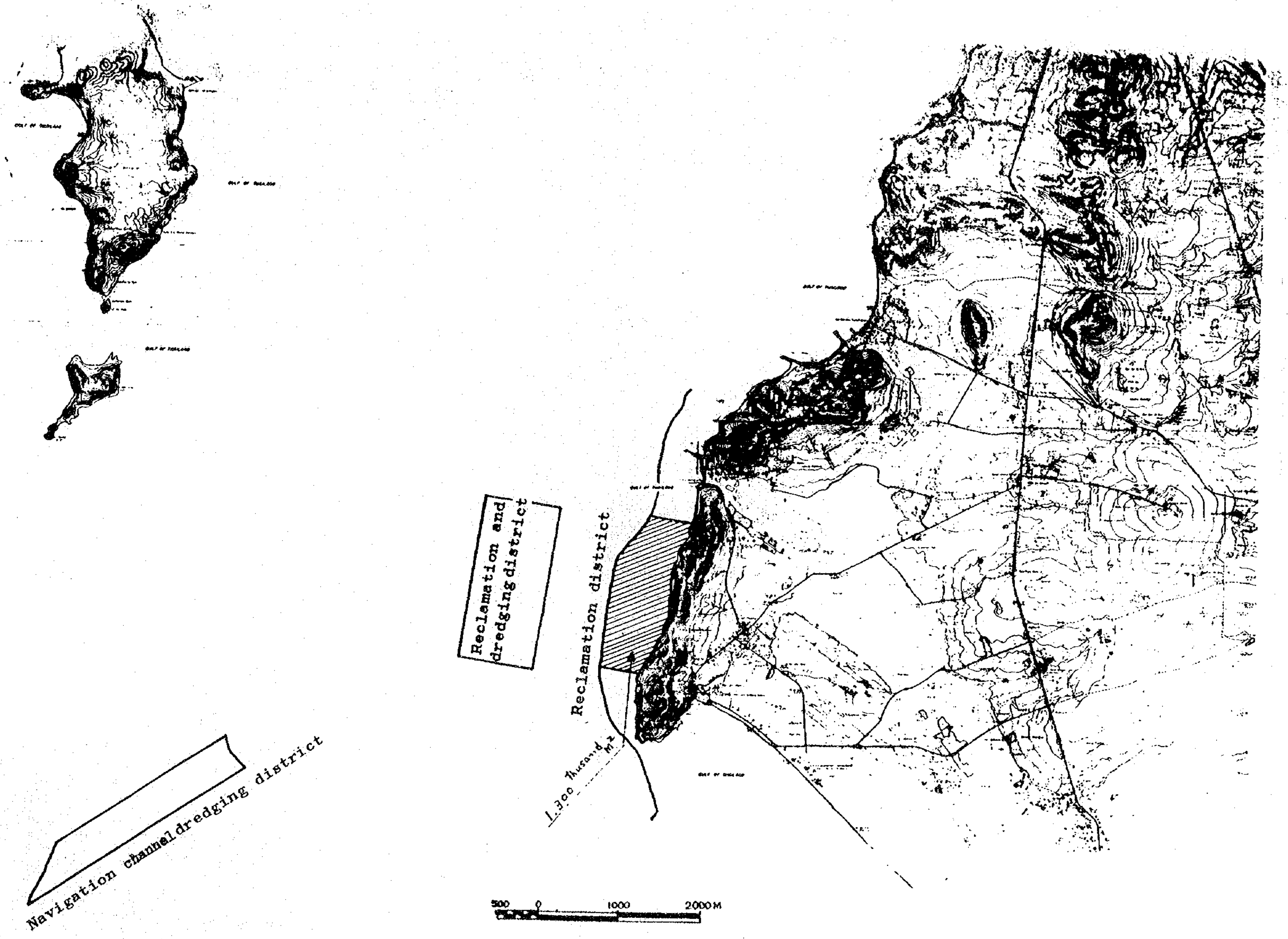


Fig. VI-6 Reclamation

3) Comparison of land purchase cost and reclamation cost by unit price

Unit: ฿/m^2

Unit price of land purchase	Unit price of reclamation			Remark
	Case 1	Case 2	Case 3	
50	478	315	459	Approximately 200,000 m^2 of land is left, by excavation, under Case 1. The unit price of reclamation will be 5 ฿/m^2 lower under Case 1, if this land is used.

The above figures indicate that purchasing will prove to be far more advantageous than reclamation in terms of unit price.

2. Water

(1) Current water supply

The following table shows the current demand and supply of industrial water at the oil refineries in Sri Racha District.

Use	ESSO	TORC
Cooling water	Sea water is circulated. (Circulating sea water is cooled by a cooling tower.)	1. Fresh water alone is used as industrial water. 2. Water is received at the rate of 3,000 m^3/day. 3. Water comes from Ban Phra Reservoir.
Process and Boiler water	Sea water is distrilled to obtain fresh water.	

ESSO uses sea water alone, while TORC uses fresh water alone. Since TORC's oil refining capacity is 65,000 BPSD, it must use 5,000 m^3/day of fresh water. Its actual supply (3,000 m^3/day) is extremely small.

Ban Phra Reservoir is located in northeast of Sri Racha. It is an artificial lake. Its maximum storage capacity and mean water depth are said to be 20,000,000 m^3 and 2 m, respectively. The area of the reservoir seems to be about 1,000 ha.

No data on the water quality of Ban Phra Reservoir could be obtained. Since it is the source of drinking water for local people, it seems suitable for ordinary purposes.

(2) Required quantity of water

It is extremely difficult to estimate the future demand for water in Sri Racha District since no decision has been made with regard to the types and the scale of large industries and no overall plan of city structure etc. has been drawn. Therefore, the demand will be estimated here from the scale of oil refining industry on the basis of estimated demand for petroleum.

As discussed in V, 1 set of 150 thousand BPSD oil refinery and one set of 165 thousand BPSD refineries are planned.

The following table shows various possibilities with regard to the industrial water required for the new oil refineries.

Proposal	Use of Water	Water Classification	System and Treatment	Application	
				Water Source	Pollution
A	Process water	River fresh water	Discharge after water treatment	Rivers have rich water.	Pollution problems are small.
	Cooling water	River fresh water	One pass		
B	Process water	River fresh water	Reuse after water treatment (closed system)	River water is not sufficient.	Pollution control measures are necessary.
	Cooling water	River fresh water	Circulation (closed system)		
C	Process water (Boiler water)	River fresh water	Reuse after water treatment - closed system	River water is extremely insufficient.	Pollution control measures are necessary.
	Cooling water	Sea water	One pass and discharge into sea		
D	Process water	River fresh water	Reuse after water treatment - closed system	River water is insufficient.	Cooling equipments are far from sea side.
	Cooling water	Sea water	Circulation		
E	Process water (Boiler water)	Fresh water obtained from sea water	Reuse after water treatment - closed system	River water is not obtainable.	Pollution control measures are necessary.
	Cooling water	Sea water	One pass and discharge into sea		
F	Process water (Boiler water)	Fresh water obtained from sea water.	Reuse after water treatment - closed system	River water is not obtainable.	Pollution control measures are neces-sary. A plant is at least 1 km from the sea side.
	Cooling water	Sea water	Circulation		

Either an air cooling system or a water cooling system can be adopted for a plant. A heat exchange system consisting of pre-heating crude oils is also available. These three systems are usually combined for a plant. The following two systems are conceivable for estimating the demand for water under the present project.

System 1	Process water, Boiler water	Fresh water alone is used by circulation. Water is treated and reused (closed system). Unused water is used for boiler water.
	Cooling water	Fresh water alone is used by circulation.
System 2	Process water, Boiler water	Fresh water alone is used by circulation. Water is treated and reused. (closed system)
	Cooling water	Sea water is used by circulation for 80% of cooling water.

The demand for water under the above two systems is shown below.

Capacity of oil refining \ Proposal	Proposal 1		Proposal 2	
	Fresh Water	Sea Water	Fresh Water	Sea Water
(1st term) 150 BPSD	m^3/day 9,250	m^3/day 0	m^3/day 3,550	m^3/day 17,750
(2nd term) 165 BPSD	10,150	0	3,900	23,600
Total	19,400	0	7,450	41,350

Under System 1, fresh water consumption of 19,400 m^3/day must be secured. It requires further utilization of Ban Phra Reservoir and the adoption of a circulation system.

VII. FACILITY DESIGN AND SCHEDULE

VII. FACILITY DESIGN AND SCHEDULE

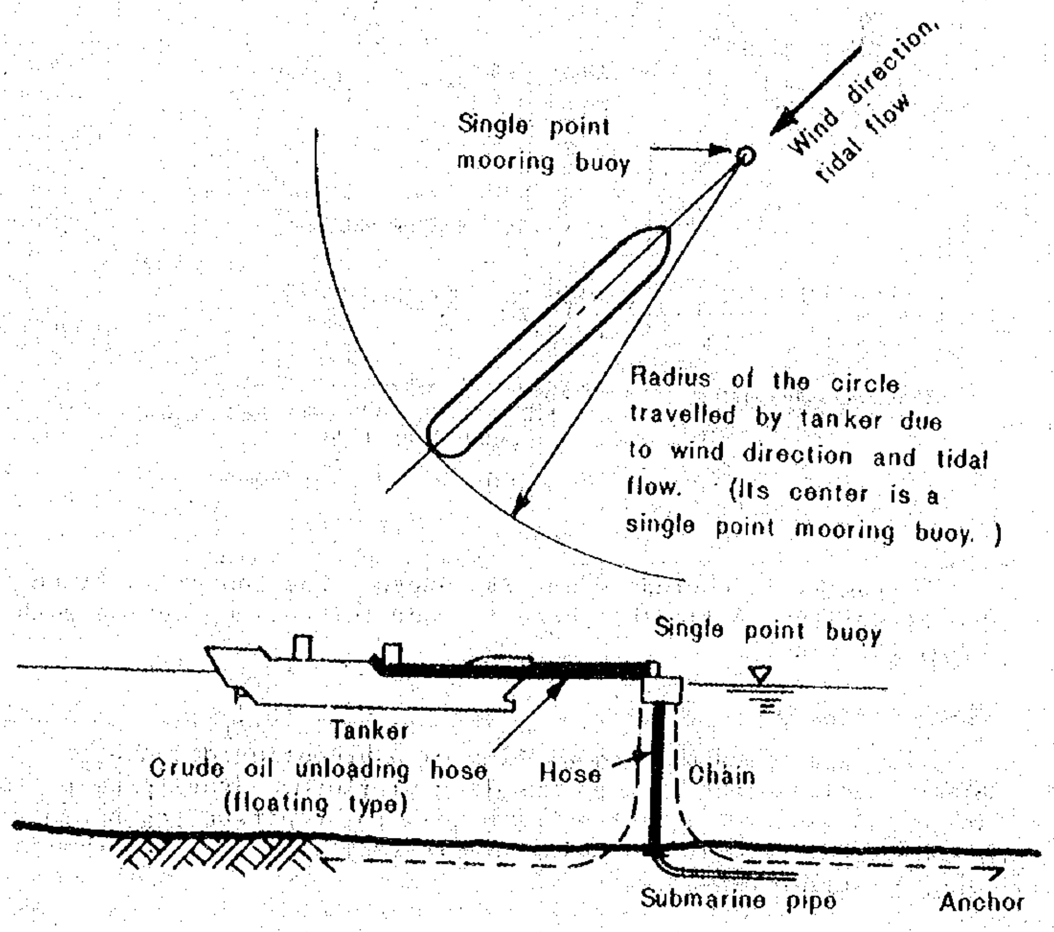
1. Selection of sea berth type

The following types of sea berths are widely used for mooring large ships.

- Single point buoy mooring type
- Spread mooring type
- Fixed pier type

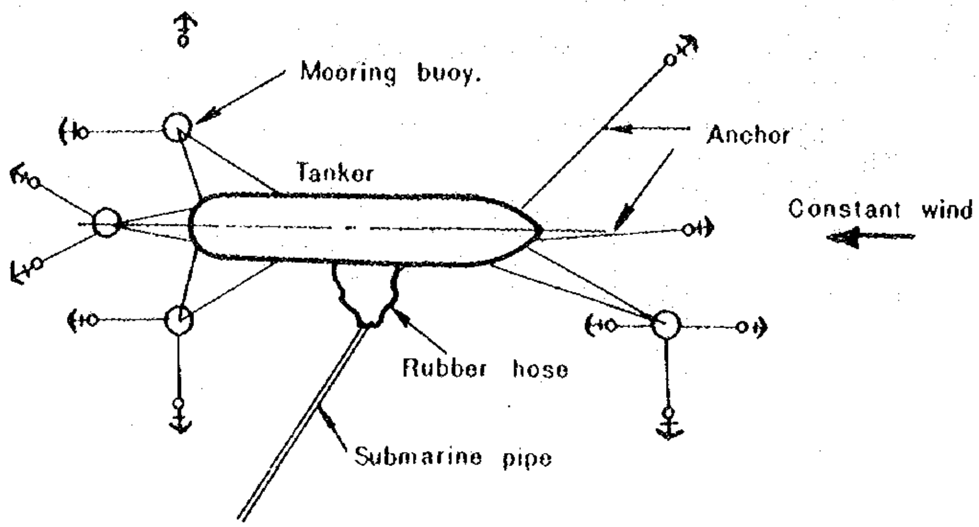
The characteristics of these three types are discussed below.

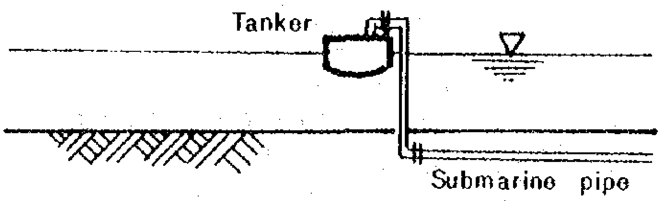
(1) Single point buoy mooring type



A buoy is installed at a point of desined water depth. The stem of a tanker is moored to the buoy by a rope. The tanker can freely move around the buoy according to wind, tidal flow and waves etc. A floating hose is used for the connection of the tanker's manifold with a submarine pipe. The buoy is fixed either by an anchor or by a pile. Typical examples include IMODOCO Buoy and ESSO Buoy.

(2) Spread mooring type

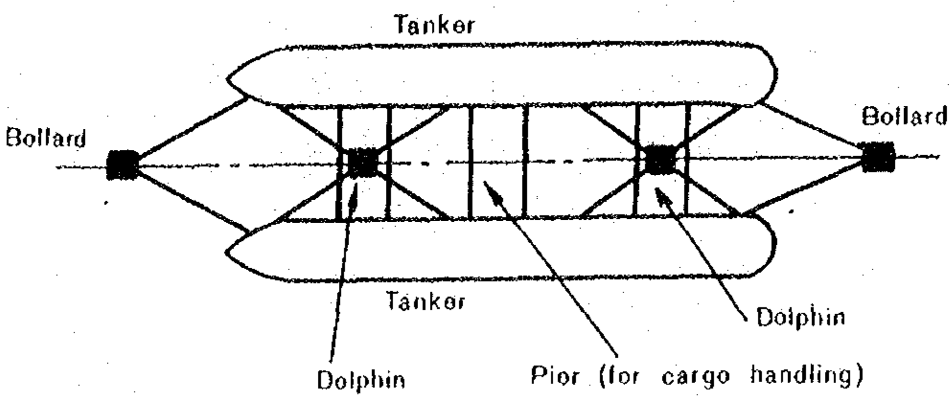


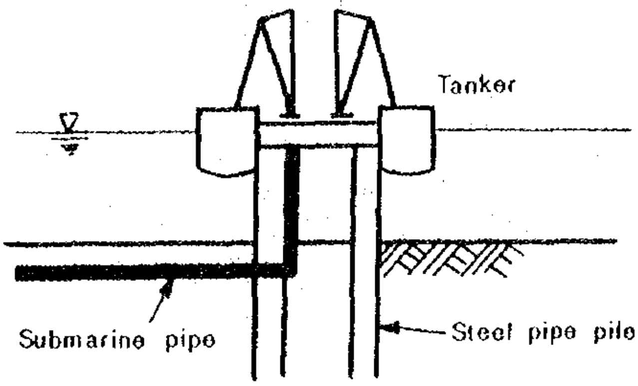


A tanker is moored by several buoys. The tanker is fixed in one direction. A flexible hose is used for the connection with a submarine pipe.

(3) Fixed pier type

It is a fixed pier consisting of a breasting dolphin, a mooring dolphin and a cargo handling platform. Steel pipe piles are usually driven into the sea bottom for constructing a sea berth of this type. A loading arm installed on the platform is used for cargo handling.





(4) Comparison of characteristics by sea berth types

1) Comparison by maneuvering and mooring safety

Table VII-1 compares the three types of sea berths in terms of the safety of maneuvering and mooring works.

Table VII-1 Characteristic Comparision of Sea Berths

Item	Multi-point	Single point mooring type	Fixed types
Direction of berth's face line	The direction of swell must be considered carefully.	Major swell, flow and wind require consideration, but their direction generally does not matter.	The direction of swell must be considered carefully.
Water area to be occupied by berth	Middle	Largest	Smallest

Item	Multi-point	Single point mooring type	Fixed types
Water area of approach to berth	Approaching channel is almost fixed.	Sufficient space is required due to swell, wind, tidal current.	Approach route is almost fixed.
Turning basin	1) It is almost included in berth-occupied water area. 2) If approaching channel has a large bent, the bent requires sufficient turning space. Either 1) or 2) is necessary.	It is included in berth-occupied water area.	1) It is necessary in front of berth. 2) If approaching channel has large bent, the bent requires sufficient turning space. Either 1) or 2) is necessary.
Docking and undocking	Difficult	Easy	Ordinary
Required time	Long	Short	Middle
Required number of tug boats	Middle	Small	Large
Difficulty of mooring operation	Large	Small	Middle
Fixedness of tanker during mooring	Middle	Small (characteristic)	Large
Allowable fixedness of tanker during cargo handling	Middle	Large	Minimum (Chiksan joints are used)
Safety of mooring	Small Weak especially against waves.	Middle Since a tanker is loosely fixed, it is safer against flow and wind. No quantitative judgement has been made.	Middle

Item	Multi-point	Single point mooring type	Fixed types
Need for berth sheltering	Large	Middle Since a berth is far from coastal line, artificial sheltering is almost impossible.	Large
Crew's feeling of safety and rest during mooring and cargo-handling	Middle	Small	Large
Contact, communication and transportation with land facilities	Poor	Poor	Middle
Evacuation at emergency	Difficult	Easiest	Difficult
Oil leakage control	Rather difficult	Difficult	Good
Danger of hull damage	Small	Small	Middle

2) Comparison of construction costs and maintenance costs

The three types of sea berths are compared in terms of economy, on the basis of demurrage loss (1978 ~ 1990) and construction costs (200 thousand ton berth).

(a) Demurrage loss

a) Port time by models

Table VII-2 Port Time by Tanker Models

Model	Loadage	Cargo Handling Rate	Cargo Handling Time	Pre- and Post-Cargo Handling Time	Ballast	Total of Required Time
Dolphin type						
	kℓ/h	kℓ/h				
100,000 tons	115,000	8,000	14+3	5	3	25
150,000 tons	170,000	10,000	17+3	5	3	28
350,000 tons	400,000	12,000	33+5	5	3	46
Buoy type						
100,000 tons	115,000	8,000	14+3	7	3	27
150,000 tons	170,000	10,000	17+3	9	3	32
350,000 tons	400,000	10,000	40+5	11	3	59

Table VII-2 reveals that the port time difference between a fixed type and a buoy type is about 7 hours in the case of 200 ~ 250 thousand class tankers.

b) Estimated import volume of crude oils for 10 years

The estimated import of crude oils between 1978 and 1990 is 232,700 thousand kℓ. (See Fig. III-15)

c) Tanker hire

The demurrage loss of 200 thousand DWT tankers is approximately 271 thousand ฿ per day and per tanker. Therefore, the merit of the fixed type due to the port time difference for 10 years can be obtained as shown below.

Load of 200 thousand DWT tanker;
200 thousand DWT ÷ 0.83 ≑ 241 thousand KL
(Crude oil 0.83 t/kℓ)

Number of tankers;
232,700 thousand kℓ ÷ 241 thousand kℓ ≑ 966 tankers

Demurrage loss;
271 thousand ฿/tanker/day × 966 × 7/24 ≑ 76 million ฿

(b) Construction costs

a) Fixed type

Construction cost (net construction cost of one berth)	271 million ฿ (See Table VIII-1)
Interest (8 p.a.)	271 million ฿×1.720=466 million ฿
(Total)	737 million ฿/one berth

b) Buoy type

Construction cost (net construction cost of 1 berth)	147 million ฿
Maintenance cost including hose replacement	150 million ฿
Interest (8 p.a.)	(147 million ฿+150 million ฿/2) × 1.720 = 382 million ฿
(Total)	679 million ฿/one berth

(c) Economic comparison

Fixed type	737 million ฿
Buoy type	679 million ฿ + 76 million ฿ = 755 million ฿

Economic comparison for the 13 years between 1978 and 1990 (when predictions are made) was made on the basis of the estimated import volume of crude oils. As a result, the fixed type was found to have the merit of about 18 million ฿. From the consideration of the sharply increasing maintenance cost for the buoy type and the high working rate of the fixed type, the fixed type is obviously more economical than the buoy type. (In Japan, all the recently constucted sea berths are of fixed type.)

3) Selection of sea berth type

The above study leads to the conclusion that a fixed type sea berth is more advantageous than a buoy type in terms of the safety of maneuvering and mooring and the economy. Although a buoy type sea berth requires less initial investment, a fixed type has long-range merits. The international tendency is directed to fixed type sea berths.

Fixed pier type will be adopted for this project also because it requires less water space.

(5) Fixed pier type sea berth

A fixed pier type sea berth usually consists of a breasting dolphin, a mooring dolphin and a platform etc. (See Fig. VII-1 for reference.)

1) Breasting dolphin

A breasting dolphin is used for absorbing energy during docking of a tanker. It is designed on the basis of the reaction force of a rubber fender.

A main breasting dolphin and a sub-breasting dolphin are usually installed. One breasting dolphin alone is occasionally constructed when the range of tanker sizes is small.

A mooring rope is also attached to a breasting dolphin.

A breasting dolphin is equipped with the following items.

Rubber fender
Quick release hook
Capstan
Boolard

2) Mooring dolphin

The mooring rope of a tanker is fixed to a mooring dolphin. Therefore, it is designed on the basis of mooring force obtained from wind pressure and tidal current force.

With a both-sides-docking type berth, one mooring dolphin can be used for the both sides. Four mooring dolphins are usually installed. Two of them are outer mooring dolphins for the bow line for stopping a tanker's longitudinal motions and for the stern line for stopping transverse motions.

A mooring dolphin is equipped with the following items.

Quick release hook
Capstan
Bollard
Boat landing

3) Unloading platform

A platform is required to secure space for unloading crude oils. It is equipped with following facilities.

Loading arm
Gang way
Control house
Navigation
Crude oil riser pipe
Piping

A platform requires about 30m × 25m (per berth). If no earthquake is assumed, a platform is designed on the basis of wind pressure, tidal current and wave force etc. as horizontal force. The major external vertical force applied to a platform is the weight of facilities.

4) Others

Walk ways for connecting dolphins and piers for supporting walk ways are also necessary.

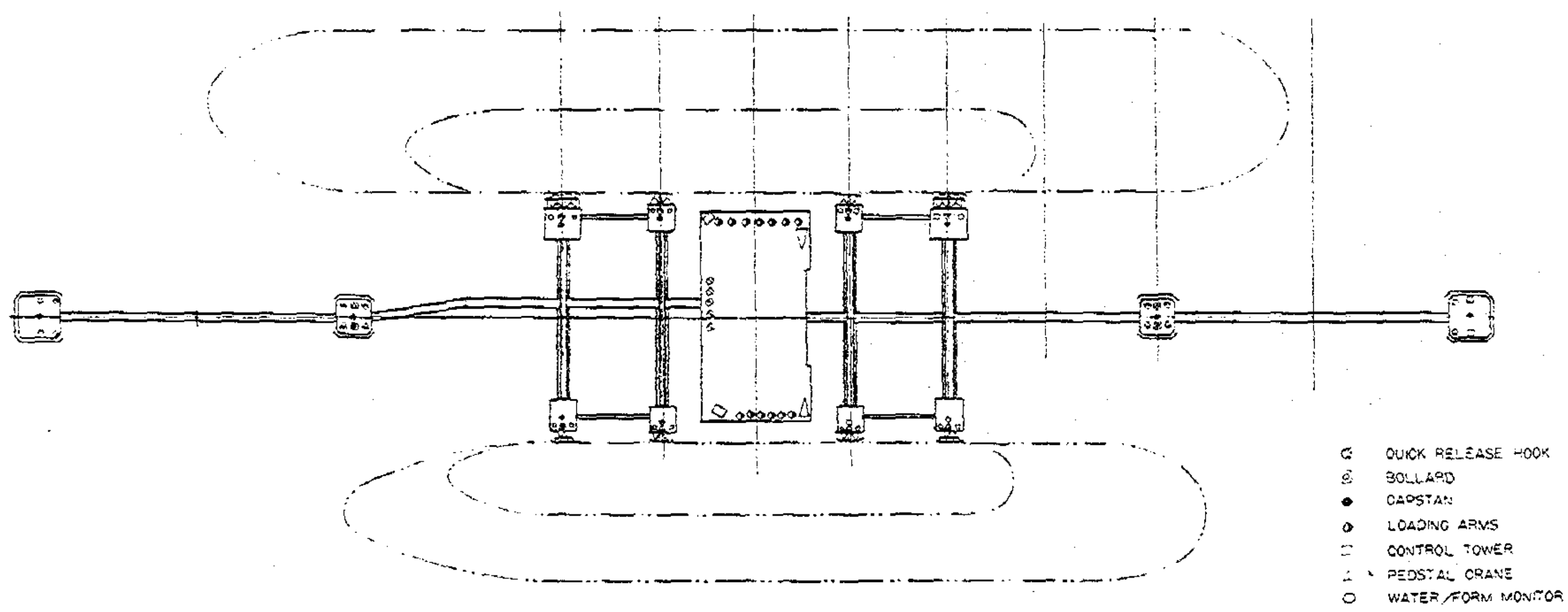


Fig. VII-1 Brief Plan of Fixed Pier Type Sea Berth

(6) Classification of fixed pier type

1) Structural types

Fixed pier type sea berths can be structurally classified as shown below. (See Fig. VII-2 for reference.)

Gravity type - Caisson type, sheet pile cell type
Pile type - Vertical pile type
Inclined type
Jacket type
Single support type

A gravity type sea berth should be heavy since it resists external forces by the frictional resistance with the sea bottom ground. The weight of a structure is supported by the strength of sea bottom foundation. Therefore, a large structure is usually used for this type.

With a pile type sea berth, a pile is driven deeply enough for bearing external forces. A vertical pile type sea berth is designed on the basis of axial force and bending moment. It has large deflection at the pile top.

With a jacket type sea berth, a structure of space truss is installed on the sea bottom. A pile is driven between columns to bear resistance. It facilitates works by shortening the free length of piles and by decreasing the number of piles.

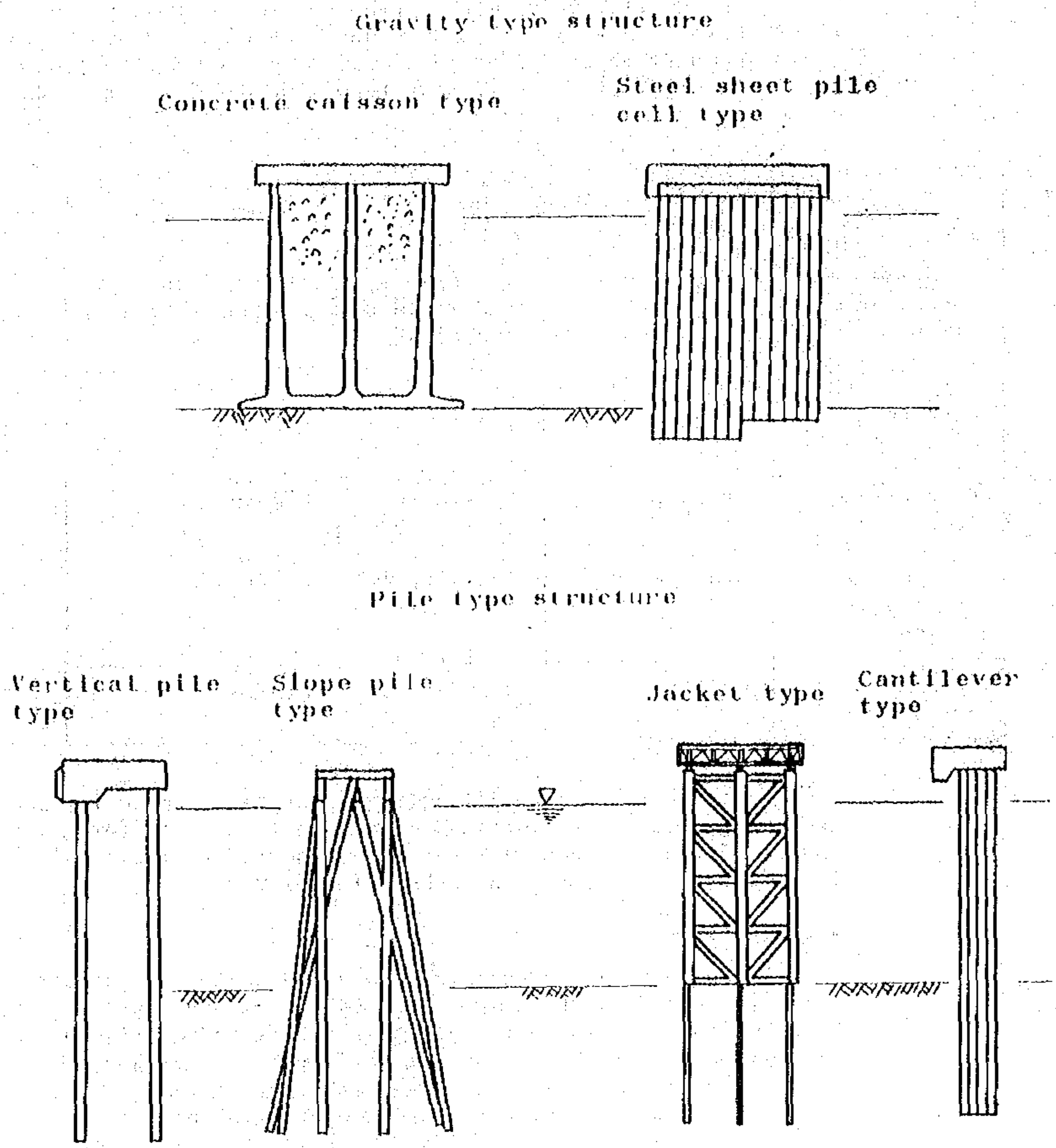


Fig. VII-2 Schematic Drawing of Structural Types

2) Comparison of structural types

Since a gravity type sea berth requires extremely high construction costs, it is usually not adopted for a sea berth of large water depth. Therefore, pile type sea berths alone are considered here. Their advantages and disadvantages are listed below for comparison.

	Vertical pile type	Slope pile type	Jacket type
Required number of piles	It requires piles of large diameter.	It requires the largest number of piles.	It requires only a small number of piles.
Displacement of structure	Largest	Smallest	Small
Pile driving work	Ordinary	Difficult	Simple
Transportation and installation	Ordinary	Ordinary	Difficult
Tunnel excavation	Ordinary	Difficult	Simple

Usually, a vertical pile type is usually adopted for an breasting dolphin, an inclined pile type is adopted for a mooring dolphin, and a vertical pile type and an inclined pile type are combined for a cargo-handling pier.

3) Facility layout

In constructing a dolphin type sea berth at a considerable distance from the shore (ex. Leam Laem Chabang District), a so-called twin type which allows berthing and mooring on the both sides will be efficient. A twin type sea berth can be simultaneously used by two ships on the both sides.

A berth will consists of a cargo-handling pier at the center, an breasting dolphin and a mooring dolphin. Their layout must be determined consideration of the overall length of applicable tankers to allow sufficient breasting and mooring.

(a) Distance breasting dolphins

The average parallel body length of a tanker is about 55 ~ 60% of the overall length. The standard distance between breasting dolphins on the both sides is 35 ~ 45% of the overall length, namely, 2/3 ~ 3/4 of the parallel body.

(b) Angle of breasting dolphin to mooring direction

A tanker must berth in parallel to mooring direction by 3 ~ 4 tug boats. However, complete parallelness is difficult to anchieve because of wind, tidal current and waves. However, berthing angle is usually kept below 35°.

(c) Layout of mooring dolphins

Mooring dolphins must be properly arranged to allow a gigantic tanker to resist external forces, such as tidal current and wind pressure and to inhibit its longitudinal and transverse movements.

2. Preliminary designing

(1) Sea berth

1) Factors related to designing

(a) Natural conditions

Wind .... Vmax. = 20 m/sec
Tidal current . Cmax = 1.5 knots (NW)
Wave .... Hmax. = 3.0 m
Swell .... Almost zero

(b) Tanker specifications

Applicable tankers
Max. 250,000 DWT
Min. 100,000 DWT

Various specifications are assumed as given below.

Item \ Model	DWT 100,000	DWT 250,000	Remark
Displacement tonnage (D.T.)	DT 115,000	287,500	
Overall length (L)	270m	330	
Molded breadth (B)	37m	53	
Molded depth (D)	20.5m	27	
Full draft (df)	14m	20.5	
Above-water projected area of profile at full load, Af above, side	2,300m^2	3,000	
Above-water projected area of profile at light load, Aℓ above, side	5,200m^2	7,000	
Underwater projected area of profile at full load, Af under, side	3,700m^2	5,000	
Underwater projected area of profile at light load, Aℓ under, side	650m^2	800	
Above-water projected area of front at full load, Af, above, front	660m^2	950	
Above-water projected area of front at light load, Aℓ, above, front	1,150m^2	1,800	
Underwater projected area of front at full load, Af, under, front	570m^2	900	
Underwater projected area of front at light load, Aℓ, under, front	100m^2	130	
Length of straight part on tanker's broadside	148m	187	

2) Determination of tanker's berthing weight

The following equation can be used for indicating kinetic energy applicable to a tanker's berthing.

$$E = \frac{W.V2.}{2g}$$

W: Assumed weight of tanker
V: Berthing velocity
g: Gravity acceleration rate

However, a tanker usually does not berth in completely parallel position. It usually berthes with some angle with a dolphin and turns after berthing. Kinetic energy is consumed for this reason and the remaining energy applies to a dolphin. This is called as effective berthing energy and expressed by the following equation.

$$E' = \frac{W.V2.}{2g} \cdot \frac{1}{1+(\frac{\ell}{r})^2}$$

ℓ = Distance from a tanker's centers of gravity and berthing point

r = Tanker's rotational radius around center of gravity

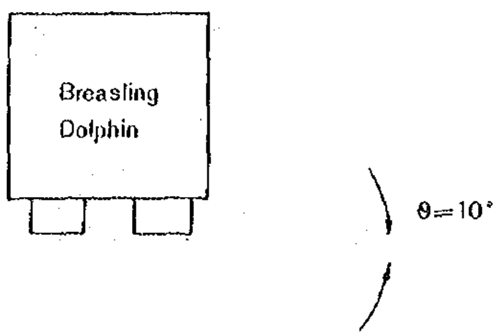
The number of breasting dolphins and their distance etc. are determined by the types of applicable tankers and maneuvering etc. Here, main breasting dolphins are designed for 250,000 DWT tankers, while sub breasting dolphins are designed for 100,000 DWT class tankers. Therefore, four dolphins are to be installed in total.

(a) Estimated berthing velocity

A tanker usually berths at velocity below 10 cm/sec. However, v = 15 cm/sec. will be adopted as design value in consideration of safety.

(b) Estimated berthing angle

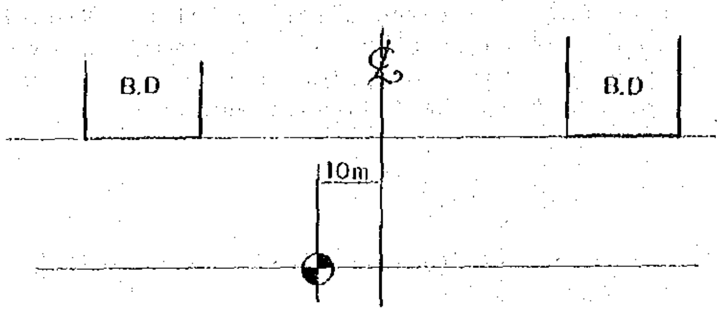
A tanker rarely berthes at a breasting delphin in parallel with it. It usually berthes at some angle. The assumption of $\Theta max = 10°$ is made here.



(c) Distance between a tanker's center of gravity and dolphin center

A tanker's center of gravity should coincide with the center between two breasting dolphins at the time of berthing. However, misalignment actually occurs. The extent of misalignment has large effects on berthing energy.

It is assumed to be 10 m, here.



(d) Tanker's additional weight at berthing

When a tanker berthes, it is not only the tanker itself but also the surrounding water that move.

The additional weight is said to be 30 ~ 80% of a tanker's displacement.

The following equation is usually used for the calculation.

$$Wm = \frac{\pi}{4} . d^2 . L . w$$

d = draft
L = Length
w = Unit weight of water

(e) Determination of inter-breasting dolphin distance

Inter-breasting dolphin distance is determined in consideration of the length of a tanker's straight part and misalignment at berthing.

Sub breasting dolphin	L = 90 m
Main	L =140 m

(f) Effective berthing energy

Effective berthing energy is calculated below.

Sub breasting dolphin	E = 142 t.m
Main breasting dolphin	E = 306 t.m

3) Absorption of berthing energy

Berthing energy is usually absorbed by the displacement of a rubber fender and a structure. However, a structure's displacement accounts only for about 10% of total energy. Even this is possible with a vertical pile type sea berth characterized by large deflection. Therefore, it is assumed here that all the energy is absorbed by a rubber fender.

A tanker berthes at an angle of $0 \sim 10°$. Therefore, a rubber fender must be designed to absorb energy at any angle.

The load that applies to dolphins by energy absorption depends on the quality and the fixing method of a rubber fender. However, the following assumptions are made here.

Load to sub breasting dolphins	250t
Load to main breasting dolphins	700t

4) Forces applied to tanker during mooring

When a tanker berthes, its mooring ropes are immediately fixed to the dolphins. After berthing, a tanker is subjected to wind pressure and tidal current force.

(a) Wind pressure applied to tanker

Wind pressure is calculated by the following equation.

$$R = \frac{1}{2}\varrho . C_{Ra} . V^2 \ (A . \cos^2\Theta + B \sin^2\Theta)$$

R: Wind pressure

ϱ: Air density 0.125 $kg.sec^2/m^4$

C_{Ra}: Wind pressure factor

V: Wind velocity

Θ: Relative wind direction

A: Upper front projected area

B: Upper side projected area

(b) Tidal current force applied to tanker

Tidal current force is determined by the following equation.

$$R = \frac{1}{2}\varrho w . C_{Rw} . v^2 . L . d$$

R: Tidal current force

Sw: Water density 104.5$kg.sec^2/m^4$

C_{Rw}: Current pressure factor

v: Tidal flow velocity

(c) Wind pressure and tidal current force applied to 100 thousand ~ 250 thousand DWT tankers.

Wind velocity (v) is assumed to be 20 m/sec and Tidal current velocity (c) is assumed to be 1.5 knot. (The direction of tidal current is assumed identical with berth direction.) Two directions (parallel to berth and perpendicular to berth) are used here.

	Direction	Wind Pressure	Tidal Current Force	Total	Remarks
100,000DWT	Front direction	18.2^t	58.6^t	76.8^t	At full load
	Side direction	123.5	-	123.5	Ballast
250,000DWT	Front direction	27.1	110.0	137.1	At full load
	Side direction	170.2	-	170.2	Ballast

The forces that apply to a tanker also depend on its condition (full load or ballast). Wind pressure is large at ballast, while tidal current force is large at full load. Therefore, full load status is used for the front and ballast status is used for the side.

(d) Designing mooring force of each mooring dolphin

According to calculation results, 137 t is applied from the front and 170 t is applied from the sides. Mooring ropes are used to resist these forces. The following mooring ropes are usually used.

4 bow and stern line	(outer mooring dolphin)
3 spring lines	(breasting mooring dolphin)
3 breast lines	(inner mooring dolphin)

If the yield strength of a mooring rope is assumed to be 80 t/rope, the maximum mooring force is as given below.

Bow and stern line	320 t
Spring line	240 t
Breast line	240 t

The capacity of a quick release hook etc. is considered.

Inner mooring dolphin	H = 250 t
Outer mooring dolphin	H = 250 t
Breasting mooring dolphin	H = 170 t

5) Determination of berth height

The tidal level at the construction site is below.

Lowest low water	+ 0.00 (DL)
Mean sea level	+ 2.48
Highest high water	+ 4.28

Unloading platform

No wave should hit the deck. The relation with the loading arm must also be considered.

DL + 8 m

Breasting dolphin mooring dolphin

DL + 7.5 m

6) Berth layout

Fig. VII-3 is the berth layout that was determined in consideration of the above factors.

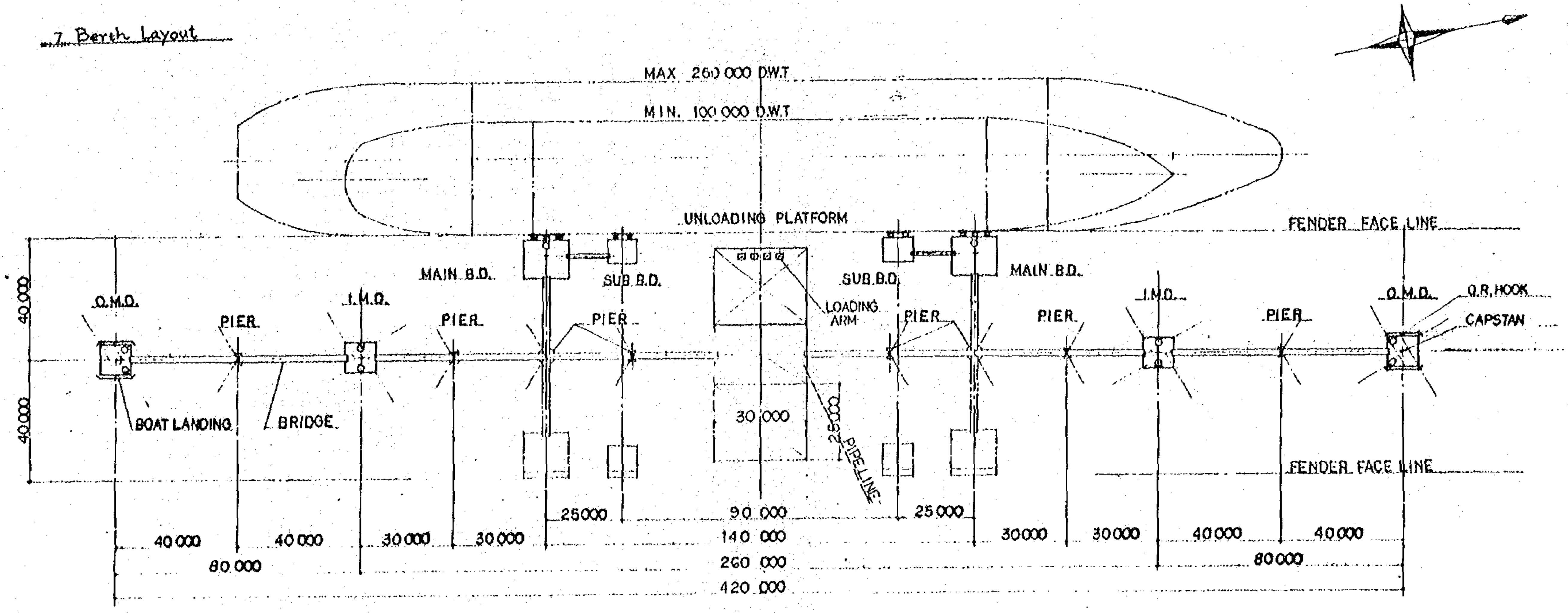
7) Weight of steel materials for berth

The weight of the steel materials that are initially used for constructing a double berthing type berth.

Dolphin	Q'ty	Steel Weight
Main Breasting D	2	1,300
Sub Breasting D	2	700
Unloading Platform	1	800
Mooring D	4	1,600
Pier	4	400
Walk Way		200
Total		5,000 ton

The construction of the opposite unit will require about 2,900 tons of steel since mooring dolphins, piers and a walk-way can be shared.

7. Berth Layout



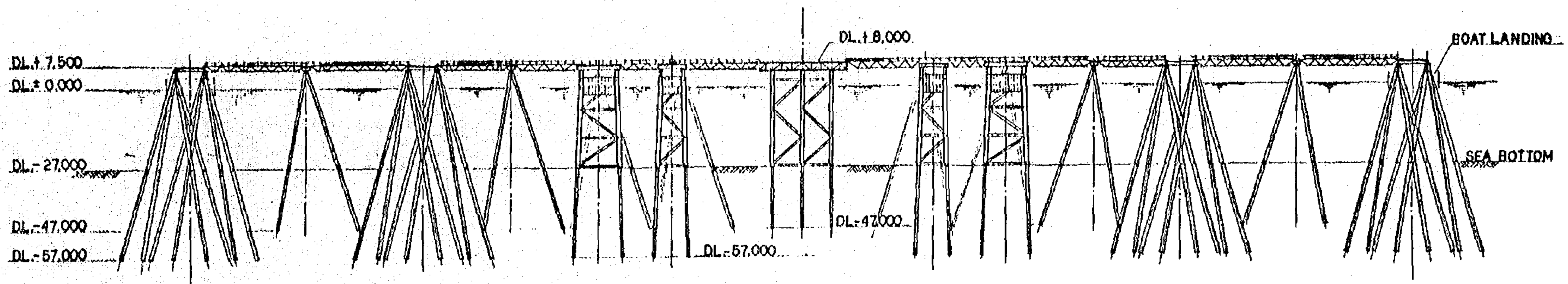


Fig. VII-3 Berth Layout

(2) Pipe line (from sea berth to buffer tank)

1) Design conditions

Coefficient of kinematic viscosity of petroleum	20 C.T.S.
Diameter of submarine pipe line	Outer dia. 48 B Thickness 15.88 mm
Length of submarine pipe line	1,000 m
Valve closure time	20 sec.
Flow velocity V = 3.85 m/sec	
Allowable circumferential tensible stress (5L - B)	$Hs = 8.64$ kg/mm^2

2) Pressure loss of piping

Reynolds number is obtained from the above conditions.

$$R = \frac{3.85 \times 1.1874}{0.00002} = 2.2 \times 10^5$$

The coefficient of friction is obtained from Moody's friction graph. $f = 0.026$

Press loss head (Ho) is obtained below from Darcy's equation.

$$H_o = \frac{f.L.v^2}{2.g.D} = 0.026 \times 10{,}000 \times (3.85)^2/2 \times 9.8 \times 1.1874$$

$$= 165.6 \text{ m}$$

g = gravity acceleration rate 9.8 m/sec^2

Therefore, the pressure loss P_1 is 16.6 kg/cm^2

3) Calculation of water hammer pressure

a: Propagation speed of water hammerging pressure 1,130 m/sec.

$$\frac{2L}{a} = 2 \times \frac{10{,}000}{1{,}130} = 17.6 \text{ sec.} \qquad 20 \text{ sec.}$$

The condition of gradual closure is met.

$$\varrho = \frac{a.v}{2gH_o} = \frac{1{,}130 \times 3.85}{2 \times 9.8 \times 165.6} = 1.34$$

$$\theta = \frac{20}{1.34} = 16.2$$

$$\varrho^2 max = \frac{(h \times H_o)}{H_o} = 1.09 \qquad h + H_o = 180.5 \text{ m}$$

Therefore, the pressure P_2 can rise to 18.1 kg/cm^2 when water hammering pressure is generated.

4) Calculation of thickness

$$t = \frac{P_2 . D}{200 H_s - P_2} + C$$

P_2: Maximum pressure in pipe kg/cm^2

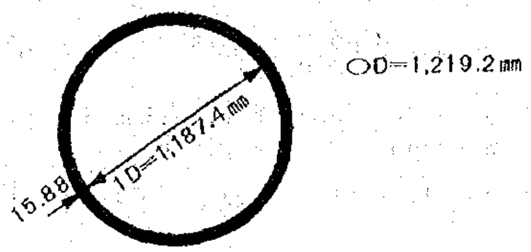
D : 48^B (ID = 1,187.4mm)

C : Corrosion margin (assumed to be 3.32mm)

$$t = \frac{18.1 \times 1,187.4}{200 \times 8.64 - 18.1} + C$$

$$t = 12.56 + C = 15.88 \text{ mm}$$

Therefore, the submarine pipe line specifications are determined as below.



5) Flow rate

Flow rate max.Q = 4.26 m^3/sec = 15,336 m^3/Hr

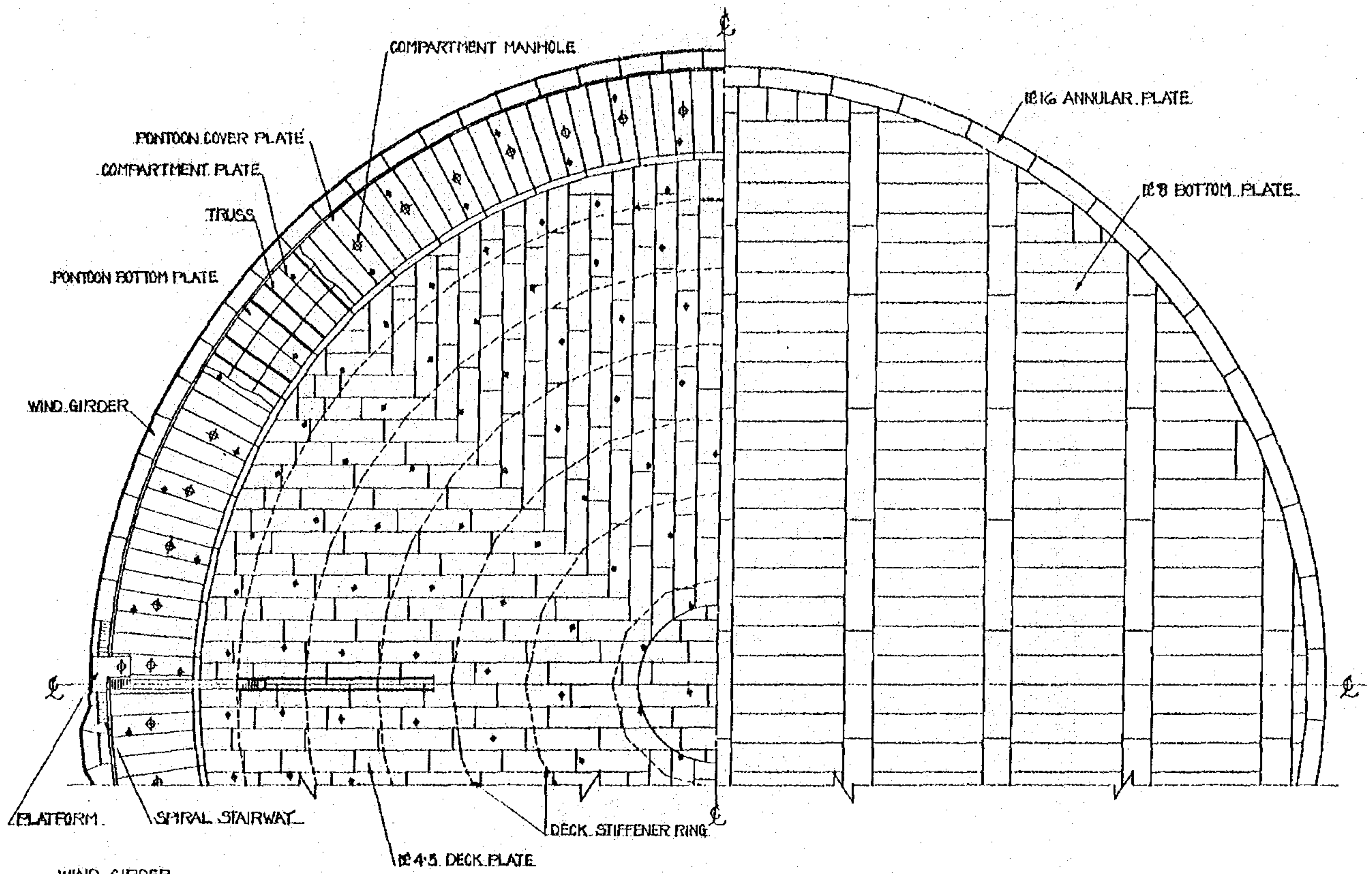
(3) Crude oil tank

1) Design specifications

The capacity is to be 150,000 KL.

2) Design drawing

The design drawing is shown in Fig. VII-4.



ACCESSORIES AND CONNECTIONS			
DESCRIPTION	SIZE	QUANT.	REMARKS
INLET NOZZLE	36"	1	
OUTLET NOZZLE	36"	1	
SPARE NOZZLE	24"	1	
ROOF DRAIN NOZZLE	12"	3	
WATER DRAW-OFF NOZZLE	8"	4	
SHELL MANHOLE	30" / 24"	1 / 3	
MIXER MANHOLE	30"	4	
ROOF MANHOLE	24"	4	
COMPARTMENT MANHOLE	20"	61	
RIM VENT NOZZLE	6"	4	
AUTOMATIC BLEEDER VENT	12"	18	
EMERGENCY ROOF DRAIN	10"	9	
GAGE HATCH NOZZLE	4"	1	
GAGE POLE	14"	1	
GUIDE POLE	8"	1	
AIR FOAM SYSTEM		1SET	
LEVEL INDICATOR	—	1	
THERMOMETER BOSS	3/4"	1	
SPIRAL STAIRWAY & PLATFORM	—	1SET	
ROLLING LADDER & RUNWAY	—	1SET	
TANK EARTH	—	7	
ROOF EARTH	—	1SET	

DESIGN SPECIFICATION	
CODE	API 650 (MODIFICATION)
WIND VELOCITY	100 m/Hr
RAINFALL	100 mm/Hr
TEMPERATURE	30° C (AVERAGE)
SEISMIC FACTOR	0.1

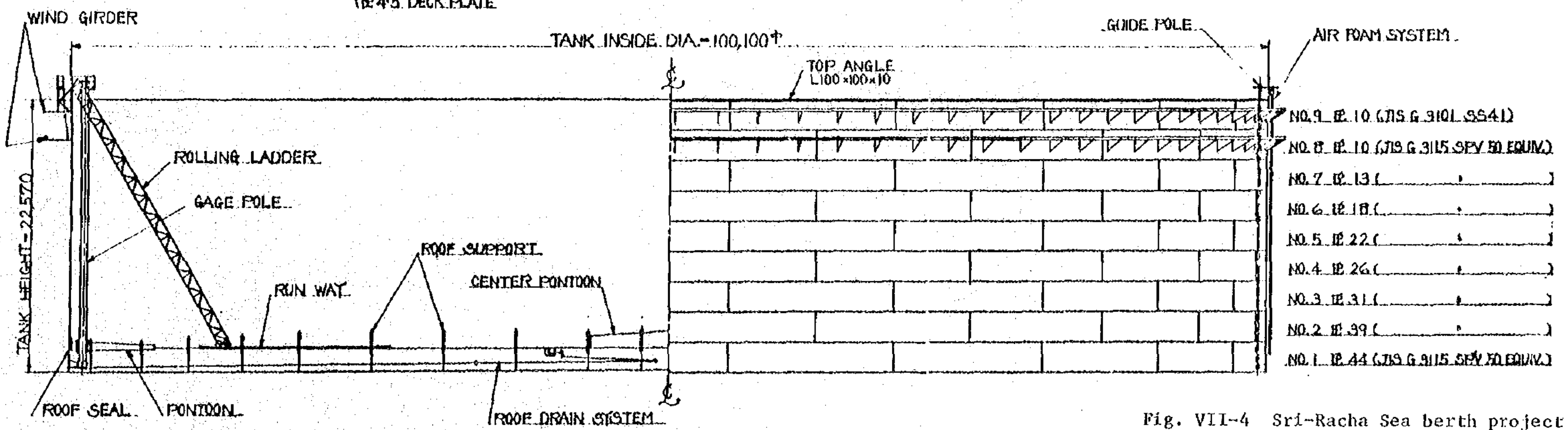
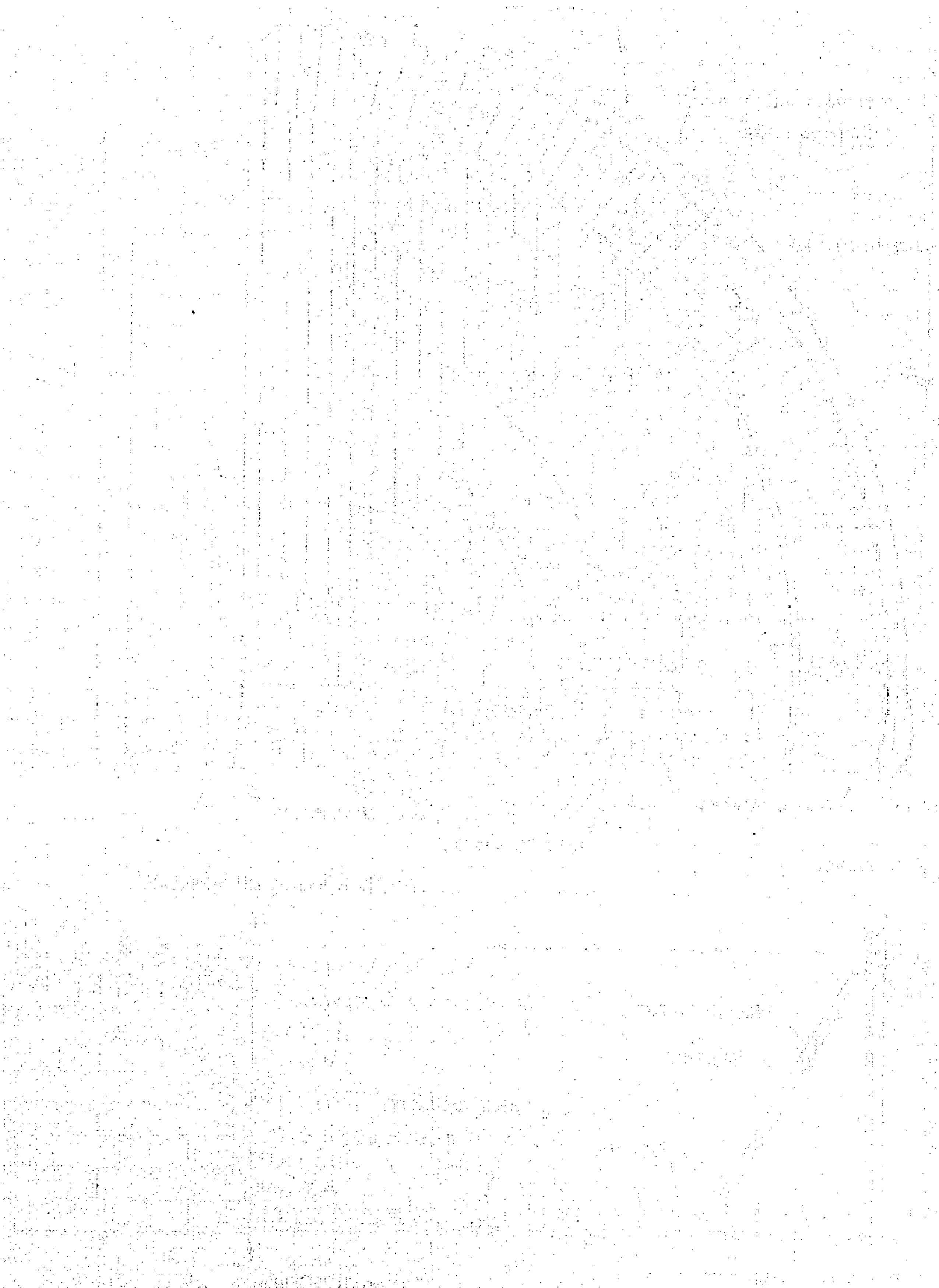


Fig. VII-4 Sri-Racha Sea berth project Thailand 150,000 KL
Floating roof Tank General view



3. Work Schedule

(1) Purchase of materials

Steel materials are the major materials for sea berth construction. Additionally, the following items are required.

Rubber fender
Loading arm
Mooring equipments
Navigation equipments

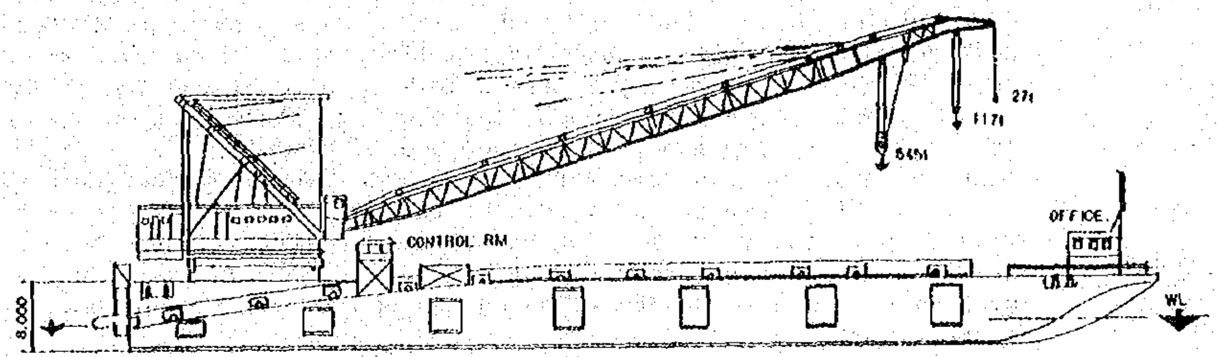
All of them are to be imported. Cement, gravel, sand and timber etc. are to be purchased in Thailand.

(2) Construction machines and ships

The following ships are required for sea berth construction.

Floating cranes (suspension capacity: 300 ~ 500 tons)
Pile driving barges (including pile driving machines)
Deck barges
Small floating cranes
Tug boats
Supply boats

A pipe laying and derick barge, as shown below, can be used not only for submarine pipeline laying, but also for pile driving, loadging and as a crane.



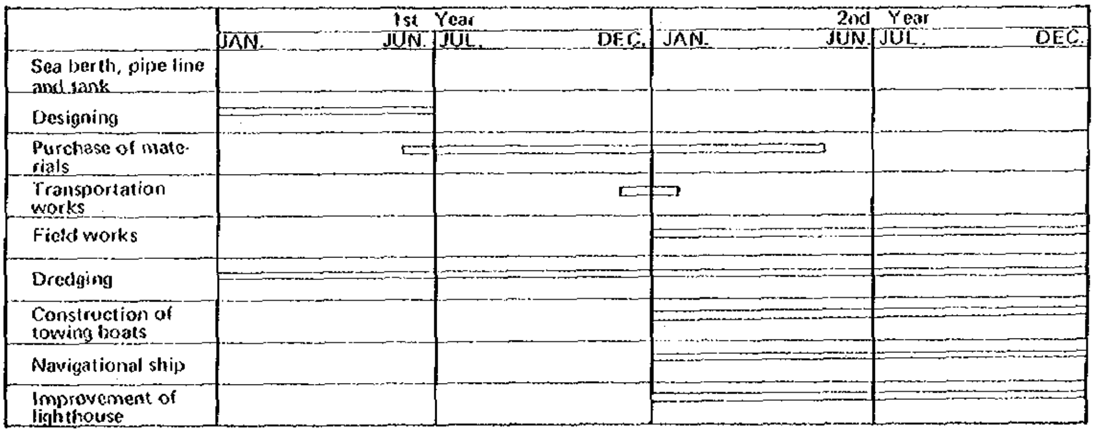
Crane trucks and trucks are also necessary at a material stock yard and a temporary work field on the ground.

One small floating crane (suspension capacity: 120 t) is available in Bangkok. Supply boats, crane trucks and trucks can be purchased in Thailand. All the other large working crafts must be brought from abroad.

(3) Work schedule

The schedule was drawn on the basis of the investigation results obtained by the First Mission and the materials and data collected by the Second Mission. The investigations results obtained by the First Mission are too general for drawing a schedule and a design. Prior to designing, geological investigations must be carried out at a sea berth construction site and along proposed submarine pipe line route. Sounding works and geological investigations of the proposed navigation channel under C must also be carried out. Table VII-3 does not include these investigations since they are assumed to be carried out in the preceding year.

Table VII-3 Work Schedule



As the above table shows, two years are assumed for sea berth construction works. The sea berth, pipe line and tank are to be designed during the first half of the first year. Materials are to be purchased immediately. Field works are to be carried in the second year. For dredging work, one 6,000 PS class suction dredger is required to pump about 1,750 thousand m^3 of soil. It is difficult to obtain suction dredger in Thailand. (Bangkok Port Authority owns a suction dredger and it can be charted. However, this work will require one-year charting and it is actually impossible.) Therefore, a suction dredger must be brought from abroad. One is sufficient even in consideration of low operating rate during the monsoon season.

Tug boat construction (4 boats), navigational aid and lighthouse improvement works were left for the second year.

VIII. CONSTRUCTION COSTS AND MAINTENANCE COSTS

[illegible]

[illegible]

VIII. CONSTRUCTION COSTS AND MAINTENANCE COSTS

1. Basis

Construction costs and maintenance costs must be estimated in consideration of the recent inflationary tendency and unstable international currency situation. However, it is extremely difficult to determine the influence of these unknown factors. The Mission estimated various costs in accordance with the following basic principles.

All the prices that are cited here are effective in 1974. Some rise in the price of commodities must be assumed by the execution of the schedule. The costs of the project are estimated in terms of both foreign capital and domestic capital. The figures of foreign capital must be changed if the exchange rate changes. The exchange rate of 1 US$ = 20.0 ฿ = 280.0 yen is used for estimating the construction costs.

The Mission decided to divide this project into two stages in relation to the volume of imported crude oils to be handled by the sea berths. The data that were used as the basis for the division are the estimated import volume of crude oils (III) and the crude oil handling capacity of a sea berth (V). The first stage of the project is the period when one berth is required, and the second stage is the period when two berths are required. Construction costs for the two stages were estimated separately. As discussed in I, the Mission directed its attention to 1980 ~ 1985 (first term) where the estimate of crude oil import is more accurate. For this reason, the first term was divided into the 1st stage (1 berth) and the 2nd stage (2 berths).

The following costs were included in the construction cost estimates.

1. Various facilities of sea berth system (main facilities and auxiliary facilities)
2. Cost of land (Land for buffer tank yard)
3. Work management cost (Maintenance and management cost for facilities under construction)
4. Cost of investigation and designing
5. Reserve fund
6. Compensation for current facilities (Sea berths belonging to ESSO, TORC and SUMMIT)

Neither petroleum refining facilities, nor product shipping facilities are included. The cost of land and the compensation for the current facilities are given below in details.

Cost of land (1st and 2nd stage)

(Unit: million ฿)

Site \ Plan	X	Y	Z	W	Remark
Site A	-	-	-	-	Ko Si Chang Island is national land
Site B	2.2	2.2	4.4	4.4	X, Y: One berth Z, W: Two berth
Site C	2.2	2.2	4.4	4.4	X, Y: One berth Z, W: Two berth

Compensation for current facilities

(Unit: million ฿)

Plan	Compensation cost	Applicable facilities (Year of construction)	Remark (To be compensated in 1978)
X	25.2	SUMMIT (1965)	Residual price 10%, 20 year depreciation 110 × 0.229=25.2
Y	84.2	ESSO (1971) TORC (1965) SUMMIT (1965)	Same as above, 90 × 0.452=40.7 80 × 0.229=18.3 110 × 0.229=25.2
Z	84.2	Same as above	Same as above
W	84.2	Same as above	Same as above

The construction costs and the maintenance costs for the sites, A, B, C are estimated below. It must be noted that one berth is sufficient at any site under X and Y Plans.

2. Construction costs

(1) Site A

Since Ko Sichang Island is used for buffer tanks (See Fig. V-1), 10.2 km long submarine pipe line for the sea berth ~ Ko Sichang Island and Ko Sichang Island Laem Chabang must be laid at the 1st stage. A booster pump is also needed for transferring oil from Ko Sichang Island to Laem Chabang. Two crude oil buffer tanks must be constructed. Since one submarine pipe line is sufficient for transferring oil from Ko Sichang Island to Laem Chabang, a 2.3km long submarine pipe line alone needs to be constructed during the 2nd stage. Another buffer tank must be constructed.

The construction costs of these facilities are given in Table VIII-1 details. The costs for each of the plans are shown in the following table.

Construction cost at Site A

(Unit: Million ฿)

Stage / Plan	1st			2nd			Total		
	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund
X	1,153	921	232	0	0	0	1,153	921	232
Y	1,212	965	247	0	0	0	1,212	965	247
Z	1,212	965	247	459	361	98	1,671	1,326	345
W	1,212	965	247	459	361	98	1,671	1,326	345

Table VIII-1 Construction Cost at Site A

(Unit: Million ฿)

	1st Stage (1976 ~ 1977)				2nd Stage (~ 1984)				Total				Remarks
	Quantity	Total	Foreign fund	Domestic fund	Quantity	Total	Foreign fund	Domestic fund	Quantity	Total	Foreign fund	Domestic fund	
Submarine pipe installation	10.2 km	266	210	56	2.3 km	110	93	17	10.2 km 12.5	266 376	210 303	56 73	1. Use of Kosichang.
Land pipe installation	1.3 km	19	14	5	0.7 km	10	7	3	1.3 km 2.0	19 29	14 21	5 8	2. Buffer tank (2nd stage)
Dredging													X, Y} Plan 2 tanks
Sea berth	1 berth	342	274	68	1 berth	200	160	40	1 berth 2 berth	342 542	274 434	68 108	Z, W} Plan 3 tanks
Booster	1 set	43	44	2					1 set	43	44	2	3. Compensation for current facilities
Crude oil tank	2 tanks	185	124	61	1 tank	75	51	24	2 tanks 3 tanks	185 260	124 175	61 85	
Land	86,000 m^2				43,000m^2				86,000 129,000m^2				X plan 25 million ฿
Navigational aids	11 locations	4	4	0					11 locations	4	4	0	Y, Z, W} plan 84 million ฿
Tug boat	4 boats	100	100	0					4 boats	100	100	0	
Lighthouse improvement	1 lighthouse	1	1	0					1 lighthouse	1	1	0	
Compensation for current facilities	1 set	25 84	19 63	6 21					1 set	25 84	19 63	6 21	
Work management cost	1 set	24	19	5	1 set	4	3	1	1 set	24 28	19 22	5 6	
Investigation and designing cost	1 set	48	38	10	1 set	20	16	4	1 set	48 68	38 54	10 14	
Reserve fund	1 set	96	77	19	1 set	40	31	9	1 set	96 136	77 108	19 28	
Total X Plan		1,153	921	232	X,Y Plan	0	0	0	X Plan Y Plan	1,153 1,212	921 965	232 247	
Total Y,Z,W Plan		1,212	965	247	Z,W Plan	459	361	98	Z,W Plan	1,671	1,326	345	

(2) Site B

A buffer tank is to be constructed at Laem Chabang side. (See Fig. V-1) A 9.0 km long submarine pipe line between the sea berths and Laem Chabang and tunnel excavation for land piping are necessary for the 1st stage. One buffer tank is to be constructed in consideration of the capacity of the existing tanks. Since one submarine pipe line is necessary for each berth for the 2nd stage, another 9.0km submarine pipe line must be constructed, as at the 1st stage. Another buffer must also be constructed.

The construction costs of these facilities are given in Table VIII-2 in details. The costs for each of the plans are shown in the following table.

Construction cost at Site B

(Unit: Million ฿)

Stage / Plan	1st			2nd			Total		
	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund
X	946	759	187	0	0	0	946	759	187
Y	1,005	803	202	0	0	0	1,005	803	202
Z	1,005	803	202	611	474	137	1,616	1,277	339
W	1,005	803	202	611	474	137	1,616	1,277	339

Table VIII-2 Construction Cost at Site B

(Unit: Million ฿)

	1st Stage (1976 ~ 1977)				2nd Stage (~1984)				Total				Remarks
	Quantity	Total	Foreigh fund	Domestic fund	Quantity	Total	Foreign fund	Domestic fund	Quantity	Total	Foreign fund	Domestic fund	
Submarine pipe installation	9.0 km	242	192	50	9.0 km	242	191	51	9.0 km 18.0	242 484	192 383	50 103	1. Kosichang is not used.
Land pipe installation	0.5 km	7	5	2	0.5 km	8	6	2	0.5 km 1.0	7 15	5 11	2 4	2. Buffer tank (2nd stage)
Dredging													
Sea berth	1 berth	342	274	68	1 berth	199	160	39	1 berth 2 berth	342 541	274 434	68 107	X, Y } plan one tank
Tunnel	220 m	5	1	4					220 m	5	1	4	Z, W } plan two tanks
Booster													3. Compensation for current facilities
Crude oil tank	1 tanks	81	54	27	1 tank	76	51	25	1 tank 2 tanks	81 157	54 105	27 52	X plan 25 million ฿
Land	43,000 m²	2	0	2	43,000m²	2	0	2	43,000 m² 86,000	2 4	0 0	2 4	Y, Z, W } plan 84 million ฿
Navigational aids	9 locations	4	3	1					9 locations	4	3	1	
Tug boat	4 boats	100	100	0					4 boats	100	100	0	
Lighthouse improvement	1 lighthouse	1	1	0					1 lighthouse	1	1	0	
Compensation for current facilities	1 set	25 84	19 63	6 21					1 set	25 84	19 63	6 21	
Work management cost	1 set	20	16	4	1 set	5	4	1	1 set	20 25	16 20	4 5	
Investigation and designing cost	1 set	39	31	8	1 set	26	21	5	1 set	39 65	31 52	8 13	
Reserve fund	1 set	78	63	15	1 set	53	41	12	1 set	78 131	63 104	15 27	
Total X Plan		946	759	187	X,Y Plan	0	0	0	X Plan Y Plan	946 1,005	759 803	187 202	
Total Y,Z,W Plan		1,005	803	202	Z,W Plan	611	474	137	Z,W Plan	1,616	1,277	339	

(3) Site C

A navigation channel is to be dredged and a sea berth and a buffer tank (at Laem Chabang side) are to be constructed. (See Fig. V-1 for reference.) A 3.0 km long submarine pipe line must be laid between the sea berth and Laem Chabang. The works for the 1st step also include tunnel excavation for land piping, dreding for the navigation channel and the construction of another buffer tank. For the 2nd step of the 1st stage, another 3.0 km submarine pipe line must be laid according to the principle of "one submarine pipe line for one berth" and another buffer tank must be consturcted.

Table VIII-3 shows the construction costs for the above facilities. The construction costs under each of the plans are shown in the following table.

Construction costs of Site C

(Unit: Million ฿)

Stage / Plan	1st			2nd			Total		
	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund
X	931	769	162	0	0	0	931	769	162
Y	990	813	177	0	0	0	990	813	177
Z	990	813	177	605	491	114	1,595	1,304	291
W	990	813	177	605	491	114	1,595	1,304	291

Table VIII-3 Construction Cost at Site C

(Unit: Million ฿)

	1st Stage (1976 ~ 1977)				2nd Stage (~1984)				Total				Remarks
	Quantity	Total	Foreign fund	Domestic fund	Quantity	Total	Foreign fund	Domestic fund	Quantity	Total	Foreign fund	Domestic fund	
Submarine pipe installation	3.0 km	124	103	21	3.0 km	124	104	20	3.0 km 6.0	124 248	103 207	21 41	1. Kosichang is not used.
Land pipe installation	0.5 km	7	5	2	0.5 km	8	6	2	0.5 km 1.0	7 15	5 11	2 4	2. Buffer tank
Dredging	1,750,000m^3	102	93	9	2,250,000 m^3	131	120	11	1,750,000m^3 4,000,000m^3	102 233	93 213	9 20	X, Y}plan one tank
Sea berth	1 berth	342	274	68	1 berth	199	160	39	1 berth 2 berths	342 541	274 434	68 107	Z, W}plan two tanks
Tunnel	220m	5	1	4					220m	5	1	4	3. Channel with (2nd stage)
Booster													
Crude oil tank	1 tank	81	55	26	1 tank	76	50	26	1 tank 2 tanks	81 157	55 105	26 52	X, Y}plan 160m
Land	43,000m^2	2	0	2	43,000m^2	2	0	2	43,000m^2 6,000m^2	2 4	0 0	2 4	Z, W}plan 450m
Navigational aids	17 locations	7	6	1					17 locations	7	6	1	4. Compensation for current facilities
Tug boat	4 boats	100	100	0					4 boats	100	100	0	X plan 25 million ฿
Lighthouse improvement	1 lighthouse	1	1	0					1 lighthouse	1	1	0	Y, Z, W}plan 84 million ฿
Compensation for current facilities	1 set	25 84	19 63	6 21					1 set	25 84	19 63	6 21	
Government management cost	1 set	19	16	3	1 set	4	3	1	1 set	19 23	16 19	3 4	
Investigation and designing cost	1 set	39	32	7	1 set	20	16	4	1 set	39 59	32 48	7 11	
Reserve fund	1 set	77	64	13	1 set	41	32	9	1 set	77 118	64 96	13 22	
Total X Plan		931	769	162	X,Y Plan	0	0	0	X Plan Y Plan	931 990	769 813	162 177	
Total Y,Z,W Plan		990	813	177	Z,W Plan	605	491	114	Z,W Plan	1,595	1,304	291	

(4) Comparison of the sites A, B, C

Table VIII-4 shows the construction costs for the sites A, B, C.

1) 1st stage

At the 1st stage, site C requires the least cost under all of the plans. The construction cost is 931 million Bahts under X plan and 990 million Bahts under Y, Z, W plans. The cost rises in the order of C < B < A. Site B and site C require almost the same foreign fund and site A requires the most foreign fund.

2) 2nd stage

At the 2nd stage, site A requires the least cost (459 million Bahts). It is followed by site C (605 million Bahts) and site B (611 million Bahts) in this order. Site A requires the least foreign fund and is followed by site B and site C in this order.

3) Total cost

When both the 1st stage and the 2nd stage are considered, site C requires the least cost under any of the plans. The total cost at site C is 931 million Bahts under X plan, 990 million Bahts under Y plan and 1,595 million Bahts under Z and W plans. The cost increases in the order of C < B < A. Site B and site C require almost the same foreign fund under X and Y plans, but site A requires the most foreign fund. It increases in the order of B < C < A under Z and W plans.

Table VIII-4 Comparison of A, B, C by Construction Costs

(Unit: Million ฿)

Site	Plan / Stage	X			Y			Z			W		
		Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund	Total	Foreign fund	Domestic fund
A	1st	1,153	921	232	1,212	965	247	1,212	965	247	1,212	965	247
	2nd	0	0	0	0	0	0	459	361	98	459	361	98
	Total	1,153	921	232	1,212	965	247	1,671	1,326	345	1,671	1,326	345
B	1st	946	759	187	1,005	803	202	1,005	803	202	1,005	803	202
	2nd	0	0	0	0	0	0	611	474	137	611	474	137
	Total	946	759	187	1,005	803	202	1,616	1,277	339	1,616	1,277	339
C	1st	931	769	162	990	813	177	990	813	177	990	813	177
	2nd	0	0	0	0	0	0	605	491	114	605	491	114
	Total	931	769	162	990	813	177	1,595	1,304	291	1,595	1,304	291

3. Maintenance costs

(1) Details of maintenance costs

The following items were included in sea berth system maintenance costs. (See Table VIII-5)

1) Sea berth

Insurance premium and repairing costs were included for sea berth maintenance costs. They were estimated to be 20.4 million ฿ (1st stage) and 32.4 million ฿ (2nd stage).

2) Pipe line

Pipe line maintenance costs depend on their length. The estimates for each of the sites and each of the stages are given in Table VIII-5.

3) Tank

It was assumed that tanks require no maintenance costs.

4) Tug boat

Personnel expense, fuel cost and repairing cost were included in tug boat maintenance costs. Since the number of operating days differs among the plans (X, Y, Z, W), maintenance costs must differ accordingly. The estimate for each of the plans is given in Table VIII-5.

5) Booster pump

A booster pump must be installed on Ko Sichang Island if a sea berth is constructed at Site A. Personnel expense, fuel cost and repairing cost were included for the maintenance cost. The estimated cost is 3.9 million ฿.

6) Periodic dredging cost

If a sea berth is constructed at Site C, the navigation channel must be dredged once every five years to maintain adequate water depth. The cost for this amounts to 11.3 million ฿ at the 1st stage and 25.7 million ฿ at the 2nd stage.

7) Personnel expense

The personnel expense that is required for sea berth management is estimated to be 2.1 million ฿ per berth.

8) Other costs

The other costs (utility cost etc.) depend on the amount of crude oils. The estimates are given in Table VIII-5.

Table VIII-5 Maintenance cost

Upper 1st stage
Lower 2nd stage (Unit: Million Ƀ)

Plan	Item	A Working	A Man-power	A Sea berth	A Pipe line	A Tug boat	A Booster pump	A Total	B Working	B Man-power	B Sea berth	B Pipe line	B Tug boat	B Others	B Total	C Working	C Man-power	C Sea berth	C Pipe line	C Tug boat	C Dredging	C Total
X	yearly	2.1 -	2.1 -	20.4 -	2.6 -	16.6 -	3.9 -	47.9 -	2.1 -	2.1 -	20.4 -	2.4 -	16.6 -	- -	43.7 -	2.1 -	2.1 -	20.4 -	1.2 -	16.6 -		42.5 -
X	every 5 year																				11.3 -	53.8 -
Y	yearly	2.6 -	2.1 -	20.4 -	2.6 -	16.8 -	3.9 -	48.6 -	2.6 -	2.1 -	20.4 -	2.4 -	16.9 -	- -	44.4 -	2.6 -	2.1 -	20.4 -	1.2 -	16.9 -		43.2 -
Y	every 5 year																				11.3 -	54.5 -
Z	yearly	1.9 3.3	2.1 4.3	20.4 32.4	2.6 3.7	17.3 17.3	3.9 3.9	48.3 64.9	1.9 3.3	2.1 4.3	20.4 32.4	2.4 4.9	17.3 17.3	- -	44.1 62.1	1.9 3.3	2.1 4.3	20.4 32.4	1.2 2.4	17.3 17.3		42.9 59.7
Z	every 5 year																				11.3 25.7	54.2 85.4
W	yearly	1.9 3.6	2.1 4.3	20.4 32.4	2.6 3.7	17.4 17.4	3.9 3.9	48.4 65.4	1.9 3.6	2.1 4.3	20.4 32.4	2.4 4.9	17.4 17.4	- -	44.3 62.6	1.9 3.6	2.1 4.3	20.4 32.4	1.2 2.4	17.4 17.4		43.1 60.1
W	every 5 year																				11.3 25.7	54.4 85.9

The amount of crude oils that are to be handled under Plan X, Y, Z, W changes yearly. The figures of the final year (1990) were used for estimating maintenance costs. This was not only to facilitate works, but also to take the safe side.

(2) Comparison of A, B, C

No large difference is found in terms of maintenance costs. They amount to 40 ~ 50 million ฿ for the 1st stage and 60 ~ 65 million ฿ for the second stage. However, Site C requires dredging cost (11.3 million ฿ at the 1st stage and 25.7 million ฿ at the 2nd stage) once every five years, which mean maintenance costs of about 55 million ฿ for the 1st stage and about 85 million ฿ for the 2nd stage.

IX. TRANSPORTATION COSTS OF CRUDE OILS

IX. TRANSPORTATION COSTS OF CRUDE OILS

1. Transportation costs by tanker categories

Use of larger tankers effectively cuts down the transportation cost of crude oils.

Under this project, 200 thousand DWT tankers are to be introduced to Sri Racha's current crude oil importing system using 60 thousand DWT ~ 90 thousand DWT tankers. The difference in transportation costs is estimated below.

(1) Components of transportation cost

The components of transportation cost are shown below.

- Transportation cost
  - Tanker cost (in wide sense)
    - Tanker cost (in narrow sense) — Crew expense, repairing cost, equipment cost, living cost, premium etc.
    - Depreciation cost
    - Interest
  - Navigation cost — Fuel cost, tax, port expense etc.

(2) Determination of transferred cost

The transportation costs required for 84 thousand DWT, 134 thousand DWT, 228 thousand DWT and 266 thousand DWT tankers are estimated below.

Table IX-1 shows the cost for each of the components of transportation cost. Note that the depreciation cost is 10% of remaining price (repayment period: 16 years). Also note that annual mean interests are cites as "interest".

Table IX-1 Details of Transportation Cost

Unit: Million ฿

Model / Item	thousand DWT 84	thousand DWT 134	thousand DWT 228	thousand DWT 266	Remark
Cost of tanker	36.6	43.4	54.1	56.8	Average specific gravity 0.83
Depreciation cost	18.0	26.3	38.2	42.8	
Interest	6.2	9.0	13.1	14.7	
Running cost	17.5	22.1	36.7	39.9	
(Total)	78.3	100.8	142.1	154.1	
Crude oil load	thousand KL 101	thousand KL 162	thousand KL 275	thousand KL 315	

The 4693 mile route between Al Ahmadi and Bangkok is assumed for this estimate. If the crusing speed of 15 knots is assumed, one way trip will require 13 days.

4,693 miles ÷ 15 knots = 313 hours = 13 days

If the number of operatable days is assumed to be 340 days/year in consideration of weather etc, 13 two-way trips can be made annually.

340 days ÷ 26 days = 13 two-way trips

Therefore, the transportation cost per 1 kℓ is as shown below.

	thousand KL 84	thousand KL 134	thousand KL 228	thousand KL 266
(1) Load	thousand KL 1,316	thousand KL 2,099	thousand KL 3,571	thousand KL 4,166
(2) Transportation cost	million ฿ 78.3	million ฿ 100.8	million ฿ 142.1	million ฿ 154.1
(2)/(1)	59.5 ฿/KL	48.0 ฿/KL	39.8 ฿/KL	37.0 ฿/KL

Their relation is shown in Fig. IX-1.

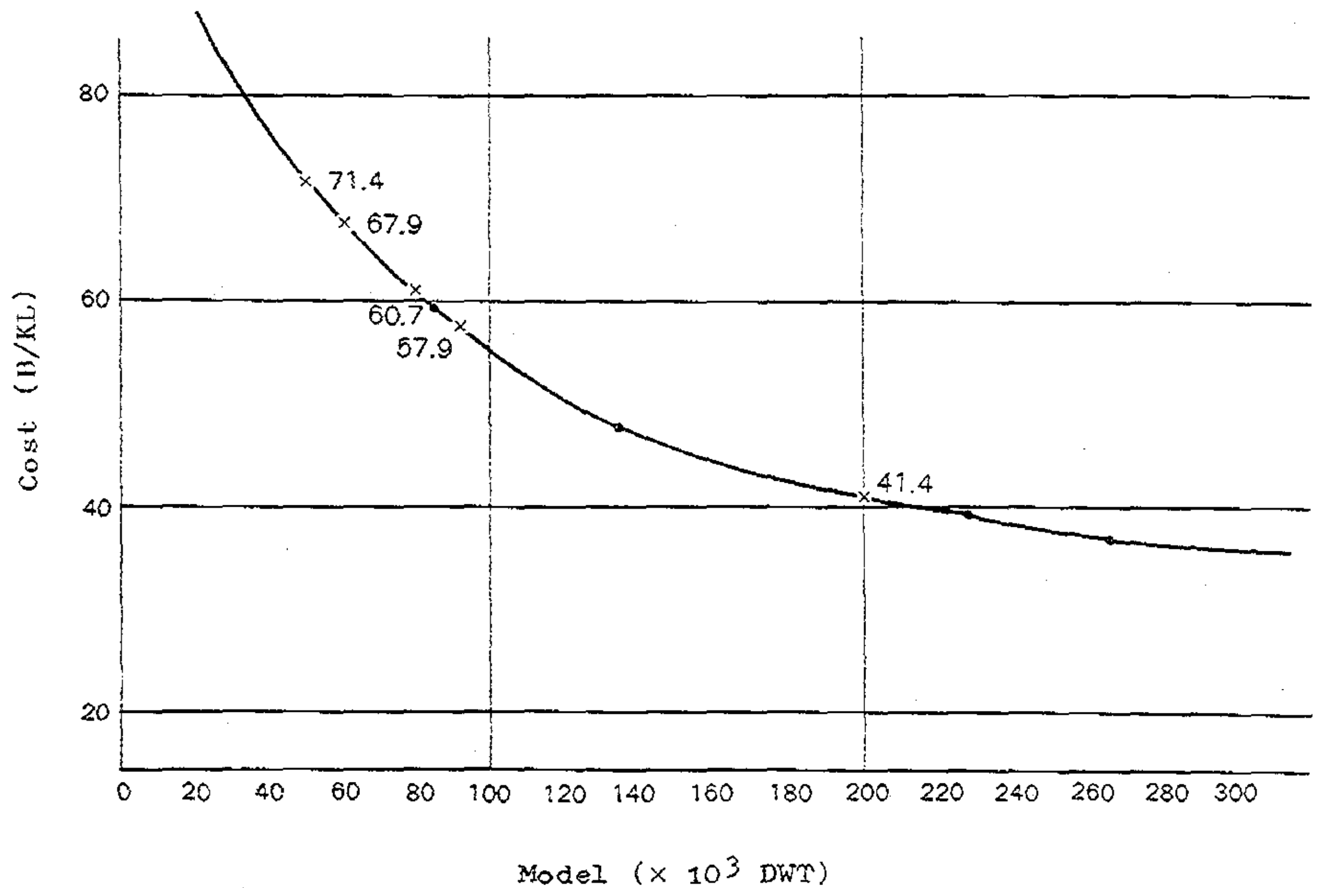


Fig. IX-1 Transportation Cost by Tanker Models

Table IX-2 Cost Difference

Transportation Cost Difference					
	Cost	Cost Difference			
		thousand DWT 60	thousand DWT 80	thousand DWT 90	thousand DWT 200
thousand DWT 50	฿/KL 71.4	3.5	10.7	13.5	30.0
60	67.9	-	7.2	10.0	26.5
80	60.7	-	-	2.8	19.3
90	57.9	-	-	-	16.5
200	41.4	-	-	-	-

(Note) Actual freight is determined by adding some profit (5 ~ 10%) to cost.

The transportation costs by 50 thousand DWT, 60 thousand DWT, 80 thousand DWT, 90 thousand DWT and 200 thousand DWT tankers can be obtained from Fig. IX-1. The cost difference is shown in Table IX-2. In other words, the transportation cost by a 200 thousand DWT tanker is 41.4 ฿/kℓ, which is lower than 60 thousand DWT and 90 thousand DWT tankers by 26.5 ฿/kℓ and 16.5 ฿/kℓ, respectively.

The technique that was used for these estimates is identical with the method that is used for obtaining the reference values of the world scale etc. The figures seems to be quite close to the real figures.

2. Demurrage loss

(1) Demurrage loss by tanker classes

The loss due to overstay at a port in as loss of tank cost. Demurrage loss per day is given below.

	thousand DWT 84	thousand DWT 134	thousand DWT 228	thousand DWT 266
Tanker cost (annual mean)	million ฿ 60.8	million ฿ 78.7	million ฿ 105.4	million ฿ 114.2
Tanker cost (daily mean)	thousand ฿ 166.6	thousand ฿ 215.6	thousand ฿ 288.8	thousand ฿ 312.9

This relation is shown in the graph of Fig. IX-2. Fig. IX-2 shows that the daily demurrage loss of a 60 thousand DWT, a 90 thousand DWT and a 200 thousand DWT tanker is 142.9 thousand ฿, 171.4 thousand ฿ and 271.4 thousand ฿, respectively.

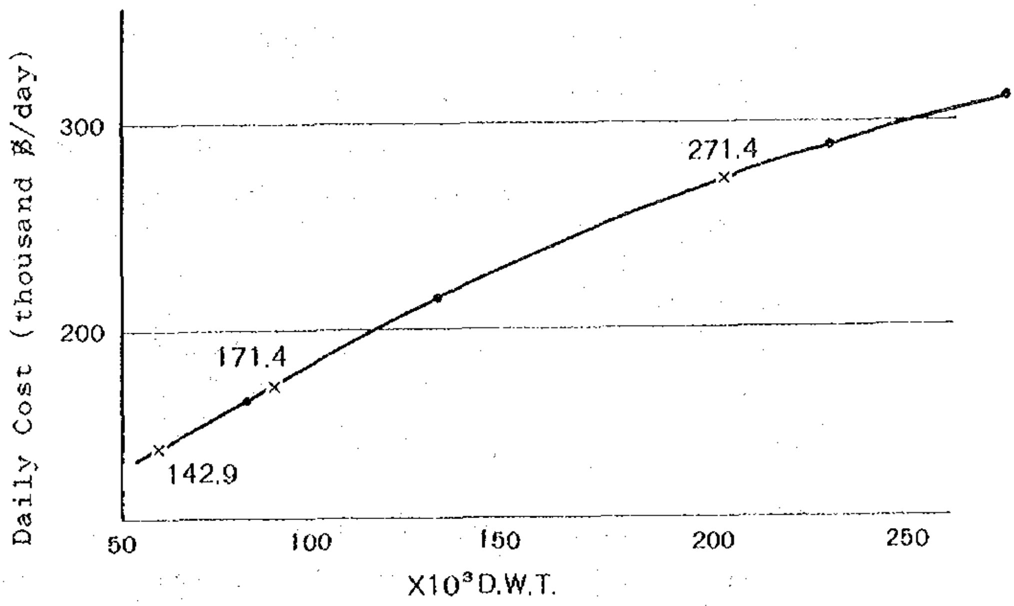


Fig. IX-2 Daily demurrage loss by Tanker classes

(2) Demurrage loss with current facilities

The demurrage losses in 1980 and 1985 under the current facilities are estimated below by using queuing theory. Attempts are also made to find the berth utilization leading to the minimum demurrage loss.

1) 1980

The 1980 import volume of crude oils is estimated to be 12,800 thousand KL according to the macro estimate. Therefore, the unknown quantities λ_{90} and λ_{60} must be obtained. The conditional equation must be satisfied and the loss function U must be the smallest.

90 thousand DWT sea berth:
90 thousand DWT class tanker
λ_{90} tanker/month (1 berth)

60 thousand DWT sea berth:
60 thousand DWT class tanker
λ_{60} tanker/month (2 berths)

Specific gravity of crude oils: 0.83 t/M^3

Quantity of crude oils handled by 90 thousand DWT sea berth:

$$90 \text{ thousand DWT} \div 0.83 \times 12 \text{ months} \times \lambda_{90}$$
$$= 1{,}300\,\lambda_{90}$$

Quantity of crude oils handled by 60 thousand DWT sea berth:

$$60 \text{ thousand DWT} \div 0.83 \times 12 \text{ months} \times \lambda_{60}$$
$$= 867\,\lambda_{60}$$
$$\therefore \quad 1{,}300\,\lambda_{90} + 867\,\lambda_{60} = 12{,}800$$

..... Conditional equation

The traffic density ρ_{90} and ρ_{60} at this time can be obtained as shown below. (μ = 30 days/2.5 days = 12)

$$\rho_{90} = \lambda_{90}/\mu = \lambda_{90}/12$$
$$\rho_{60} = \lambda_{60}/c\mu = \lambda_{60}/24$$

Queuing time Wd_{90} and Wd_{60} can be obtained by the following equations. (one month as time unit)

$$Wd_{90} = \frac{1}{\mu(1-\rho_{90})} = \frac{1}{12(1-\lambda_{90}/12)}$$

$$Wd_{60} = \frac{1}{c\mu(1-\rho_{60})} = \frac{1}{24\,(1-\lambda_{60}/24)}$$

Queu length Ld_{90} and Ld_{60} at this time can be obtained by the following equations.

$$Ld_{90} = \frac{1}{1-\rho_{90}} = \frac{1}{1-\lambda_{90}/12}$$

$$Ld_{60} = \frac{1}{1-\rho_{60}} = \frac{1}{1-\lambda_{60}/24}$$

Loss function $U = U_{90} + U_{60}$

$$U_{90} = (Wd_{90} \times 30 \text{ days}) \times (Ld_{90} \times 12 \text{ months})$$
$$\times 171.4 \text{ thousand } ฿ = \frac{5142.9}{(1-\lambda_{90}/12)^2} \text{ (thousand ฿)}$$

$$U_{60} = (Wd_{60} \times 30 \text{ days}) \times (Ld_{60} \times 12 \text{ months})$$
$$\times 142.9 \text{ thousand } ฿ = \frac{2142.9}{(1-\lambda_{60}/24)^2} \text{ (thousand ฿)}$$

$$U = \frac{5142.9}{(1-\lambda_{90}/12)^2} + \frac{2142.9}{(1-\lambda_{60}/24)^2} \text{ (thousand ฿)}$$

Fig. IX-3 shows this in a graph.
U min. = U (λ_{90} = 2.5, λ_{60} = 11.0) = 15.5 million ฿ can be obtained from Fig. IX-3.

Wd_{90} = 3.2 days $\quad$ Wd_{60} = 2.3 days

Ld_{90} = 1.3 tankers/month $\quad$ Ld_{60} = 1.8 tankers/month

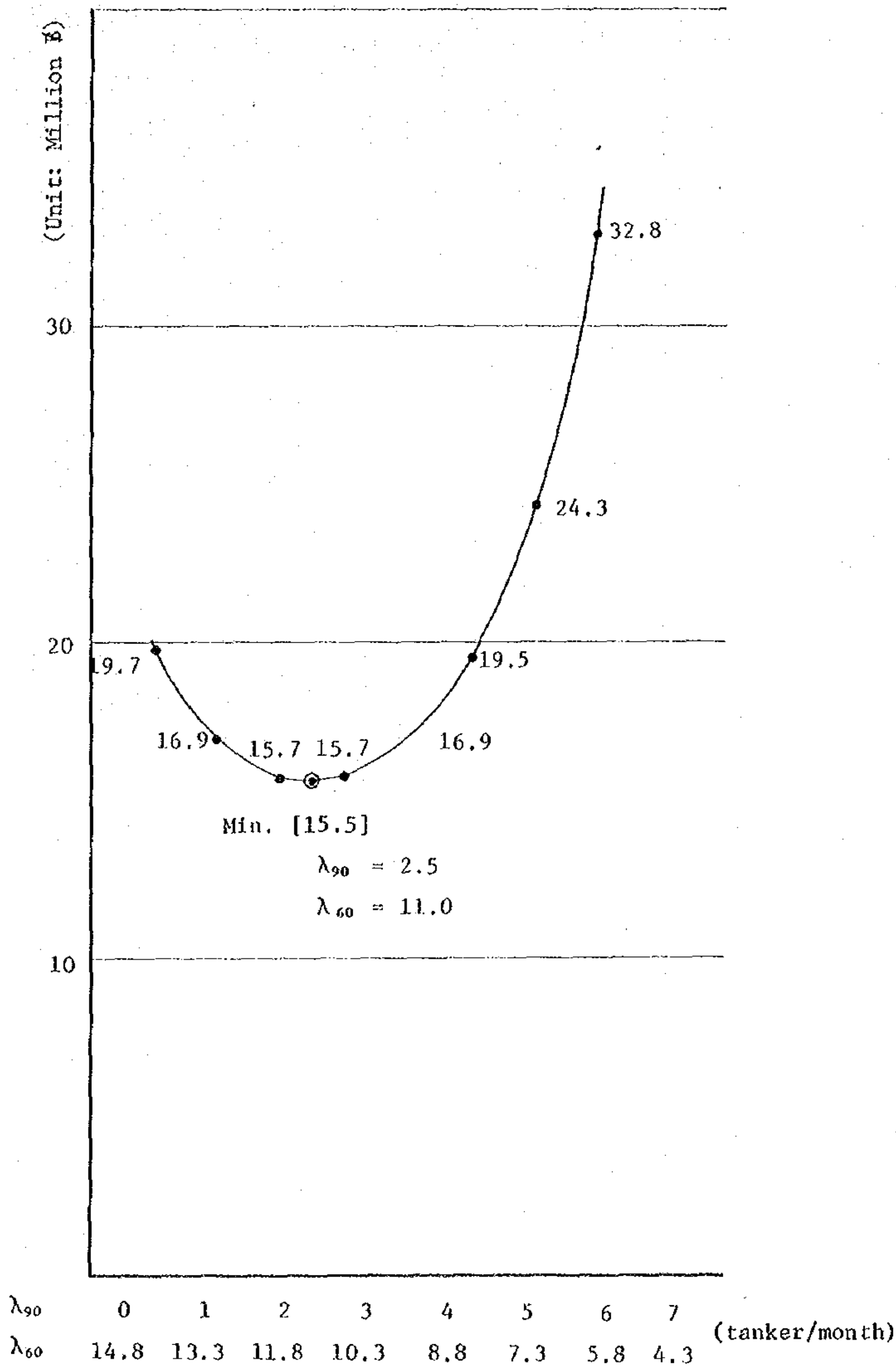


Fig. IX-3 Loss Function (1980)

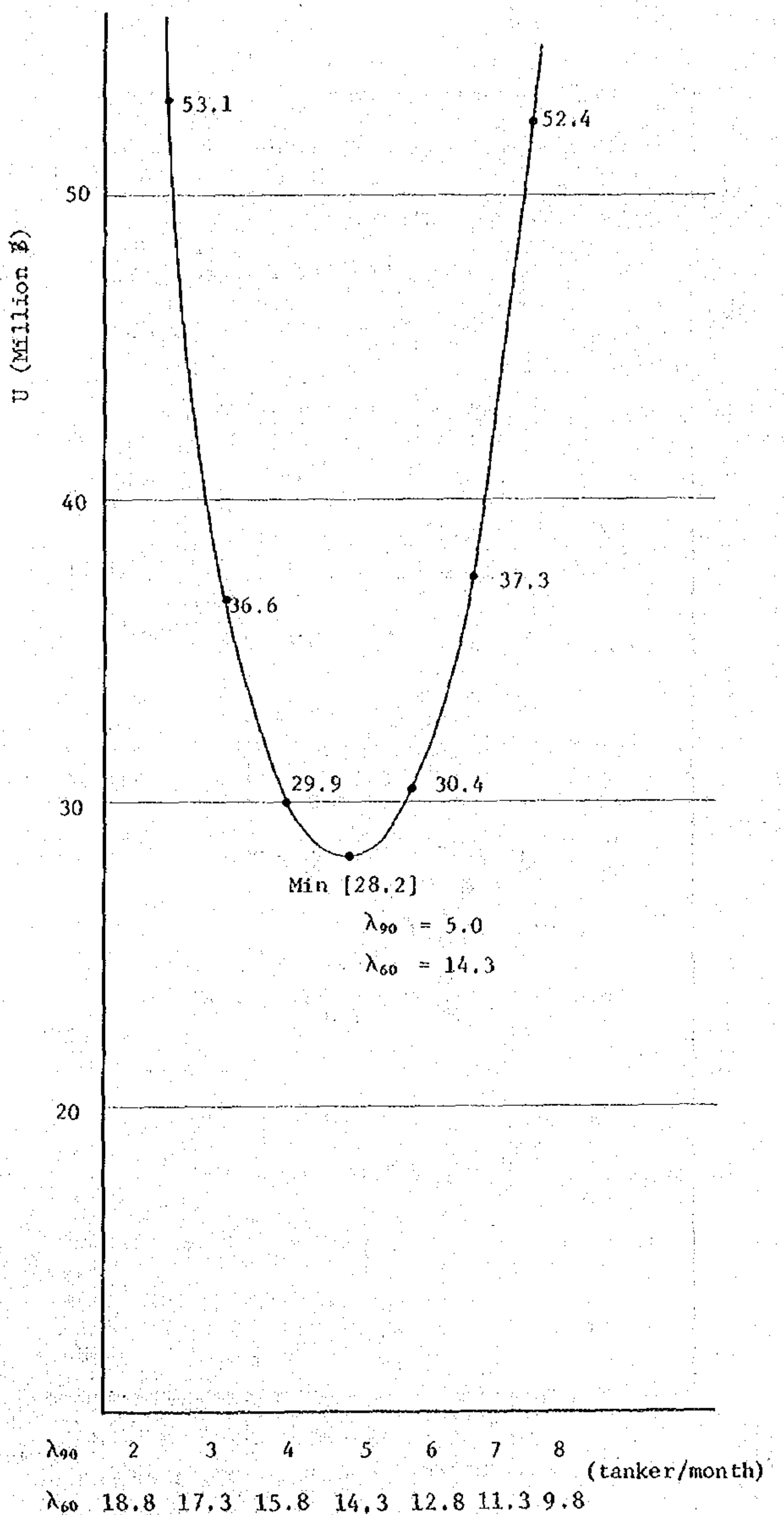


Fig. IX-4 Loss Function (1985)

2) 1985

The identical method was used for 1985 under the condition of $1,300\lambda_{90} + 867\lambda_{60} = 18,900$

Fig. IX-4 shows U in graph.
It gives $U\,min. \doteqdot U(\lambda_{90} = 5.0,\ \lambda_{60} = 14.3)$
$\doteqdot 28.2$ million ฿

Wd_{90} = 4.3 days Wd_{60} = 3.1 days
Ld_{90} = 1.7 tankers/months Ld 60 = 2.5 tankers/month

These results give demurrage loss per 1 kℓ.
Table IX-3 give the figures.

Table IX-3 Demurrage per KL

Year	Berth	Number of arriving tankers	Quantity of unloaded crude oils	Waiting time (day)	Number of waiting tankers	Loss	Loss per KL
	thousand DWT	tanker/day	thousand KL	days/tanker	tanker/day	million ฿	
1980	90	2.5	3,250	3.2	1.3	8.2	2.52฿/KL
	60	11.0	9,550	2.3	1.8	7.3	0.76
	Total		12,800			15.5	1.21
1985	90	5.0	6,500	4.3	1.7	15.1	2.32
	60	14.3	12,400	3.1	2.5	13.1	1.06
	Total		18,900			28.2	1.49